Toyota Technical Center, U.S.A., Inc.
Arizona Proving Grounds

Drainage Calculations
Volume 1

September 1991

Prepared for:

Taisei-Bechtel Joint Venture

Prepared by:

Sverdrup Corporation
432 North 44th Street
Suite 250
Phoenix, Arizona 85008

Bradford D. Olbert

Toyota Technical Center, U.S.A., Inc.
Arizona Proving Grounds

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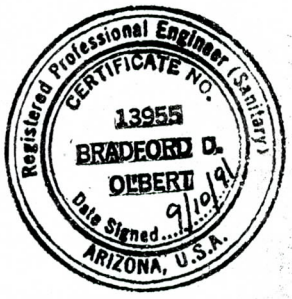


Bradford D. Olbert

Toyota Arizona Proving Grounds
Drainage Calculations

Culvert Number / Concentration Point Listing

Listed by Culvert Number

Culvert Number	Roadway	Concentration Point	Culvert Size
1	Oval Track	70 E	(5) 10 x 5
2	Oval Track	70 C	(1) 24" RCP
3	Oval Track	69	(3) 10 x 4
4	Oval Track	67 E	(1) 10 x 4
5	Oval Track	67 F	(1) 36" RCP
6	Oval Track	67 A	(5) 10 x 4
7	Oval Track	67 B	(1) 10 x 4
8	Oval Track	67 C	(2) 10 x 5
9	Oval Track	67 D	(2) 10 x 4
10	Oval Track	60 C	(1) 24" RCP
11	Oval Track	60 B	(1) 24" RCP
12	Oval Track	60 A	(5) 10 x 4
13	Oval Track	60 F	(1) 10 x 4
14	Oval Track	60 G	(1) 10 x 4
15	Oval Track	60 E	(1) 24" RCP
16A	Oval Track	60 D-6	(1) 10 x 4
16B	Oval Track	60D-5	(1) 10 x 4
16C	Oval Track	60D-4	(1) 10 x 4
16D	Oval Track	60D-3	(1) 10 x 4
16E	Oval Track	60D-2	(1) 10 x 4
16F	Oval Track	60D-1	(1) 10 x 4
17	Loop Road A	60 J-1	(1) 6 x 4
18	Oval Track	60 J-2	(1) 10 x 4
19	Loop Road A	67 H-1	(7)10 x 4
20	Oval Track	67 H-2	(8) 10 x 4
21	Loop Road A	67 I-1	(1) 10 x 4
22	Oval Track	67 I-2	(1) 10 x 4
23	Loop Road A	67 J-1	(1) 10 x 4
24	Oval Track	67 J-2	(1) 10 x 4
25	Loop Road A	67 L-1	(1) 24" RCP
26	Oval Track	67 L-2	(1) 24" RCP
27	Loop Road A	70 Q-1	(2) 10 x 5
28	Oval Track	70 Q-2	(2) 10 x 6
29	Loop Road A	70 P-1	(5) 10 x 6
30	Oval Track	70 P-2	(4) 10 x 6
31	Oval Track	70 O	(2) 10 x 4
32	Rampway A	70 M-1	(1) 24" RCP
33	Rampway B	70 M-2	(1) 6 x 4
34	Oval Track	76J	(6)10 X 4
35	Cornering Course	70 A	(3) 10 x 5
36	Cornering Course	76 F	(5) 10 x 6
37	Cornering Course	70 B	(3) 10 x 5
38	Cornering Course	76 G	(4) 10 x 5
39	Access Rd A-1	76 E	(2) 10 x 5
40	Access Rd A-1	76 F	(1) 10 x 4
41	Access Rd G-1	N/A	(1) 49" x 33" CMP Arch
42	Access Rd G-1	N/A	(2) 49" x 33" CMP Arch
43	Access Rd E-1	N/A	(2) 49" x 33" CMP Arch
44	Access Rd E-1	N/A	(2) 49" x 33" CMP Arch
45	Access Rd A-2	N/A	(1) 49" x 33" CMP Arch
46	Access Rd A-2	N/A	(2) 49" x 33" CMP Arch
47	Access Rd A-2	N/A	(2) 49" x 33" CMP Arch

Listed by Concentration Point

Concentration Point	Roadway	Culvert Number	Culvert Size
60 A	Oval Track	12	(5) 10 x 4
60 B	Oval Track	11	(1) 24" RCP
60 C	Oval Track	10	(1) 24" RCP
60 D-1	Oval Track	16F	(1) 10 x 4
60 D-2	Oval Track	16E	(1) 10 x 4
60 D-3	Oval Track	16D	(1) 10 x 4
60 D-4	Oval Track	16C	(1) 10 x 4
60 D-5	Oval Track	16B	(1) 10 x 4
60 D-6	Oval Track	16A	(1) 10 x 4
60 E	Oval Track	15	(1) 24" RCP
60 F	Oval Track	13	(1) 10 x 4
60 G	Oval Track	14	(1) 10 x 4
60 J-1	Loop Road A	17	(1) 6 x 4
60 J-2	Oval Track	18	(1) 10 x 4
67 A	Oval Track	6	(5) 10 x 4
67 B	Oval Track	7	(1) 10 x 4
67 C	Oval Track	8	(2) 10 x 5
67 D	Oval Track	9	(2) 10 x 4
67 E	Oval Track	4	(1) 10 x 4
67 F	Oval Track	5	(1) 36" RCP
67 H-1	Loop Road A	19	(7)10 x 4
67 H-2	Oval Track	20	(8) 10 x 4
67 I-1	Loop Road A	21	(1) 10 x 4
67 I-2	Oval Track	22	(1) 10 x 4
67 J-1	Loop Road A	23	(1) 10 x 4
67 J-2	Oval Track	24	(1) 10 x 4

Concentration Point	Roadway	Culvert Number	Culvert Size
67 L-1	Loop Road A	25	(1) 24" RCP
67 L-2	Oval Track	26	(1) 24" RCP
69	Oval Track	3	(3) 10 x 4
70 A	Cornering Course	35	(3) 10 x 5
70 B	Cornering Course	37	(3) 10 x 5
70 C	Oval Track	2	(1) 24" RCP
70 E	Oval Track	1	(5) 10 x 5
70 M-1	Rampway A	32	(1) 24" RCP
70 M-2	Rampway B	33	(1) 6 x 4
70 O	Oval Track	31	(2) 10 x 4
70 P-1	Loop Road A	29	(5) 10 x 6
70 P-2	Oval Track	30	(4) 10 x 6
70 Q-1	Loop Road A	27	(2) 10 x 5
70 Q-2	Oval Track	28	(2) 10 x 6
76 E	Access Rd A-1	39	(2) 10 x 5
76 F	Cornering Course	36	(5) 10 x 6
76 F	Access Rd A-1	40	(1) 10 x 4
76 G	Cornering Course	38	(4) 10 x 5
76 J	Oval Track	34	(6)10 X 4
N/A	Access Rd G-1	41	(1) 49" x 33" CMP Arch
N/A	Access Rd G-1	42	(2) 49" x 33" CMP Arch
N/A	Access Rd E-1	43	(2) 49" x 33" CMP Arch
N/A	Access Rd E-1	44	(2) 49" x 33" CMP Arch
N/A	Access Rd A-2	45	(1) 49" x 33" CMP Arch
N/A	Access Rd A-2	46	(2) 49" x 33" CMP Arch
N/A	Access Rd A-2	47	(2) 49" x 33" CMP Arch

VERDR

JOB 4047 Toyota

SHEET NO 1 OF

DATE 6/24/91

COMPUTATIONS FOR Proposed Culvert 70E [1]

BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

DESIGNER:

STATION: 357+20 Oval Track

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 4.36 sq. miles

Q_1 = 2683 cfs

Q_2 = ____

TW_1 = 2.6' Exist. Channel

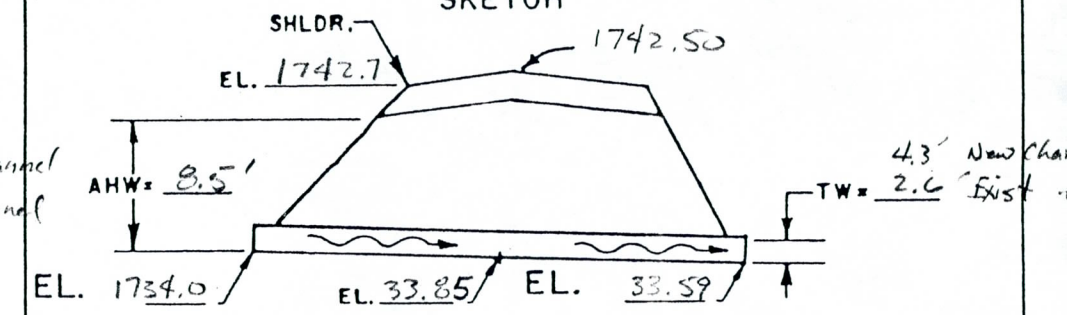
TW_2 = 4.3' New Channel

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY Q_{25}) Q_{100}

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050 ft/ft L = 83' L/100 S_o = ____

MEAN STREAM VELOCITY = 3.3 fps

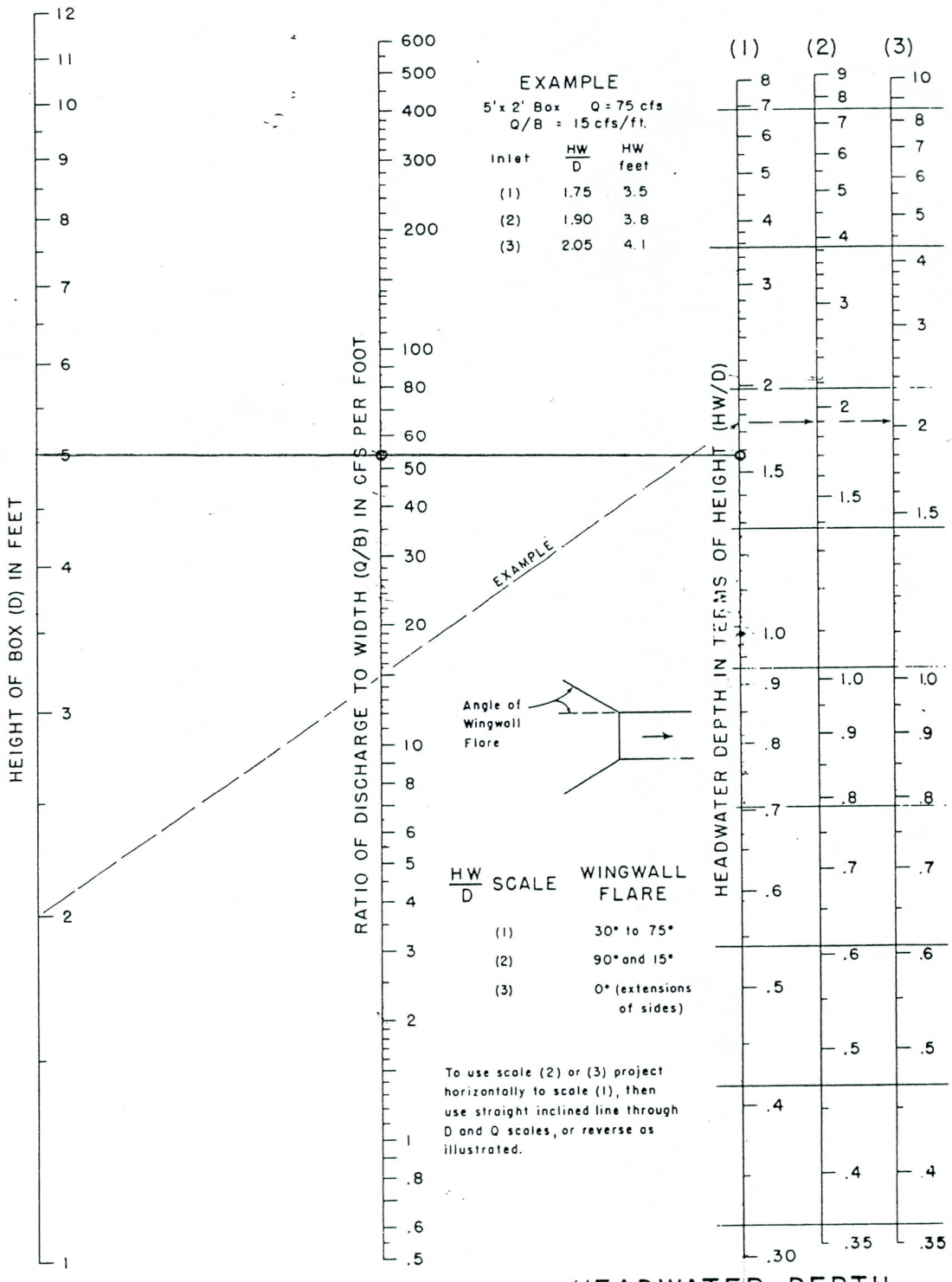
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(5) Barrel 10'x5'	15° Headwalls w/ Drop Inlet	2683/5 537		1.58	7.9	0.2	2.5	4.4	4.7	4.3	4.7	0.49	6.76	7.90	14.5		1741.90	Inlet Control

SUMMARY & RECOMMENDATIONS

B-10

Culvert 70 E

CHART 1

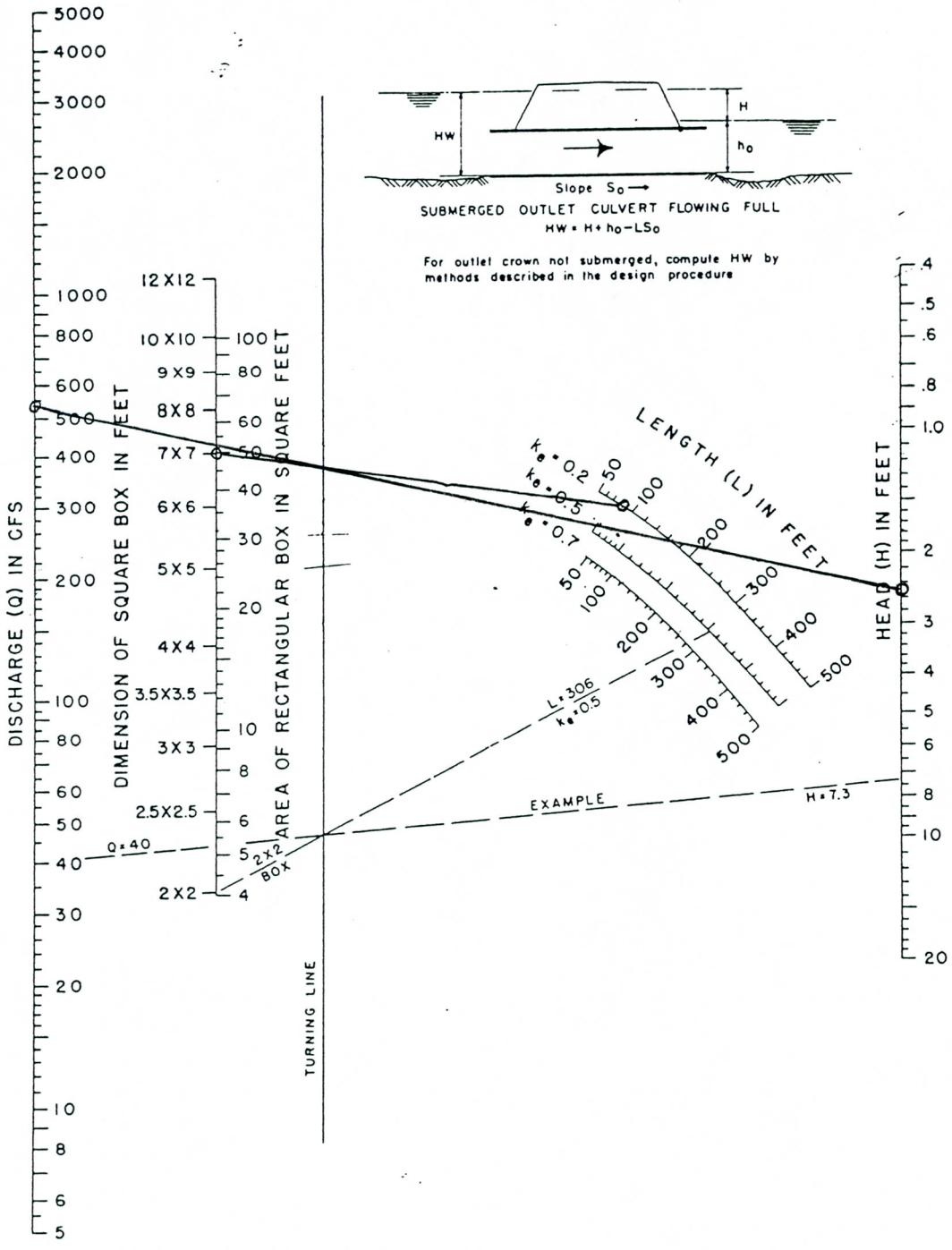


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 70E

CHART 8

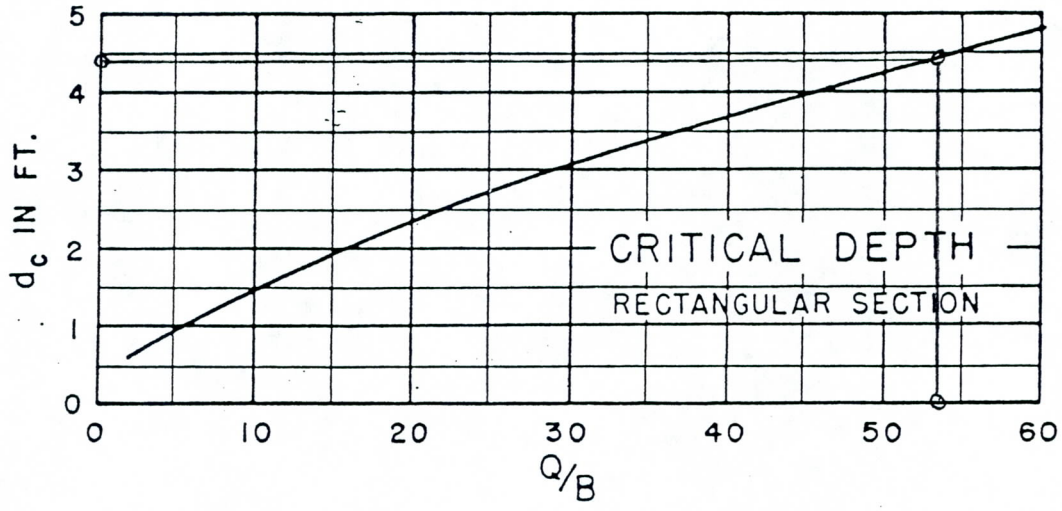


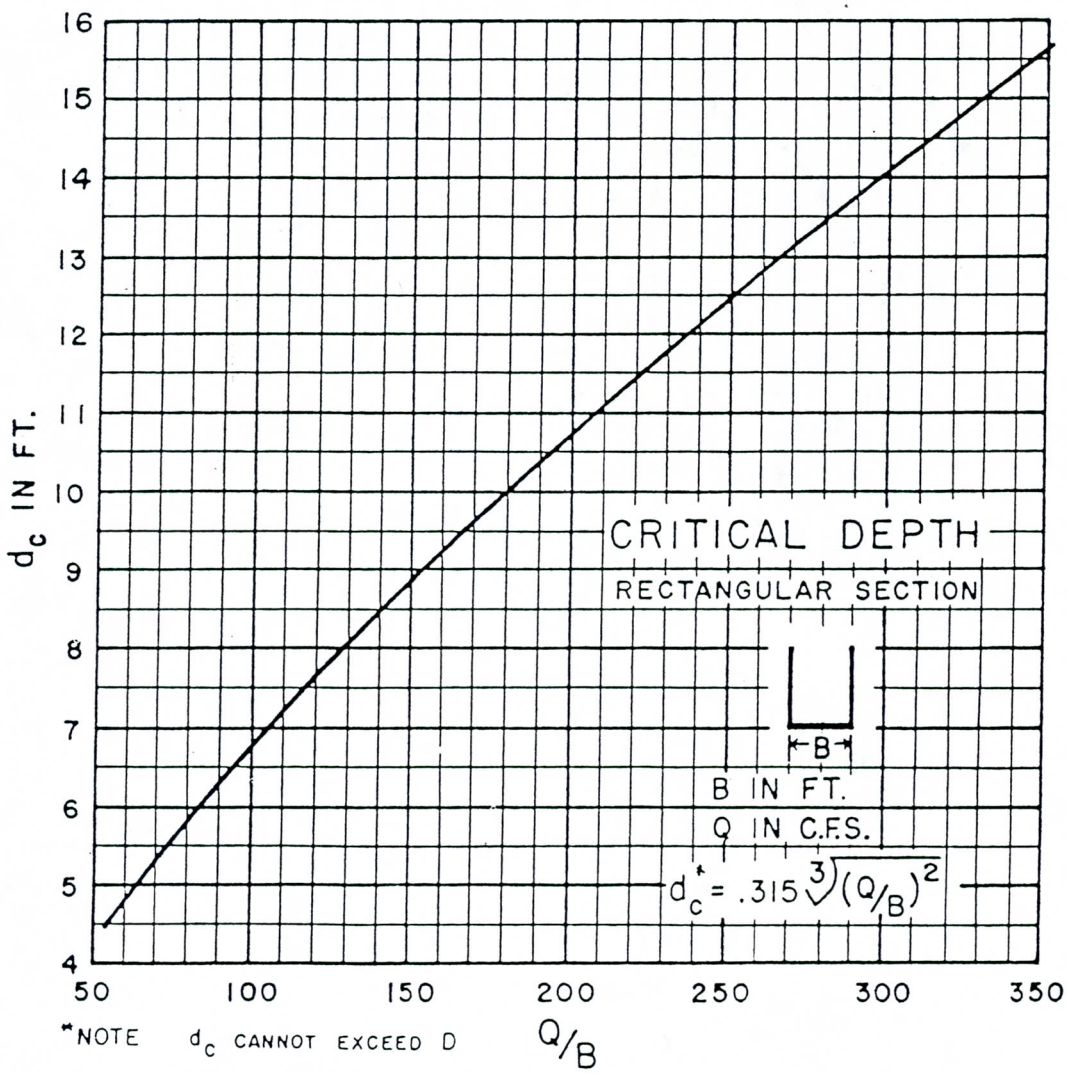
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 70E

CHART 15





*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Box Culvert 70 E

SHEET NO. 5 OF

DATE 6/24/91

BY BDO CHKD RJT

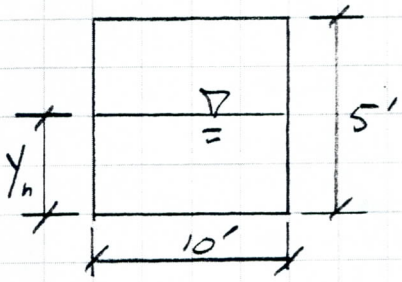
Check depth of flow using Mannings Equation

$Q_{100} = 2683$ cfs, $Q_{100/barrel} = 537$ cfs

$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 3.70'$



$A = 3.70 \times 10 = 37.0$ ft^2

$WP = 10 + 2(3.70) = 17.4$

$R_h = A/WP = 37.0/17.4 = 2.1264'$

$$V = \frac{1.49}{.012}(2.1264)^{.666}(.005)^{.5} = 14.50 \text{ fps}$$

$Q = VA = 14.5 \times 37.0 = 536$ cfs (OK)

Check Froude Number

$$F = \frac{V}{\sqrt{g\,Y_c}} = \frac{14.5}{\sqrt{32.2(3.70)}} = 1.33$$ Supercritical

Channel needs protection, use soil cement lined channel to reduce outlet velocities and contain hydraulic jump within channel.

SVERDRUP

JOB 40477 Toyota SHEET NO. 6 OF

DATE 6/24/91

COMPUTATIONS FOR Channel Section Downstream of Box Culvert 70 E BY BDO CHKD RTT

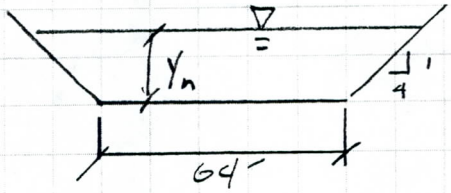
Check depth of flow using Mannings Eqn.

$Q100 = 2683$ cfs

$n = 0.02$

$S_o = 0.0020$ ft/ft

$Y_n \sim 4.30'$



$A = 349.3$ ft^2

$WP = 2(17.73) + 64 = 99.46$

$R_h = A/WP = 349.3 / 99.46 = 3.5120'$

$$V = \frac{1.49}{.02}(3.5120)^{.666}(.002)^{.5} = 7.69 \text{ fps}$$

$Q = VA = 7.69(349.3) = 2686$ cfs OK

Check Froude Number

$$F = \frac{V}{\sqrt{g \times Y_c}} = \frac{7.69}{\sqrt{32.2 \times 4.30}} = 0.65, \text{ Subcritical}$$

Energy Grade Line $4.30 + \frac{(7.69)^2}{2(32.2)} = 5.22'$

Use 5.0' deep channel – Flare channel section to reduce velocity and depth of flow.

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Channel Section. Downstream Culvert 70E

SHEET NO. 7 OF

DATE 6/25/91

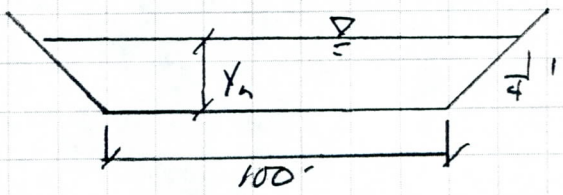
BY BDO CHKD RJT

For 100' wide bottom width check depth of flow and velocity.

$Q100 = 2683$ cfs

$n = 0.02$

$S_o = 0.0020$ ft/ft



$Y_n \approx 3.40'$

$A = 386.4$ ft^2

$WP = 2(14.02) + 100 = 128.04$

$R_h = A/WP = \frac{386.4}{128.0} = 3.0188'$

$V = \frac{1.49}{0.02}(3.0188)^{.666}(.002)^{.5} = 6.95$ fps

— check —

$Q = VA = (6.95)\ 386.4 = 2685$ cfs (OK)

Check Froude Number

$F = \frac{V}{\sqrt{g \times Y_e}} = \frac{6.95}{\sqrt{32.2 \times 3.4}} = 0.66$, Subcritical

Energy Grade Line $= 3.40 + \frac{(6.95)^2}{64.4} = 4.15'$

Check cutoff wall depth at end of channel

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Cutoff wall at end of channel. Culvert 70E

SHEET NO. 8 OF

DATE 6/25/91

BY BDO CHKD RTT

Cutoff wall Design for channel

Per HEC No 14 Hydraulic Design of Energy Dissipator for Culverts and Channels by FHWA, and Drainage and Channel Design Standards for Floodplain Management Within Pima County, Ariz. by Pima County DOT & FCD:

The Downstream depth of Scour is:

$$h_s = \alpha\, Y_e^{\gamma} \left(Q/Y_e^{2.5}\right)^{\beta} t^{\theta}$$

For $TW > 0.5D$ (From Table V-1 HEC No 14)

$\alpha = 0.76$ $\beta = 0.375$ $\theta = 0.10$ and $\gamma = 1.0$

$$\therefore\ h_s = 0.76\, Y_e \left(Q/Y_e^{2.5}\right)^{.375} t^{0.1}$$

$Q = VA$ and $A = 2Y_e^2$

$$\therefore\ h_s = 0.76\, Y_e \left(\frac{V(2Y_e^2)}{Y_e^{2.5}}\right)^{.375} t^{0.1}$$

where

V = average velocity, fps
Y_e = max depth of flow for a channel section, ft.
t = time duration, minutes

From previous sheets the average Velocity is 6.95 fps and the max. depth of flow is 3.40 ft. The time of duration is 35 minutes from the hydrograph.

$$h_s = 0.76\,(3.40)\left(\frac{6.95(2)(3.40)^2}{(3.40)^{2.5}}\right)^{.375} 35^{0.1}$$

$$= 7.86',\ \text{Use } 8'$$

SVERDRUP

JOB 40477 Toyota SHEET NO. 9 OF

COMPUTATIONS FOR Channel Riprap DATE 7/8/91

BY BDO CHKD RJT

Check Rock Size and Length of Riprap Apron length:

Per PCDOT & FCD Manual for Drainage and Channel Design:

Length of Riprap Apron = $D_c \times 8$

where D_c = Culvert Depth, use 3.40'

$L = 3.4' \times 8 = 27.2'$ Use 50' for protection and matching existing conditions

Rock Size: per Practical Guidance for Estimating and Controlling Erosion at Culvert Outlets w/ Modifications per PCDOT & FCD Manual for Drainage and Channel Design, Pg VI-11, VI-14,

$$d_{50} = 0.02 \left[\frac{D_c^2}{TW}\right](R)^{4/3}, \text{ where } R = \frac{Q/B}{D_c^{1.5}}$$

$$R_{100} = \frac{2683/100}{(3.4)^{1.5}} = 4.28, \quad R_{10} = \frac{1020/100}{(1.93)^{1.5}} = 3.80$$

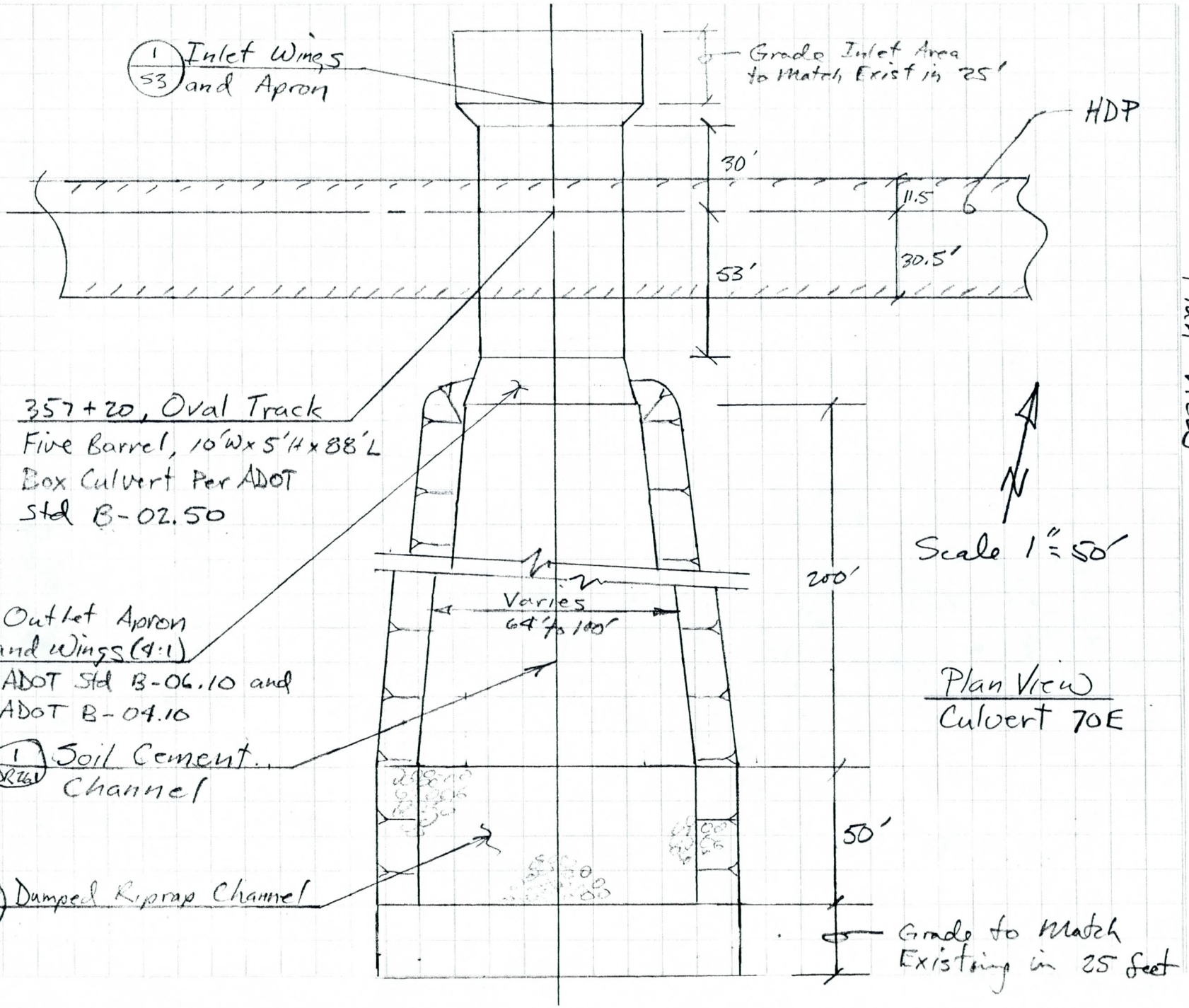
$TW = 2.6', 2.1'$

$D_c = 3.4', 1.93'$

$$d_{50}(Q100) = 0.02\left(\frac{3.40^2}{2.6}\right)(4.28)^{4/3} = 0.62'$$

$$d_{50}(Q10) = 0.02\left(\frac{1.93^2}{2.1}\right)(3.80)^{4/3} = 0.21'$$

Use 6" Rock w/ minimum thickness 1.0'.



SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Box Culvert 70E [1]
Plan View

SHEET NO. 10 OF

DATE 6/24/91

BY BDO CHKD RJT

SVERDRUP

JOB 40477 Toyota SHEET NO. 11 OF

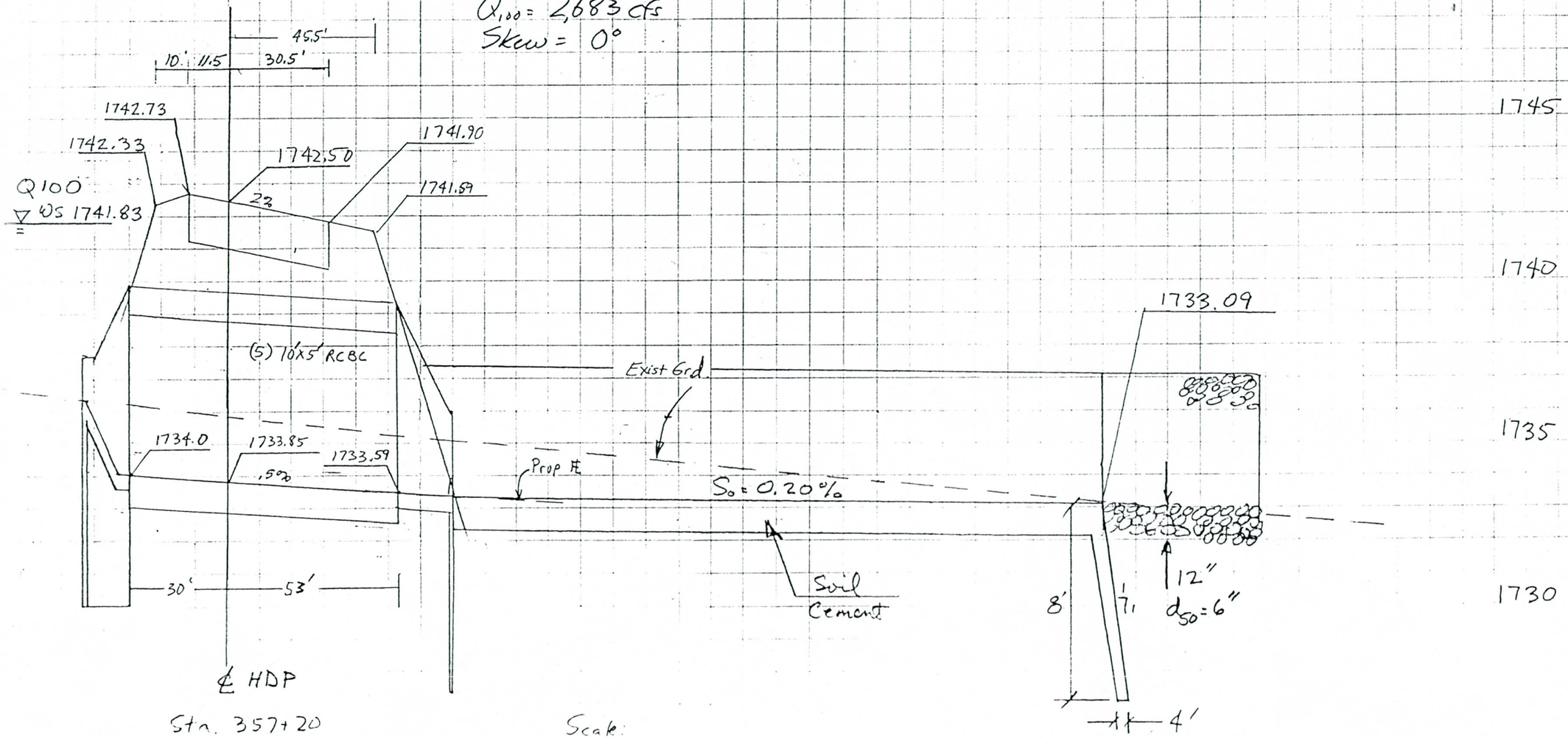
COMPUTATIONS FOR Culvert Profile 70E [1] DATE 6-24-91

HST Sta. 357+20 BY DFP CHKD RJT

Culvert 70E [1]

Q_{100} = 2,683 cfs

Skew = 0°



℄ HDP

Sta. 357+20

Oval Track

Scale:

Horiz. 1" = 40'

Vert. 1 = 4'

SECTION NUMBER TW70E 6/24/91

Channel Slope: 0.0091 ft./ft.

CROSS SECTION DATA:

OFFSET	-400	-240	-120	0	79.2	171.2	175.2	179.9	182.1	199.2	204.8	209.4	277.3	310	400
ELEV.	37	35	36.5	35.8	36.01	35.65	33.86	34.31	35.54	35.51	33.91	35.14	35.83	36.5	35
N	N/A	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035

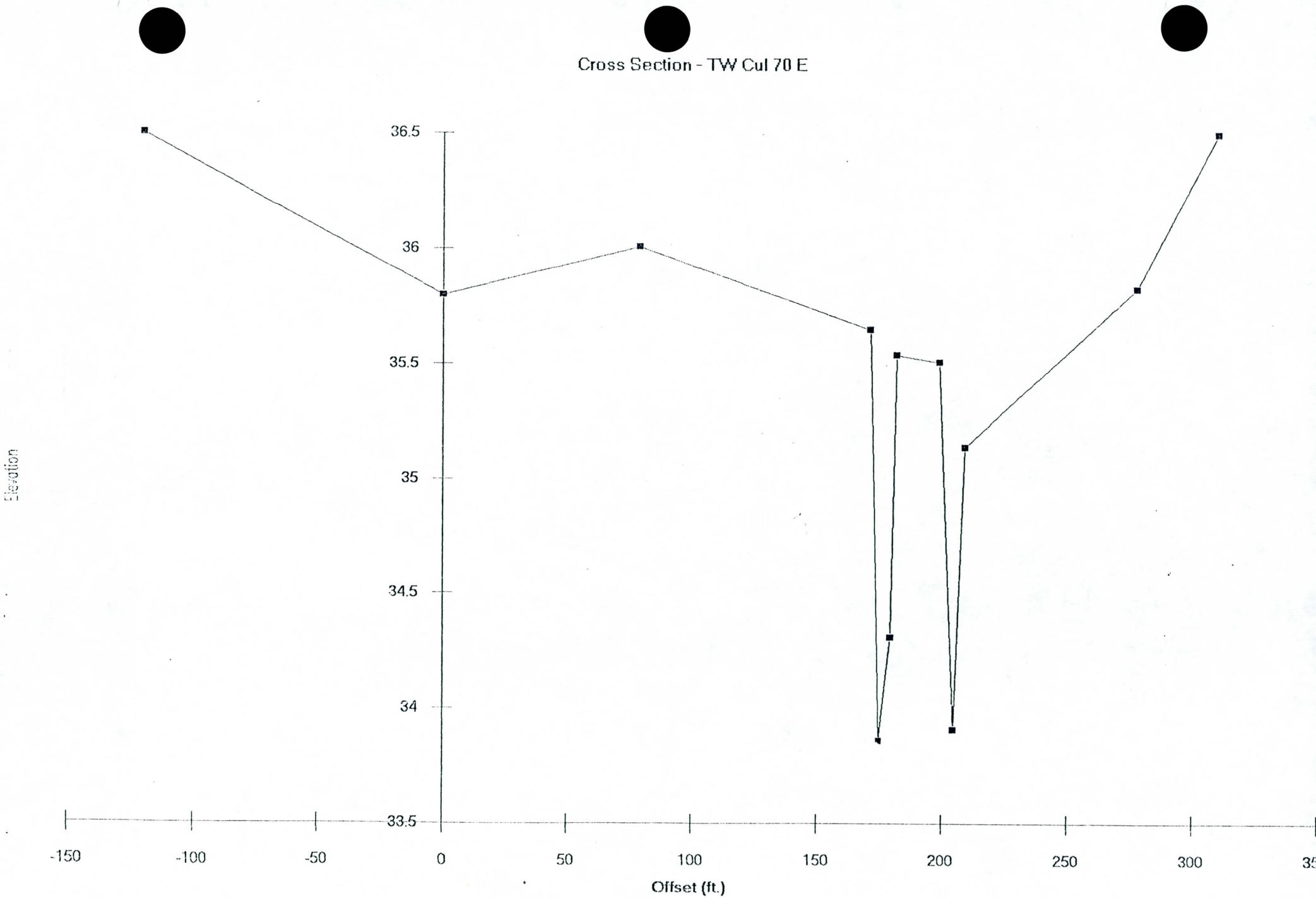
STAGE-DISCHARGE DATA:

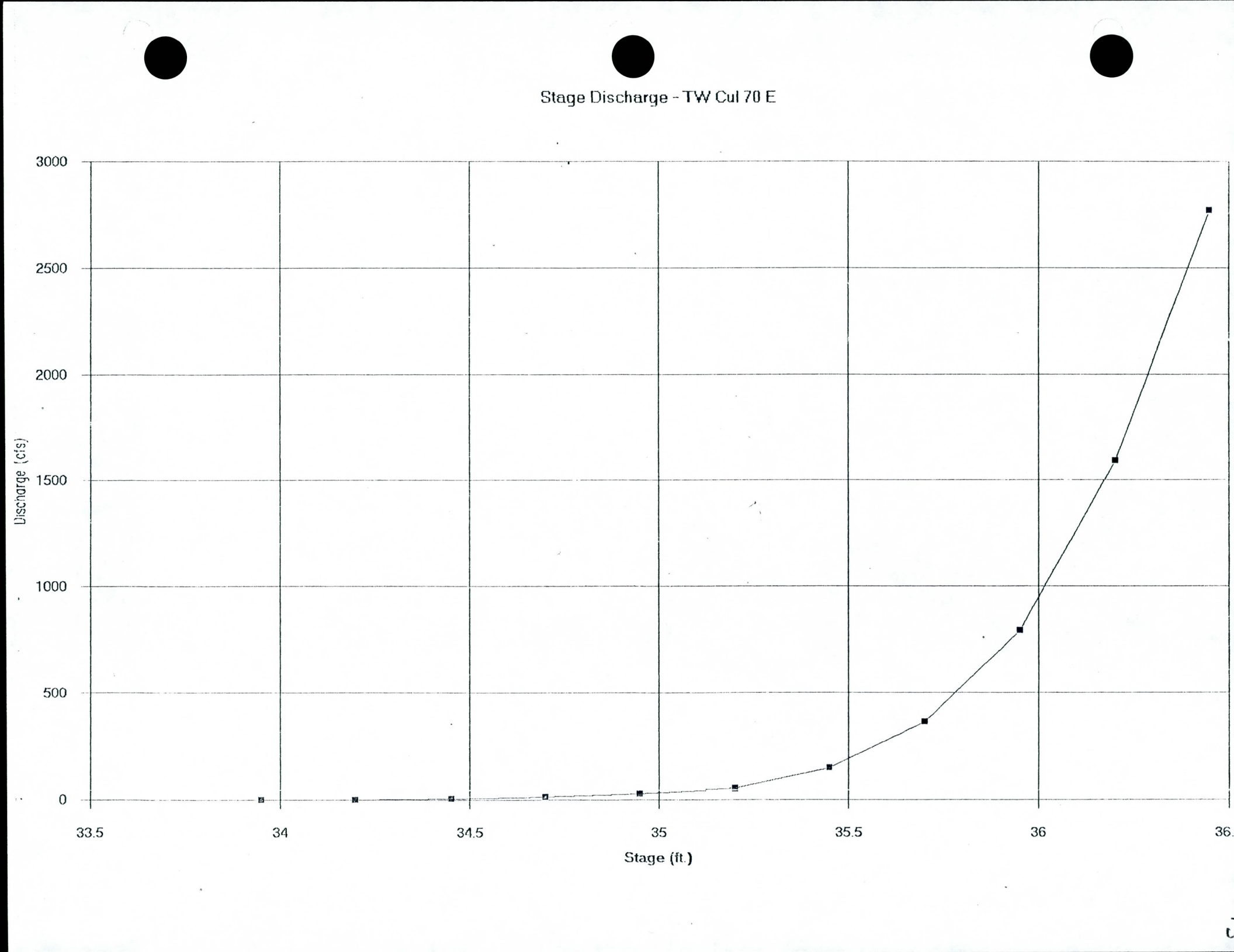
STAGE: 33.95														
WET PER.	0.0	0.0	0.0	0.0	0.0	0.2	1.2	0.0	0.0	0.2	0.3	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0 0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE: 34.2														
WET PER.	0.0	0.0	0.0	0.0	0.0	0.8	4.4	0.0	0.0	1.1	2.2	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.1	0.7	0.0	0.0	0.1	0.3	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.1	0.1	0.0	0.0	0.0
Q	0	0	0	0	0	0	1	0	0	0	0	0	0	0
STAGE: 34.45														
WET PER.	0.0	0.0	0.0	0.0	0.0	1.4	6.2	6.5	0.0	2.0	4.1	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.4	2.1	2.1	0.0	0.5	1.1	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.3	0.3	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	4	0	0	2	0	0	0
STAGE: 34.7														
WET PER.	0.0	0.0	0.0	0.0	0.0	2.1	6.8	7.6	0.0	2.9	5.9	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.8	3.7	3.8	0.0	1.1	2.3	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.5	0.0	0.4	0.4	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	10	0	0	5	0	0	0
STAGE: 34.95														
WET PER.	0.0	0.0	0.0	0.0	0.0	2.7	7.4	8.7	0.0	3.8	7.8	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	1.3	5.4	5.8	0.0	1.9	3.9	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.5	0.7	0.7	0.0	0.5	0.5	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	18	0	0	10	0	0	0
STAGE: 35.2														
WET PER.	16.0	32.0	0.0	0.0	0.0	3.3	8.0	9.8	0.0	4.7	9.5	15.4	0.0	12.0
AREA	1.6	3.2	0.0	0.0	0.0	2.0	7.2	8.0	0.0	2.9	6.0	6.2	0.0	1.2
HYD.RAD.	0.1	0.1	0.0	0.0	0.0	0.6	0.9	0.8	0.0	0.6	0.6	0.4	0.0	0.1
Q	0	3	0	0	0	0	0	28	0	0	0	14	0	0

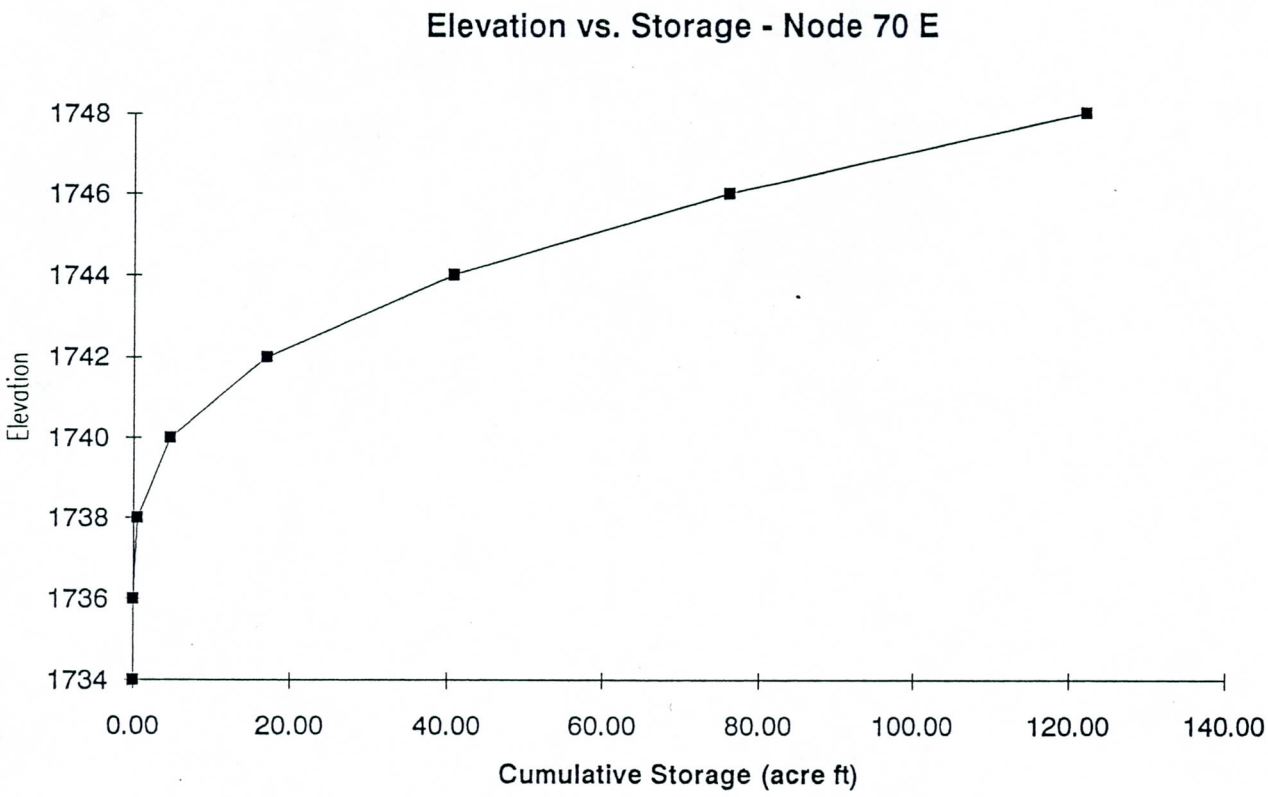
SECTION NUMBER TW70E 6/24/91

STAGE:	35.45													
WET PER.		36.0	72.0	0.0	0.0	0.0	3.9	8.6	11.0	0.0	5.6	10.4	40.9	0.0	27.0
AREA		8.1	16.2	0.0	0.0	0.0	2.8	9.2	10.4	0.0	4.2	8.4	13.1	0.0	6.1
HYD.RAD.		0.2	0.2	0.0	0.0	0.0	0.7	1.1	0.9	0.0	0.7	0.8	0.3	0.0	0.2
Q		0	24	0	0	0	0	0	41	0	0	0	25	0	0
STAGE:	35.7														
WET PER.		56.0	112.0	0.0	0.0	12.8	17.2	21.9	24.4	41.5	47.3	52.1	107.2	0.0	42.0
AREA		19.6	39.2	0.0	0.0	0.3	4.1	11.7	13.4	16.4	21.9	27.3	42.8	0.0	14.7
HYD.RAD.		0.4	0.4	0.0	0.0	0.0	0.2	0.5	0.5	0.4	0.5	0.5	0.4	0.0	0.3
Q		0	79	0	0	0	0	0	0	0	0	0	94	0	0
STAGE:	35.95														
WET PER.		76.0	152.0	25.7	56.6	75.7	81.1	85.8	88.3	105.4	111.2	116.0	183.9	189.7	57.0
AREA		36.1	72.2	1.9	4.2	11.5	16.3	25.0	27.3	34.6	41.5	48.1	79.6	80.0	27.1
HYD.RAD.		0.5	0.5	0.1	0.1	0.1	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5
Q		0	178	1	4	0	0	0	0	0	0	0	0	182	0
STAGE:	36.2														
WET PER.		96.0	192.0	68.6	79.2	92.0	96.4	101.1	103.6	120.7	126.5	131.3	199.2	217.3	72.0
AREA		57.6	115.2	13.7	23.4	34.0	39.8	49.8	52.6	64.1	72.5	80.2	128.7	132.0	43.2
HYD.RAD.		0.6	0.6	0.2	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6
Q		0	332	19	59	0	0	0	0	0	0	0	0	384	0
STAGE:	36.45														
WET PER.		116.0	232.0	111.4	79.2	92.0	96.4	101.1	103.6	120.7	126.5	131.3	199.2	229.5	87.0
AREA		84.1	168.2	36.2	43.2	57.0	63.8	74.9	78.3	94.1	103.9	112.7	178.2	187.6	63.1
HYD.RAD.		0.7	0.7	0.3	0.5	0.6	0.7	0.7	0.8	0.8	0.8	0.9	0.9	0.8	0.7
Q		0	550	69	163	0	0	0	0	0	0	0	0	665	0

W.S. Elev.	33.95	34.2	34.45	34.7	34.95	35.2	35.45	35.7	35.95	36.2	36.45
Q	0	1	6	15	28	51	148	362	794	1592	2770
A	0.1	1.0	3.2	6.1	9.7	25.0	78.7	176.2	332.0	561.3	839.6
V	0.5	1.2	1.8	2.4	2.9	2.0	1.9	2.1	2.4	2.8	3.3


Cross Section - TW Cul 70 E
Elevation
36.5
36
35.5
35
34.5
34
33.5
-150
-100
-50
0
50
100
150
200
250
300
Offset (ft.)


Stage Discharge - TW Cul 70 E
3000
2500
2000
1500
1000
500
0
Discharge (cfs)
33.5
34
34.5
35
35.5
36
Stage (ft.)


Elevation vs. Storage - Node 70 E
1748
1746
1744
1742
1740
1738
1736
1734
Elevation
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Cumulative Storage (acre ft)

SVERDRI

JOB 40477 Toyota

SHEET NO. 1 OF _____

DATE 6/24/91

COMPUTATIONS FOR Proposed Culvert 70 C 2

BY EDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT: _____

STATION: 341+00 Oval Track

DESIGNER: _____

DATE: _____

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 0.19 Sq. Mils

Q_1 = 41 cfs

Q_2 = _____

TW_1 = 1.66'

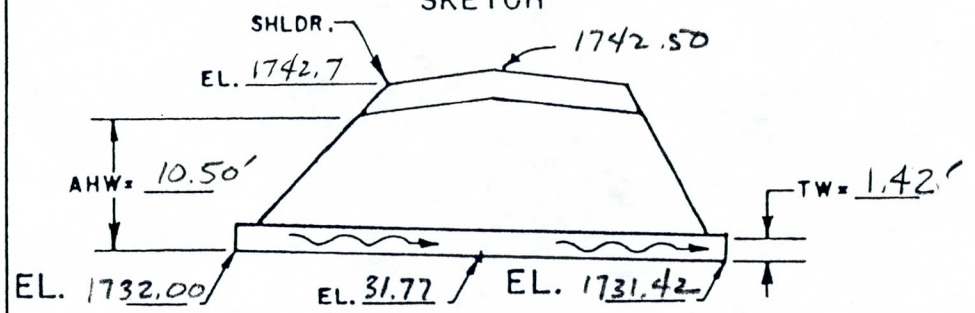
TW_2 = _____

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q25~~) Q100

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_0 = .0050 ft/ft L = 116' L/100 S_0 = _____

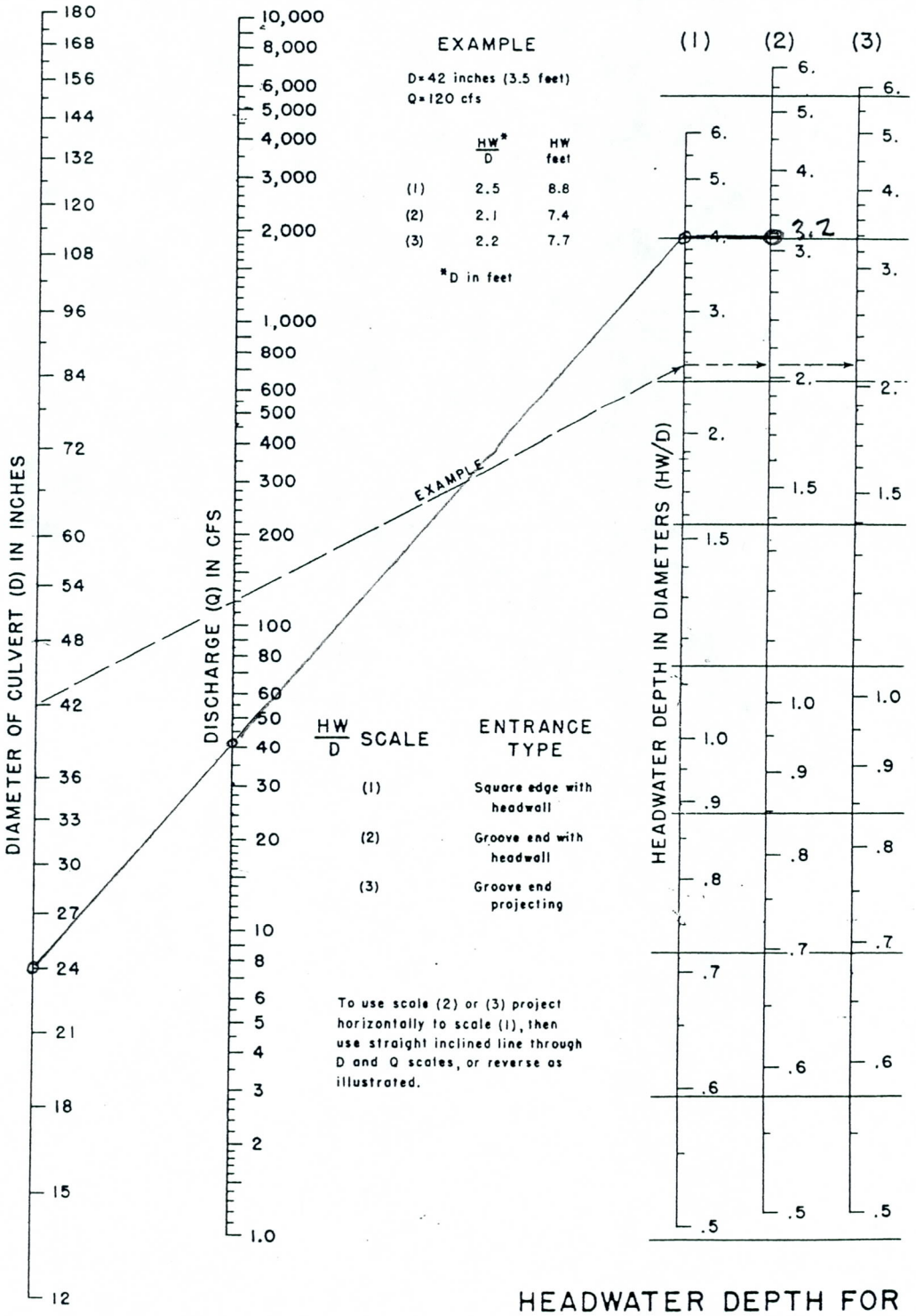
MEAN STREAM VELOCITY = 4.28 fps

CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL HW = H + h_o − LS_o												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
24" RCP	Headwalls	41		3.2	6.4	0.2	6.3	2.0	2.0	1.42	2.0	0.58	7.72	7.72	13.0		1739.72	Outlet Control

SUMMARY & RECOMMENDATIONS Use grouted riprap plunge basin to control erosion downstream of culvert.

Culvert 70 C

CHART 2

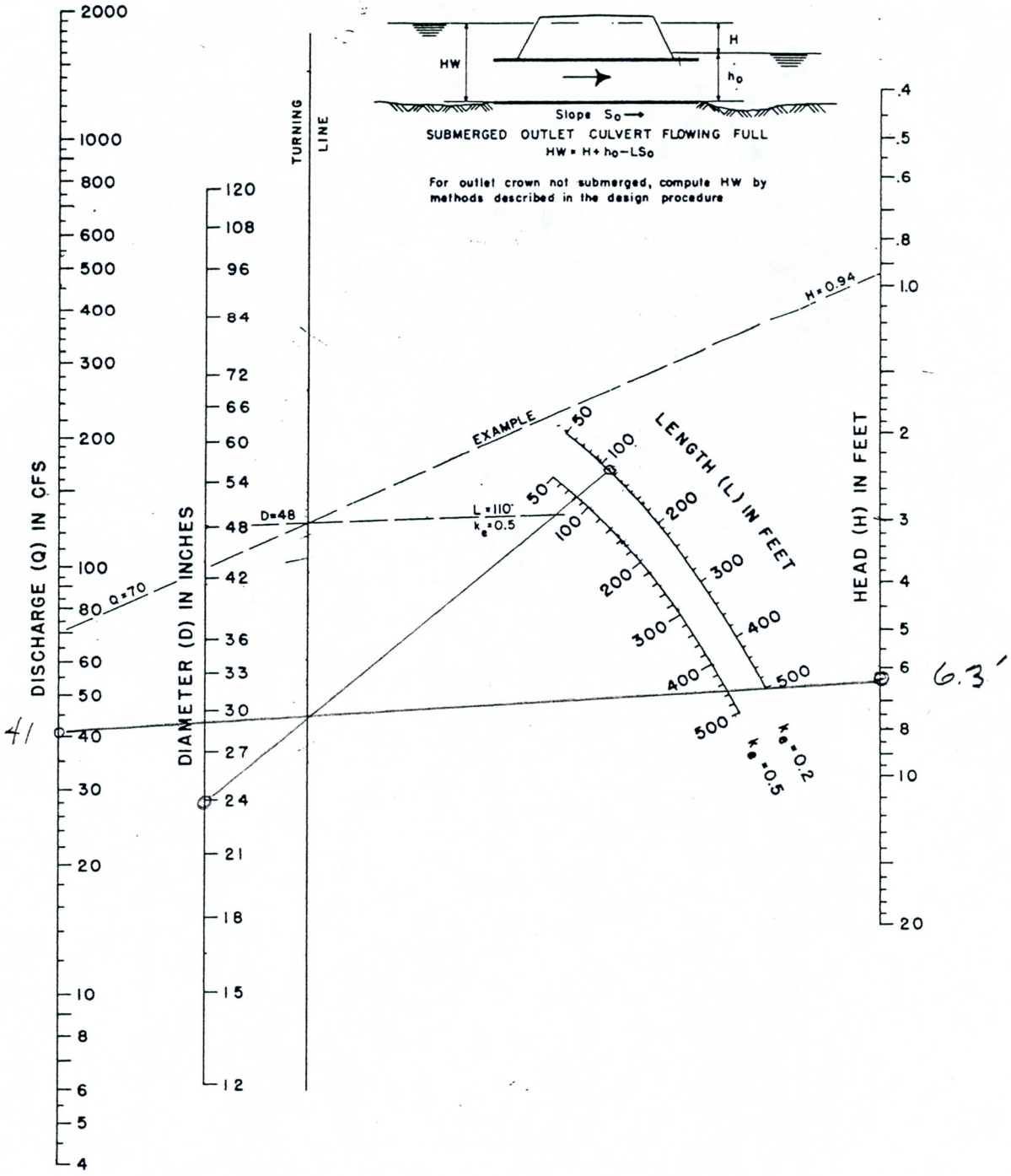


HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 70 C

CHART 9

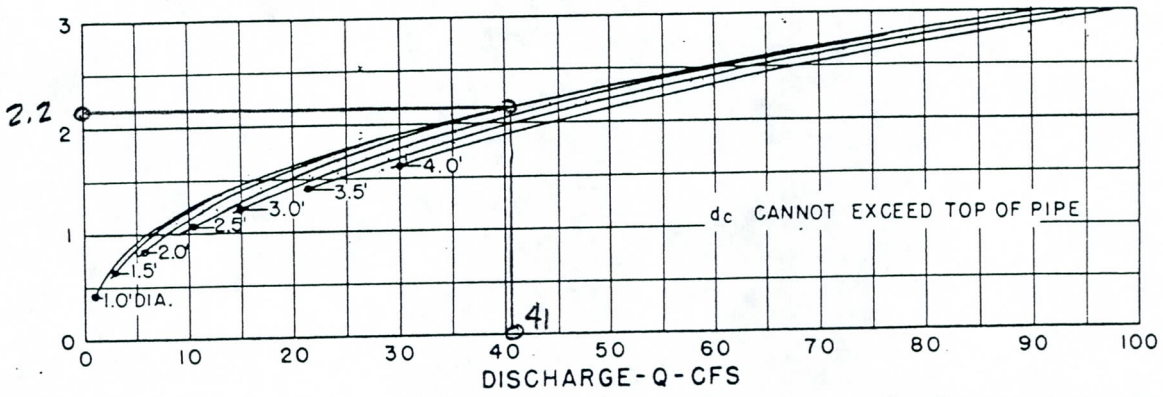


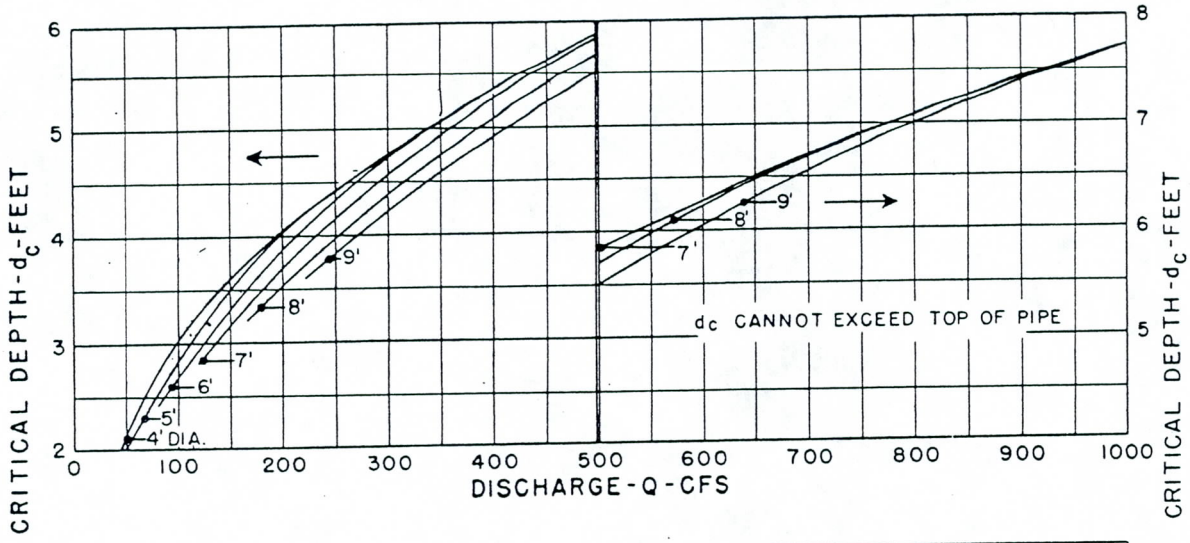
HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

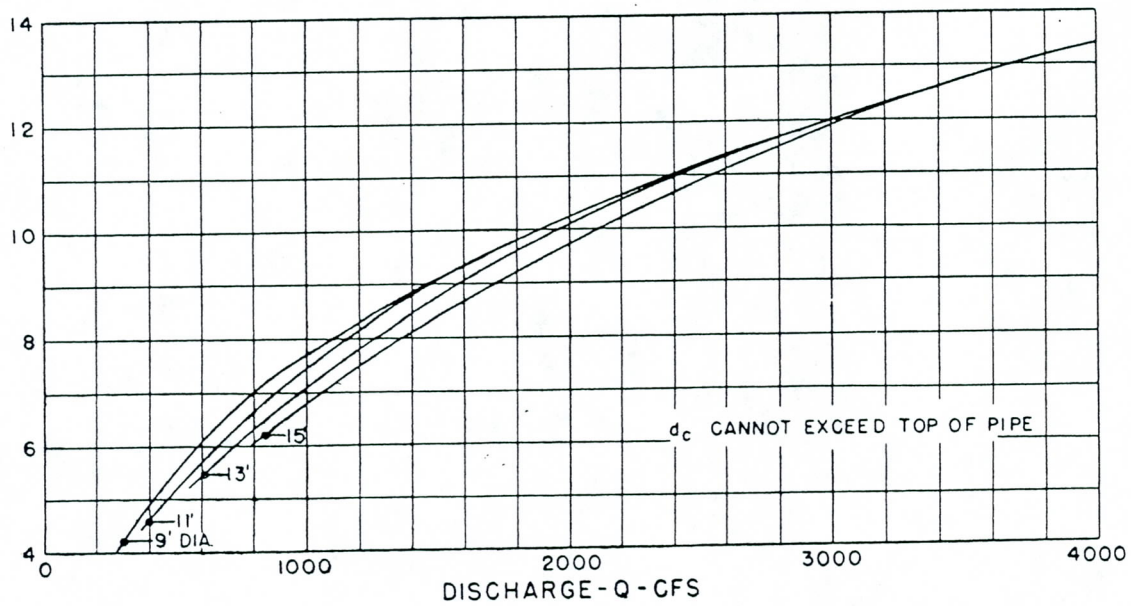
BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 70 C

CHART 16







BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Proposed Culvert 70C

SHEET NO. 5 OF

DATE 6/24/91

BY BDO CHKD RJT

Check outlet velocity for 24" Pipe

$Q_{100} = 41$ cfs $\quad n = 0.013 \quad d = 2.0' \quad S = 0.0050\%$

$$K = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{41(.013)}{(2)^{8/3}(.005)^{1/2}} = 1.188$$

(Beyond limits of Open Channel Flow :: Pipe Full)

$$V = Q/A = 41 \text{ ft}^3/\text{sec} / 3.142 \text{ ft}^2 = \underline{13.0 \text{ fps}}$$

Check Froude Number

$$F = \frac{V}{\sqrt{g y_o}} = \frac{13.0}{\sqrt{32.2(2)}} = 1.62$$

Use Grouted Riprap Plunge Basin $F = 1.62 < 3.0$ (OK)

SVERDRUP

JOB 40477 Toyota

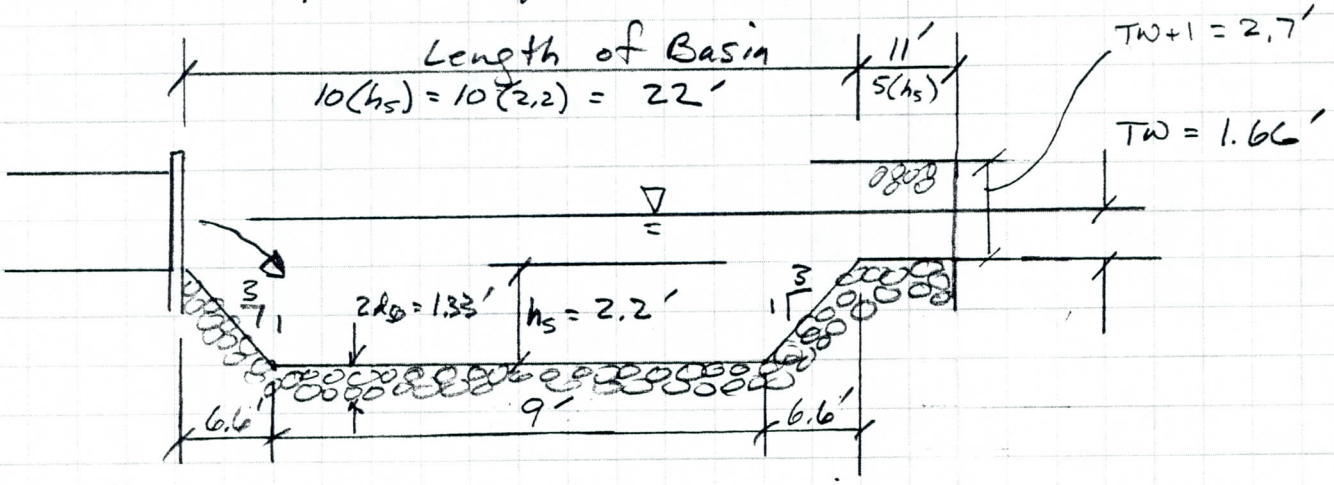
COMPUTATIONS FOR Erosion Protection Culvert 70 C

SHEET NO. 6 OF

DATE 6/25/91

BY BDO CHKD RJT

Riprap Plunge Basin Design.



Check Rock Size (From Figure XI-2, HEC No. 14)

For $Y_o = 2.0'$ $d_{50} = 6''$ or $0.50'$

$$d_{50}/Y_o = \frac{0.50}{2.00} = 0.25 \text{ , } F = 1.62$$

$$h_s/Y_o = 1.45 \quad h_s = 1.45(2.0) = 2.90'$$

Check $\frac{h_s}{d_{50}} = \frac{2.90}{0.50} = 5.80 > 4.0$ (N.G)

Try $d_{50} = 8''$ or $0.67'$

$$d_{50}/Y_o = \frac{0.67}{2.00} = 0.335$$

$$h_s/Y_o = 1.1 \text{ , } h_s = 1.1(2.0) = 2.2'$$

Check $\frac{h_s}{d_{50}} = \frac{2.2}{0.67} = 3.28 < 4.0$ and > 2 $\therefore$ (OK)

Culvert 70 C

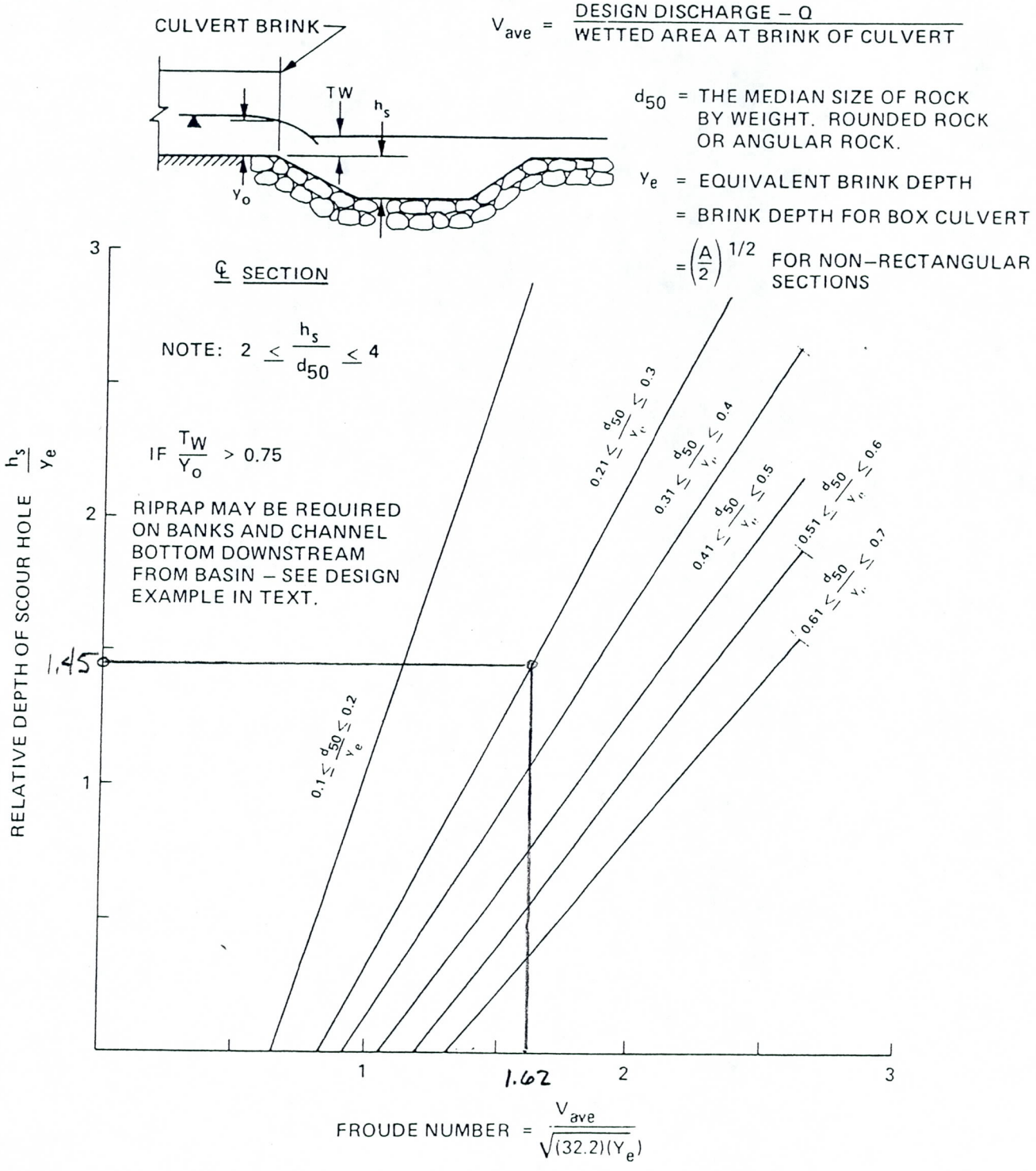


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Erosion Protection Culvert 70 C

SHEET NO. 8 OF

DATE 6/25/91

BY BDO CHKD RJT

$TW/Y_o = \frac{1.66'}{2.0'} = 0.83 > 0.75$ ∴ Check downstream riprap lining for channel

Utilize figure XI-3 for estimating average velocity along channel.

From downstream X-section Q100 velocity is 4.2 fps.

L/D_c	L	V_L/V_o	V_L
10	20 ft	.59	7.7 fps
15	30 ft	.36	4.7 fps
20	40 ft	.30	3.9 fps

Plunge Basin Length is 33' ∴ Release velocity should be less than 4.7 fps (OK)

SVERDRUP

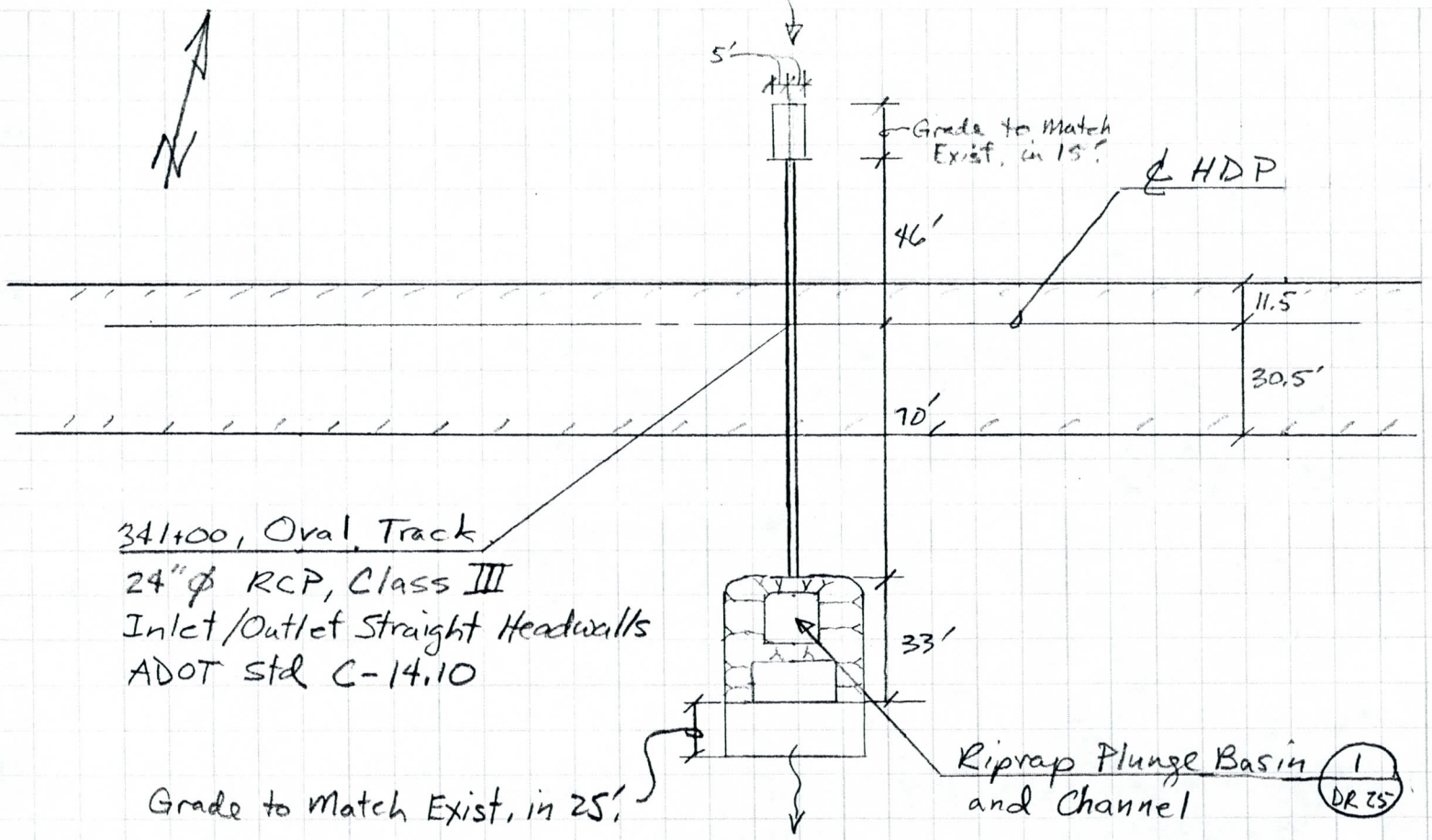
JOB 40477 Toyota

COMPUTATIONS FOR Pipe Culvert 70C [2]
Plan View

SHEET NO. 9 OF

DATE 6/25/91

BY BDD CHKD RTT



Plan View
Culvert 70C

SVERDRUP

JOB 4D477 Toyota

COMPUTATIONS FOR Culvert Profile 70C [2]

HST Sta 341+00 ±

SHEET NO. 10 OF

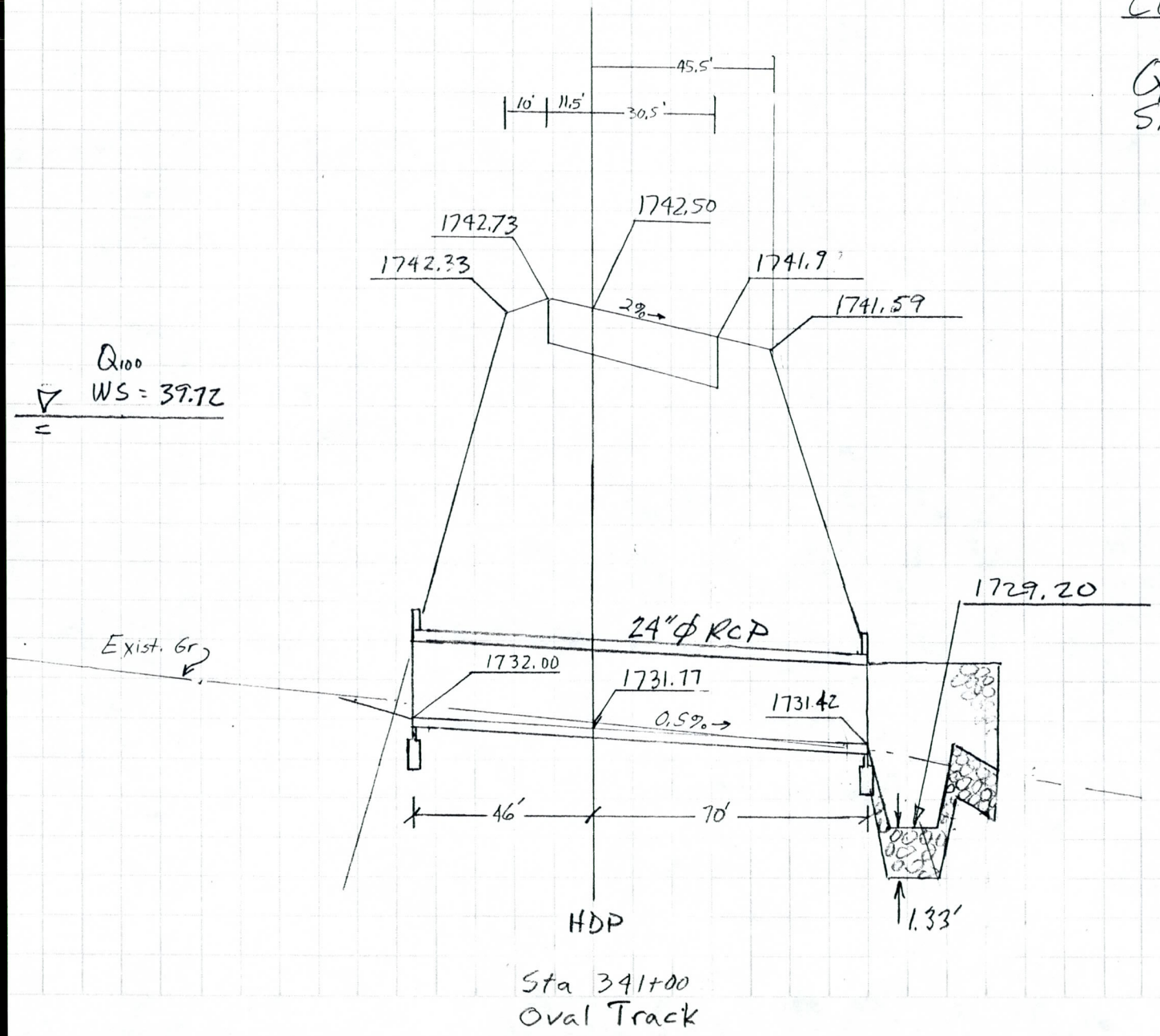
DATE 6-4-91

BY DFP CHKD RTT

Culvert 70C [2]

Q_{100} = 41 cfs

Skew = 0°



Sta 341+00
Oval Track

Scale:
Horiz: 1" = 40'
Vert: 1" = 4'

SECTION NUMBER TW70C 6/10/91

Channel Slope: 0.0126 ft./ft.

CROSS SECTION DATA:

OFFSET	15.9	21.8	57.3	77.1	79.7	82.4	84	88.4	120.9
ELEV.	33.21	34.37	34.24	30.17	29.16	29.38	30.52	31.92	33.2
N	N/A	0.035	0.035	0.035	0.04	0.025	0.04	0.035	0.035

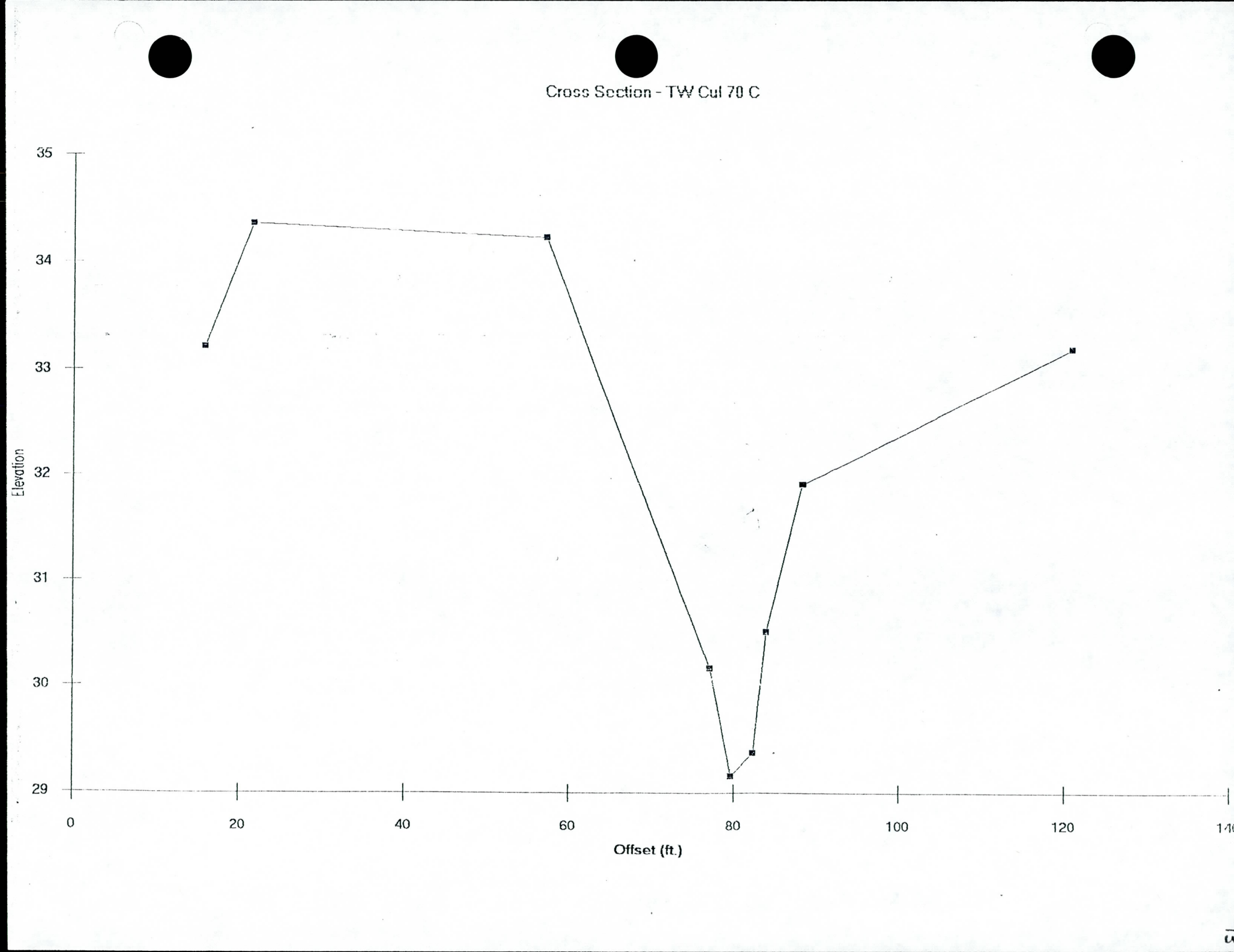
STAGE-DISCHARGE DATA:

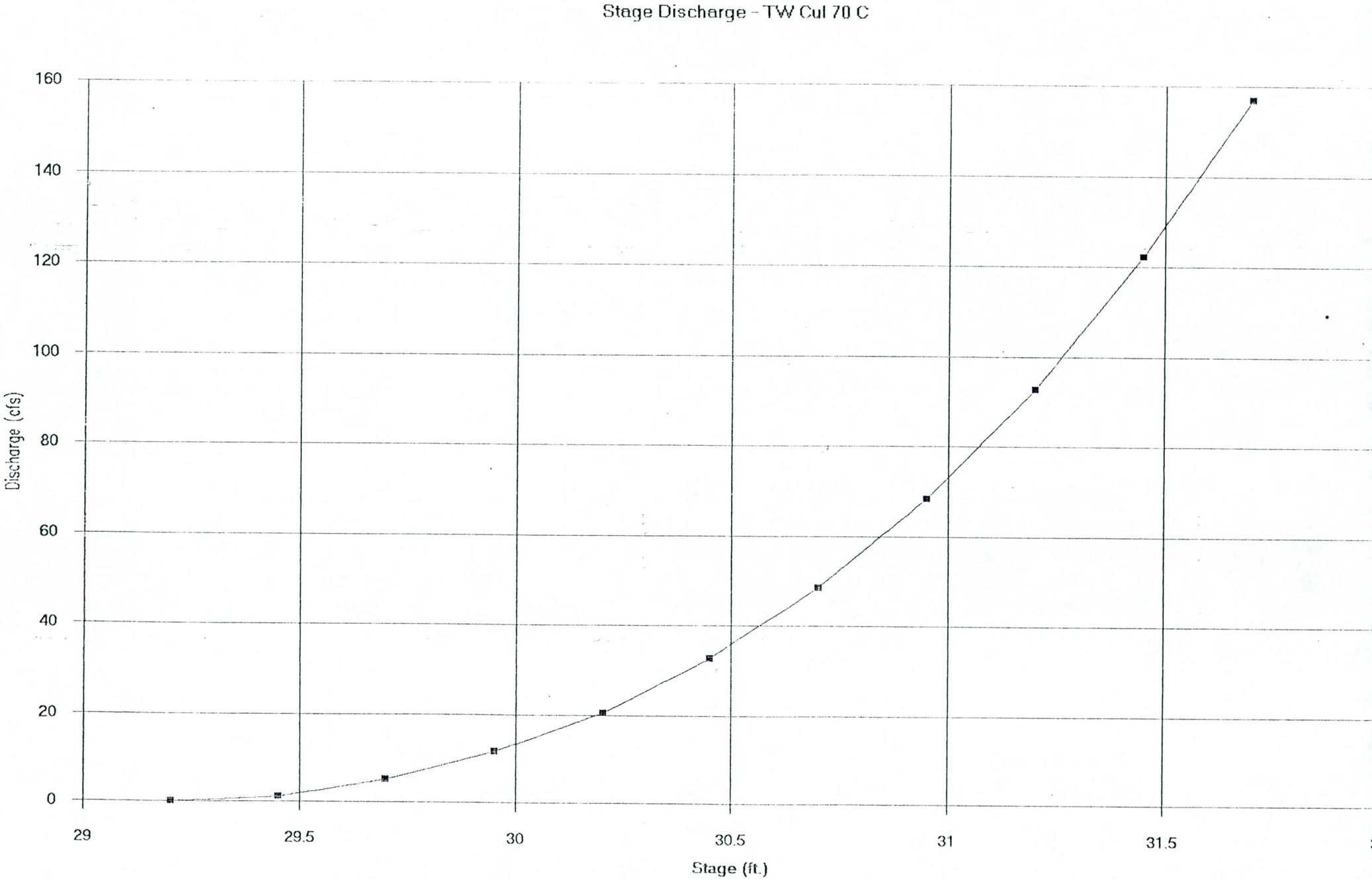
STAGE:	29.2											
WET PER.		0.0	0.0	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	29.45											
WET PER.		0.0	0.0	0.0	0.8	2.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	1	0	0	0	0	0	0	0
STAGE:	29.7											
WET PER.		0.0	0.0	0.0	1.5	2.7	0.6	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.4	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.3	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	1	4	0	0	0	0	0	0	0
STAGE:	29.95											
WET PER.		0.0	0.0	0.0	2.2	2.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.8	1.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.4	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	2	9	0	0	0	0	0	0	0
STAGE:	30.2											
WET PER.		0.0	0.0	0.2	2.8	2.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	1.4	2.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.5	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	4	16	1	0	0	0	0	0	0
STAGE:	30.45											
WET PER.		0.0	0.0	1.4	2.8	2.7	1.8	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.2	2.0	3.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.7	1.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	7	24	2	0	0	0	0	0	0

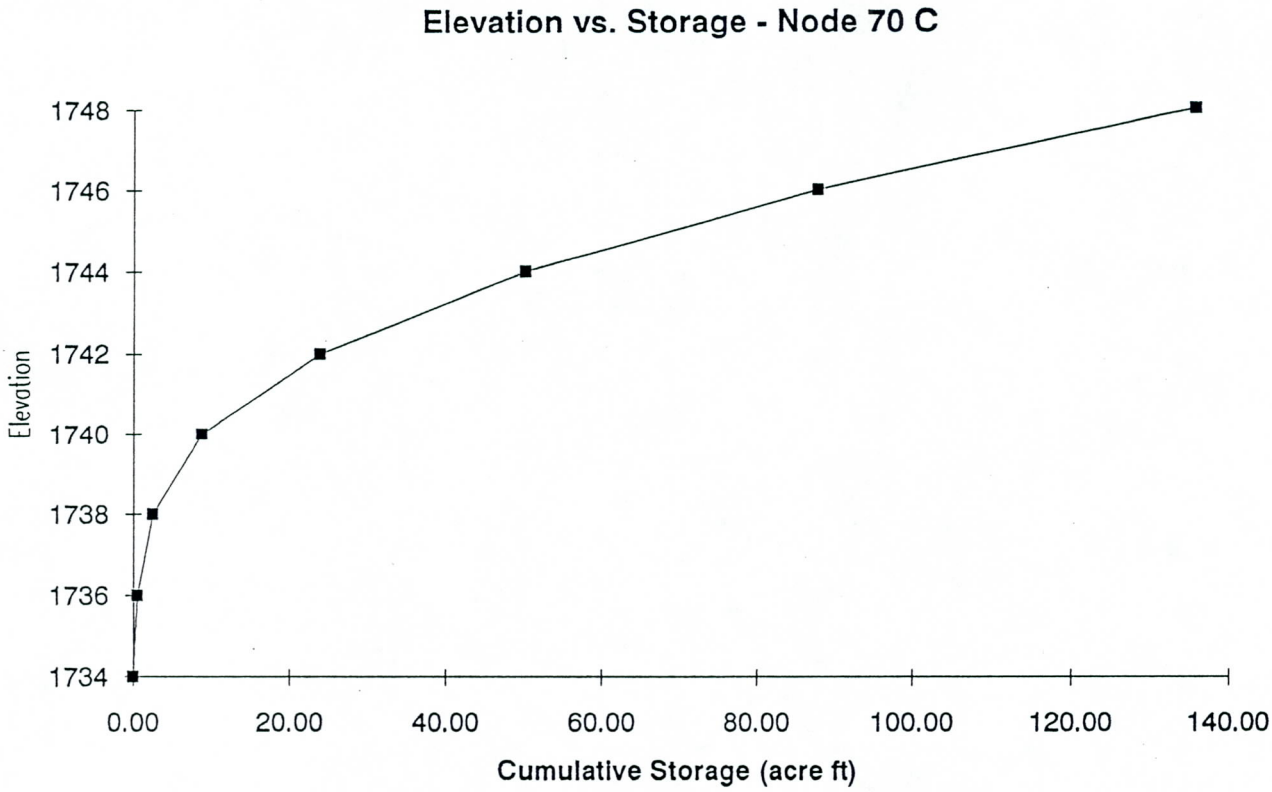
SECTION NUMBER TW70C 6/10/91

STAGE:	30.7											
WET PER.		0.0	0.0	2.6	2.8	2.7	2.0	0.6	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.7	2.7	3.9	1.2	0.1	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.3	1.0	1.4	0.6	0.1	0.0	0.0	0.0	0.0	0.0
Q		0	0	1	11	33	4	0	0	0	0	0	0
STAGE:	30.95												
WET PER.		0.0	0.0	3.9	2.8	2.7	2.0	1.4	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.5	3.3	4.5	1.6	0.3	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.4	1.2	1.7	0.8	0.2	0.0	0.0	0.0	0.0	0.0
Q		0	0	4	16	43	6	0	0	0	0	0	0
STAGE:	31.2												
WET PER.		0.0	0.0	5.1	2.8	2.7	2.0	2.2	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	2.6	4.0	5.2	2.0	0.7	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.5	1.4	1.9	1.0	0.3	0.0	0.0	0.0	0.0	0.0
Q		0	0	8	21	54	8	2	0	0	0	0	0
STAGE:	31.45												
WET PER.		0.0	0.0	6.4	2.8	2.7	2.0	3.1	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	4.0	4.6	5.9	2.4	1.4	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.6	1.7	2.2	1.2	0.4	0.0	0.0	0.0	0.0	0.0
Q		0	0	14	27	66	11	4	0	0	0	0	0
STAGE:	31.7												
WET PER.		0.0	0.0	7.6	2.8	2.7	2.0	3.9	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	5.7	5.3	6.6	2.8	2.2	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.7	1.9	2.4	1.4	0.6	0.0	0.0	0.0	0.0	0.0
Q		0	0	22	34	79	15	7	0	0	0	0	0

W.S. Elev.	29.2	29.45	29.7	29.95	30.2	30.45	30.7	30.95	31.2	31.45	31.7
Q	0	1	5	12	21	33	49	68	93	122	157
A	0.0	0.6	1.6	2.9	4.4	6.2	8.5	11.2	14.5	18.3	22.5
V	0.5	1.9	3.2	4.0	4.7	5.3	5.7	6.1	6.4	6.7	7.0


Cross Section - TW Cul 70 C
35
34
33
32
31
30
29
Elevation
0
20
40
60
80
100
120
Offset (ft.)


Stage Discharge - TW Cul 70 C
160
140
120
100
80
60
40
20
0
Discharge (cfs)
29
29.5
30
30.5
31
31.5
Stage (ft.)


Elevation vs. Storage - Node 70 C
1748
1746
1744
1742
1740
1738
1736
1734
Elevation
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Cumulative Storage (acre ft)

SVERDR

JOB 404 Toyota

SHEET NO. ____ OF ____

DATE 6/26/91

COMPUTATIONS FOR Proposed Culvert 69 [3] BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT: ____

STATION: 331+40, Oval Track

DESIGNER: ____

DATE: ____

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 3.81 sq. miles

Q_1 = 1706 cfs

Q_2 = ____

TW_1 = 4.6'

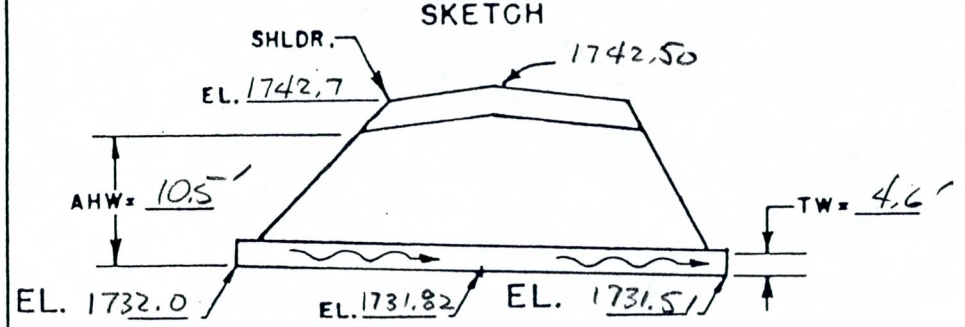
TW_2 = ____

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~ Q_{100})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = 0.0050', L = 98' L/100 S_o = ____

MEAN STREAM VELOCITY = 4.7 fps

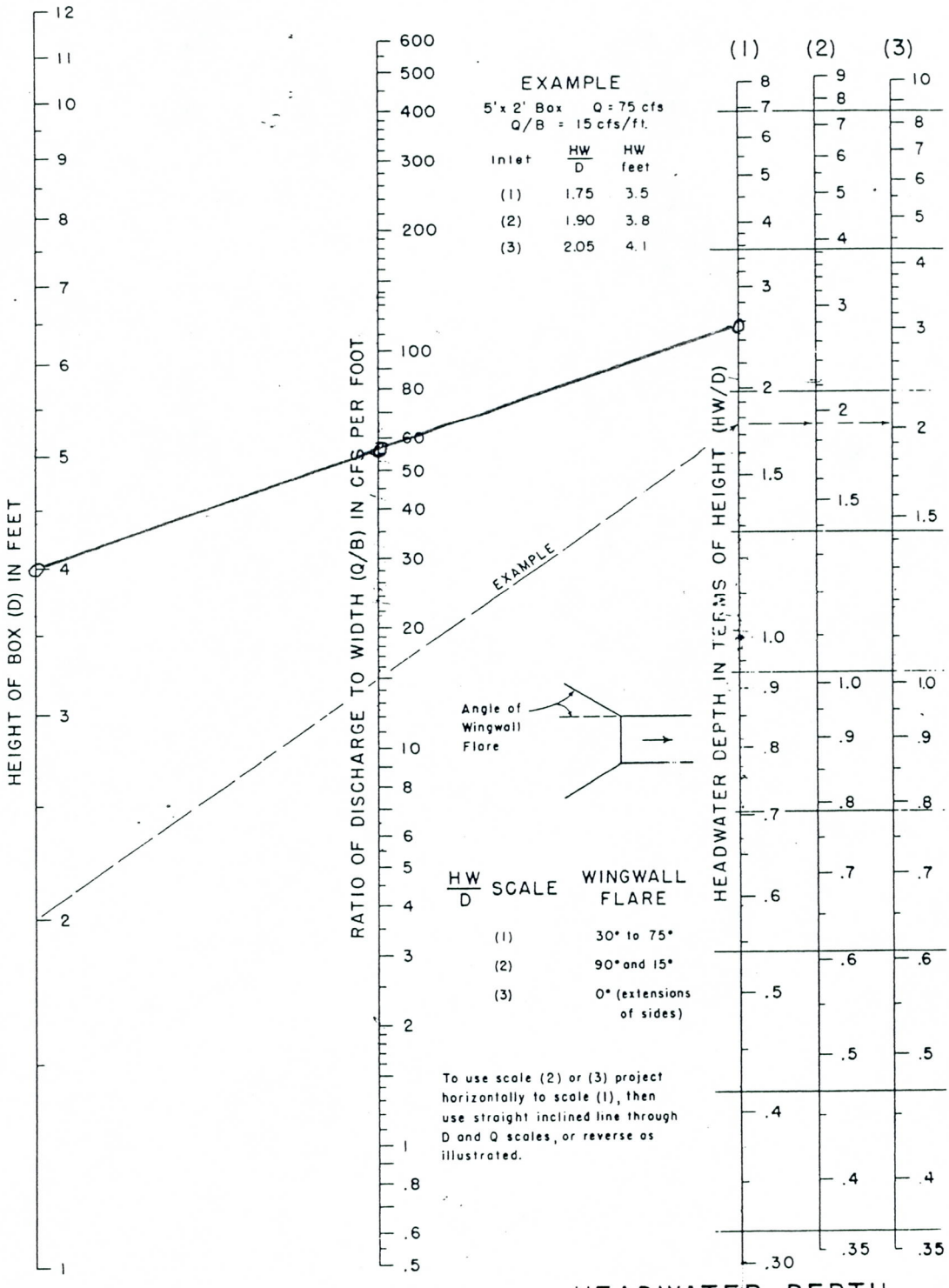
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
3 Barrel 10x4	Drop Inlet	1704/3 = 569		2.55	10.2	0.2	4.6'	4.0'	4.0'	4.6'	4.6'	0.49	8.7	10.2	14.7		1742.20	Inlet Control

SUMMARY & RECOMMENDATIONS

B-10

Culvert 69

CHART 1

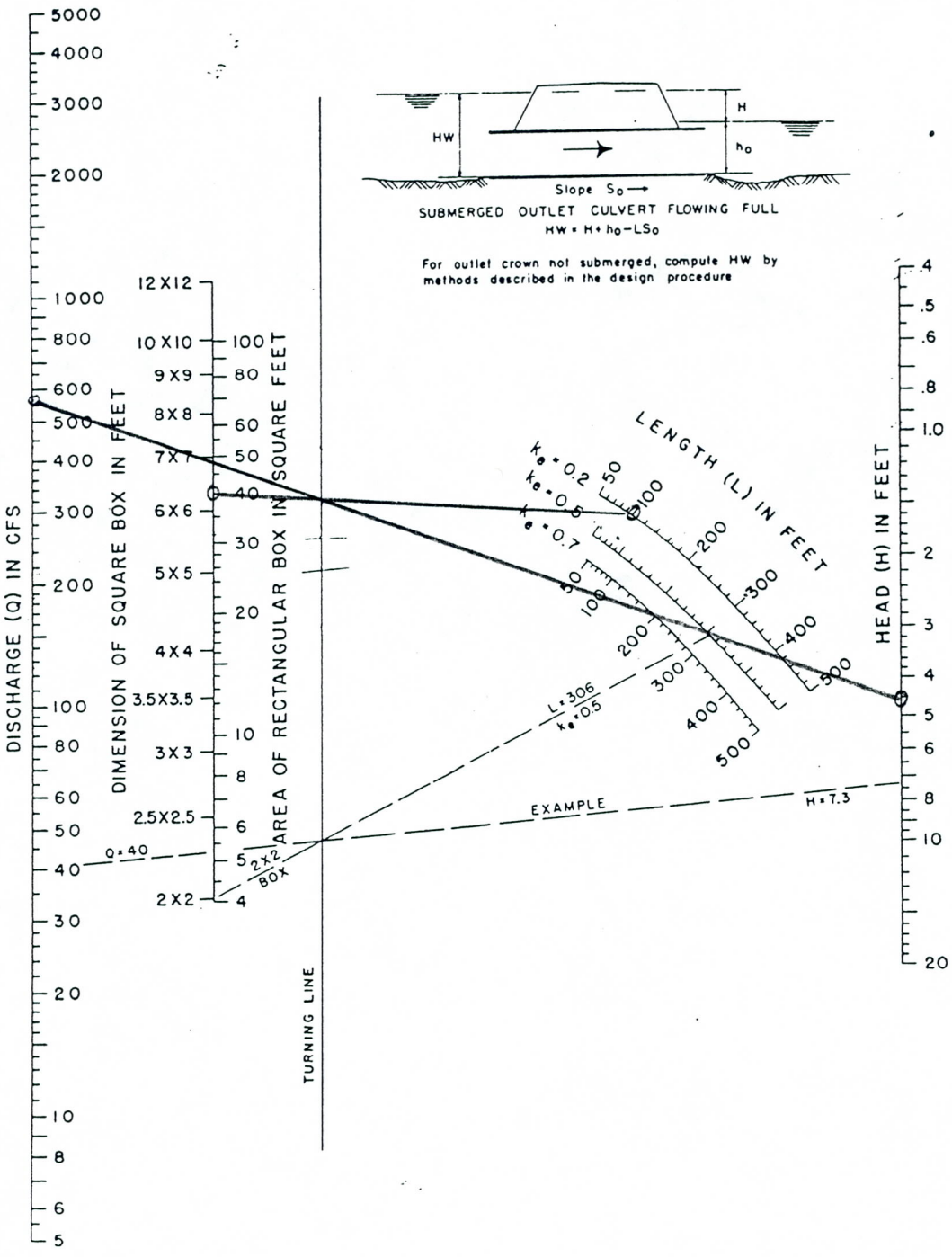


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 69

CHART 8

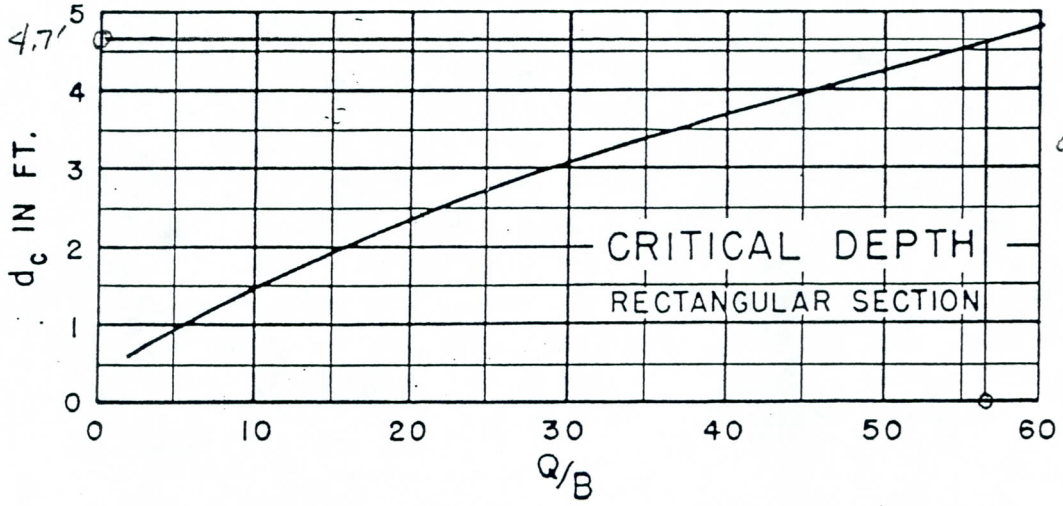


HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

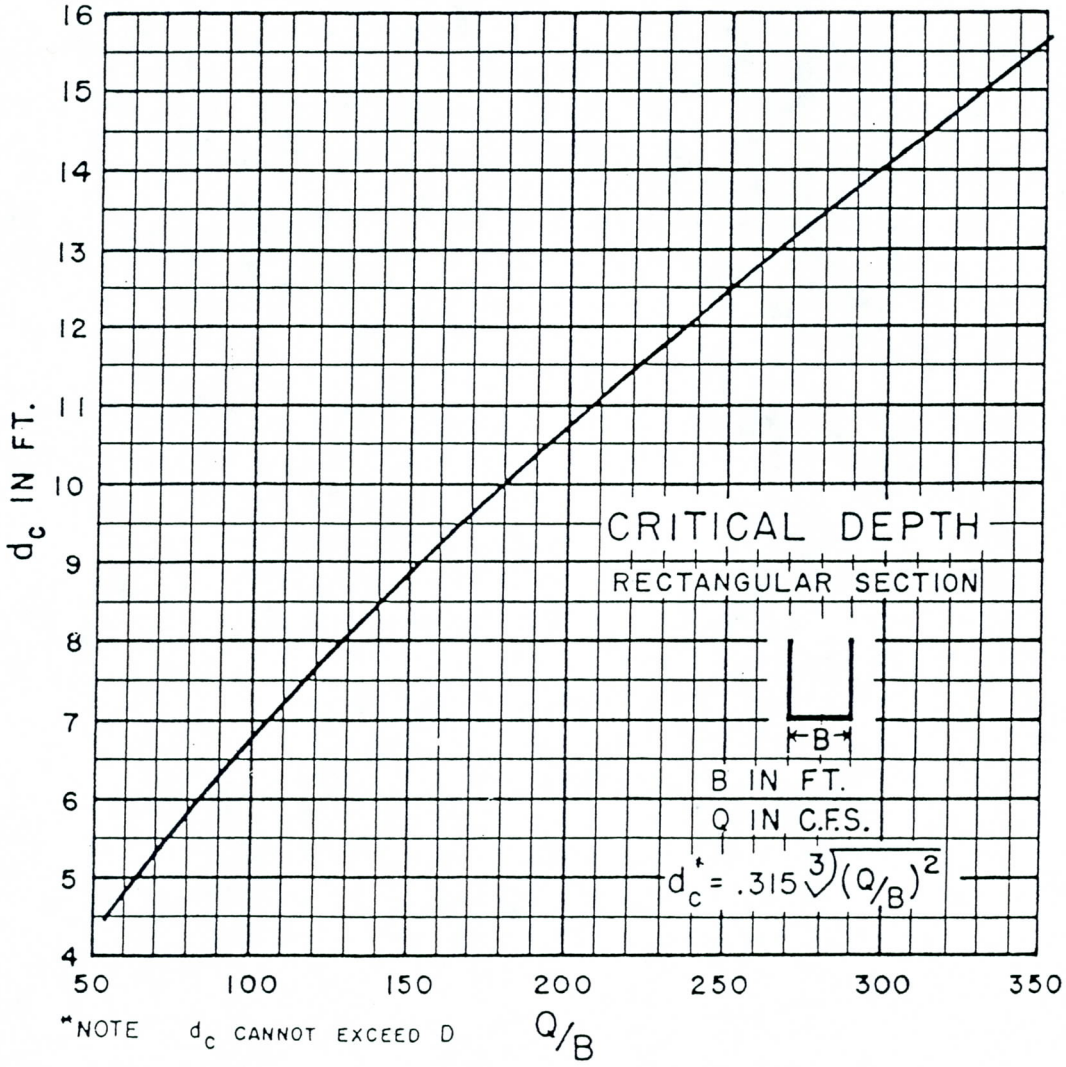
Culvert 69

CHART 15



$d_c = 4.7' > D = 4.0'$

$\therefore$ Use 4.0'



*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Box Culvert 69

SHEET NO. 5 OF

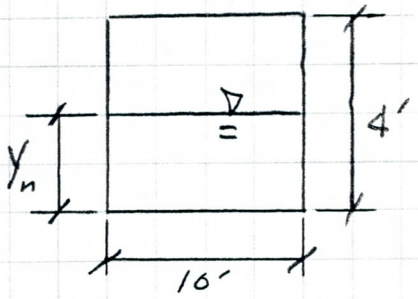
DATE 6/26/91

BY BDO CHKD RJT

Check Depth of Flow using Mannings Equation

$Q_{100} = 1706$ cfs

$Q/barrel = 569$ cfs



$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 3.85'$

$A = 3.85 \times 10 = 38.5$ ft^2

$WP = 2(3.85) + 10 = 17.70$

$R_h = A/WP = 38.5/17.70 = 2.1751$

$$V = \frac{1.49}{0.012}(2.1751)^{.666}(.0050)^{.5} = 14.73$$

$Q = VA = 14.73(38.5) = 567$ cfs (OK)

Check Froude Number

$$F = \frac{V}{\sqrt{g Y_c}} = \frac{14.73}{\sqrt{32.2(3.85)}} = 1.32$$ Supercritical

Channel need protection, Use grouted riprap plunge basin $F < 3.0$ ∴ (OK)

$Q_{10} = 517$ cfs ⇒ 172 cfs/barrel

$Y_n = 1.68'$ Vel. = 10.2 fps, $F = 1.39$, Supercritical

SVERDRUP

JOB 40477 Toyota

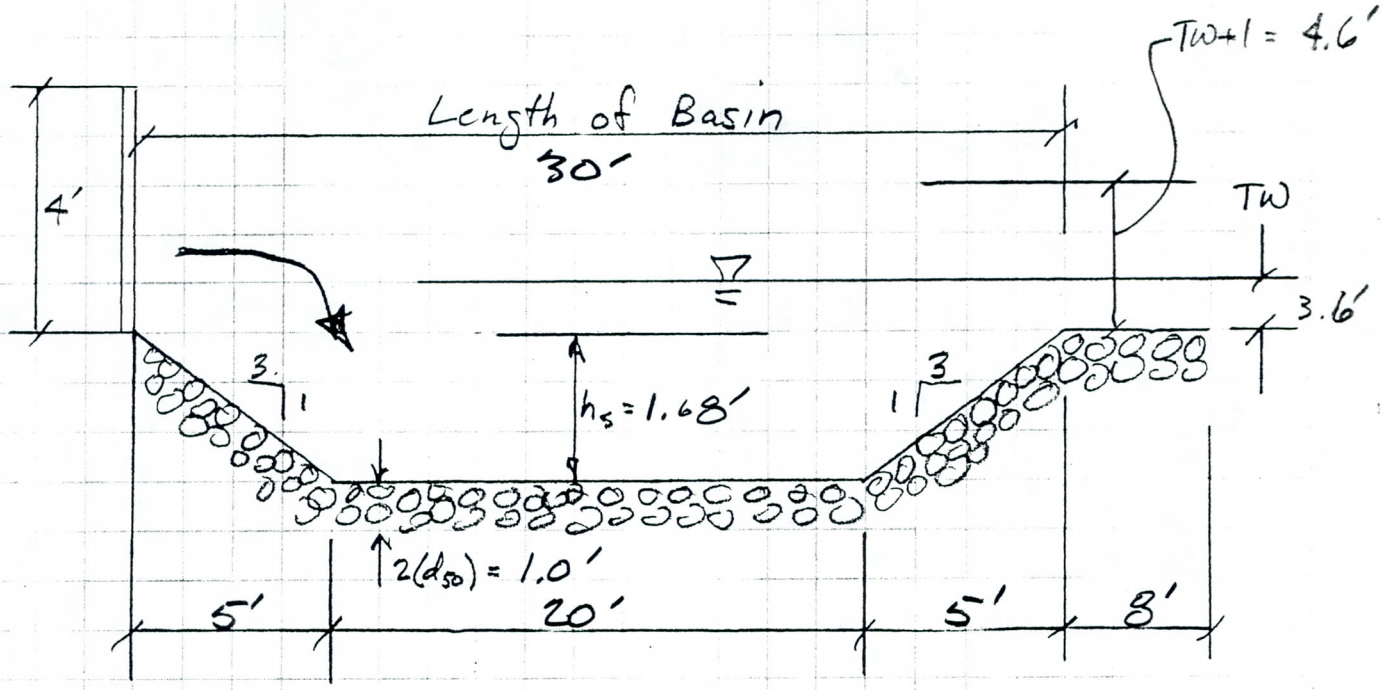
COMPUTATIONS FOR Box Culvert 69

SHEET NO. 6 OF

DATE 6/30/91

BY BDO CHKD RJT

Riprap Plunge Basin Design (Q10)



Check Rock Size (From Figure XI-2, HEC No 14)

For Y_o = 1.68 d_{50} = 6" or 0.5'

$d_{50}/Y_o = \frac{0.50}{1.68} = 0.30$, F = 1.39

$\frac{h_s}{Y_o} = 1.0$ $h_s = 1.0\ (1.68') = 1.68'$

Check $\frac{h_s}{d_{50}} = \frac{1.68'}{0.50'} = 3.36 < 4$ but > 2 ∴ OK

Length of Basin

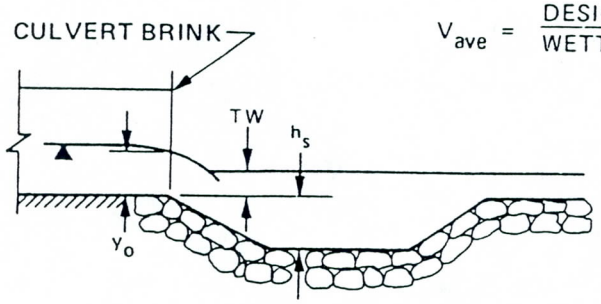
$10\ h_s = 10\ (1.68') = 16.8'$

or

$3(w_o) = 3\ (10') = 30'$

Use 30'

Culvert 69



$$V_{ave} = \frac{\text{DESIGN DISCHARGE} - Q}{\text{WETTED AREA AT BRINK OF CULVERT}}$$

d_{50} = THE MEDIAN SIZE OF ROCK BY WEIGHT. ROUNDED ROCK OR ANGULAR ROCK.

Y_e = EQUIVALENT BRINK DEPTH

= BRINK DEPTH FOR BOX CULVERT

$= \left(\frac{A}{2}\right)^{1/2}$ FOR NON–RECTANGULAR SECTIONS

℄ SECTION

NOTE: $2 \leq \frac{h_s}{d_{50}} \leq 4$

IF $\frac{T_W}{Y_o} > 0.75$

RIPRAP MAY BE REQUIRED ON BANKS AND CHANNEL BOTTOM DOWNSTREAM FROM BASIN – SEE DESIGN EXAMPLE IN TEXT.

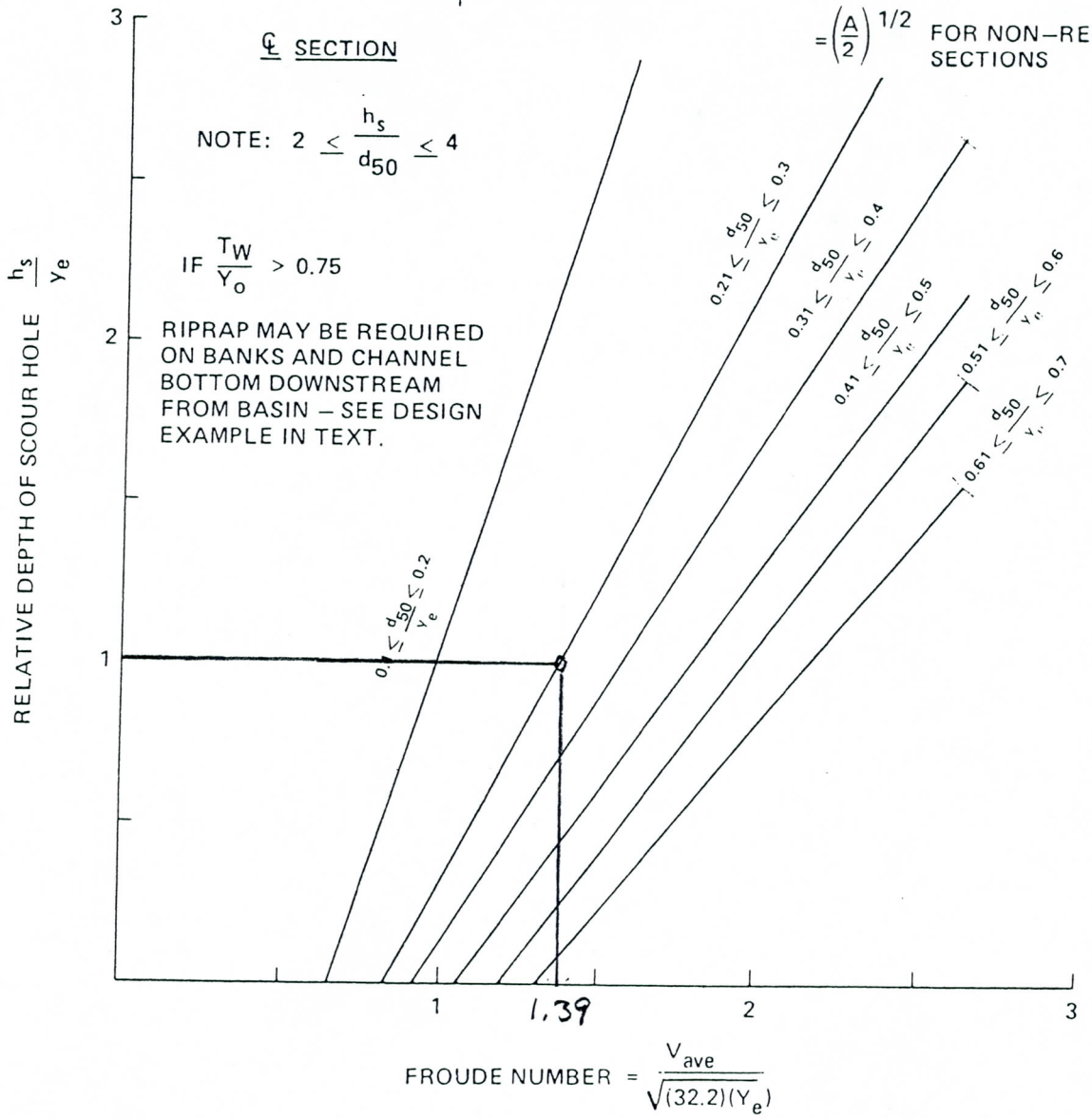


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota SHEET NO. 8 OF

COMPUTATIONS FOR Box Culvert 69 DATE 6/30/91

BY BDO CHKD RJT

$TW/Y_o = \frac{3.6}{1.68} = 2.14 > 0.75$ ∴ Check downstream riprap lining for channel protection.

Utilize figure XI-3 for existing average velocity along channel. Compute equivalent circular diameter D_e for brink area from:

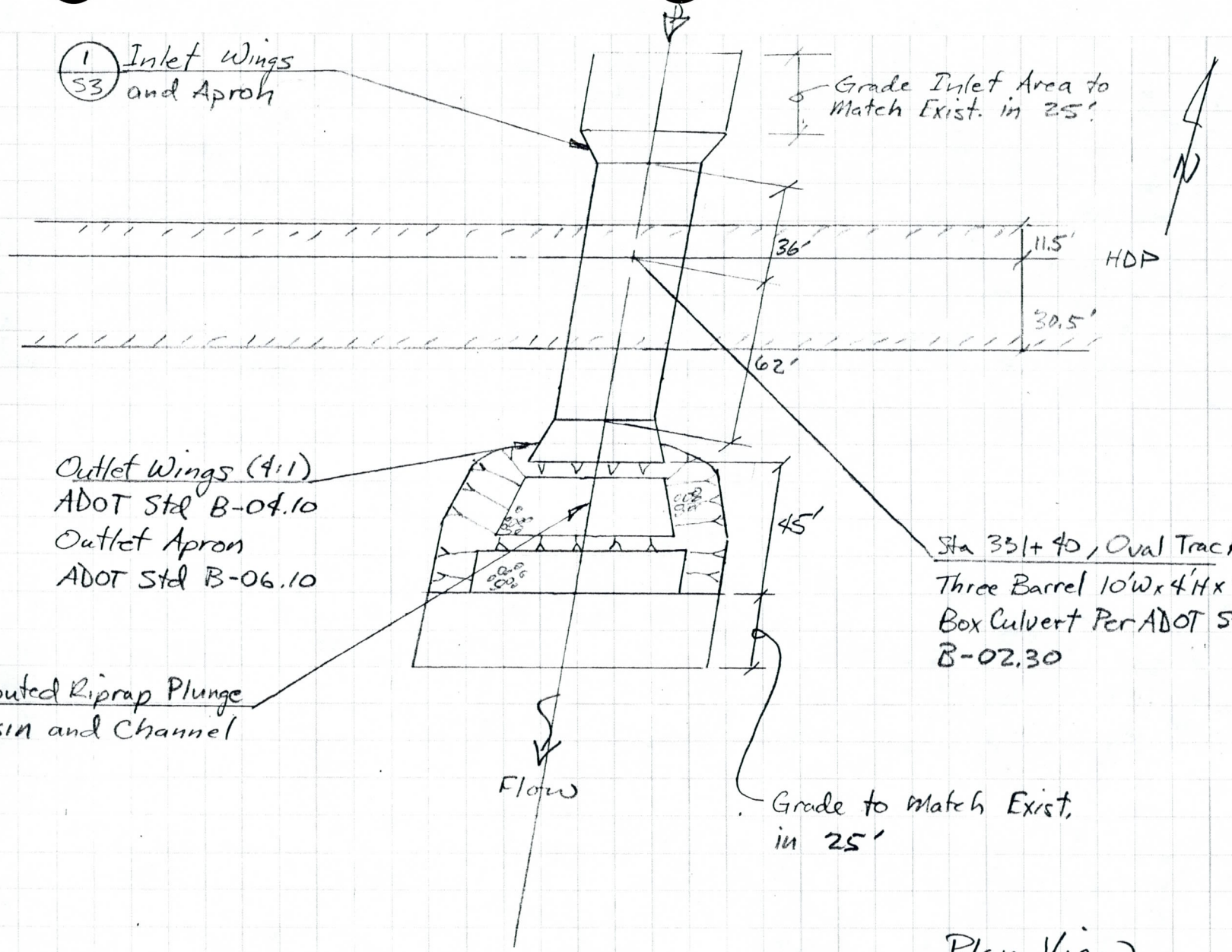
$A = \pi D_e^2/4 = Y_o(W_o) = 16.8\ ft^2$

$D_e = (16.8(4)/\pi)^{1/2} = 4.63'$

From downstream cross section Q10 velocity is 6.0 fps. Culvert outlet velocity is 10.2 fps.

L/D_e	L	V_L/V_o	V_L	
10	46.3'	.59	6.0 fps	OK
15	69.5'	.36	3.7 fps	
20	92.6'	.30	3.1 fps	

∴ Need riprap lining for approximately 45 feet from the end of the culvert outlet apron.



Plan View
Culvert 69

Scale 1" = 50'

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Box Culvert 69 [3]
Plan View

SHEET NO. 9 OF

DATE 6/24/91

BY BDO CHKD RTT

SVERDRUP

JOB 40477 Toyota SHEET NO. 10 OF

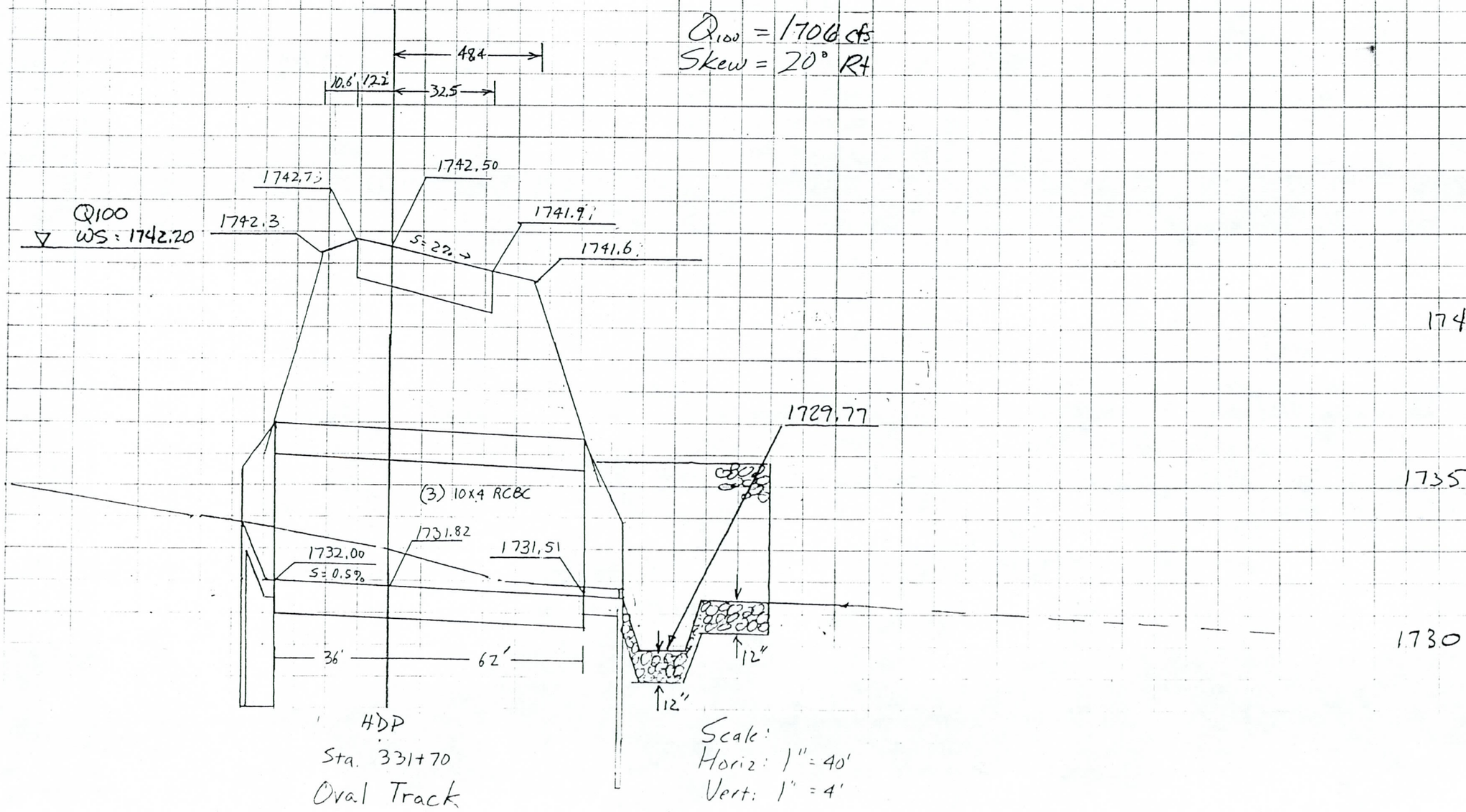
COMPUTATIONS FOR Culvert Profile 69 [3] DATE 6-26-91

Oval Track Sta 331+70 BY DFP CHKD RJT

Culvert 69 [3]

Q_{100} = 1706 cfs

Skew = 20° Rt



SECTION NUMBER TW69 6/10/91

Channel Slope: 0.011 ft./ft.

CROSS SECTION DATA:

OFFSET	11	253.5	271.4	299	310.5	322.4	338.3	341.2	347.4	348.9	436.3	475	500	525	550
ELEV.	36	34.15	32.56	34.77	33.06	34.55	33.85	30.55	30.42	33.61	34.34	35	34	35	34
N	N/A	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.035	0.035	0.035

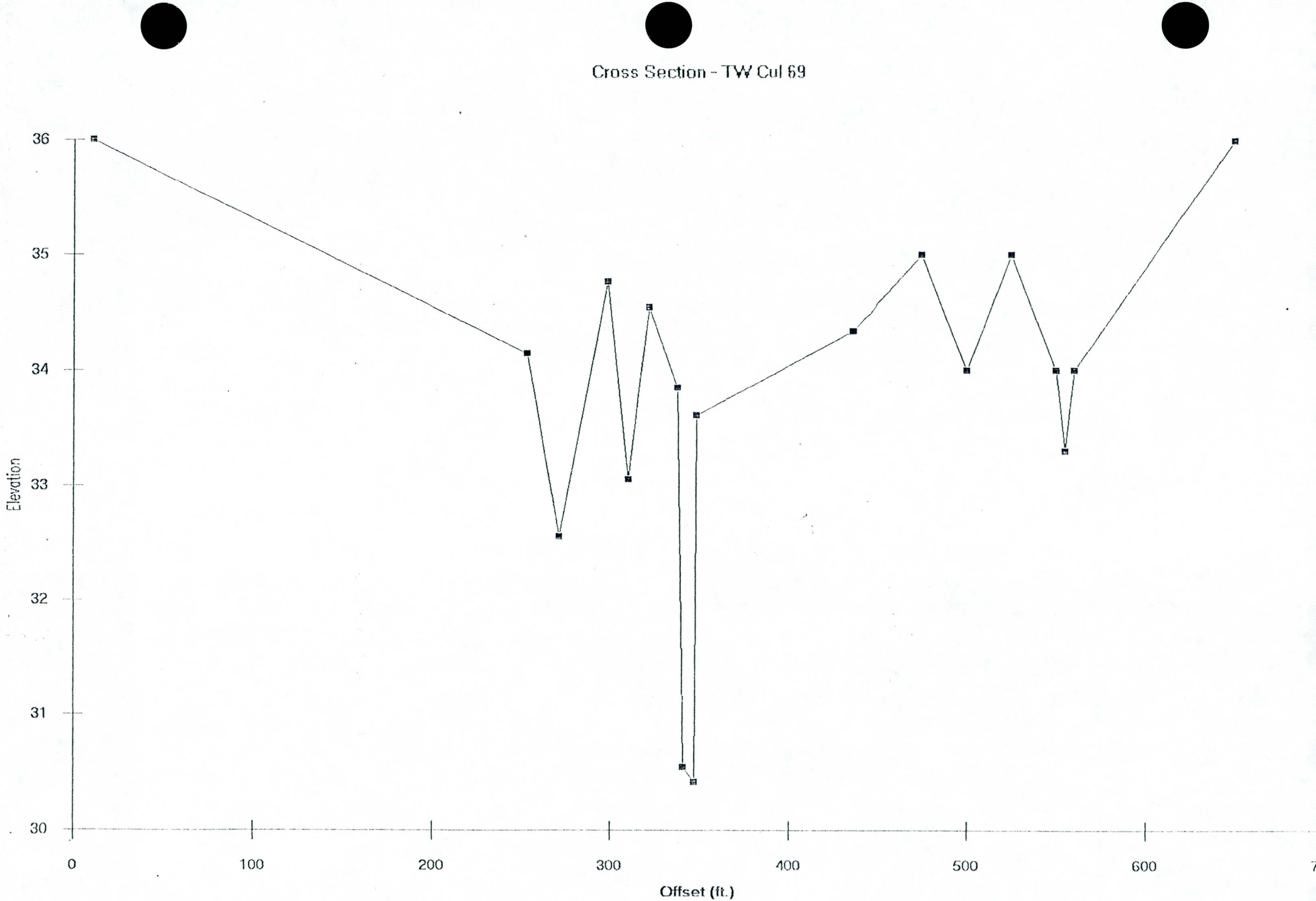
STAGE-DISCHARGE DATA:

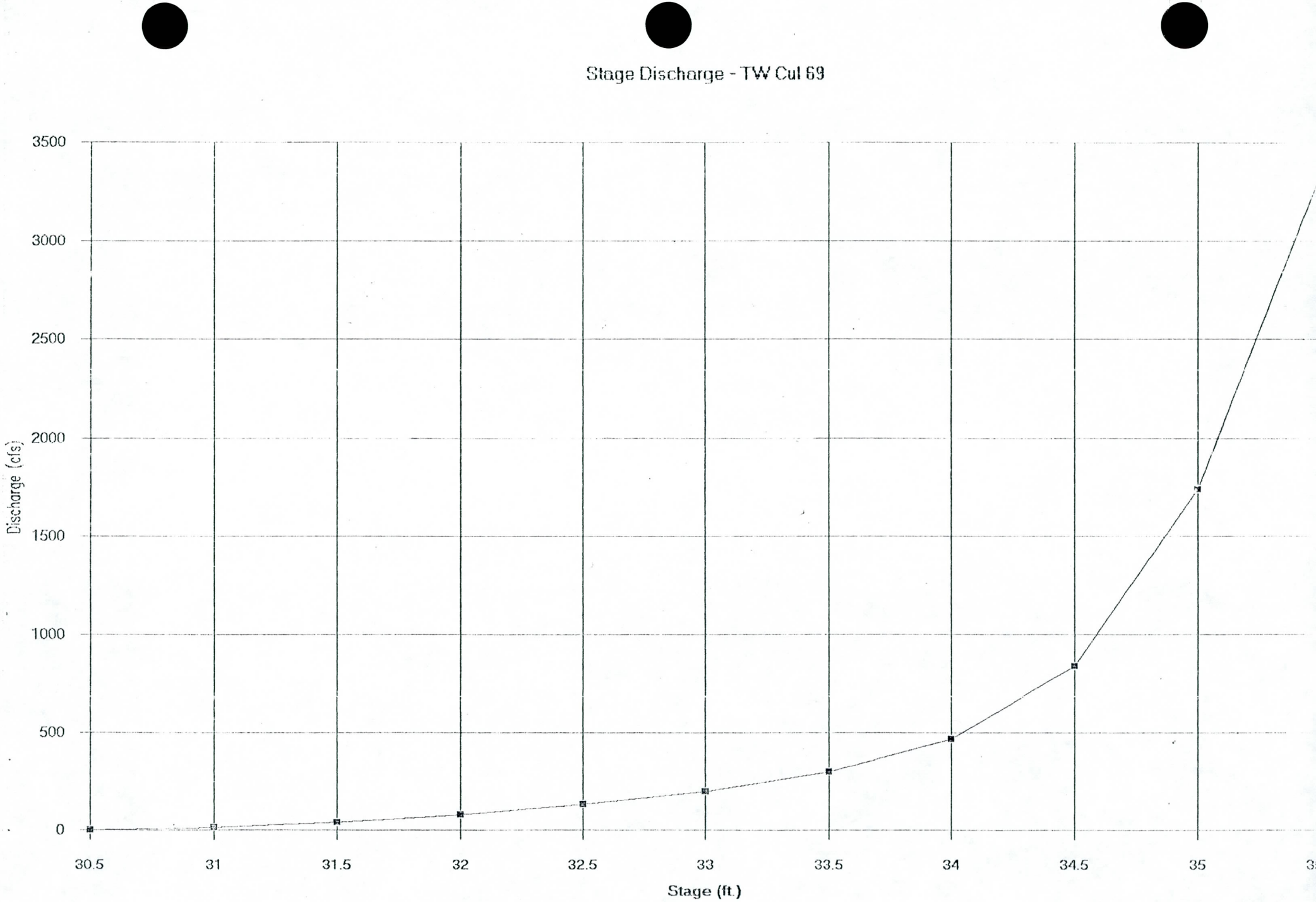
STAGE:	30.5													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.1	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	31													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.6	6.2	0.6	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.1	3.2	0.1	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.1	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	13	0	0	0	0	0	0
STAGE:	31.5													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	1.3	6.2	1.2	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.4	6.3	0.3	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.2	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	1	40	0	0	0	0	0	0
STAGE:	32													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	1.9	6.2	1.8	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.9	9.4	0.6	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.5	0.3	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	3	77	1	0	0	0	0	0
STAGE:	32.5													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	2.6	6.2	2.3	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	1.7	12.5	1.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.6	2.0	0.4	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	6	124	3	0	0	0	0	0
STAGE:	33													
WET PER.	0.0	5.0	10.5	0.0	0.0	0.0	3.3	6.2	2.9	0.0	0.0	0.0	0.0	0.0
AREA	0.0	1.1	2.3	0.0	0.0	0.0	2.6	15.6	1.6	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.2	0.2	0.0	0.0	0.0	0.8	2.5	0.5	0.0	0.0	0.0	0.0	0.0
Q	0	0	4	0	0	0	10	180	5	0	0	0	0	0

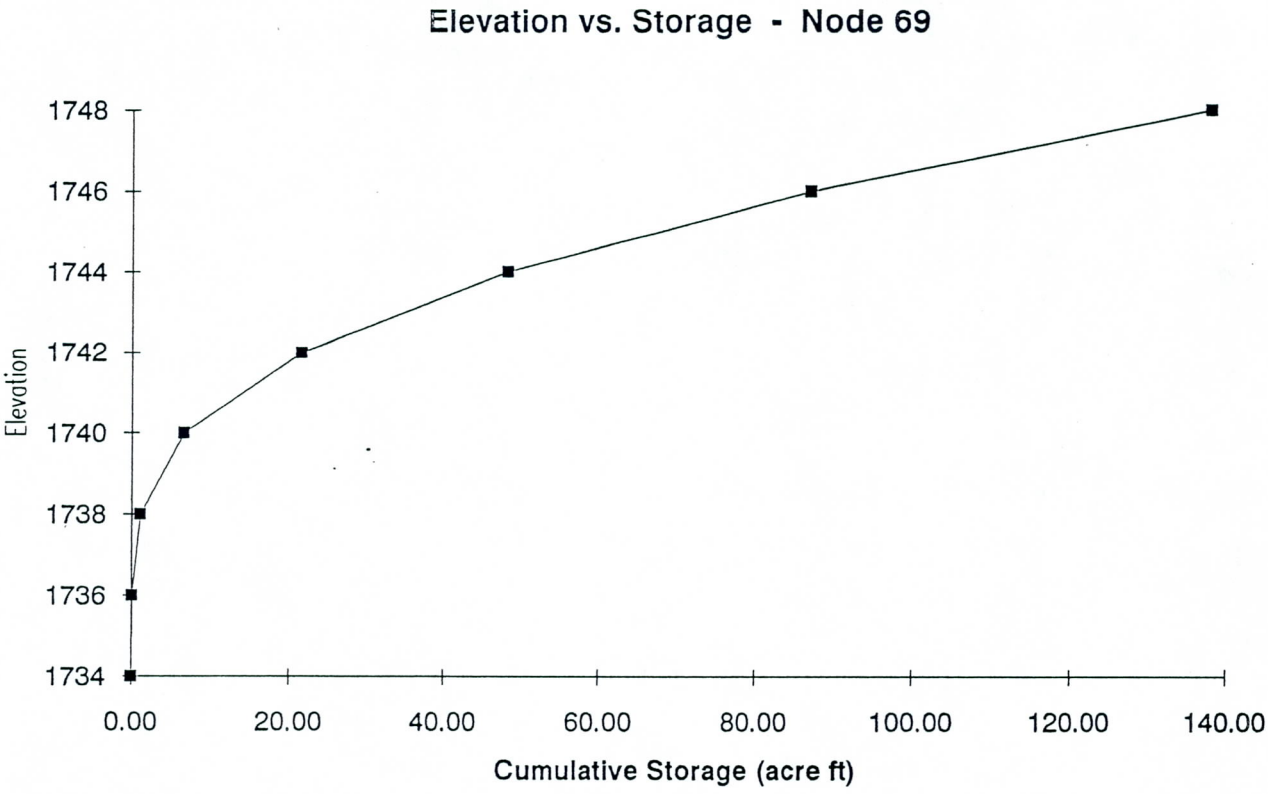
SECTION NUMBER TW69 6/10/91

STAGE:	33.5													
WET PER.		0.0	10.6	22.4	3.0	6.5	0.0	3.9	6.2	3.4	0.0	0.0	0.0	0.0	0.0
AREA		0.0	5.0	10.5	0.7	1.4	0.0	3.8	18.7	2.2	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.5	0.5	0.2	0.2	0.0	1.0	3.0	0.7	0.0	0.0	0.0	0.0	0.0
Q		0	0	28	0	2	0	17	243	7	0	0	0	0	0
STAGE:	34														
WET PER.		0.0	16.3	34.3	6.4	14.0	3.4	7.8	6.2	3.5	50.2	0.0	0.0	0.0	0.0
AREA		0.0	11.7	24.6	3.0	6.5	0.3	5.5	21.8	3.0	12.1	0.0	0.0	0.0	0.0
HYD RAD.		0.0	0.7	0.7	0.5	0.5	0.1	0.7	3.5	0.8	0.2	0.0	0.0	0.0	0.0
Q		0	0	88	0	17	0	19	314	0	21	0	0	0	0
STAGE:	34.5														
WET PER.		45.9	63.9	88.2	9.8	21.4	14.8	19.2	6.2	3.5	90.9	100.3	12.5	25.0	12.5
AREA		8.0	28.5	52.0	7.0	15.3	4.8	11.5	24.9	3.7	49.6	50.4	3.1	6.3	3.1
HYD.RAD.		0.2	0.4	0.6	0.7	0.7	0.3	0.6	4.0	1.1	0.5	0.5	0.2	0.2	0.2
Q		0	0	163	0	54	0	36	392	0	0	142	0	11	0
STAGE:	35														
WET PER.		111.4	129.4	157.1	168.7	180.7	196.6	201.0	6.2	3.5	90.9	129.6	25.0	50.0	25.0
AREA		47.4	76.8	113.6	126.1	140.3	153.1	161.2	28.0	4.5	94.1	106.8	12.5	25.0	12.5
HYD.RAD.		0.4	0.6	0.7	0.7	0.8	0.8	0.8	4.5	1.3	1.0	0.8	0.5	0.5	0.5
Q		0	0	0	0	0	0	619	477	0	0	418	0	70	0
STAGE:	35.5														
WET PER.		177.0	194.9	222.6	234.2	246.2	262.2	266.5	6.2	3.5	90.9	129.6	154.7	179.7	204.7
AREA		119.4	157.8	208.5	226.7	246.9	267.6	277.1	31.1	5.2	138.5	170.6	195.6	220.6	245.6
HYD RAD.		0.7	0.8	0.9	1.0	1.0	1.0	1.0	5.0	1.5	1.5	1.3	1.3	1.2	1.2
Q		0	0	0	0	0	0	1266	568	0	0	0	0	0	0

W.S. Elev.	30.5	31	31.5	32	32.5	33	33.5	34	34.5	35	35.5
Q	0	13	41	81	132	198	298	467	839	1739	3341
A	0.2	3.4	7.0	10.9	15.2	22.1	36.9	74.0	177.5	369.5	623.0
V	0.7	3.9	5.9	7.4	8.7	9.0	8.1	6.3	4.7	4.7	5.4


Cross Section - TW Cul 69
36
35
34
33
32
31
30
Elevation
0
100
200
300
400
500
600
Offset (ft.)


Stage Discharge - TW Cul 69
3500
3000
2500
2000
1500
1000
500
0
Discharge (cfs)
30.5
31
31.5
32
32.5
33
33.5
34
34.5
35
Stage (ft.)


Elevation vs. Storage - Node 69
1748
1746
1744
1742
1740
1738
1736
1734
Elevation
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
Cumulative Storage (acre ft)

SVERDR

JOB 404 Toyota SHEET NO. 1 OF

DATE 6/19/91

COMPUTATIONS FOR Proposed Culvert 67F4 BY RDO CHKD RVT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 316+40 Oval Track

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 0.58 Sq. miles

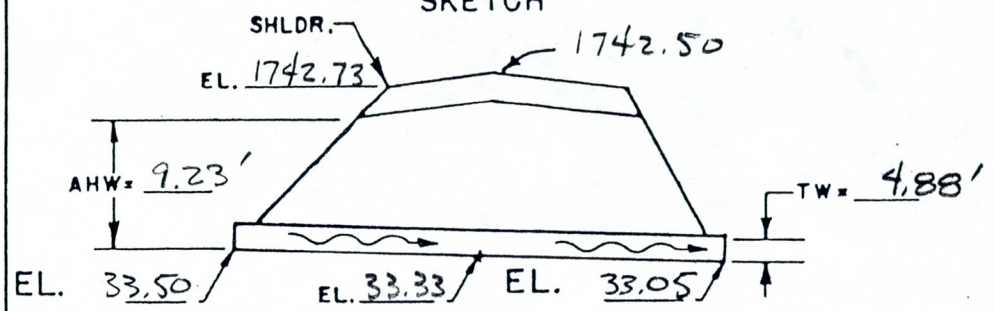
Q_1 = 506 cfs TW_1 = 4.88'

Q_2 = ____ TW_2 = ____

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~ Q_{100}; Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050% L = 90' L/100 S_o = ____

MEAN STREAM VELOCITY = 5.5 fps

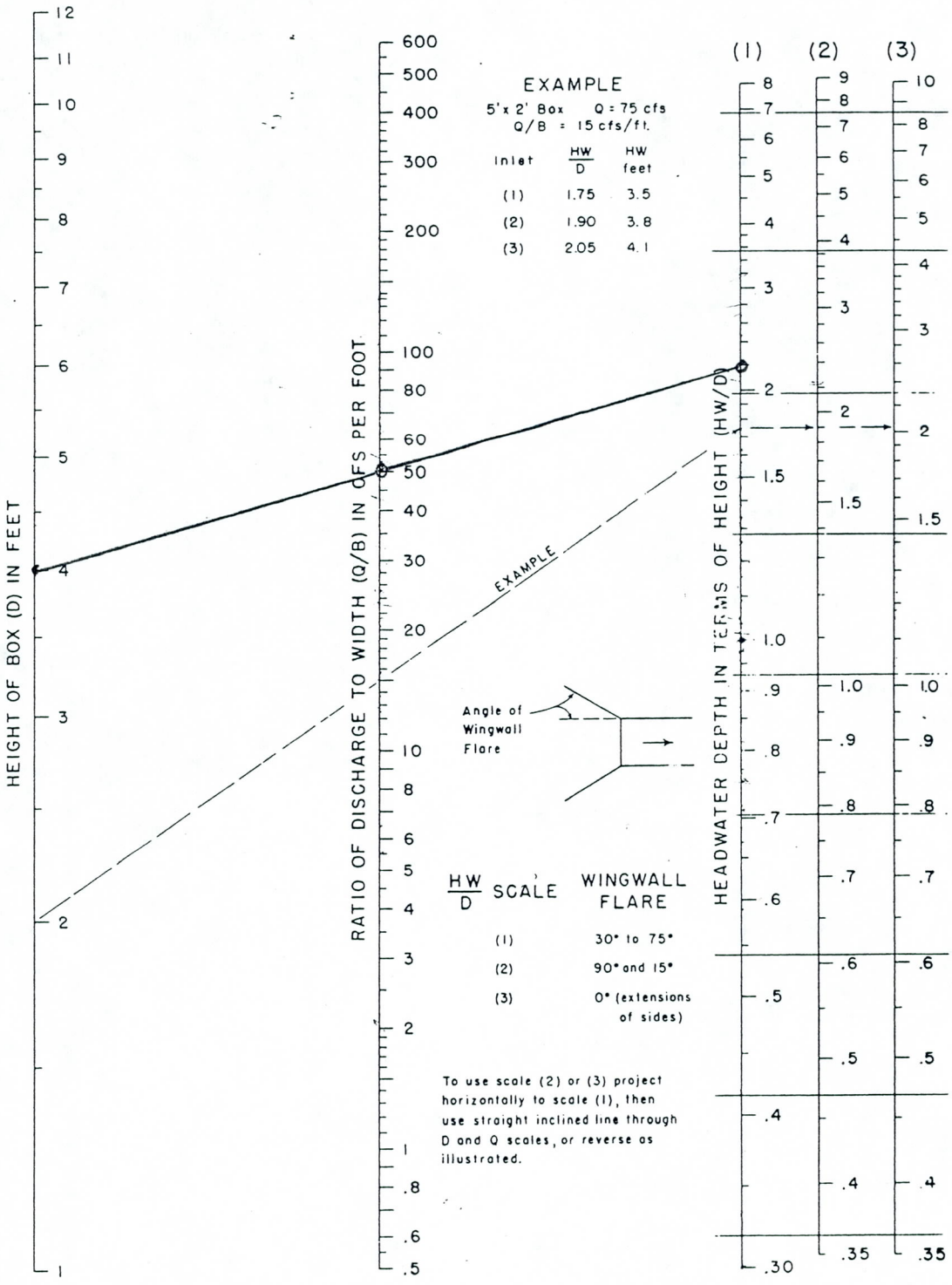
CULVERT DESCRIPTION SIZE	CULVERT DESCRIPTION ENTR. TYPE	Q	CAP. CHART HW	HEADWATER COMPUTATION: INLET CONT. HW/D	INLET CONT. HW	OUTLET CONTROL HW = H + h_o − LS_o: K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW	CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
(1) 10x4	Drop Inlet	506		2.2	8.8	0.20	3.75	4.0	4.0	4.88	4.88	0.45	8.18	8.8	14.3		1742.30	Inlet Control

SUMMARY & RECOMMENDATIONS

B-10

Culvert 67E

CHART 1

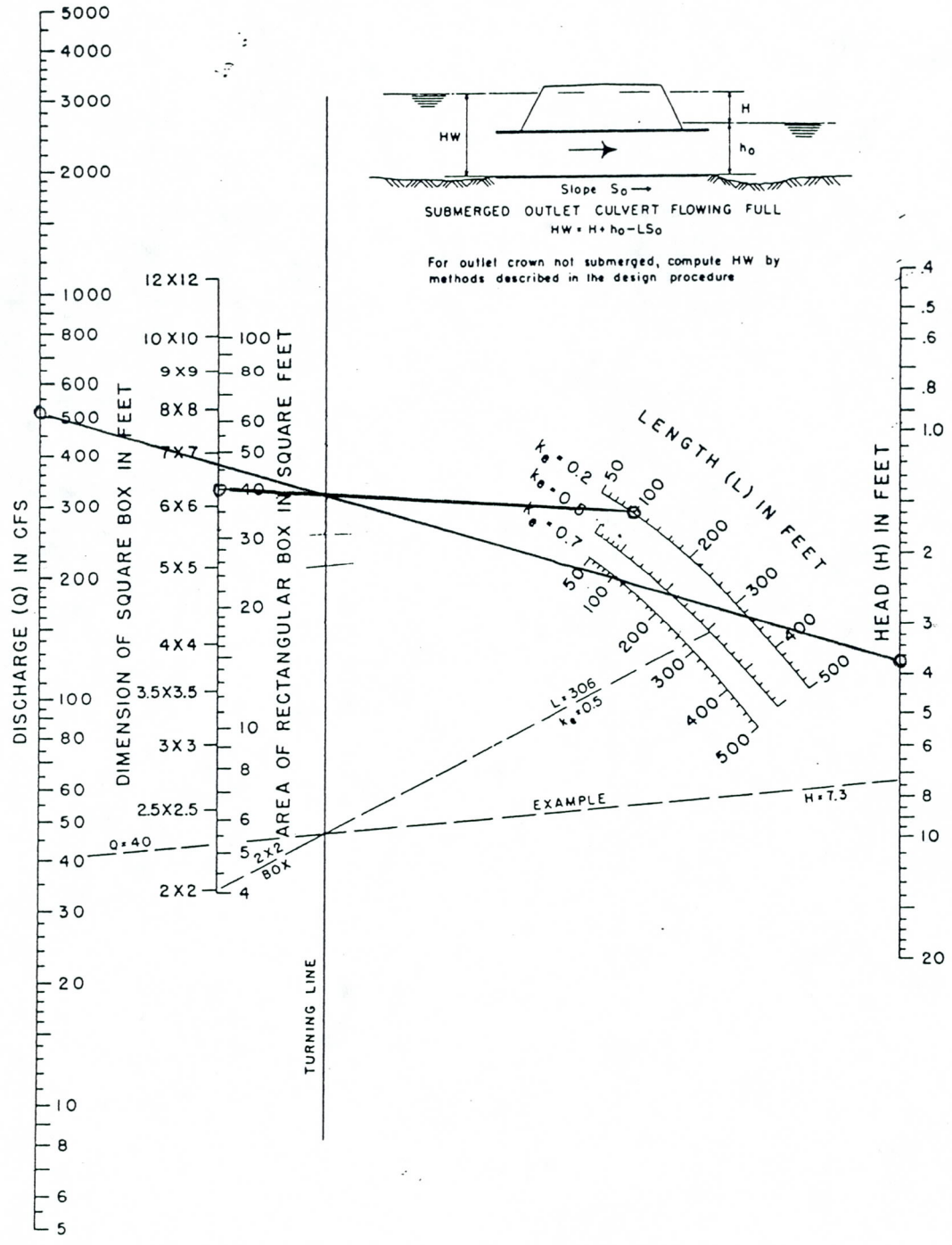


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 67E

CHART 8

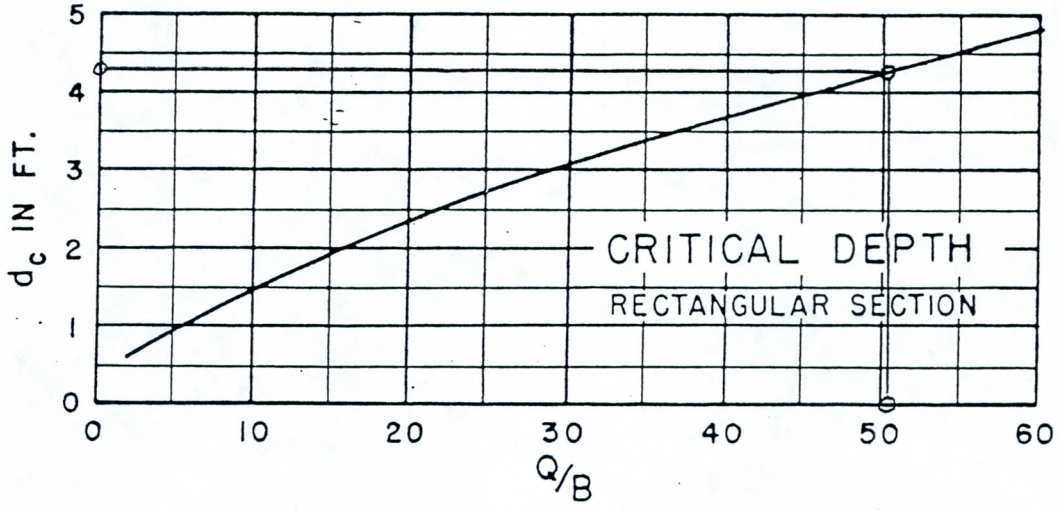


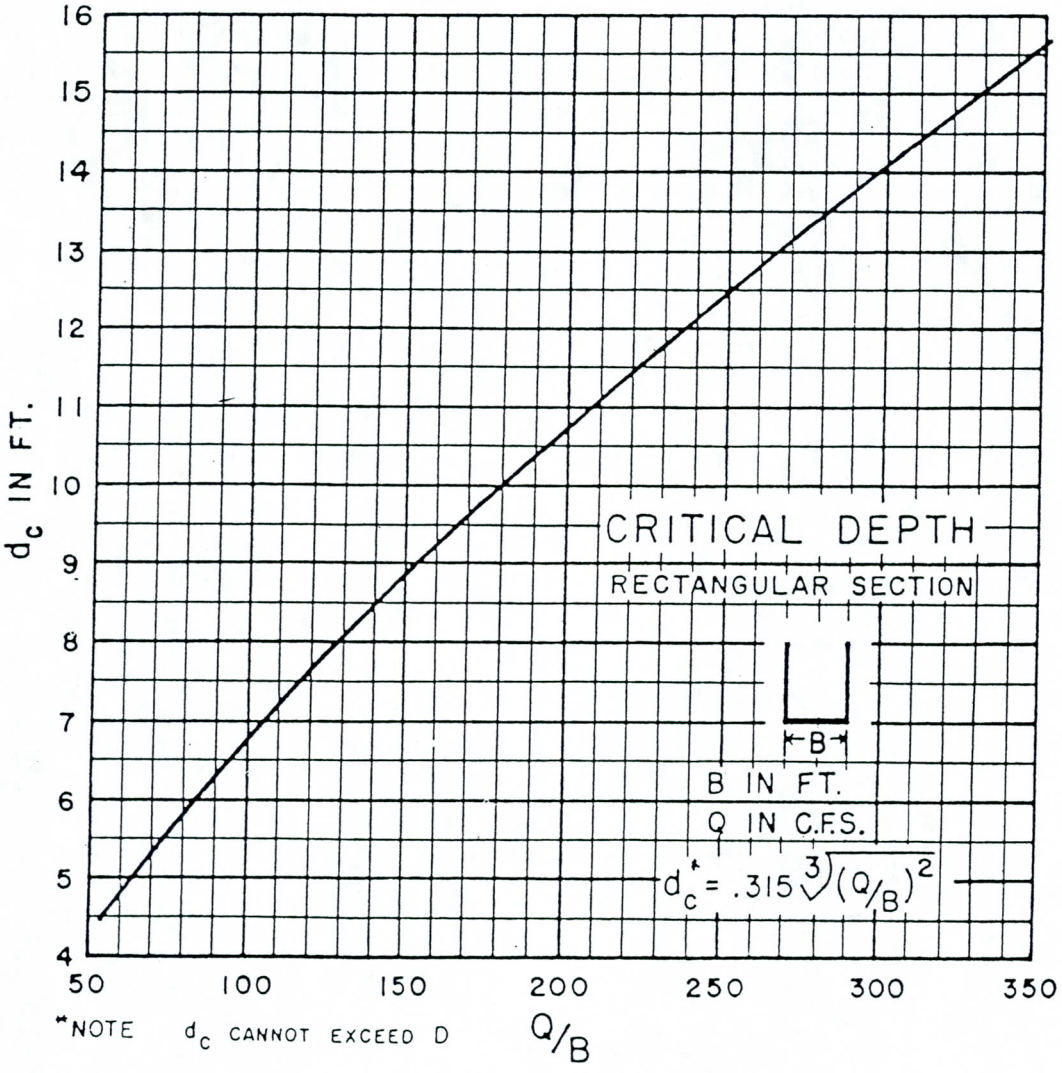
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 67E

CHART 15





*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Box Culvert 67 E

SHEET NO. 5 OF

DATE 6/19/91

BY BDO CHKD RJT

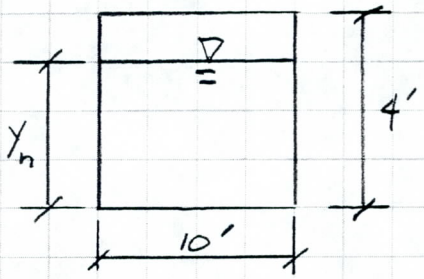
Check depth of Flow using Mannings Equation

$Q_{100} = 506$ cfs

$n = 0.012$

$S_o = 0.0050\%$

$Y_n \sim 3.55'$



$A = 3.55 \times 10 = 35.5\ ft^2$

$wP = 3.55 \times 2 + 10 = 17.1\ ft$

$R_h = A/wP = 35.5\ ft^2 / 17.1\ ft = 2.0760$

$$V = \frac{1.49}{.012}(2.0760)^{.666}(.005)^{1/2} = 14.28\ fps$$

$Q = VA = 14.28\,(35.5) = 507\ cfs \sim 506$ (OK)

Check Froude Number

$$F = \frac{V}{\sqrt{g\,Y_c}} = \frac{14.28}{\sqrt{32.2\,(3.55)}} = 1.34$$ Supercritical

Channel needs protection, Use Grouted Riprap
Plunge Basin $F < 3.0$ OK.

$Q_{10} = 346$ cfs

$Y_n = 2.71'$, Vel. = 12.7 fps, $F = 1.36$, Supercritical

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JOB 40477 Toyota

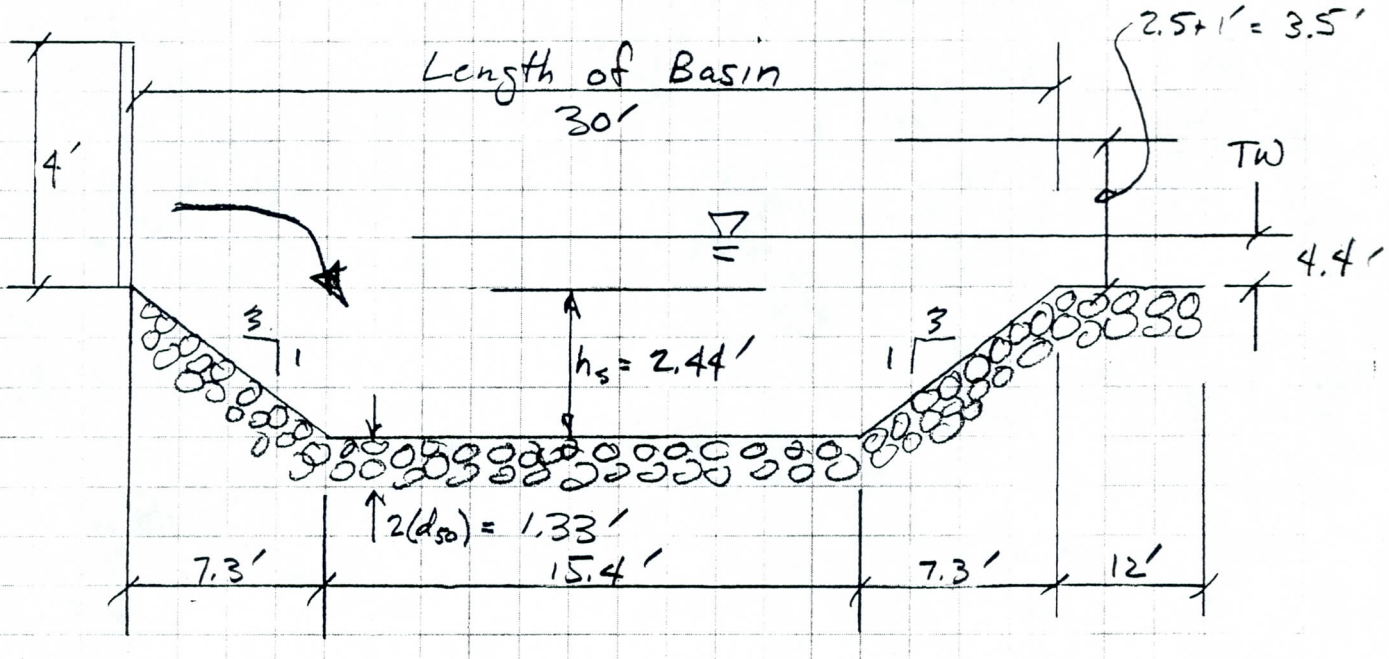
COMPUTATIONS FOR Box Culvert 67E

SHEET NO. 6 OF

DATE 6/30/91

BY BDO CHKD RJT

Riprap Plunge Basin Design (Q10)



Check Rock Size (From Figure XI-2, HEC No 14)

For Y_o = 2.71 d_{50} = 8" or 0.67

$d_{50}/Y_o = \frac{0.67'}{2.71'} = 0.25$, $F = 1.36$

$\frac{h_s}{Y_o} = 0.95$ $h_s = 0.95(2.71') = 2.57'$

Check $\frac{h_s}{d_{50}} = \frac{2.57}{0.67} = 3.84 < 4$ but > 2 ∴ ok

Length of Basin

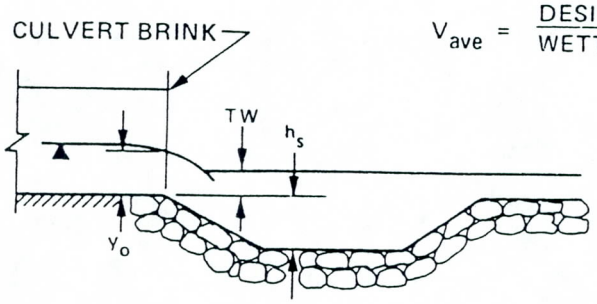
$10\,h_s = 10(2.57') = 25.7'$

or

$3(W_o) = 3(10') = 30'$

Use 30'

Culvert 67 E



$$V_{ave} = \frac{\text{DESIGN DISCHARGE} - Q}{\text{WETTED AREA AT BRINK OF CULVERT}}$$

d_{50} = THE MEDIAN SIZE OF ROCK BY WEIGHT. ROUNDED ROCK OR ANGULAR ROCK.

Y_e = EQUIVALENT BRINK DEPTH

= BRINK DEPTH FOR BOX CULVERT

$= \left(\frac{A}{2}\right)^{1/2}$ FOR NON–RECTANGULAR SECTIONS

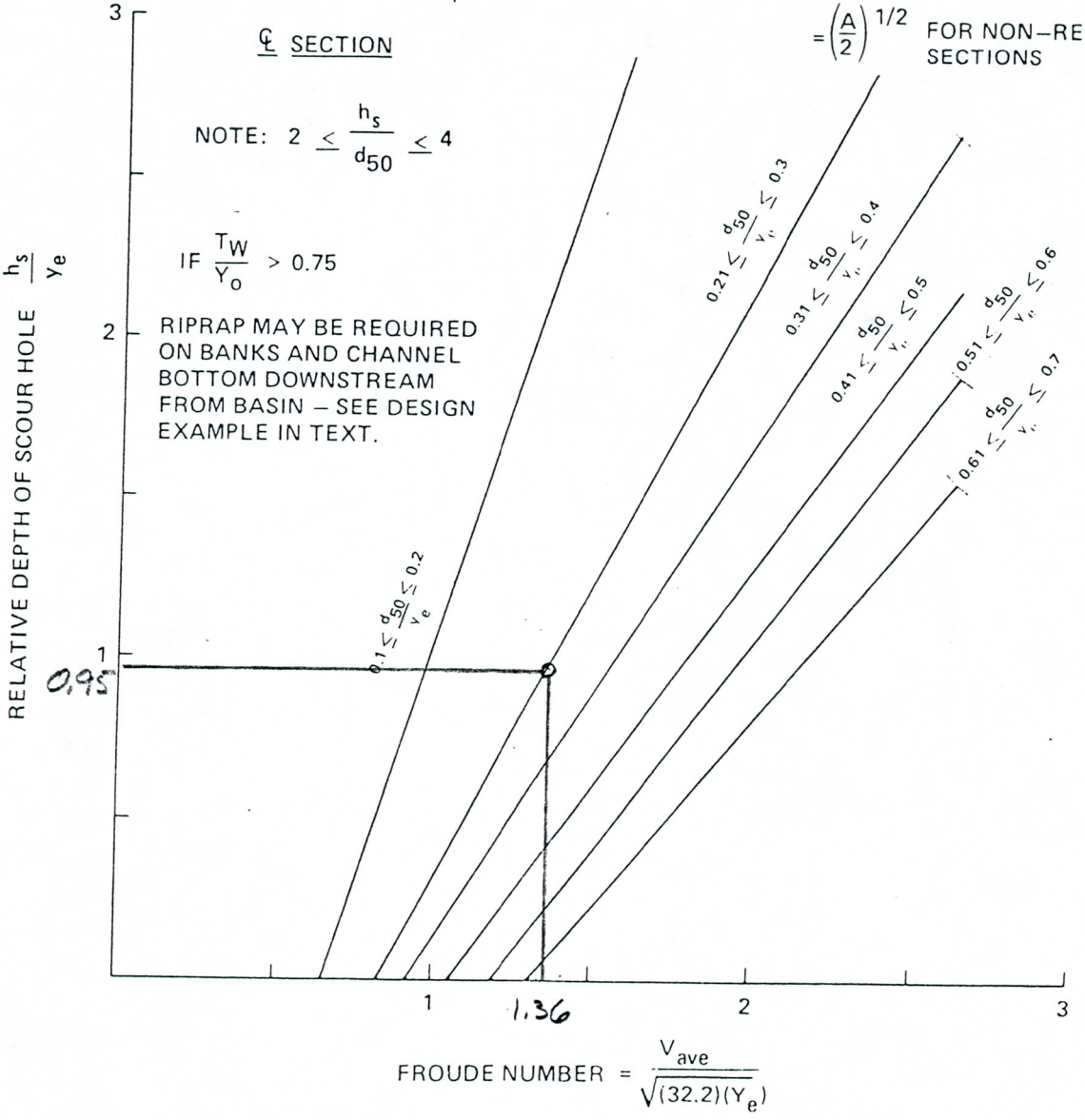


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

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JOB 40477 Toyota

COMPUTATIONS FOR Box Culvert 67E
Erosion Protection

SHEET NO. 8 OF

DATE 6/20/91

BY BDO CHKD RJT

$TW/Y_o = 4.4/2.71' = 1.62 > 0.75$ ∴ Check downstream riprap lining for channel.

Utilize figure XI-3 for estimating average velocity along channel. Compute equivalent circular diameter D_c for brink area from:

$A = \pi D_c^2/4 = Y_o W_o = 2.71(10) = 27.1 \text{ ft}^2$

$D_c = [27.1(4)/\pi]^{1/2} = 5.87'$

Culvert outlet velocity is 12.7 fps
From the downstream cross section Q10 velocity is 5.9 fps.

L/D_c	L	V_L/V_o	V_L
10	58.7	0.59	7.5
13	76.4	0.43	5.5 < 5.9 fps (OK)

∴ Need riprap lining for approximately 75 feet from the end of the culvert outlet apron.

SECTION NUMBER: TW67E 6/10/91

Channel Slope: 0.0076 ft./ft.

CROSS SECTION DATA:

OFFSET	50.7	82.4	97.6	133	136.6	140.5	142.8	215.4
ELEV.	37.86	38.27	36.69	36.21	32.48	32.71	36.38	37.96
N	N/A	0.035	0.035	0.035	0.035	0.025	0.035	0.035

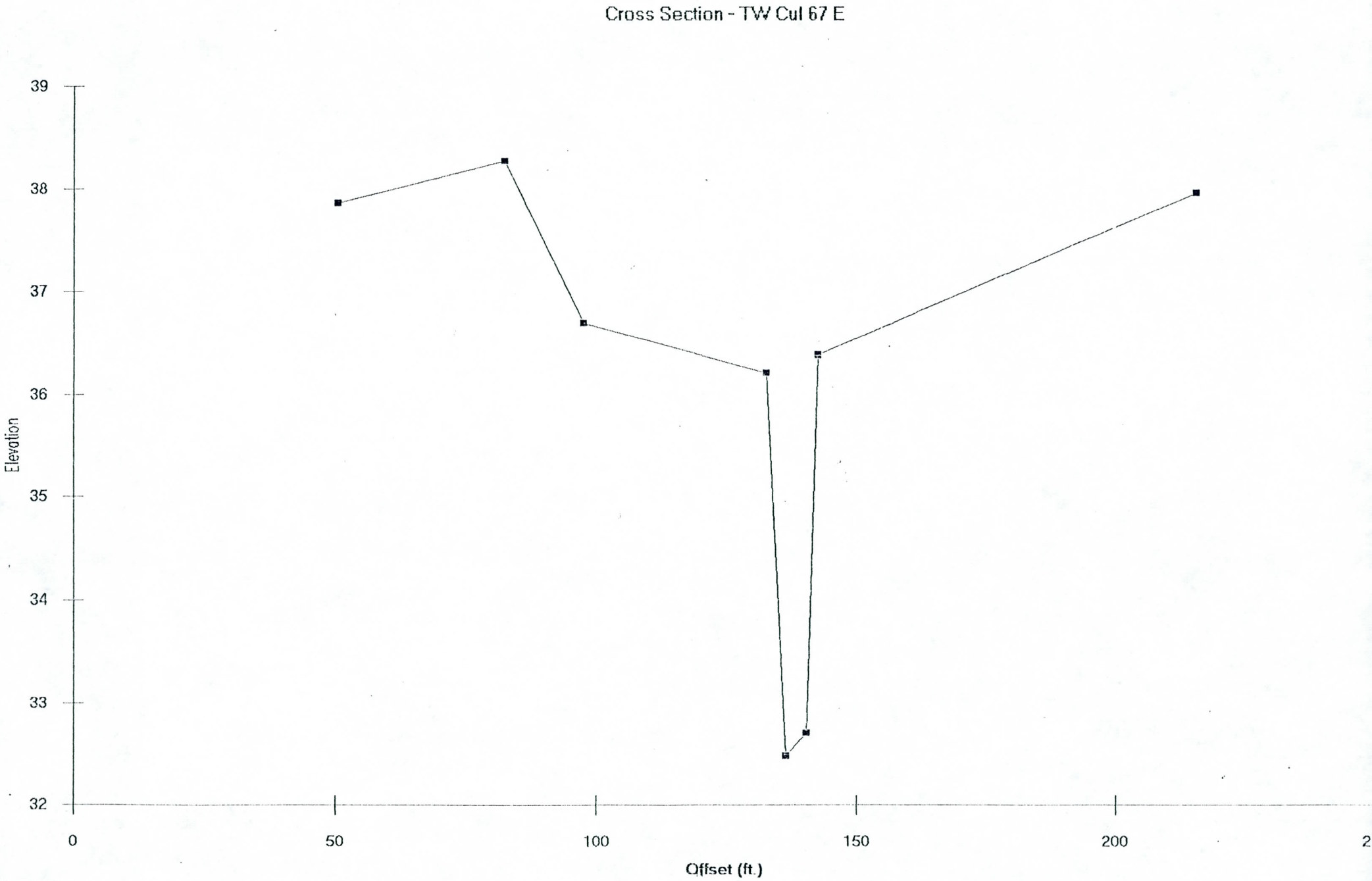
STAGE-DISCHARGE DATA:

STAGE:	32.9											
WET PER.		0.0	0.0	0.0	0.6	3.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	3	0	0	0	0	0	0	0
STAGE:	33.4												
WET PER.		0.0	0.0	0.0	1.3	3.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.4	3.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.3	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	1	14	0	0	0	0	0	0	0
STAGE:	33.9												
WET PER.		0.0	0.0	0.0	2.0	3.9	1.4	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	1.0	5.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.5	1.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	2	31	1	0	0	0	0	0	0
STAGE:	34.4												
WET PER.		0.0	0.0	0.0	2.7	3.9	2.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	1.8	7.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.7	1.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	5	54	2	0	0	0	0	0	0
STAGE:	34.9												
WET PER.		0.0	0.0	0.0	3.4	3.9	2.6	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	2.8	9.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.8	2.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	9	81	4	0	0	0	0	0	0
STAGE:	35.4												
WET PER.		0.0	0.0	0.0	4.1	3.9	3.2	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	4.1	10.9	2.3	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	1.0	2.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	15	113	7	0	0	0	0	0	0

SECTION NUMBER TW07E 6/10/91

STAGE:	35.9											
WET PER.		0.0	0.0	0.0	4.8	3.9	3.8	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	5.6	12.9	3.2	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	1.2	3.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	23	148	11	0	0	0	0	0	0
STAGE:	36.4												
WET PER.		0.0	0.0	14.0	19.2	3.9	4.3	5.3	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.3	8.7	14.8	4.3	4.3	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.5	3.8	1.0	0.8	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	19	187	0	14	0	0	0	0	0
STAGE:	36.9												
WET PER.		0.0	2.0	37.4	42.6	3.9	4.3	28.2	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.2	16.1	25.3	16.8	5.4	11.6	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.1	0.4	0.6	4.3	1.3	0.4	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	66	230	0	24	0	0	0	0	0
STAGE:	37.4												
WET PER.		0.0	6.9	42.3	47.5	3.9	4.3	51.2	0.0	0.0	0.0	0.0	0.0
AREA		0.0	2.4	36.1	47.1	18.7	6.6	30.5	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.4	0.9	1.0	4.8	1.5	0.6	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	173	276	0	80	0	0	0	0	0
STAGE:	37.9												
WET PER.		3.1	11.7	47.1	52.3	3.9	4.3	74.2	0.0	0.0	0.0	0.0	0.0
AREA		0.1	7.0	58.4	71.2	20.7	7.7	60.8	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.6	1.2	1.4	5.3	1.8	0.8	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	324	326	0	197	0	0	0	0	0

W.S. Elev.	32.9	33.4	33.9	34.4	34.9	35.4	35.9	36.4	36.9	37.4	37.9
Q	3	15	34	61	94	135	182	220	320	529	846
A	1.3	3.7	6.5	9.7	13.3	17.3	21.7	27.8	53.8	96.3	152.7
V	2.2	4.0	5.3	6.3	7.1	7.8	8.4	7.9	6.0	5.5	5.5


Cross Section - TW Cul 67 E
39
38
37
36
35
34
33
32
Elevation
0
50
100
150
200
Offset (ft.)

SVERDRUP

JOB 10477 Toyota

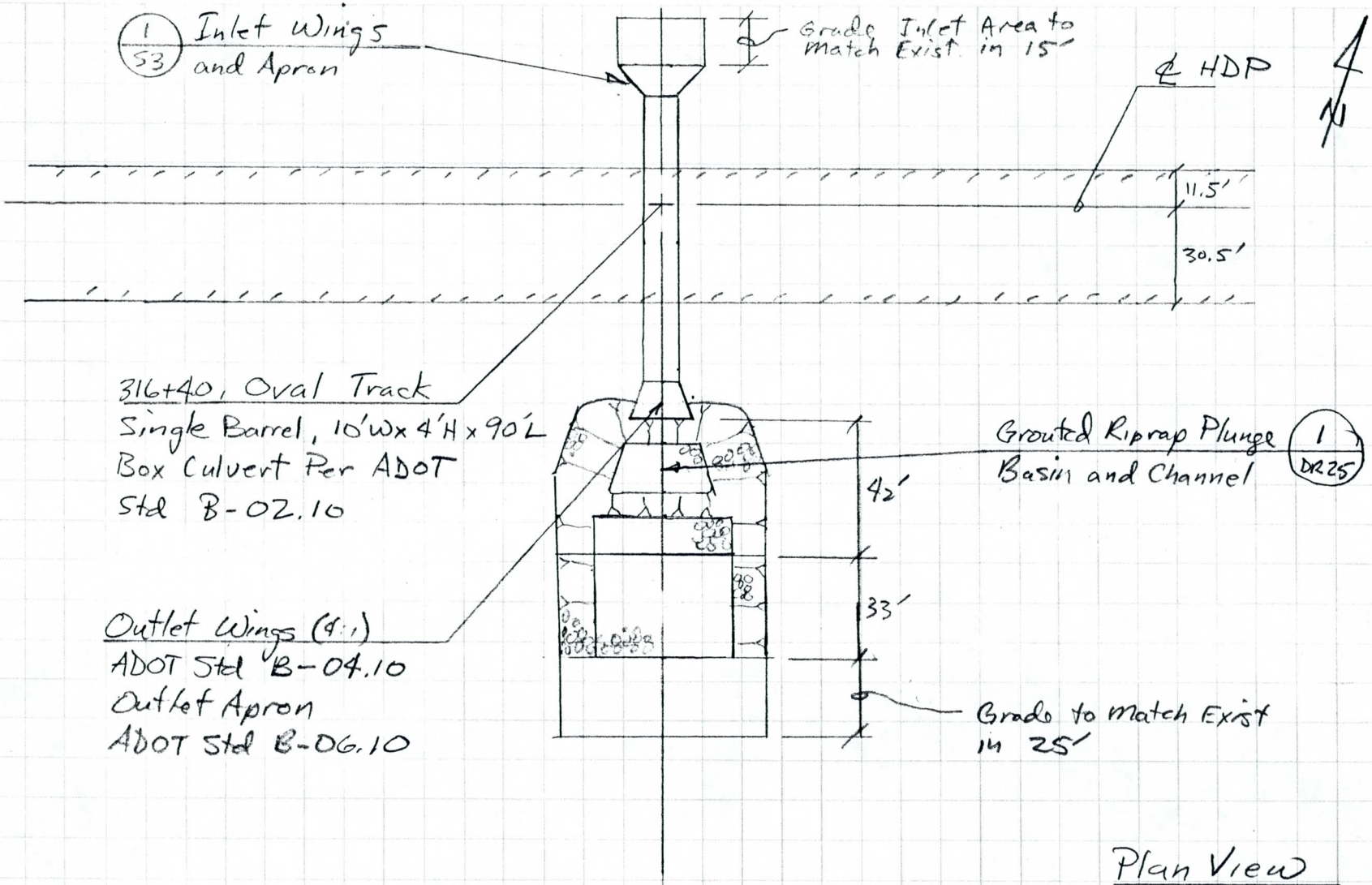
COMPUTATIONS FOR Box Culvert 67E 4

Plan View

SHEET NO. 9 OF

DATE 6/25/91

BY BDO CHKD RTT



Plan View
Culvert 67E

Scale 1"=50'

SVERDRUP

JOB 40477 Toyota SHEET NO. 10 OF

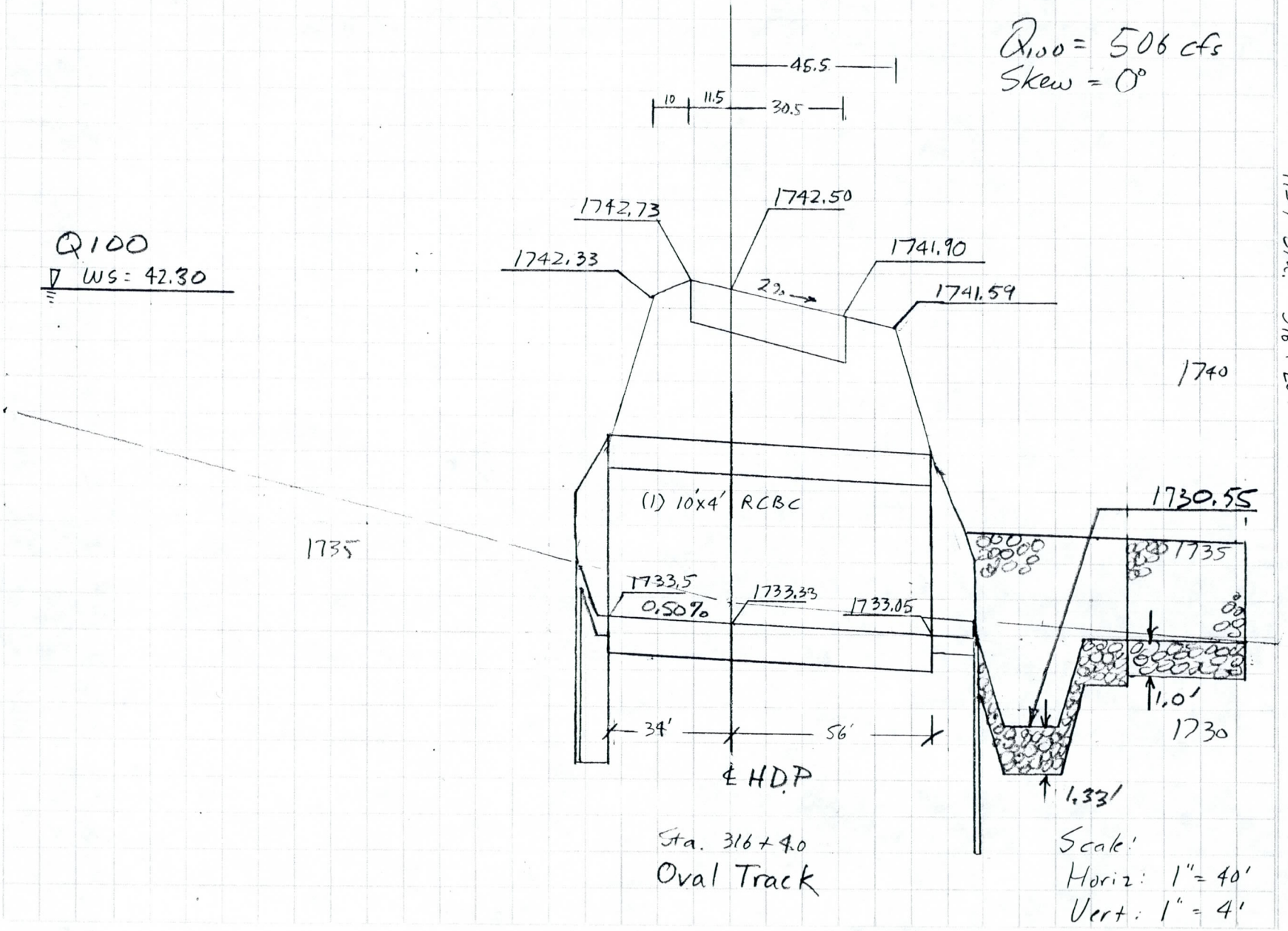
COMPUTATIONS FOR Culvert Profile 67E 4 DATE 6-25-91

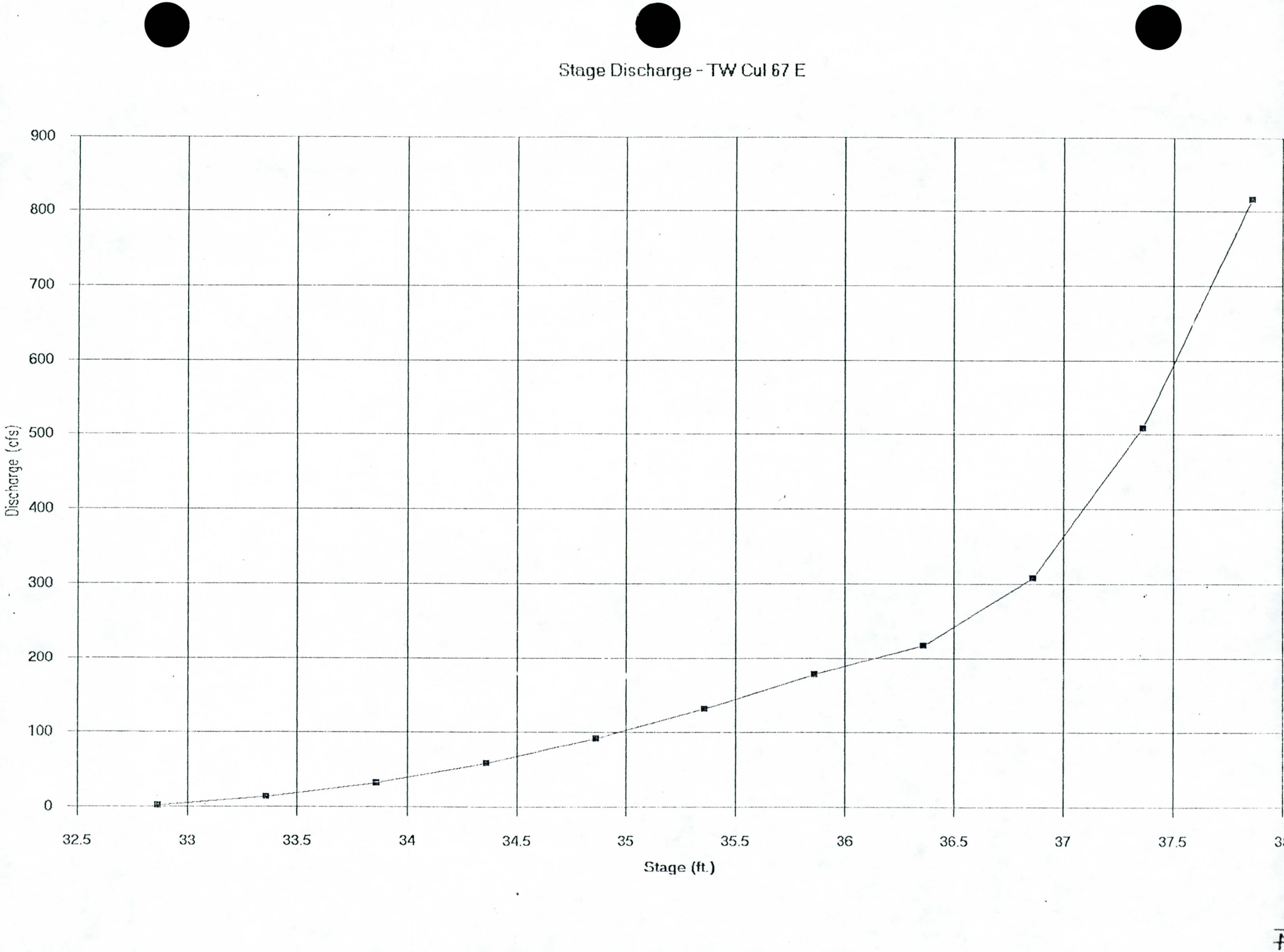
HST Sta. 316+20 BY DFP CHKD RJT

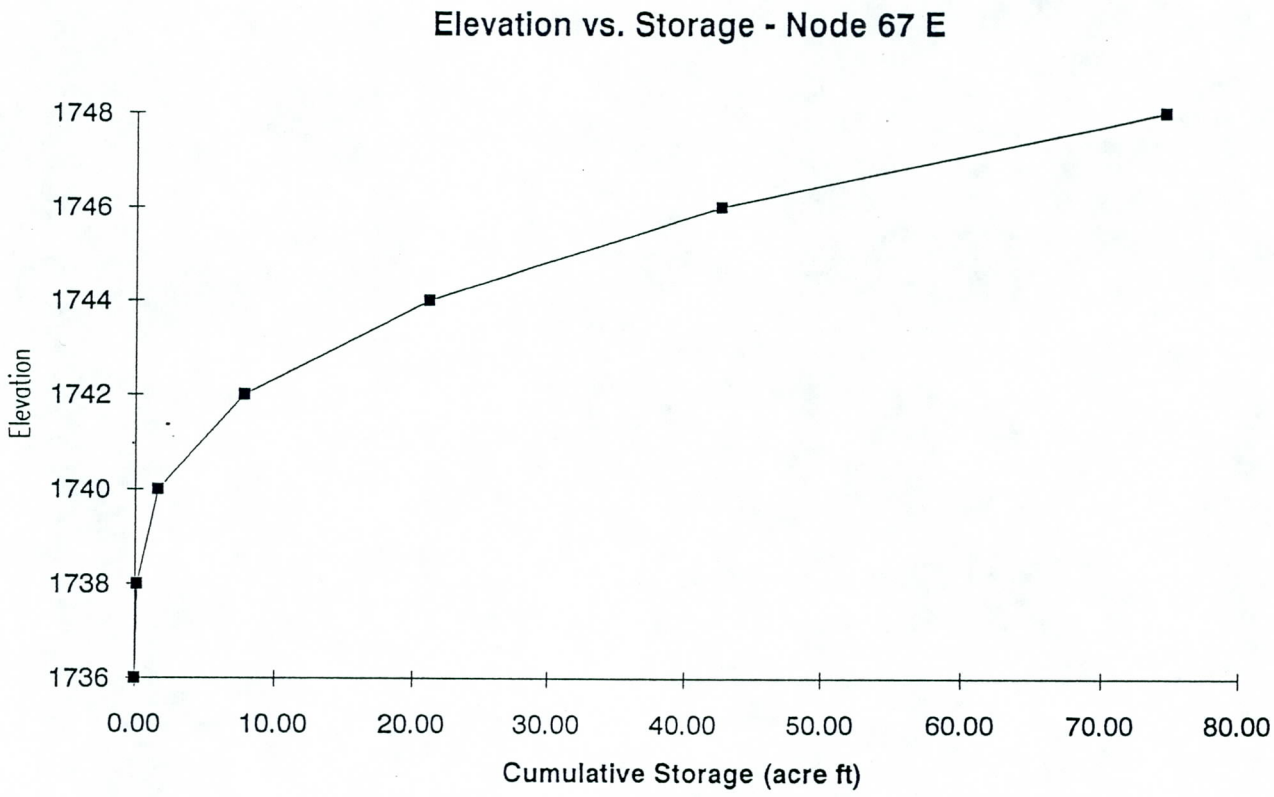
Culvert 67E 4

Q_{100} = 506 cfs

Skew = 0°




Stage Discharge - TW Cul 67 E
900
800
700
600
500
400
300
200
100
0
Discharge (cfs)
32.5
33
33.5
34
34.5
35
35.5
36
36.5
37
37.5
Stage (ft.)


Elevation vs. Storage - Node 67 E
1748
1746
1744
1742
1740
1738
1736
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Cumulative Storage (acre ft)

SVERDF

JOB 4047 Toyota

SHEET NO 1 OF

DATE 6/27/91

COMPUTATIONS FOR Proposed Culvert 67 F 5 BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

DESIGNER:

STATION: 305+75, Oval Track

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 0.06 Sq. miles

Q_1 = 68 cfs

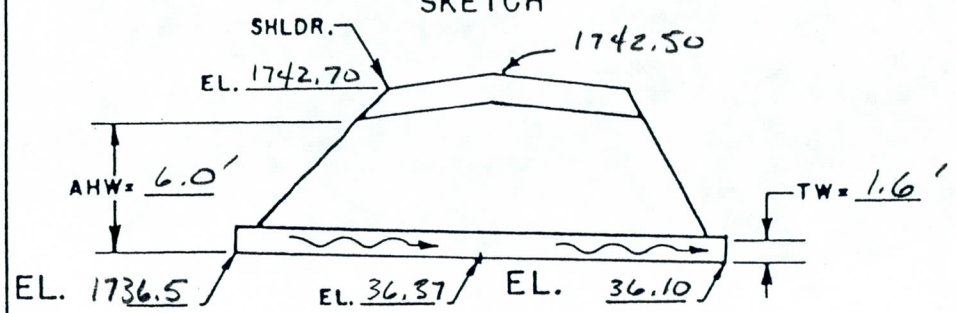
Q_2 =

TW_1 = 1.6'

TW_2 =

(Q_1 = DESIGN DISCHARGE, SAY Q_{25})
(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050 ft/ft L = 81' L/100 S_o =

MEAN STREAM VELOCITY = 1.6 fps

CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL HW = H + h_o − LS_o												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(1) 36" RCP	Drop Inlet	68		1.60	4.80	0.2	2.44	2.63	2.82	1.6	2.82	0.40	4.86	4.86	11.6*		1741.36	Outlet Control

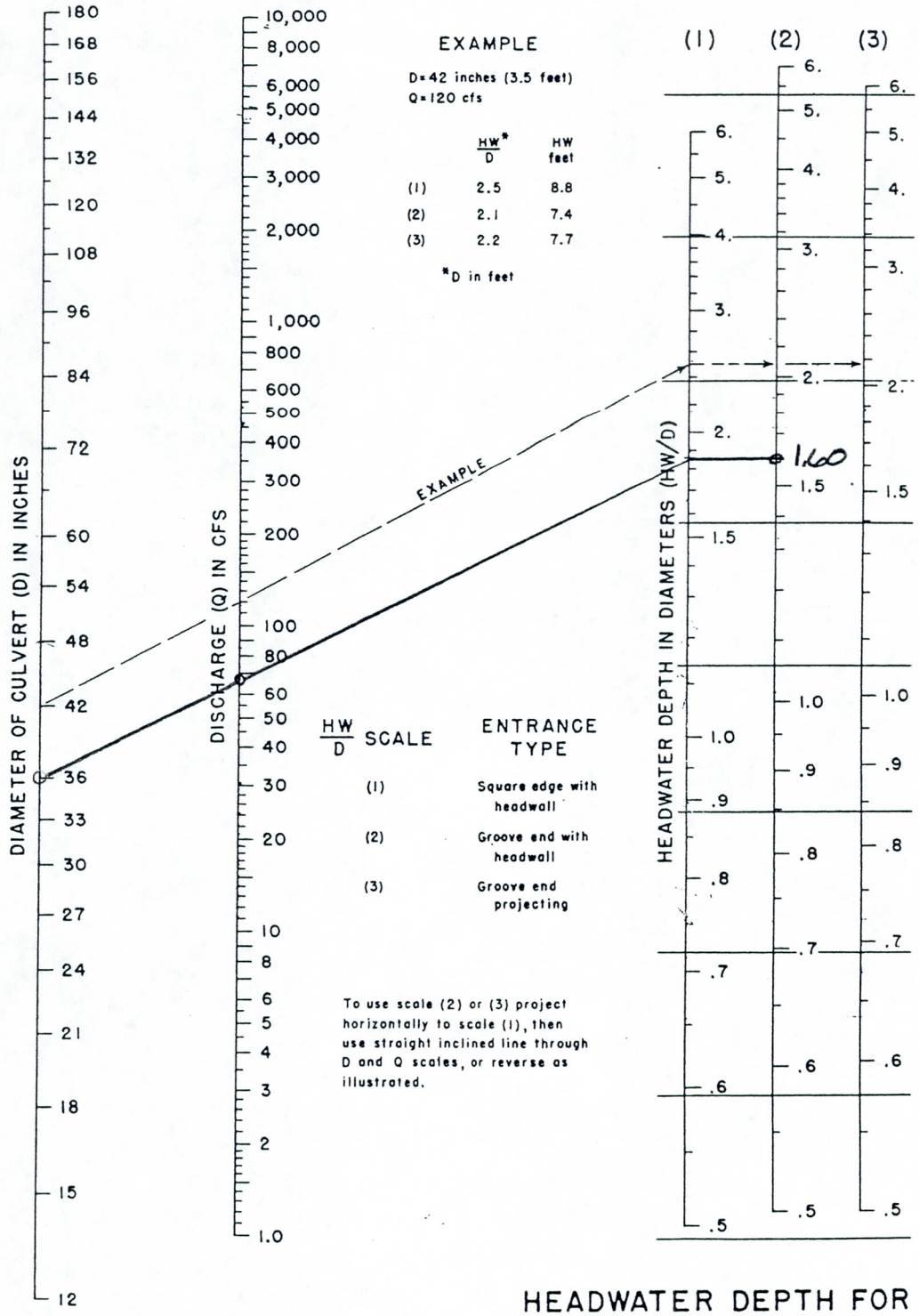
SUMMARY & RECOMMENDATIONS Use riprap plunge basin to control downstream erosion.

* Outlet velocity based upon brink depth of 2.31'

B-10

Culvert 67 F

CHART 2

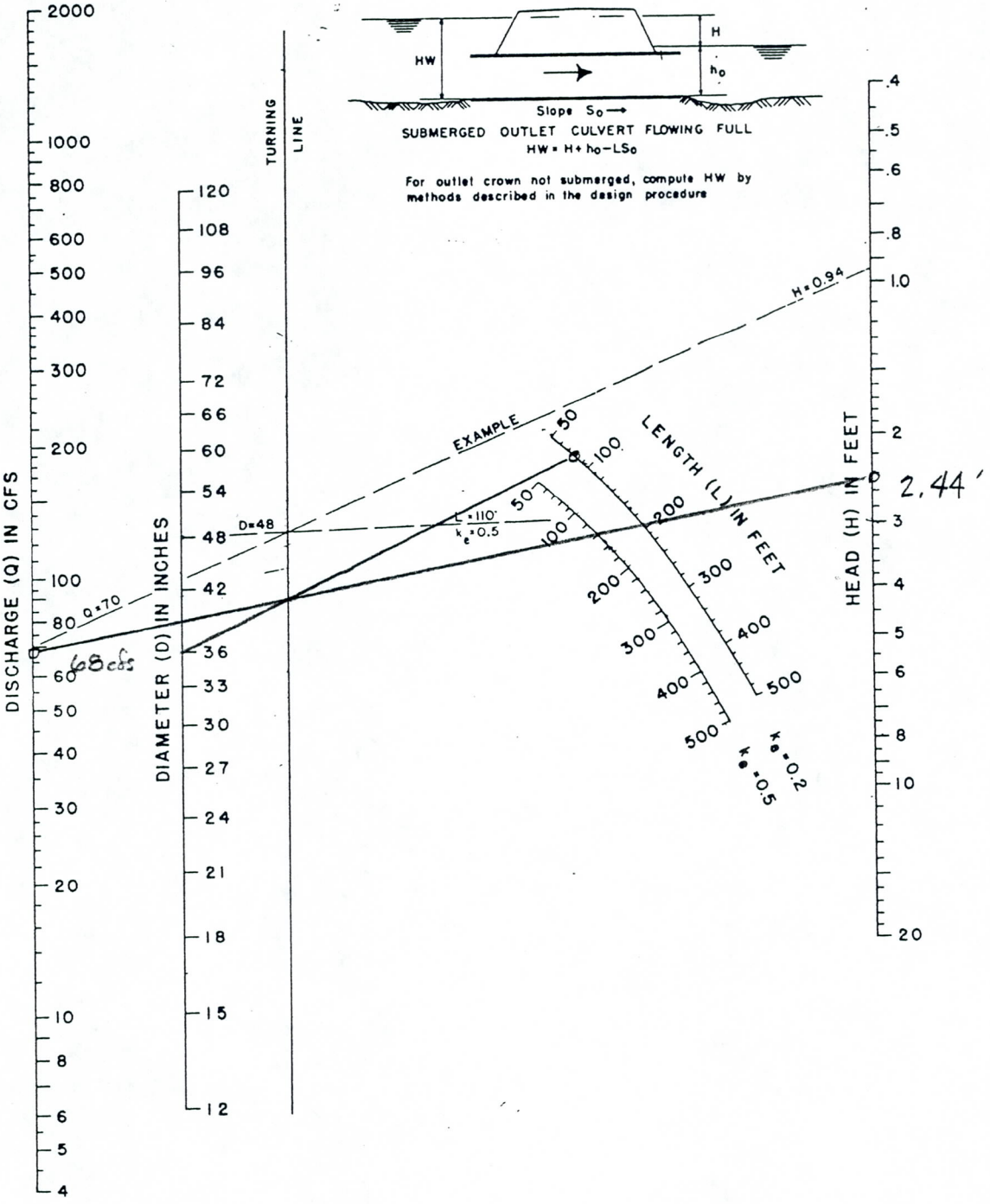


HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 67 F

CHART 9

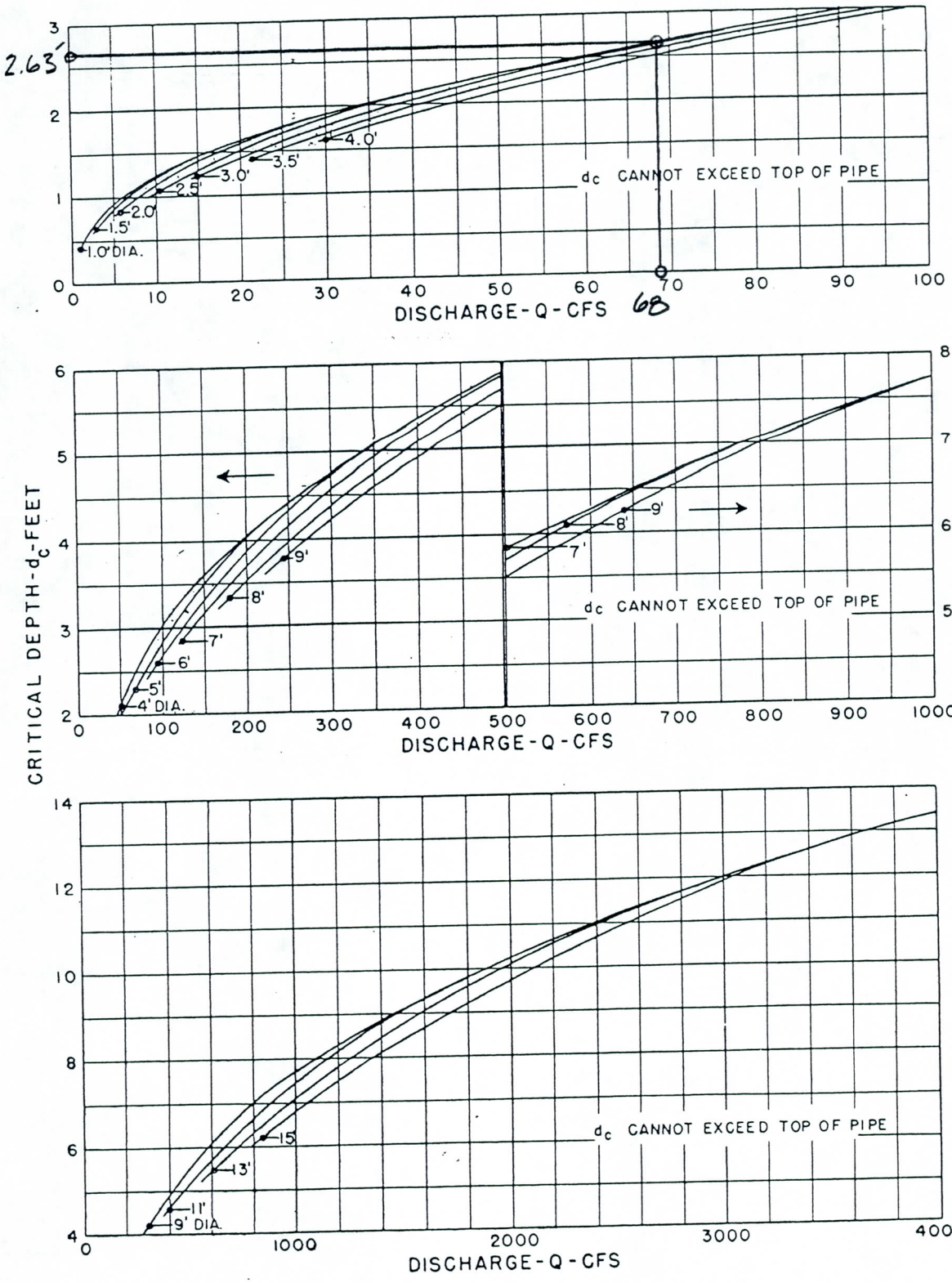


HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 67 F

CHART 16



BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

SVERDRUP

JOB 40477 Toyota SHEET NO. 5 OF

COMPUTATIONS FOR Culvert 67F DATE 6/27/91 BY BDO CHKD RJT

Check outlet velocity for 36" Pipe

$Q_{100} = 68$ cfs $\quad n = 0.013 \quad d = 3.0' \quad S = 0.0050$ ft/ft

$$K' = \frac{Q\,n}{d^{8/3}\,S^{1/2}} = \frac{68\,(.013)}{(3)^{8/3}\,(.005)^{1/2}} = 0.6678$$

(Beyond limits of Open Channel Flow ∴ Pipe Full)

$V = Q/A = 68/7.07 = 9.62$ fps

Check critical depth

$$K_c' = \frac{Q}{d^{5/2}} = \frac{68}{(3)^{2.5}} = 4.3622$$

from Table 11-4, Page 8-80, King

$$\frac{D_c}{d} = 0.88 \Rightarrow D_c = 0.876(3) = 2.63'$$

Check if pipe flowing full for part of barrel length.

$$D + (1 + K_e)\frac{V^2}{2g} = 3 + (1 + 0.2)\frac{9.62^2}{64.4} = 4.72'$$

HW = 4.86' > 4.72' & $D_c < D$ ∴ full flow for only part of length

(See Pgs 5-5 to 5-12, HEC No 5)

SVERDRUP

JOB 40477 Toyota SHEET NO. 6 OF

COMPUTATIONS FOR Culvert 67F DATE 6/27/91

BY BDO CHKD RJT

Check Brink depth

$\frac{Q}{D^{2.5}} = \frac{68}{(3)^{2.5}} = 4.3622$, $\frac{Tw}{D} = \frac{1.6}{3} = 0.5333$

From Fig III-10 (HEC No 14) $\frac{Y_o}{D} = 0.77$

$Y_o = 0.77\ D = 0.77(3) = 2.31'$

From Table 84 (King)

$\frac{D}{d} = \frac{2.31}{3} = 0.77 \quad C = 0.649$

$A = C d^2 = 0.649 (3)^2 = 5.84\ ft^2$

$V = Q/A = 68\ cfs / 5.84\ ft^2 = \underline{\underline{11.64\ fps}}$

$F = \frac{V_o}{\sqrt{32.2\ Y_c}} \qquad Y_c = \left(\frac{A}{2}\right)^{1/2} = \left(\frac{5.84}{2}\right)^{1/2} = 1.71$

$= \frac{11.64}{\sqrt{32.2 \times 1.71}} = \underline{\underline{1.57}}$

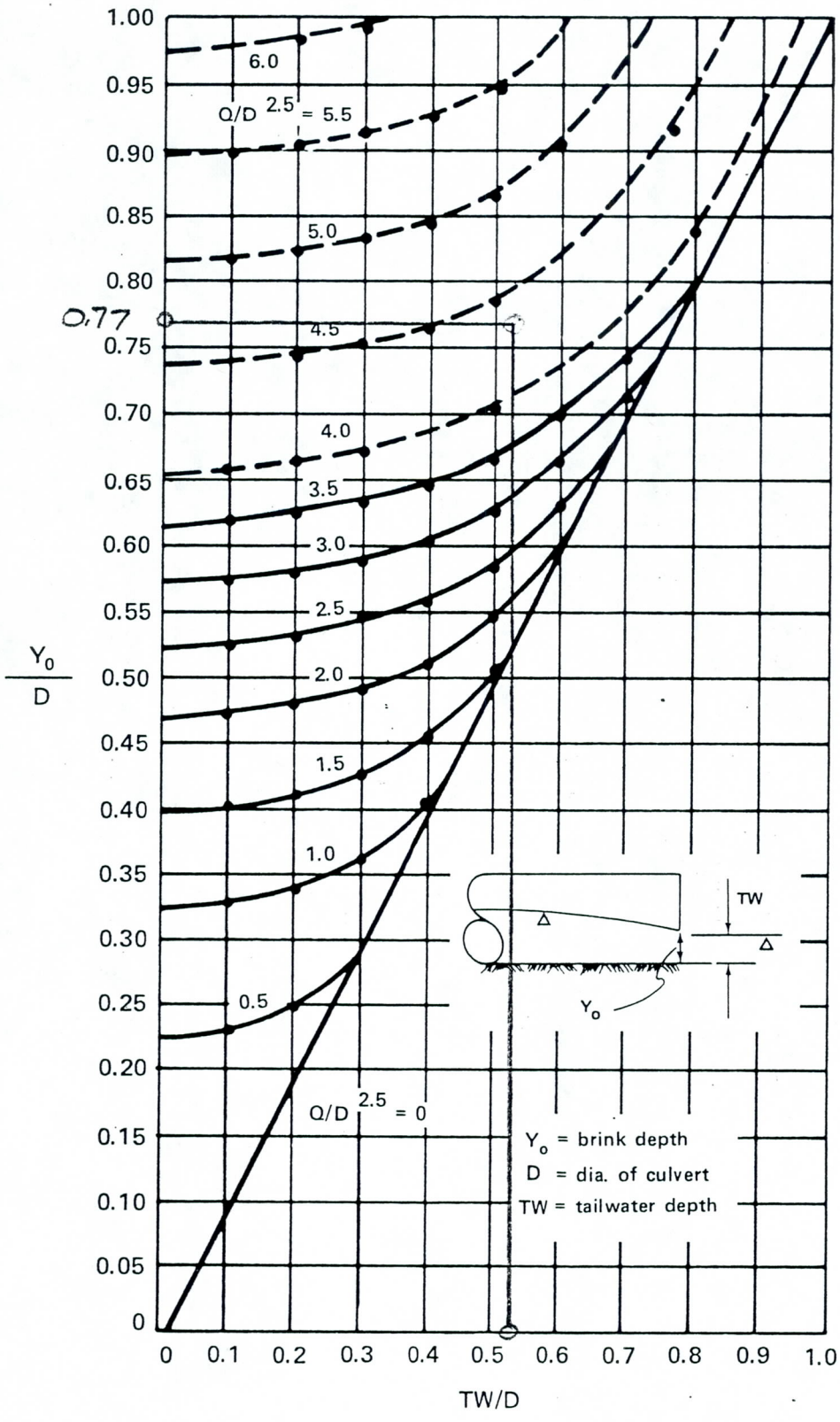


Figure III-10 Dimensionless Rating Curve for the Outlets of Circular Culverts on Horizontal and Mild Slopes from Reference III-2

SVERDRUP

JOB 40477 Toyota

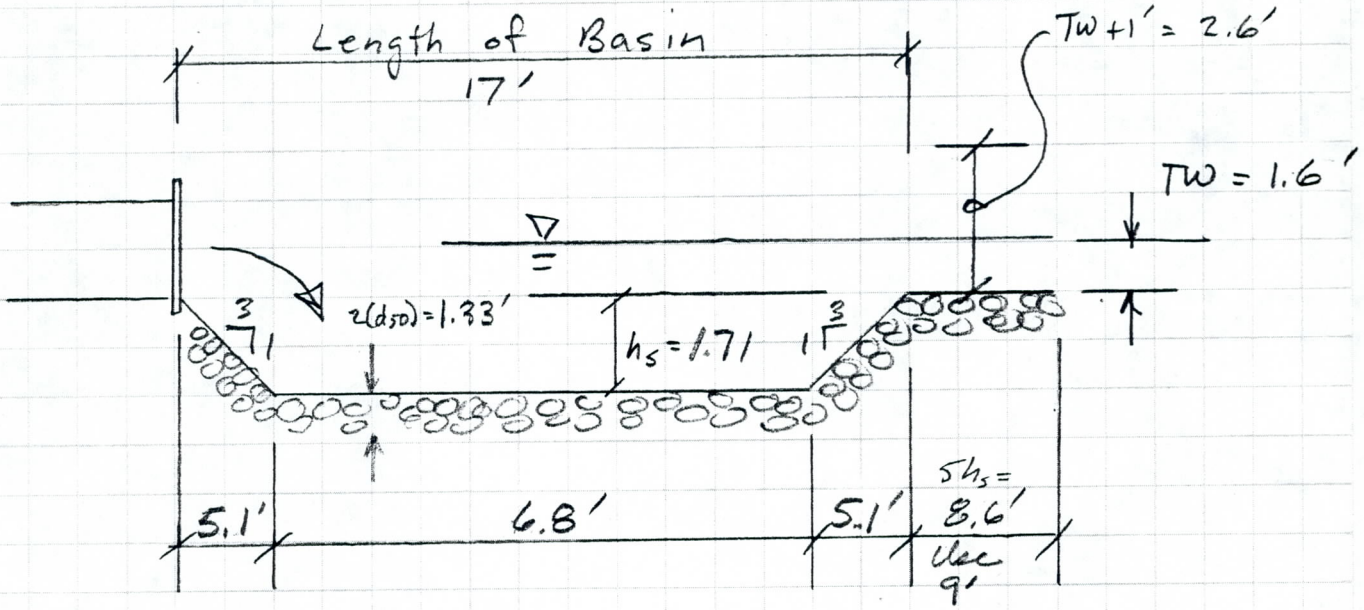
COMPUTATIONS FOR Erosion Protection Culvert 67 F

SHEET NO. 8 OF

DATE 6/27/91

BY BDO CHKD RJT

Riprap Plunge Basin Design



Check For Rock Size (From Figure XI-2, NEC No14)

For $Y_o = 2.31'$ $d_{50} = 8''$ or $0.67'$ $Y_e = 1.71'$

$$d_{50}/Y_e = \frac{0.67'}{1.71'} = 0.39 \quad , \quad F = 1.57$$

$$h_s/Y_e = 1.00 \qquad h_s = 1.00(1.71') = 1.71'$$

Check $\frac{h_s}{d_{50}} = \frac{1.71'}{0.67'} = 2.55 > 2$ but < 4 (OK)

$$TW/Y_o = \frac{1.6}{2.31} = 0.69 < 0.75 \quad \text{(OK)}$$

Length of Basin

$10(h_s) = 10(1.71) = 17.1'$

or $3(W_o) = 3(3) = 9'$ $\therefore$ Use 17'

SVERDRUP

JOB 40477 Toyota

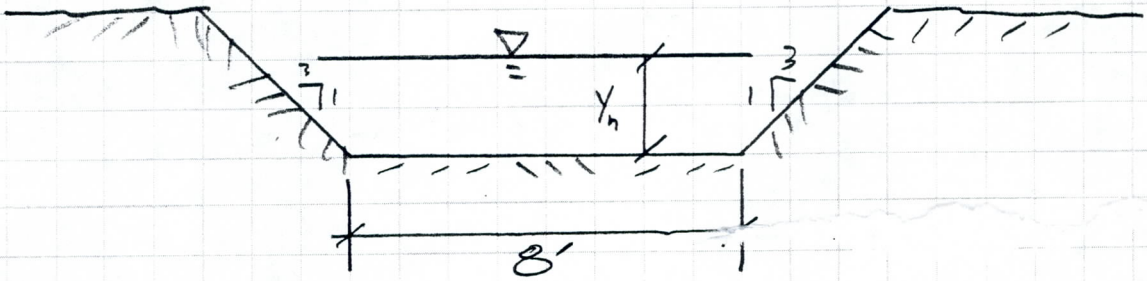
SHEET NO. 10 OF

DATE 6/27/91

COMPUTATIONS FOR Channel Downstream of Culvert 67F

BY BDO CHKD RJT

Check depth of Flow and Velocity



$Q_{100} = 68$ cfs

$n = 0.03$ (Earthen Channel)

$S_o = 0.0040$ ft/ft

$Y_n \sim 1.58'$

$A = 20.13$ SF

$WP = 8 + 2(5.00) = 18.00$ ft

$R_h = A/WP = 20.13/18.00 = 1.1183'$

$V = \frac{1.49}{.03}(1.1183)^{.666}(.004)^{.5} = 3.38$ fps

Check

$Q = VA = 3.38(20.13) = 68$ cfs (OK)

Check Froude Number $D = A/T = 20.13/17.48 = 1.15'$

$F = \frac{3.38}{\sqrt{32.2 \times 1.15'}} = 0.56$, Subcritical

Culvert 67 F

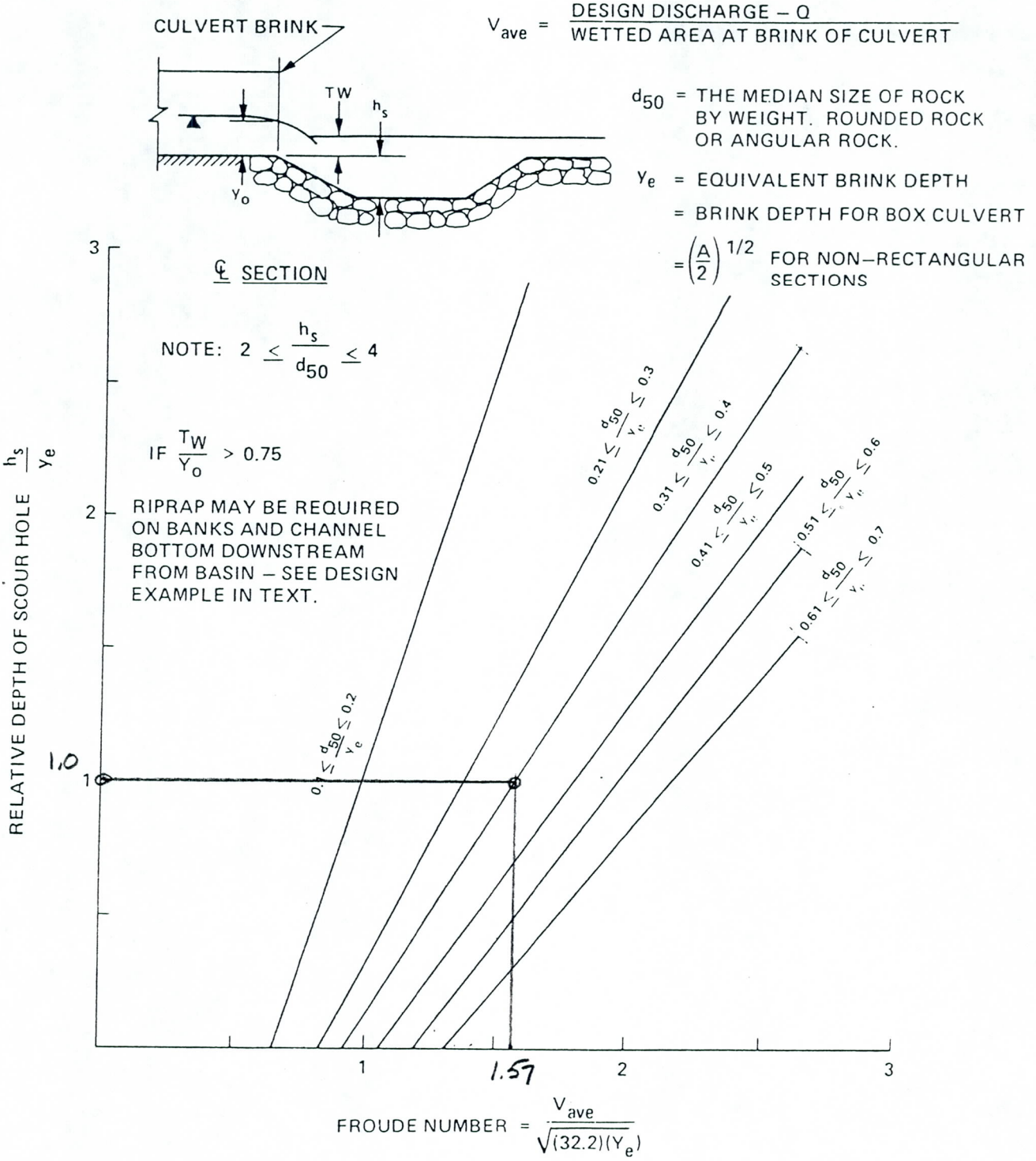


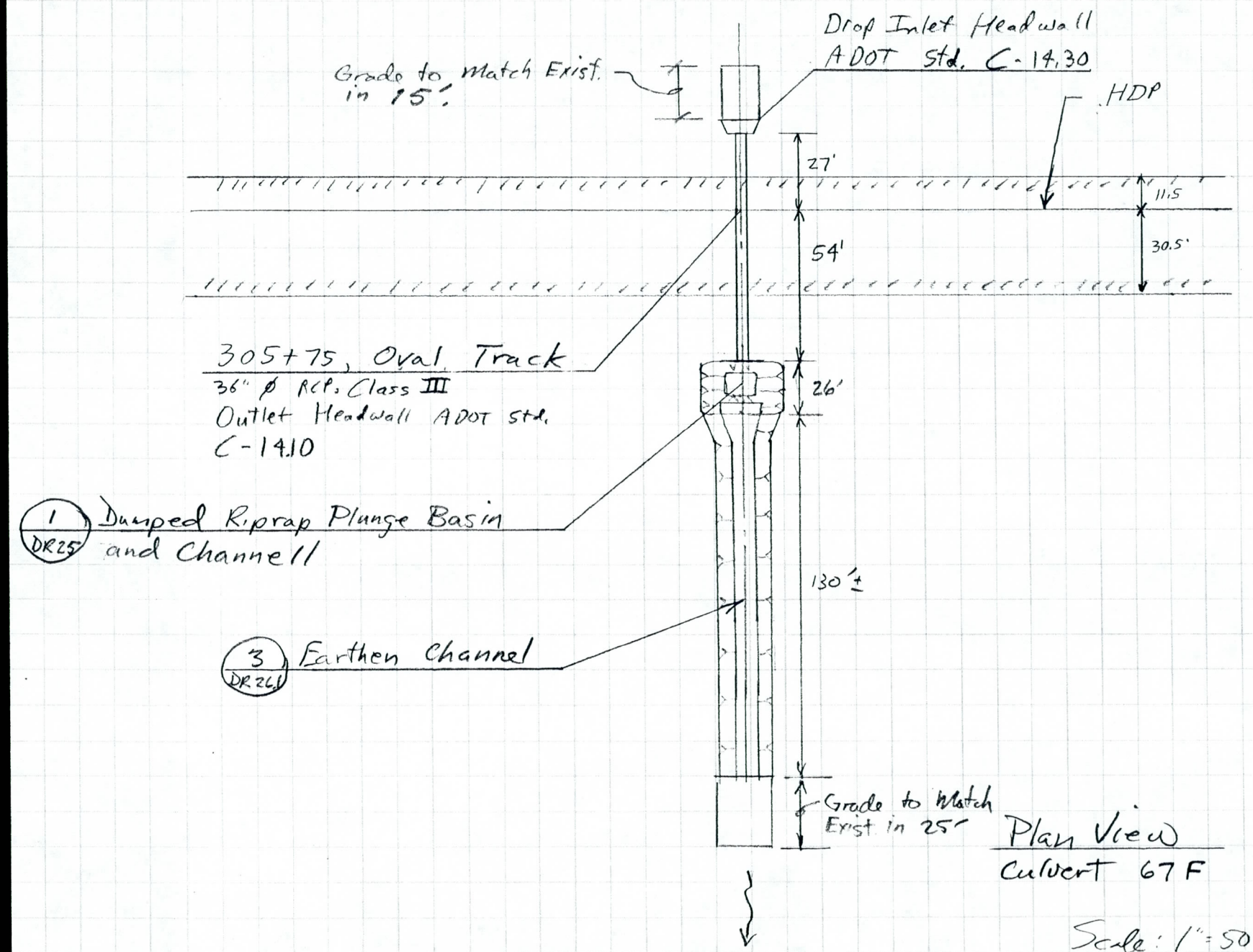
FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota SHEET NO. 11 OF

COMPUTATIONS FOR Pipe Culvert 67F 5 DATE 6-25-91

Plan View, HST Sta. 305+75 BY DFP CHKD RTT



Plan View
Culvert 67F

Scale: 1" = 50'

SVERDRUP

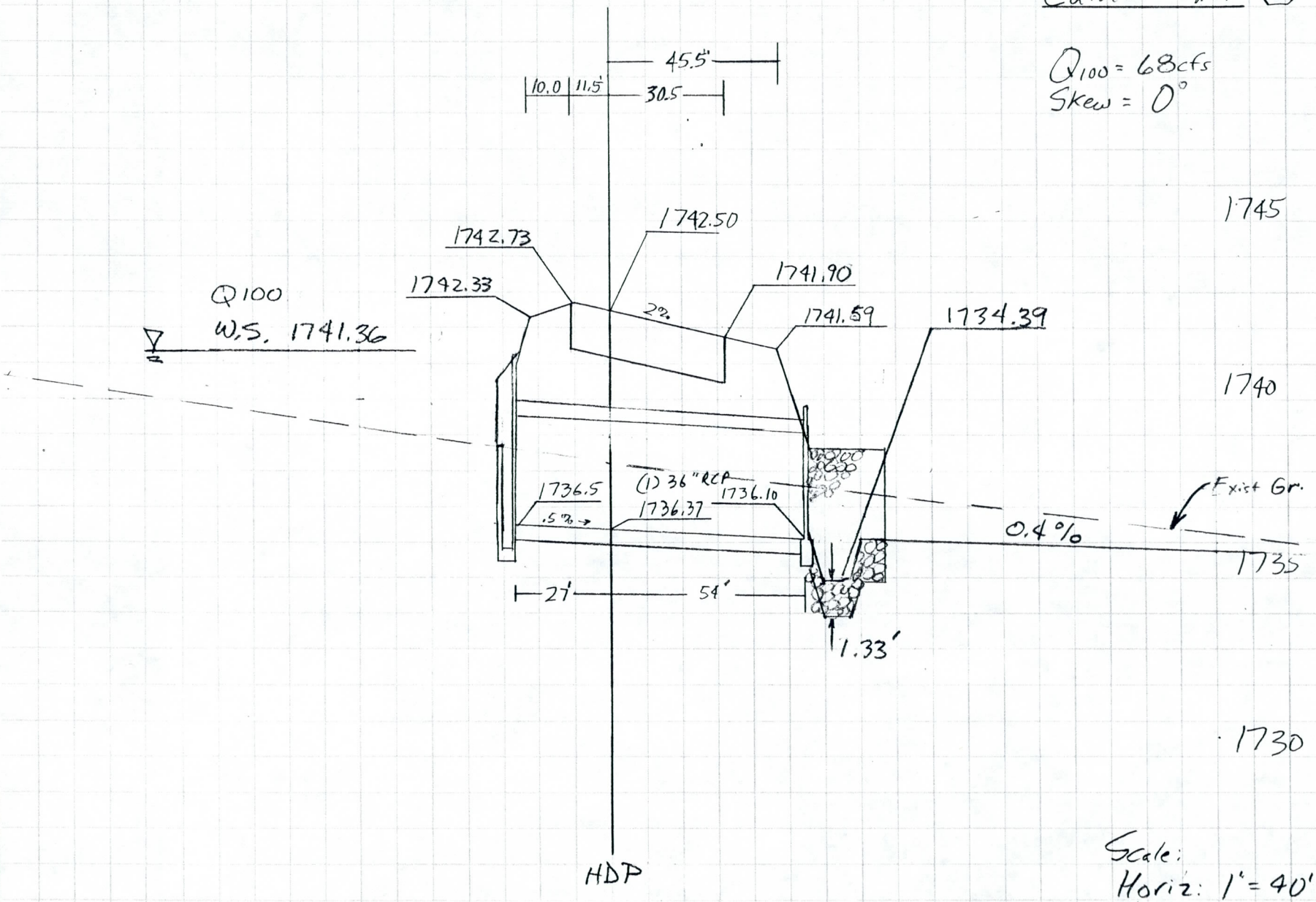
JOB 40477 Toyota SHEET NO. 12 OF

COMPUTATIONS FOR Culvert Profile 67F 5 DATE 6-17-91

H.S.T. Sta 305+75 BY DFP CHKD RJT

Culvert 67 F (5)

Q_{100} = 68 cfs
Skew = 0°



Scale:
Horiz: 1" = 40'
Vert. 1" = 4'

SECTION NUMBER TW67F 6/13/91

Channel Slope: 0.0125 ft./ft.

CROSS SECTION DATA:

OFFSET	-30	0	34	49.9	121.6	125.8	129.8	154.4	159.4	164.4	222.7	320
ELEV.	38.8	38.1	37.92	37.39	37.39	35.84	36.94	36.84	36.01	36.99	37.37	37.8
N	N/A	0.035	0.035	0.035	0.035	0.4	0.4	0.035	0.4	0.4	0.035	0.035

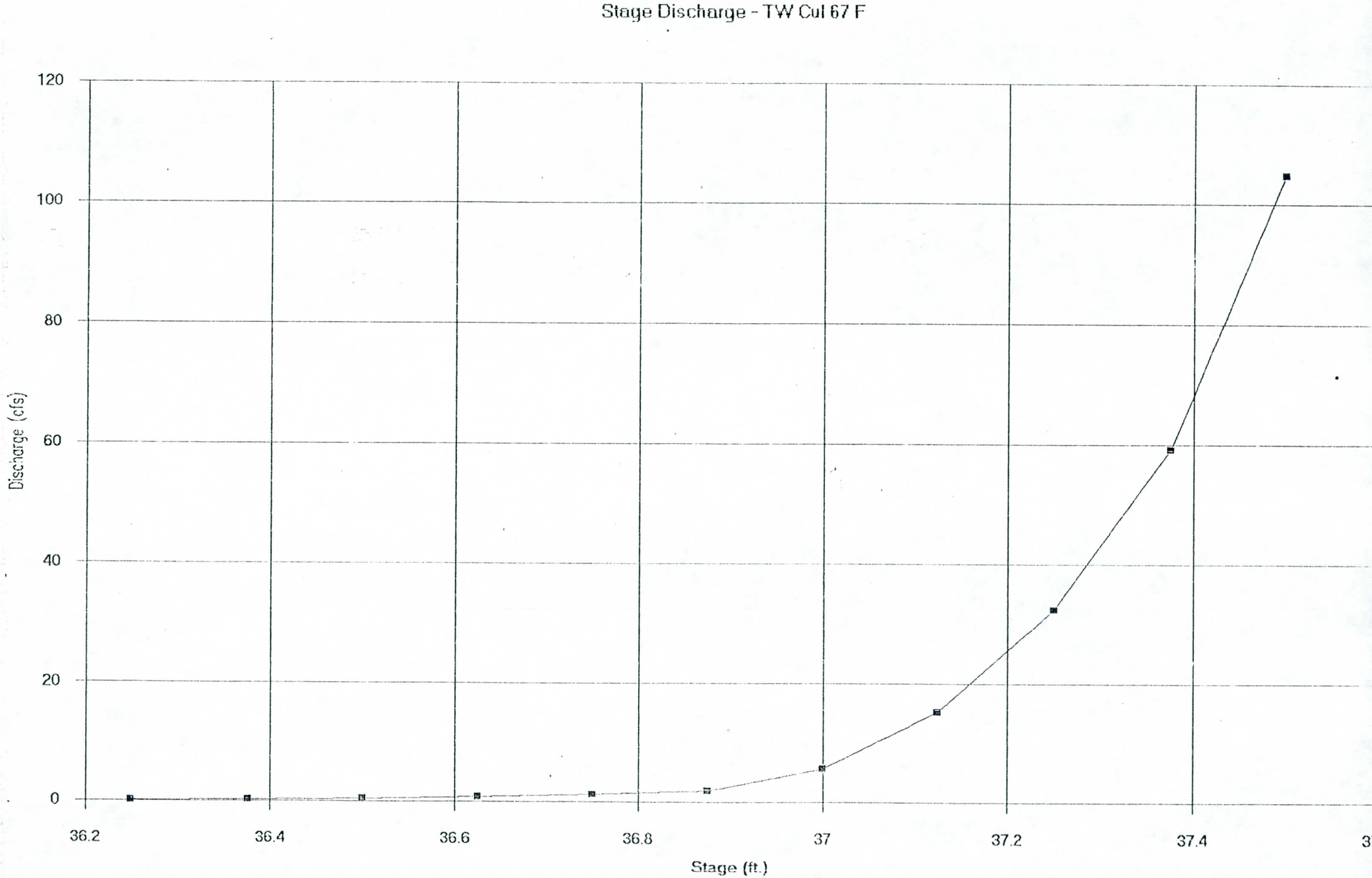
STAGE-DISCHARGE DATA:

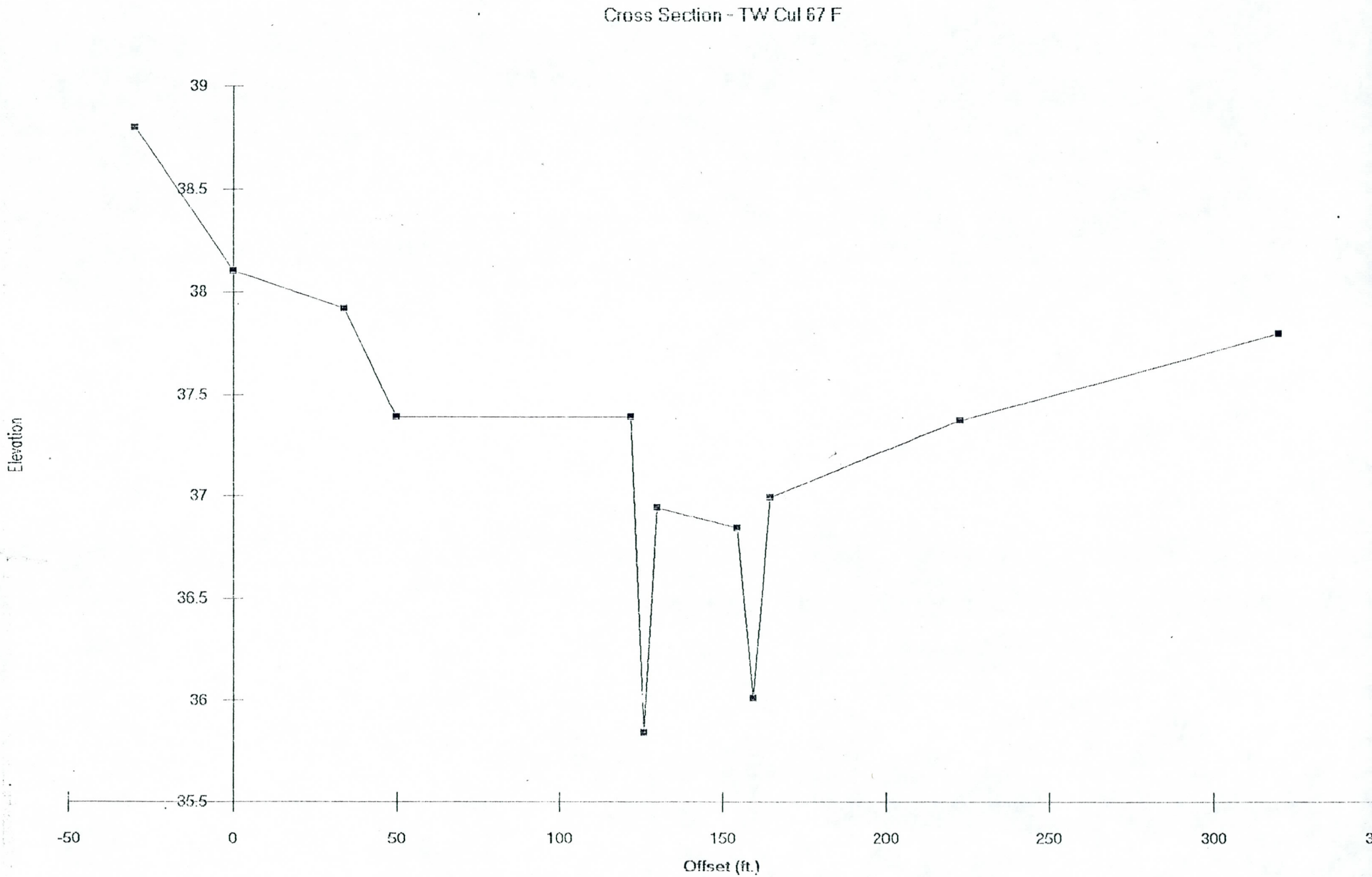
STAGE:	36.25											
WET PER.		0.0	0.0	0.0	0.0	1.2	2.7	0.0	1.5	2.7	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.2	0.5	0.0	0.2	0.3	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.1	0.1	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	36.375												
WET PER.		0.0	0.0	0.0	0.0	1.6	3.6	0.0	2.2	4.1	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.4	0.9	0.0	0.4	0.7	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.2	0.2	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	36.5												
WET PER.		0.0	0.0	0.0	0.0	1.9	4.4	0.0	3.0	5.5	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.6	1.4	0.0	0.7	1.3	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.2	0.2	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	36.625												
WET PER.		0.0	0.0	0.0	0.0	2.3	5.2	0.0	3.8	7.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.8	2.0	0.0	1.1	2.1	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.3	0.3	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	36.75												
WET PER.		0.0	0.0	0.0	0.0	2.6	6.1	0.0	4.5	8.4	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	1.1	2.6	0.0	1.6	3.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.4	0.4	0.0	0.0	0.0
Q		0	0	0	0	0	1	0	0	1	0	0	0
STAGE:	36.875												
WET PER.		0.0	0.0	0.0	0.0	3.0	6.9	8.6	5.1	9.6	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	1.5	3.4	0.2	2.3	4.2	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.4	0.4	0.0	0.0	0.0
Q		0	0	0	0	0	1	0	0	1	0	0	0

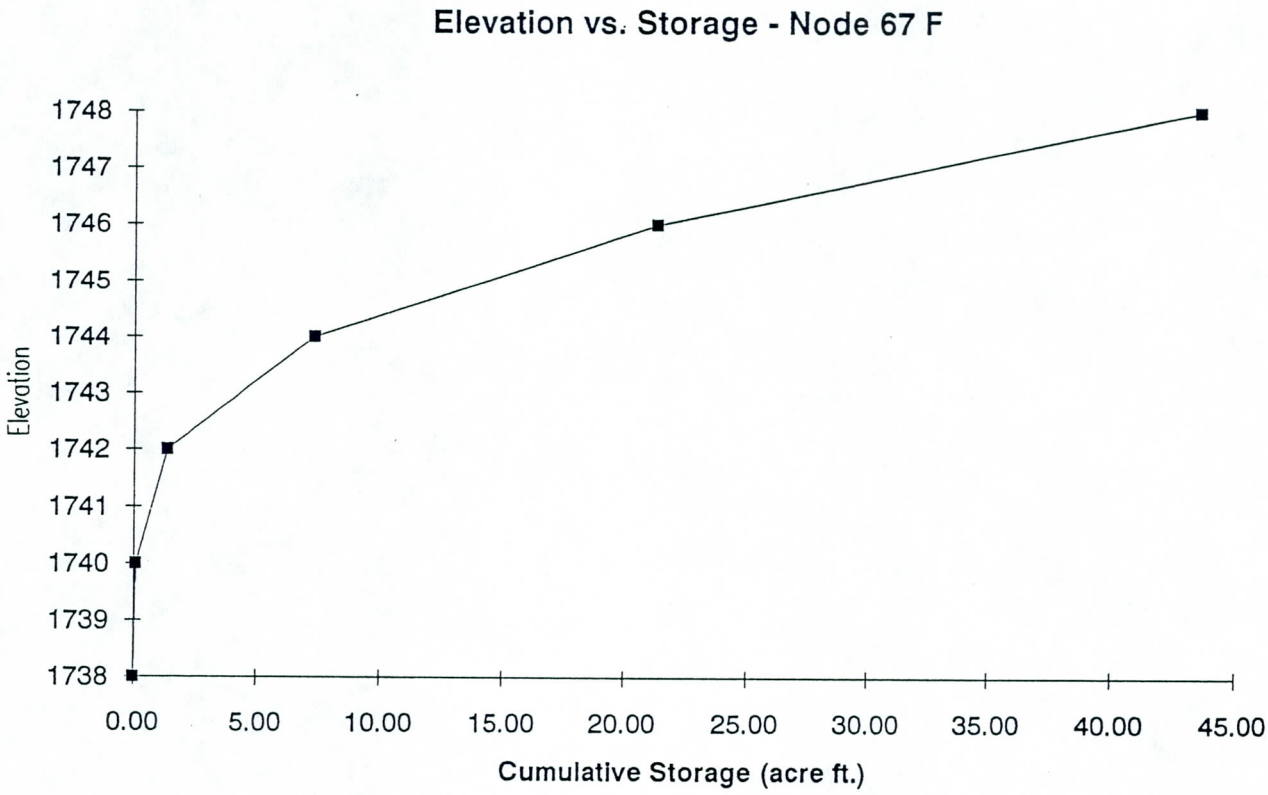
SECTION NUMBER TW67F 6/13/91

STAGE:	37											
WET PER.		0.0	0.0	0.0	0.0	3.4	7.5	24.6	5.1	10.2	1.5	0.0	0.0
AREA		0.0	0.0	0.0	0.0	1.8	4.3	2.7	2.9	5.4	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.5	0.6	0.1	0.6	0.5	0.0	0.0	0.0
Q		0	0	0	0	0	1	3	0	1	0	0	0
STAGE:	37.125												
WET PER.		0.0	0.0	0.0	0.0	3.7	7.9	24.6	5.1	10.2	20.7	0.0	0.0
AREA		0.0	0.0	0.0	0.0	2.2	5.2	5.8	3.5	6.6	1.4	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.6	0.7	0.2	0.7	0.7	0.1	0.0	0.0
Q		0	0	0	0	0	2	10	0	2	1	0	0
STAGE:	37.25												
WET PER.		0.0	0.0	0.0	0.0	4.1	8.2	24.6	5.1	10.2	39.9	0.0	0.0
AREA		0.0	0.0	0.0	0.0	2.7	6.1	8.9	4.1	7.9	5.2	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.7	0.7	0.4	0.8	0.8	0.1	0.0	0.0
Q		0	0	0	0	0	2	21	0	3	6	0	0
STAGE:	37.375												
WET PER.		0.0	0.0	0.0	0.0	4.4	8.6	24.6	5.1	10.2	58.3	59.4	0.0
AREA		0.0	0.0	0.0	0.0	3.2	7.1	11.9	4.8	9.1	11.4	11.4	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.7	0.8	0.5	0.9	0.9	0.2	0.2	0.0
Q		0	0	0	0	0	3	35	0	4	0	18	0
STAGE:	37.5												
WET PER.		0.0	0.0	3.3	75.0	4.5	8.6	24.6	5.1	10.2	58.3	87.7	0.0
AREA		0.0	0.0	0.2	8.1	3.7	8.2	15.0	5.4	10.4	18.7	20.6	0.0
HYD.RAD.		0.0	0.0	0.1	0.1	0.8	0.9	0.6	1.1	1.0	0.3	0.2	0.0
Q		0	0	0	9	0	3	51	0	4	0	37	0

W.S. Elev.	36.25	36.375	36.5	36.625	36.75	36.875	37	37.125	37.25	37.375	37.5
Q	0	0	0	1	1	2	6	15	32	59	105
A	0.9	1.6	2.7	4.1	5.7	7.7	12.4	19.0	28.1	39.6	62.2
V	0.1	0.2	0.2	0.2	0.2	0.2	0.5	0.8	1.2	1.5	1.7


Stage Discharge - TW Cul 67 F
120
100
80
60
40
20
0
Discharge (cfs)
36.2
36.4
36.6
36.8
37
37.2
37.4
Stage (ft.)


Cross Section - TW Cul 67 F
Elevation
39
38.5
38
37.5
37
36.5
36
35.5
-50
0
50
100
150
200
250
300
Offset (ft.)


Elevation vs. Storage - Node 67 F
Elevation
1748
1747
1746
1745
1744
1743
1742
1741
1740
1739
1738
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
Cumulative Storage (acre ft.)

SVERDR

JOB 4047 Toyota SHEET NO. 1 OF

DATE 6/26/91

COMPUTATIONS FOR Proposed Culvert 67A [6] BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 288+90 Oval Track

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 7.56 sq miles

Q_1 = 2,891 cfs

Q_2 =

TW_1 = 3.3' Exist. Channel

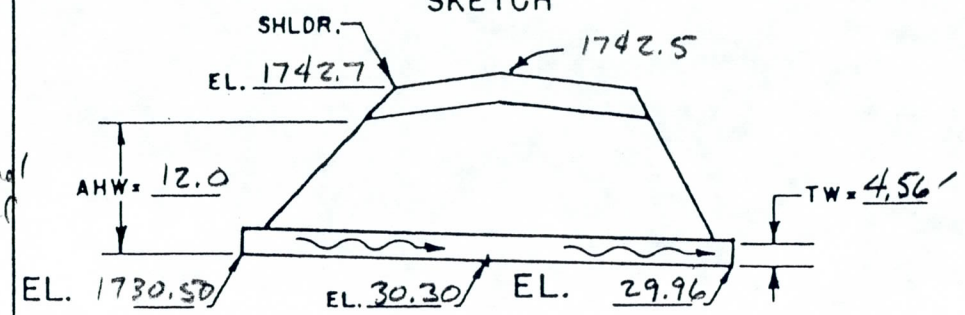
TW_2 = 4.56' New Channel

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~) Q_{100}

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050 ft/ft L = 108' L/100 S_o =

MEAN STREAM VELOCITY = 4.5 fps

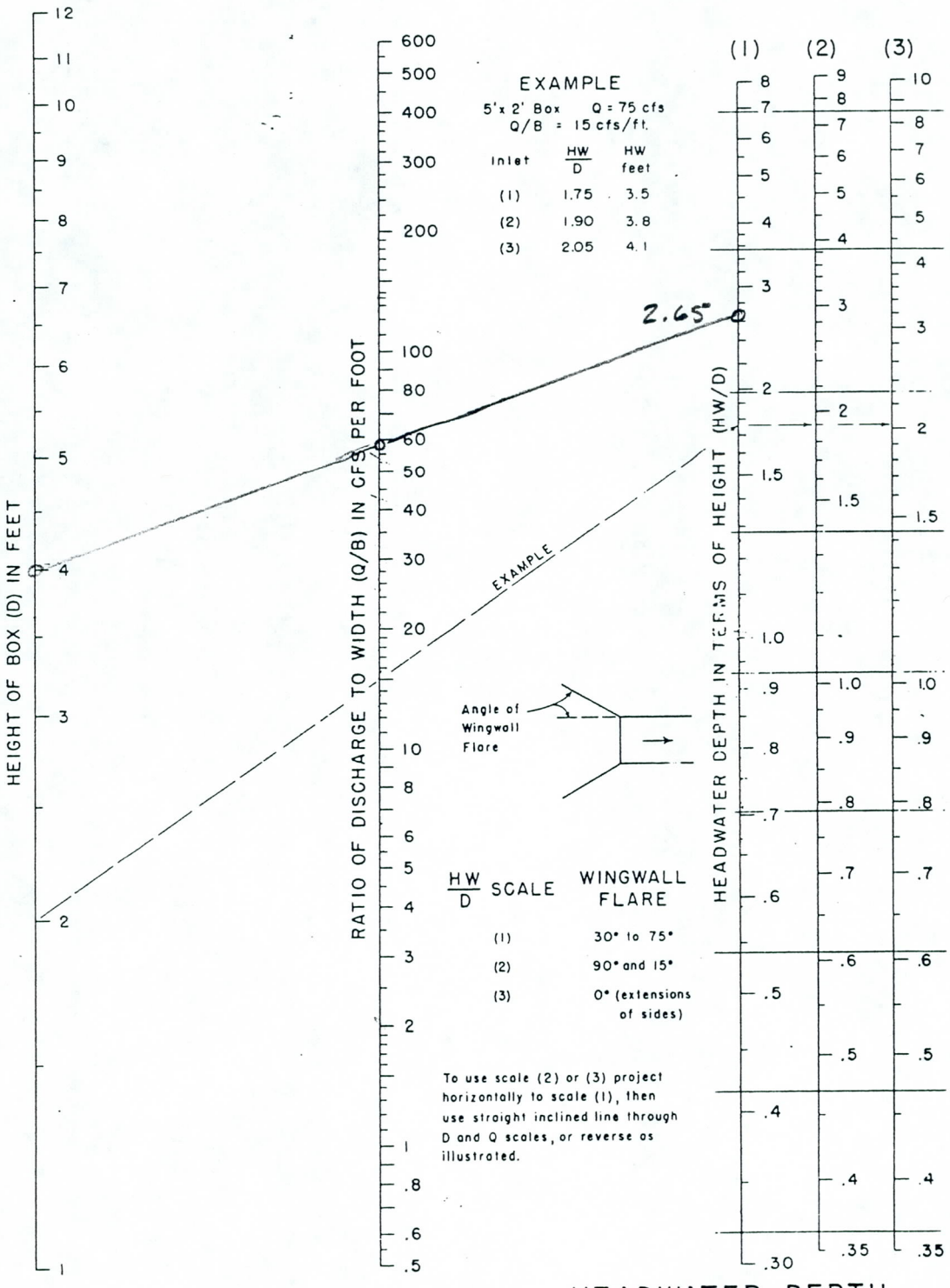
CULVERT DESCRIPTION SIZE	CULVERT DESCRIPTION ENTR. TYPE	Q	CAP. CHART HW	HEADWATER COMPUTATION: INLET CONT. HW/D	INLET CONT. HW	OUTLET CONTROL HW = H + h_o − LS_o: K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW	CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
5 Barrel 10'x4'	Drop Inlet	2891/5 578		2.65	10.6	0.2	4.7	4.0	4.0	4.56	4.56	.54	8.72	10.6	14.8		1741.10	Inlet Control

SUMMARY & RECOMMENDATIONS

B-1

Culvert 67 A

CHART 1

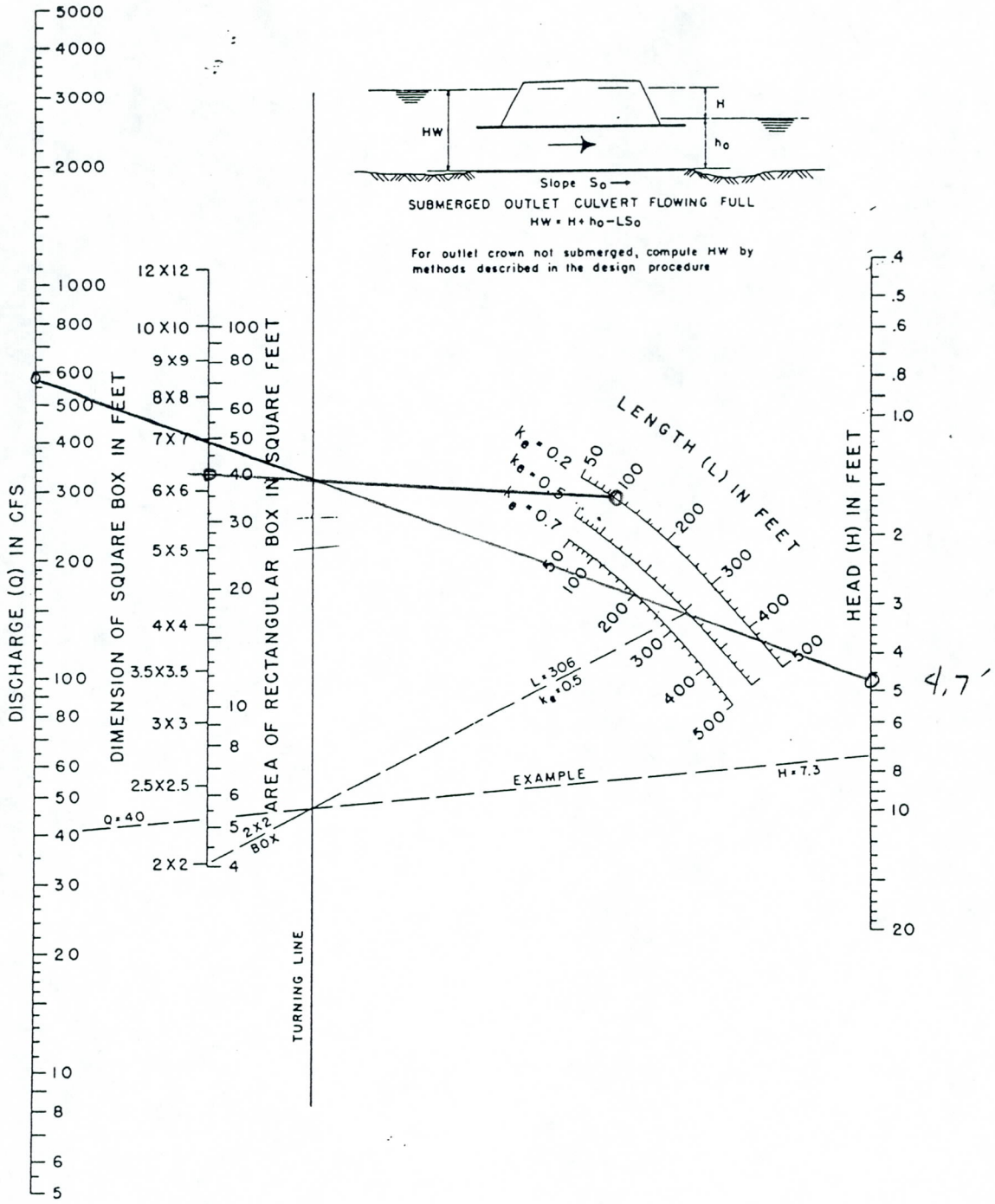


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 67 A

CHART 8

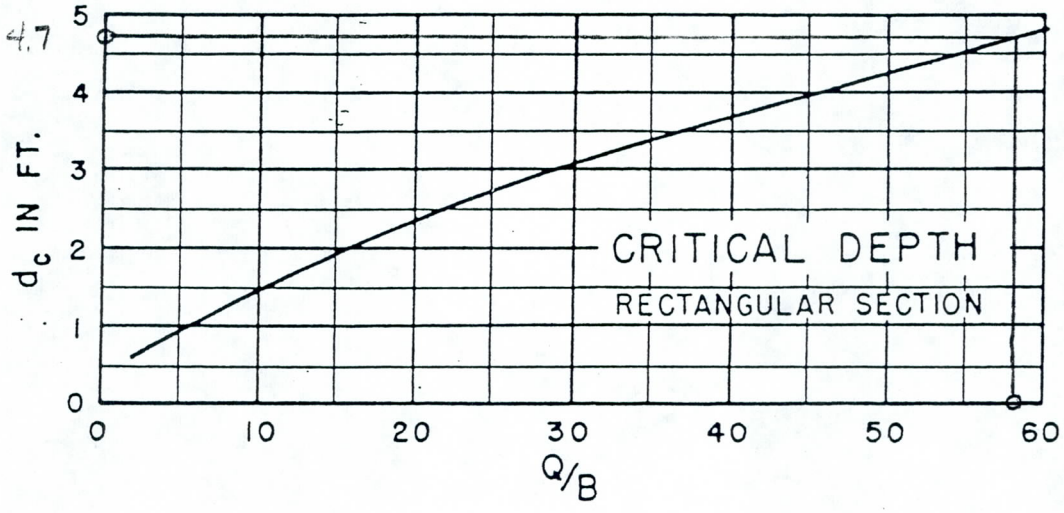


HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

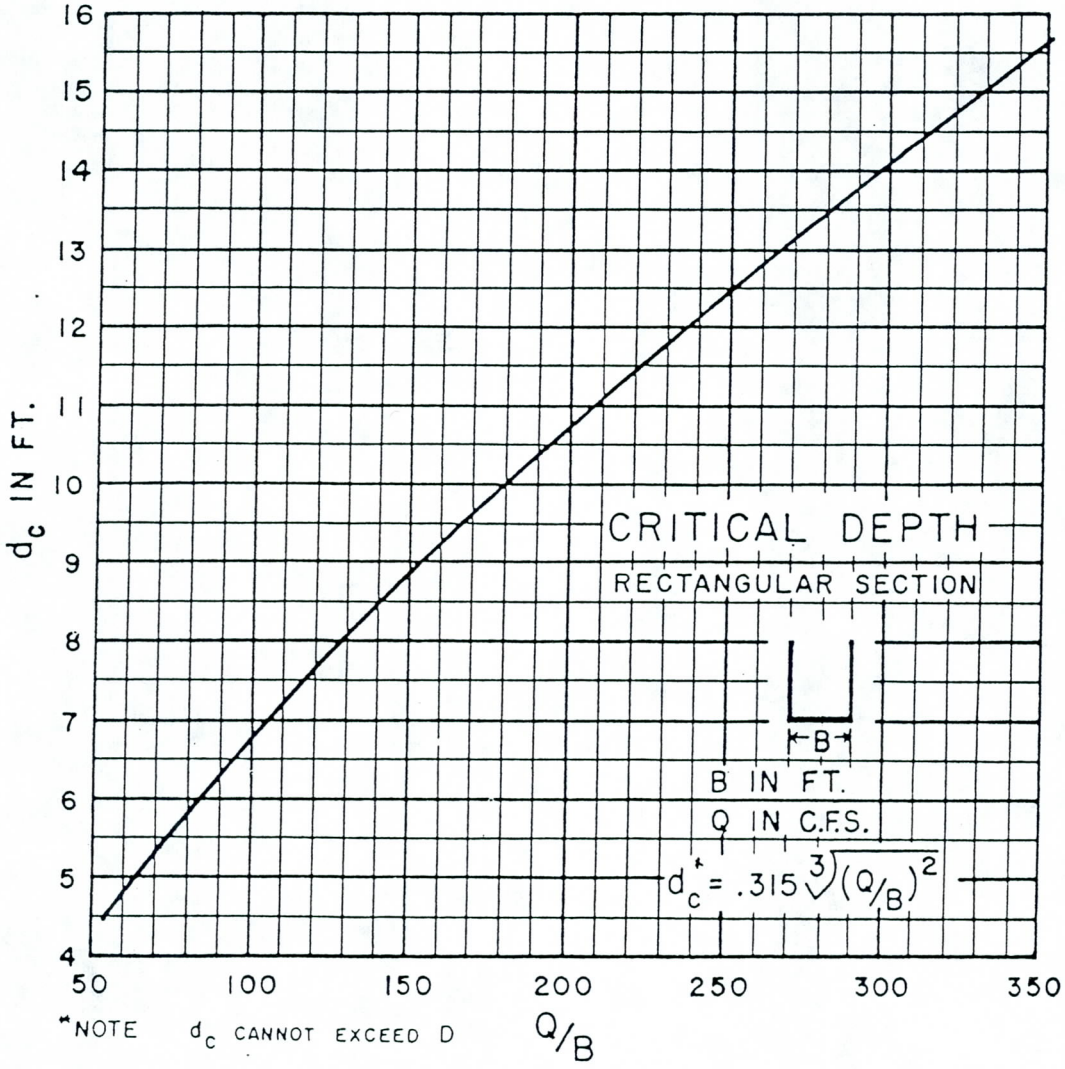
Culvert 67 A

CHART 15



$d_c = 4.7' > D = 4.0'$

$\therefore$ Use 4.0'



*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Box Culvert 67 A

SHEET NO. 5 OF

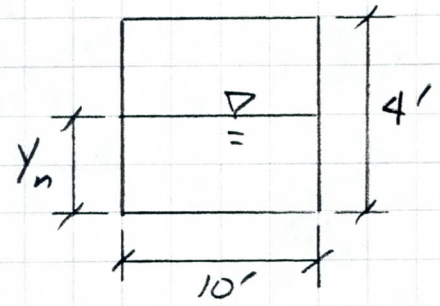
DATE 6/26/91

BY BDO CHKD RJT

Check Depth of Flow using Mannings Equation

$Q100 = 2891$ cfs

$Q/barrel = 578$ cfs



$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 3.90'$

$A = 39.0$ ft²

$WP = 10 + 2(3.90) = 17.80'$

$R_h = A/WP = 39.0/17.8 = 2.1910'$

$$V = \frac{1.49}{.012}(2.1910)^{.666}(.005)^{.5} = 14.80 \text{ fps}$$

Check

$Q = VA = 14.8(39.0) = 577$ cfs (OK)

Check Froude Number

$$\# = \frac{V}{\sqrt{g\,Y_n}} = \frac{14.8}{\sqrt{32.2(3.9)}} = 1.32, \text{ Supercritical}$$

$Q10 = 1041$ cfs $\Rightarrow$ 208 cfs/barrel

$Y_n = 1.91'$ Vel. = 10.88 fps, # = 1.39, Supercritical

SVERDRUP

JOB 40477 Toyota

SHEET NO. 6 OF

DATE 7/1/91

COMPUTATIONS FOR Channel Section Downstream of Box Cul. 67A

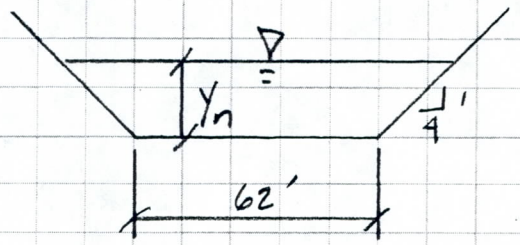
BY BDO CHKD RTT

Check depth of flow using Mannings Eqn.

$Q100 = 2891$ cfs

$n = 0.02$

$S_o = 0.0020$ ft/ft



50
3.67
3.55
62.22'
Use 62'

$Y_n \sim 4.56'$

$A = 365.4$ ft^2

$WP = 2(18.80) + 62 = 99.60'$

$R_h = A/WP = 365.4/99.6 = 3.6687'$

$V = \frac{1.49}{.02}(3.6687)^{.666}(.002)^{.5} = 7.92$ fps

Check

$Q = VA = 7.92(365.4) = 2894$ cfs ~ 2891 cfs (OK)

Check Froude Number

$F = \frac{7.92'}{\sqrt{32.2(4.56)}} = 0.65$, Subcritical

Energy Grade Line $= 4.56' + \frac{7.92^2}{2(32.2)} = 5.53'$

Use 5.5' deep channel - Flare channel section to reduce velocity and depth of flow.

SVERDRUP

JOB 40477 Toyota

SHEET NO. 7 OF

DATE 7/1/91

COMPUTATIONS FOR Channel Section Downstream of Box Culv. G7 A

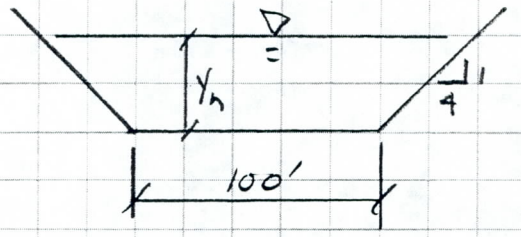
BY BDO CHKD RJT

Check depth of flow using Mannings Eqn.

$Q100 = 2891$ cfs

$n = 0.02$

$S_o = 0.002$ ft/ft



$Y_n \sim 3.55'$

$A = 405.7$ ft^2

$WP = 2(14.64) + 100 = 129.3$

$R_h = A/WP = 405.7/129.3 = 3.1377$ ft

$V = \frac{1.49}{.02}(3.1377)^{.666}(.002)^{.5} = 7.14$ fps

Check

$Q = VA = 7.14(405.7) = 2897$ cfs (OK)

Check Froude Number

$\# = \frac{7.14}{\sqrt{32.2(3.55)}} = 0.67$, Subcritical

Energy Grade Line $= 3.55' + \frac{(7.14)^2}{64.4} = 4.34'$

Check cutoff wall depth at end of channel

$h_s = 0.76(3.55)\left(\frac{7.14(2)(3.55)^2}{(3.55)^{2.5}}\right)^{.375} 35^{0.1}$

$= 8.23'$ Use 8'

SVERDRUP

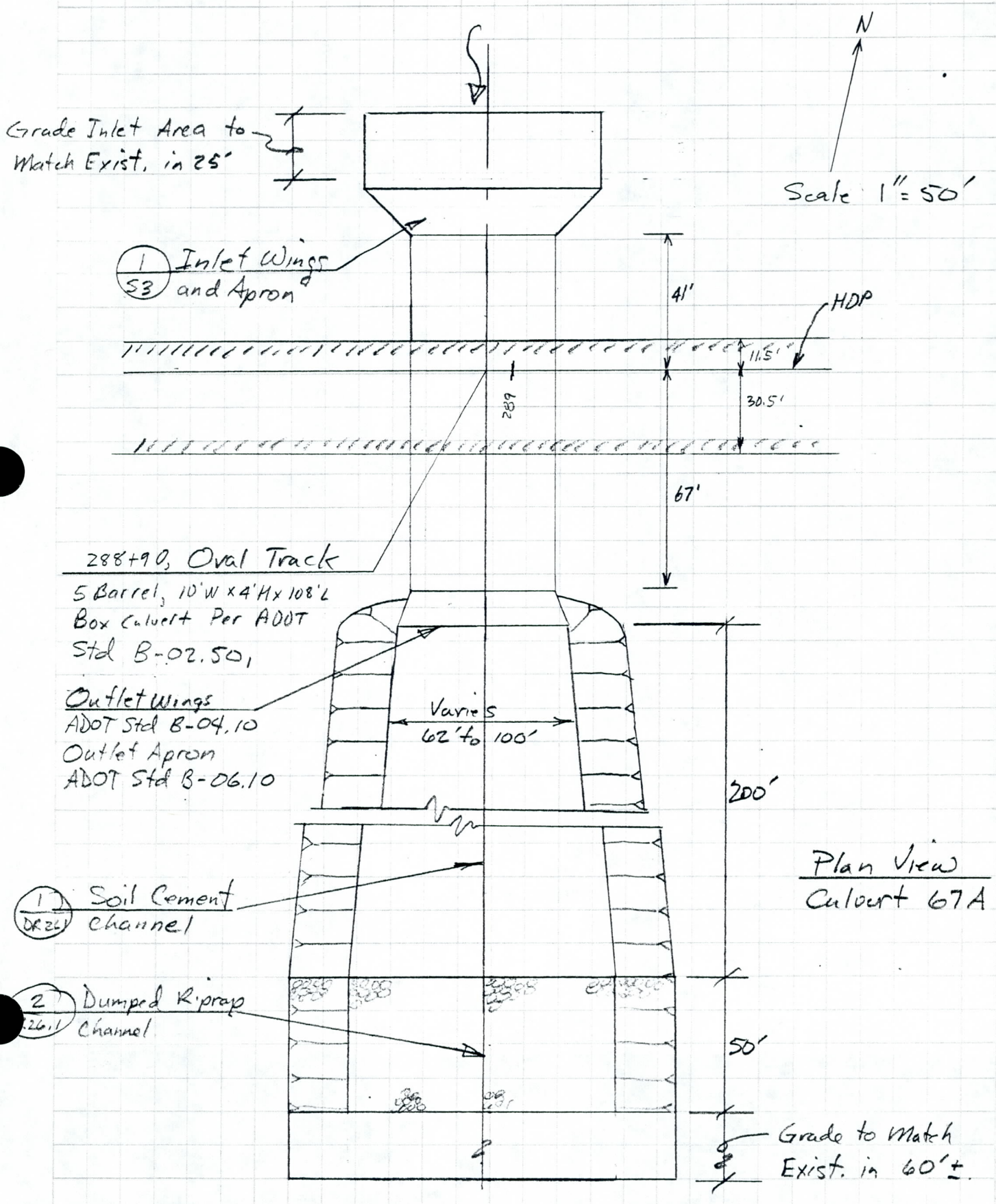
JOB 40477 Toyota

COMPUTATIONS FOR Box Culvert 67A [6]
Plan View - Sta 288+90

SHEET NO. 8 OF

DATE 6-26-91

BY DFP CHKD RJT



SVERDRUP

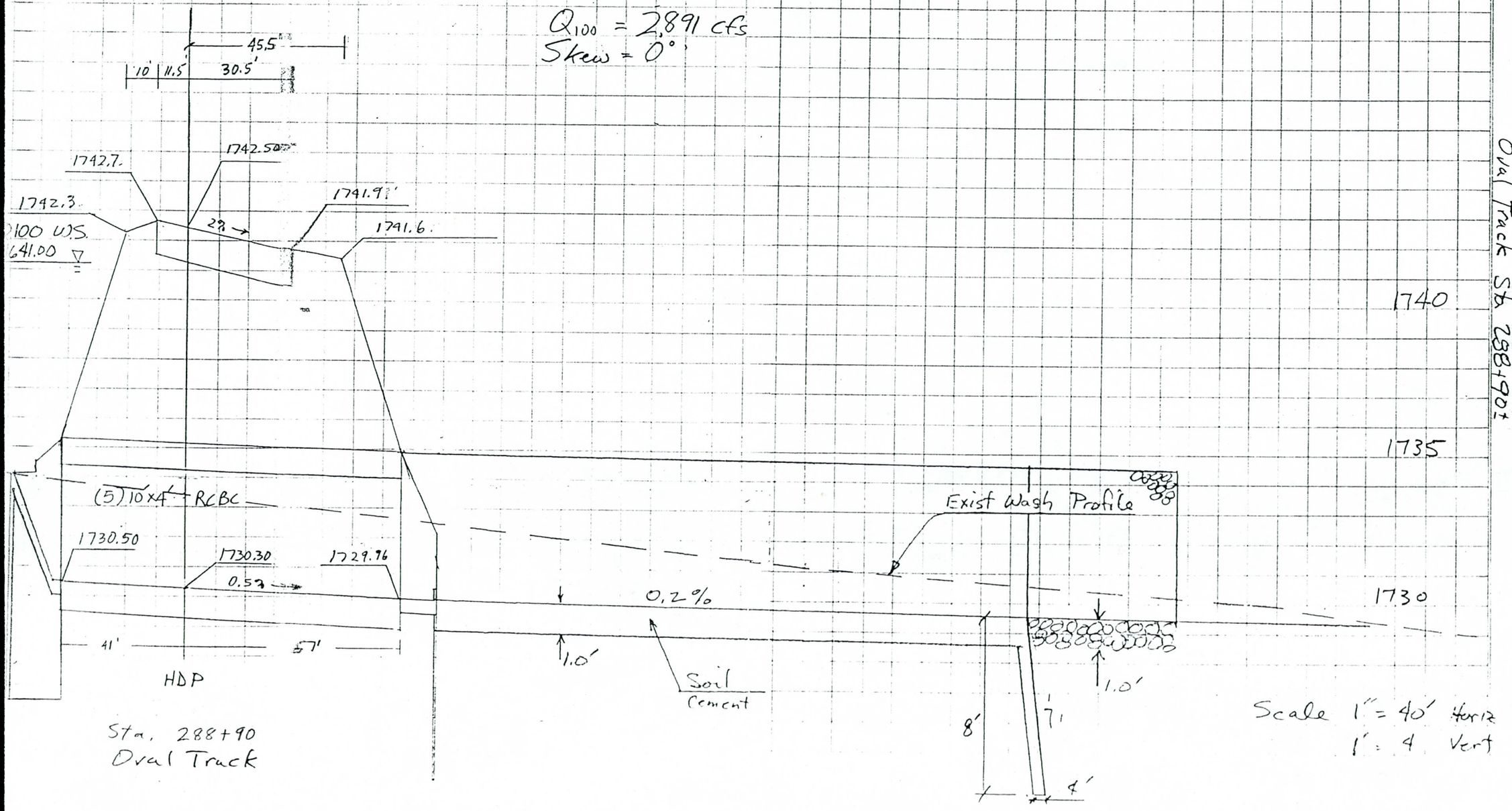
JOB 40477 Toyota SHEET NO. 9 OF

COMPUTATIONS FOR Culvert Profile 67A [6] DATE 6-26-91

Oval Track Sta 288+90± BY DFP CHKD RJT

Culvert 67A [6]

Q_{100} = 2,891 cfs
Skew = 0°



Sta. 288+90
Oval Track

Scale 1" = 40' Horiz
1" = 4 Vert

SECTION NUMBER TW67A 6/11/91

Channel Slope: 0.0077 ft./ft.

CROSS SECTION DATA:

OFFSET	1	42	105.2	123.9	128.4	131.7	137.1	179.8	186.5	225.5	229.2	235.1	238.3	265.8	320.6
ELEV.	35.5	33.94	33.84	32.9	31.24	31.56	33.67	34.3	33.38	33.95	32	31.95	33.11	34.55	32.56
N	N/A	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.035

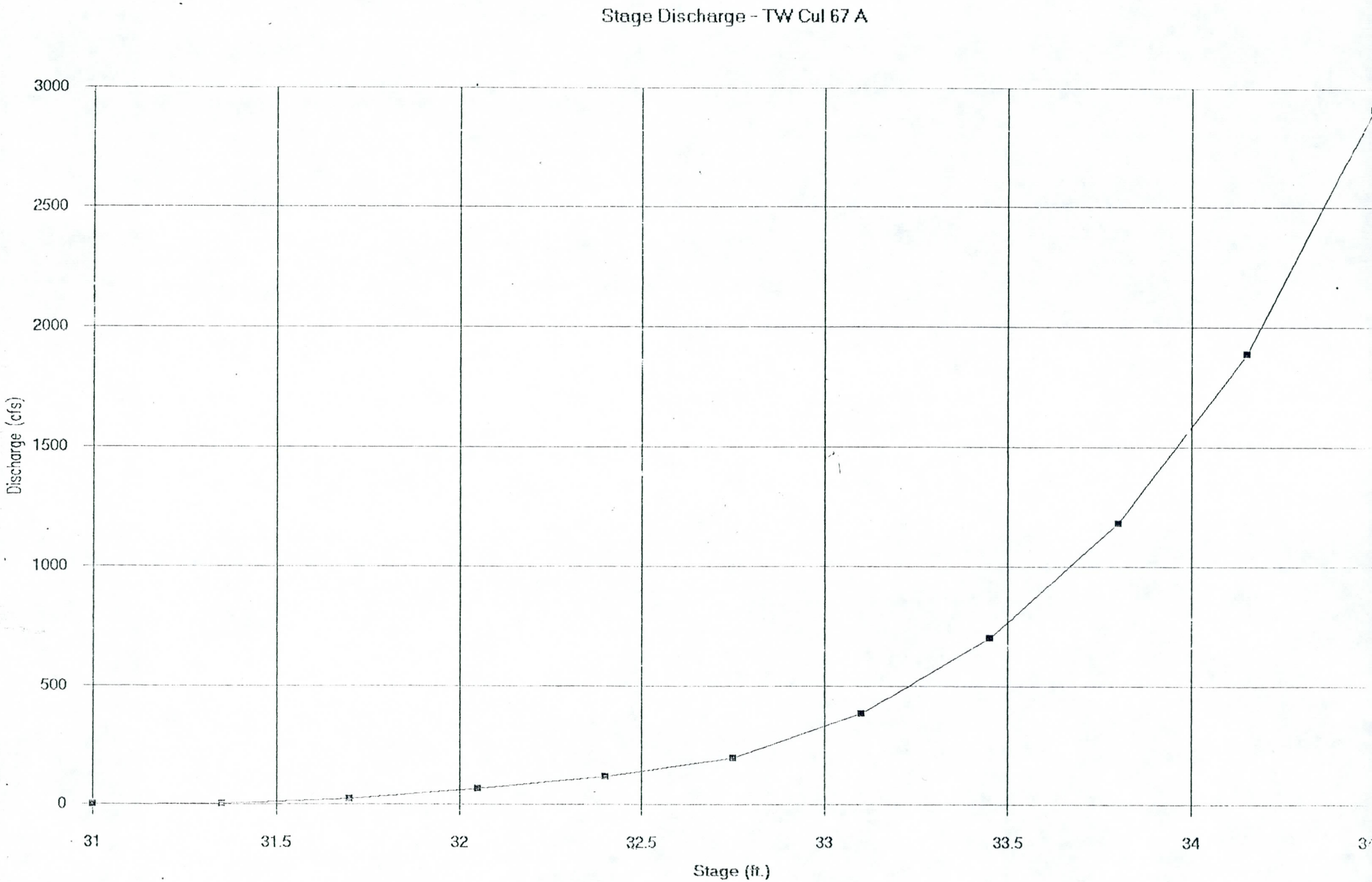
STAGE-DISCHARGE DATA:

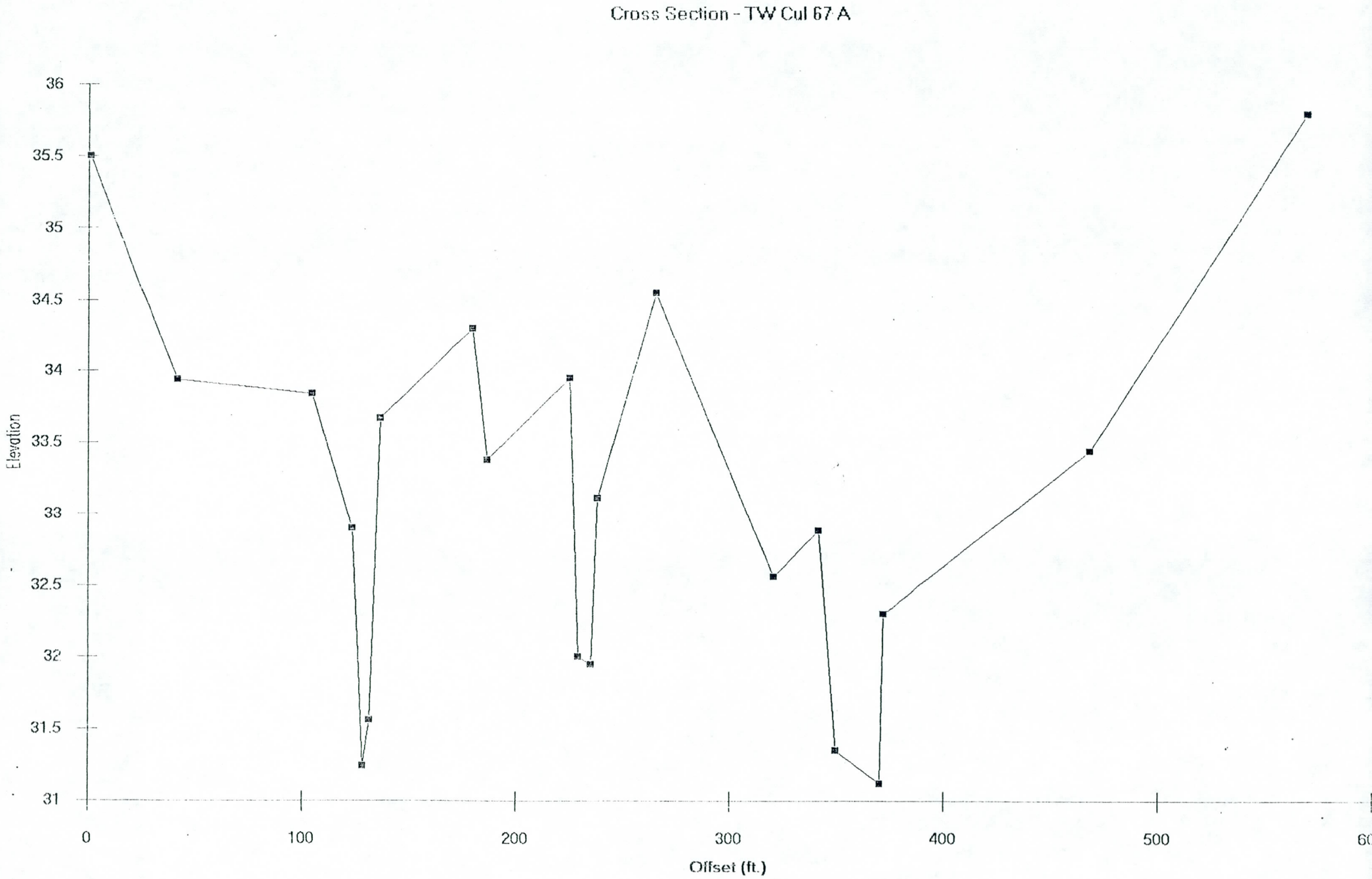
STAGE:	31													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	31.35													
WET PER.	0.0	0.0	0.0	0.3	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	31.7													
WET PER.	0.0	0.0	0.0	1.3	3.3	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.3	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	1	0	2	0	0	0	0	0	0	0	0
STAGE:	32.05													
WET PER.	0.0	0.0	0.0	2.3	3.3	4.7	0.0	0.0	0.0	0.1	5.9	6.2	0.0	0.0
AREA	0.0	0.0	0.0	0.9	2.1	2.5	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.4	0.6	0.5	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0
Q	0	0	0	2	0	6	0	0	0	0	0	0	0	0
STAGE:	32.4													
WET PER.	0.0	0.0	0.0	3.4	3.3	5.6	0.0	0.0	0.0	0.9	5.9	7.2	0.0	0.0
AREA	0.0	0.0	0.0	1.8	3.3	4.2	0.0	0.0	0.0	0.2	2.5	2.8	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.5	1.0	0.7	0.0	0.0	0.0	0.2	0.4	0.4	0.0	0.0
Q	0	0	0	6	0	13	0	0	0	0	0	6	0	0
STAGE:	32.75													
WET PER.	0.0	0.0	0.0	4.4	3.3	6.6	0.0	0.0	0.0	1.6	5.9	8.3	0.0	5.2
AREA	0.0	0.0	0.0	3.1	4.5	6.3	0.0	0.0	0.0	0.5	4.6	5.5	0.0	0.5
HYD.RAD.	0.0	0.0	0.0	0.7	1.3	1.0	0.0	0.0	0.0	0.3	0.8	0.7	0.0	0.1
Q	0	0	0	13	0	23	0	0	0	1	0	15	0	0

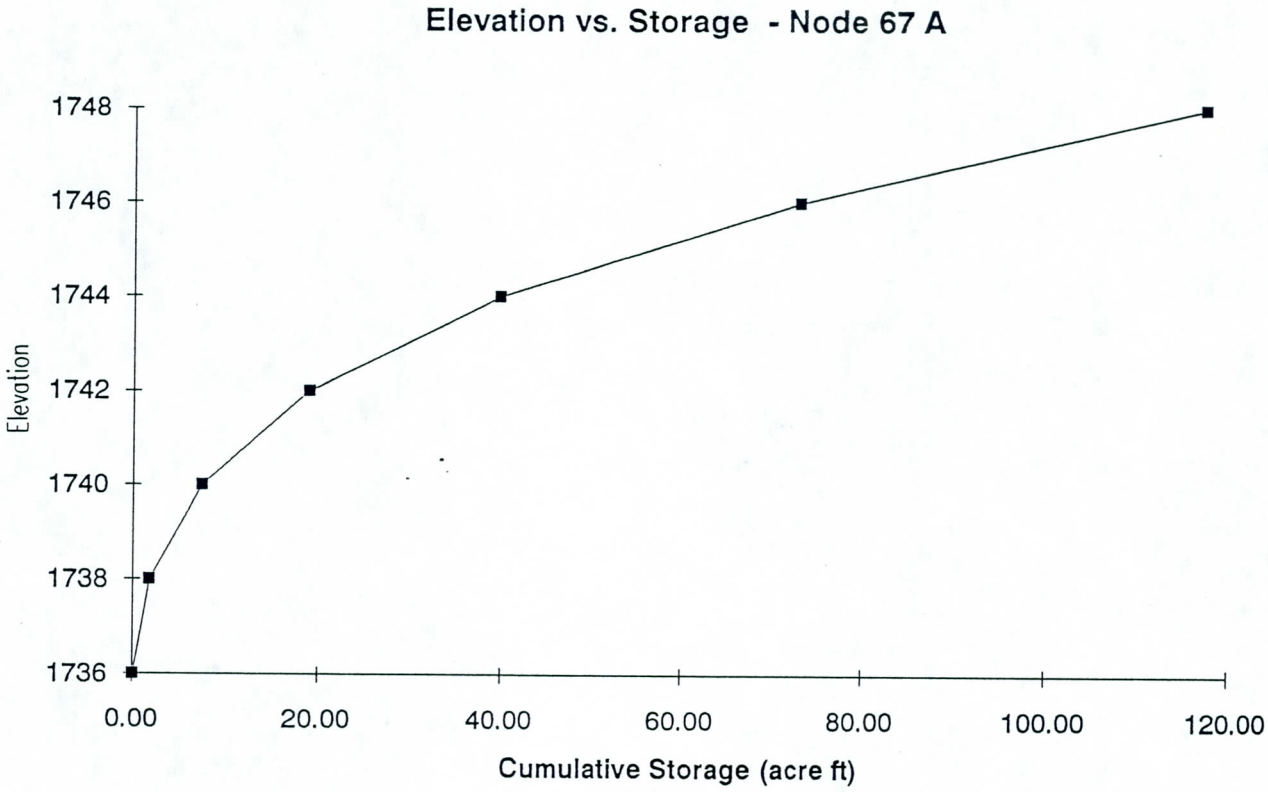
SECTION NUMBER TW07A 6/11/91

STAGE:	33.1													
WET PER.		0.0	0.0	4.0	4.8	3.3	7.5	0.0	0.0	0.0	2.4	5.9	9.3	0.0	14.9
AREA		0.0	0.0	0.4	4.6	5.6	8.6	0.0	0.0	0.0	1.1	6.6	8.5	0.0	4.0
HYD.RAD.		0.0	0.0	0.1	1.0	1.7	1.1	0.0	0.0	0.0	0.5	1.1	0.9	0.0	0.3
Q		0	0	0	24	0	35	0	0	0	4	0	30	0	0
STAGE:	33.45														
WET PER.		0.0	0.0	11.0	4.8	3.3	8.5	0.0	0.5	5.3	3.1	5.9	9.3	15.8	24.5
AREA		0.0	0.0	3.0	6.2	6.8	11.3	0.0	0.0	0.2	2.0	8.7	11.6	12.8	10.9
HYD.RAD.		0.0	0.0	0.3	1.3	2.0	1.3	0.0	0.0	0.0	0.6	1.5	1.3	0.8	0.4
Q		0	0	5	38	0	51	0	0	0	8	0	0	41	0
STAGE:	33.8														
WET PER.		0.0	0.0	17.9	4.8	3.3	9.1	17.9	3.1	31.8	3.9	5.9	9.3	22.5	34.2
AREA		0.0	0.0	8.1	7.8	7.9	14.3	14.9	0.6	6.7	3.1	10.8	14.8	19.4	21.2
HYD.RAD.		0.0	0.0	0.4	1.6	2.4	1.6	0.8	0.2	0.2	0.8	1.8	1.6	0.9	0.6
Q		0	0	18	56	0	0	49	0	9	14	0	0	65	0
STAGE:	34.15														
WET PER.		5.5	68.7	87.4	4.8	3.3	9.1	41.7	5.7	44.7	4.2	5.9	9.3	29.2	43.8
AREA		0.6	17.0	31.6	9.4	9.1	17.4	25.2	2.2	21.1	4.3	12.8	18.0	28.3	34.8
HYD.RAD.		0.1	0.2	0.4	2.0	2.7	1.9	0.6	0.4	0.5	1.0	2.2	1.9	1.0	0.8
Q		0	0	60	76	0	0	67	0	48	23	0	0	104	0
STAGE:	34.5														
WET PER.		14.7	77.9	96.7	4.8	3.3	9.1	51.8	58.6	97.6	4.2	5.9	9.3	35.9	53.5
AREA		4.1	42.7	63.8	10.9	10.2	20.4	42.4	46.8	79.4	5.6	14.9	21.2	39.7	51.8
HYD.RAD.		0.3	0.5	0.7	2.3	3.1	2.2	0.8	0.8	0.8	1.3	2.5	2.3	1.1	1.0
Q		0	0	180	99	0	0	0	0	258	36	0	0	158	0

W.S. Elev.	31	31.35	31.7	32.05	32.4	32.75	33.1	33.45	33.8	34.15	34.5
Q	0	2	24	67	118	195	384	700	1181	1887	2912
A	0.0	2.5	11.4	22.4	37.4	65.3	123.0	203.2	310.1	464.6	650.6
V	0.0	0.9	2.1	3.0	3.2	3.0	3.1	3.4	3.8	4.1	4.5


Stage Discharge - TW Cul 67 A
3000
2500
2000
1500
1000
500
0
Discharge (cfs)
31
31.5
32
32.5
33
33.5
34
Stage (ft.)


Cross Section - TW Cul 67 A
Elevation
36
35.5
35
34.5
34
33.5
33
32.5
32
31.5
31
0
100
200
300
400
500
Offset (ft.)


Elevation vs. Storage - Node 67 A
1748
1746
1744
1742
1740
1738
1736
Elevation
0.00
20.00
40.00
60.00
80.00
100.00
120.00
Cumulative Storage (acre ft)

SVERDR

JOB 4047 Toyota

SHEET NO. 1 OF

DATE 6/26/91

COMPUTATIONS FOR Proposed Culvert 67B [7]

BY BDO CHKD RVT

CULVERT COMPUTATION SHEET

PROJECT:

DESIGNER:

STATION: 278+50, Oval Track

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

1697 Total
1207 67C
490 cfs 67B

DRAINAGE AREA 3.99 sq. miles (Combined areas of 67B & 67C)

Q_1 = 490 cfs

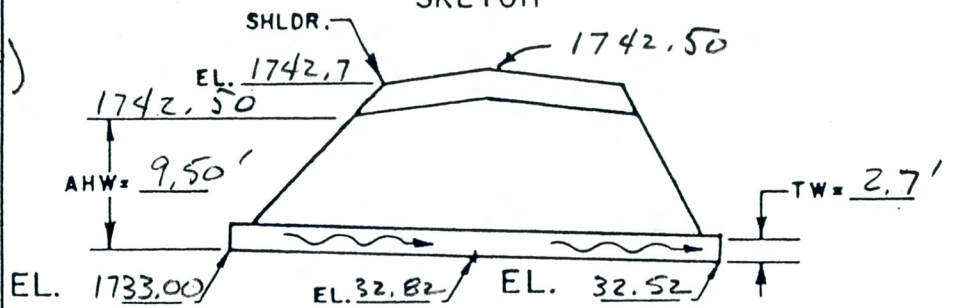
Q_2 =

TW_1 = 2.7'

TW_2 =

Peak Outlet Discharge
(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~) Q100
(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_0 = .0050' L = 96' L/100 S_0 =

MEAN STREAM VELOCITY = 4.2 fps

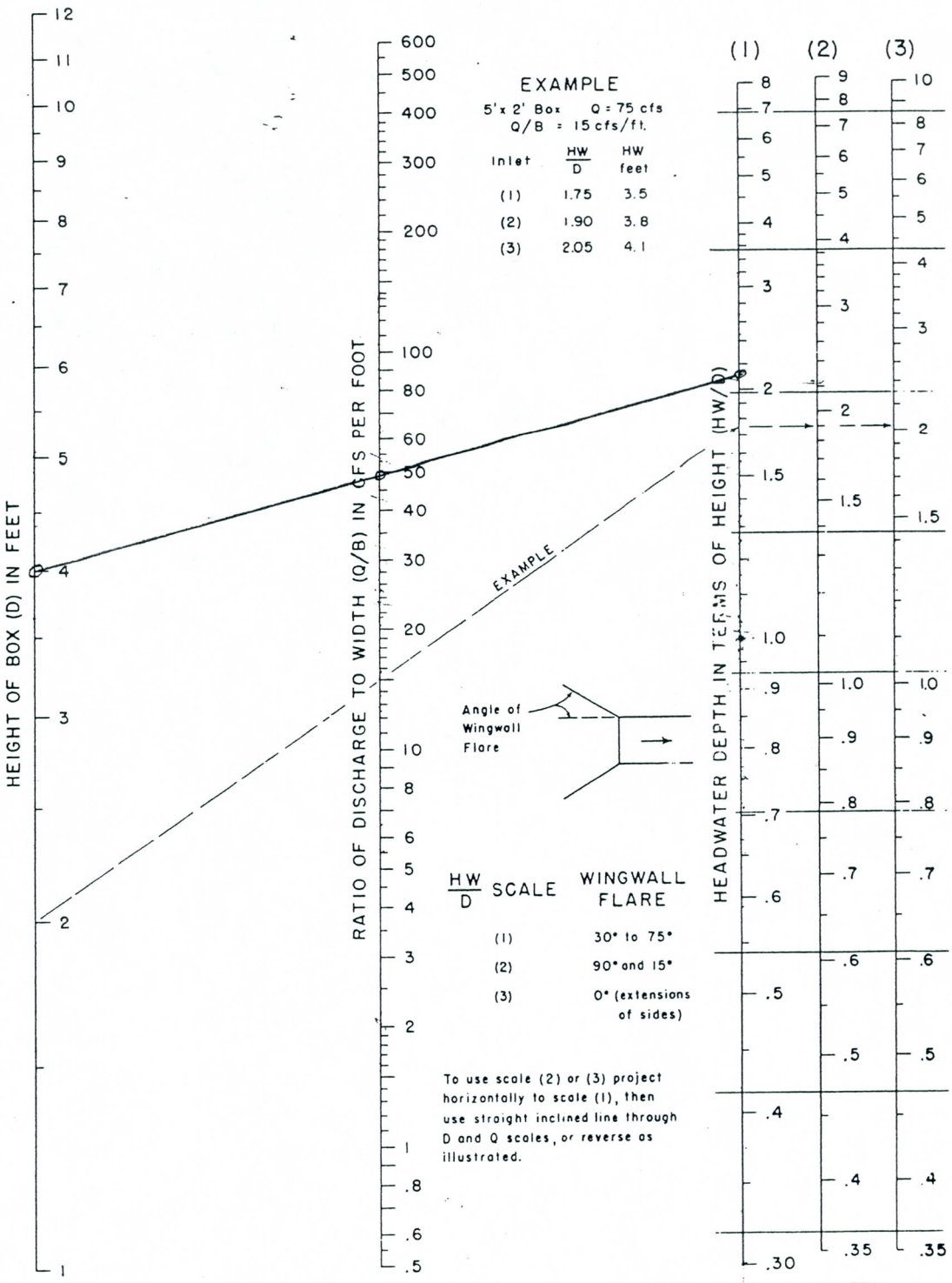
CULVERT DESCRIPTION SIZE	CULVERT DESCRIPTION ENTR. TYPE	Q	CAP. CHART HW	HEADWATER COMPUTATION: INLET CONT. HW/D	INLET CONT. HW	OUTLET CONTROL K_e	OUTLET CONTROL H	OUTLET CONTROL d_c	OUTLET CONTROL $\frac{d_c+D}{2}$	OUTLET CONTROL TW	OUTLET CONTROL h_o	OUTLET CONTROL LS_o	OUTLET CONTROL HW	CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
(1) Barrel 10x4	Drop Inlet	490		2.13	8.52	0.2	3.4	4.0	4.0	2.7	4.0	0.48	6.92	8.52	14.1		1741.52	Inlet Control

SUMMARY & RECOMMENDATIONS Use dumped riprap plunge basin to reduce culvert outlet velocities.

B-1

Culvert 67 B

CHART 1

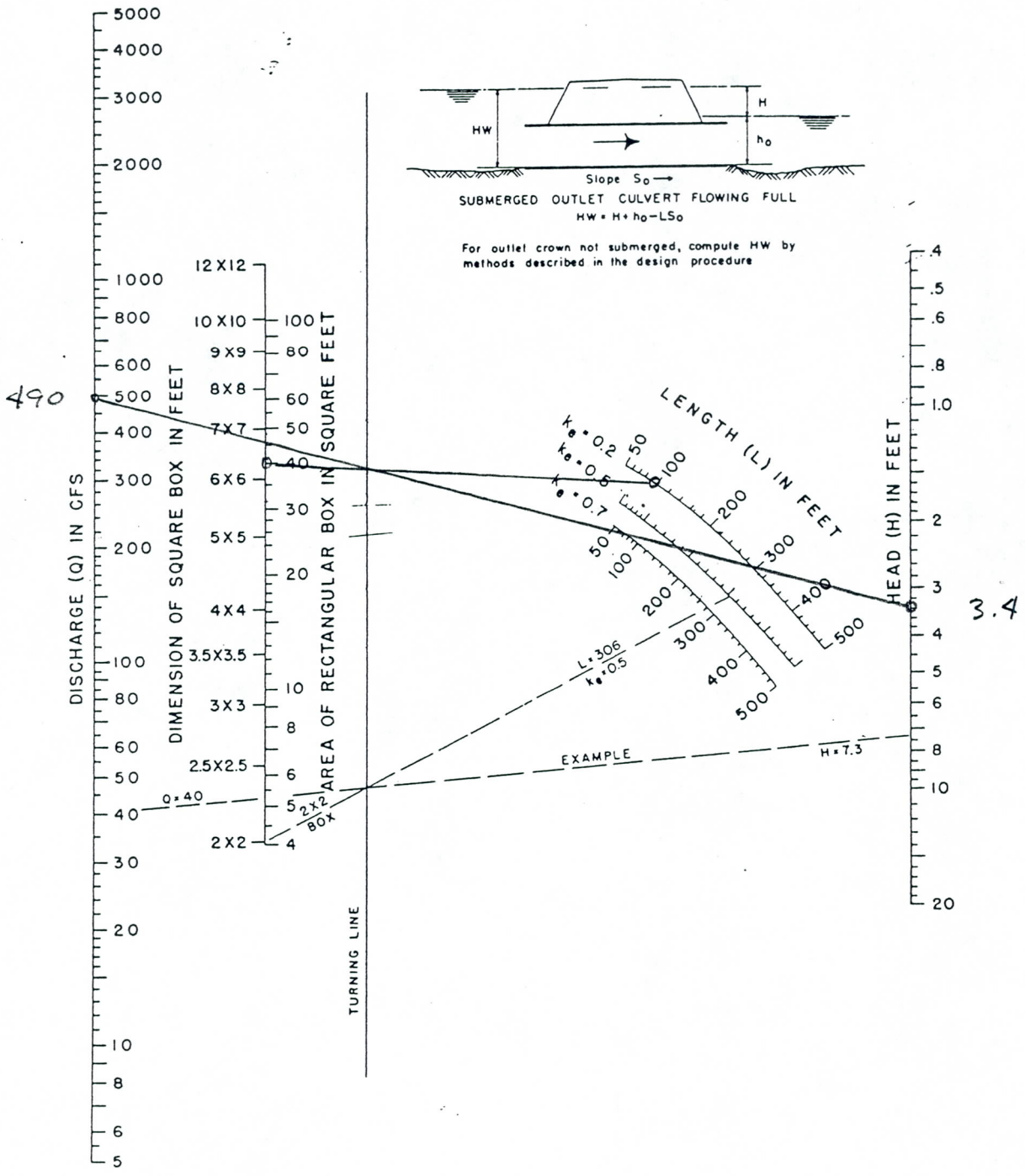


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 67B

CHART 8

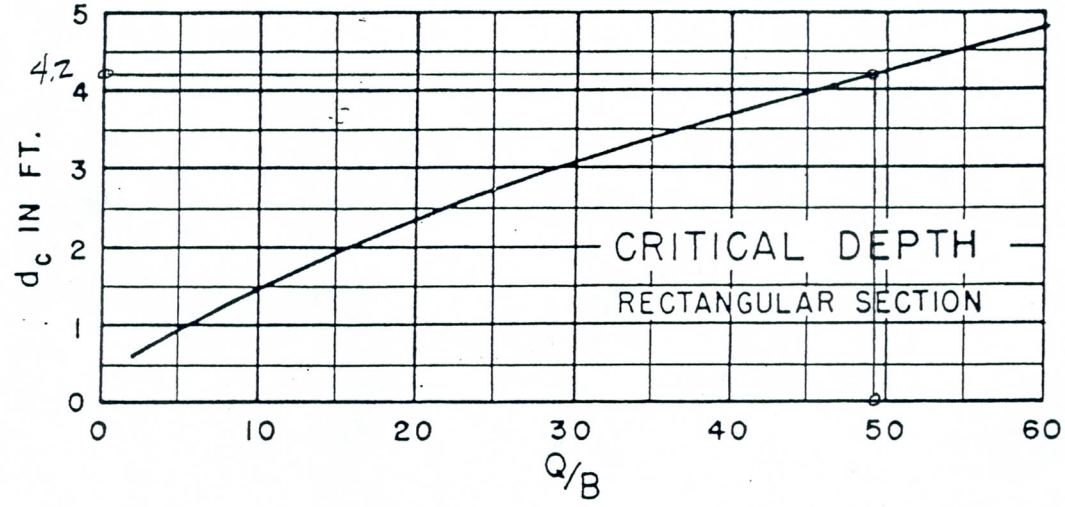


HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

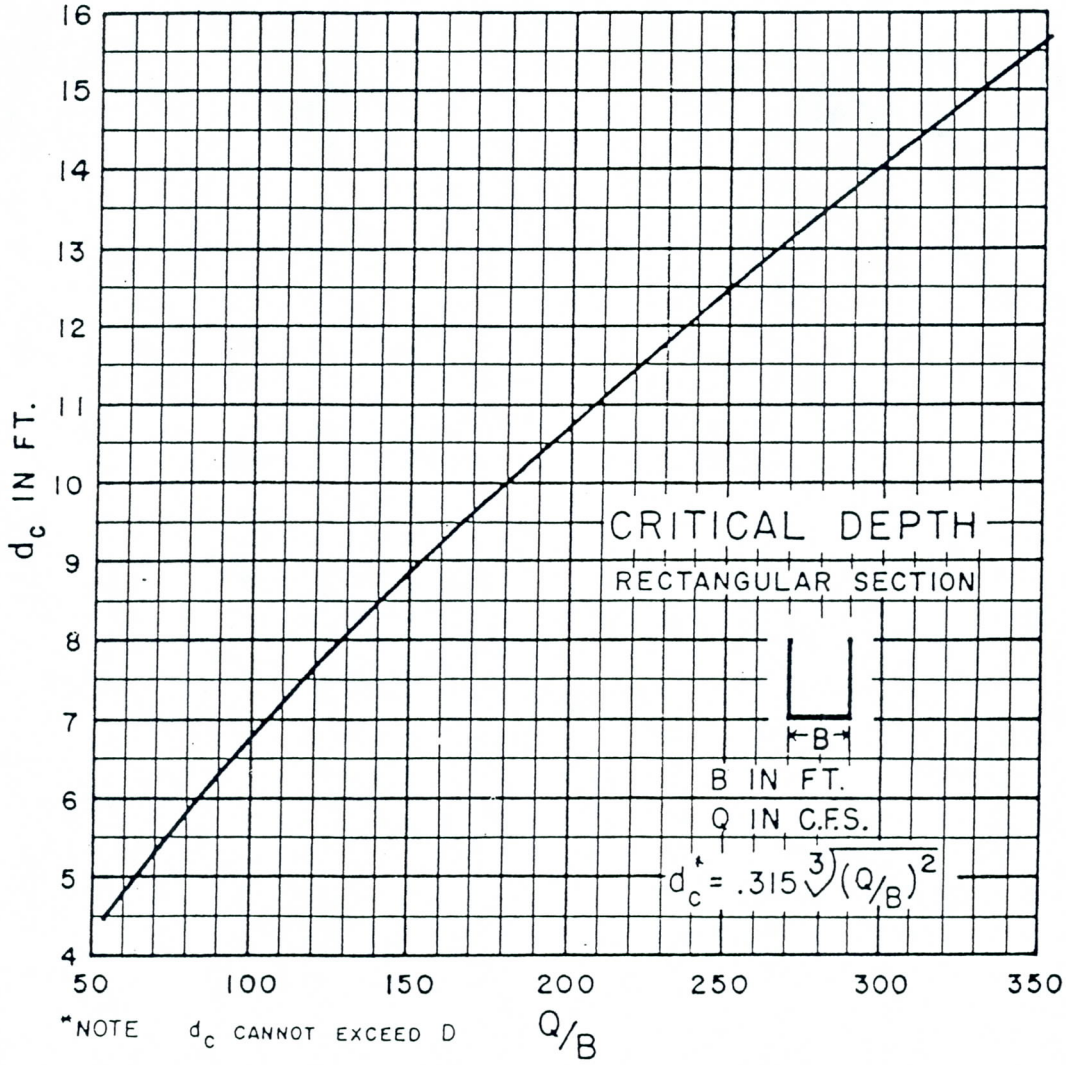
Culvert 67 B

CHART 15



$d_c = 4.2' > 4.0$

$\therefore$ Use 4.0'



*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 67B

SHEET NO. 5 OF

DATE 6/26/91

BY BDO CHKD RJT

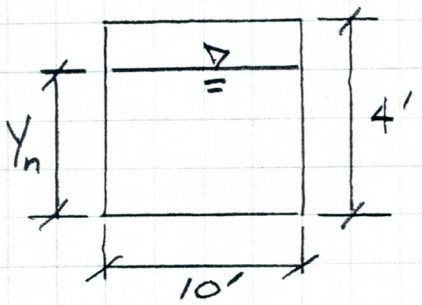
Check Depth of Flow using Mannings Equation

$Q100 = 490$ cfs

$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 3.47'$



$A = 34.7$ ft^2

$WP = 10 + 2(3.47) = 16.94'$

$R_h = A/WP = 34.7/16.94 = 2.0484'$

$$V = \frac{1.49}{.012}(2.0484)^{.666}(.005)^{.5} = 14.15 \text{ fps}$$

Check

$Q = VA = 14.15(34.7) = 491$ cfs (OK)

Check Froude Number

$$F = \frac{V}{\sqrt{g\,Y_e}} = \frac{14.15}{\sqrt{32.2(3.47)}} = 1.34$$ Supercritical

$Q10 = 102$ cfs

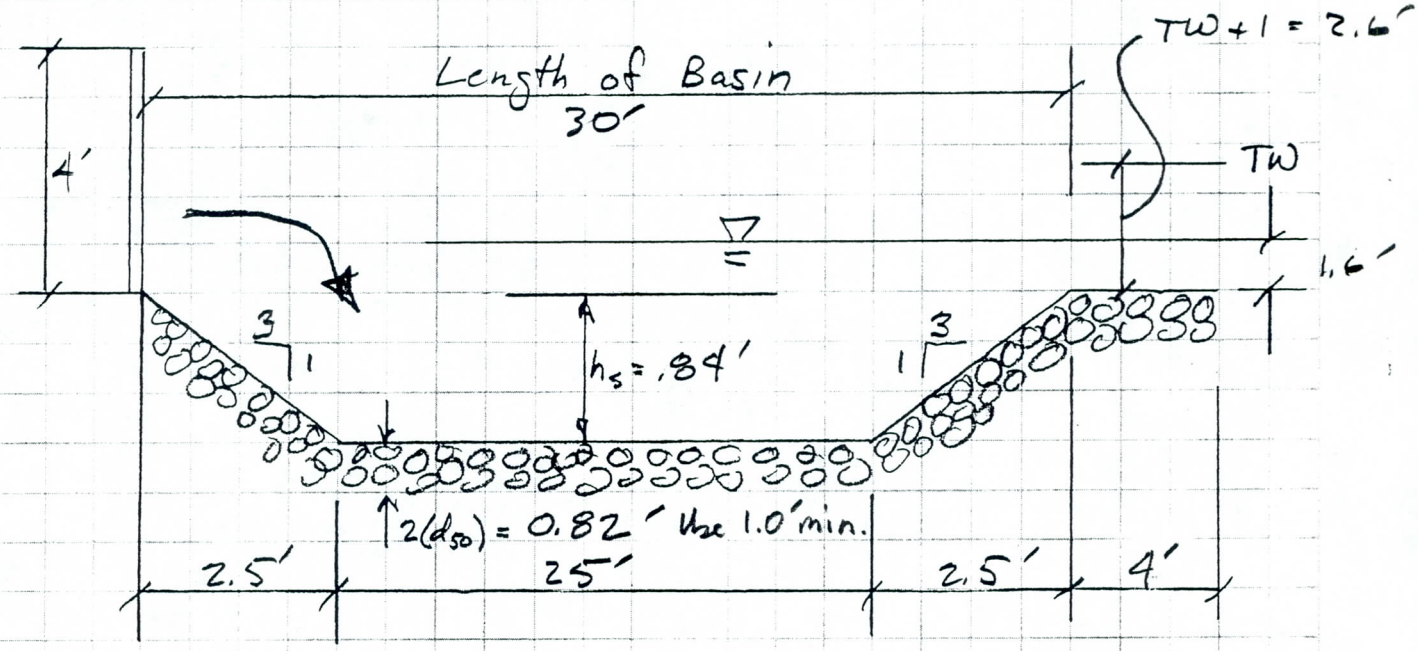
$Y_n = 1.19'$, Vel. = 8.55 fps, $F = 1.38$, Supercritical

SVERDRUP

JOB 4077 Toyota SHEET NO. 6 OF

COMPUTATIONS FOR Box Culvert 67B DATE 7/1/91 BY BDO CHKD RJT

Riprap Plunge Basin Design (Q10)



Check Rock Size (From Figure XI-2, HEC No 14)

For Y_o = 1.19' d_{50} = 5" or 0.42'

$d_{50}/Y_o = \frac{0.42}{1.19} = 0.35$, $F = 1.38$

$\frac{h_s}{Y_o} = 0.71$ $h_s = 0.71\,(1.19) = 0.84'$

Check $\frac{h_s}{d_{50}} = \frac{0.84}{0.42} = 2.0 \geq 2$ and < 4 ∴ OK

Length of Basin

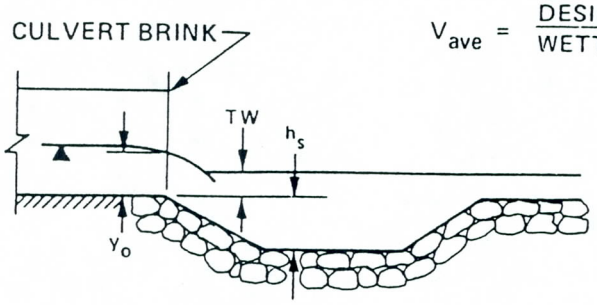
$10\,h_s = 10\,(0.84') = 8.4'$

or

$3(w_o) = 3\,(10') = 30'$ Use 30'

Culvert 67B

7



V_{ave} = DESIGN DISCHARGE – Q / WETTED AREA AT BRINK OF CULVERT

d_{50} = THE MEDIAN SIZE OF ROCK BY WEIGHT. ROUNDED ROCK OR ANGULAR ROCK.

Y_e = EQUIVALENT BRINK DEPTH

= BRINK DEPTH FOR BOX CULVERT

$= \left(\frac{A}{2}\right)^{1/2}$ FOR NON–RECTANGULAR SECTIONS

℄ SECTION

NOTE: $2 \leq \frac{h_s}{d_{50}} \leq 4$

IF $\frac{T_W}{Y_o} > 0.75$

RIPRAP MAY BE REQUIRED ON BANKS AND CHANNEL BOTTOM DOWNSTREAM FROM BASIN – SEE DESIGN EXAMPLE IN TEXT.

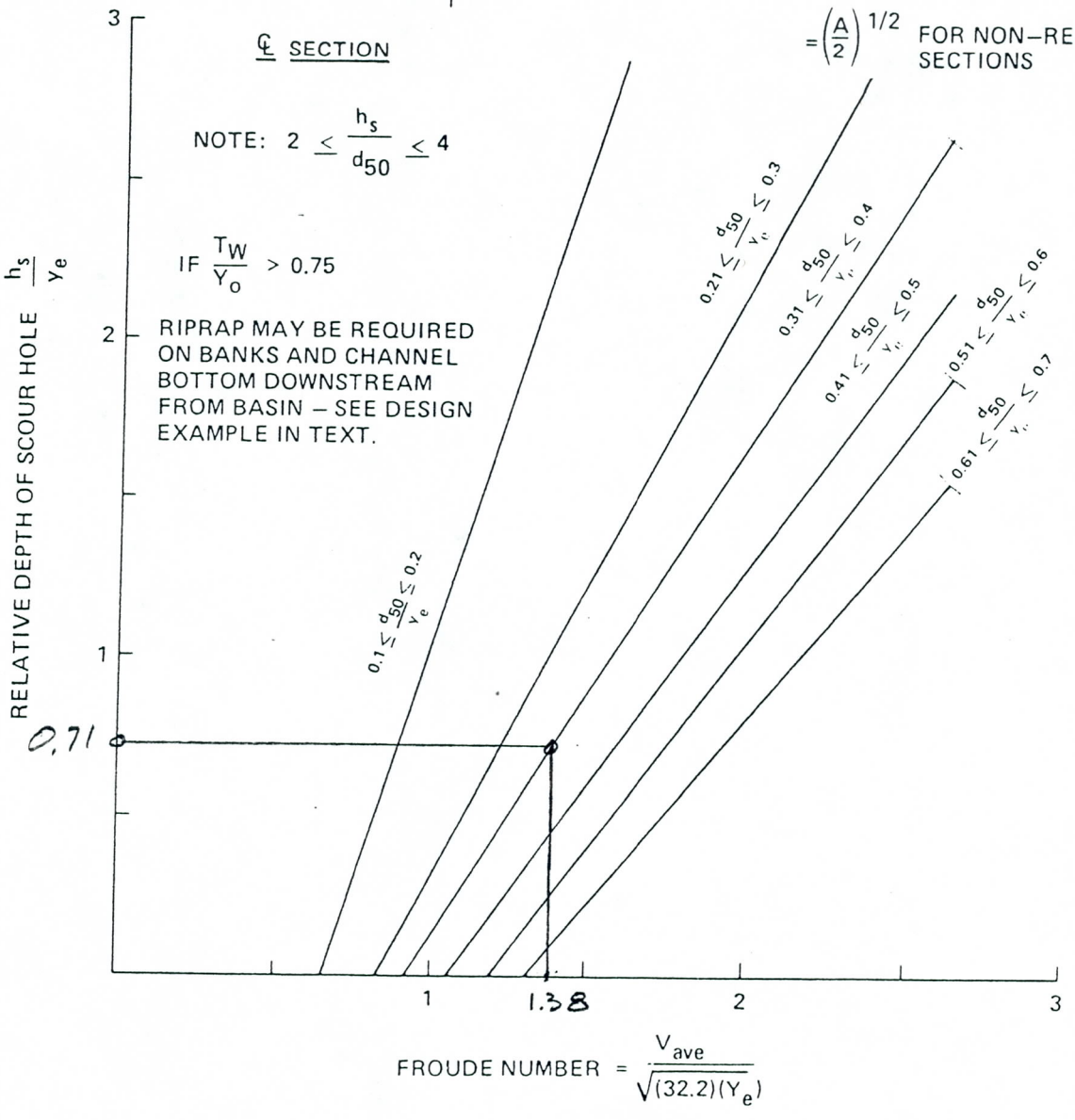


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota SHEET NO. 8 OF

COMPUTATIONS FOR Box Culvert 67B DATE 7/1/91 BY BDO CHKD RJT

$TW/Y_o = \frac{1.65'}{1.19'} = 1.39 > 0.75$ ∴ Check downstream riprap lining for channel protection.

Utilize figure XI-3 for existing average velocity along channel. Compute equivalent circular diameter D_e for brink area from:

$A = \pi D_e^2/4 = Y_o(W_o) = 11.9\ ft^2$

$D_e = (11.9(4)/\pi)^{1/2} = 3.89$

From downstream cross section Q10 velocity is 6.5 fps. Culvert outlet velocity is 8.55 fps.

L/D_e	L	V_L/V_o	V_L
7	27.2'	.76	6.5 = 6.5 fps (OK)
10	38.9'	.59	5.0

∴ Need riprap lining for approximately 27 feet from the end of the culvert outlet apron. Minimum length of plunge basin is 34 feet. ∴ No additional riprap

SVERDRUP

JOB 40477 Toyota SHEET NO. 9 OF

DATE 7/1/91

COMPUTATIONS FOR Channel Section Downstream of Box Culvert 67B BY BDO CHKD RJT

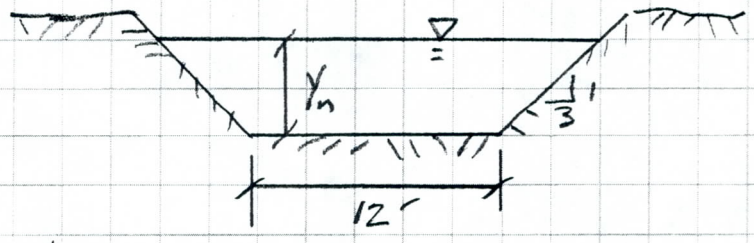
Check depth of flow using Mannings Eqn.

~Q10 = 102 cfs

$n = .03$

$S_o = .0040$ ft/ft

$Y_n \sim 1.65'$



$A = 28.1$ ft²

$WP = 2(5.08) + 12 = 22.16'$

$R_h = A/WP = 28.1/22.16 = 1.2681'$

$$V = \frac{1.49}{.03}(1.2681)^{.666}(.004)^{.5} = 3.68 \text{ fps}$$

check

$Q = VA = 3.68(28.1) = 103$ cfs (OK)

SVERDRUP

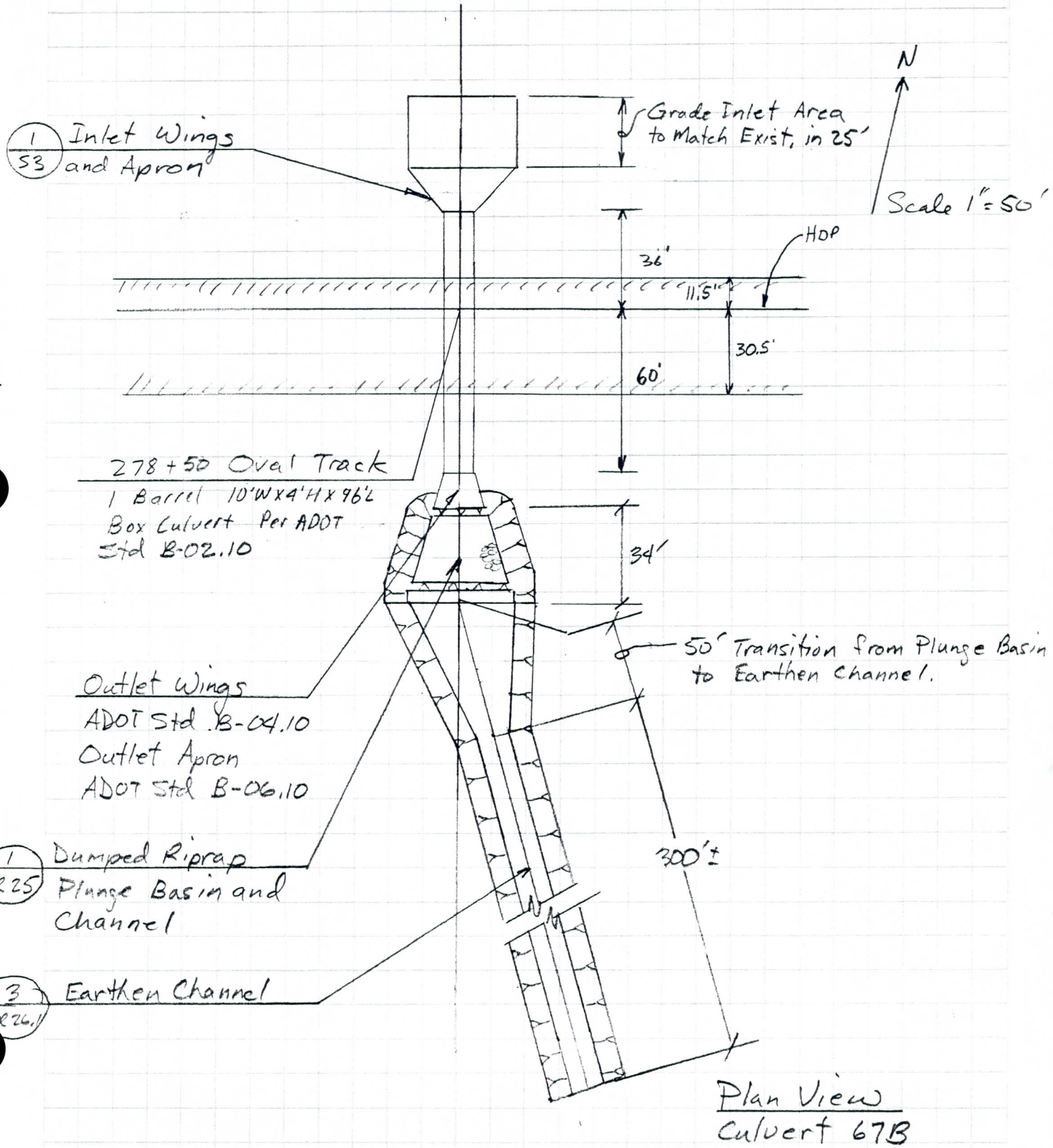
JOB 40477 Toyota

COMPUTATIONS FOR Culvert 67B [7]
Plan View - Sta 278+50

SHEET NO. 10 OF

DATE 6-26-91

BY DFP CHKD RJT



Plan View
Culvert 67B

SVERDRUP

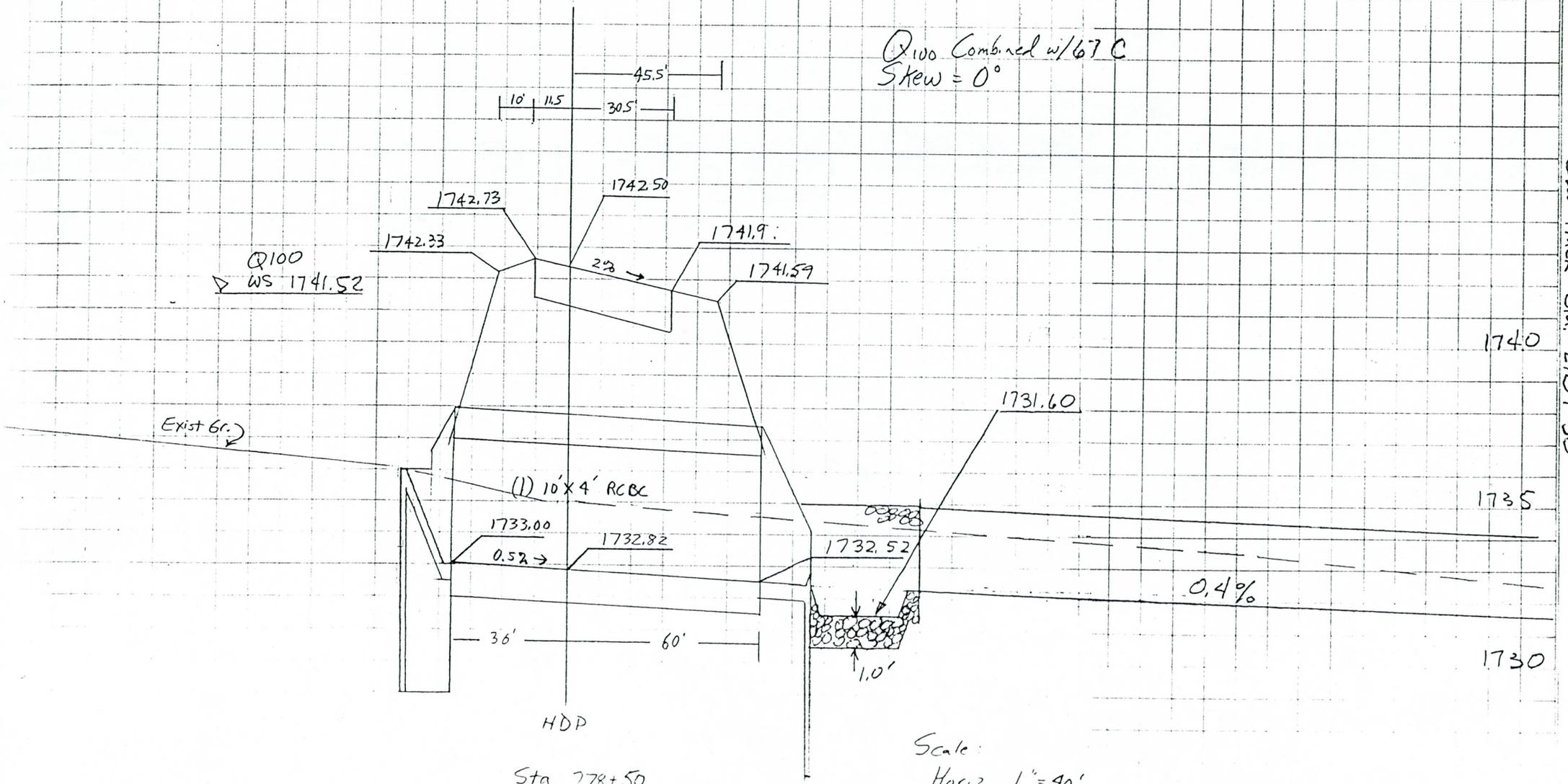
JOB 40477 Toyota SHEET NO. 11 OF

COMPUTATIONS FOR Culvert Profile 67B [7] DATE 7/1/91

Oval Track Sta. 278+50 BY BDO CHKD RTT

Culvert 67B [7]

Q_{100} Combined w/67C
Skew = 0°



Sta. 278+50
Oval Track

Scale:
Horiz 1" = 40'
Vert 1" = 4'

SECTION NUMBER TW67B 6/11/91

Channel Slope: 0.0097 ft./ft.

CROSS SECTION DATA:

OFFSET	35	73	160.8	163.5	172.4	177.7	271.2	310
ELEV.	37.5	35.37	35.87	33.92	33.57	35.92	36.11	36.5
N	N/A	0.035	0.035	0.035	0.025	0.035	0.035	0.035

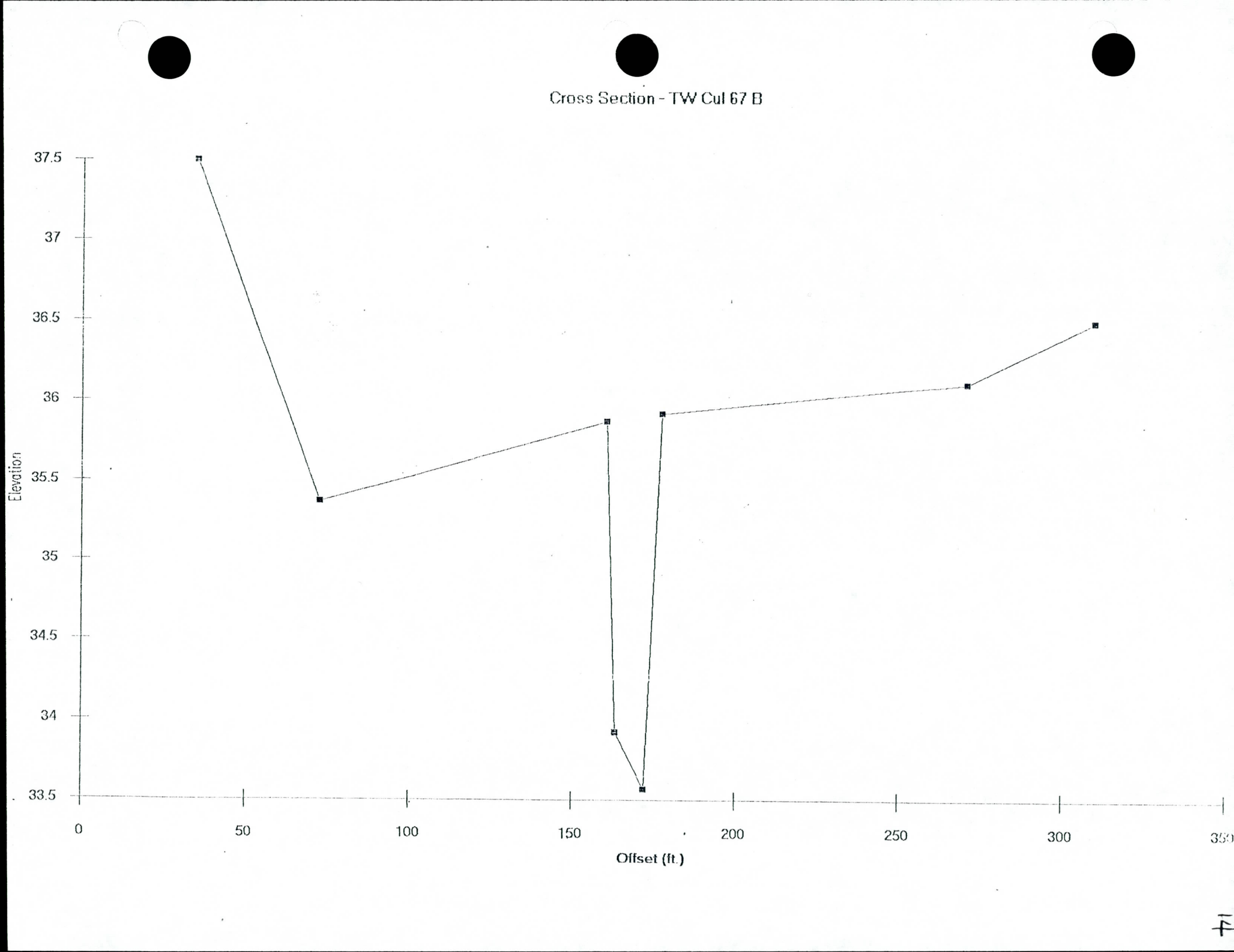
STAGE-DISCHARGE DATA:

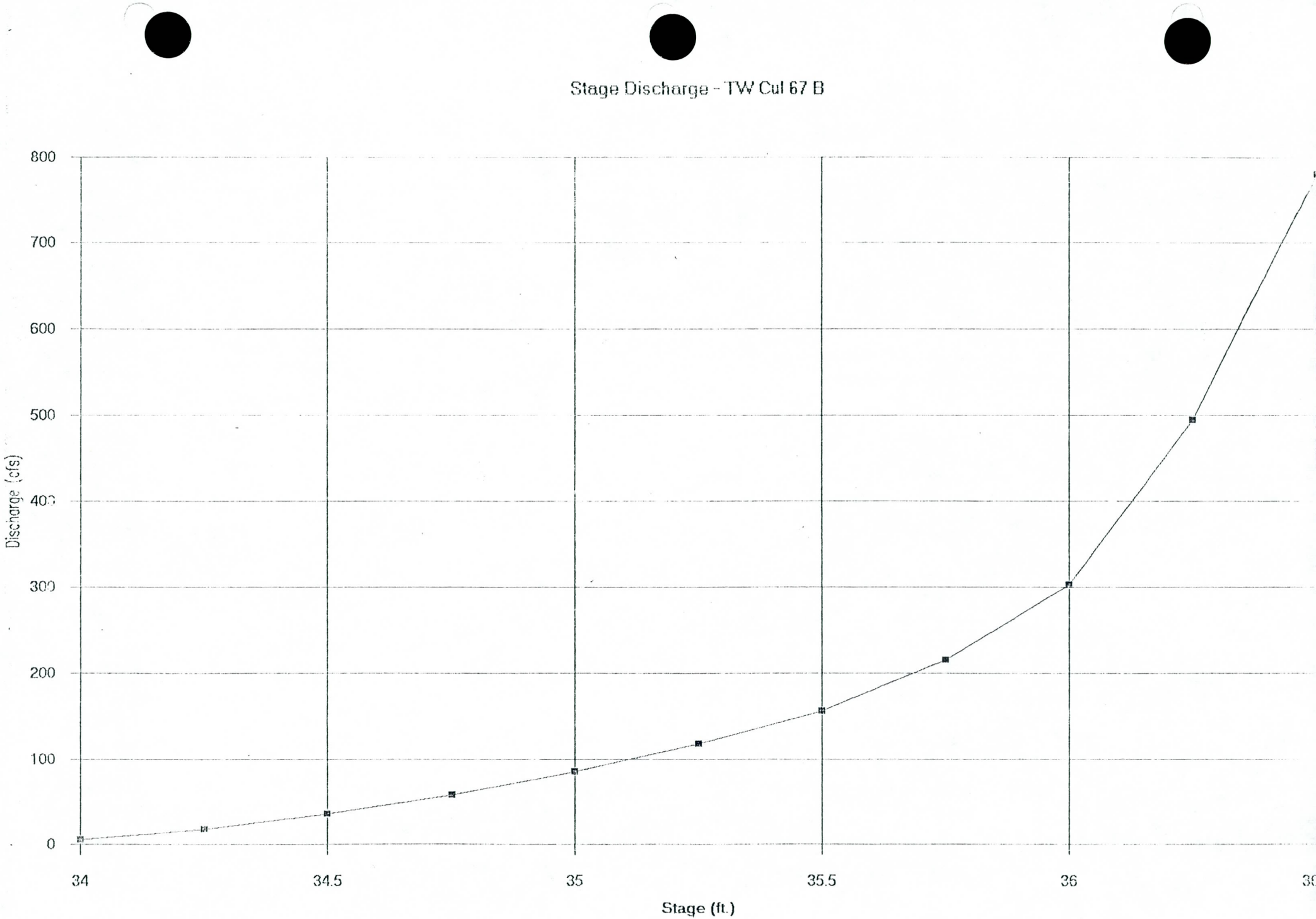
STAGE:	34											
WET PER.		0.0	0.0	0.1	8.9	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	2.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	5	0	0	0	0	0	0	0	0
STAGE:	34.25												
WET PER.		0.0	0.0	0.6	8.9	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.1	4.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	17	1	0	0	0	0	0	0	0
STAGE:	34.5												
WET PER.		0.0	0.0	1.0	8.9	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.2	6.7	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.2	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	33	2	0	0	0	0	0	0	0
STAGE:	34.75												
WET PER.		0.0	0.0	1.4	8.9	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.5	8.9	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.3	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	1	53	4	0	0	0	0	0	0	0
STAGE:	35												
WET PER.		0.0	0.0	1.8	8.9	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.8	11.2	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.4	1.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	2	76	7	0	0	0	0	0	0	0
STAGE:	35.25												
WET PER.		0.0	0.0	2.3	8.9	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.2	13.4	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.5	1.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	3	103	11	0	0	0	0	0	0	0

SECTION NUMBER TW67B 6/11/91

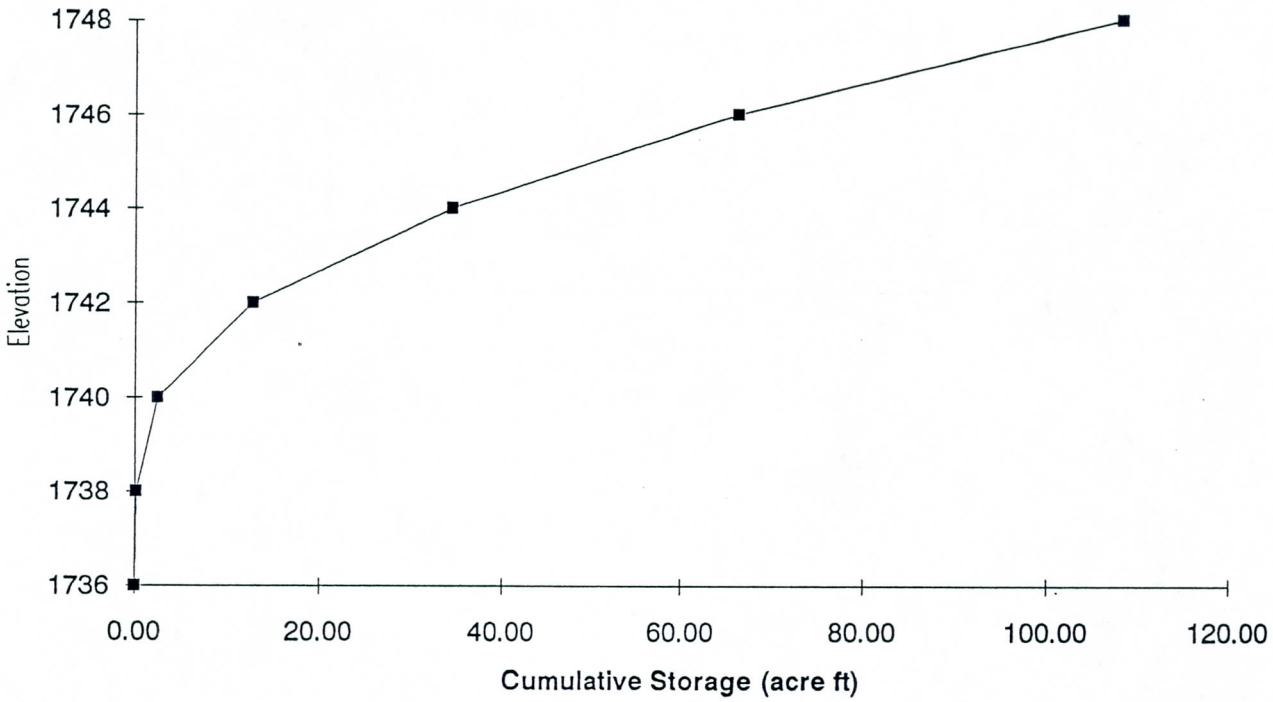
STAGE:	35.5											
WET PER.		2.3	25.2	2.7	8.9	4.8	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.2	1.6	1.7	15.6	4.2	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.1	0.1	0.6	1.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	1	5	133	16	0	0	0	0	0	0
STAGE:	35.75											
WET PER.		6.8	73.5	3.1	8.9	5.4	0.0	0.0	0.0	0.0	0.0	0.0
AREA		1.3	14.0	2.3	17.8	5.4	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.2	0.2	0.7	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	19	8	166	22	0	0	0	0	0	0
STAGE:	36											
WET PER.		11.3	99.1	102.4	8.9	5.8	45.2	0.0	0.0	0.0	0.0	0.0
AREA		3.5	36.9	39.9	20.1	6.7	8.2	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.3	0.4	0.4	2.3	1.1	0.2	0.0	0.0	0.0	0.0	0.0
Q		0	0	89	202	0	11	0	0	0	0	0
STAGE:	36.25											
WET PER.		15.7	103.5	106.9	8.9	5.8	99.3	113.2	0.0	0.0	0.0	0.0
AREA		6.9	62.2	65.9	22.3	8.0	29.9	30.9	0.0	0.0	0.0	0.0
HYD.RAD.		0.4	0.6	0.6	2.5	1.4	0.3	0.3	0.0	0.0	0.0	0.0
Q		0	0	200	241	0	0	54	0	0	0	0
STAGE:	36.5											
WET PER.		20.2	108.0	111.3	8.9	5.8	99.3	138.1	0.0	0.0	0.0	0.0
AREA		11.4	88.7	93.0	24.5	9.3	54.6	62.2	0.0	0.0	0.0	0.0
HYD.RAD.		0.6	0.8	0.8	2.8	1.6	0.6	0.5	0.0	0.0	0.0	0.0
Q		0	0	345	282	0	0	153	0	0	0	0

W.S. Elev.	34	34.25	34.5	34.75	35	35.25	35.5	35.75	36	36.25	36.5
Q	6	18	35	58	85	117	156	216	302	495	780
A	2.5	5.1	7.9	11.0	14.3	17.8	23.2	39.5	68.2	119.1	179.7
V	2.3	3.5	4.5	5.3	6.0	6.6	6.7	5.5	4.4	4.2	4.3


Cross Section - TW Cul 67 B
37.5
37
36.5
36
35.5
35
34.5
34
33.5
Elevation
0
50
100
150
200
250
300
Offset (ft.)


Stage Discharge - TW Cul 67 B
800
700
600
500
400
300
200
100
0
Discharge (cfs)
34
34.5
35
35.5
36
Stage (ft.)

Elevation vs. Storage - Node 67 B



SVERDR

JOB 40477 Toyota

SHEET NO. 1 OF

DATE 6/26/91

COMPUTATIONS FOR Proposed Culvert 67C [8] BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 272+60, Oval Track

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

1697 cfs
490 cfs
1207 cfs

DRAINAGE AREA 5.99 sq. miles (Combined drainage area 67B+67C)

Q_1 = 1207 cfs

Q_2 =

TW_1 = 4.0'

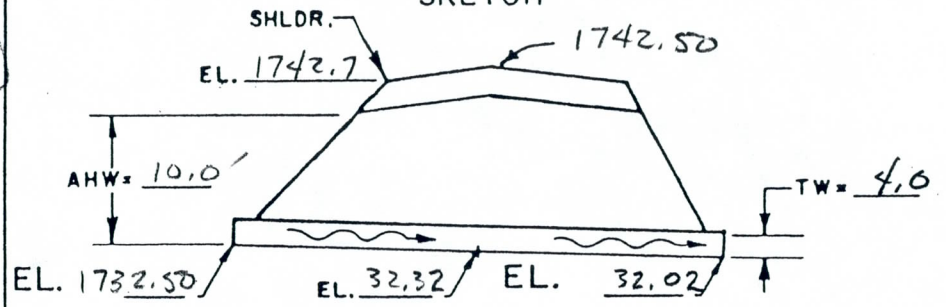
TW_2 =

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~ Q_{100})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050 ft/ft L = 96' L/100 S_o =

MEAN STREAM VELOCITY = 5.9 fps

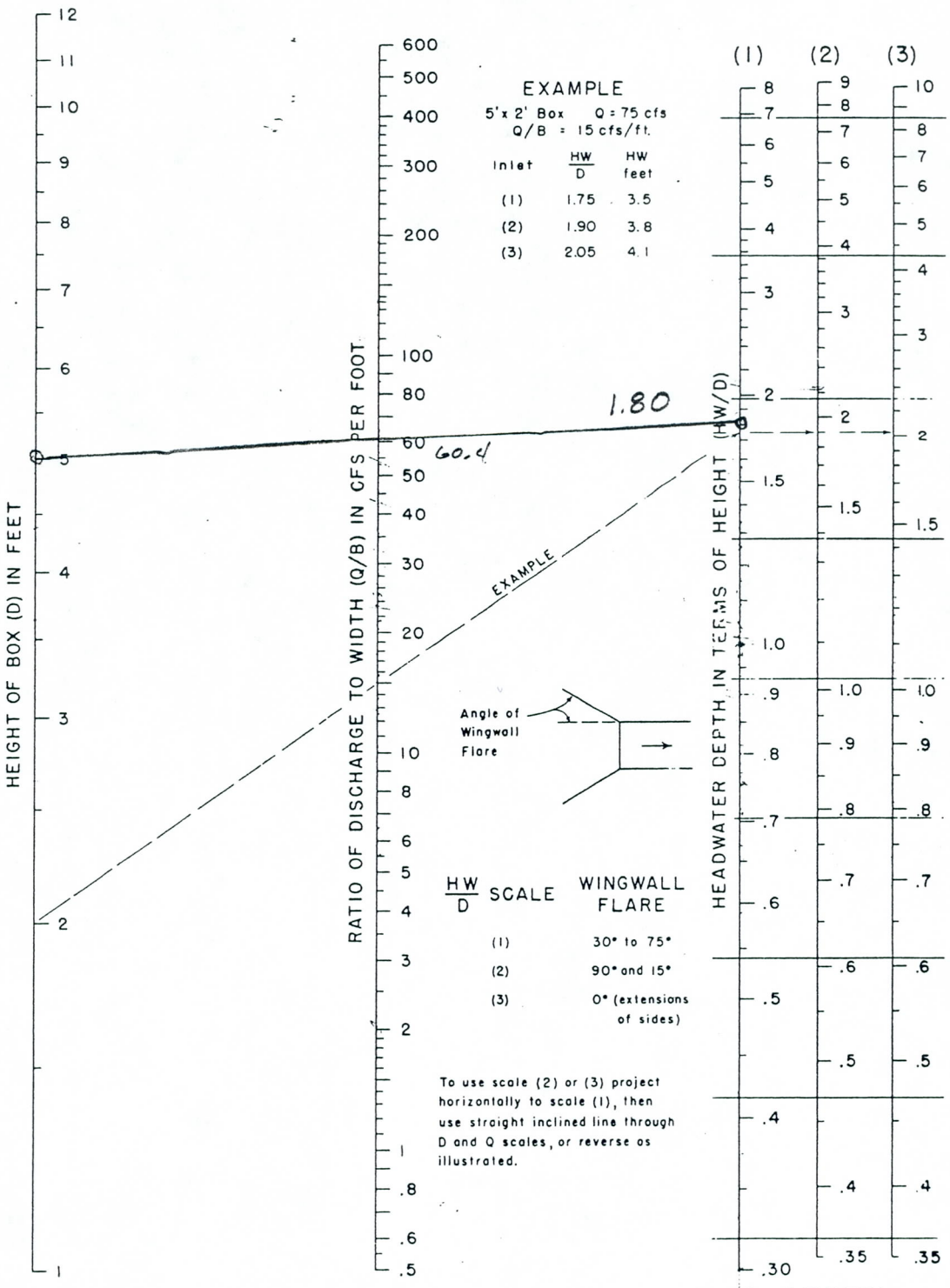
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL HW = H + h_o − LS_o												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(2) Barrel 10x5	Drop Inlet	1207/2 = 604		1.80	9.00	0.2	3.3	4.90	4.95	4.0	4.95	0.48	7.77	9.0	15.0		1741.50	Inlet Control

SUMMARY & RECOMMENDATIONS

B-1

Culvert 67 C

CHART 1

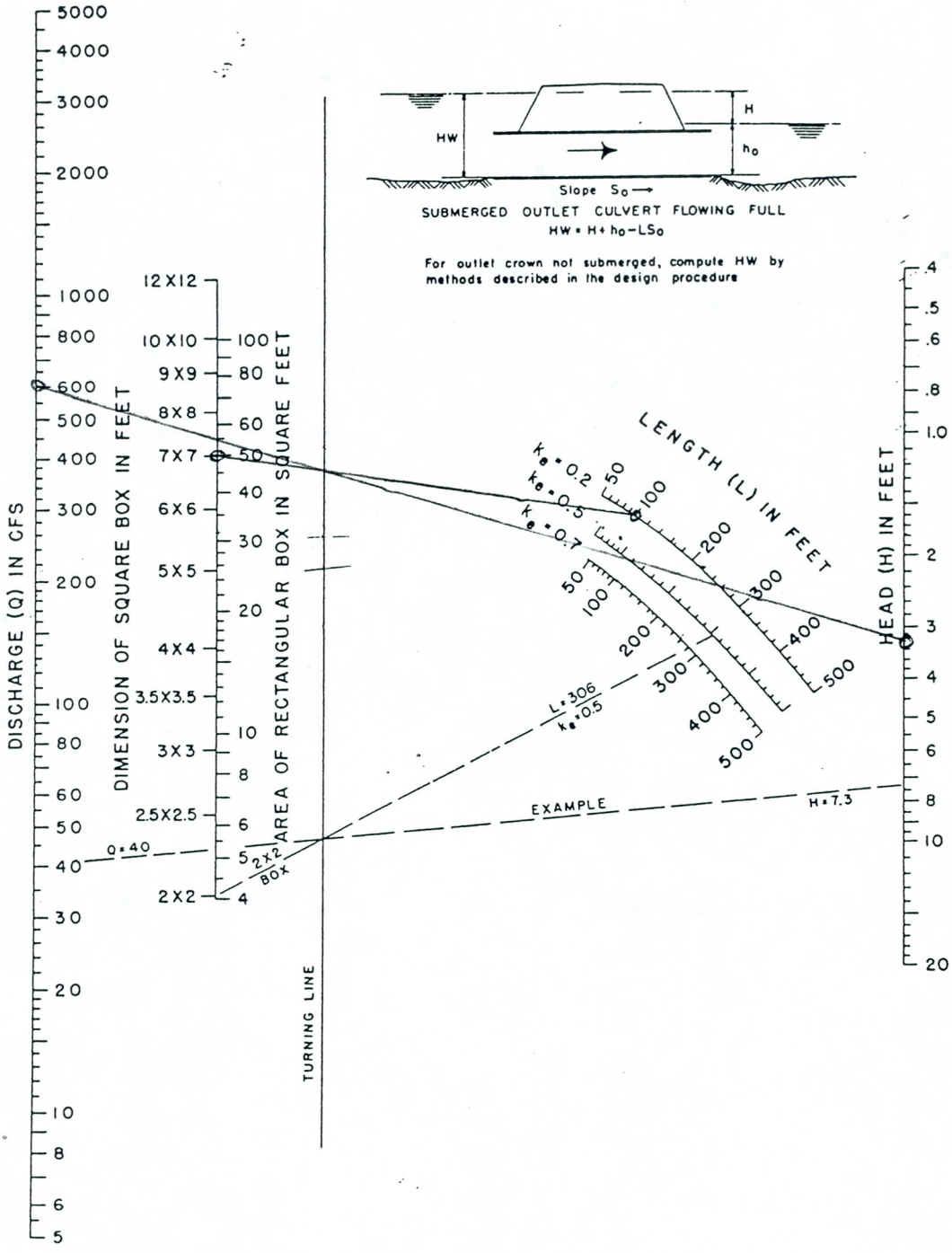


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 67 C

CHART 8

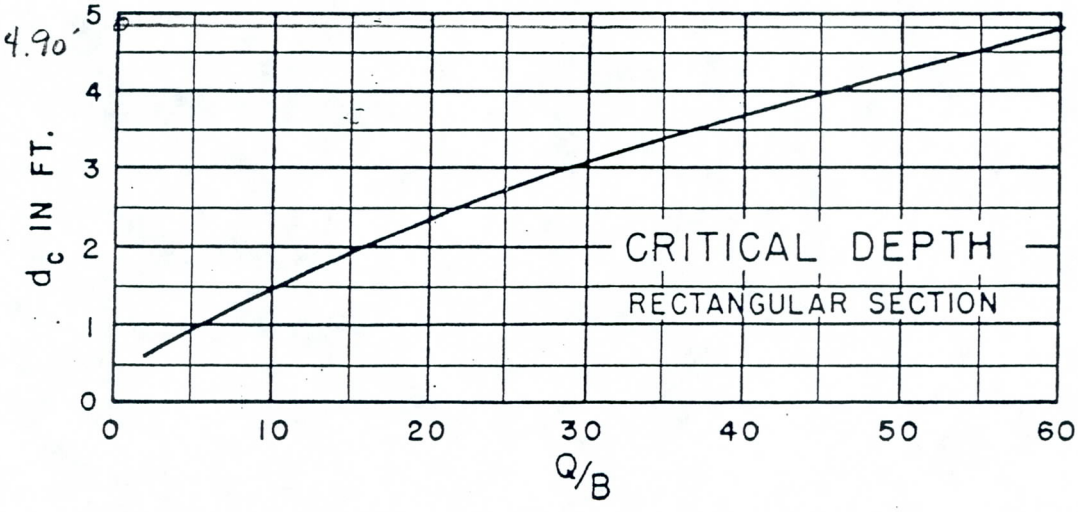


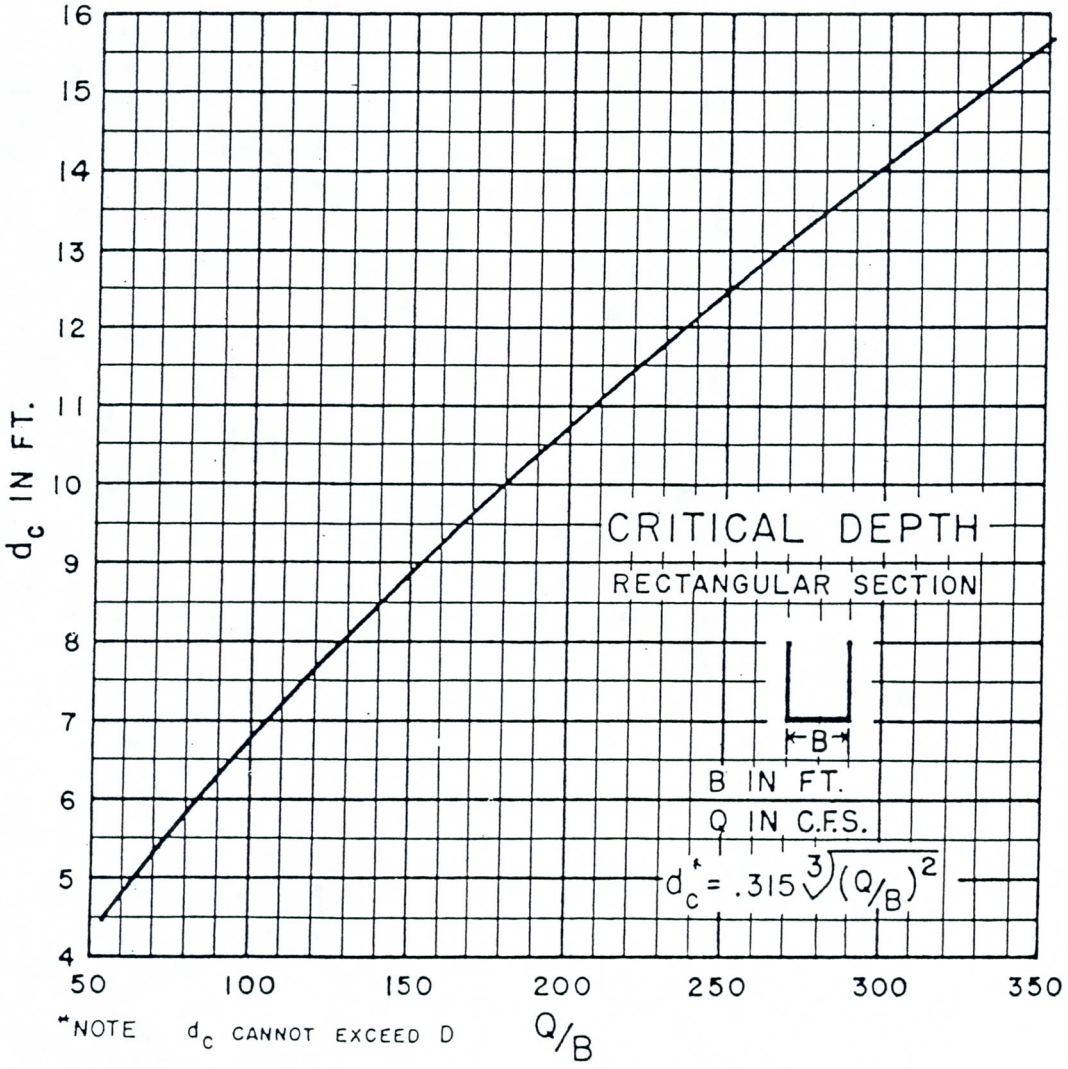
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 67 C

CHART 15





BUREAU OF PUBLIC ROADS JAN. 1963

SVERDRUP

JOB 40477 Toyota SHEET NO. 5 OF

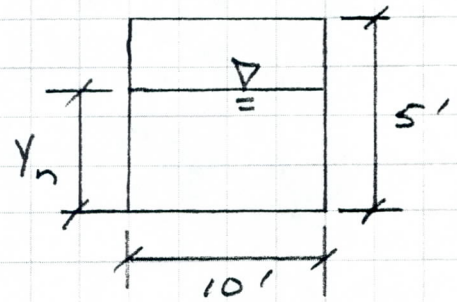
COMPUTATIONS FOR Culvert 67C DATE 6/26/91

BY BDO CHKD RJT

Check Depth of Flow using Mannings Equation

$Q_{100} = 1207$ cfs

$Q/barrel \sim 604$ cfs



$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 4.03'$

$A = 40.3$ ft^2

$WP = 10 + 2(4.03) = 18.06$ ft

$R_h = A/WP = 40.3/18.06 = 2.2315'$

$$V = \frac{1.49}{.012}(2.2315)^{.666}(.005)^{.5} = 14.98 \text{ fps}$$

Check

$Q = VA = 14.98\,(40.3) = 604$ cfs (OK)

Check Froude Number

$$F = \frac{V}{\sqrt{g\,Y_c}} = \frac{14.98}{\sqrt{32.2\,(4.03)}} = 1.32 \quad \text{Supercritical}$$

$Q_{10} = 204$ cfs $\Rightarrow$ 102 cfs/barrel

$Y_n = 1.19'$, Vel. $= 8.55$ fps, $F = 1.38$, Supercritical

SVERDRUP

JOB 40477 Toyota

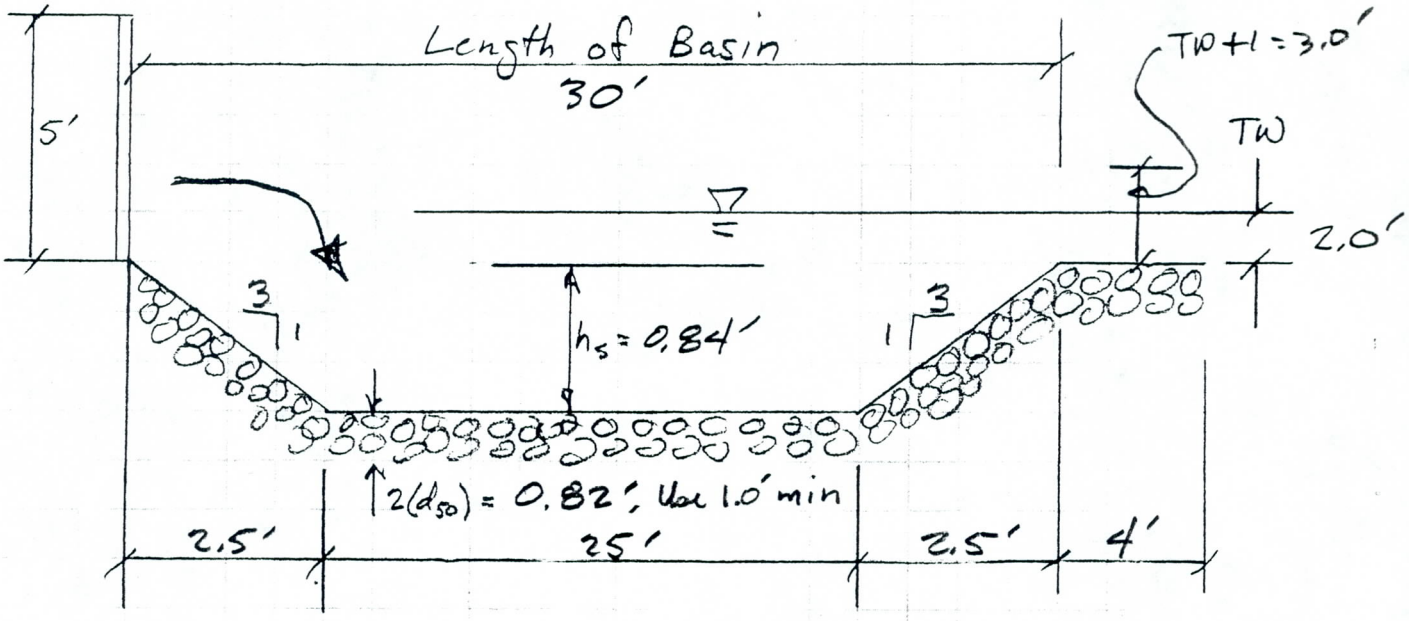
COMPUTATIONS FOR Box Culvert 67C

SHEET NO. 6 OF

DATE 7/1/91

BY BDO CHKD RJT

Riprap Plunge Basin Design (Q10)



Check Rock Size (From Figure XI-2, HEC No 14)

For Y_o = 1.19' d_{50} = 5" or 0.42'

$d_{50}/Y_o = \frac{0.42'}{1.19'} = 0.35$, $F = 1.38$

$\frac{h_s}{Y_o} = 0.71$, $h_s = 0.71\ (1.19') = 0.84'$

Check $\frac{h_s}{d_{50}} = \frac{0.84}{0.42} = 2.0 < 4$ and ≥ 2 ∴ OK

Length of Basin

$10\ h_s = 10\ (0.84') = 8.4'$

or

$3\ (w_o) = 3\ (10') = 30'$

∴ Use 30'

Culvert 67 C

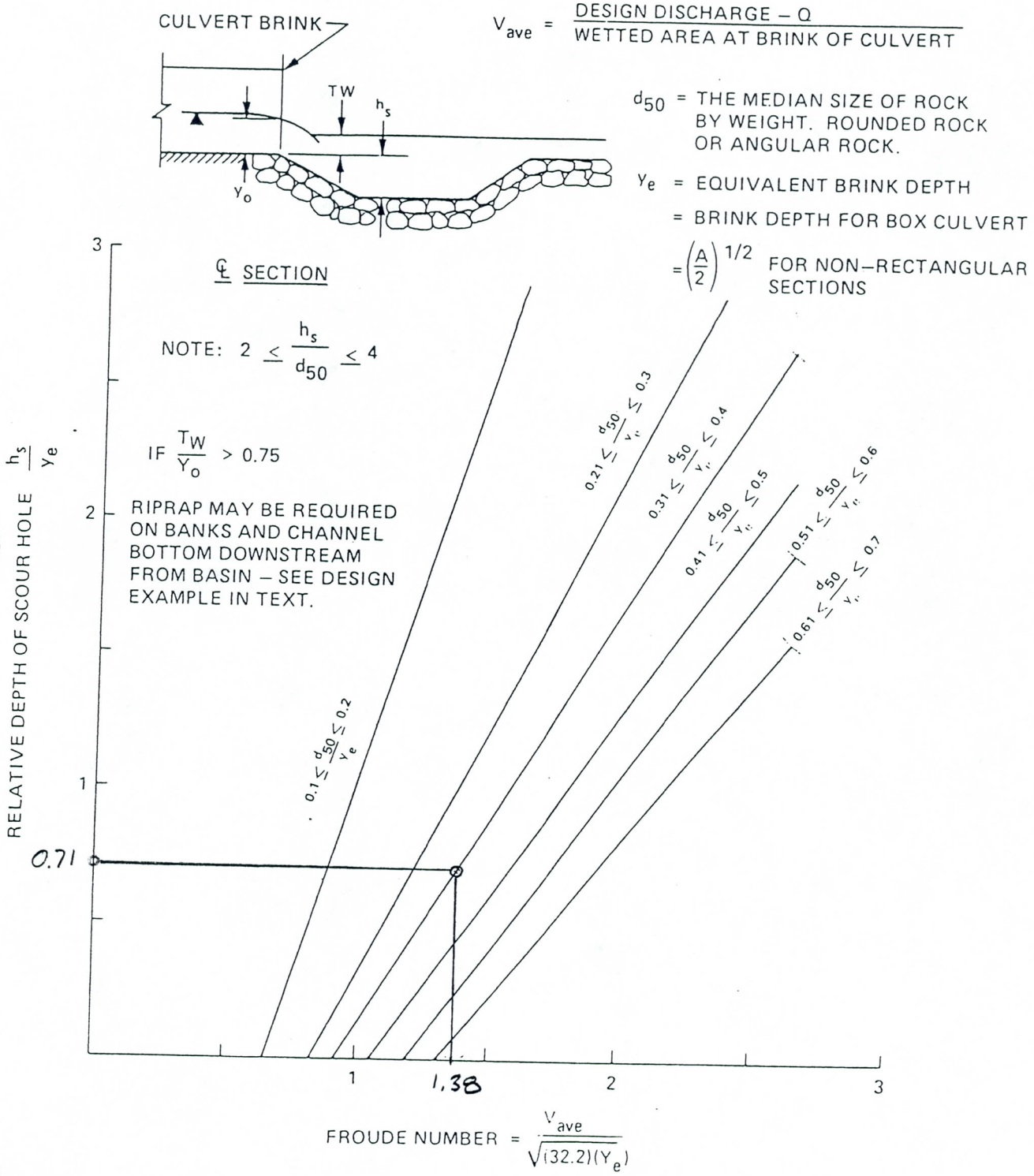


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota SHEET NO. 8 OF

COMPUTATIONS FOR Box Culvert 67C DATE 7/1/91

BY BDO CHKD RJT

$TW/Y_o = \frac{2.25}{1.19} = 1.89 > 0.75$ ∴ Check downstream riprap lining for channel protection.

Utilize figure XI-3 for existing average velocity along channel. Compute equivalent circular diameter D_e for brink area from:

$A = \pi D_e^2/4 = Y_o(W_o) = 11.9\ ft^2$

$D_e = (11.9(4)/\pi)^{1/2} = 3.89'$

From downstream cross section Q10 velocity is 7.5 fps. Culvert outlet velocity is 8.55 fps.

L/D_e	L	V_L/V_o	V_L
5	19.5'	.87	7.4 < 7.5 fps ∴ OK
10	38.9'	.59	5.0

∴ Need riprap lining for approximately 20 feet from the end of the culvert outlet apron. 20' < length of plunge basin (30'). Therefore no extra lining required.

SVERDRUP

JOB 40477 Toyota SHEET NO. 9 OF

DATE 7/2/91

COMPUTATIONS FOR Channel Section Downstream of Culvert 67C BY BDO CHKD RJT

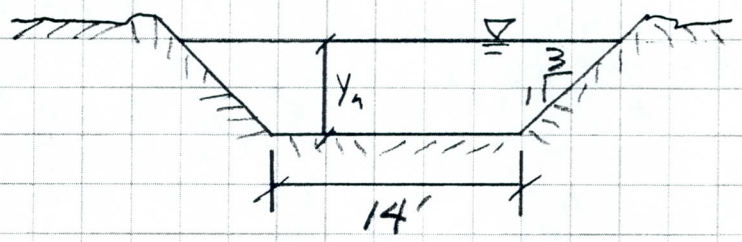
Check depth of flow using Mannings Eqn.

$Q_{10} = 204$ cfs

$n = 0.03$

$S_o = 0.0040$ ft/ft

$Y_n \sim 2.25'$



$A = 46.6$ ft^2

$WP = 2(7.12) + 14 = 28.24$ ft

$R_h = A/WP = 46.6/28.24 = 1.6501$ ft

$$V = \frac{1.49}{.03}(1.6501)^{.666}(.0040)^{.5} = 4.38 \text{ fps}$$

Check

$Q = VA = 4.38(46.6) = 204$ cfs ∴ O/K

SVERDRUP

JOB 40477 Toyota

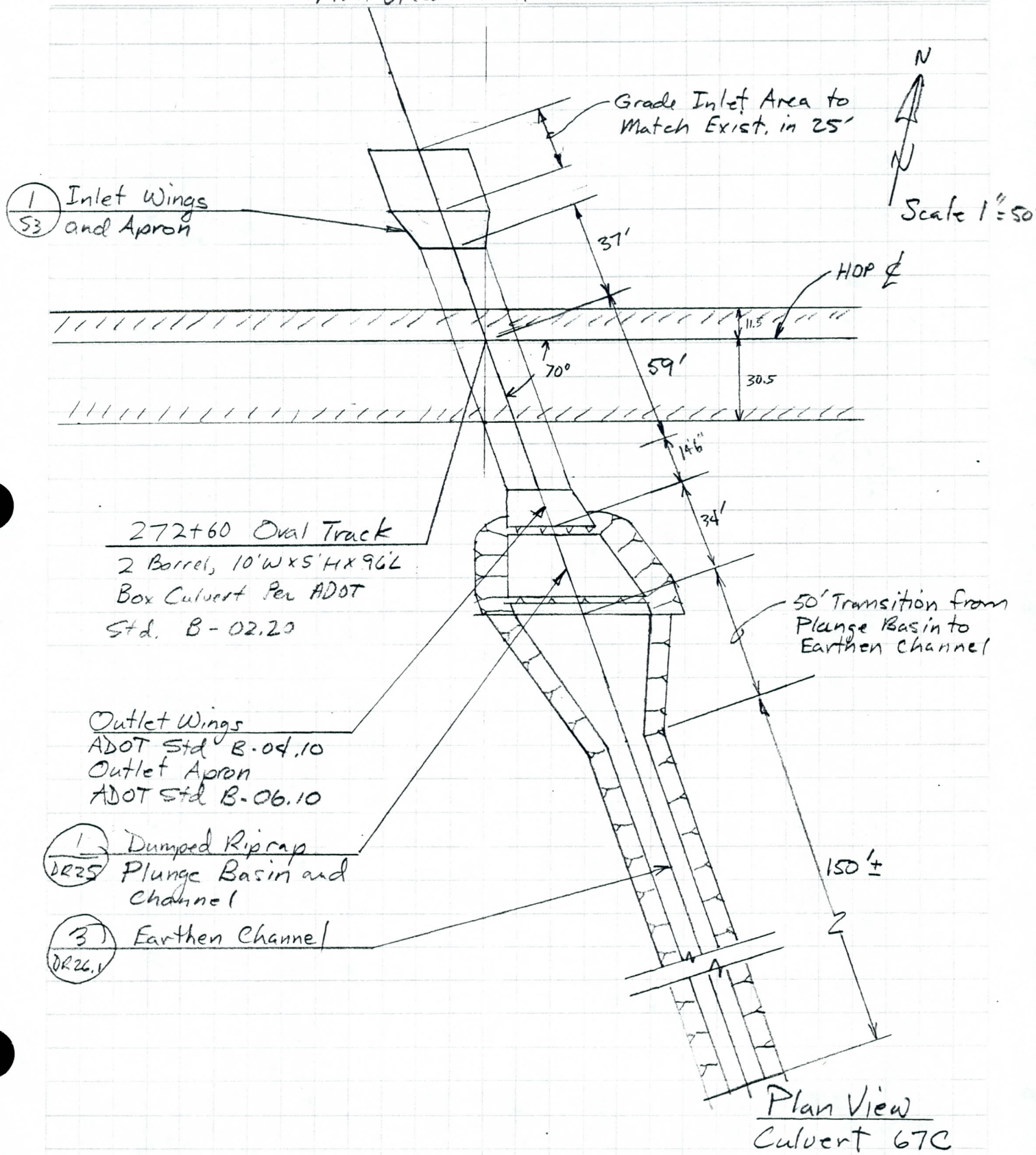
COMPUTATIONS FOR Culvert 67C [8]

SHEET NO. 10 OF

DATE 6-26-91

BY DFP CHKD RJT

Plan View - Sta. 272+60



Plan View
Culvert 67C

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert Profile 67C 8

HST Sta. 272+60

SHEET NO. 11 OF

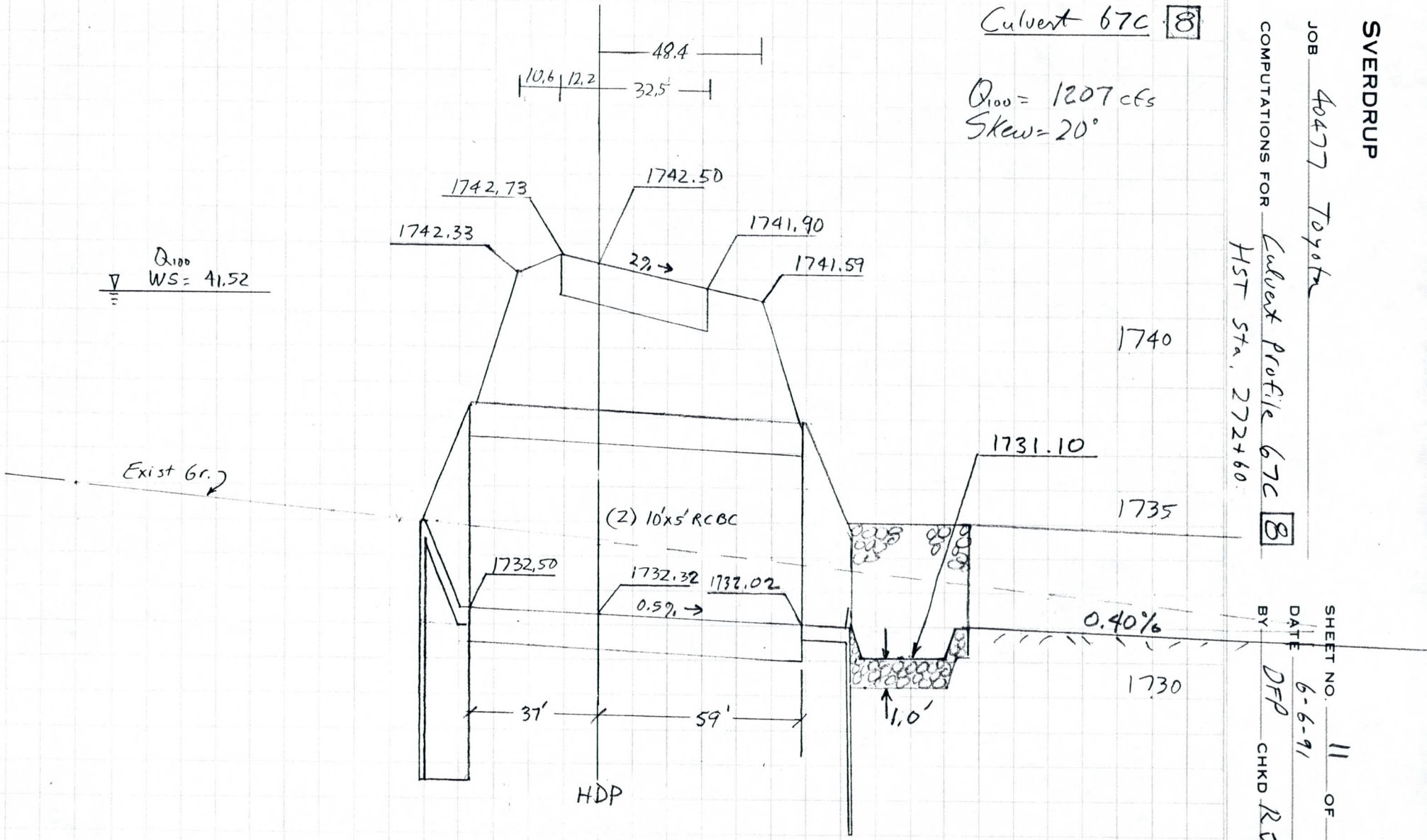
DATE 6-6-91

BY DFP CHKD RJT

Culvert 67C 8

Q_{100} = 1207 cfs

Skew = 20°



Sta 272+60

Oval Track

Scale:

Horiz: 1" = 40'

Vert: 1" = 4'

SECTION NUMBER TW67C 6/11/91

Channel Slope: 0.0094 ft./ft.

CROSS SECTION DATA:

OFFSET	45	127.6	204.7	212.8	225	227.4	307.2	370
ELEV.	37.5	35.95	35.14	32.69	32.36	35.09	36.08	37.3
N	N/A	0.035	0.035	0.035	0.025	0.035	0.035	0.035

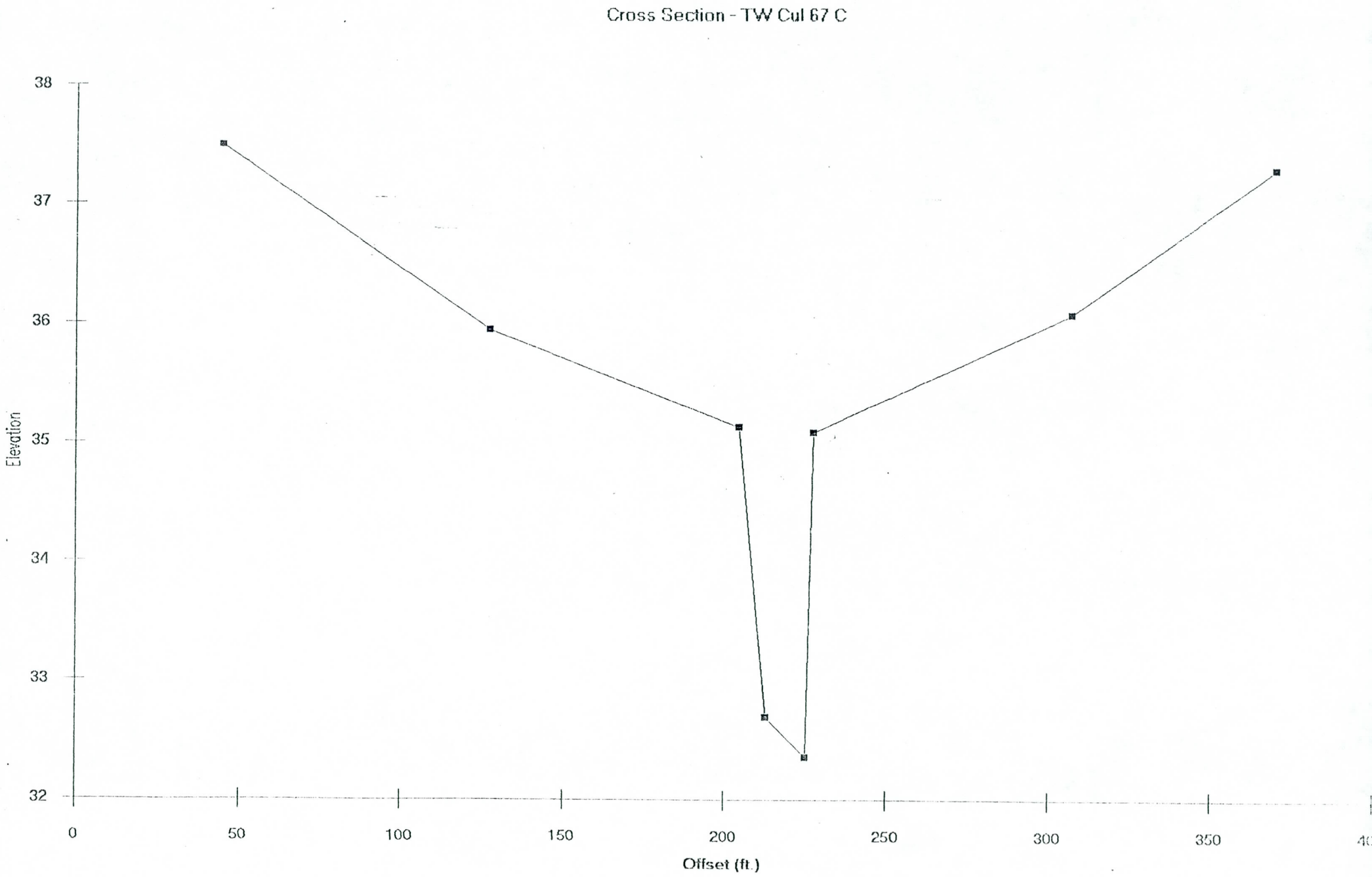
STAGE-DISCHARGE DATA:

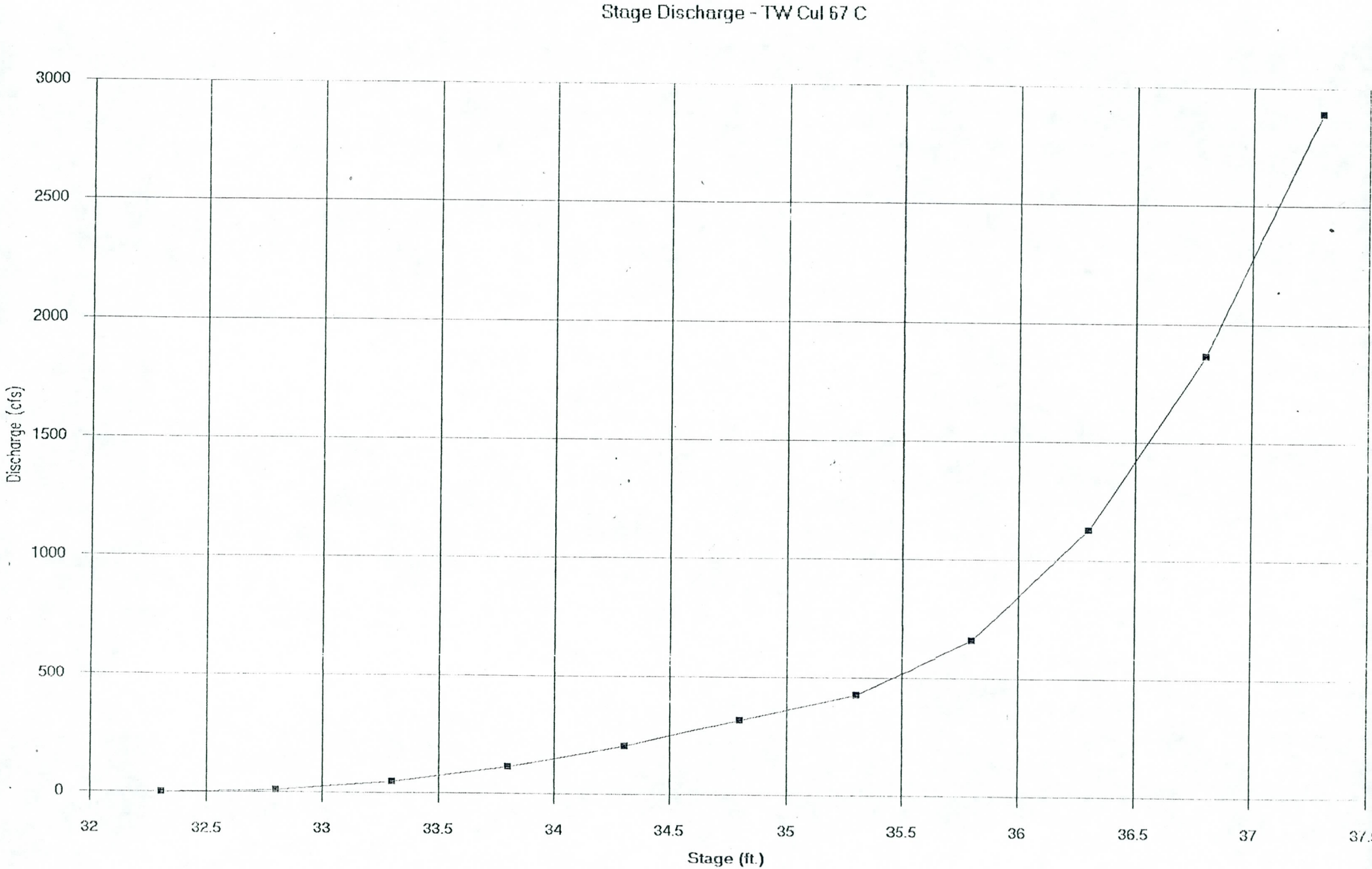
STAGE:	32.4											
WET PER.		0.0	0.0	0.0	1.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	32.8												
WET PER.		0.0	0.0	0.4	12.2	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	3.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	8	0	0	0	0	0	0	0	0
STAGE:	33.2												
WET PER.		0.0	0.0	1.8	12.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.4	8.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.2	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	1	37	1	0	0	0	0	0	0	0
STAGE:	33.6												
WET PER.		0.0	0.0	3.1	12.2	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.4	13.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.4	1.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	3	79	2	0	0	0	0	0	0	0
STAGE:	34												
WET PER.		0.0	0.0	4.5	12.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	2.8	18.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.6	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	9	134	3	0	0	0	0	0	0	0
STAGE:	34.4												
WET PER.		0.0	0.0	5.9	12.2	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	4.8	22.9	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.8	1.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	17	200	6	0	0	0	0	0	0	0

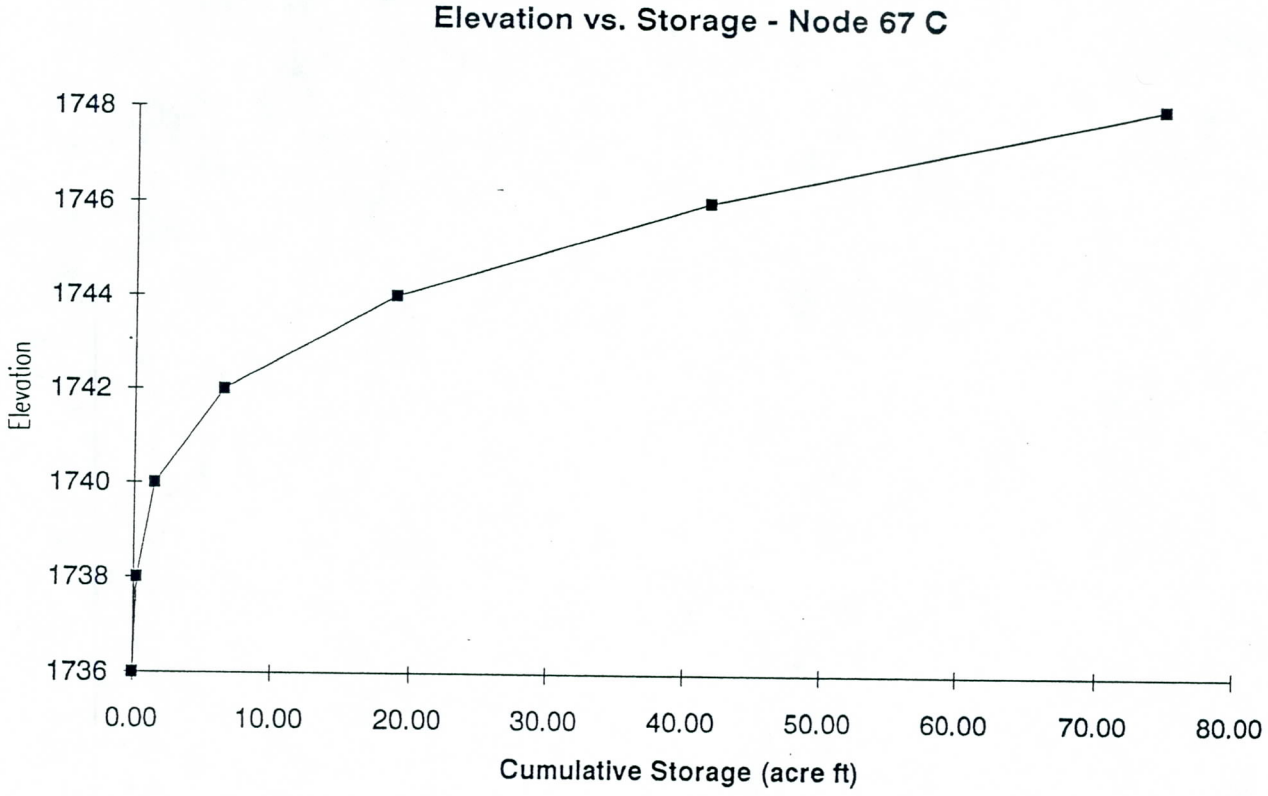
SECTION NUMBER TW67C 6/11/91

STAGE:	34.8											
WET PER.		0.0	0.0	7.3	12.2	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	7.4	27.8	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	1.0	2.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	30	277	9	0	0	0	0	0	0	0
STAGE:	35.2												
WET PER.		0.0	5.7	14.2	12.2	3.6	12.5	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.2	10.6	32.6	3.5	4.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.7	2.7	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	36	362	0	8	0	0	0	0	0	0
STAGE:	35.6												
WET PER.		0.0	43.8	52.3	12.2	3.6	44.7	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	10.1	23.7	37.5	4.5	15.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.2	0.5	3.1	1.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	58	457	0	30	0	0	0	0	0	0
STAGE:	36												
WET PER.		2.7	79.8	88.2	12.2	3.6	77.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.1	35.1	52.0	42.4	5.5	38.8	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.4	0.6	3.5	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	151	560	0	101	0	0	0	0	0	0
STAGE:	36.4												
WET PER.		24.0	101.1	109.5	12.2	3.6	83.4	99.9	0.0	0.0	0.0	0.0	0.0
AREA		5.4	71.3	91.4	47.3	6.4	71.5	74.1	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.2	0.7	0.8	3.9	1.8	0.9	0.7	0.0	0.0	0.0	0.0	0.0
Q		0	0	334	672	0	0	250	0	0	0	0	0

W.S. Elev.	32.4	32.8	33.2	33.6	34	34.4	34.8	35.2	35.6	36	36.4
Q	0	8	38	84	146	224	316	406	544	812	1256
A	0.0	3.5	9.0	15.2	22.0	29.5	37.7	47.2	76.2	133.3	212.8
V	0.4	2.4	4.2	5.5	6.6	7.6	8.4	8.6	7.1	6.1	5.9


Cross Section - TW Cul 67 C
38
37
36
35
34
33
32
Elevation
0
50
100
150
200
250
300
350
Offset (ft.)


Stage Discharge - TW Cul 67 C
3000
2500
2000
1500
1000
500
0
Discharge (cfs)
32
32.5
33
33.5
34
34.5
35
35.5
36
36.5
37
Stage (ft.)


Elevation vs. Storage - Node 67 C
1748
1746
1744
1742
1740
1738
1736
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Cumulative Storage (acre ft)

SVERDF

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 67 D [9]

SHEET NO. 1 OF

DATE 6/28/91

BY KDO CHKD RTT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 257+60, Oval Track

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 0.40 Sq. Miles

Q_1 = 590 cfs

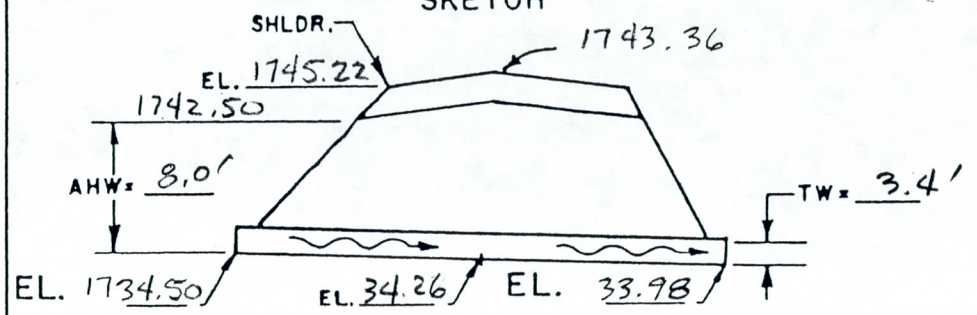
Q_2 = ____

TW_1 = 3.43' New Channel

TW_2 = 2.9' Exist. Channel

(Q_1 = DESIGN DISCHARGE, SAY Q_{25}; Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050' L = 104' L/100 S_o = ____

MEAN STREAM VELOCITY = 3.8 fps

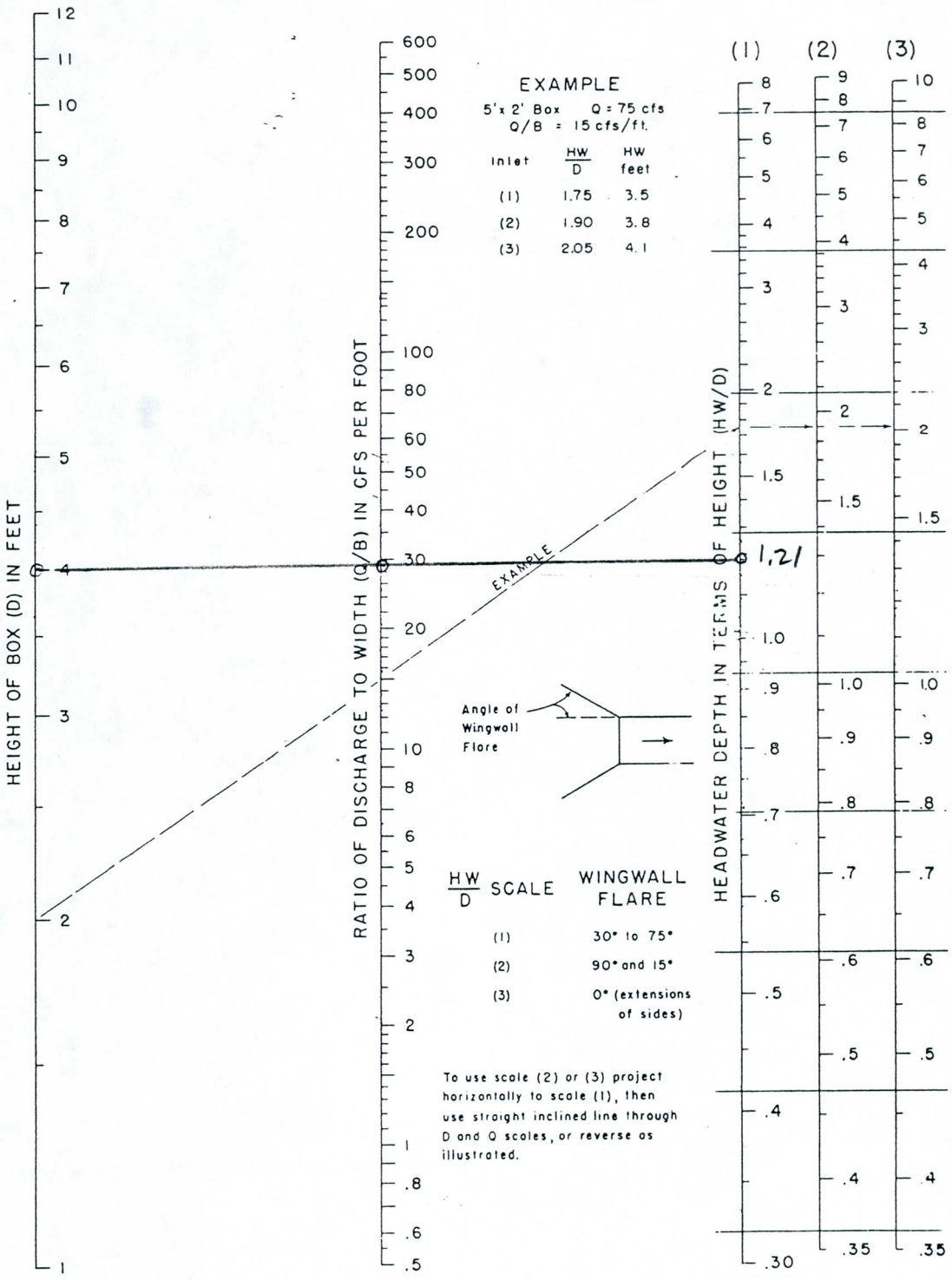
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(2) Barrel 10'x4'	Drop Inlet	590/2 = 295		1.21	4.84	0.2	1.25	3.1	3.55	3.43	3.55	.48'	4.32	4.84	12.2		1739.34	Inlet control

SUMMARY & RECOMMENDATIONS Use Soil cement channel downstream of culvert to reduce outlet velocities and help daylight channel.

B-10

Culvert 67 D

CHART 1

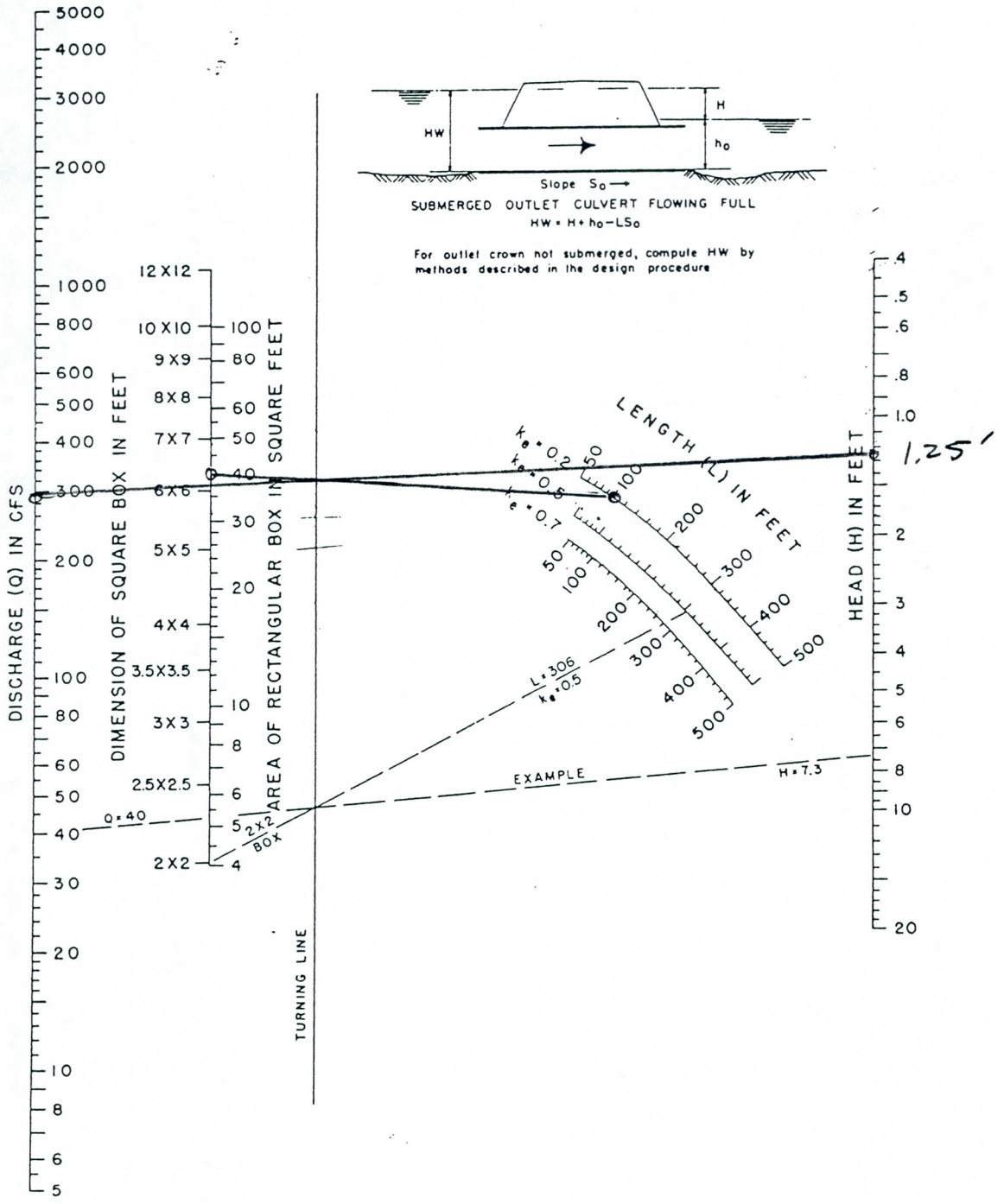


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN 1963

Culvert 67 D

CHART 8

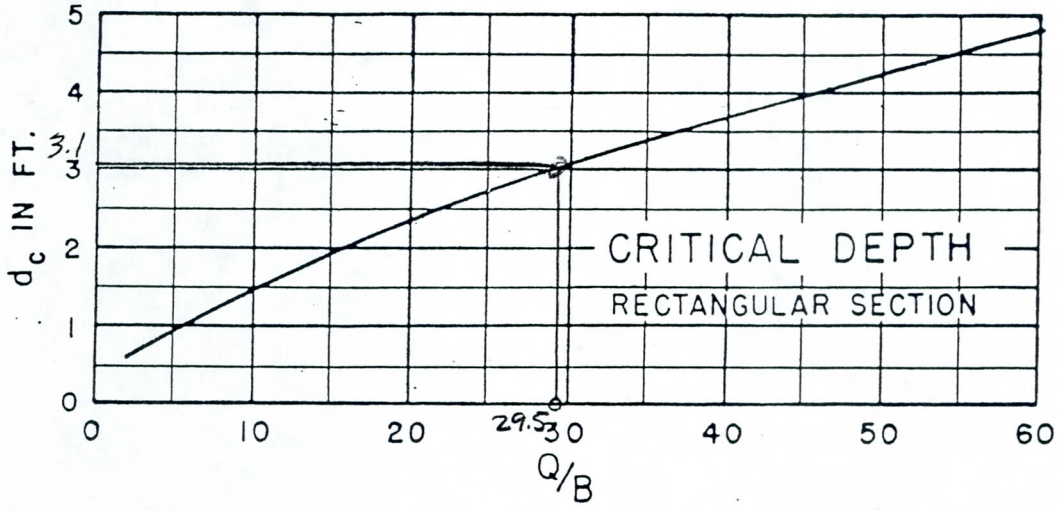


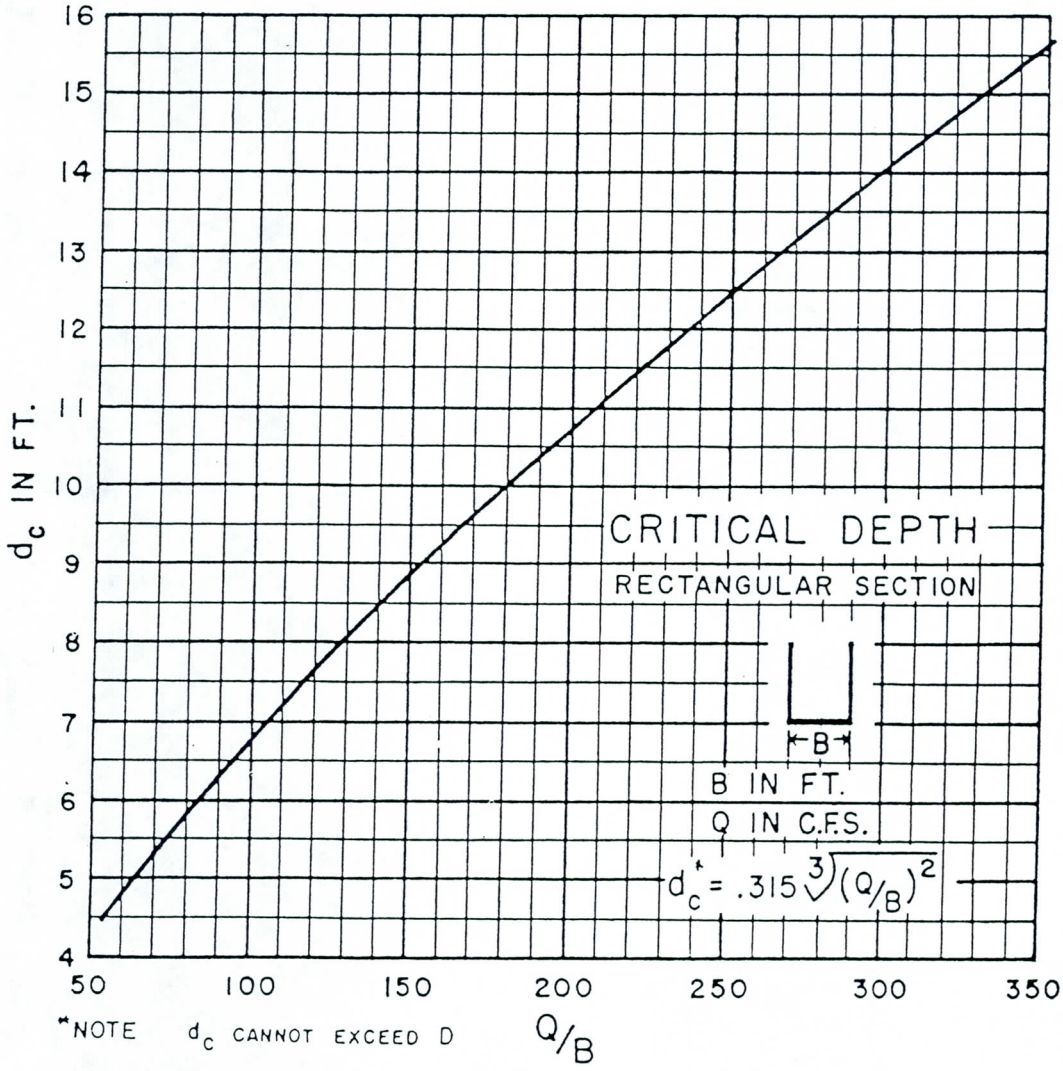
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 67 D

CHART 15





BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 67D

SHEET NO. 5 OF

DATE 7/2/91

BY BDO CHKD RJT

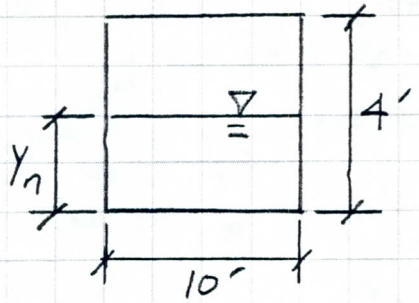
Check depth of flow using Mannings Equation

$Q100 = 590$ cfs $Q/barrel = 295$ cfs/barrel

$n = 0.012$

$S_o = 0.0050\ ft/ft$

$Y_n \sim 2.43'$



$A = 24.3\ ft^2$

$WP = 2(2.43) + 10 = 14.86'$

$R_h = A/WP = 24.3 / 14.86' = 1.6353'$

$$V = \frac{1.49}{.012}(1.6353)^{.666}(.005)^{.5} = 12.18 \text{ fps}$$

Check

$Q = VA = 12.18\ (24.3) = 296$ cfs. (OK)

Check Froude Number -

$$F = \frac{12.18}{\sqrt{32.2 \times 2.43}} = 1.38, \text{ Supercritical}$$

$Q10 = 262$ cfs $\Rightarrow$ 131 cfs/barrel

$Y_n = 1.41'$, Velocity = 9.32 fps, $F = 1.38$ Supercritical

SVERDRUP

JOB 40477 Toyota SHEET NO. 6 OF

DATE 7/2/91

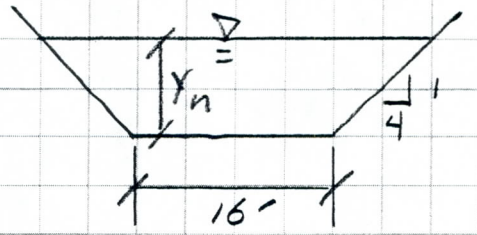
COMPUTATIONS FOR Channel Section Downstream of Box Culvert 67D BY BDO CHKD RJT

Check depth of Flow using Mannings Eqn.

$Q100 = 590$ cfs

$n = 0.02$ (Soil Cement)

$S_o = 0.0020$ ft/ft



$Y_n \sim 3.43'$

$A = 101.80 ft^2$

$WP = 2(14.14) + 16 = 44.28$

$R_h = A/WP = 101.80/44.28 = 2.2988'$

$V = \frac{1.49}{.02}(2.2988)^{.666}(.002)^{.5} = 5.80$ fps

check

$Q = AV = 101.80(5.80) = 590$ cfs OK

Check Froude Number $D = A/T = 101.8/43.44 = 2.34'$

$F = \frac{5.80}{\sqrt{32.2 \times 2.34}} = 0.67$ Subcritical

Energy Grade Line $= 3.43 + \frac{5.80^2}{2 \times 32.2} = 3.95'$

Check cutoff wall depth at end of channel

$h_s = 0.76(3.43)\left(\frac{(5.80)(2)(3.43)^2}{(3.43)^{2.5}}\right)^{.375} 20^{0.1}$

$= 7.00'$, Use 7 feet

SVERDRUP

JOB 80477 Toyota SHEET NO. 7 OF

DATE 7/9/91

COMPUTATIONS FOR Channel Section Downstream of Riprap lining Culvert 67D BY BDO CHKD RJT

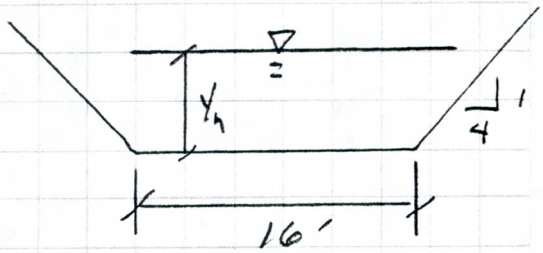
Check depth of Flow using Mannings Equation

$Q100 = 590$ cfs

$n = 0.03$ (Earth Channel)

$S_o = 0.0040$ ft/ft

$Y_n \sim 3.53'$



$A = 106.3$ ft^2

$WP = 2(14.55) + 16 = 45.10$ ft

$R_h = A/WP = 106.3/45.1 = 2.3570'$

$$V = \frac{1.49}{.03}(2.3570)^{.666}(.004)^{.5} = 5.56 \text{ fps}$$

check

$Q = VA = 5.56(106.3) = 591$ cfs (OK)

Check Froude Number $D = A/T = 106.3/44.24 = 2.40'$

$$F = \frac{5.56}{\sqrt{32.2 \times 2.40'}} = 0.63, \text{ Subcritical}$$

SVERDRUP

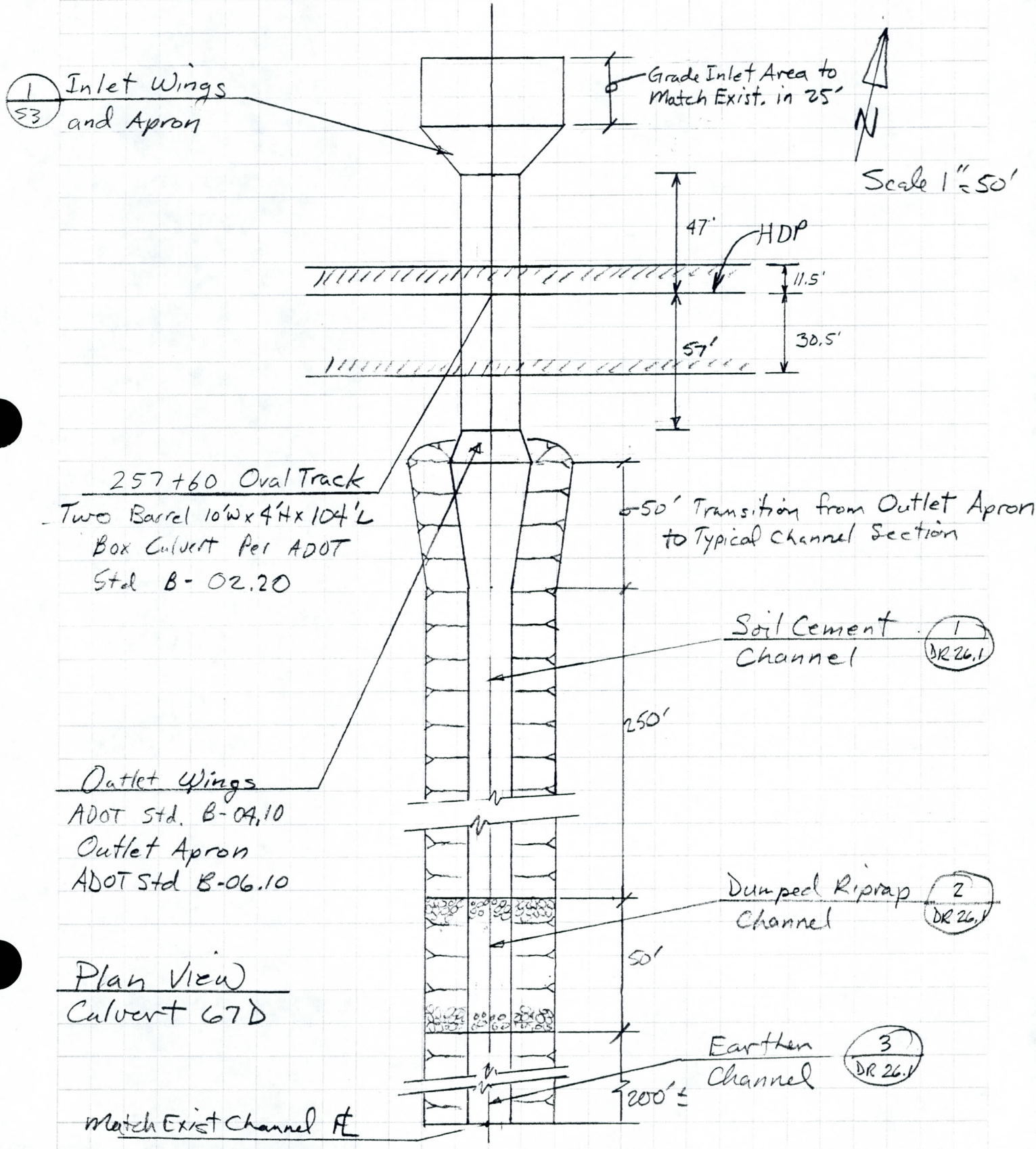
JOB 40477 Toyota

COMPUTATIONS FOR Culvert 67D [9]
Plan View Sta. 257+60

SHEET NO. 8 OF

DATE 6-26-91

BY DFP CHKD RJT



Plan View
Culvert 67D

SVERDRUP

JOB 4047.77 Toyota

COMPUTATIONS FOR Culvert Profile 67D [9]
Oval Track Sta 257+60

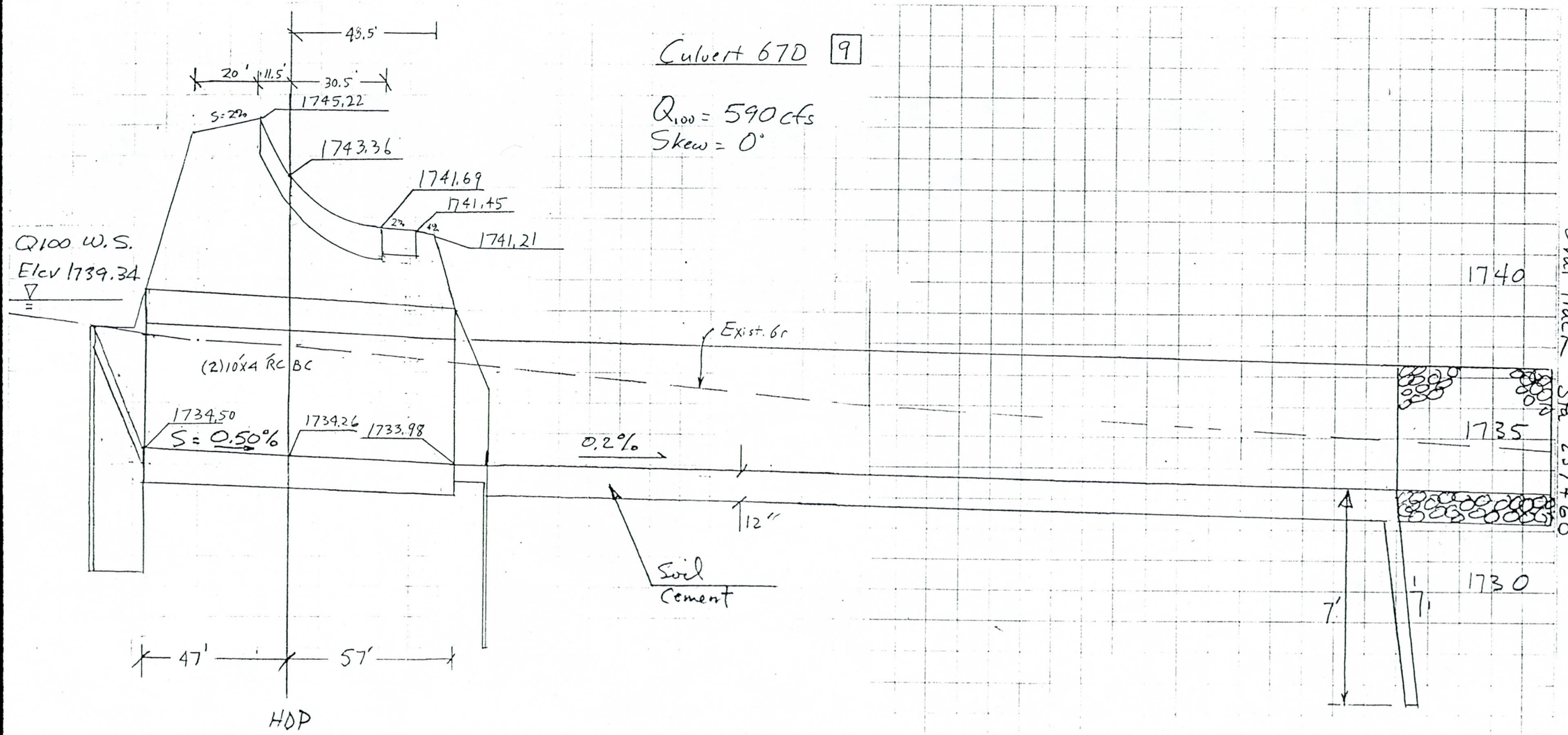
SHEET NO. 9 OF

DATE 7/2/91

BY BDO CHKD RJT

Culvert 67D [9]

Q_{100} = 590 cfs
Skew = 0°



Sta. 257+60
Oval Track

Scale:
Horiz. 1" = 40'
Vert. 1" = 4'

SECTION NUMBER TW67D 6/12/91

Channel Slope: 0.0105 ft./ft.

CROSS SECTION DATA:

OFFSET	-87	31.9	116.8	119.1	122.9	124.9	217.3	240
ELEV.	40	38.36	37.98	35.95	36.02	38.11	38.18	38.9
N	N/A	0.035	0.035	0.04	0.025	0.04	0.035	0.035

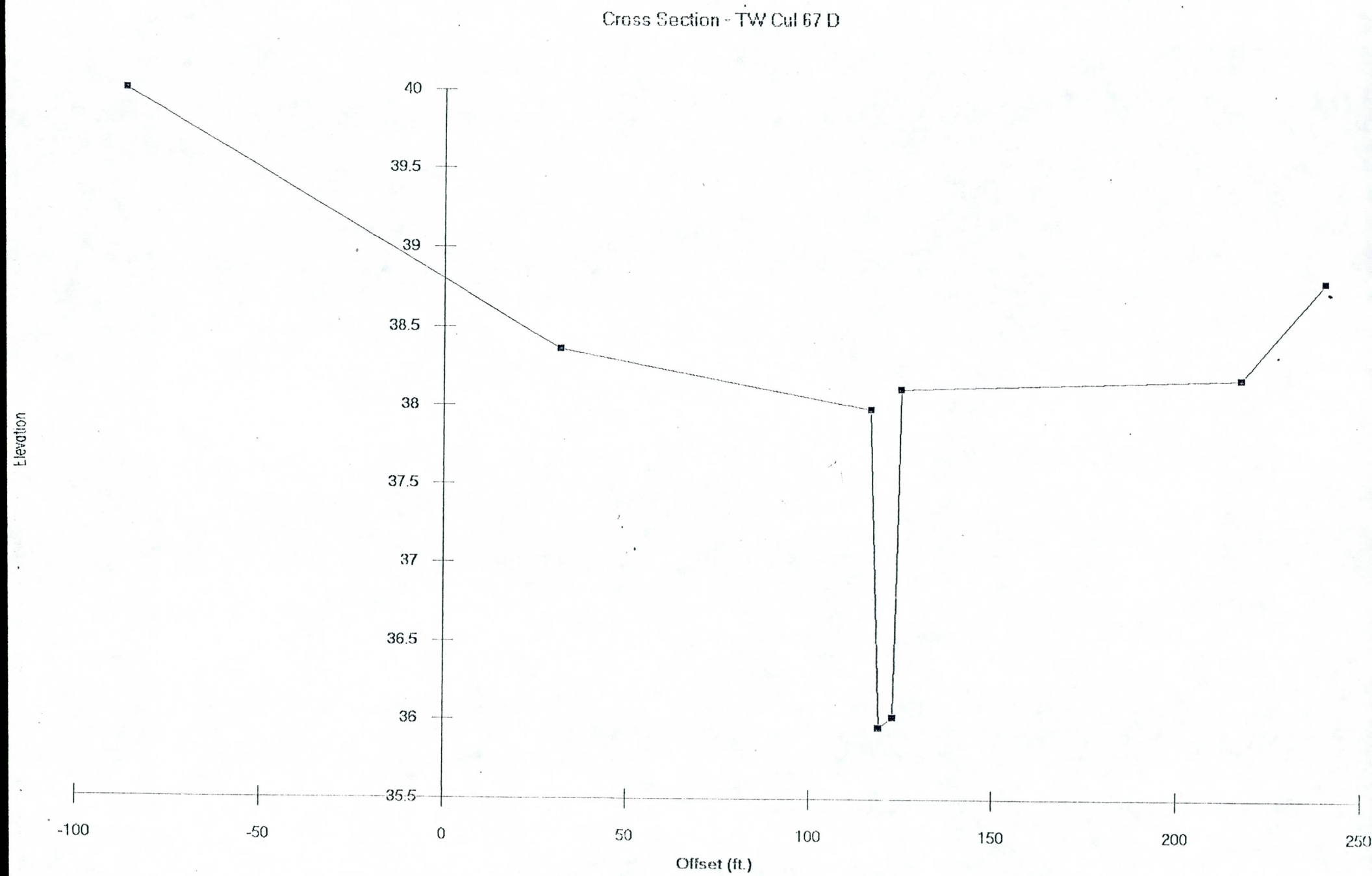
STAGE-DISCHARGE DATA:

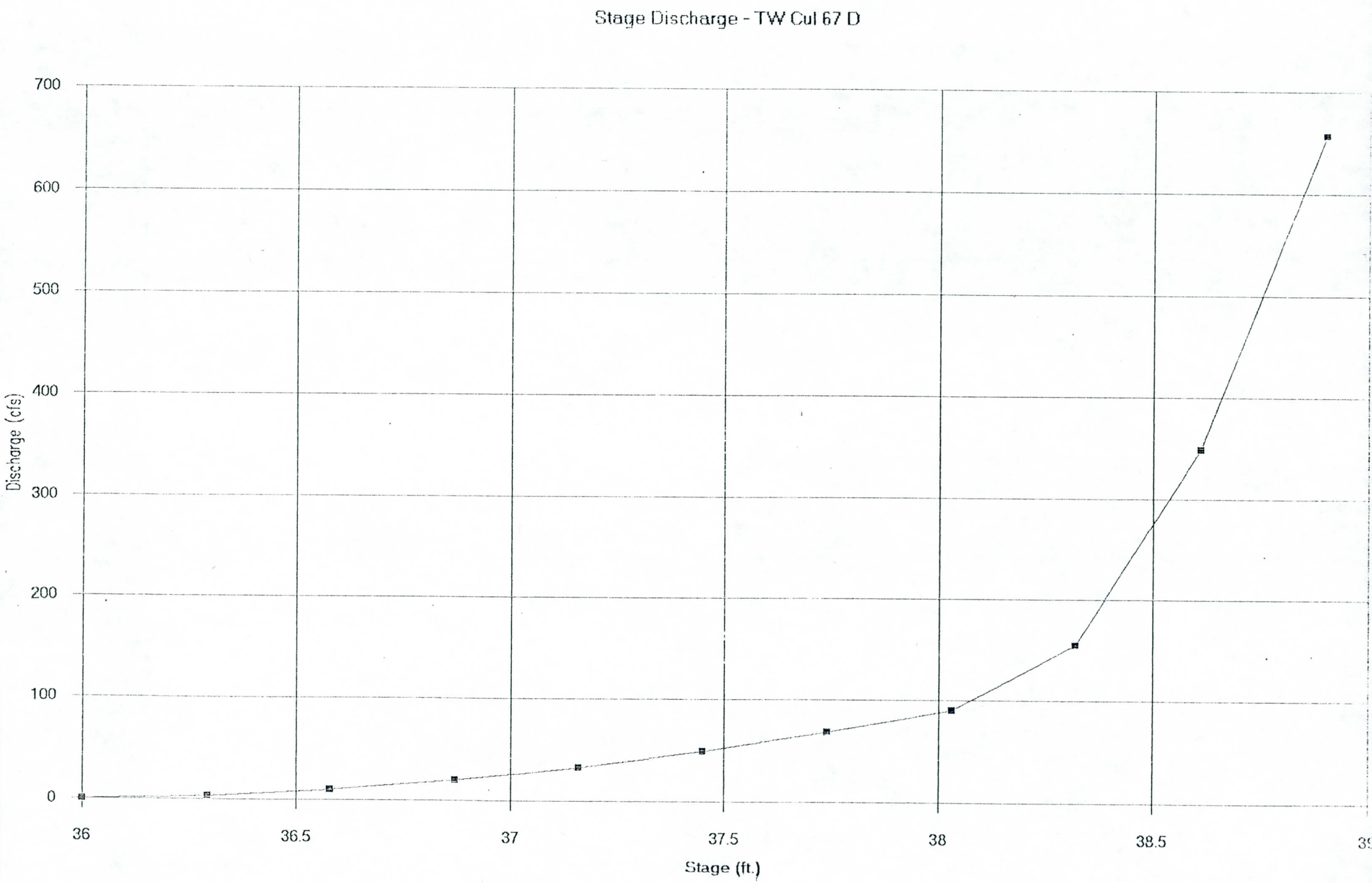
STAGE:	36													
WET PER.		0.0	0.0	0.1	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	36.29														
WET PER.		0.0	0.0	0.5	3.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	3	0	0	0	0	0	0	0	0	0	0
STAGE:	36.58														
WET PER.		0.0	0.0	1.0	3.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.2	2.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.2	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	10	0	0	0	0	0	0	0	0	0	0
STAGE:	36.87														
WET PER.		0.0	0.0	1.4	3.8	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.5	3.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.3	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	1	19	1	0	0	0	0	0	0	0	0	0
STAGE:	37.16														
WET PER.		0.0	0.0	1.8	3.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.8	4.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.5	1.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	2	30	1	0	0	0	0	0	0	0	0	0
STAGE:	37.45														
WET PER.		0.0	0.0	2.3	3.8	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.3	5.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.6	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	3	44	2	0	0	0	0	0	0	0	0	0

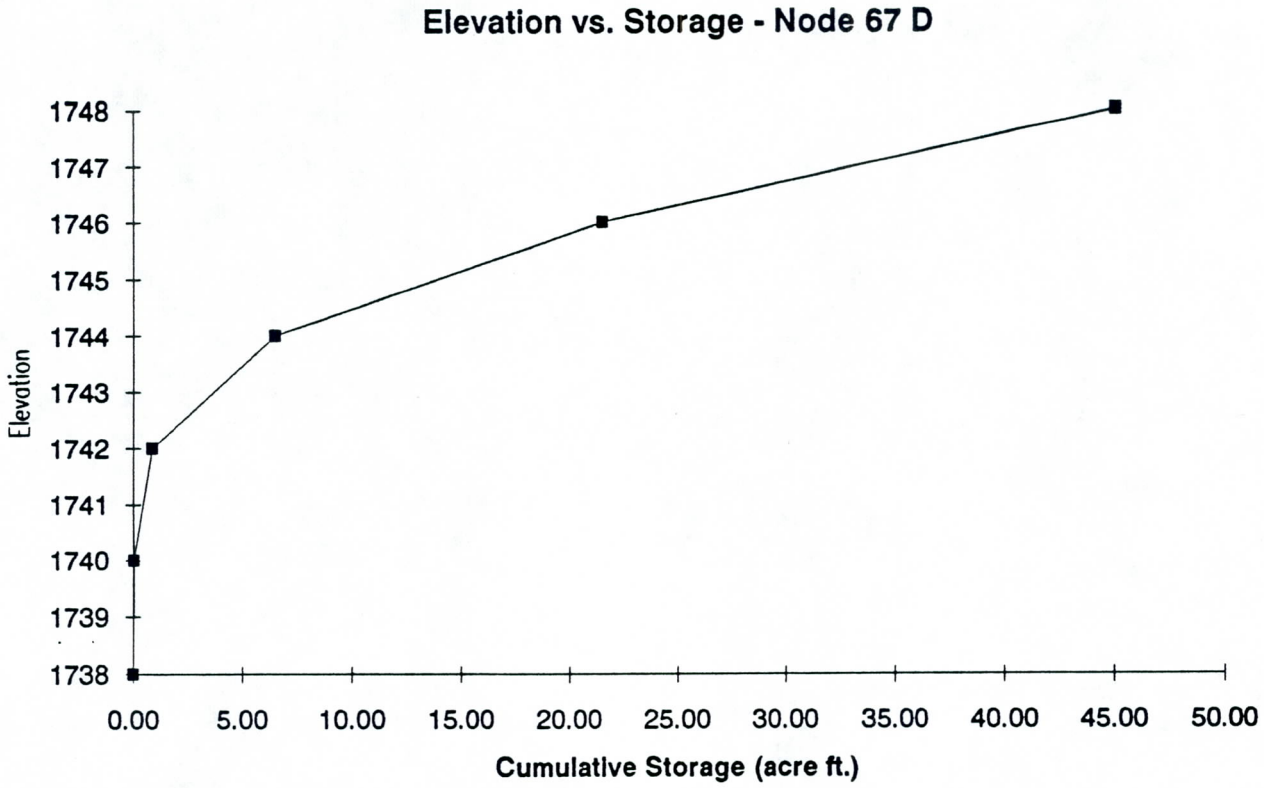
SECTION NUMBER TW67D 6/12/91

STAGE:	37.74													
WET PER.		0.0	0.0	2.7	3.8	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.8	6.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.7	1.8	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	5	59	4	0	0	0	0	0	0	0	0
STAGE:	38.03													
WET PER.		0.0	11.2	3.1	3.8	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.3	2.4	7.8	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.8	2.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	8	76	6	0	0	0	0	0	0	0	0
STAGE:	38.32													
WET PER.		0.0	76.0	3.1	3.8	2.9	92.4	96.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	12.9	3.1	8.9	2.5	16.2	16.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.2	1.0	2.3	0.9	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	17	12	95	9	0	22	0	0	0	0	0	0	0
STAGE:	38.61													
WET PER.		18.1	103.0	3.1	3.8	2.9	92.4	106.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		2.3	39.6	3.8	10.0	3.1	43.0	45.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.1	0.4	1.2	2.6	1.1	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	91	17	115	12	0	114	0	0	0	0	0	0	0
STAGE:	38.9													
WET PER.		39.2	124.1	3.1	3.8	2.9	92.4	115.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		10.6	72.5	4.5	11.1	3.7	69.8	77.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.3	0.6	1.5	2.9	1.3	0.8	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	220	22	137	16	0	261	0	0	0	0	0	0	0

W.S. Elev.	36	36.29	36.58	36.87	37.16	37.45	37.74	38.03	38.32	38.61	38.9
Q	0	3	10	20	33	49	68	90	155	349	657
A	0.1	1.3	2.6	4.2	5.9	7.8	9.9	12.4	43.9	102.4	169.7
V	0.5	2.6	3.9	4.9	5.6	6.3	6.9	7.2	3.5	3.4	3.9


Cross Section - TW Cul 67 D
Elevation
40
39.5
39
38.5
38
37.5
37
36.5
36
35.5
-100
-50
0
50
100
150
200
250
Offset (ft.)


Stage Discharge - TW Cul 67 D
700
600
500
400
300
200
100
0
Discharge (cfs)
36
36.5
37
37.5
38
38.5
Stage (ft.)


Elevation vs. Storage - Node 67 D
Elevation
1748
1747
1746
1745
1744
1743
1742
1741
1740
1739
1738
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00
50.00
Cumulative Storage (acre ft.)

SVERDR

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60 C [10]

SHEET NO. ____ OF ____

DATE 7/12/91

BY BDO CHKD RJT 7-22-91

CULVERT COMPUTATION SHEET

PROJECT: ____

STATION: 246+70

DESIGNER: ____

DATE: ____

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 0.11 sq. miles

Q_1 = 40cfs

Q_2 = ____

TW_1 = 1.1' Exist. Channel

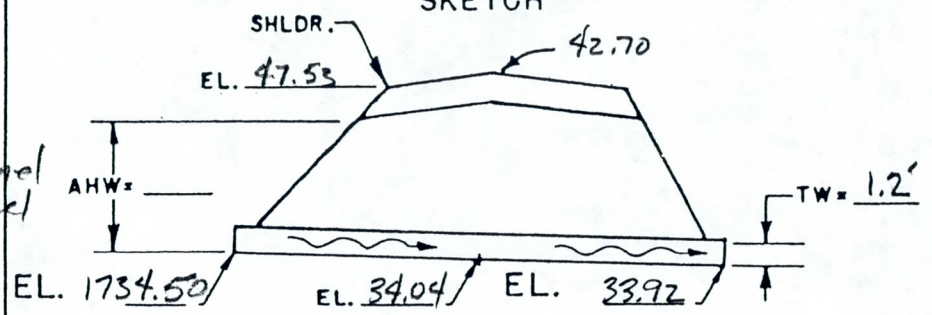
TW_2 = 1.2' New Channel

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~ Q_{100})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050 ft/ft L = 116 L/100 S_o = ____

MEAN STREAM VELOCITY = 2.3 fps

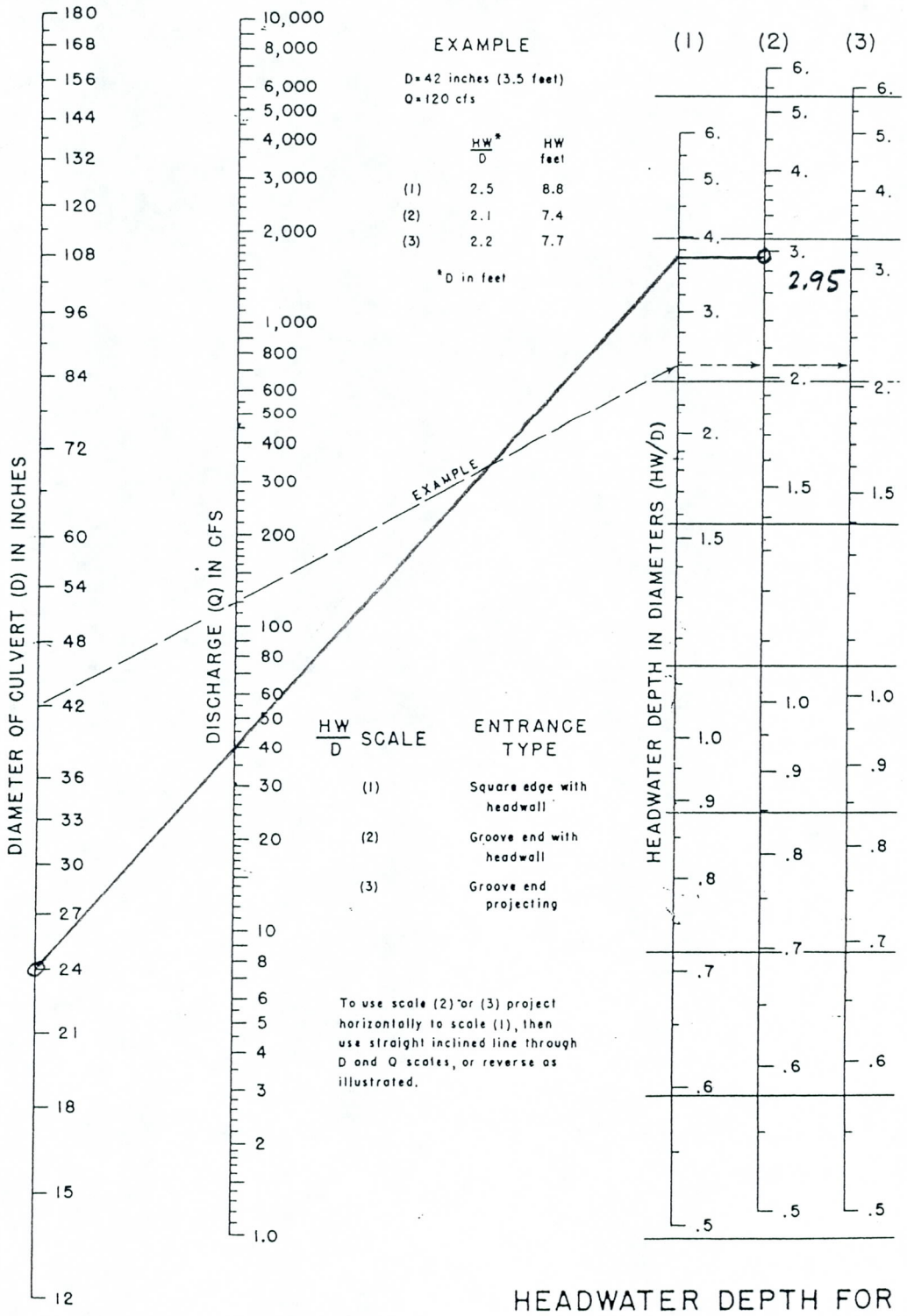
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(1) 24" RCP	Drop Inlet	40		2.95	5.90	0.2	6.10	2.0	2.0	1.2'	2.0	0.58	7.52	7.52	12.7		1742.02	Outlet Control

SUMMARY & RECOMMENDATIONS Use grouted riprap plunge basin for outlet erosion control.

B-1

Culvert 60 C

CHART 2

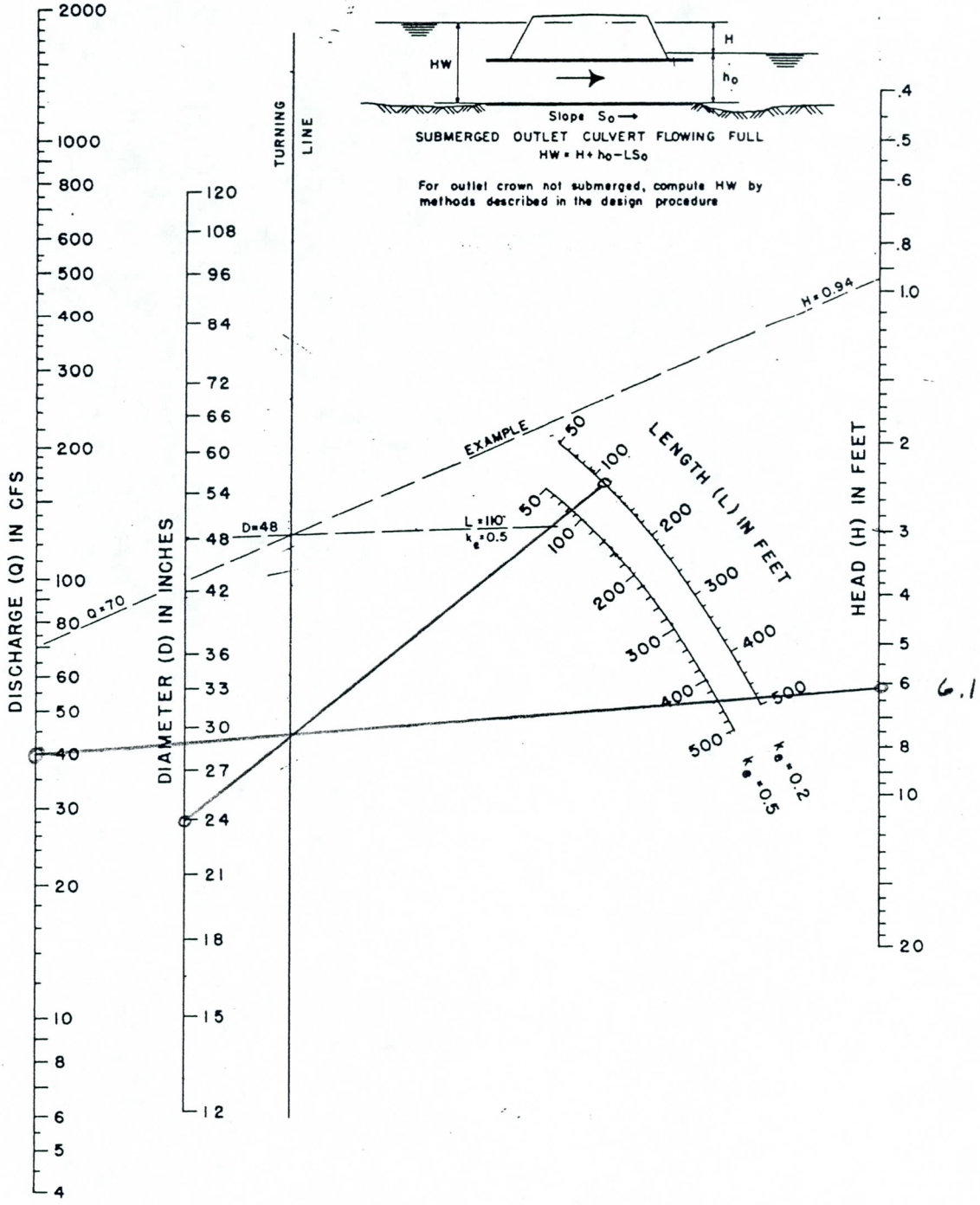


HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 C

CHART 9

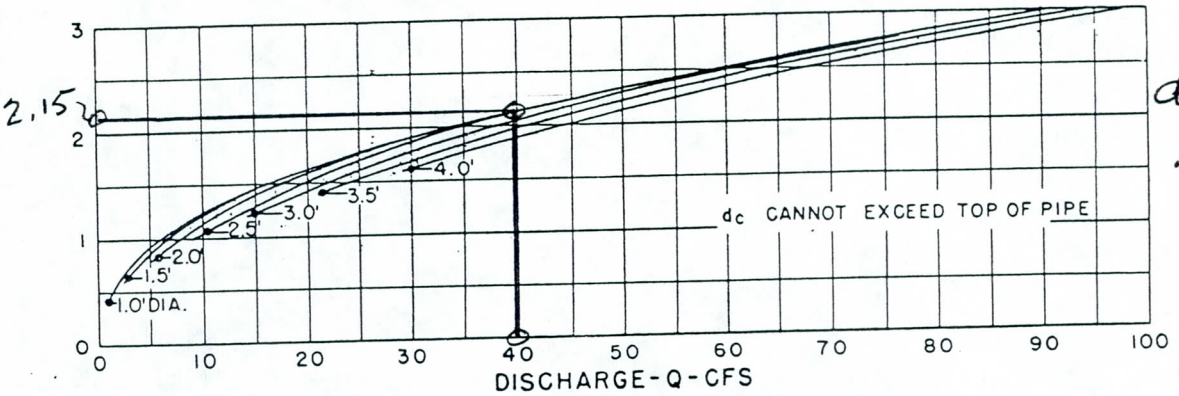


HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

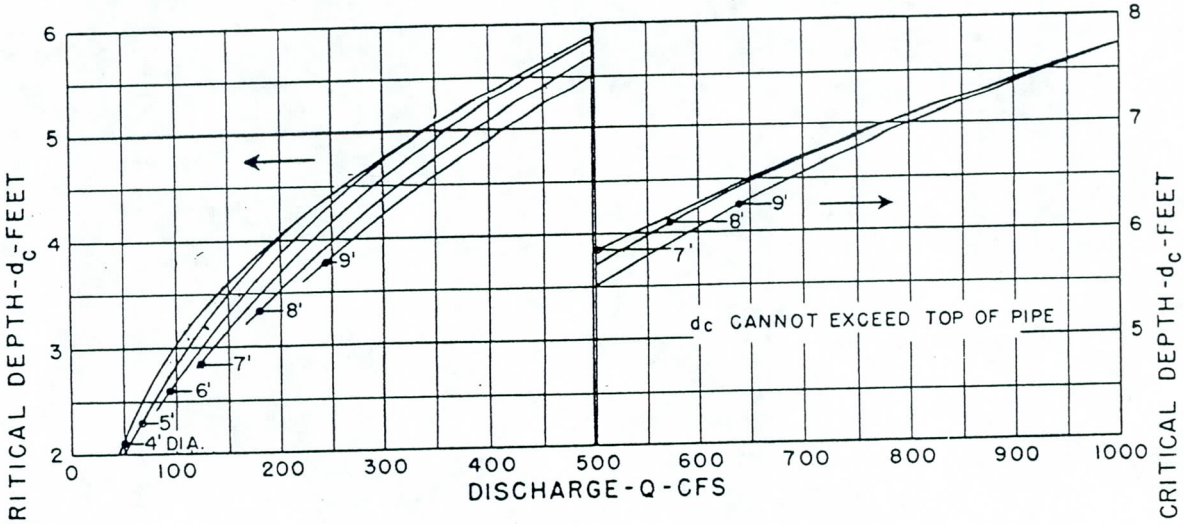
Culvert 60C

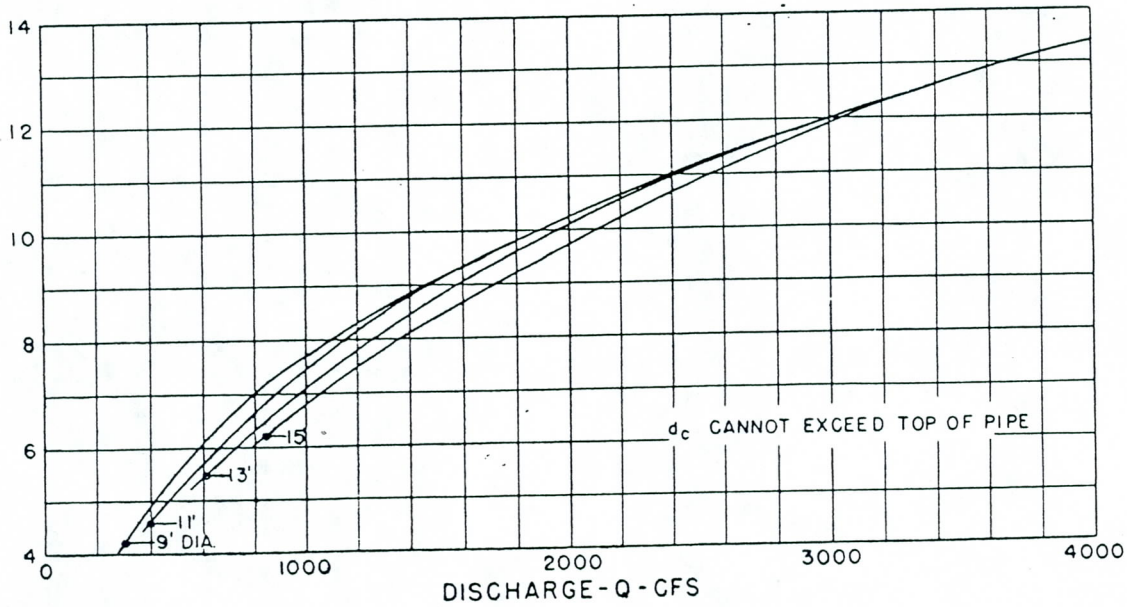
CHART 16



$d_c = 2.15 > 2.0'$

$\therefore$ Use 2.0'





BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH CIRCULAR PIPE

SVERDRUP

JOB 40477 Toyota SHEET NO. 5 OF

COMPUTATIONS FOR Culvert 60 C DATE 7/13/91

BY BDO CHKD RJT 7-22-91

Check outlet velocity for 24" Pipe

$Q_{100} = 40$ cfs $n = 0.013$ $d = 2.0'$ $S = 0.0050$ ft/ft

$$K' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{40\,(.013)}{(2)^{8/3}\,(.005)^{1/2}} = 1.16$$

(Beyond limits of Open Channel Flow ∴ Pipe Full)

$V = Q/A = 40 \text{ cfs} / 3.14 \text{ ft}^2 = 12.73$ fps

Check Froude Number

$$\mathcal{F} = \frac{V}{\sqrt{g \cdot Y_h}} = \frac{12.73}{\sqrt{32.2 \times 2}} = 1.59$$, Supercritical

Use grouted riprap plunge basin for erosion control.

SVERDRUP

JOB 40477 Toyota

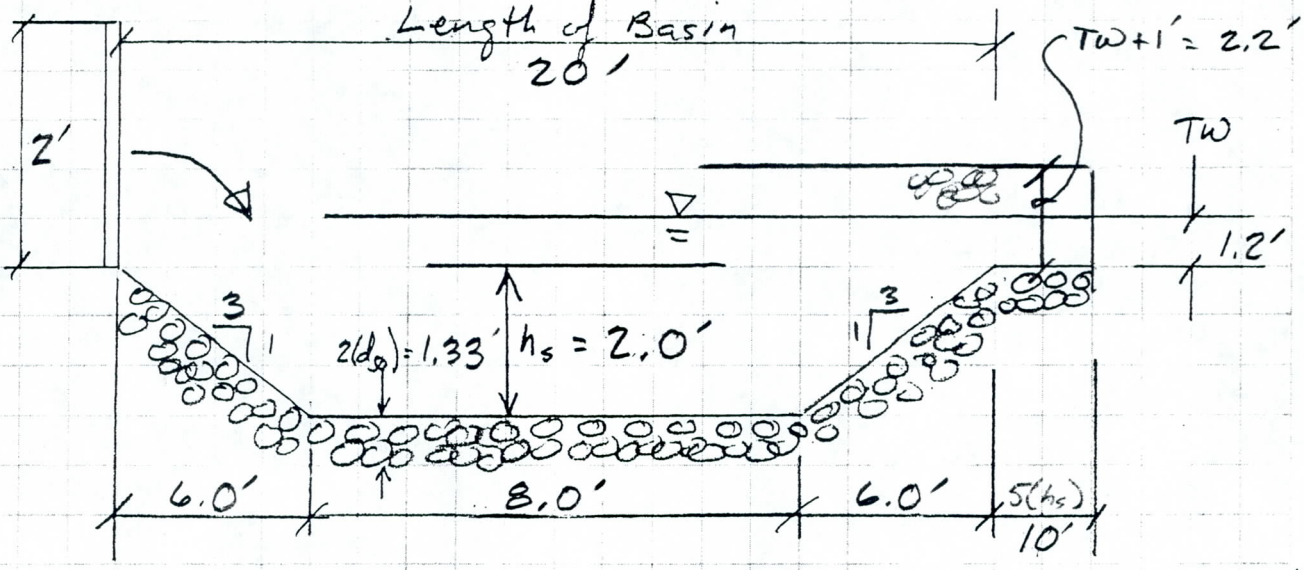
COMPUTATIONS FOR Box Culvert 60C

SHEET NO. 6 OF

DATE 7/13/91

BY BDO CHKD RJT 7-22-91

Riprap Plunge Basin Design (Q100)



Check Rock Size (From Figure XI-2, HEC No. 14)

For $y_o = 2.0'$ $\quad d_{50} = 8''$ or $0.67'$

$$d_{50}/y_o = \frac{0.67'}{2.00'} = 0.335 \quad , \quad F = 1.59$$

$$\frac{h_s}{y_o} = 1.0 \qquad h_s = 1.0\,(2.0') = 2.0'$$

Check $\dfrac{h_s}{d_{50}} = \dfrac{2.0'}{0.67'} = 2.99 < 4$ and > 2 ∴OK

Length of Basin

$10\,h_s = 10\,(2.0') = 20'$

or

$3(W_o) = 3(2') = 6'$

$\dfrac{TW}{h_s} = \dfrac{1.2}{2.0} = 0.60 < 0.75$

∴OK

Use 20'

Culvert 60 C

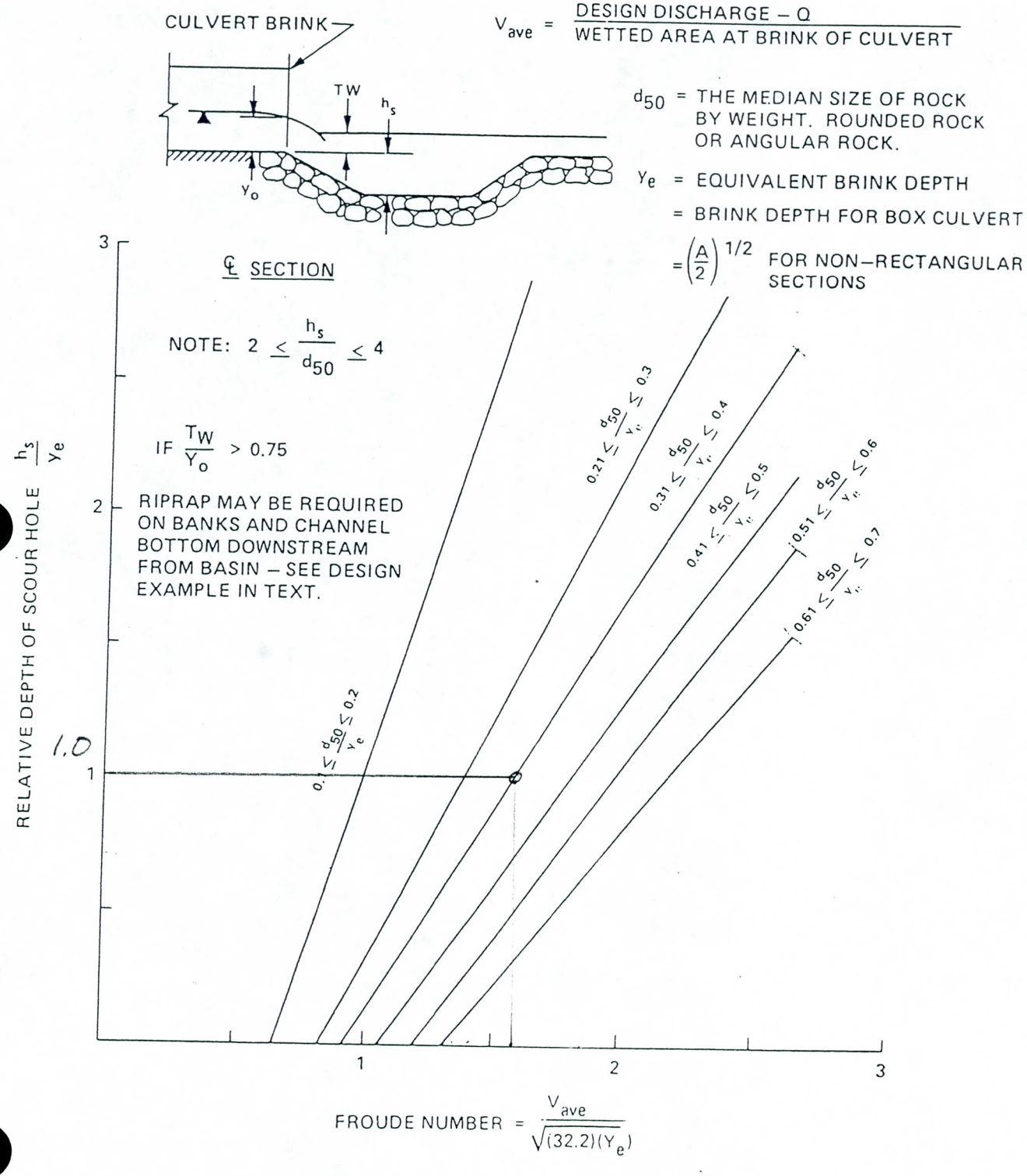


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Channel Downstream of Culvert 60 C

SHEET NO. 8 OF

DATE 7/14/91

BY BDO CHKD RJT 7-22-91

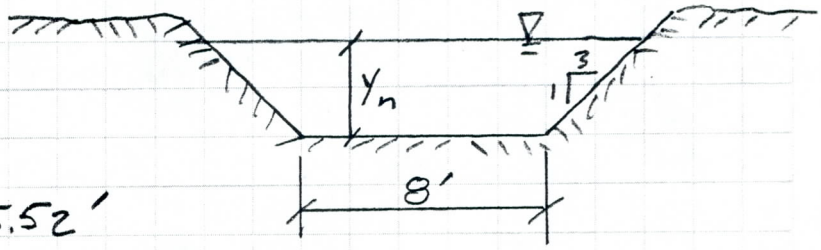
Check depth of Flow using Mannings Equation

$Q_{100} = 40$ cfs

$n = 0.03$ (Earth channel)

$S_o = 0.0040$ ft/ft

$Y_n \sim 1.19'$



$A = 13.81$ ft^2

$WP = 2(3.76) + 8 = 15.52'$

$R_h = A/WP = 13.81/15.52 = 0.8898'$

$$V = \frac{1.49}{.03}(.8898)^{.666}(.004)^{.5} = 2.91 \text{ fps}$$

Check

$Q = VA = 2.91\,(13.81) = 40$ cfs (OK)

Check Froude Number

$$FF = \frac{2.91}{\sqrt{32.2 \times 1.19}} = 0.47, \text{ Subcritical}$$

SVERDRUP

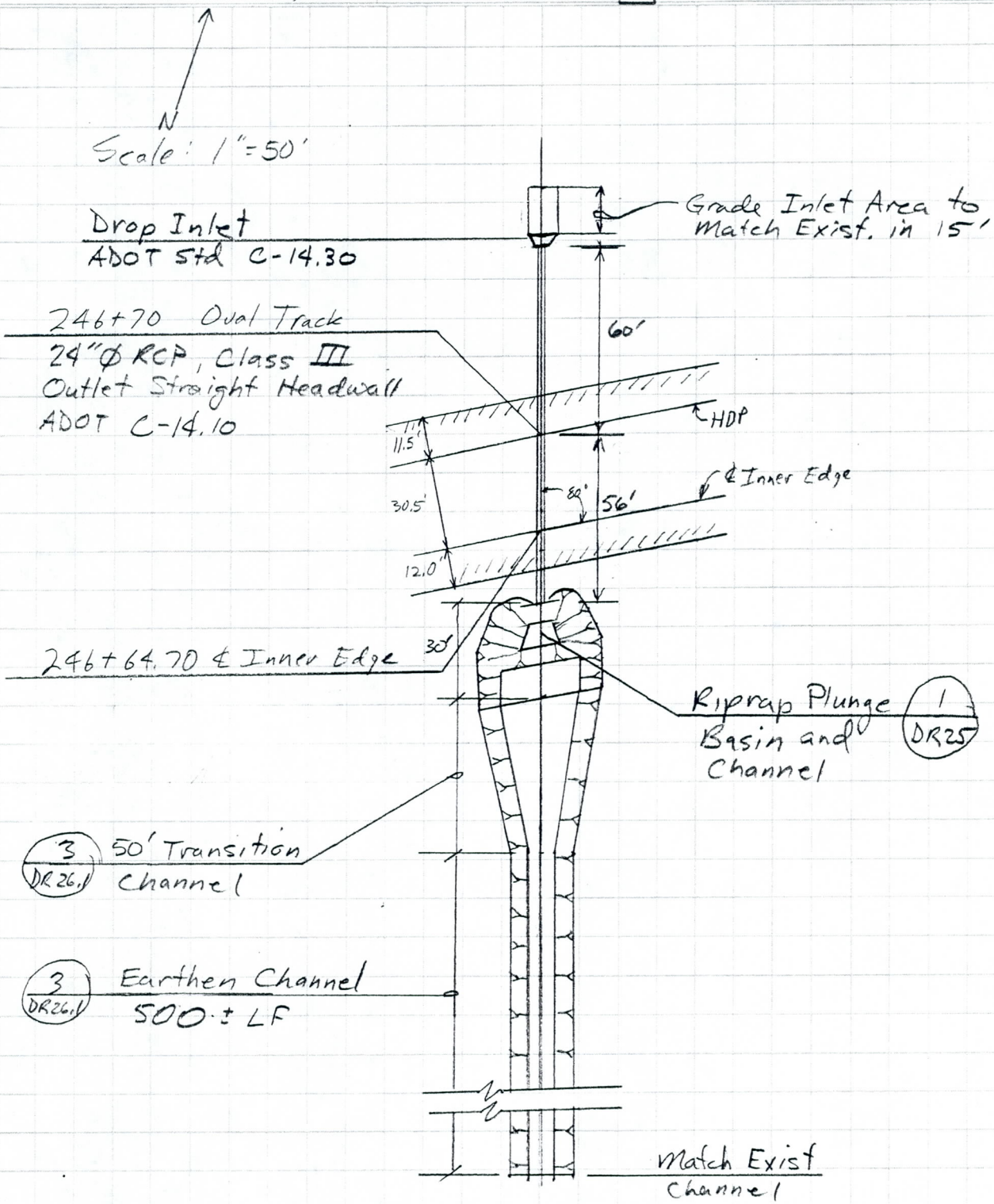
JOB 40477 Toyota

SHEET NO. 9 OF

DATE 7-20-91

COMPUTATIONS FOR Culvert 60 C Plan View
HDP Sta 246+70 [10]

BY DFP CHKD RJT 7-22-91



Plan View
Culvert 60 C

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60C [10]

Sta 246+70 HDP Oval Track

SHEET NO. 10 OF

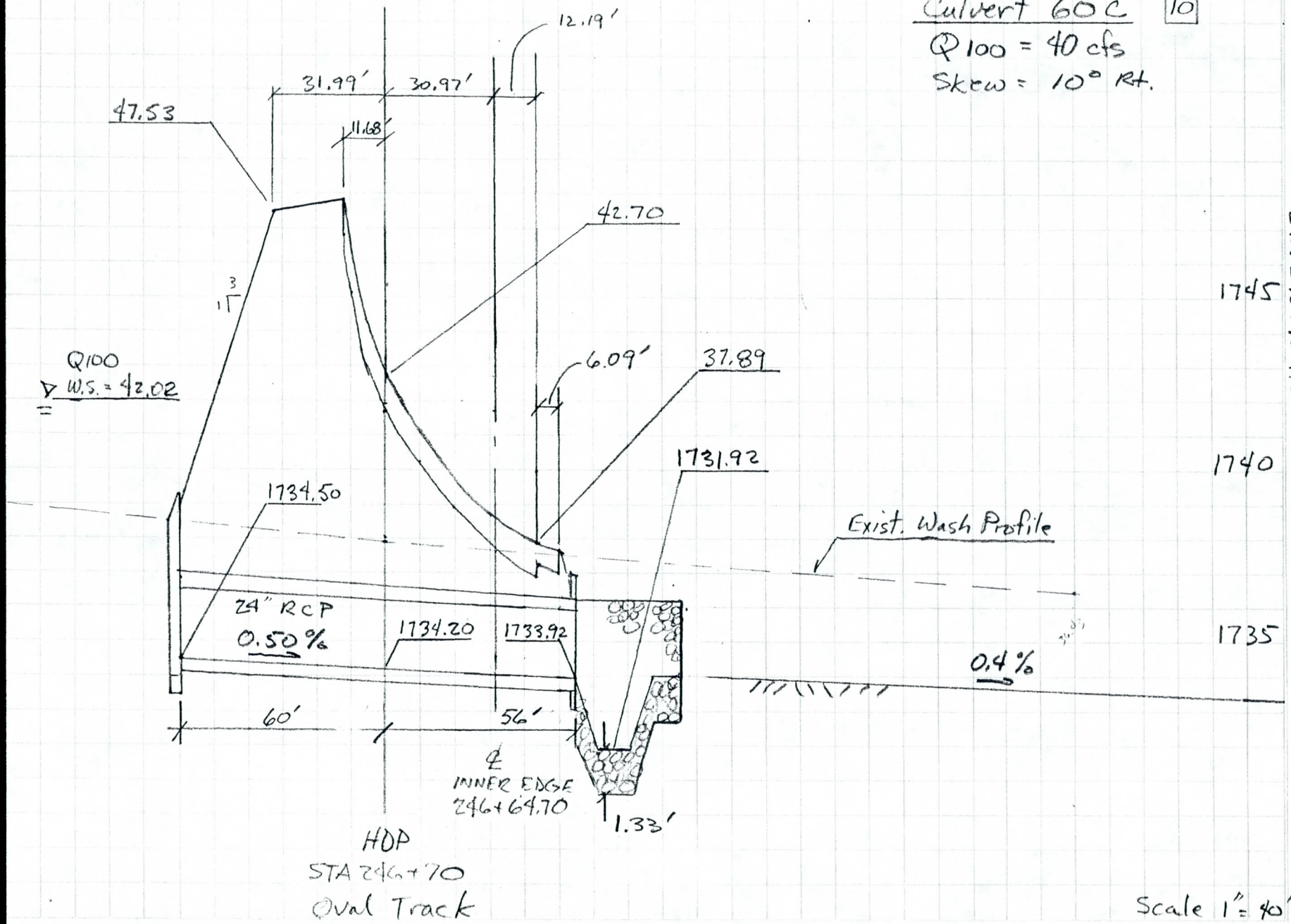
DATE 7/13/91

BY BDO CHKD RVT 7-22-91

Culvert 60C [10]

Q100 = 40 cfs

Skew = 10° Rt.



Scale 1" = 40' Horiz

1" = 4' Vert.

SECTION NUMBER TW60C 7/13/91

Channel Slope: 0.0081 ft./ft.

CROSS SECTION DATA:

OFFSET	11.9	102.8	104.5	108.4	110.3
ELEV.	37.18	37.61	36.46	36.43	37.62
N	N/A	0.035	0.04	0.025	0.04

STAGE-DISCHARGE DATA:

STAGE: 36.4												
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0

STAGE: 36.52												
WET PER.	0.0	0.1	3.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0

STAGE: 36.64												
WET PER.	0.0	0.3	3.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	1	0	0	0	0	0	0	0	0	0

STAGE: 36.76												
WET PER.	0.0	0.5	3.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.1	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	3	0	0	0	0	0	0	0	0	0

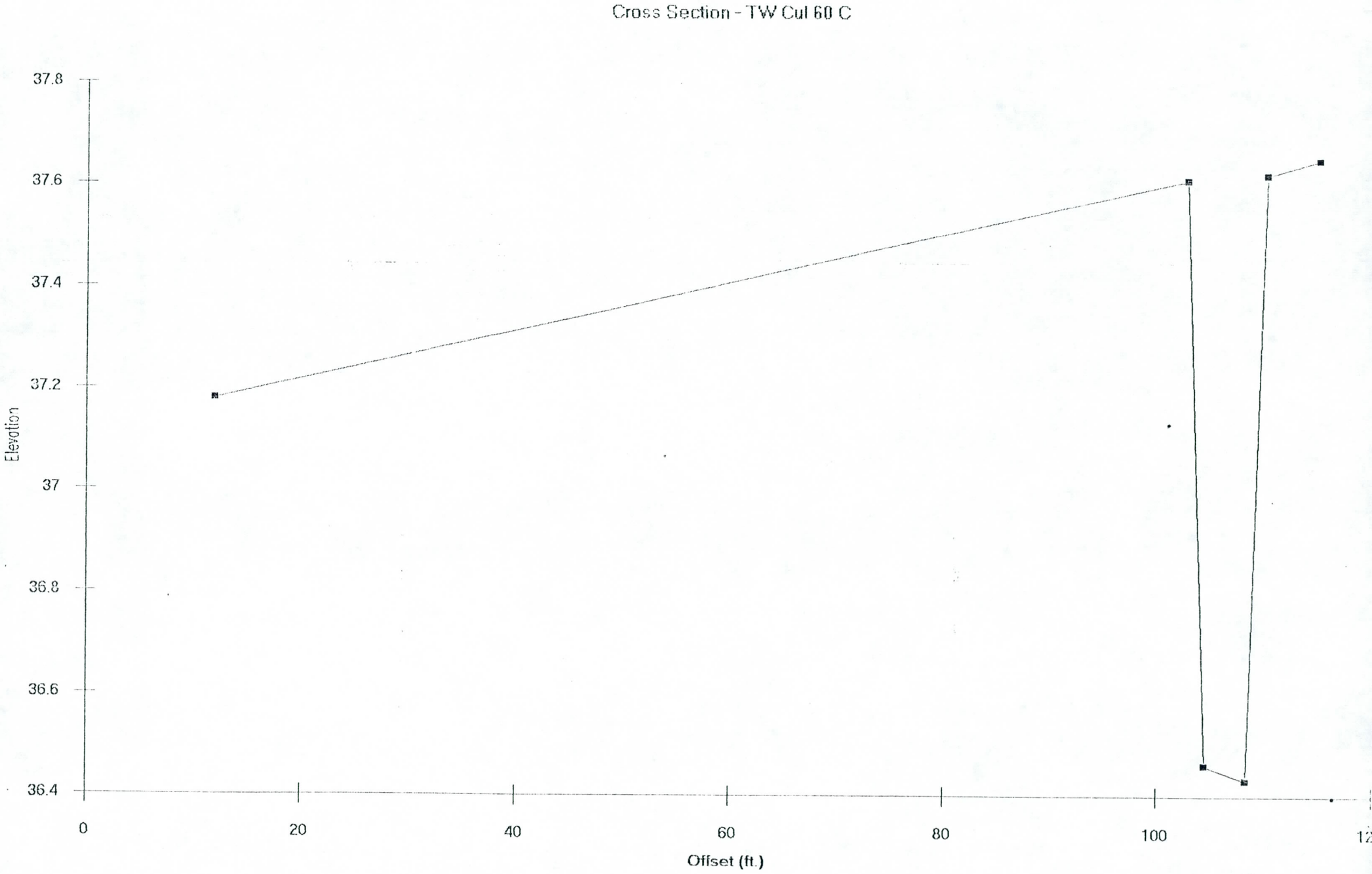
STAGE: 36.88												
WET PER.	0.0	0.8	3.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.1	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	5	0	0	0	0	0	0	0	0	0

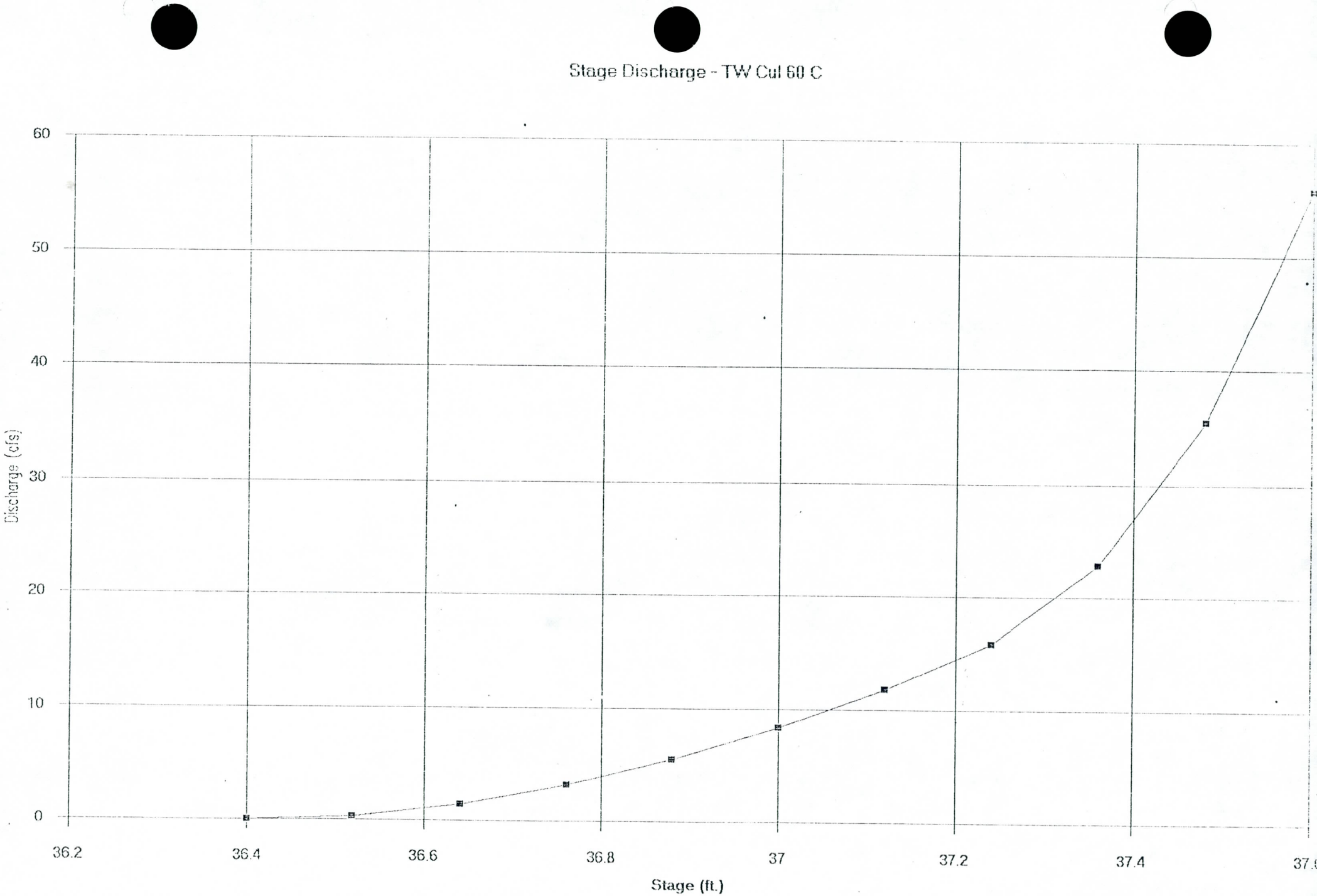
STAGE: 37												
WET PER.	0.0	1.0	3.9	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.2	2.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.2	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	8	0	0	0	0	0	0	0	0	0

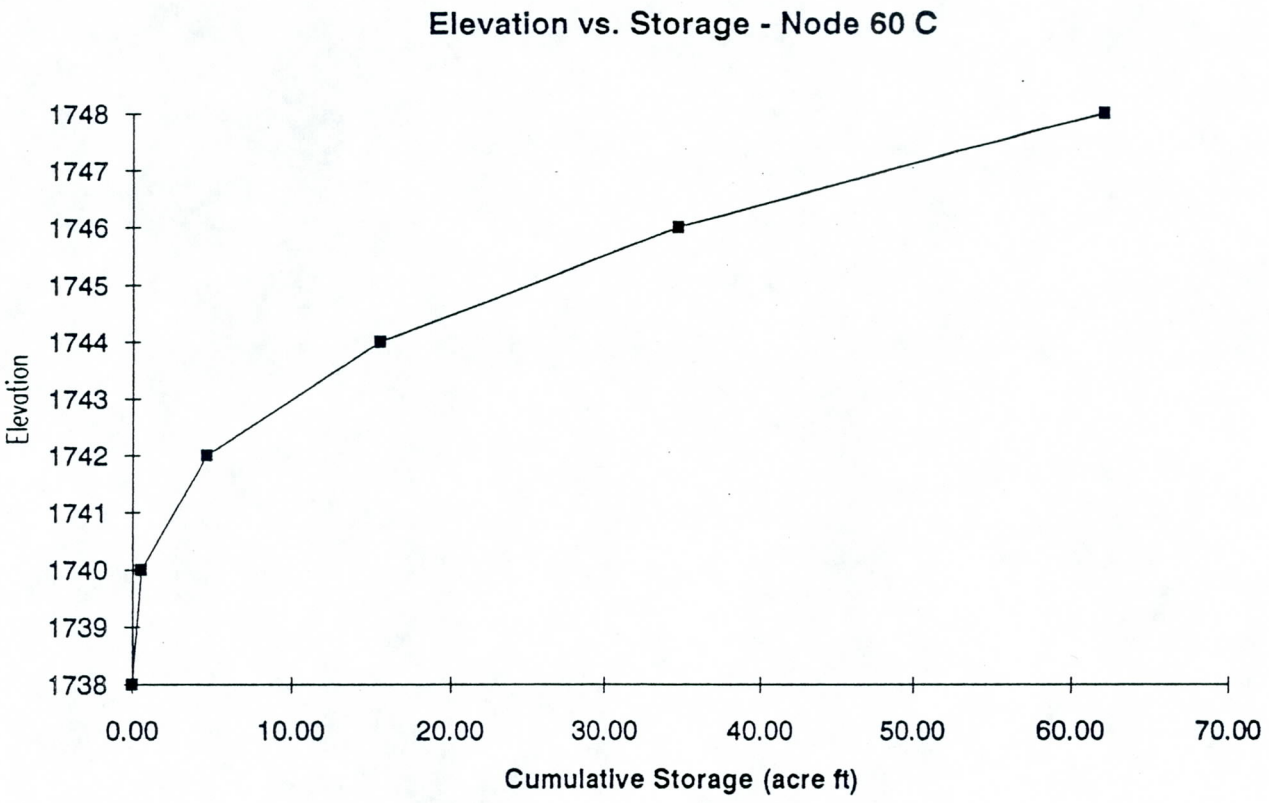
SECTION NUMBER TW60C 7/15/[illegible]

STAGE:	37.12											
WET PER.		0.0	1.2	3.9	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.3	2.6	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.3	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	11	1	0	0	0	0	0	0	0	0
STAGE:	37.24												
WET PER.		12.7	1.4	3.9	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.4	0.4	3.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.3	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	1	14	1	0	0	0	0	0	0	0	0
STAGE:	37.36												
WET PER.		38.1	1.6	3.9	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		3.4	0.6	3.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.1	0.4	0.9	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		3	1	18	1	0	0	0	0	0	0	0	0
STAGE:	37.48												
WET PER.		63.4	1.8	3.9	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		9.5	0.8	4.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.1	0.4	1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		10	1	22	2	0	0	0	0	0	0	0	0
STAGE:	37.6												
WET PER.		88.8	2.0	3.9	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		18.6	1.0	4.5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.2	0.5	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		25	2	26	2	0	0	0	0	0	0	0	0

W.S. Elev.	36.4	36.52	36.64	36.76	36.88	37	37.12	37.24	37.36	37.48	37.6
Q	0	0	1	3	6	8	12	16	23	35	56
A	0.0	0.3	0.8	1.4	2.0	2.6	3.3	4.5	8.3	15.2	25.2
V	0.0	0.9	1.7	2.3	2.8	3.2	3.5	3.6	2.8	2.3	2.2


Cross Section - TW Cul 60 C
37.8
37.6
37.4
37.2
37
36.8
36.6
36.4
Elevation
0
20
40
60
80
100
Offset (ft.)


Stage Discharge - TW Cul 60 C
60
50
40
30
20
10
0
Discharge (cfs)
36.2
36.4
36.6
36.8
37
37.2
37.4
Stage (ft.)


Elevation vs. Storage - Node 60 C
Elevation
1748
1747
1746
1745
1744
1743
1742
1741
1740
1739
1738
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
Cumulative Storage (acre ft)

SVERD[illegible]P

JOB 4044 Toyota

COMPUTATIONS FOR Culvert 60B [11]

SHEET NO. ____ OF ____

DATE 7/3/91

BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT: ____

STATION: 241+55, Oval Track

DESIGNER: ____

DATE: ____

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 0.12 Sq. Miles

Q_1 = 43 cfs

Q_2 = ____

TW_1 = 1.24' New channel

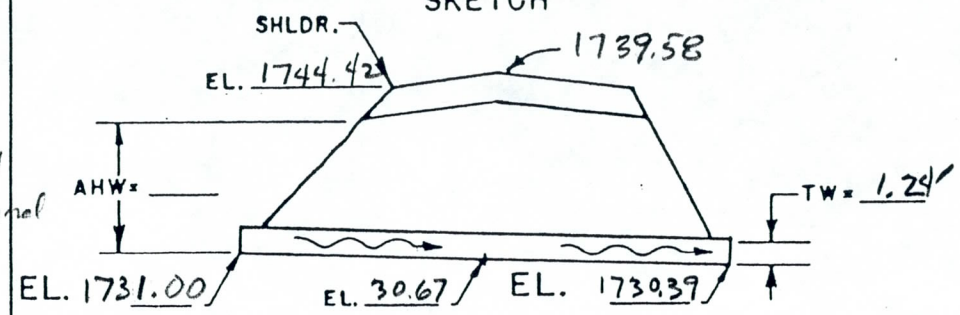
TW_2 = 1.8' Exist. channel

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~ Q_{100})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050 L = 122' L/100 S_o = ____

MEAN STREAM VELOCITY = 6.55 fps

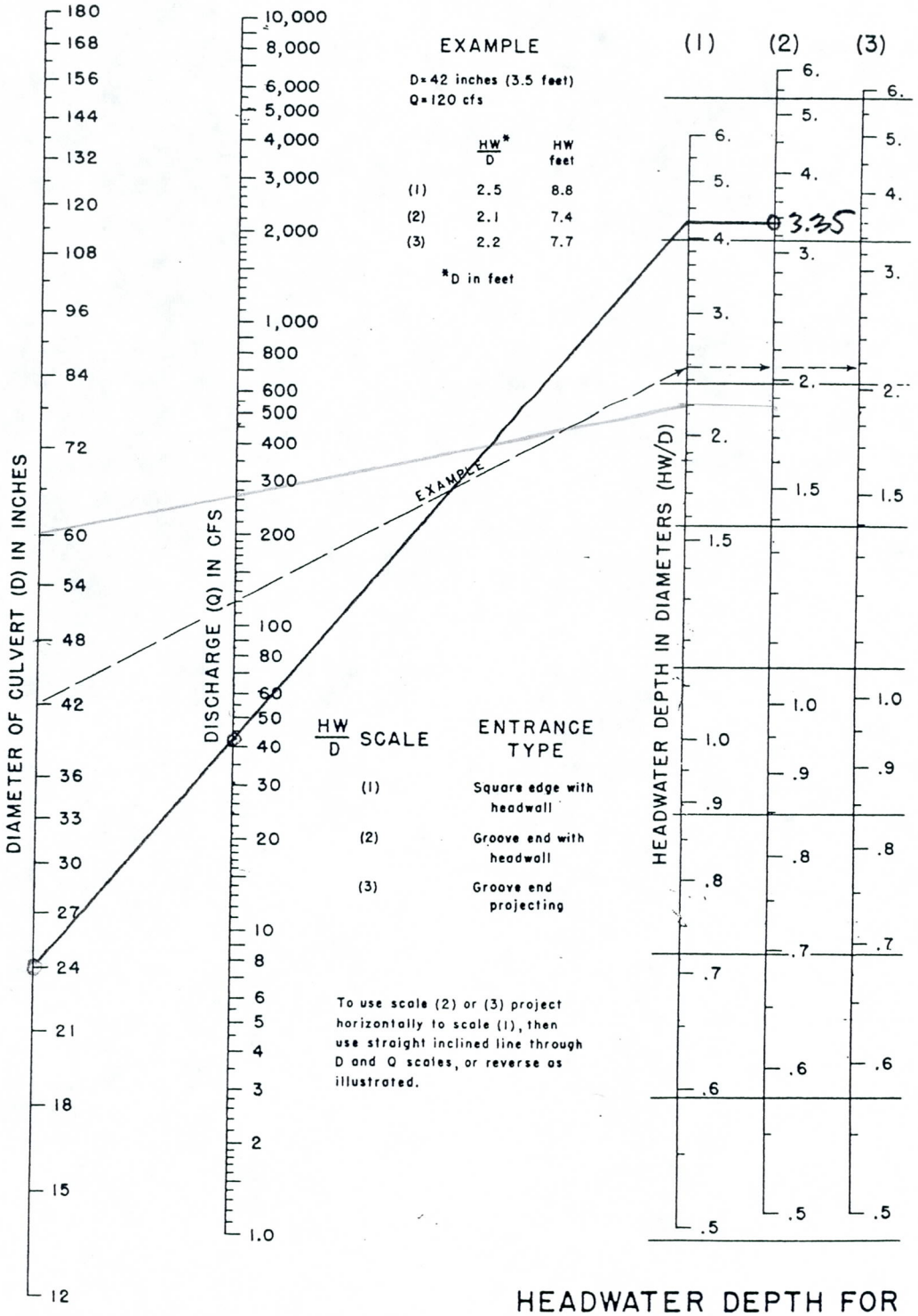
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
11'24" RCP	Drop Inlet	43		3.35	6.7	0.2	7.6	2.0	2.0	1.24	2.0	.61	8.99	8.99	13.7		1739.99	Outlet Control
2-60" RCP	"	550/2=275		4.7'	8.5		4.2	5.0	5.0		5.0	(100)(.005) .5	9.7					

SUMMARY & RECOMMENDATIONS Use grouted riprap plunge basin to reduce outlet velocity.

B-1

Culvert 60B

CHART 2

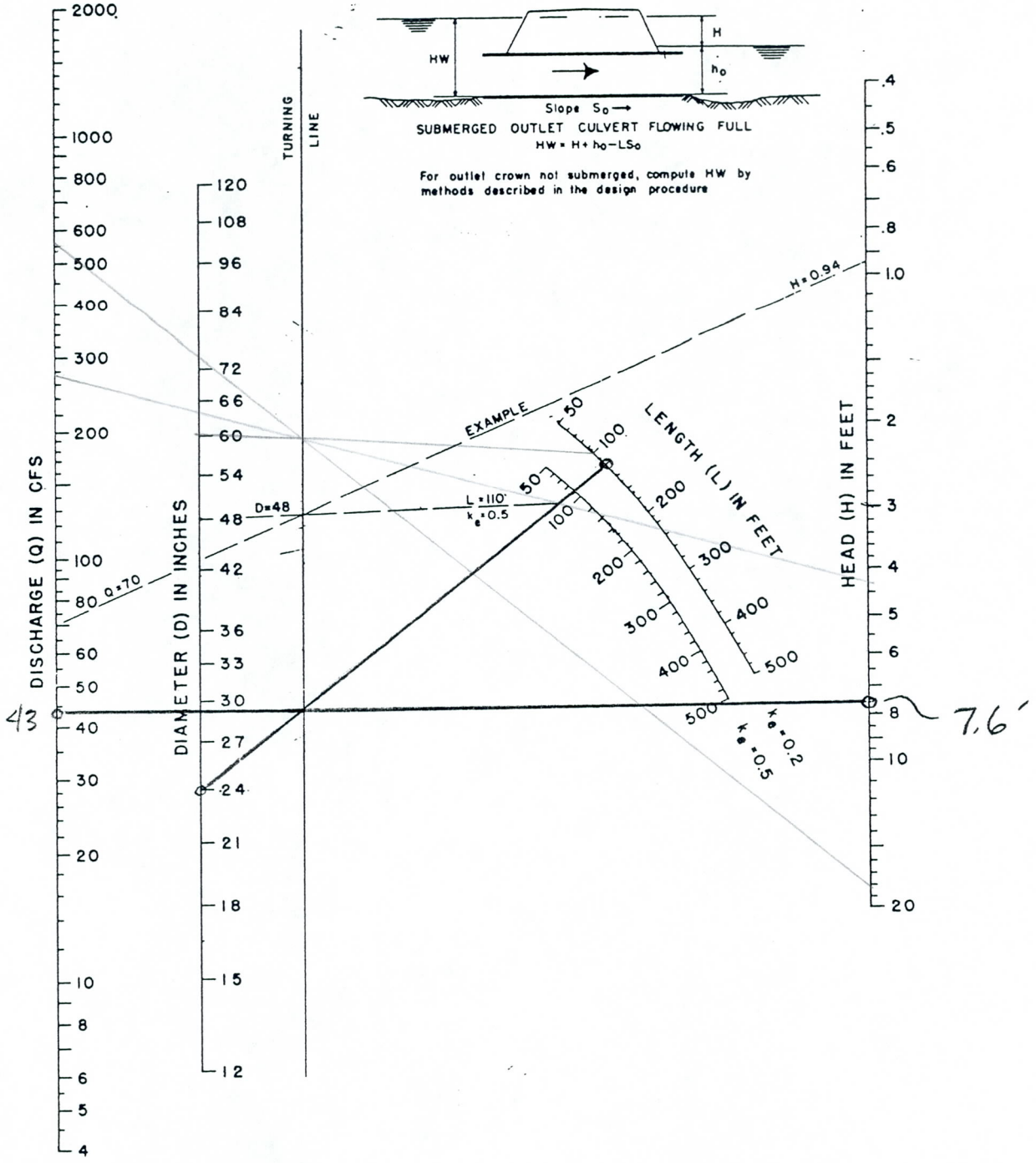


HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 B

CHART 9

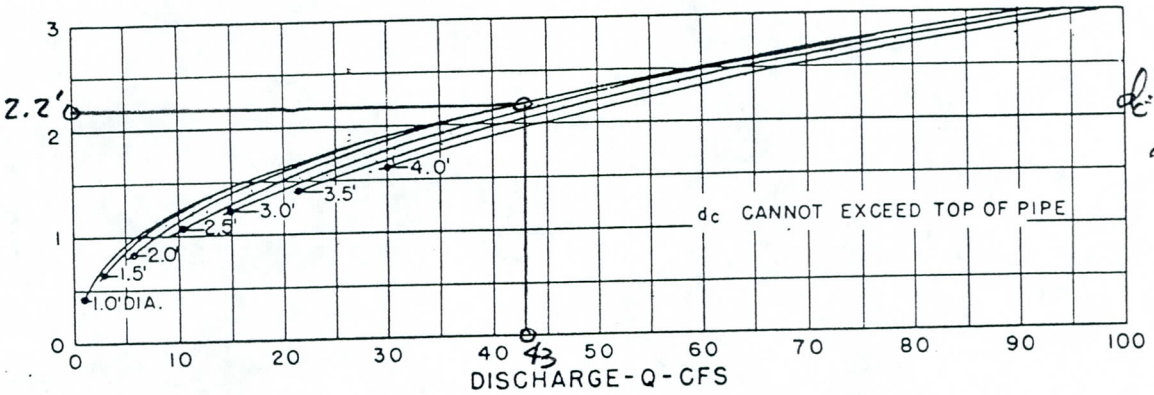


HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

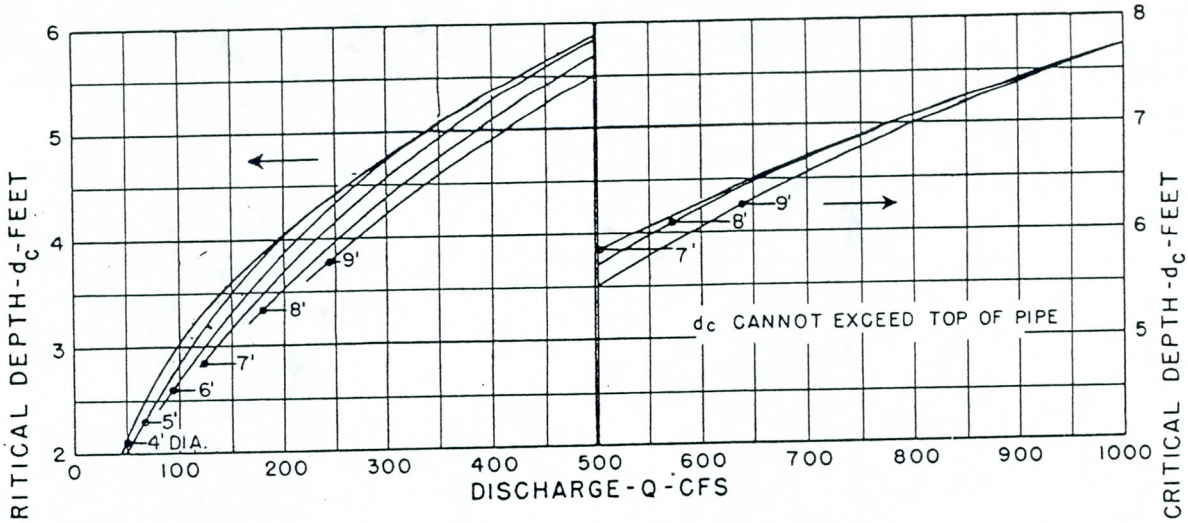
BUREAU OF PUBLIC ROADS JAN. 1963

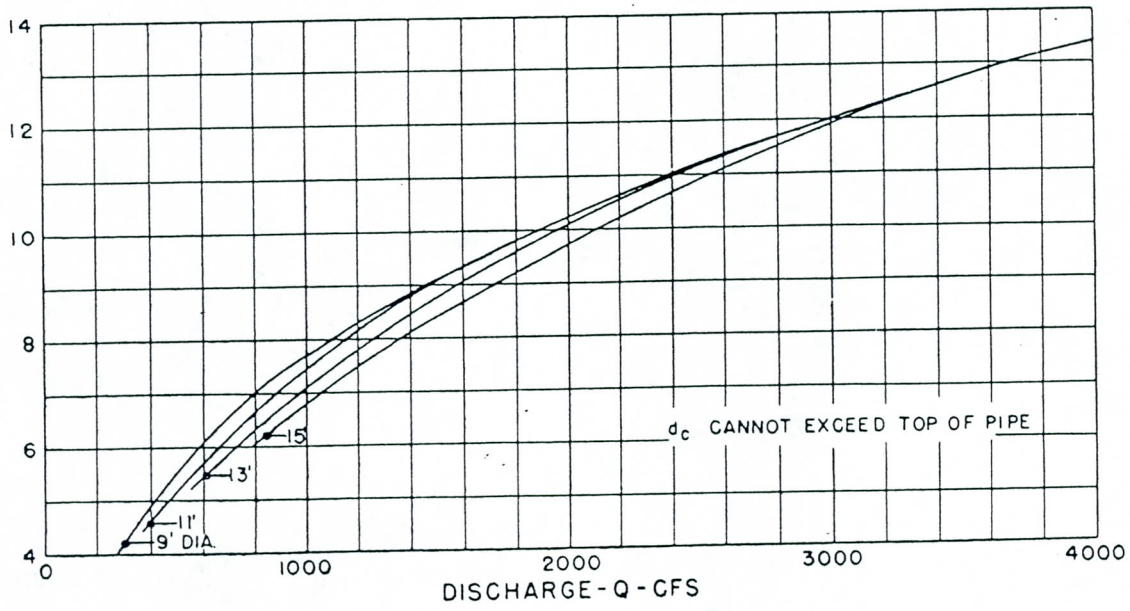
Culvert 60 B

CHART 16



$d_c = 2.2' > 2'$ pipe ϕ
$\therefore$ use 2'





BUREAU OF PUBLIC ROADS
JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

SVERDRUP

JOB 40477 Toyota SHEET NO. 5 OF

COMPUTATIONS FOR Culvert 60B DATE 7/13/91

BY BDO CHKD RJT

Check Outlet Velocity for 24" Pipe

$Q_{100} = 43$ cfs $n = 0.013$ $d = 2.0'$ $S = 0.0050$ ft/ft

$$K' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{43\,(.013)}{(2)^{8/3}\,(.005)^{1/2}} = 1.25$$

(Beyond limits of Open Channel Flow ∴ Pipe Full)

$V = Q/A = .43 \text{ cfs}/3.14 \text{ ft}^2 = 13.69$ fps

Check Froude Number

$$F = \frac{V}{\sqrt{g \times y_n}} = \frac{13.69}{\sqrt{32.2 \times 2}} = 1.70,$$ Supercritical

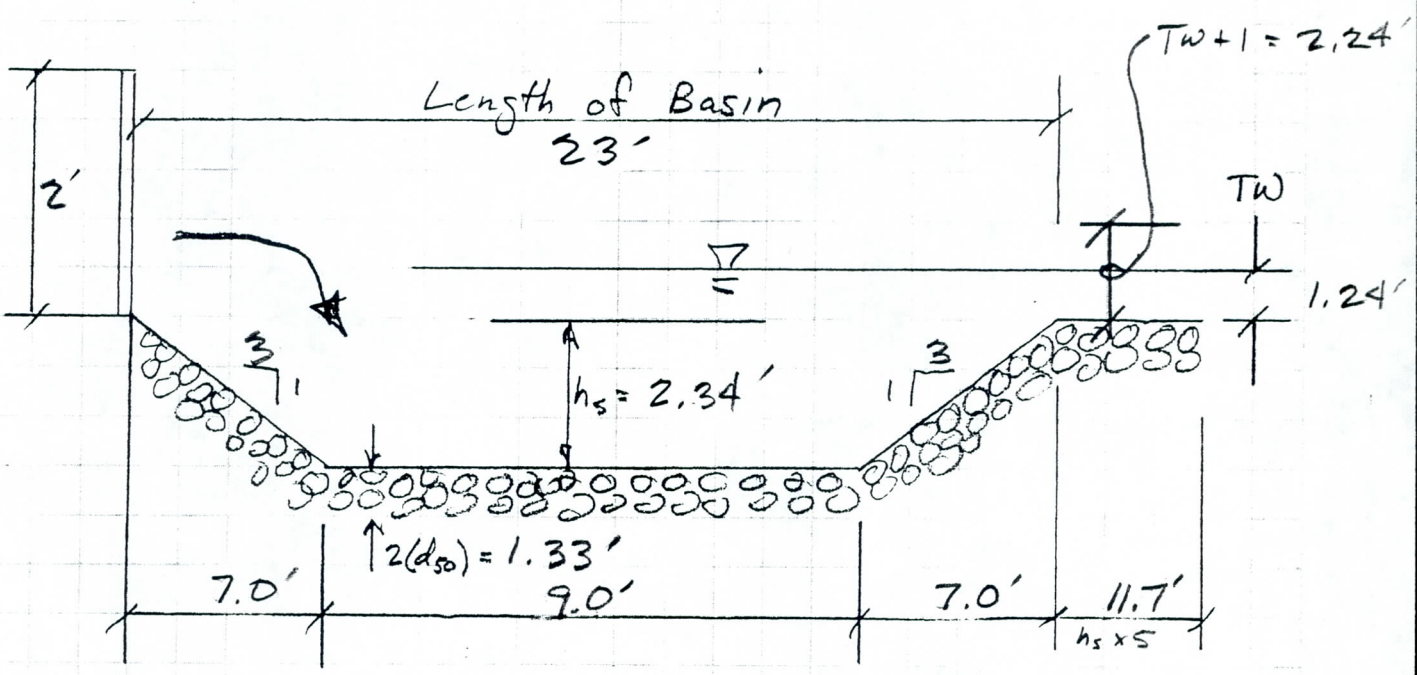
Use grouted riprap plunge basin for erosion control.

SVERDRUP

JOB 40477 Toyota SHEET NO. 6 OF

COMPUTATIONS FOR Box Culvert 60B DATE 7/3/91 BY BDO CHKD RVT

Riprap Plunge Basin Design (Q100)



Check Rock Size (From Figure XI-2, HEC No 14)

For Y_o = 2.0' d_{50} = 8" or 0.67'

$d_{50}/Y_o = \frac{0.67'}{2.0'} = 0.335$, F = 1.70

$\frac{Tw}{h_s} = \frac{1.24}{2.0} = 0.62 < 1.75$ OK

$\frac{h_s}{Y_o} = 1.17$, $h_s = 1.17\ (2.00') = 2.34'$

Check $\frac{h_s}{d_{50}} = \frac{2.34}{0.67} = 3.49 < 4$ and > 2 ∴ OK

Length of Basin

$10\ h_s = 10\ (2.34) = 23.4'$

or

$3\ (w_o) = 3\ (2') = 6'$

Use 23'

Culvert 60 B.

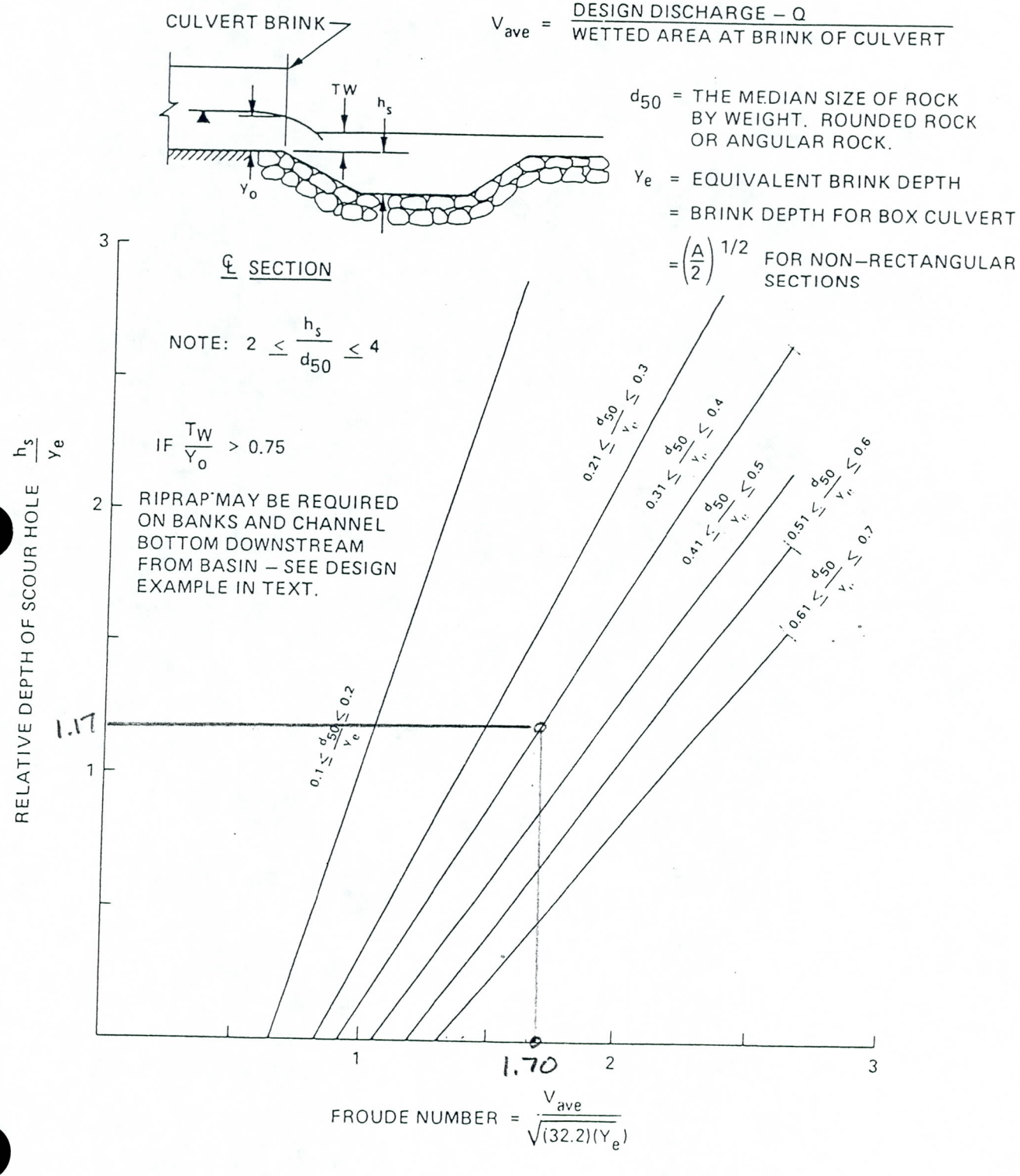


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Channel Downstream of Culvert 60B

SHEET NO. 8 OF

DATE 7/3/91

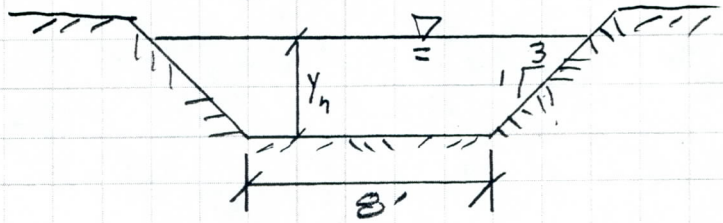
BY BDO CHKD RJT

Check depth of Flow and Velocity

$Q_{100} = 43$ cfs

$n = 0.03$ (Earth Channel)

$S_o = 0.0040$ ft/ft



$y_n \sim 1.24'$

$A = 14.53$ ft^2

$WP = 2(3.92) + 8 = 15.84$ ft

$R_h = A/WP = 14.53/15.84 = 0.9173'$

$$V = \frac{1.49}{.03}(0.9173)^{.666}(.004)^{.5} = 2.96 \text{ fps}$$

Check

$Q = VA = (2.96)(14.53) = 43$ cfs (OK)

Check Froude Number

$$F = \frac{2.96}{\sqrt{32.2 \cdot 0.94}} = 0.54, \text{ subcritical}$$

$$h = \frac{A}{T} = \frac{14.53}{15.44} = 0.94'$$

SVERDRUP

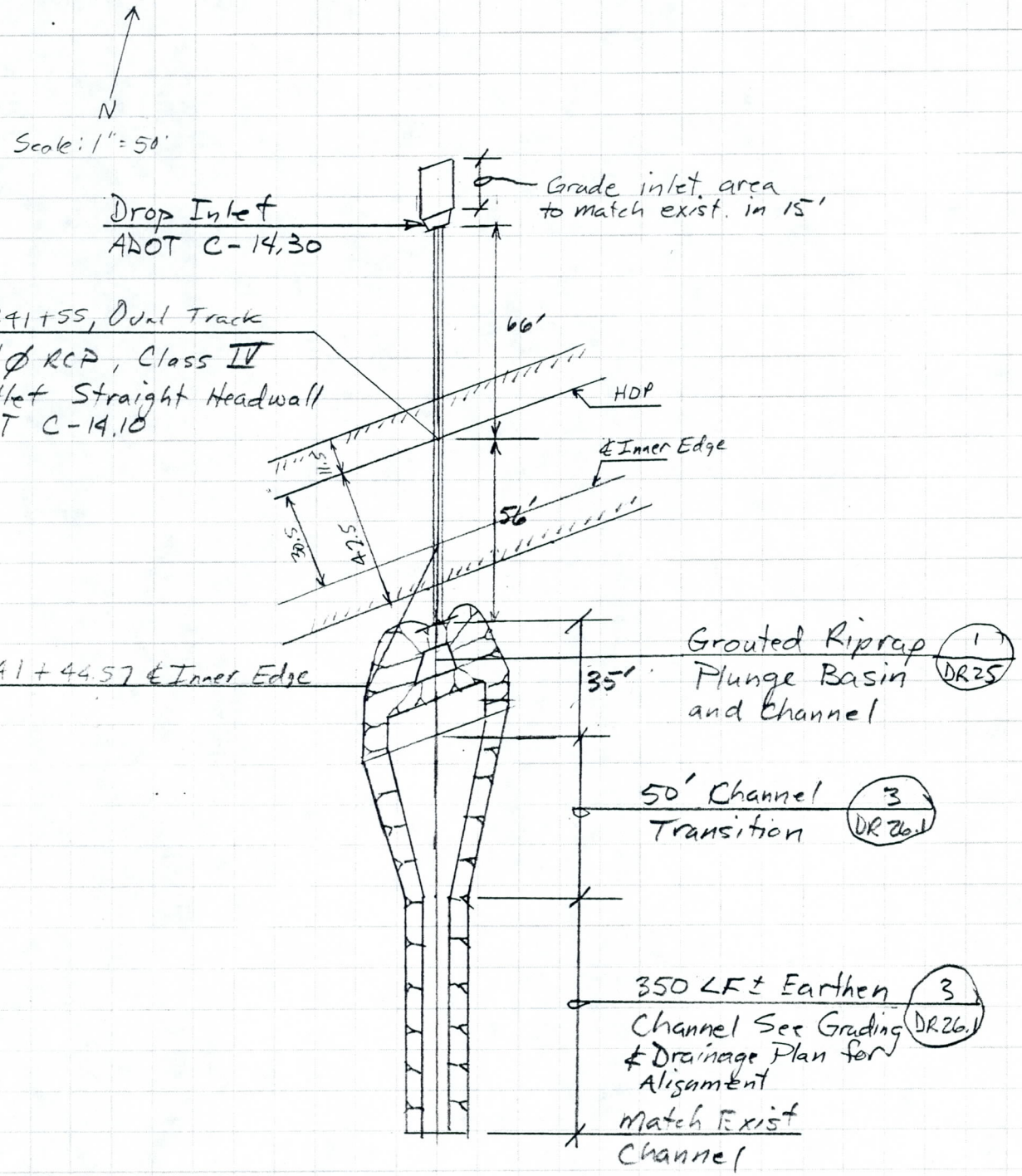
JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60 B Plan View
HDP Sta. 241+55 [11]

SHEET NO. 9 OF

DATE 7-16-91

BY BDO CHKD RJT



Plan View
Culvert 60 B

SVERDRUP

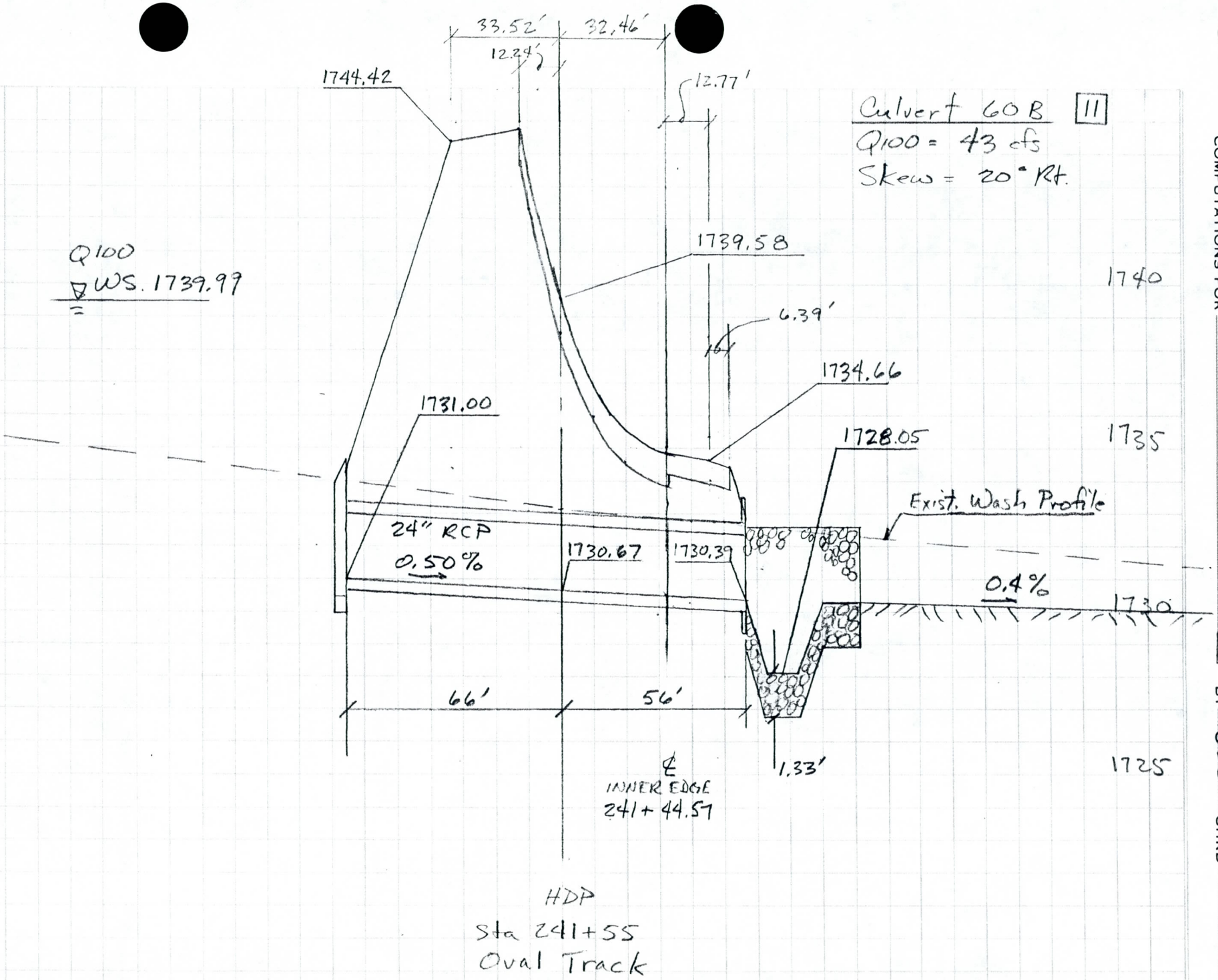
JOB 40477 Toyota

COMPUTATIONS FOR Culvert Profile 60B II

SHEET NO. 10 OF

DATE 7/3/91

BY SDO CHKD RVT



Culvert 60B II

Q100 = 43 cfs

Skew = 20° Rt.

Q100

WS. 1739.99

HDP

Sta 241+55

Oval Track

SECTION NUMBER TW60B 6/13/91

Channel Slope: 0.0093 ft./ft.

CROSS SECTION DATA:

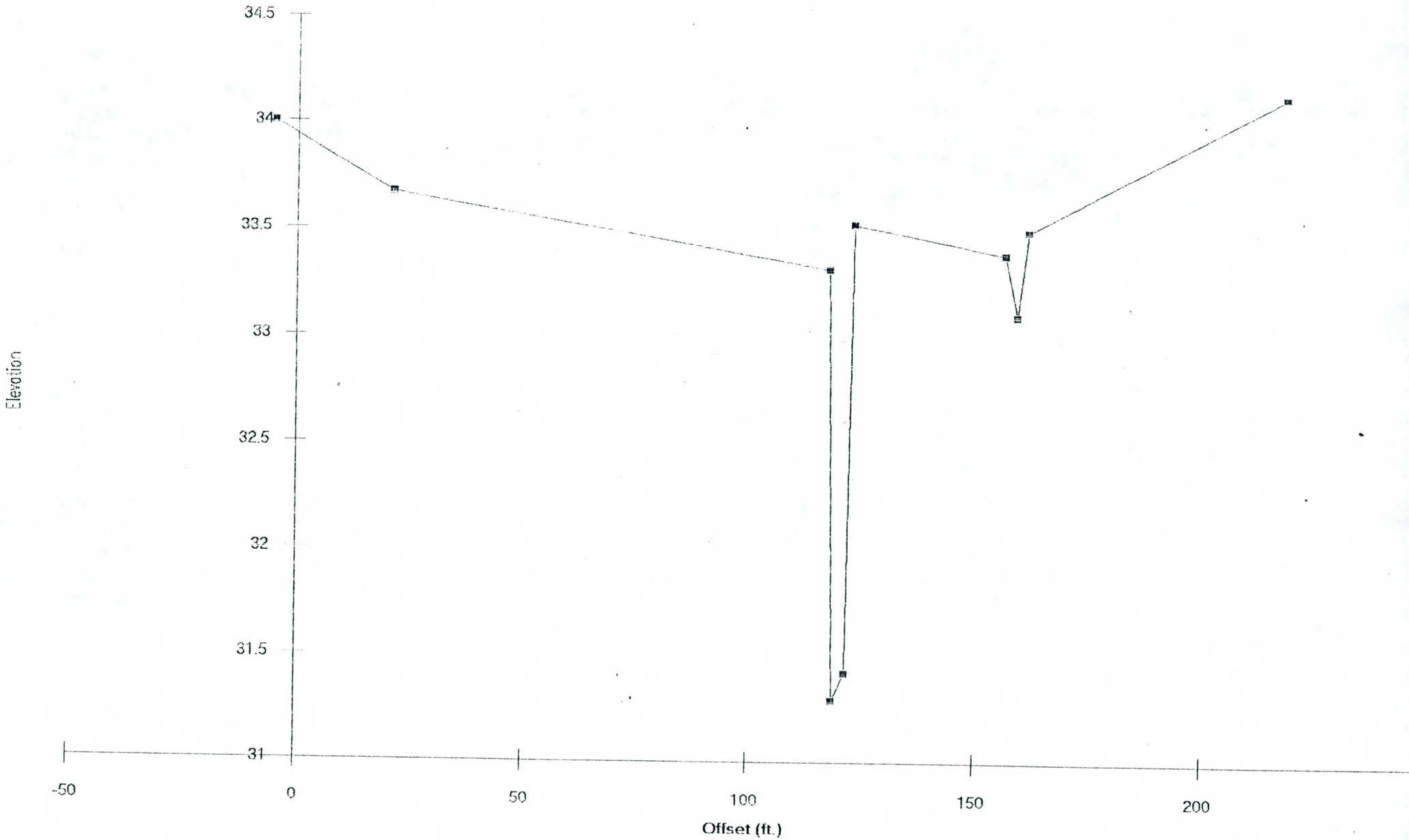
OFFSET	-5	21.4	117.8	118.9	121.6	123.1	156.3	159.1	161.4	218		
ELEV.	34	33.67	33.32	31.29	31.42	33.53	33.39	33.1	33.5	34.14		
N	N/A	0.035	0.035	0.04	0.025	0.04	0.035	0.035	0.035	0.035		

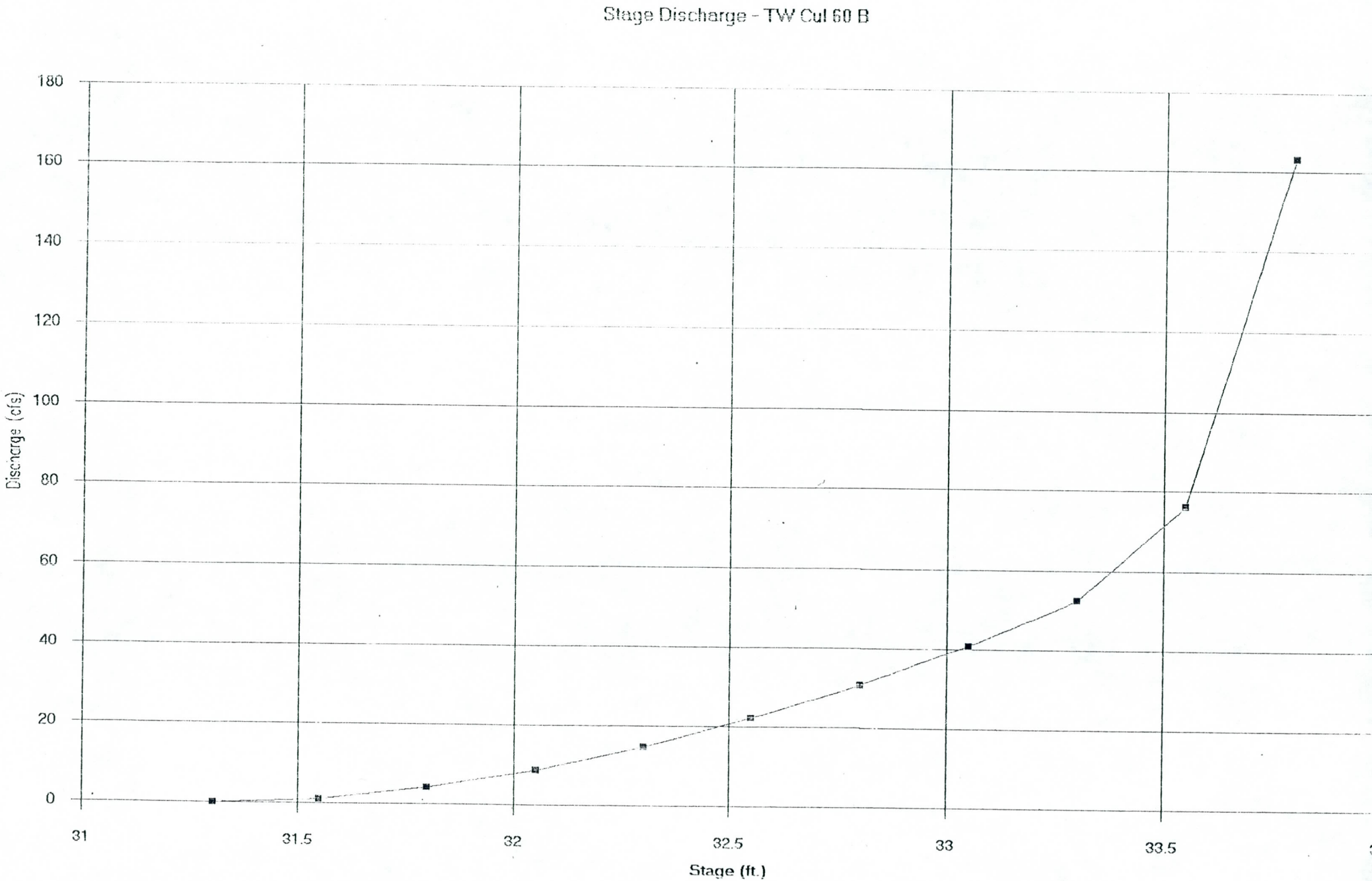
STAGE-DISCHARGE DATA:

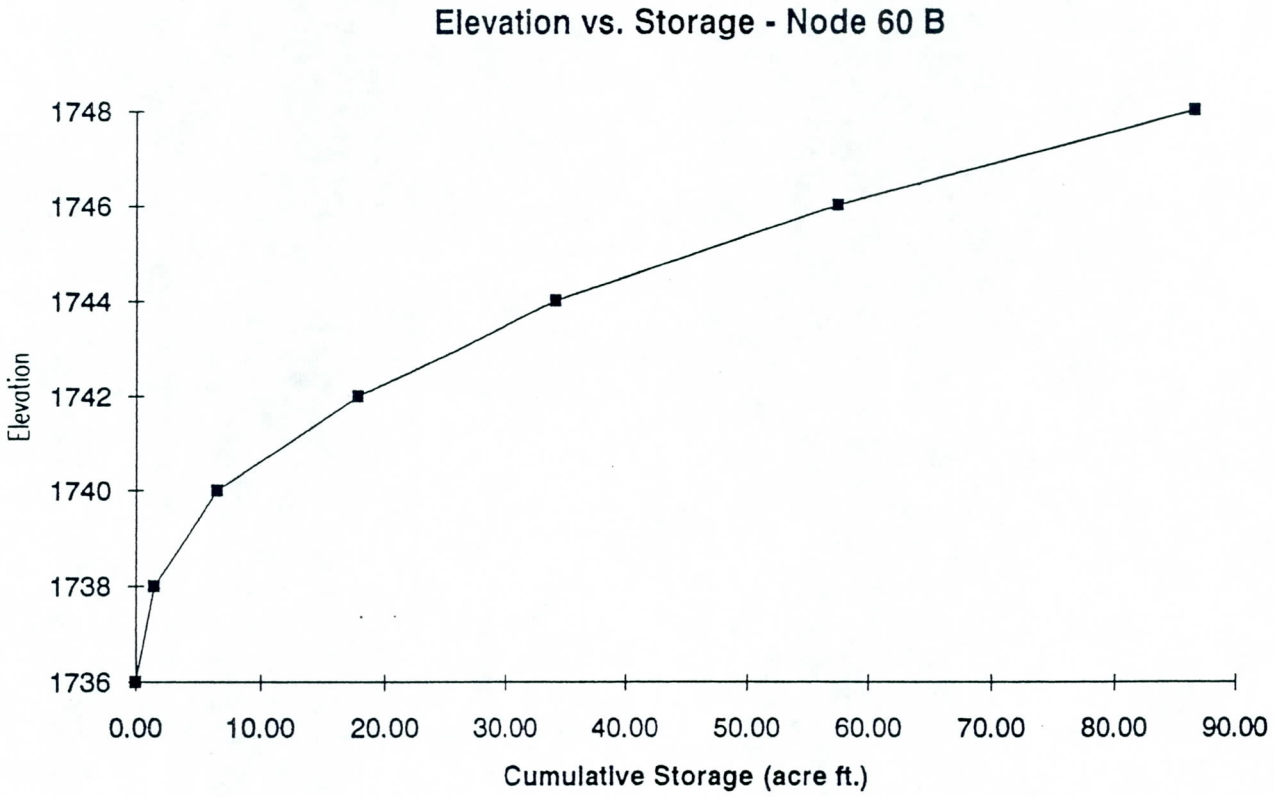
STAGE:	31.3											
WET PER.		0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	31.55												
WET PER.		0.0	0.0	0.3	2.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	1	0	0	0	0	0	0	0	0
STAGE:	31.8												
WET PER.		0.0	0.0	0.6	2.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.1	1.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	4	0	0	0	0	0	0	0	0
STAGE:	32.05												
WET PER.		0.0	0.0	0.9	2.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.2	1.9	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.2	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	8	0	0	0	0	0	0	0	0
STAGE:	32.3												
WET PER.		0.0	0.0	1.2	2.7	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.3	2.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.2	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	14	0	0	0	0	0	0	0	0
STAGE:	32.55												
WET PER.		0.0	0.0	1.4	2.7	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.4	3.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.3	1.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	1	21	1	0	0	0	0	0	0	0

STAGE:	32.8											
WET PER.		0.0	0.0	1.7	2.7	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.6	3.9	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.4	1.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	1	29	1	0	0	0	0	0	0	0
STAGE:	33.05												
WET PER.		0.0	0.0	2.0	2.7	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.8	4.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.4	1.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	2	37	2	0	0	0	0	0	0	0
STAGE:	33.3												
WET PER.		0.0	0.0	2.3	2.7	2.3	0.0	1.9	3.1	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.1	5.3	1.3	0.0	0.2	0.3	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.5	1.9	0.5	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Q		0	0	2	47	3	0	0	0	0	0	0	0
STAGE:	33.55												
WET PER.		0.0	63.4	2.3	2.7	2.6	33.2	36.0	38.3	42.8	0.0	0.0	0.0
AREA		0.0	7.3	1.4	5.9	1.6	3.0	3.8	4.4	4.5	0.0	0.0	0.0
HYD.RAD.		0.0	0.1	0.6	2.2	0.6	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Q		0	7	3	57	4	0	0	0	4	0	0	0
STAGE:	33.8												
WET PER.		10.4	106.8	2.3	2.7	2.6	33.2	36.0	38.3	64.9	0.0	0.0	0.0
AREA		0.7	30.1	1.6	6.6	2.0	11.3	12.8	14.0	18.0	0.0	0.0	0.0
HYD.RAD.		0.1	0.3	0.7	2.4	0.8	0.3	0.4	0.4	0.3	0.0	0.0	0.0
Q		0	53	5	69	6	0	0	0	31	0	0	0

W.S. Elev.	31.3	31.55	31.8	32.05	32.3	32.55	32.8	33.05	33.3	33.55	33.8
Q	0	1	4	9	15	22	31	41	52	76	163
A	0.0	0.6	1.3	2.2	3.1	4.1	5.2	6.4	7.9	20.7	58.3
V	0.2	1.9	3.1	4.0	4.8	5.4	6.0	6.4	6.6	3.7	2.8


Cross Section - TW Cul 60 B
34.5
34
33.5
33
32.5
32
31.5
31
Elevation
-50
0
50
100
150
200
Offset (ft.)


Stage Discharge - TW Cul 60 B
180
160
140
120
100
80
60
40
20
0
Discharge (cfs)
31
31.5
32
32.5
33
33.5
Stage (ft.)


Elevation vs. Storage - Node 60 B
1748
1746
1744
1742
1740
1738
1736
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
Cumulative Storage (acre ft.)

SVERDR

JOB 4047.1 Toyota

COMPUTATIONS FOR Culvert 60A [12]

SHEET NO. ____ OF ____

DATE 7/12/91

BY BDO CHKD RJT 7-22-91

CULVERT COMPUTATION SHEET

PROJECT: ____

STATION: 223+00, Oval Track

DESIGNER: ____

DATE: ____

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 9.33 sq. miles

Q_1 = 2517 cfs

Q_2 = ____

TW_1 = 4.47' New Channel

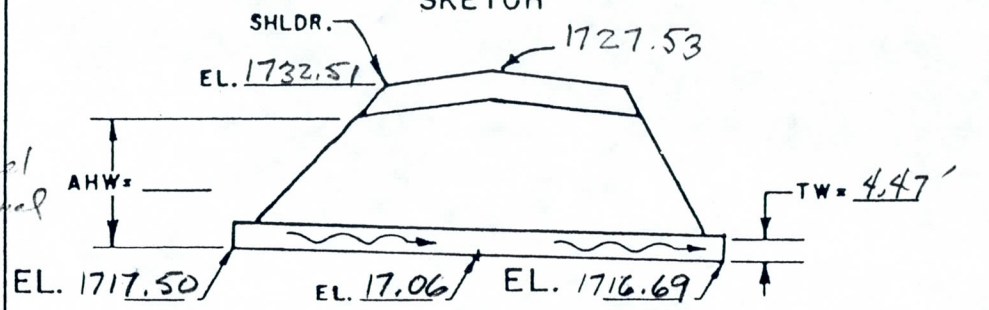
TW_2 = 3.4' Exist. Channel

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY Q_{25})

(Q_2 = CHECK DISCHARGE, SAY Q_{50}) Q100

SKETCH



S_o = 0.0050 ft/ft L = 162' L/100 S_o = ____

MEAN STREAM VELOCITY = 5.3 fps

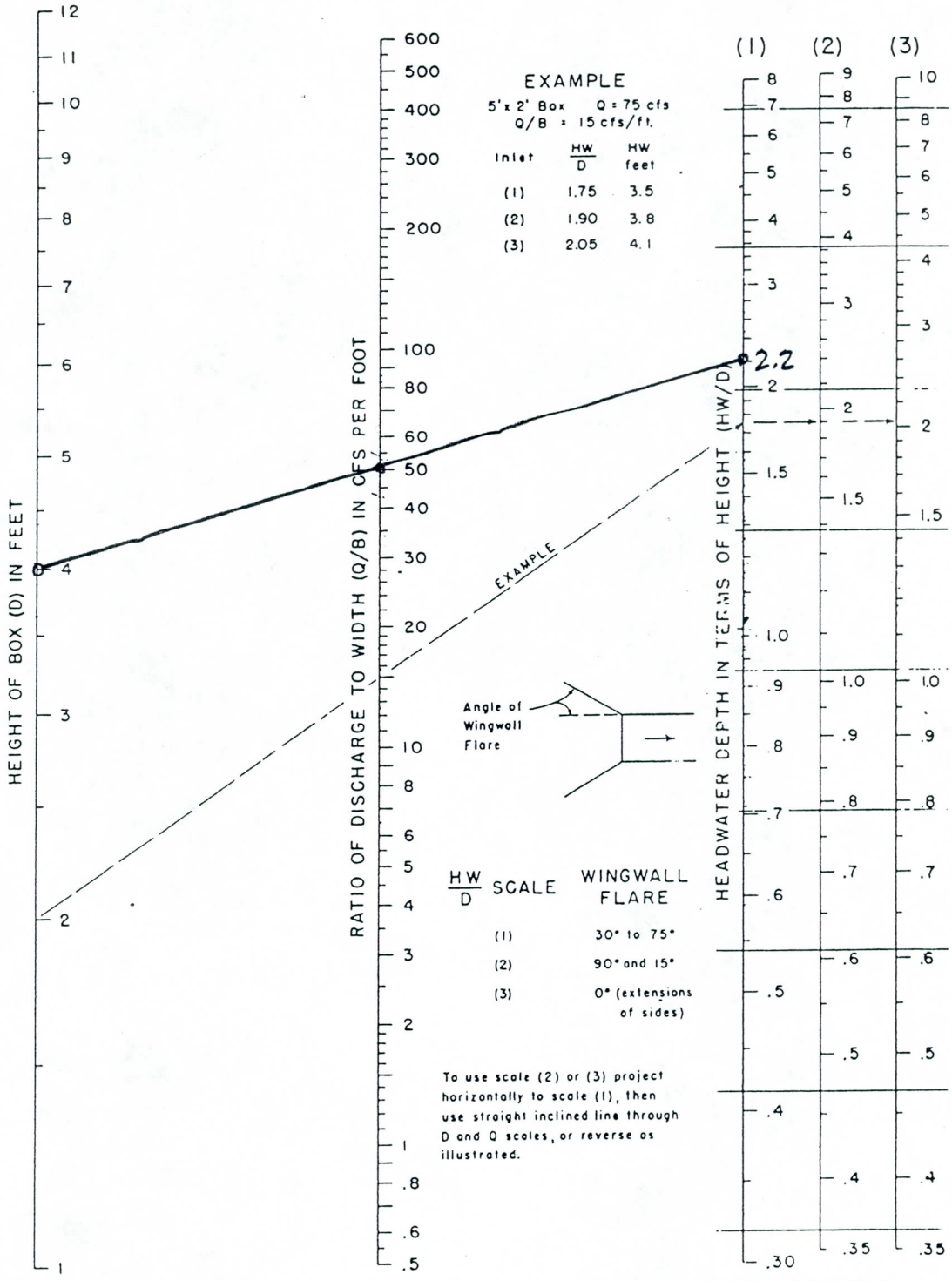
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(5) Barrel 10'x4'	Drop Inlet	2517/5 = 503		2.2	8.8	0.2	3.9	4.0	4.0	4.47	4.47	0.81	7.56	8.8	14.2		1726.30	Inlet Control

SUMMARY & RECOMMENDATIONS Use Soil cement lined channel downstream of culvert.

B-1

Culvert 60A

CHART 1

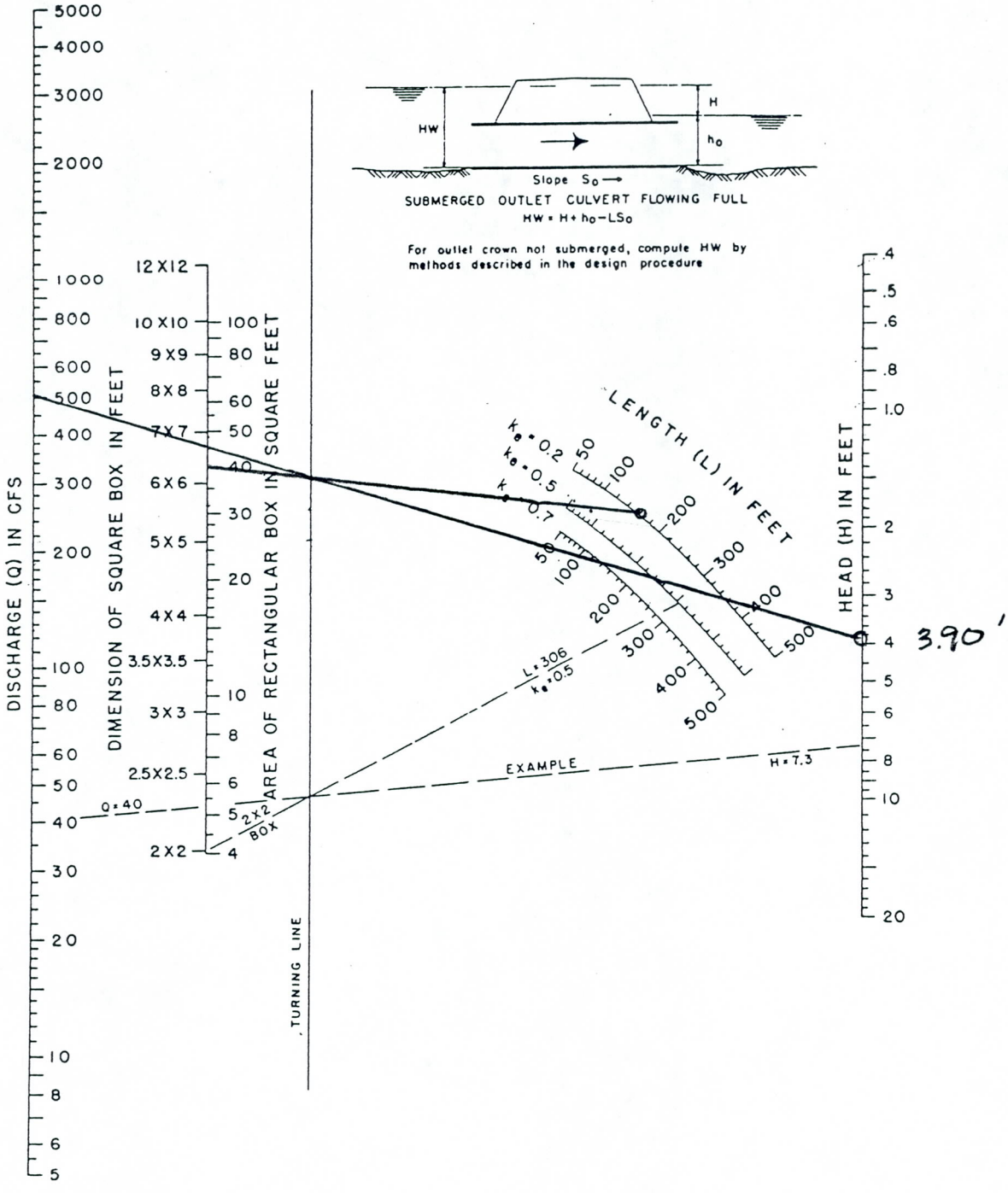


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 A

CHART 8

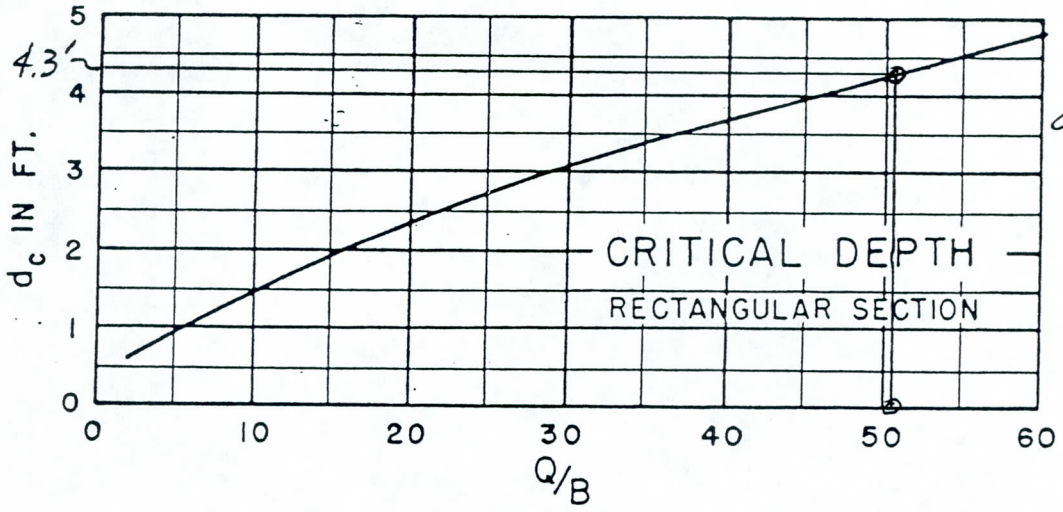


HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

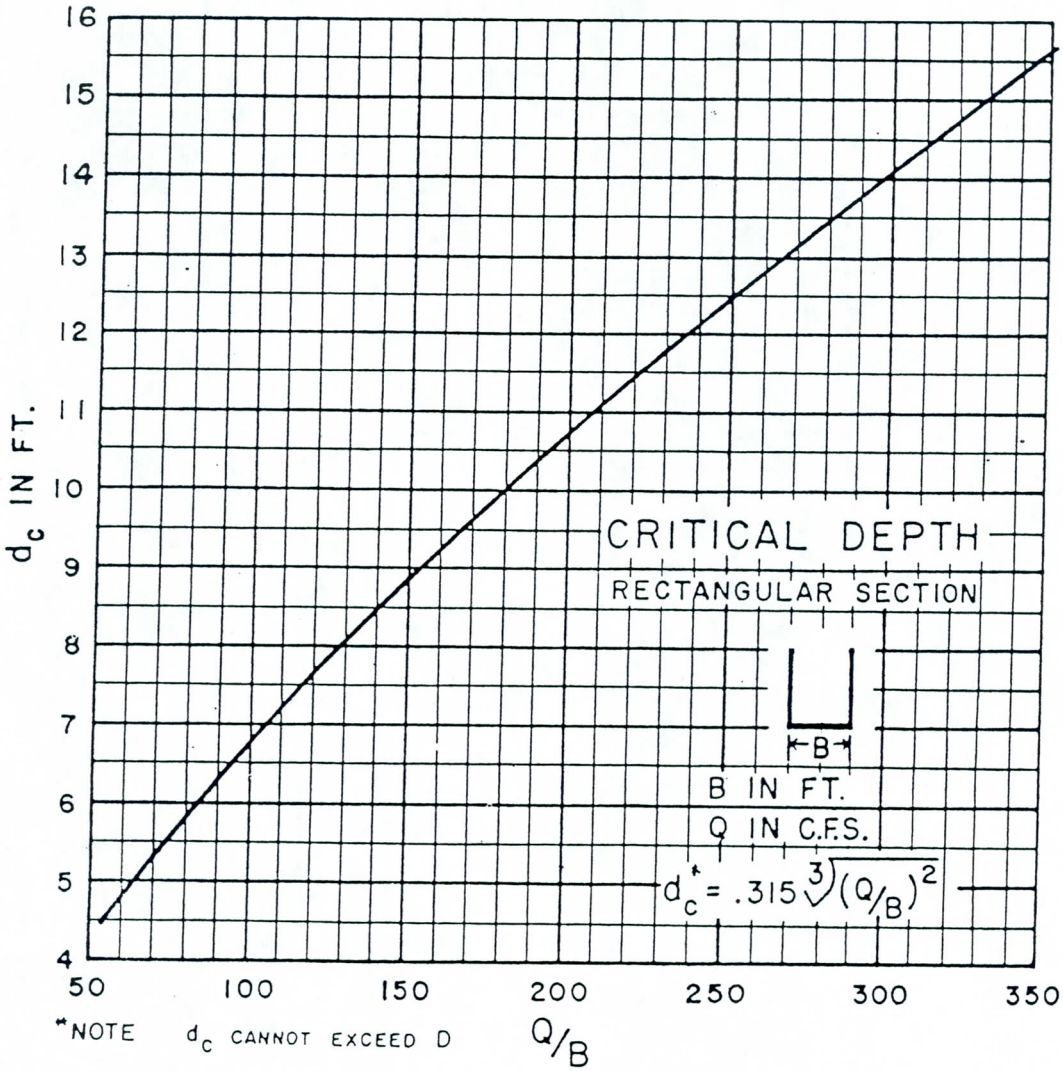
BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60A

CHART 15



$d_c = 4.3' > 4'$
$\therefore$ use 4'



*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota SHEET NO. 5 OF

DATE 7/12/91

COMPUTATIONS FOR Channel Section Downstream of Box Culvert 60 A BY BDO CHKD RJT 7-22-91

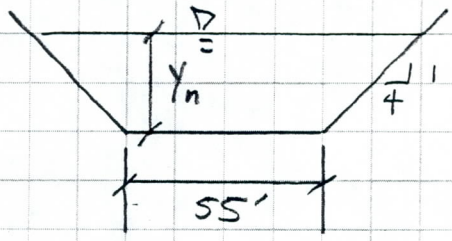
Check depth of Flow using Mannings Equation

$Q100 = 2517$ cfs

$n = 0.02$

$S_o = 0.0020$ ft/ft

$Y_n \sim 4.47'$



$A = 325.6$ SF

$WP = 2(18.43) + 55 = 91.86'$

$R_h = A/WP = 325.6/91.86 = 3.5445$

$$V = \frac{1.49}{0.02}(3.5445)^{.666}(.0020)^{.5} = 7.74 \text{ fps}$$

Check

$Q = VA = 7.74\,(325.6) = 2{,}520$ cfs OK

Check Froude Number

$$FF = \frac{7.74}{\sqrt{32.2 \times 4.47}} = 0.65, \text{ Subcritical}$$

Energy Grade Line $= 4.47' + \frac{(7.74)^2}{2 \times 32.2} = 5.40'$, Use $6.0'$

Check cutoff wall depth at end of channel

$$h_s = 0.76\,(4.47)\left(\frac{(7.74)(2)(4.47)^2}{(4.47)^{2.5}}\right)^{.375} 35^{0.1}$$

$= 10.23'$, Use $10'$

SVERDRUP

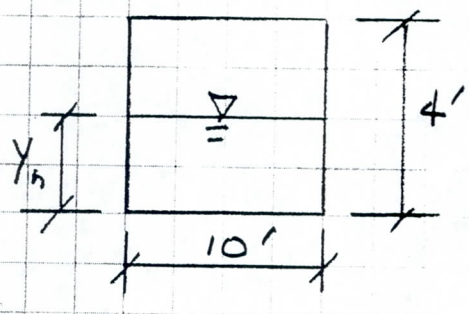
JOB 40477 Toyota SHEET NO. 6 OF

COMPUTATIONS FOR Culvert 60A DATE 7/16/91

BY BDO CHKD RJT 7-22-91

Check depth of Flow using Manning Eqn.

$Q100 = 2517$ cfs, $Q = 503$ cfs/barrel



$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 3.53'$

$A = 35.3\ ft^2$

$WP = 2(3.53) + 10 = 17.06$ ft

$R_h = A/WP = 35.3/17.06' = 2.0692'$

$$V = \frac{1.49}{.012}(2.0692)^{.666}(.005)^{.5} = 14.25 \text{ fps}$$

Check

$Q = VA = 14.25\,(35.3) = 503$ cfs

Check Froude Number

$$\mathcal{F} = \frac{V}{\sqrt{g \times Y_n}} = \frac{14.25}{\sqrt{32.2 \times 3.53}} = 1.34$$, Supercritical

$Q10 = 587/5 = 117$ cfs

$Y_n = 1.31'$, Velocity $= 8.97$ fps, $\mathcal{F} = 1.38$

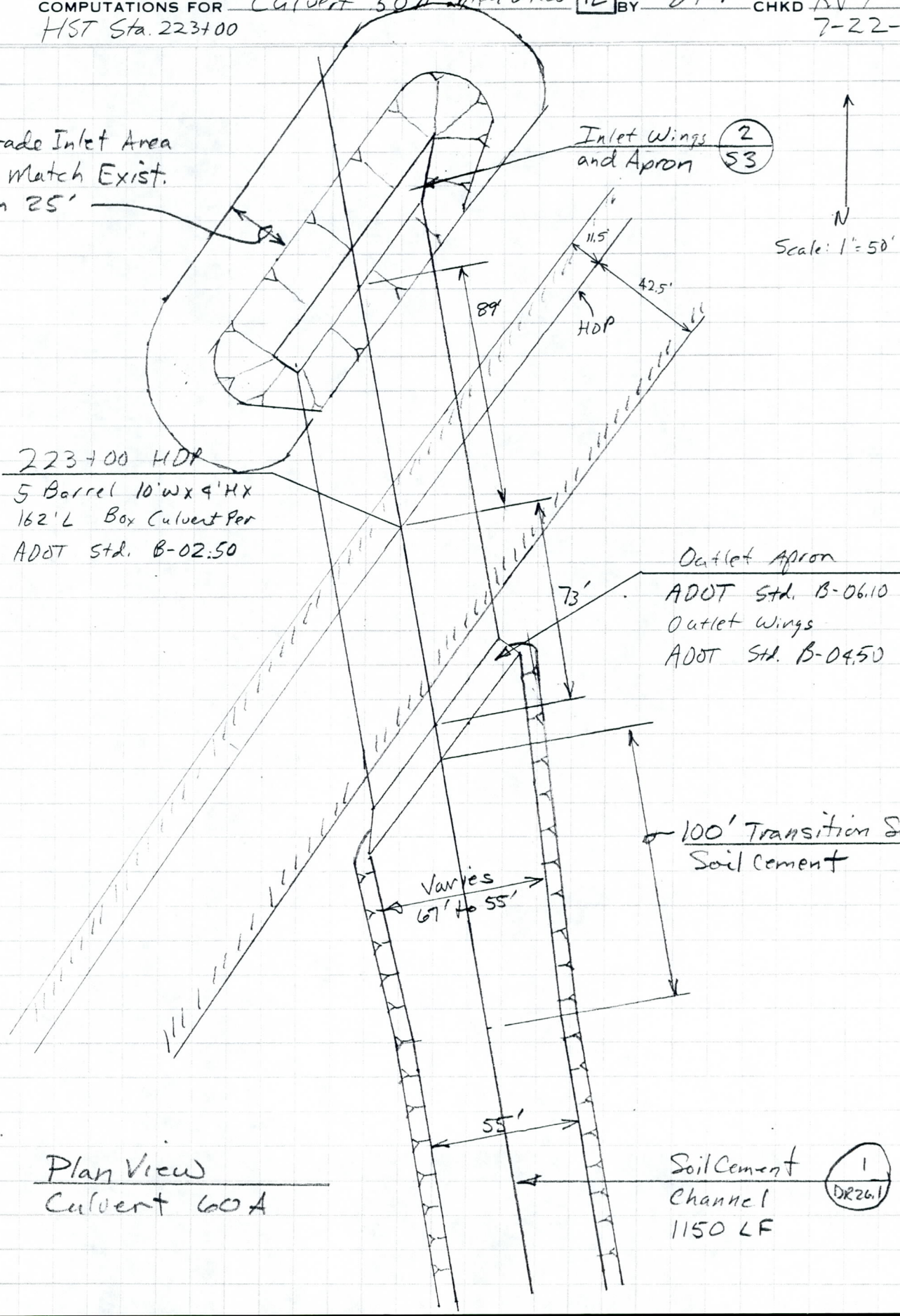
SVERDRUP

JOB 40477 Togota SHEET NO. 7 OF

DATE 7-16-91

COMPUTATIONS FOR Culvert 60A Plan View 12 BY DFP CHKD RVT 7-22-91

HST Sta. 223+00



Plan View
Culvert 60A

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert Profile 60 A. 12

DATE 7-13-94 BY DEP CHKD RJT

SHEET NO. 8 OF

Culvert 60A 12

Skew = 45° RT.

Q_{100} = 2517 cfs

41.55' 40.10' 8.49'

14.26' 43.13'

1732.51

1727.53

1722.50

Exist Wash Profile

Top of Proposed Channel

Q100 W.S. = Elev. 1726.30

(5) 10'x4' RCBC

1717.50

S=0.005'/'

1717.055

1716.69

89' 73'

℄ HOP Sta 223+00 Oval Track

S=0.0020'/'

12"

Soil Cement

1250'± Soil Cement Channel

Exist Wash Profile

10'

7'

1728

1724

1720

1716

1712

Scale:
Horiz: 1" = 40'
Vert: 1" = 4'

SECTION NUMBER TW60A 7/10/[illegible]

Channel Slope: 0.0129 ft./ft.

CROSS SECTION DATA:

OFFSET	-100	48	86.8	90	92.7	163.5	166.6	170.7	173.7	201.2	206.3	210.2	269.3	340
ELEV.	27.5	25.86	26.02	25.15	26.11	26.34	24.09	24.16	25.54	26.2	24.94	25.89	26.33	27.5
N	N/A	0.035	0.035	0.035	0.035	0.035	0.04	0.025	0.04	0.035	0.035	0.035	0.035	0.035

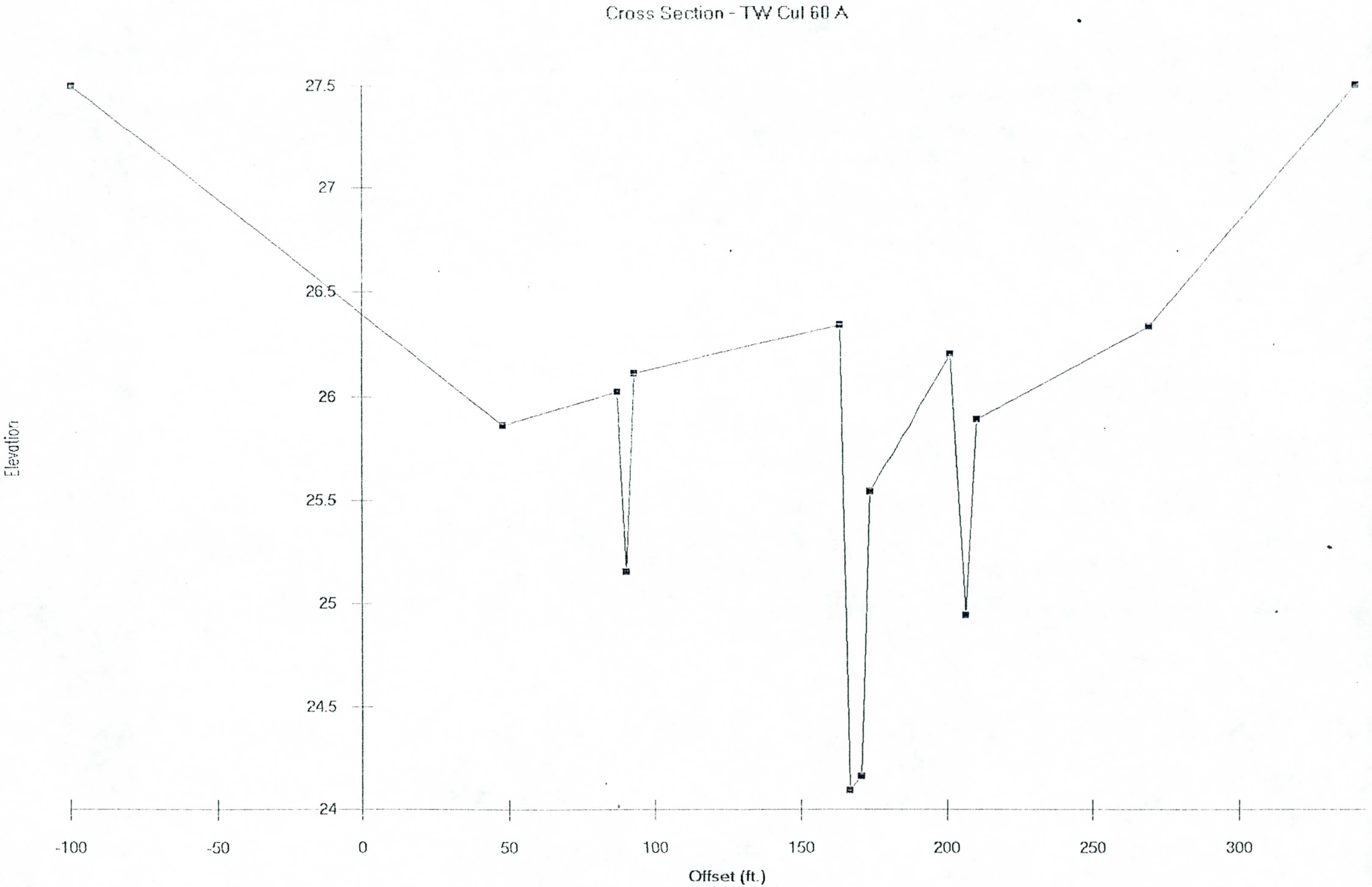
STAGE-DISCHARGE DATA:

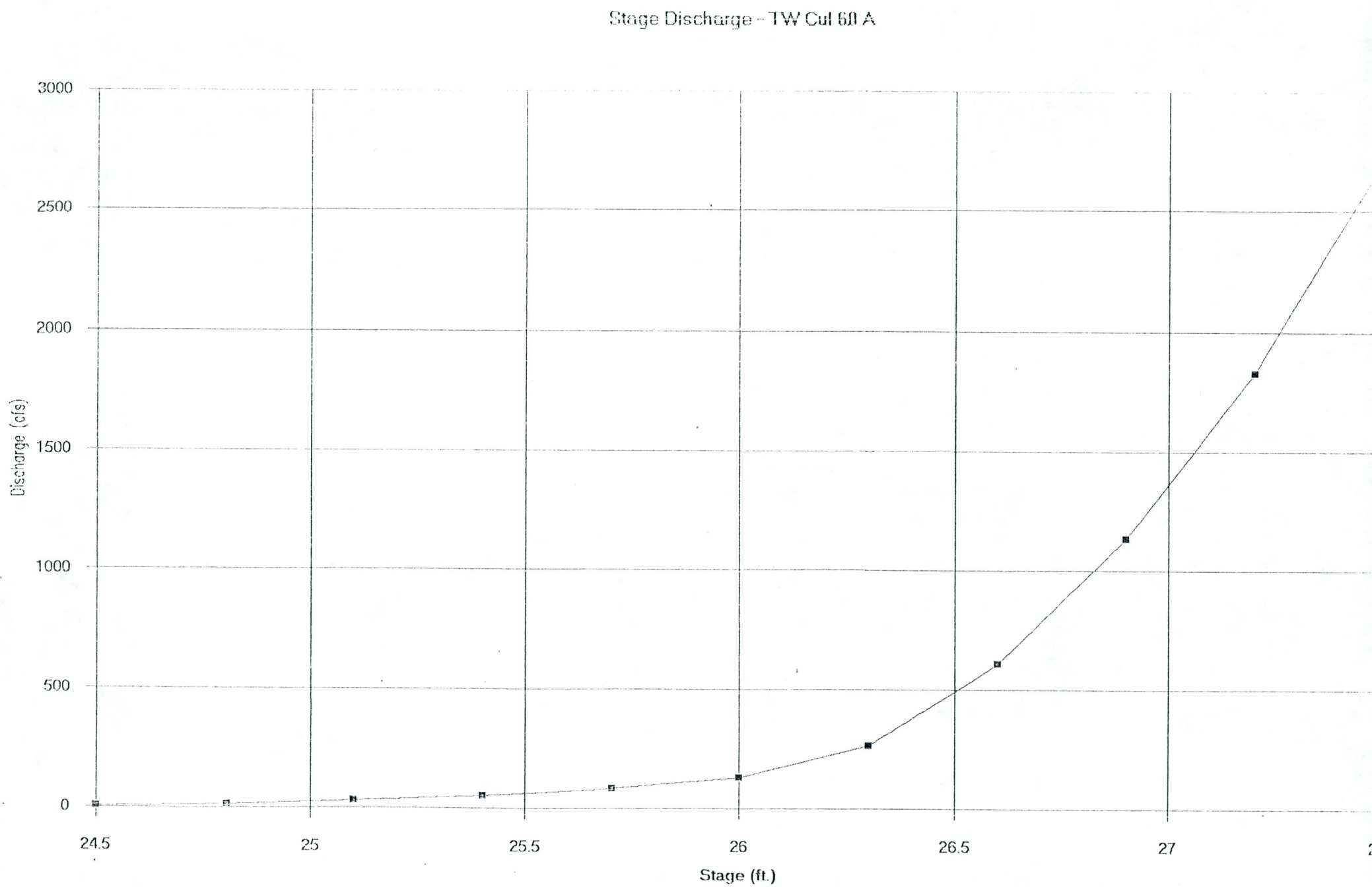
STAGE:	24.5													
WET PER.		0.0	0.0	0.0	0.0	0.0	0.7	4.1	0.8	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.1	1.5	0.1	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.2	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	5	0	0	0	0	0	0
STAGE:	24.8													
WET PER.		0.0	0.0	0.0	0.0	0.0	1.2	4.1	1.5	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.3	2.8	0.4	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.3	0.7	0.3	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	1	14	1	0	0	0	0	0
STAGE:	25.1													
WET PER.		0.0	0.0	0.0	0.0	0.0	1.7	4.1	2.3	0.0	0.7	1.4	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.7	4.0	1.0	0.0	0.1	0.1	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.4	1.0	0.4	0.0	0.1	0.1	0.0	0.0
Q		0	0	0	0	0	2	27	2	0	0	0	0	0
STAGE:	25.4													
WET PER.		0.0	0.0	1.0	1.7	0.0	2.2	4.1	3.0	0.0	1.9	3.9	0.0	0.0
AREA		0.0	0.0	0.1	0.2	0.0	1.2	5.2	1.7	0.0	0.4	0.9	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.1	0.0	0.5	1.3	0.6	0.0	0.2	0.2	0.0	0.0
Q		0	0	0	0	0	3	41	5	0	0	2	0	0
STAGE:	25.7													
WET PER.		0.0	0.0	2.1	3.7	0.0	2.7	4.1	3.3	6.7	3.2	6.4	0.0	0.0
AREA		0.0	0.0	0.6	1.0	0.0	1.8	6.5	2.6	0.5	1.2	2.4	0.0	0.0
HYD.RAD.		0.0	0.0	0.3	0.3	0.0	0.7	1.6	0.8	0.1	0.4	0.4	0.0	0.0
Q		0	0	0	2	0	6	59	9	0	0	6	0	0
STAGE:	26													
WET PER.		12.6	46.6	3.2	5.8	0.0	3.3	4.1	3.3	19.2	4.4	8.4	23.2	0.0
AREA		0.9	3.3	1.3	2.3	0.0	2.5	7.7	3.5	4.4	2.3	4.6	5.4	0.0
HYD.RAD.		0.1	0.1	0.4	0.4	0.0	0.8	1.9	1.0	0.2	0.5	0.5	0.2	0.0
Q		0	3	0	6	0	9	79	15	8	0	0	10	0

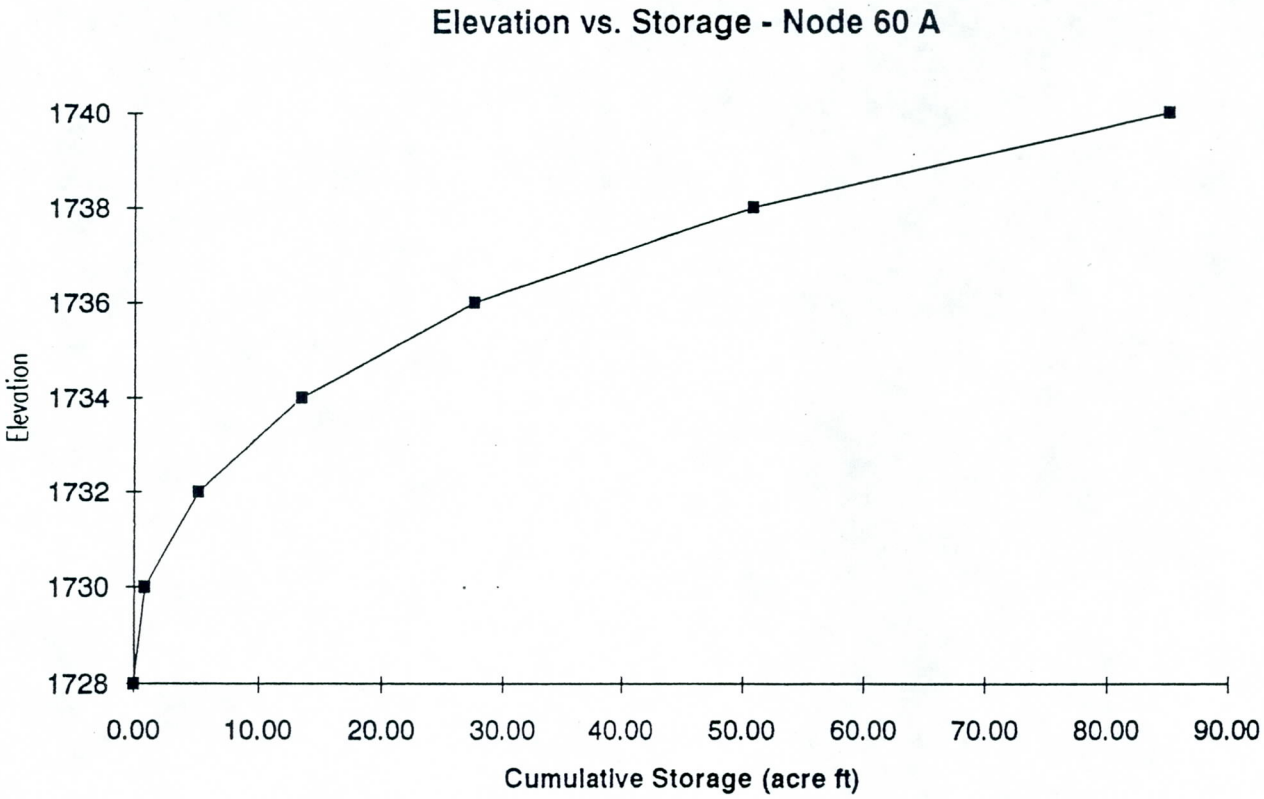
SECTION NUMBER TW60A 7/10/[illegible]

STAGE:	26.3												
WET PER.		39.7	78.5	81.8	84.7	143.2	3.8	4.1	3.3	27.5	32.8	36.8	91.8	0.0
AREA		8.7	22.7	25.0	26.8	32.4	3.4	8.9	4.4	11.8	15.5	19.0	30.3	0.0
HYD.RAD.		0.2	0.3	0.3	0.3	0.2	0.9	2.2	1.3	0.4	0.5	0.5	0.3	0.0
Q		0	0	0	0	58	13	101	22	0	0	0	70	0
STAGE:	26.6													
WET PER.		66.8	105.6	108.9	111.8	182.6	3.8	4.1	3.3	27.5	32.8	36.8	95.9	112.2
AREA		24.7	50.3	53.6	56.2	82.7	4.3	10.1	5.3	20.1	25.3	29.9	58.9	61.1
HYD.RAD.		0.4	0.5	0.5	0.5	0.5	1.1	2.5	1.6	0.7	0.8	0.8	0.6	0.5
Q		0	0	0	0	235	20	125	30	0	0	0	0	197
STAGE:	26.9													
WET PER.		93.9	132.7	136.0	138.8	209.6	3.8	4.1	3.3	27.5	32.8	36.8	95.9	130.3
AREA		48.8	86.1	90.3	93.7	141.5	5.2	11.4	6.2	28.3	35.1	40.9	87.6	97.4
HYD.RAD.		0.5	0.6	0.7	0.7	0.7	1.4	2.8	1.9	1.0	1.1	1.1	0.9	0.7
Q		0	0	0	0	525	27	152	39	0	0	0	0	387
STAGE:	27.2													
WET PER.		120.9	159.7	163.0	165.9	236.7	3.8	4.1	3.3	27.5	32.8	36.8	95.9	148.5
AREA		81.0	129.9	135.1	139.3	208.3	6.2	12.6	7.1	36.6	44.9	51.8	116.3	139.1
HYD.RAD.		0.7	0.8	0.8	0.8	0.9	1.6	3.1	2.1	1.3	1.4	1.4	1.2	0.9
Q		0	0	0	0	923	36	180	49	0	0	0	0	643
STAGE:	27.5													
WET PER.		148.0	186.8	190.1	193.0	263.8	3.8	4.1	3.3	27.5	32.8	36.8	95.9	166.6
AREA		121.4	181.9	188.0	193.1	283.3	7.1	13.8	8.0	44.8	54.7	62.8	144.9	186.3
HYD.RAD.		0.8	1.0	1.0	1.0	1.1	1.8	3.4	2.4	1.6	1.7	1.7	1.5	1.1
Q		0	0	0	0	1433	45	210	60	0	0	0	0	968

W.S. Elev.	24.5	24.8	25.1	25.4	25.7	26	26.3	26.6	26.9	27.2	27.5
Q	6	16	31	51	82	129	264	607	1130	1830	2716
A	1.8	3.6	5.8	9.1	14.7	29.0	79.3	163.5	261.6	373.3	498.5
V	3.2	4.4	5.3	5.6	5.6	4.5	3.3	3.7	4.3	4.9	5.4


Cross Section - TW Cul 60 A
27.5
27
26.5
26
25.5
25
24.5
24
Elevation
-100
-50
0
50
100
150
200
250
300
Offset (ft.)


Stage Discharge - TW Cul 60 A
3000
2500
2000
1500
1000
500
0
Discharge (cfs)
24.5
25
25.5
26
26.5
27
Stage (ft.)


Elevation vs. Storage - Node 60 A
1740
1738
1736
1734
1732
1730
1728
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
Cumulative Storage (acre ft)

SVERDR

JOB 4047 Toyota

COMPUTATIONS FOR Culvert 60F [13]

SHEET NO. ___ OF ___

DATE 7/17/91

BY BDO CHKD RJT 7-22-91

CULVERT COMPUTATION SHEET

PROJECT: ___

STATION: 194+20

DESIGNER: ___

DATE: ___

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 0.14 Sq miles

Q_1 = 292 cfs

Q_2 = ___

TW_1 = 1.4' Exist. Channel

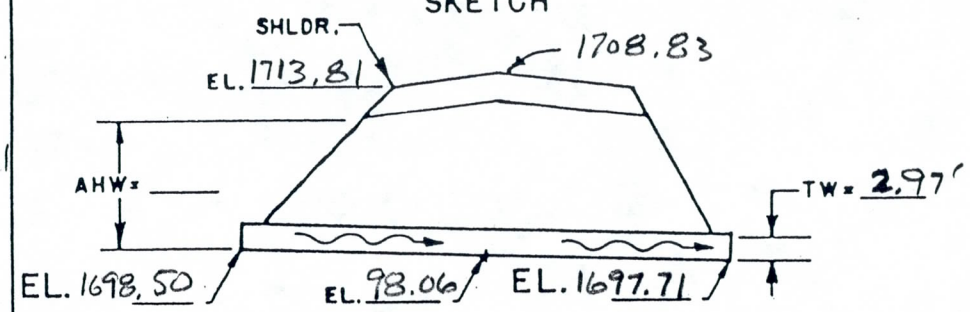
TW_2 = 2.97' New Channel

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY Q_{25}) Q100

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050 ft/ft L = 160' L/100 S_o = ___

MEAN STREAM VELOCITY = 2.4 fps

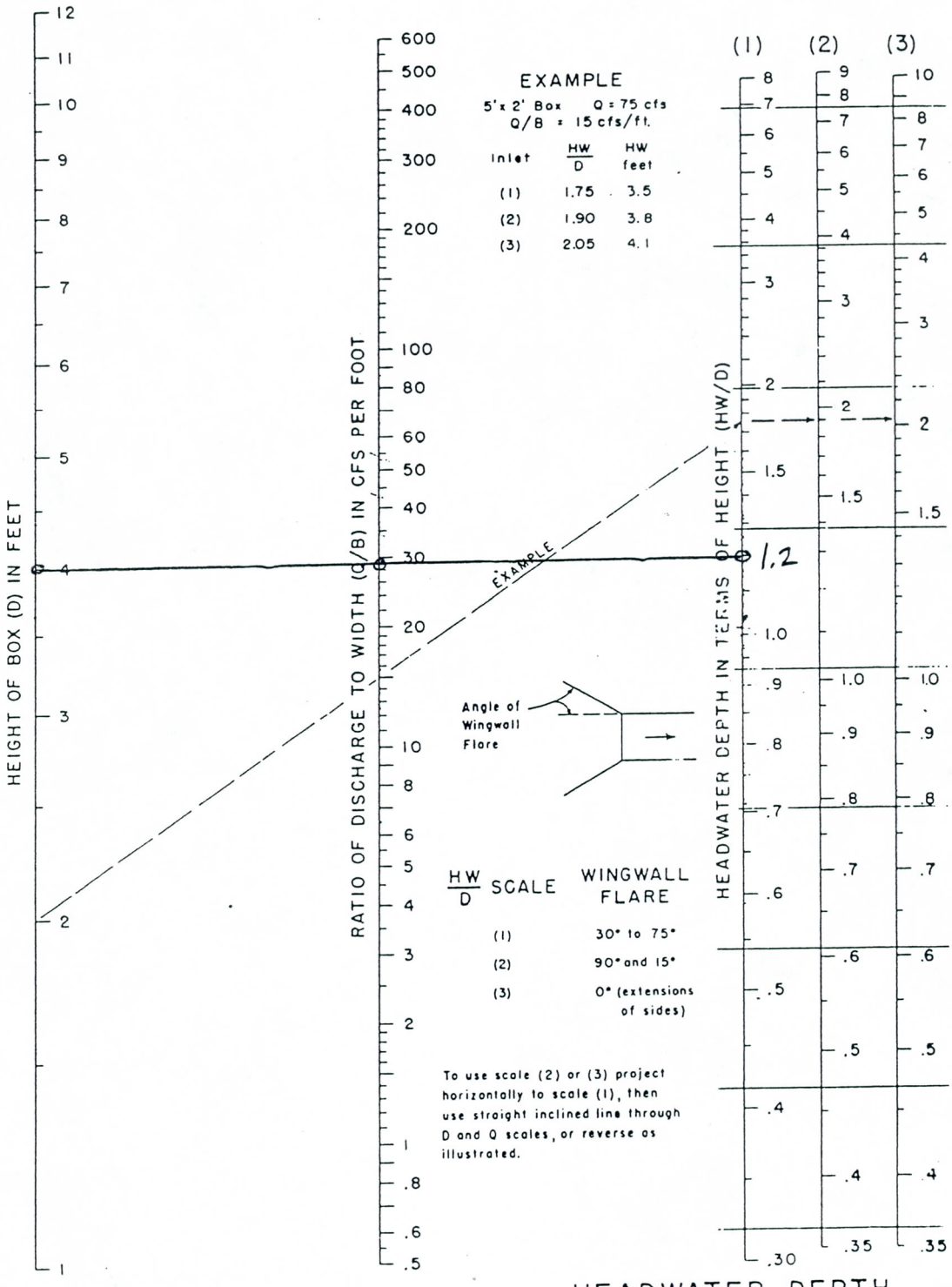
CULVERT DESCRIPTION SIZE	CULVERT DESCRIPTION ENTR. TYPE	Q	CAP. CHART HW	HEADWATER COMPUTATION: INLET CONT. HW/D	INLET CONT. HW	OUTLET CONTROL K_e	OUTLET CONTROL H	OUTLET CONTROL d_c	OUTLET CONTROL $\frac{d_c + D}{2}$	OUTLET CONTROL TW	OUTLET CONTROL h_o	OUTLET CONTROL LS_o	OUTLET CONTROL HW	CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
(1) Barrel 10'x4'	Drop Inlet	292		1.2	4.80	0.20	1.35	3.0	3.50	2.97	3.50	0.80	4.05	4.80	12.1		1703.30	Inlet Control

SUMMARY & RECOMMENDATIONS Use soil cement channel downstream of culvert to daylight channel.

B-1

Culvert 60 F

CHART 1

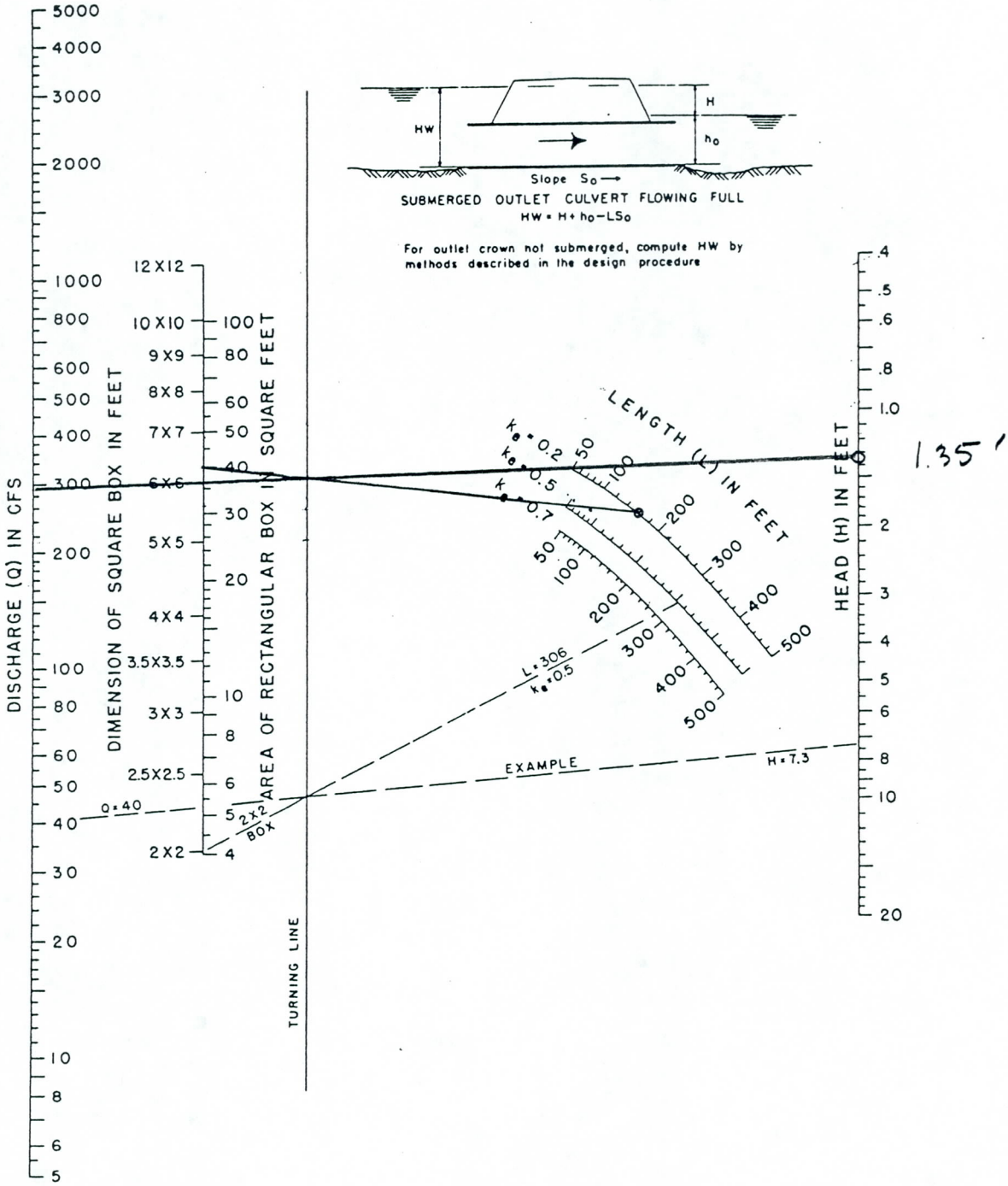


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 F

CHART 8



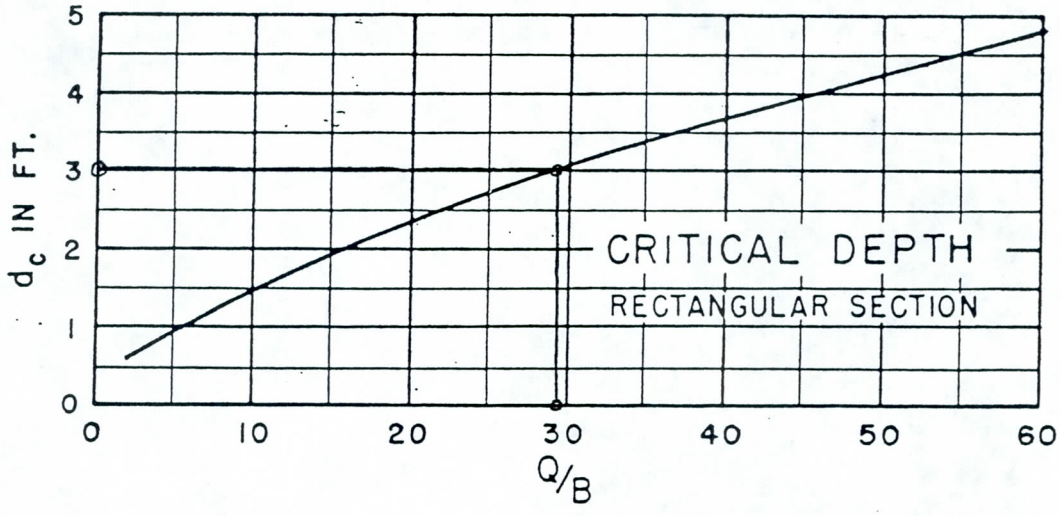
1.35'

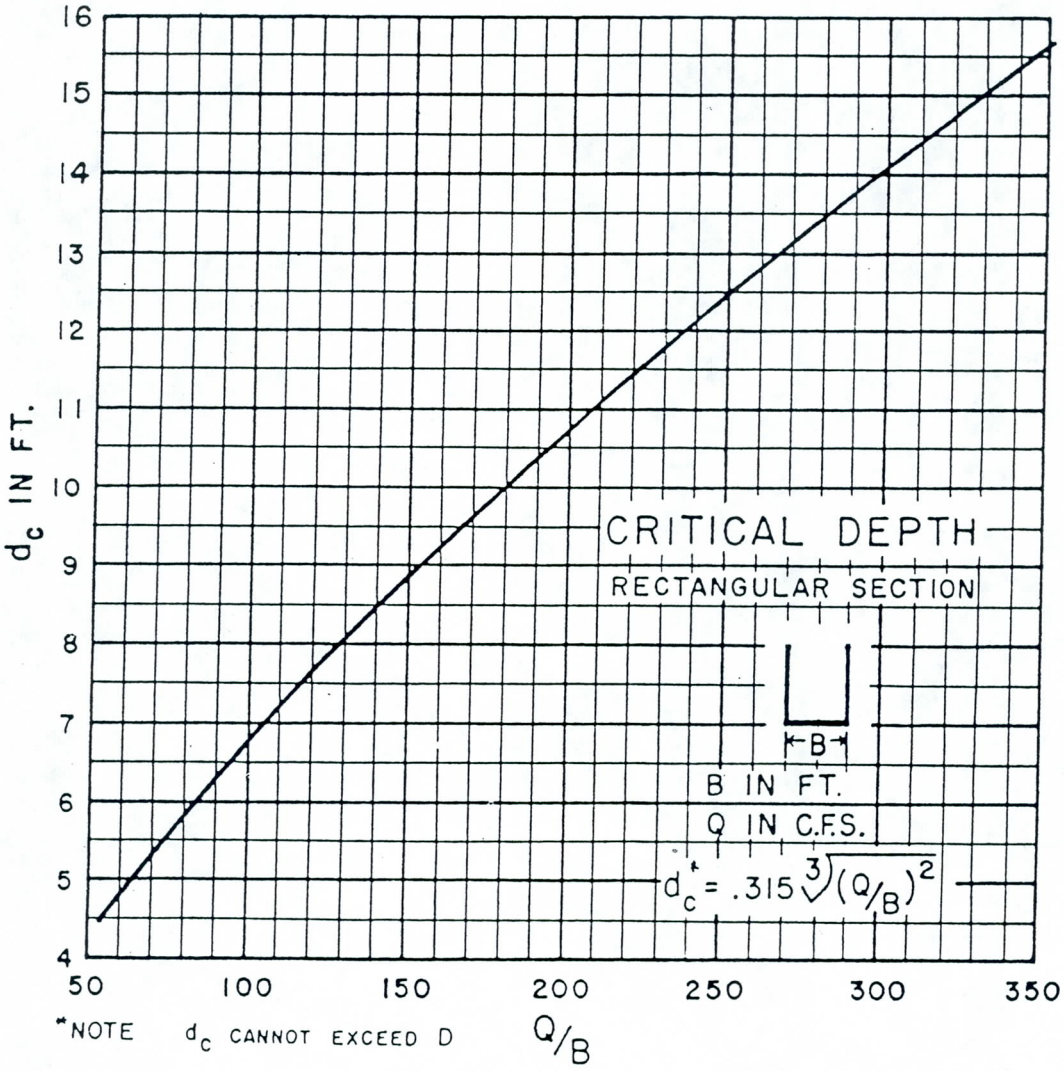
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 F

CHART 15





BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60F

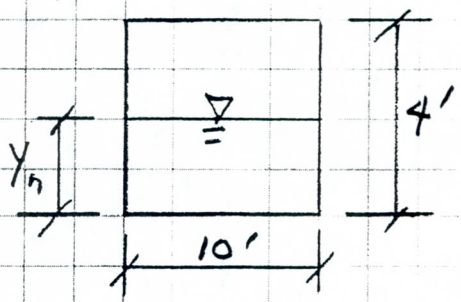
SHEET NO. 5 OF

DATE 7/16/91

BY BDO CHKD RJT 7-22-91

Check depth of Flow using Manning Eqn.

$Q100 = 292$ cfs



$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 2.41'$

$A = 24.1$ ft^2

$WP = 2(2.41) + 10 = 14.82'$

$R_h = A/WP = 24.10/14.82' = 1.6262'$

$$V = \frac{1.49}{.012}(1.6262)^{.666}(.005)^{.5} = 12.14 \text{ fps}$$

Check

$Q = VA = 12.14\ (24.10) = 293$ cfs (OK)

Check Froude Number

$$\mathcal{F} = \frac{V}{\sqrt{g \times Y_n}} = \frac{12.14}{\sqrt{32.2 \times 2.41}} = 1.38$$, Supercritical

$Q10 = 121$ cfs

$Y_n = 1.33'$, Velocity = 9.07 fps, $\mathcal{F} = 1.39$

SVERDRUP

JOB 40477 Toyota

SHEET NO. 6 OF

DATE 7/17/91

COMPUTATIONS FOR Channel Downstream of Culvert 60 F

BY BDO CHKD RJT 7-22-91

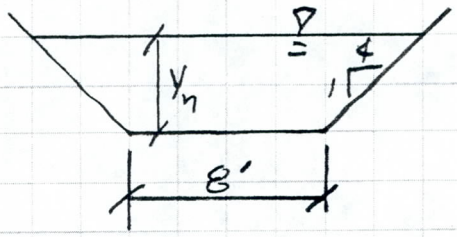
Check depth of flow and velocity

$Q_{100} = 292$ cfs

$n = 0.02$

$S = 0.0020$ ft/ft

$Y_n \sim 2.97'$



$A = 59.0$ ft^2

$WP = 2(12.25) + 8 = 32.5$ ft.

$R_h = A/WP = 59.0/32.5 = 1.8154$ ft

$$V = \frac{1.49}{0.02}(1.8154)^{.666}(.002)^{.5} = 4.96 \text{ fps}$$

Check

$Q = VA = (4.96)(59.0) = 293$ cfs ∴ OK

Check Froude Number

$$FF = \frac{4.96}{\sqrt{32.2 \times 2.97}} = 0.51, \text{ Subcritical}$$

Energy Grade Line $= 2.97 + \frac{4.96^2}{64.4} = 3.35'$ Use 4.0'

Check Cutoff Wall Depth at end of Channel

$$h_s = 0.76(2.97)\left(\frac{4.96(2)(2.97)^2}{(2.97)^{2.5}}\right)^{.375} 20^{0.1} = 5.87'$$

Use 6.0'

SVERDRUP

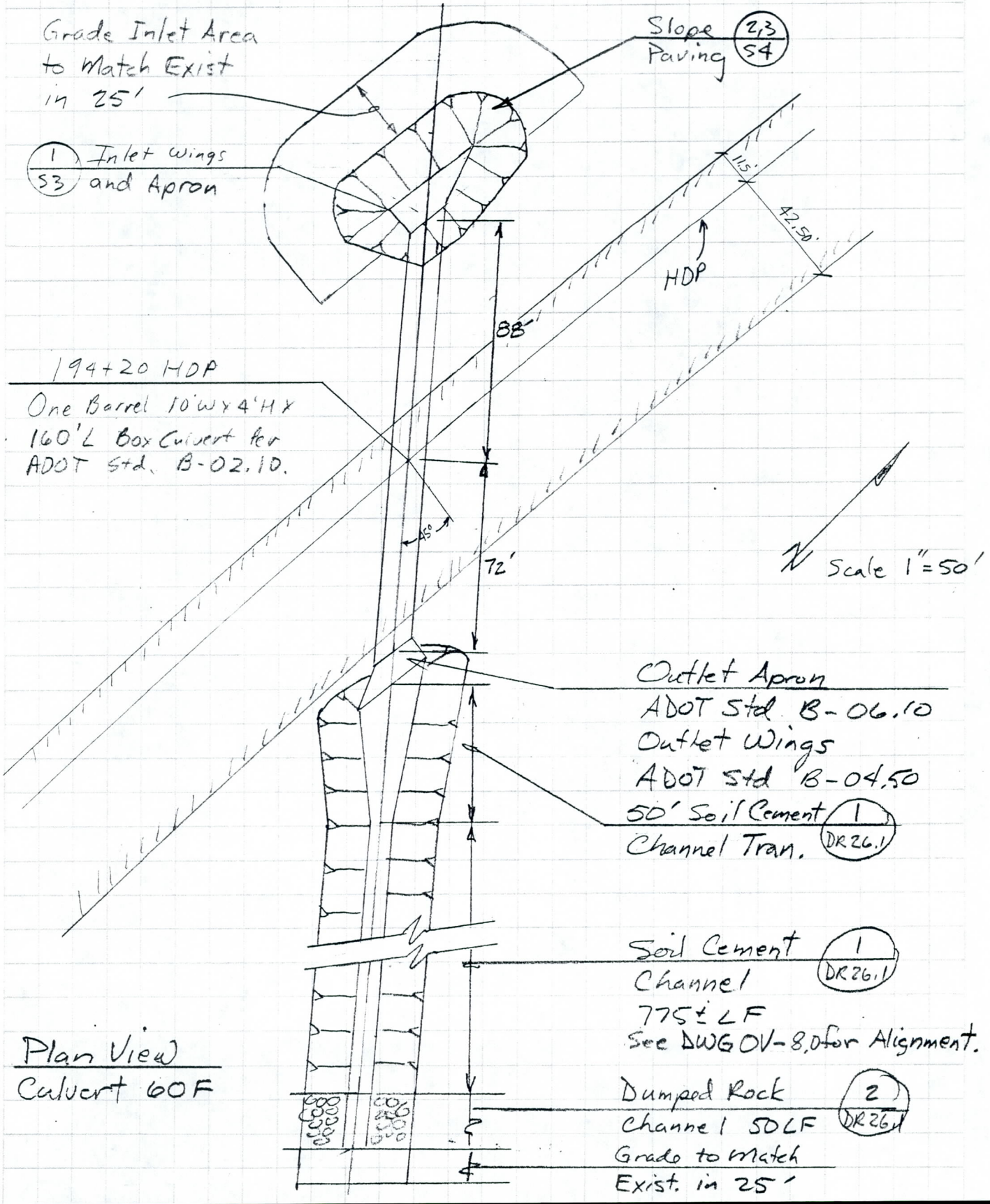
JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60F Plan View
MST Sta. 194+20 [13]

SHEET NO. 7 OF

DATE 7-16-91

BY BDO CHKD RTT 7-22-91



Plan View
Culvert 60F

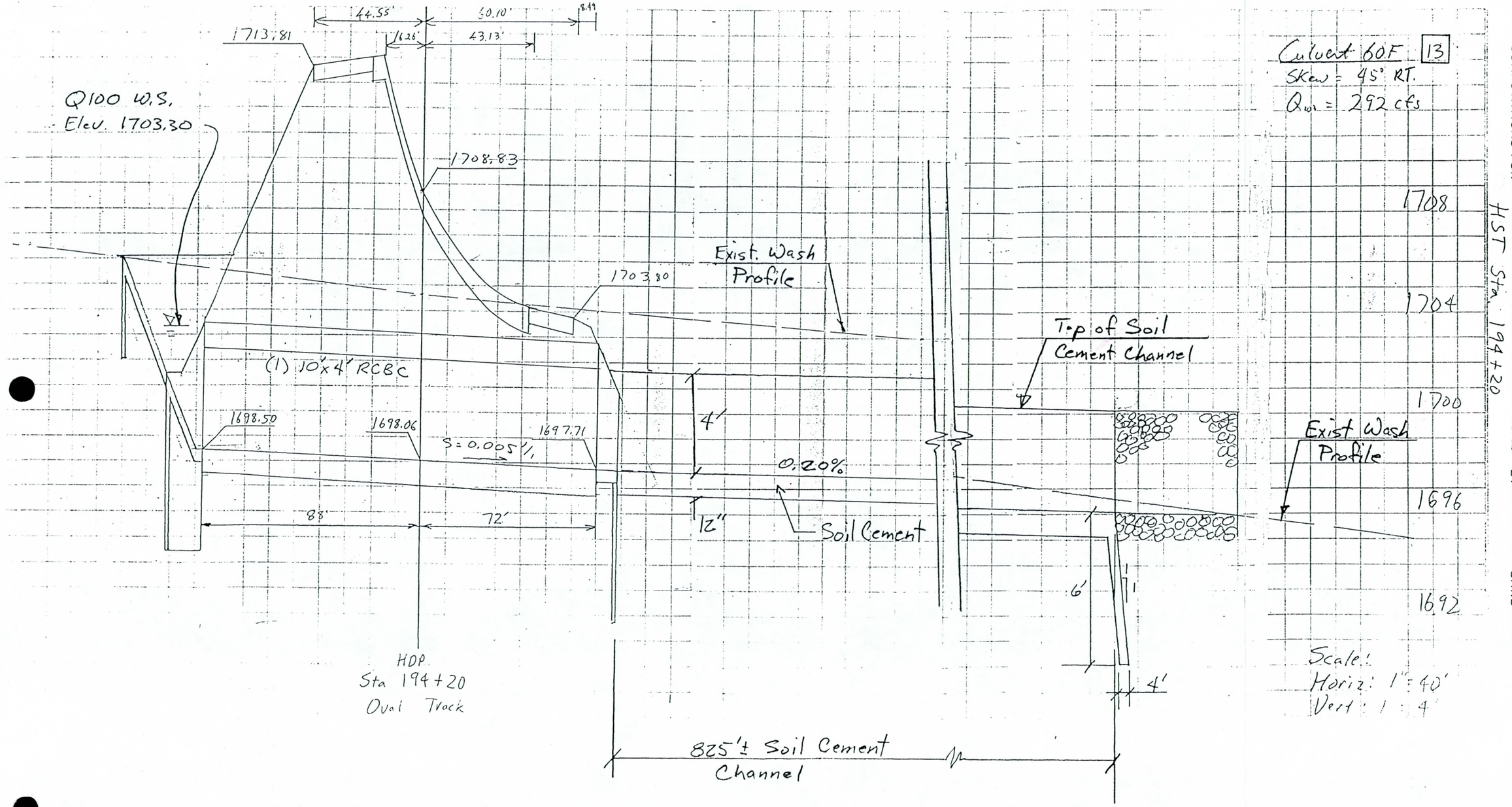
SVERDRUP

JOB 4077 Toyota

COMPUTATIONS FOR Culvert Profile 60F 13
HST Sta 194+20

BY DFP CHKD RJT DATE 7-17-91 SHEET NO. 8 OF

Culvert 60F 13
Skew = 45° RT.
Q_{100} = 292 cfs



SECTION NUM[redacted] TW60F 7/10/9[redacted]

Channel Slope: 0.0079 ft./ft.

CROSS SECTION DATA:

OFFSET	-260	-170	-80	57.1	116.5	118.9	121.4	123.7	151.2	152.8	154.5	157.2	195.2	196.6	198.4
ELEV.	4	4.9	4	4.44	4.48	3.96	3.9	4.39	3.91	3.22	3.12	4	3.49	2.98	3.33
N	N/A	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.035

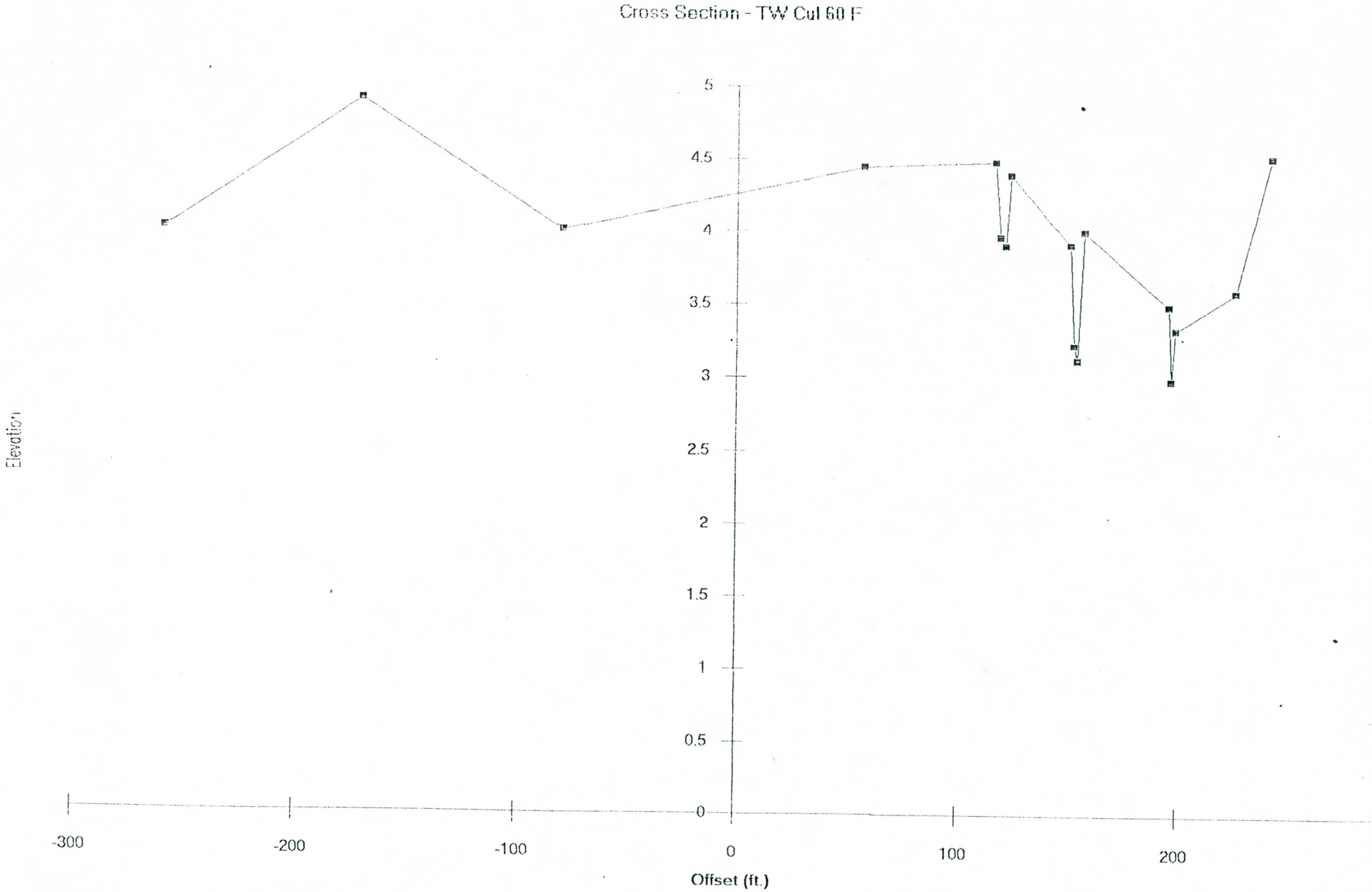
STAGE-DISCHARGE DATA:

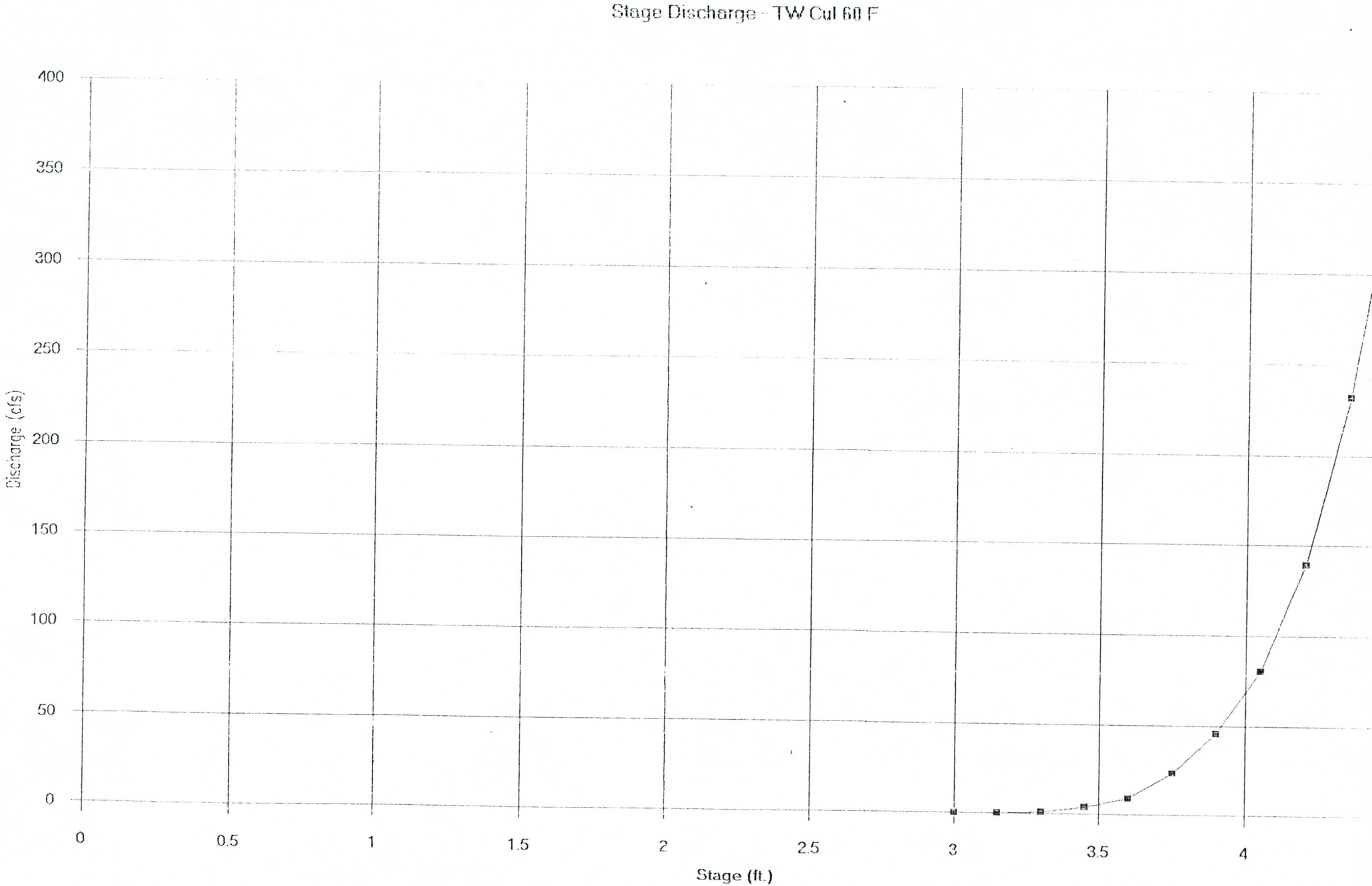
STAGE:	3													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	3.15													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	0.5	1.4
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	3.3													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.7	0.6	0.0	0.9	2.6
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.4
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2	0.2
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	3.45													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.7	1.1	0.0	1.4	3.2
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.5	0.2	0.0	0.3	0.8
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.2	0.0	0.2	0.3
Q	0	0	0	0	0	0	0	0	0	1	0	0	0	0
STAGE:	3.6													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.7	1.6	8.2	9.7	11.5
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.4	0.5	1.0	1.8
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.2	0.1	0.1	0.2
Q	0	0	0	0	0	0	0	0	0	2	0	0	0	0
STAGE:	3.75													
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.7	2.0	19.4	20.9	22.7
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	0.6	2.5	3.2	4.3
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.3	0.1	0.2	0.2
Q	0	0	0	0	0	0	0	0	0	4	1	0	0	0

SECTION NUMBER TW60F 7/10/91

STAGE:	3.9													
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.7	2.5	30.6	32.0	33.9
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.2	0.9	6.3	7.2	8.5
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.7	0.4	0.2	0.2	0.3
Q		0	0	0	0	0	0	0	0	1	5	2	0	0	0
STAGE:	4.05														
WET PER.		5.0	5.0	20.6	0.0	0.4	2.9	3.7	8.0	9.8	1.7	2.8	40.8	42.3	44.2
AREA		0.1	0.1	0.5	0.0	0.0	0.3	0.4	0.6	1.3	1.5	1.3	12.9	14.1	15.7
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.9	0.5	0.3	0.3	0.4
Q		0	0	0	0	0	0	0	0	1	7	0	0	0	0
STAGE:	4.2														
WET PER.		20.0	20.0	82.3	0.0	1.1	3.6	5.1	16.6	18.4	1.7	2.8	40.8	42.3	44.2
AREA		2.0	2.0	8.2	0.0	0.1	0.8	1.0	2.4	3.4	1.8	1.7	19.0	20.4	22.3
HYD.RAD.		0.1	0.1	0.1	0.0	0.1	0.2	0.2	0.1	0.2	1.0	0.6	0.5	0.5	0.5
Q		2	0	7	0	0	0	1	0	4	9	0	0	0	0
STAGE:	4.35														
WET PER.		35.0	35.0	144.1	0.0	1.8	4.3	6.5	25.2	27.0	1.7	2.8	40.8	42.3	44.2
AREA		6.1	6.1	25.2	0.0	0.4	1.4	1.9	5.5	6.8	2.0	2.1	25.1	26.7	28.8
HYD.RAD.		0.2	0.2	0.2	0.0	0.2	0.3	0.3	0.2	0.3	1.2	0.8	0.6	0.6	0.7
Q		7	0	30	0	0	0	3	0	10	12	0	0	0	0
STAGE:	4.5														
WET PER.		50.0	50.0	187.1	246.5	249.0	251.5	253.8	281.3	283.1	1.7	2.8	40.8	42.3	44.2
AREA		12.5	12.5	50.9	53.3	53.9	55.4	56.2	65.8	67.3	2.3	2.5	31.2	33.0	35.4
HYD.RAD.		0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	1.3	0.9	0.8	0.8	0.8
Q		19	0	0	0	0	0	0	0	97	14	0	0	0	0

W.S. Elev.	3	3.15	3.3	3.45	3.6	3.75	3.9	4.05	4.2	4.35	4.5
Q	0	0	1	4	9	23	46	80	139	232	363
A	0.0	0.1	0.7	3.9	6.8	14.3	24.0	37.3	61.9	99.9	152.8
V	0.2	0.7	1.1	1.0	1.3	1.6	1.9	2.1	2.2	2.3	2.4


Cross Section - TW Cul 60 F
Elevation
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
-300
-200
-100
0
100
200
Offset (ft.)


Stage Discharge - TW Cul 60 F
Discharge (cfs)
400
350
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5
4
Stage (ft.)

SVERDR

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60 G [14]

SHEET NO. 1 OF

DATE 7/16/91

BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 146+50, Oval Track

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 0.30 sq. miles

Q_1 = 229 cfs

Q_2 =

TW_1 = 0.8'

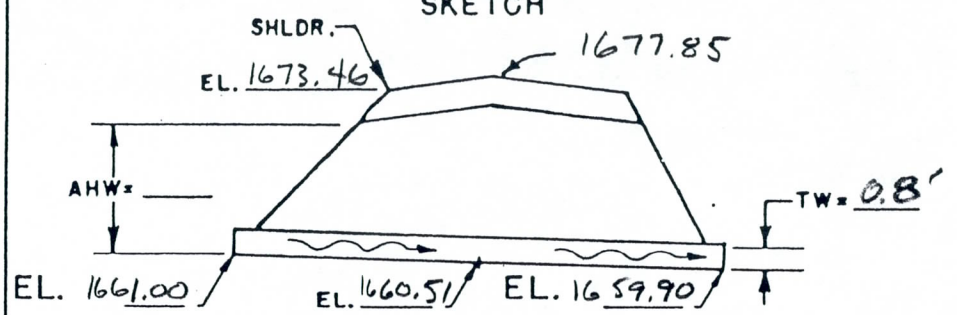
TW_2 =

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY Q_{25}) Q100

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050 ft/ft L = 220' L/100 S_o =

MEAN STREAM VELOCITY = 1.8 fps

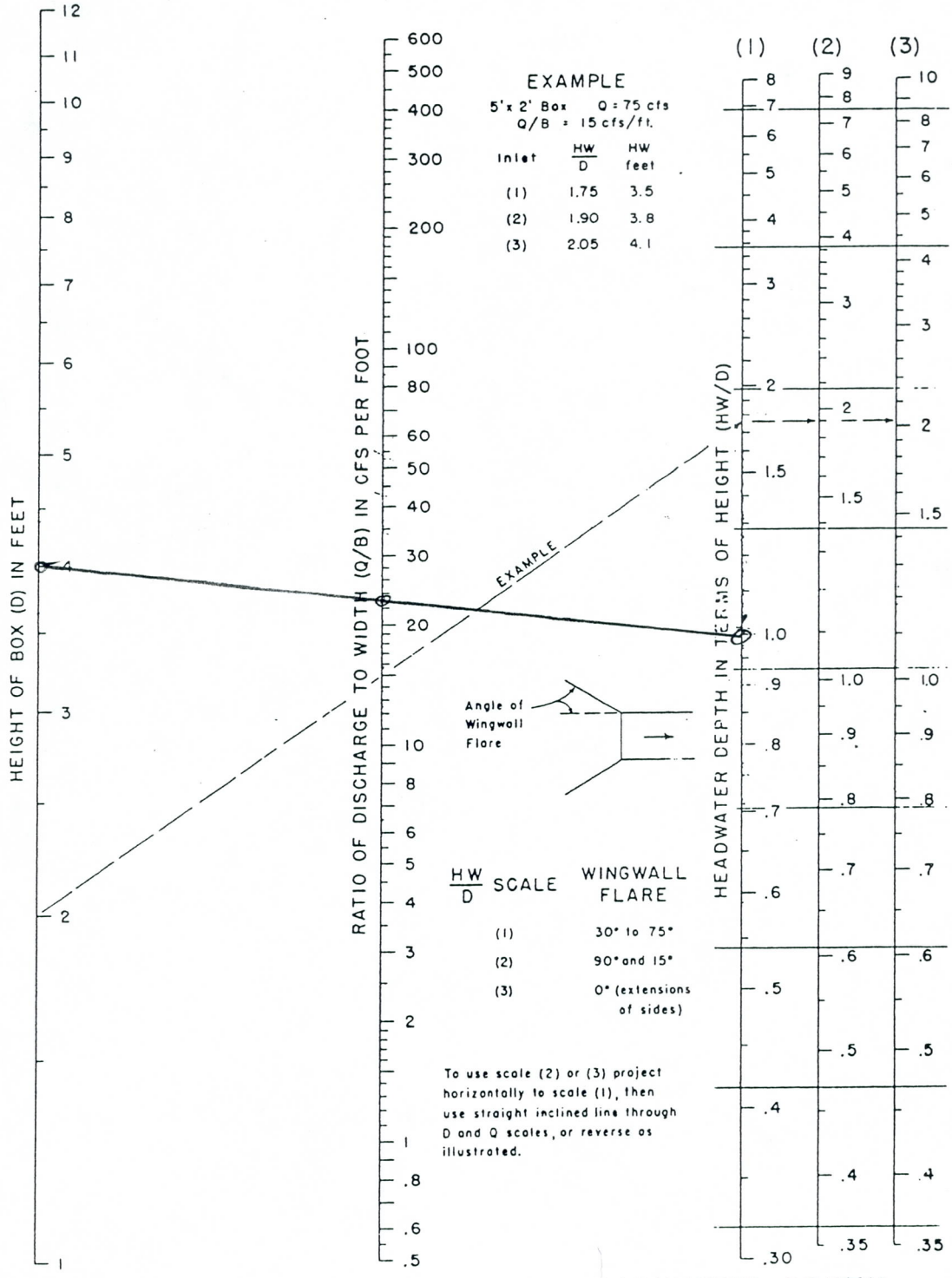
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(1) Barrel 10'x4'	Headwall	229		1.00	4.00	0.2	0.91	2.55	3.28	0.8'	3.28	1.10	3.09	4.00	11.2		1665.00	Inlet Control

SUMMARY & RECOMMENDATIONS Use riprap plunge basin for erosion control downstream of culvert.

B-1

Culvert 60 G

CHART 1

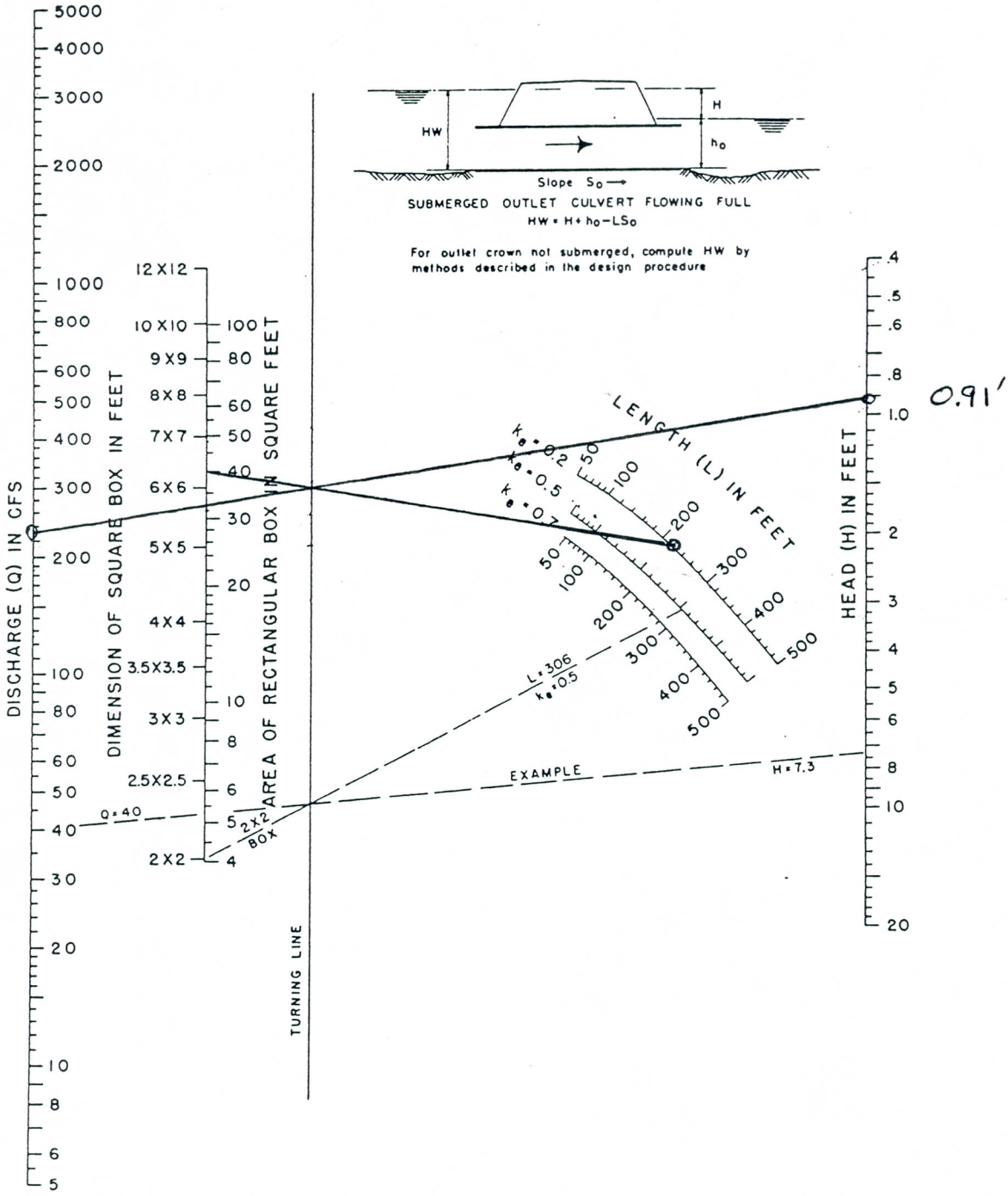


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 G

CHART 8



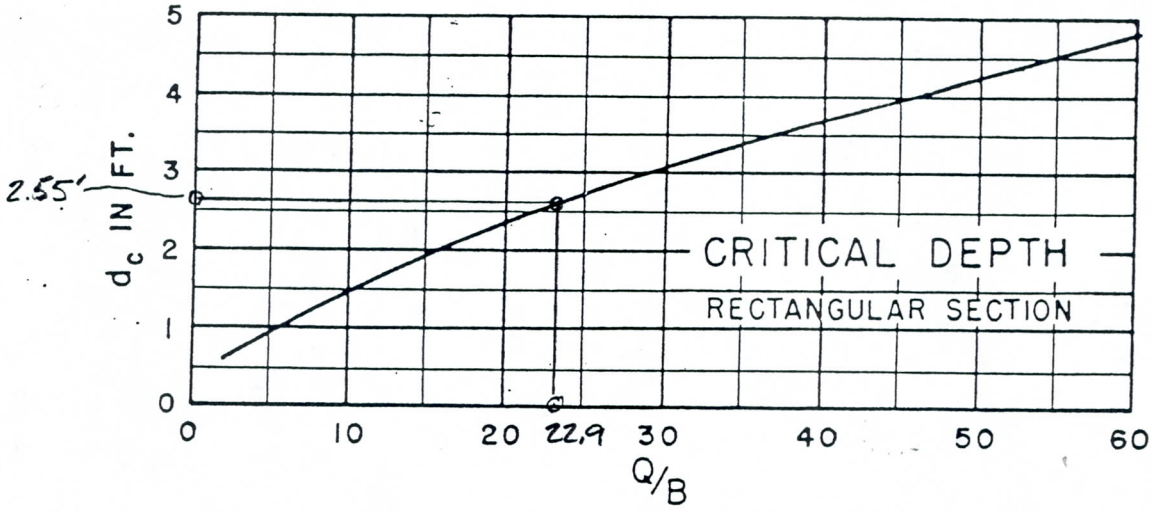
0.91'

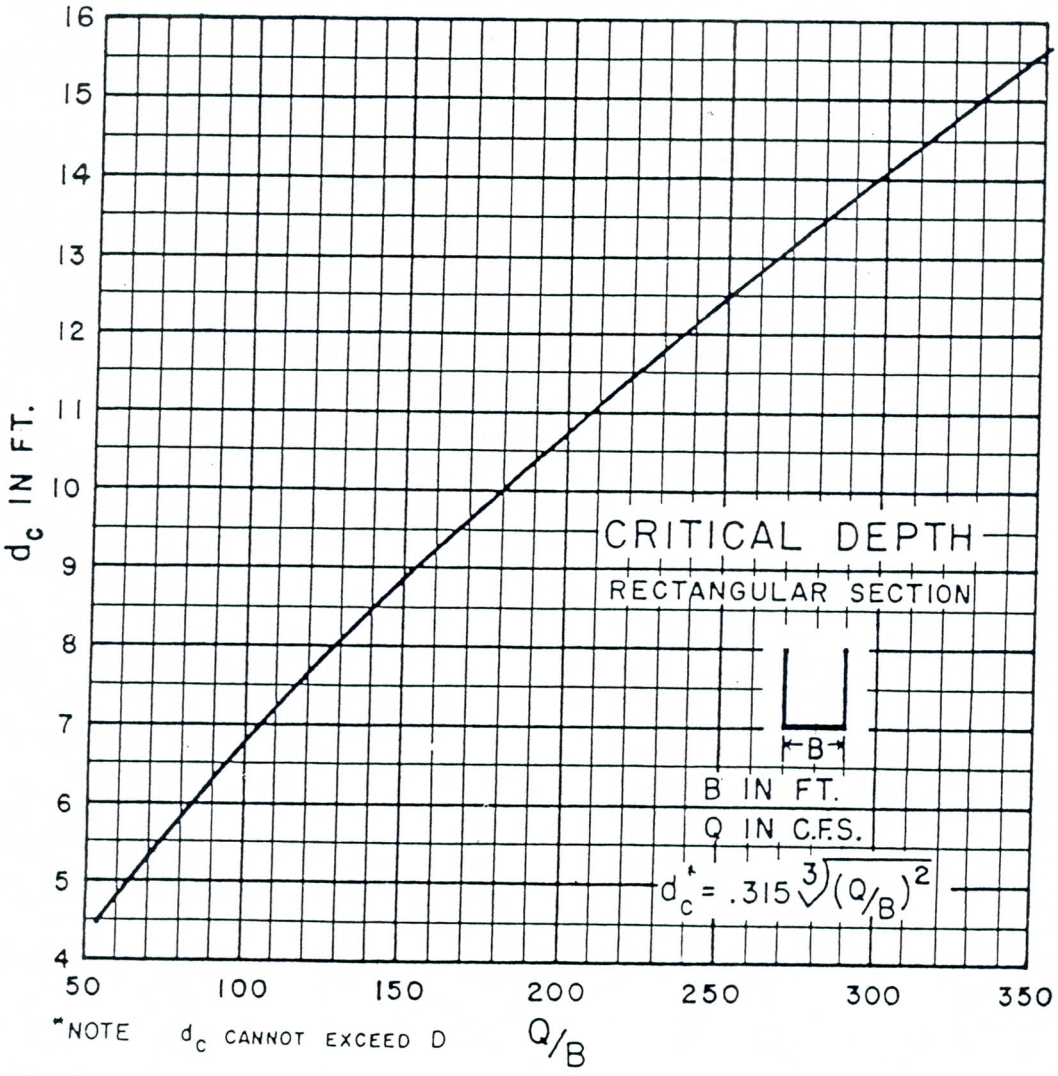
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 G

CHART 15





BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60G

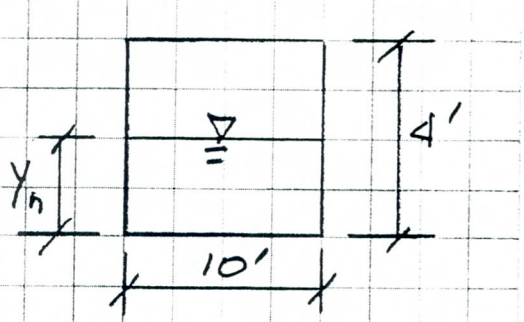
SHEET NO. 5 OF

DATE 7/27/91

BY BDO CHKD RJT

Check depth of Flow using Manning Eqn.

$Q100 = 229$ cfs



$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 2.04'$

$A = 20.4$ ft²

$WP = 2(2.04) + 10 = 14.08'$

$R_h = A/WP = 20.4/14.08 = 1.4489'$

$$V = \frac{1.49}{.012}(1.4489)^{.666}(.005)^{.5} = 11.24 \text{ fps}$$

Check

$Q = VA = 11.24\ (20.4) = 229$ cfs (OK)

Check Froude Number

$$\# = \frac{V}{\sqrt{g \times Y_n}} = \frac{11.24}{\sqrt{32.2 \times 2.04}} = 1.39$$, Supercritical

$Q10 = 126$ cfs

$Y_n = 1.37'$, Velocity = 9.20 fps, # = 1.39

SVERDRUP

JOB 40477 Toyota

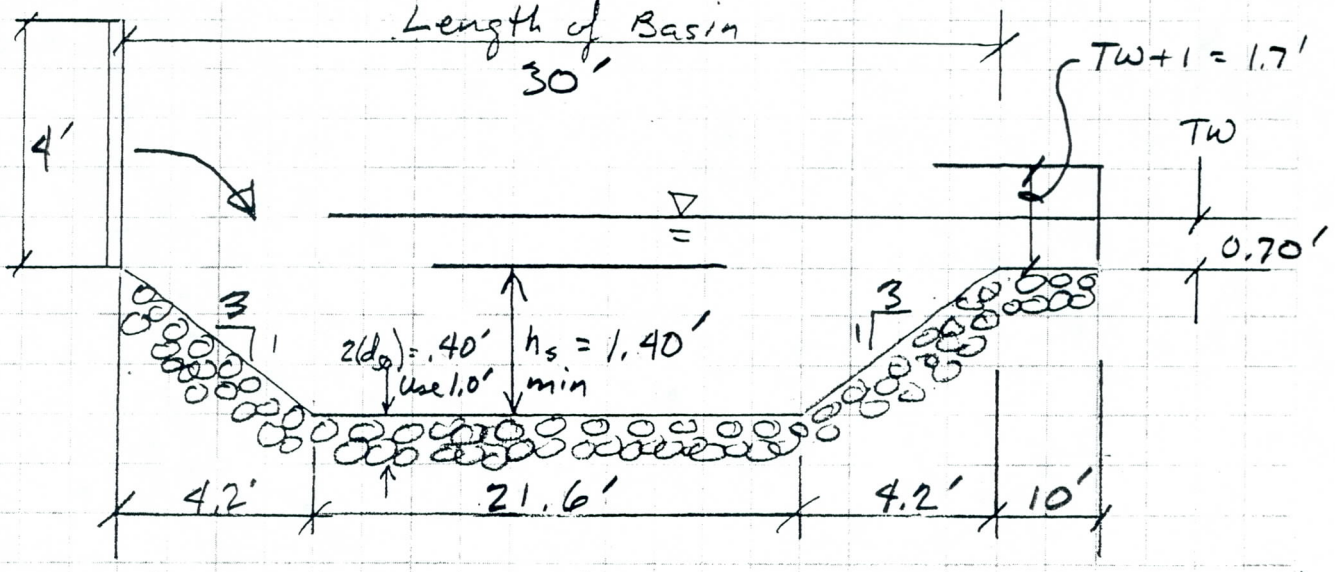
COMPUTATIONS FOR Box Culvert 60 G

SHEET NO. 6 OF

DATE 7/16/91

BY BDO CHKD RJT

Riprap Plunge Basin Design (Q10)



Check Rock Size (From Figure XI-2, HEC No. 14)

For $y_o = 1.37'$ $d_{50} = 0.4'$ or

$$d_{50}/y_o = \frac{0.40'}{1.37'} = 0.29 \quad , \quad FF = 1.39$$

$$\frac{h_s}{y_o} = 1.02 \qquad h_s = 1.02(1.37') = 1.40'$$

Check $\frac{h_s}{d_{50}} = \frac{1.40'}{0.40'} = 3.50 < 4$ and > 2

Length of Basin

$10\,h_s = 10(1.40') = 14.0'$

or

$3(w_o) = 3(10') = 30'$

Use 30'

$TW/y_o = \frac{0.7'}{1.40'} = 0.50 < 0.75$

∴ OK

Culvert 60 G

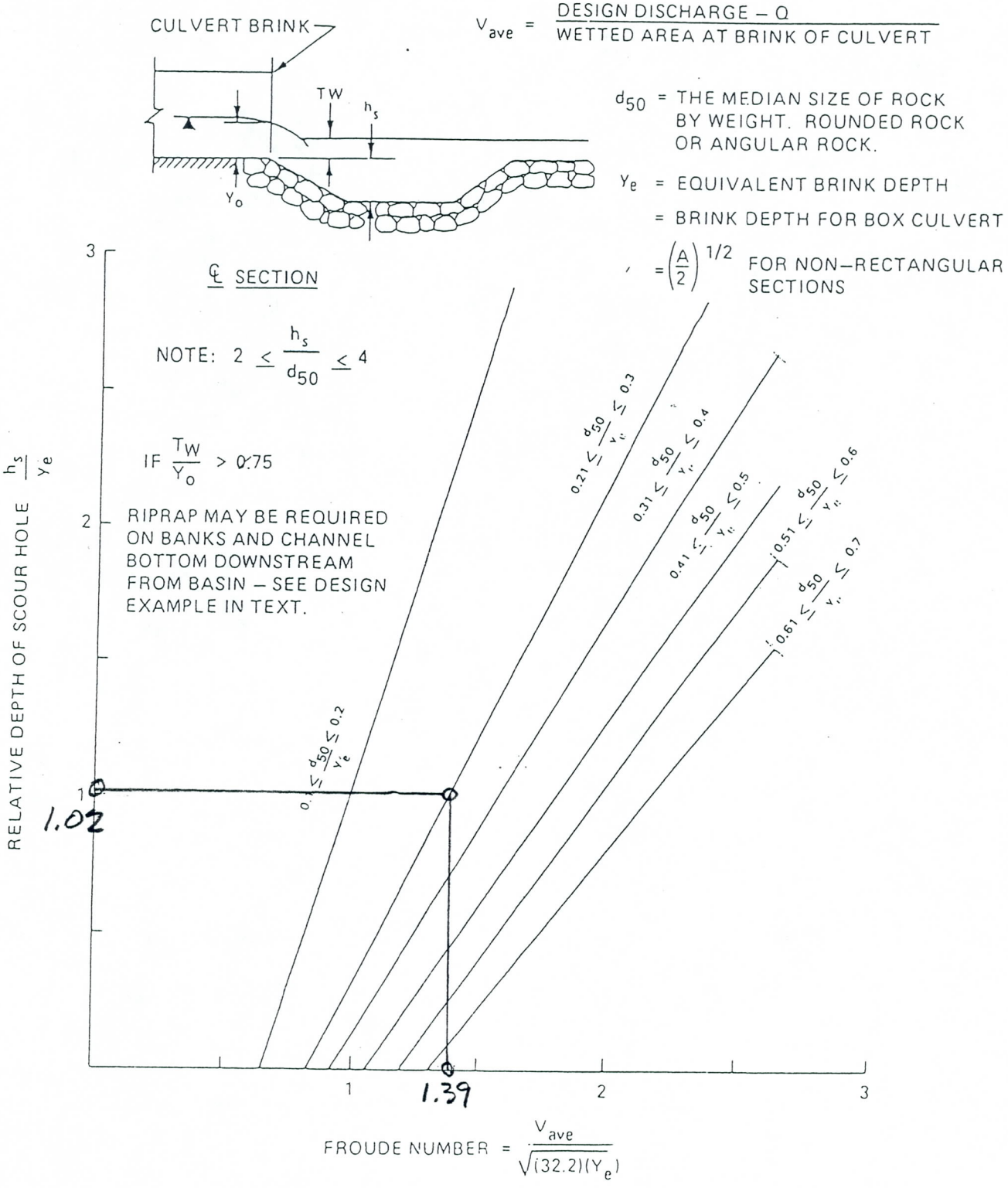


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

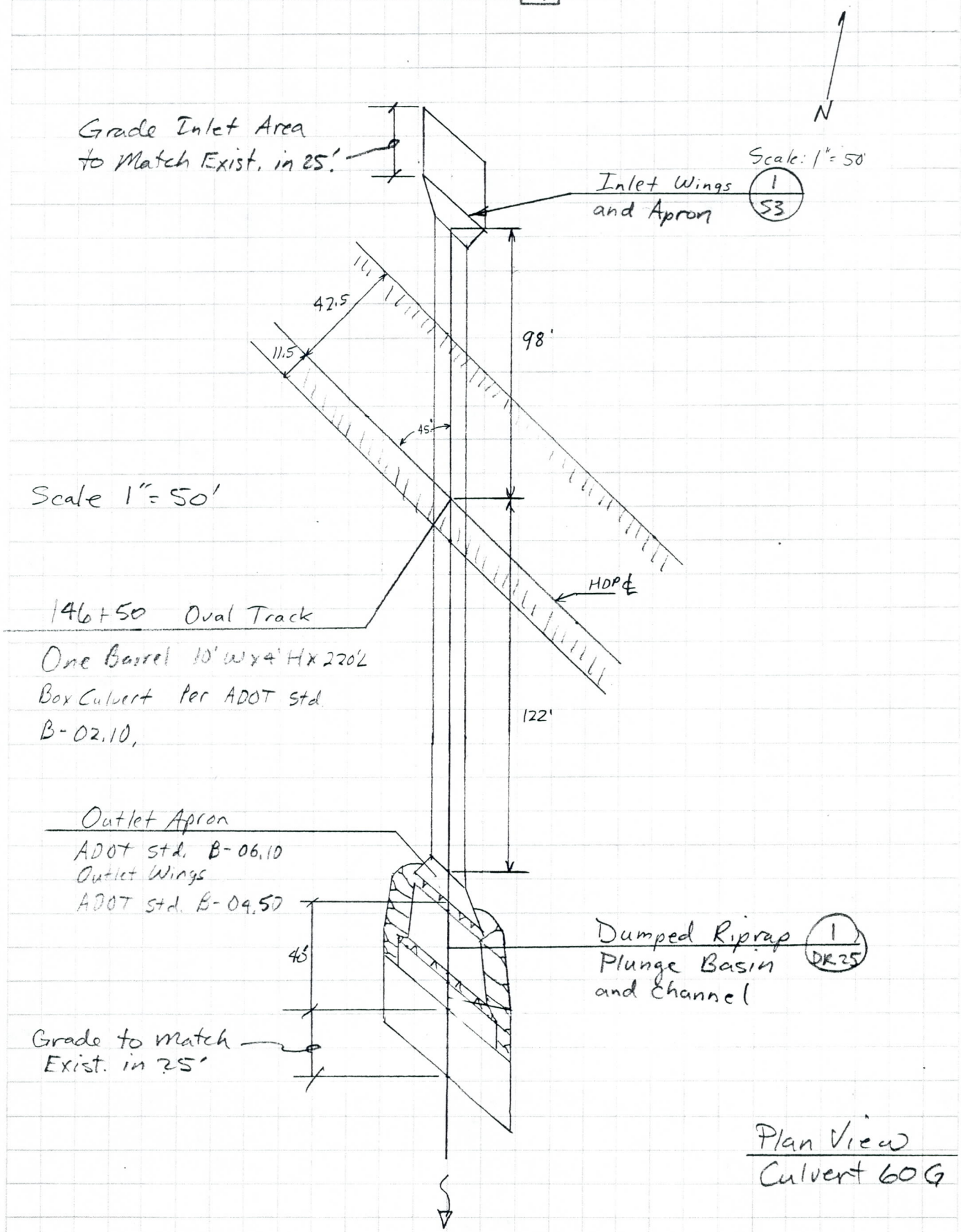
JOB 40477 Toyota

SHEET NO. 8 OF

DATE 7-20-91

COMPUTATIONS FOR Culvert 60G Plan View
HDP Sta 146+50 [14]

BY BDO CHKD RJT



Scale 1" = 50'

146+50 Oval Track

One Barrel 10' W x 4' H x 220' L
Box Culvert Per ADOT Std.
B-02.10,

Plan View
Culvert 60G

SVERDRUP

JOB 40477 Toyota

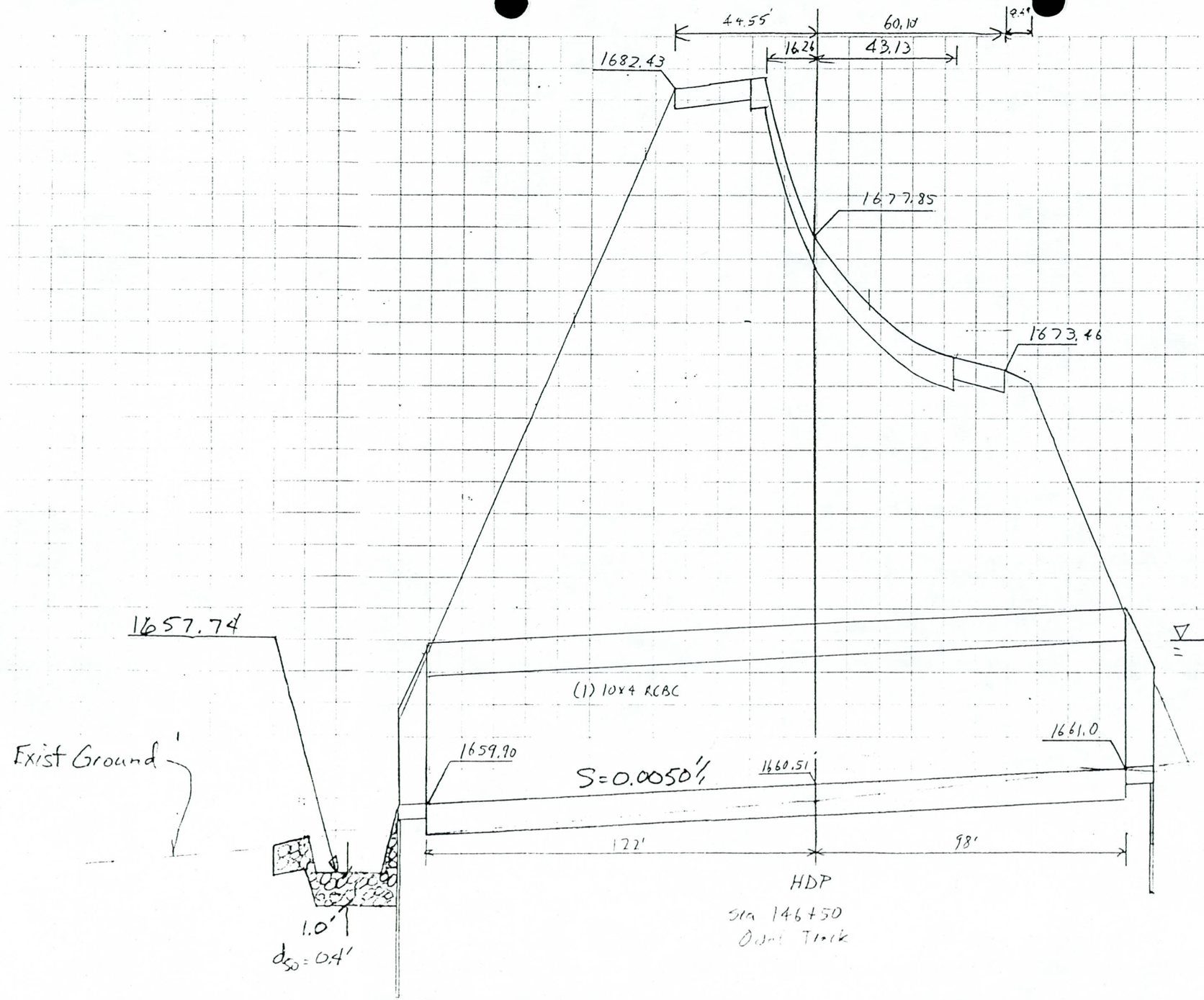
COMPUTATIONS FOR Culvert 606 14

HST Sta. 146+50

SHEET NO. 9 OF

DATE 7-13-91

BY BDO CHKD RVT



Culvert 606 14

Skew = 45°

Q_{100} = 229 cfs

1680

1676

1672

1668

Q100
WS Elev
1665.00

1664

Scale:

Horiz 1" = 10'

Vert 1" = 4'

Channel Slope: 0.009 ft./ft.

CROSS SECTION DATA:

OFFSET	10	128	301.5	399.4	465.5	467.4	471.4	473.1	502.9	540	740	
ELEV.	60.9	60	60.18	59.81	59.86	59.45	59.49	59.81	59.85	60	62	
N	N/A	0.035	0.035	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.035	

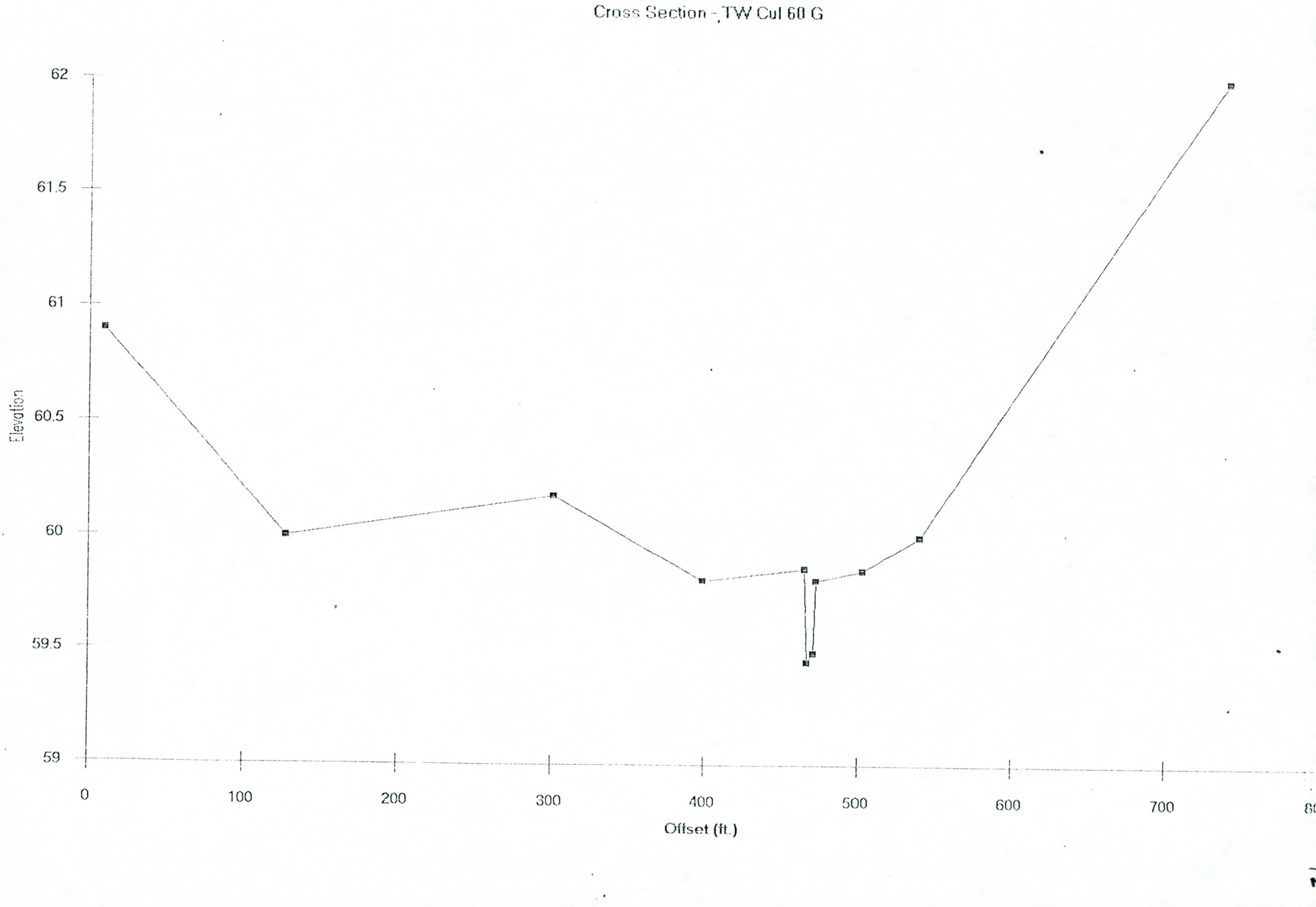
STAGE-DISCHARGE DATA:

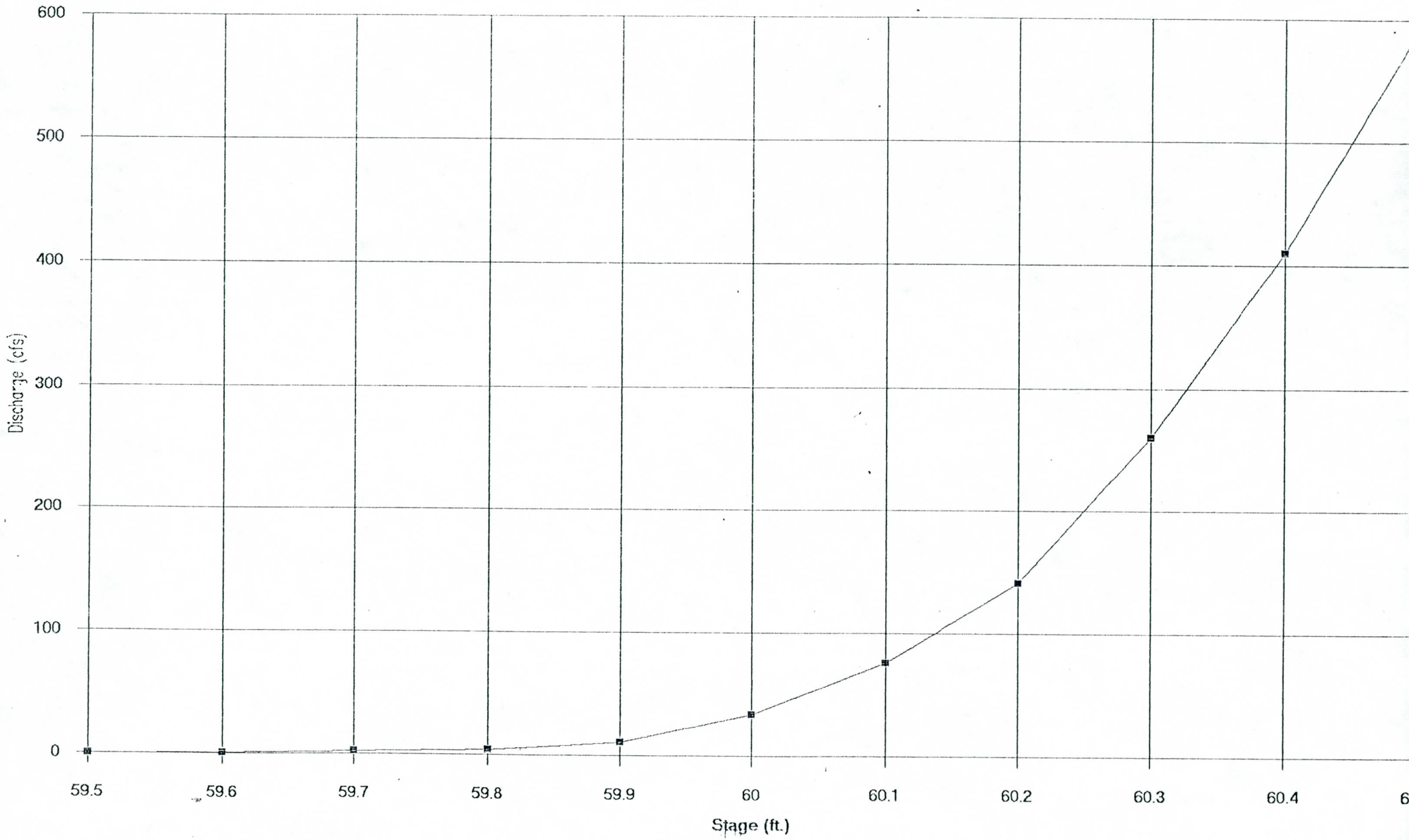
STAGE:	59.5											
WET PER.		0.0	0.0	0.0	0.0	0.2	4.0	0.1	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	59.6											
WET PER.		0.0	0.0	0.0	0.0	0.7	4.0	0.6	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	1	0	0	0	0	0	0
STAGE:	59.7											
WET PER.		0.0	0.0	0.0	0.0	1.2	4.0	1.1	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.1	0.9	0.1	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	2	0	0	0	0	0	0
STAGE:	59.8											
WET PER.		0.0	0.0	0.0	0.0	1.7	4.0	1.7	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.3	1.3	0.3	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.2	0.3	0.2	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	4	0	0	0	0	0	0
STAGE:	59.9											
WET PER.		0.0	0.0	23.8	89.9	91.9	4.0	1.7	31.5	43.9	0.0	0.0	0.0
AREA		0.0	0.0	1.1	5.4	5.8	1.7	0.4	2.5	2.8	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.1	0.1	0.4	0.2	0.1	0.1	0.0	0.0	0.0
Q		0	0	0	0	4	6	0	0	2	0	0	0
STAGE:	60											
WET PER.		0.0	0.0	50.3	116.4	118.3	4.0	1.7	31.5	68.6	0.0	0.0	0.0
AREA		0.0	0.0	4.8	15.7	16.3	2.1	0.6	5.7	8.4	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.1	0.1	0.5	0.3	0.2	0.1	0.0	0.0	0.0
Q		0	0	0	0	18	8	0	0	8	0	0	0

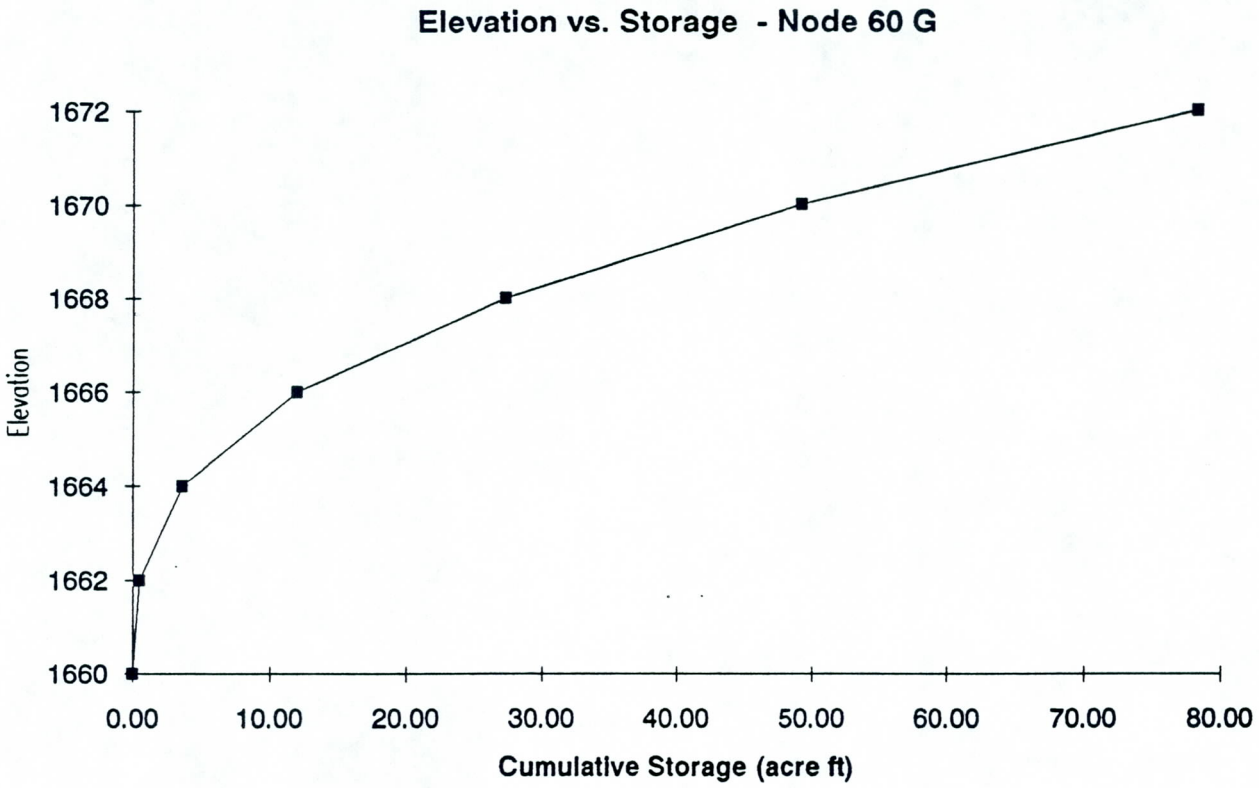
SECTION N[redacted]R TW60G 7/1[redacted]

STAGE:	60.1											
WET PER.		13.1	109.5	76.7	142.8	144.8	4.0	1.7	31.5	68.6	78.6	0.0	0.0
AREA		0.7	5.5	11.1	28.6	29.5	2.5	0.8	8.8	15.3	15.8	0.0	0.0
HYD.RAD.		0.1	0.1	0.1	0.2	0.2	0.6	0.4	0.3	0.2	0.2	0.0	0.0
Q		0	3	0	0	41	10	0	0	0	22	0	0
STAGE:	60.2												
WET PER.		26.2	199.7	297.6	363.7	365.7	4.0	1.7	31.5	68.6	88.6	0.0	0.0
AREA		2.6	21.7	41.8	65.9	66.9	2.9	0.9	12.0	22.2	24.2	0.0	0.0
HYD.RAD.		0.1	0.1	0.1	0.2	0.2	0.7	0.5	0.4	0.3	0.3	0.0	0.0
Q		0	0	0	0	87	13	0	0	0	41	0	0
STAGE:	60.3												
WET PER.		39.3	212.8	310.7	376.8	378.8	4.0	1.7	31.5	68.6	98.6	0.0	0.0
AREA		5.9	42.3	72.2	102.9	104.2	3.3	1.1	15.1	29.0	33.5	0.0	0.0
HYD.RAD.		0.2	0.2	0.2	0.3	0.3	0.8	0.6	0.5	0.4	0.3	0.0	0.0
Q		0	0	0	0	178	17	0	0	0	66	0	0
STAGE:	60.4												
WET PER.		52.5	226.0	323.9	390.0	391.9	4.0	1.7	31.5	68.6	108.6	0.0	0.0
AREA		10.5	64.3	103.9	141.3	142.7	3.7	1.3	18.3	35.9	43.9	0.0	0.0
HYD.RAD.		0.2	0.3	0.3	0.4	0.4	0.9	0.7	0.6	0.5	0.4	0.0	0.0
Q		0	0	0	0	294	20	0	0	0	97	0	0
STAGE:	60.5												
WET PER.		65.6	239.1	337.0	403.1	405.0	4.0	1.7	31.5	68.6	118.6	0.0	0.0
AREA		16.4	87.5	137.0	180.9	182.5	4.1	1.4	21.4	42.7	55.2	0.0	0.0
HYD.RAD.		0.2	0.4	0.4	0.4	0.5	1.0	0.8	0.7	0.6	0.5	0.0	0.0
Q		0	0	0	0	433	24	0	0	0	134	0	0

W.S. Elev.	59.5	59.6	59.7	59.8	59.9	60	60.1	60.2	60.3	60.4	60.5
Q	0	1	2	4	11	34	77	141	260	410	591
A	0.1	0.6	1.2	1.9	10.4	26.9	53.3	94.0	141.0	190.3	241.9
V	0.5	1.3	1.9	2.3	1.1	1.3	1.4	1.5	1.8	2.2	2.4


Cross Section - TW Cul 60 G
62
61.5
61
60.5
60
59.5
59
Elevation
0
100
200
300
400
500
600
700
Offset (ft.)


Stage Discharge - TW Cul 60 G
600
500
400
300
200
100
0
Discharge (cfs)
59.5
59.6
59.7
59.8
59.9
60
60.1
60.2
60.3
60.4
Stage (ft.)


Elevation vs. Storage - Node 60 G
1672
1670
1668
1666
1664
1662
1660
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Cumulative Storage (acre ft)

SVERDRUP

JOB 40477 Toyota

SHEET NO. 1 OF

DATE 7/13/91

COMPUTATIONS FOR Culvert 60 E 15

BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 136+67, Oval Track

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA 0.13 sq. miles

Q_1 = 23 cfs

Q_2 =

TW_1 = 0.75'

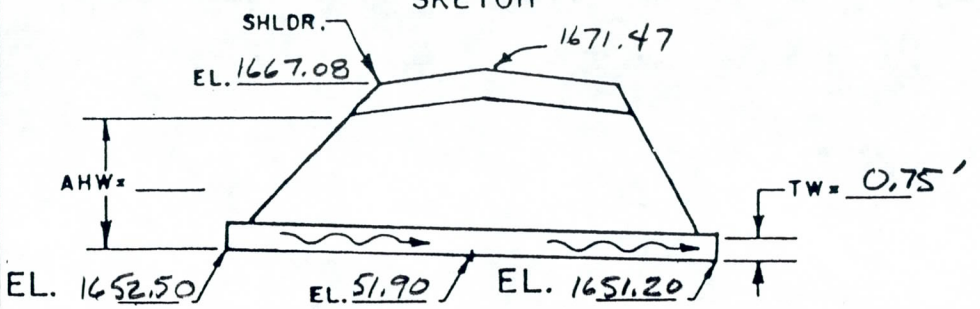
TW_2 =

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~)

(Q_2 = CHECK DISCHARGE, SAY Q_{50}) Q100

SKETCH



S_o = 0.0050', L = 260' L/100 S_o =

MEAN STREAM VELOCITY = 1.7 fps

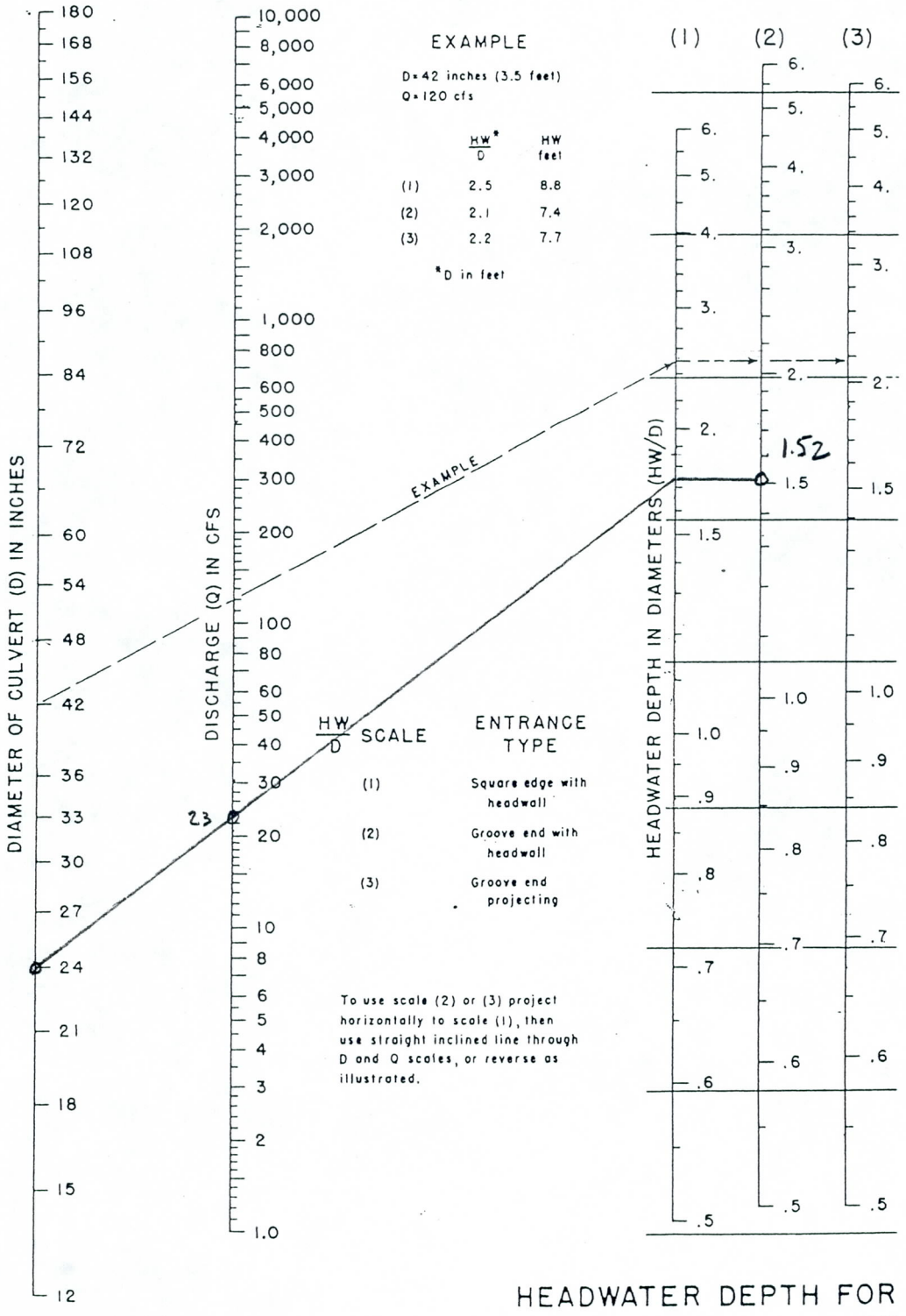
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(1) 24" RCP	Headwall	23		1.52	3.04	0.2	3.35	1.7	1.85	0.75	1.85	1.30	3.90	3.90	7.3		1656.40	Outlet Control

SUMMARY & RECOMMENDATIONS Use dumped riprap plunge basin to control downstream erosion.

B-1

Culvert 60 E

CHART 2

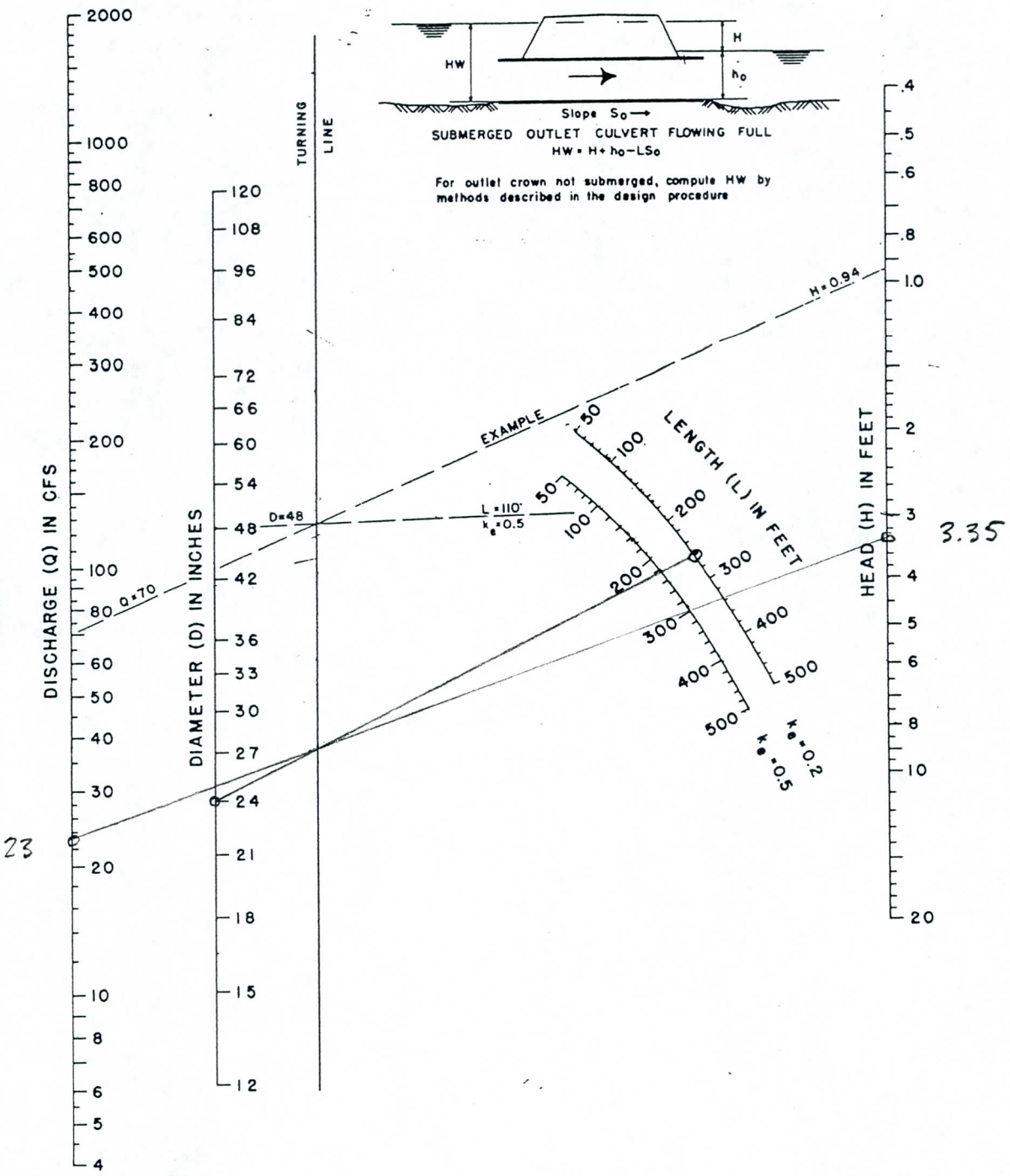


HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 E

CHART 9

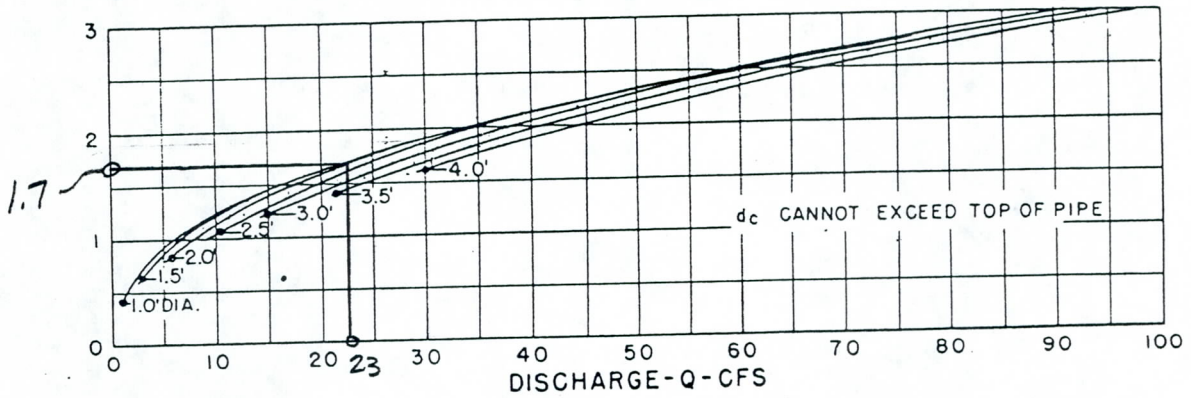


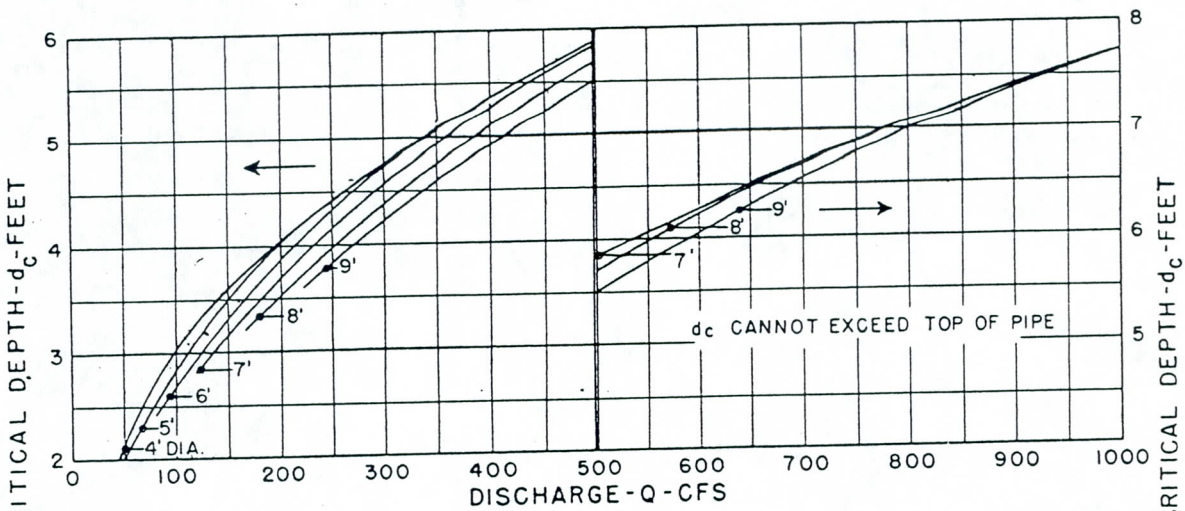
HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

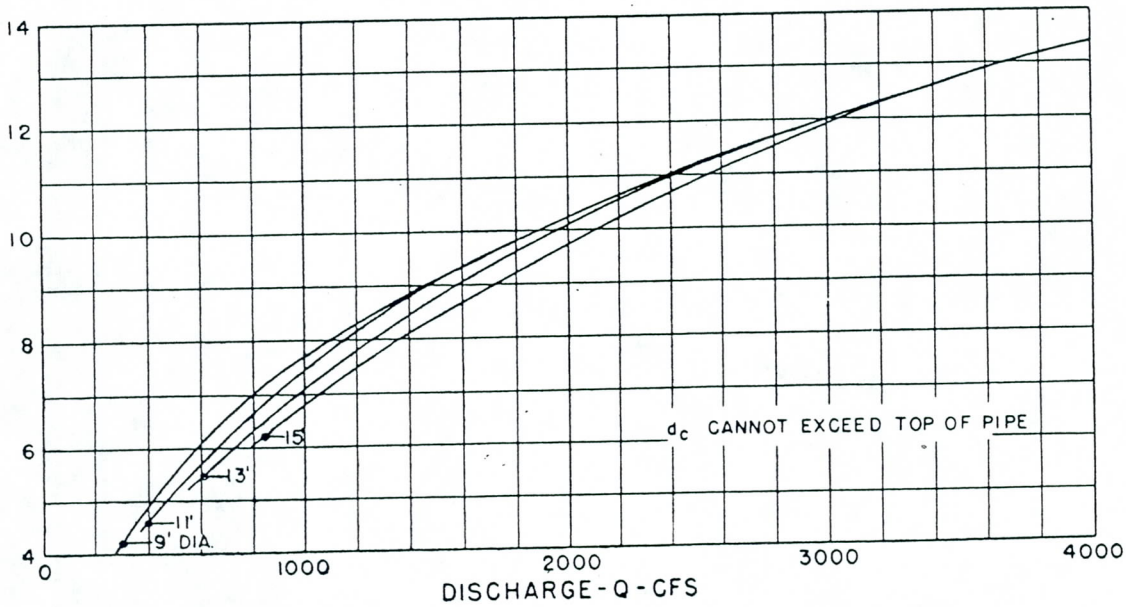
BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 E

CHART 16







BUREAU OF PUBLIC ROADS

JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

SVERDRUP

JOB 40477 Toyota SHEET NO. 5 OF

COMPUTATIONS FOR Culvert 60E DATE 7/13/91

BY BDO CHKD RJT

Check Outlet Velocity for 24" Pipe

$Q_{100} = 23$ cfs $n = 0.013$ $d = 2.0'$ $S = 0.0050$ ft/ft

$$K' = \frac{Qn}{d^{8/3} S^{1/2}} = \frac{23(.013)}{(2)^{8/3}(.005)^{1/2}} = 0.67$$

(Beyond limits of Open Channel Flow ∴ Pipe Full)

$$V = Q/A = 23 \text{ cfs} / 3.14 \text{ ft}^2 = 7.32 \text{ fps}$$

Check Fronde Number

$$F = \frac{V}{\sqrt{g \times y_n}} = \frac{7.32}{\sqrt{32.2 \times 2}} = 0.91, \text{ Subcritical}$$

Use dumped riprap plunge basin for erosion control.

SVERDRUP

JOB 40477 Toyota

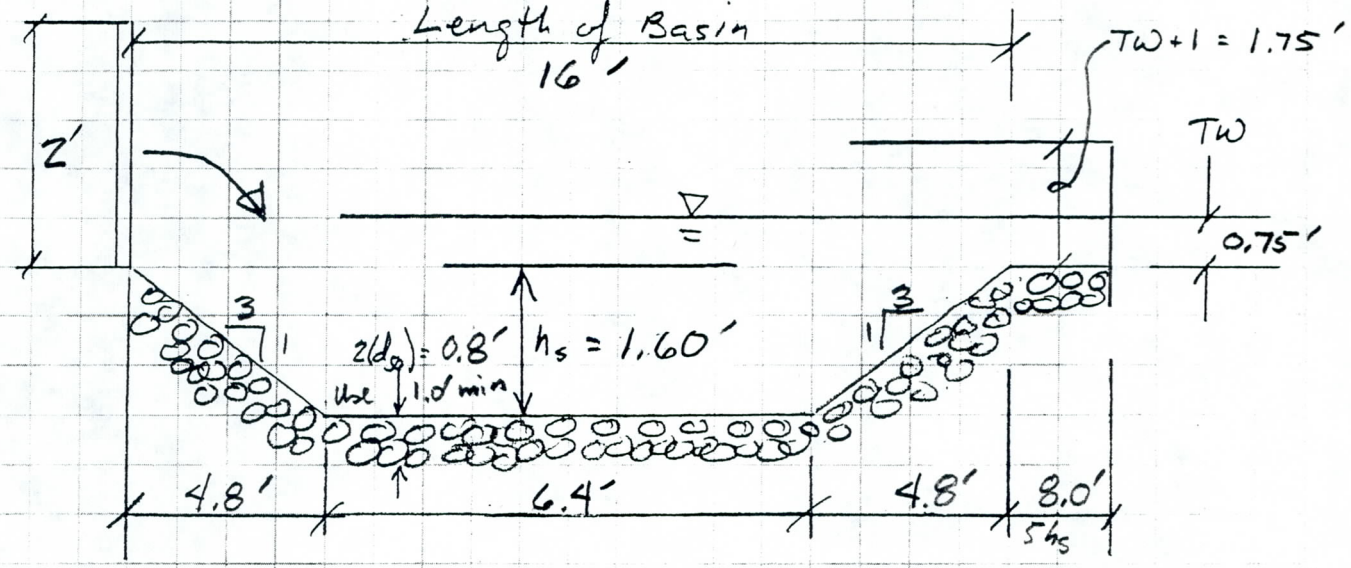
COMPUTATIONS FOR Box Culvert 60E

SHEET NO. 6 OF

DATE 7/13/91

BY BDO CHKD RJT

Riprap Plunge Basin Design (Q100)



Check Rock Size (From Figure XI-2, HEC No. 14)

For $y_o = 2.0'$ $\quad d_{50} = 0.40'$

$$d_{50}/y_o = \frac{0.40'}{2.0'} = .20 \quad , \quad F = 0.91$$

$$\frac{h_s}{y_o} = 0.80 \quad h_s = 0.80(2.0') = 1.60'$$

Check $\dfrac{h_s}{d_{50}} = \dfrac{1.60'}{0.40'} = 4.00 \leq 4$ and > 2 ∴ OK

Length of Basin

$10\,h_s = 10(1.60) = 16.0'$

or

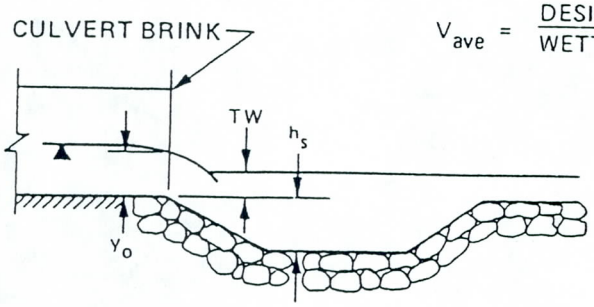
$3(W_o) = 3(2) = 6'$

$$\frac{TW}{y_o} = \frac{0.75}{2.00} = 0.375$$

< 0.75 ∴ OK

Use 16'

Culvert 60 E



$$V_{ave} = \frac{\text{DESIGN DISCHARGE} - Q}{\text{WETTED AREA AT BRINK OF CULVERT}}$$

d_{50} = THE MEDIAN SIZE OF ROCK BY WEIGHT. ROUNDED ROCK OR ANGULAR ROCK.

Y_e = EQUIVALENT BRINK DEPTH

= BRINK DEPTH FOR BOX CULVERT

$= \left(\frac{A}{2}\right)^{1/2}$ FOR NON–RECTANGULAR SECTIONS

℄ SECTION

NOTE: $2 \leq \frac{h_s}{d_{50}} \leq 4$

IF $\frac{T_W}{Y_o} > 0.75$

RIPRAP MAY BE REQUIRED ON BANKS AND CHANNEL BOTTOM DOWNSTREAM FROM BASIN – SEE DESIGN EXAMPLE IN TEXT.

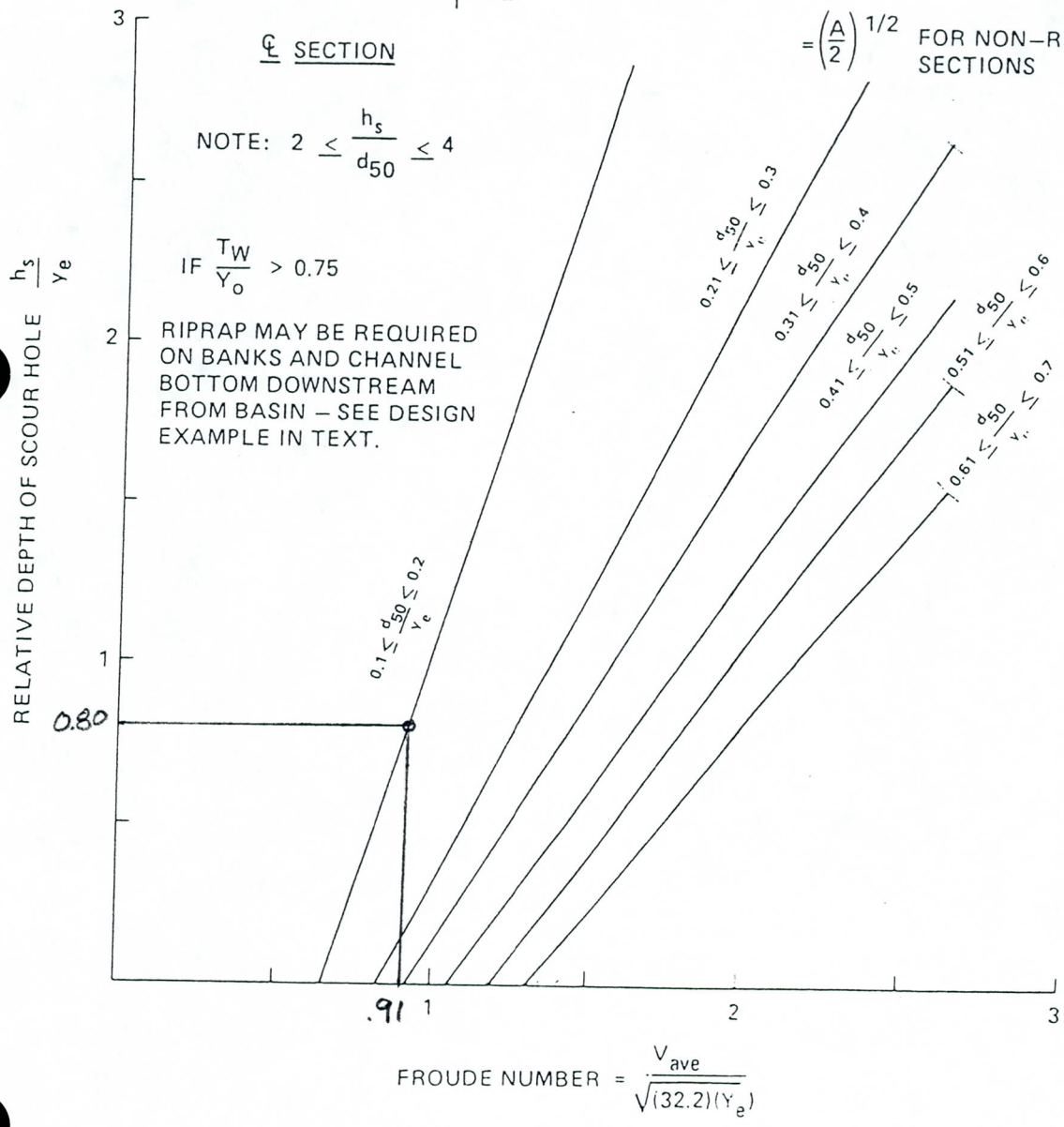


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

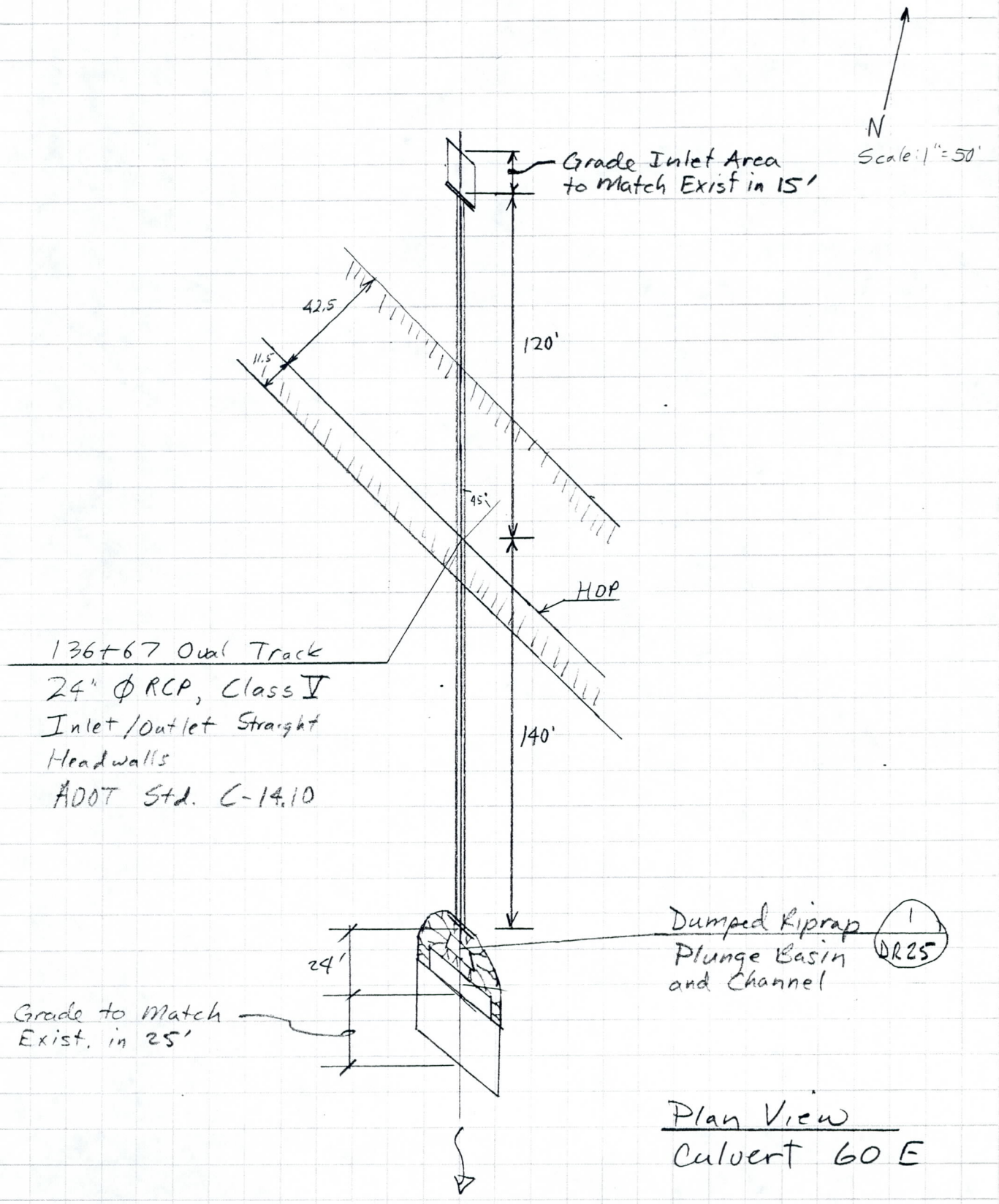
JOB 40477 Toyota

SHEET NO. 8 OF

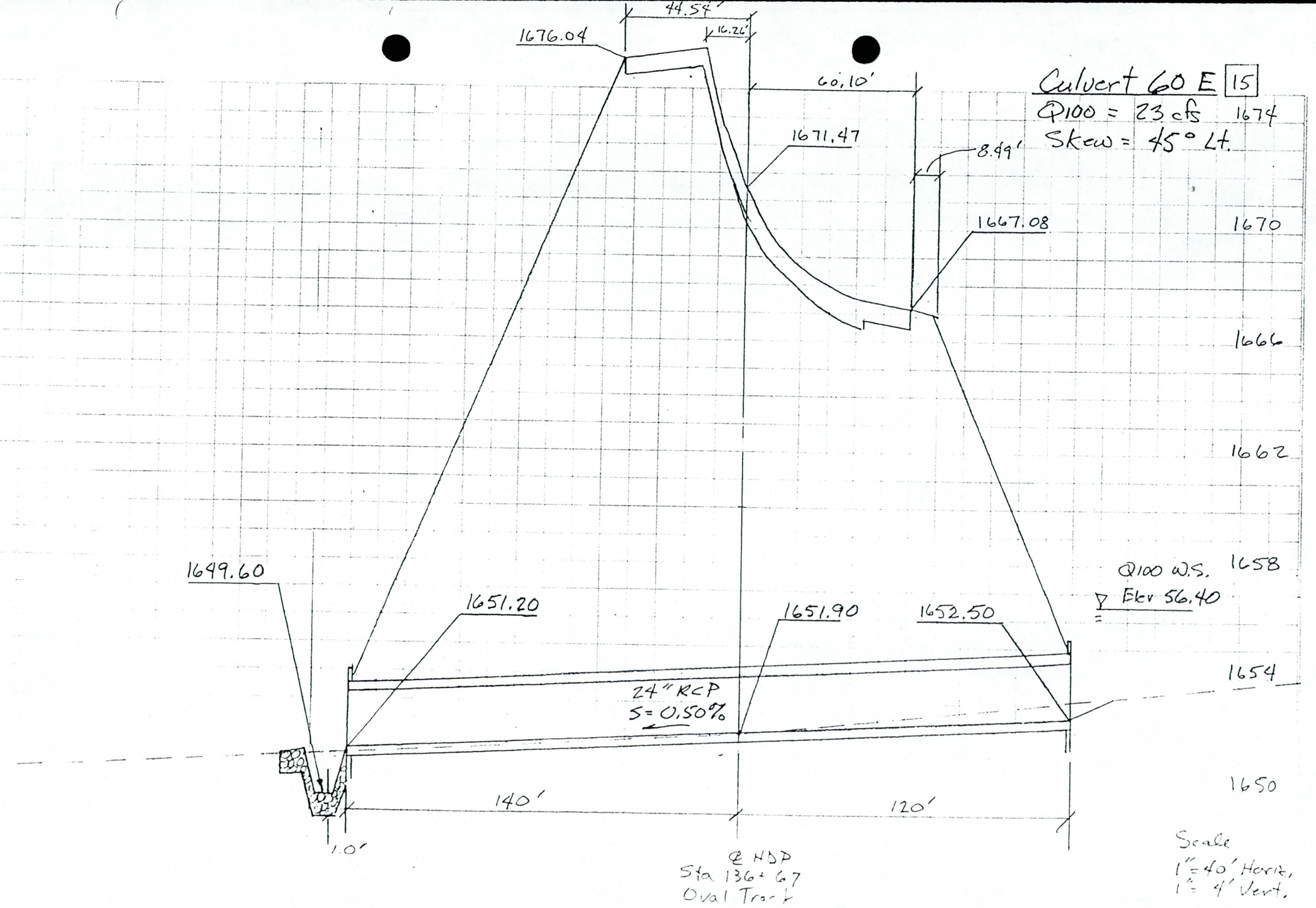
DATE 7-20-91

COMPUTATIONS FOR Culvert 60 E Plan View
HDP Sta 136+67 15

BY DFP CHKD RJT



Plan View
Culvert 60 E



Culvert 60 E 15

Q100 = 23 cfs

Skew = 45° Lt.

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60 E 15

SHEET NO. 9 OF

DATE 7/13/91

BY BDO CHKD RVT

Scale
1" = 40' Horiz.
1" = 4' Vert.

SECTION NUMBER TW60E 7/10/91

Channel Slope: 0.0061 ft./ft.

CROSS SECTION DATA:

OFFSET	22.5	70.6	73.4	74.8	121.9	122.2	123.9	124.5	162.4	164.1	170.8	172.9	176.6	179.6	183.6
ELEV.	52.31	51.41	50.99	51.35	51.55	50.78	50.71	51.53	51.29	51.06	51.04	51.63	51.62	50.86	50.99
N	N/A	0.035	0.035	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.025

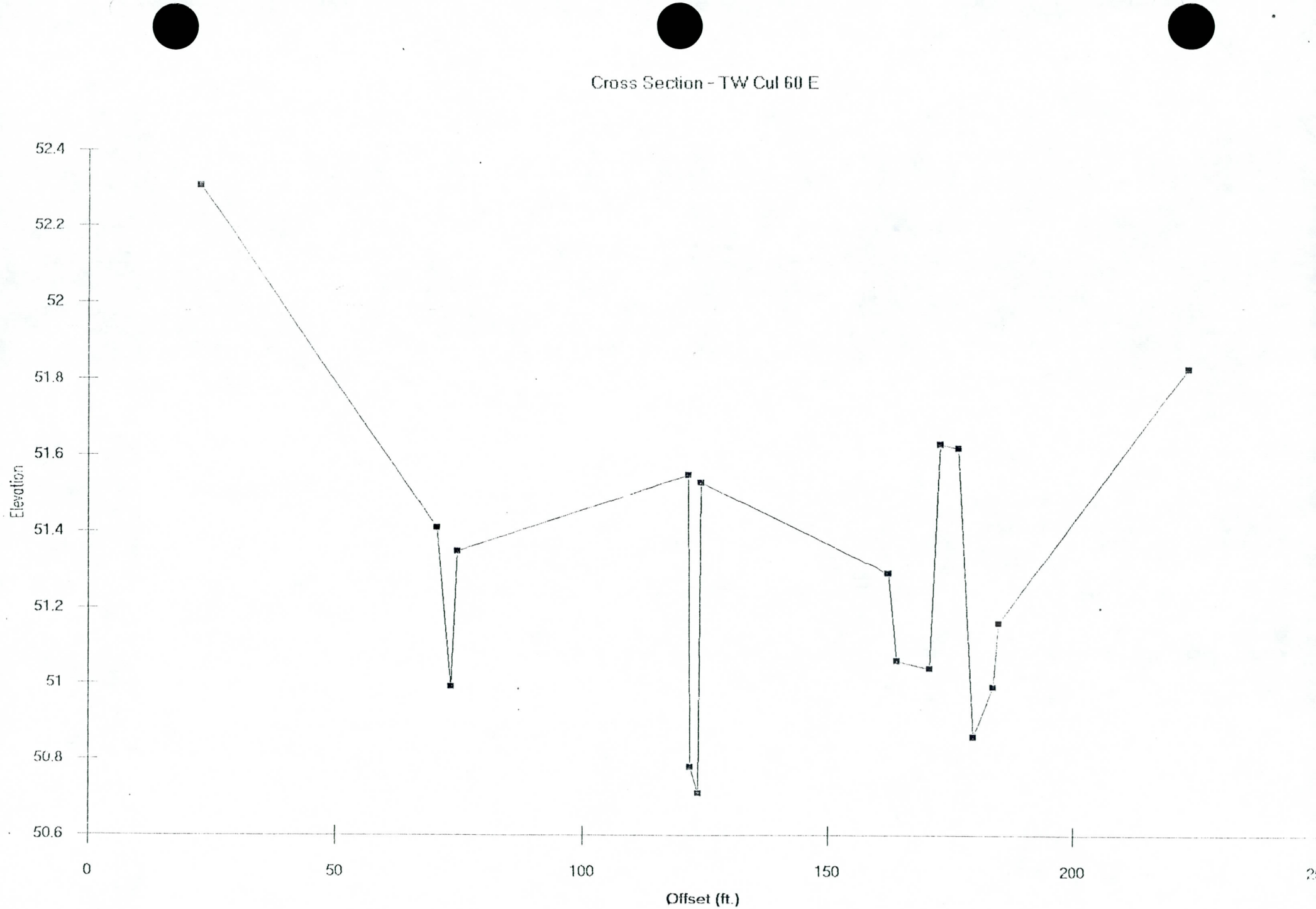
STAGE-DISCHARGE DATA:

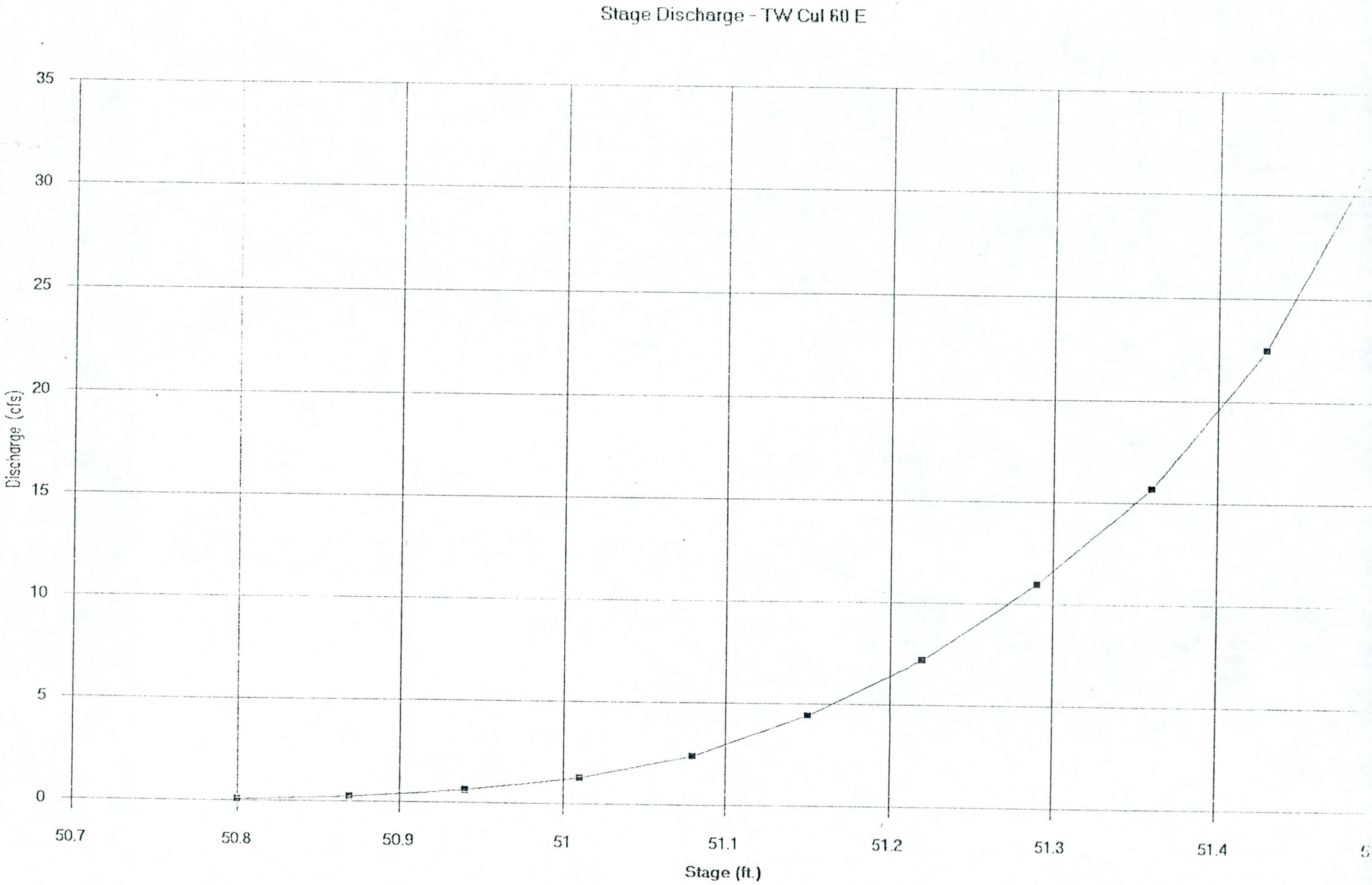
STAGE:	50.8														
WET PER.		0.0	0.0	0.0	0.0	0.0	1.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	50.87														
WET PER.		0.0	0.0	0.0	0.0	0.1	1.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3
AREA		0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	50.94														
WET PER.		0.0	0.0	0.0	0.0	0.2	1.7	0.3	0.0	0.0	0.0	0.0	0.0	0.3	2.5
AREA		0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	1	0	0	0	0	0	0	0	0
STAGE:	51.01														
WET PER.		0.0	0.1	0.2	0.0	0.3	1.7	0.4	0.0	0.0	0.0	0.0	0.0	0.6	4.0
AREA		0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Q		0	0	0	0	0	1	0	0	0	0	0	0	0	0
STAGE:	51.09														
WET PER.		0.0	0.6	1.0	0.0	0.3	1.7	0.5	0.0	0.2	6.7	0.2	0.0	0.9	4.0
AREA		0.0	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.0	0.2	0.0	0.0	0.1	0.6
HYD.RAD.		0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.2
Q		0	0	0	0	0	1	0	0	0	0	0	0	0	1
STAGE:	51.15														
WET PER.		0.0	1.1	1.7	0.0	0.4	1.7	0.6	0.0	0.7	6.7	0.4	0.0	1.2	4.0
AREA		0.0	0.1	0.1	0.0	0.0	0.7	0.1	0.0	0.0	0.7	0.0	0.0	0.2	0.9
HYD.RAD.		0.0	0.1	0.1	0.0	0.1	0.4	0.1	0.0	0.0	0.1	0.1	0.0	0.1	0.2
Q		0	0	0	0	0	2	0	0	0	1	0	0	0	2

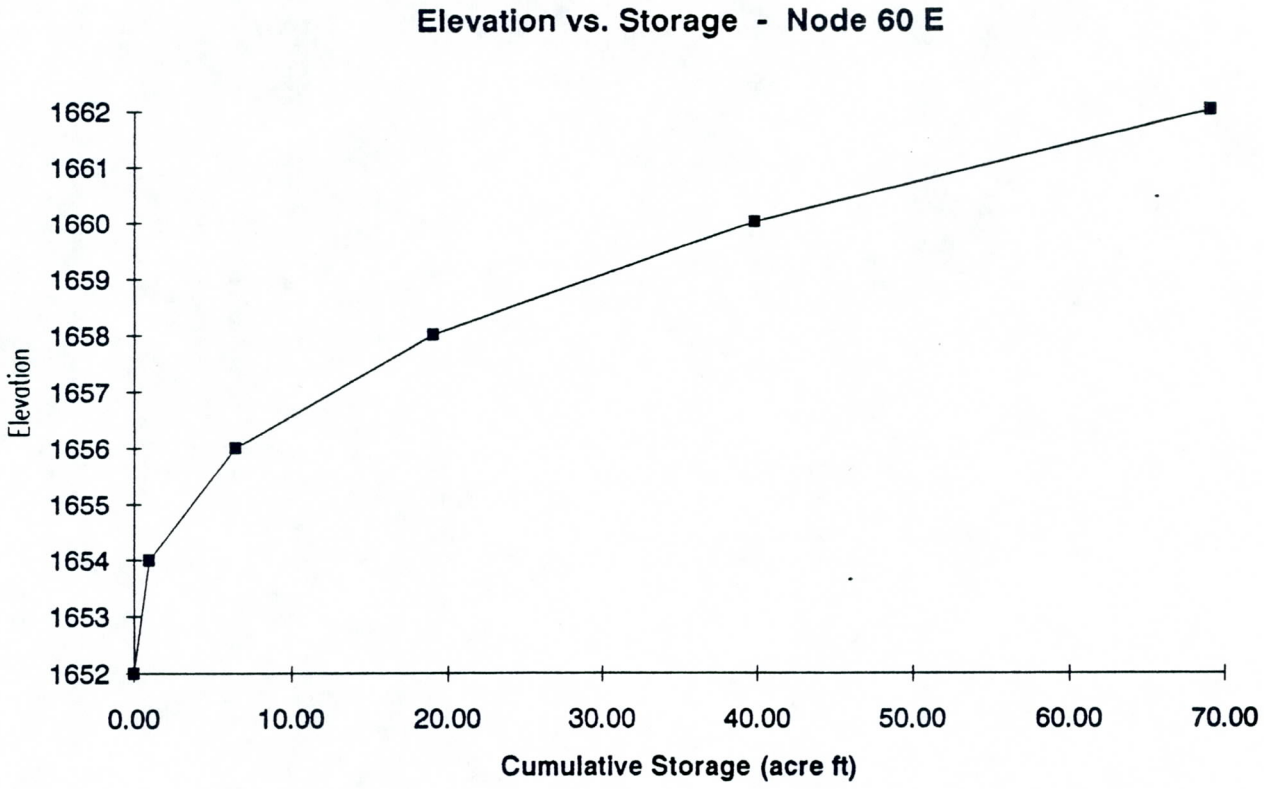
SECTION NUMBER TW60E 7/10/91

STAGE: 51.22													
WET PER.	0.0	1.6	2.5	0.0	0.5	1.7	0.6	0.0	1.2	6.7	0.7	0.0	1.5	4.0
AREA	0.0	0.2	0.3	0.0	0.0	0.8	0.1	0.0	0.1	1.1	0.1	0.0	0.3	1.2
HYD.RAD.	0.0	0.1	0.1	0.0	0.1	0.5	0.2	0.0	0.1	0.2	0.1	0.0	0.2	0.3
Q	0	0	0	0	0	2	0	0	0	2	0	0	0	2
STAGE: 51.29														
WET PER.	0.0	2.0	3.2	0.0	0.6	1.7	0.7	0.0	1.7	6.7	0.9	0.0	1.8	4.0
AREA	0.0	0.3	0.5	0.0	0.1	0.9	0.1	0.0	0.2	1.6	0.1	0.0	0.4	1.5
HYD.RAD.	0.0	0.1	0.1	0.0	0.1	0.5	0.2	0.0	0.1	0.2	0.1	0.0	0.2	0.4
Q	0	0	0	0	0	3	0	0	0	3	0	0	0	3
STAGE: 51.36														
WET PER.	0.0	2.5	3.9	6.3	0.6	1.7	0.8	11.1	12.8	6.7	1.2	0.0	2.0	4.0
AREA	0.0	0.5	0.7	0.7	0.1	1.0	0.2	0.4	0.7	2.1	0.2	0.0	0.5	1.7
HYD.RAD.	0.0	0.2	0.2	0.1	0.1	0.6	0.2	0.0	0.1	0.3	0.2	0.0	0.2	0.4
Q	0	0	0	1	0	4	0	0	0	4	0	0	1	5
STAGE: 51.43														
WET PER.	1.1	3.9	5.3	24.2	0.7	1.7	0.9	22.1	23.8	6.7	1.4	0.0	2.3	4.0
AREA	0.0	0.7	1.0	1.8	0.1	1.2	0.2	1.5	2.0	2.5	0.3	0.0	0.6	2.0
HYD.RAD.	0.0	0.2	0.2	0.1	0.1	0.7	0.2	0.1	0.1	0.4	0.2	0.0	0.3	0.5
Q	0	0	0	1	0	4	0	0	1	6	0	0	1	6
STAGE: 51.5														
WET PER.	4.8	7.6	9.1	44.4	0.8	1.7	1.0	33.2	34.9	6.7	1.7	0.0	2.6	4.0
AREA	0.2	1.1	1.5	4.2	0.1	1.3	0.2	3.5	4.0	3.0	0.4	0.0	0.8	2.3
HYD.RAD.	0.0	0.1	0.2	0.1	0.1	0.8	0.2	0.1	0.1	0.4	0.2	0.0	0.3	0.6
Q	0	0	0	3	0	5	0	0	3	8	0	0	1	7

W.S. Elev.	50.8	50.87	50.94	51.01	51.08	51.15	51.22	51.29	51.36	51.43	51.5
Q	0	0	1	1	2	4	7	11	16	22	33
A	0.1	0.2	0.5	0.9	1.7	2.9	4.2	6.1	8.7	13.2	20.2
V	0.7	1.1	1.3	1.4	1.4	1.5	1.7	1.8	1.8	1.7	1.6


Cross Section - TW Cul 60 E
52.4
52.2
52
51.8
51.6
51.4
51.2
51
50.8
50.6
Elevation
0
50
100
150
200
Offset (ft.)


Stage Discharge - TW Cul 60 E
35
30
25
20
15
10
5
0
Discharge (cfs)
50.7
50.8
50.9
51
51.1
51.2
51.3
51.4
Stage (ft.)


Elevation vs. Storage - Node 60 E
1662
1661
1660
1659
1658
1657
1656
1655
1654
1653
1652
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
Cumulative Storage (acre ft)

SVERDRUP

JOB 404-7[redacted] Toyota

SHEET NO. [redacted] OF

DATE 7/13/91

COMPUTATIONS FOR Culvert 60 D-6 16A

BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 116+50, Oval Track

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

2034/6 = 339 cfs

DRAINAGE AREA 10.98 sq. miles

Q_1 = 339 cfs

Q_2 = ____

TW_1 = 2.4' Exist. Channel

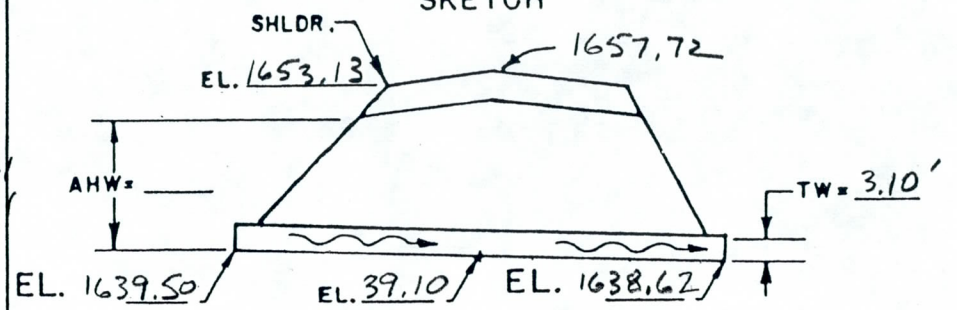
TW_2 = 3.10' New Channel

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY Q_{25})

(Q_2 = CHECK DISCHARGE, SAY Q_{50}) Q100

SKETCH



S_o = 0.0050', L = 176' L/100 S_o = ____

MEAN STREAM VELOCITY = 2.6 fps

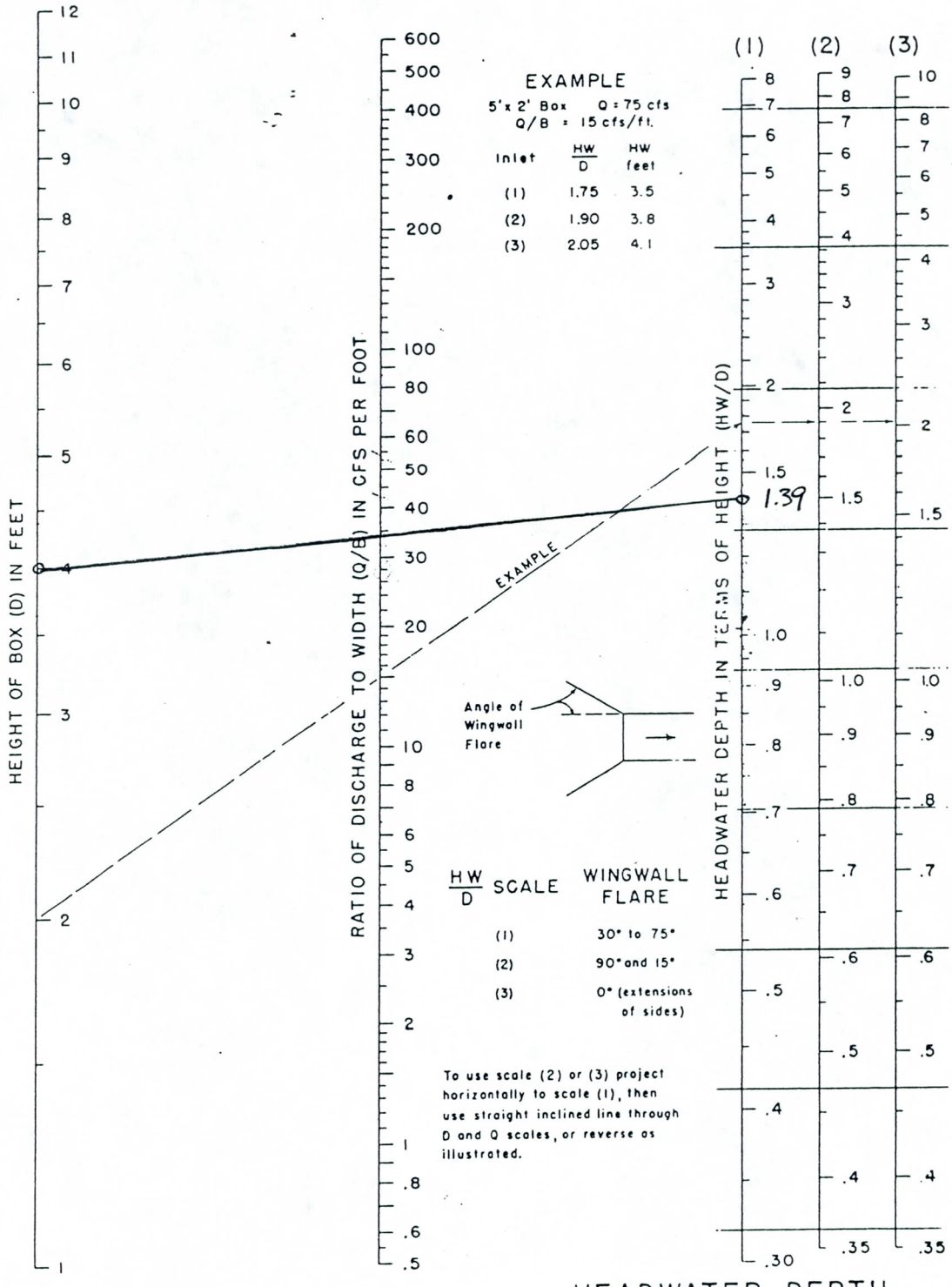
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(1) Barrel 10'x4'	Drop Inlet	339		1.39	5.56	0.2	1.75	3.30	3.65	3.10	3.65	0.88	4.52	5.56	12.7		1645.06	Inlet Control

SUMMARY & RECOMMENDATIONS Use dumped riprap plunge basin downstream of culvert for erosion protection.

B-10

Culvert 60 D-6

CHART 1

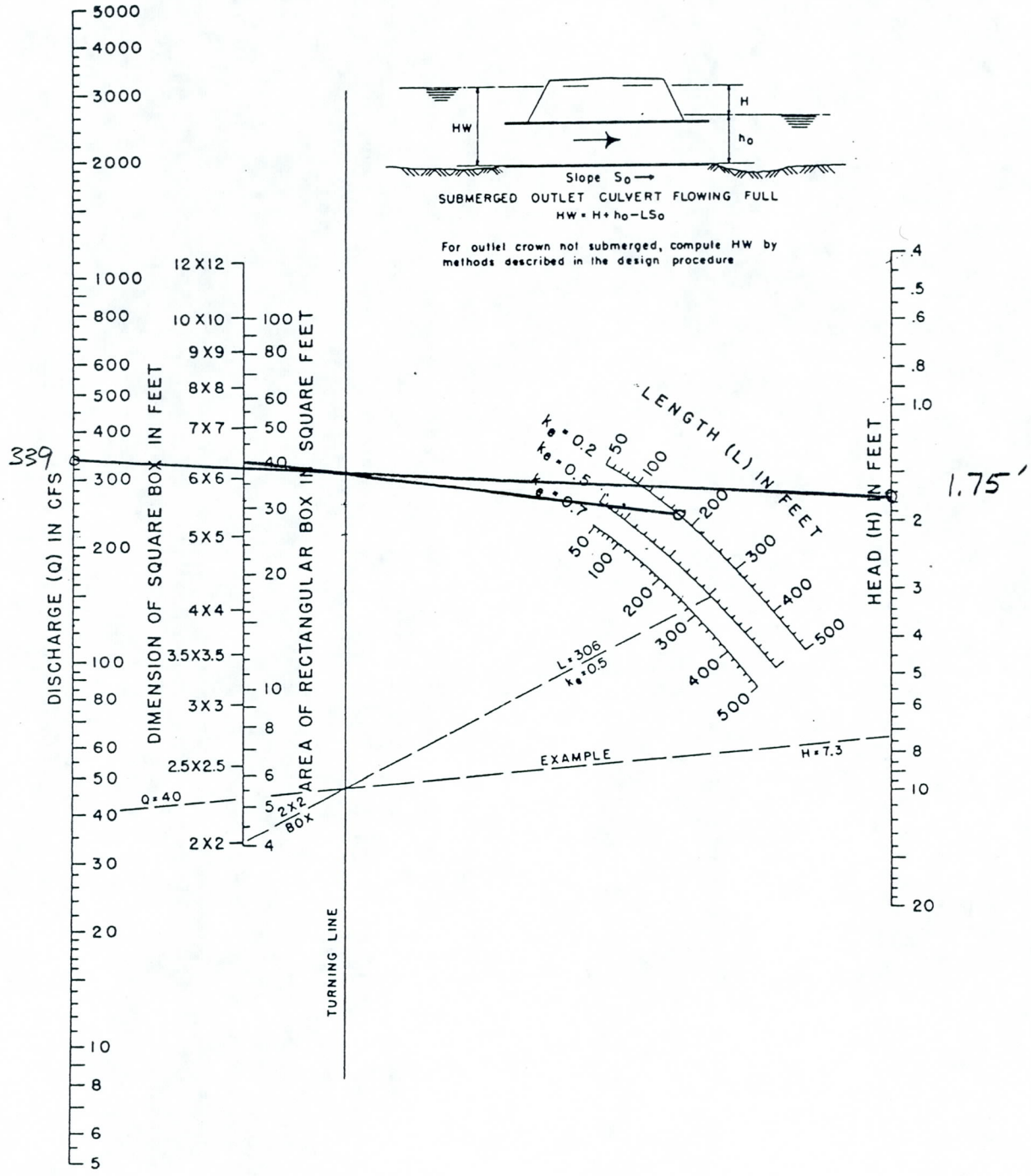


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1953

Culvert 60 D-6

CHART 8

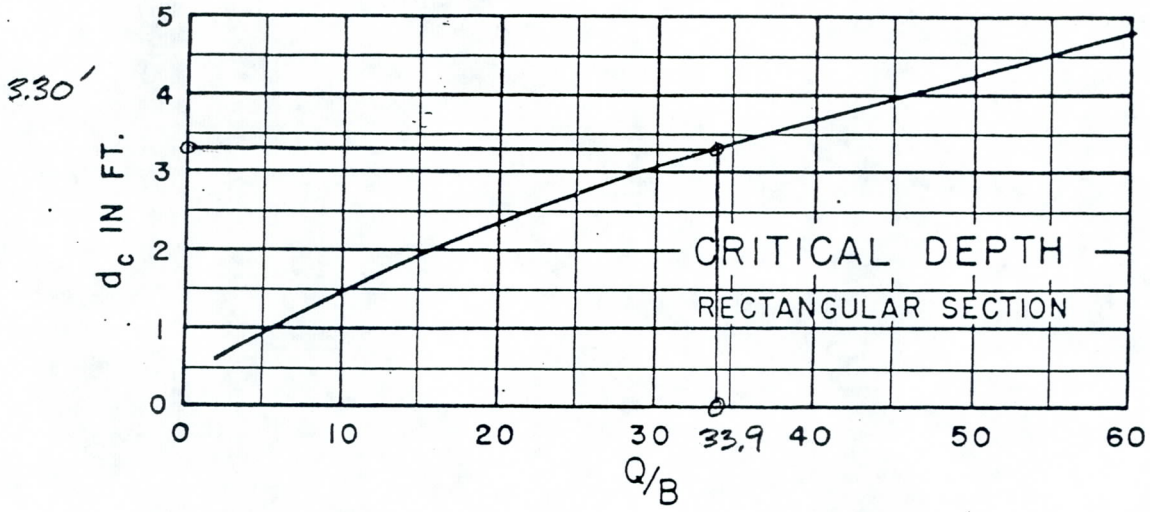


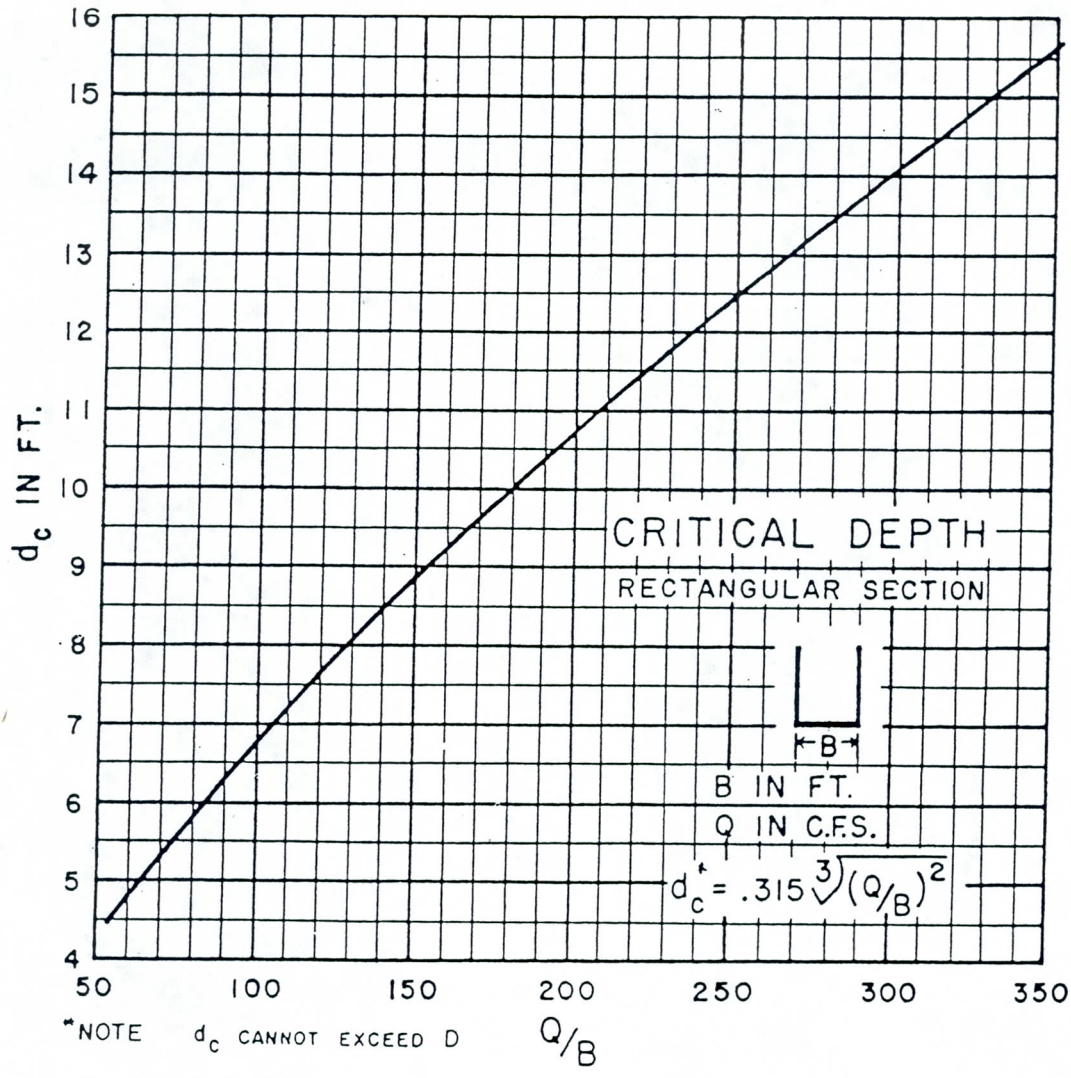
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60D-6

CHART 15





*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60 D-6

SHEET NO. 5 OF

DATE 7/13/91

BY BDO CHKD RJT

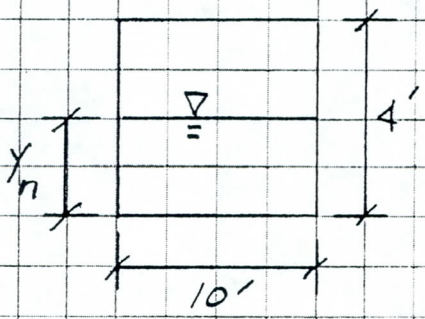
Check depth of Flow using Mannings Equation

$Q100 = 2034$ cfs, $Q = 339$ cfs/culvert

$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 2.67'$



$A = 26.7$ ft^2

$WP = 15.34$ ft

$R_h = A/WP = 26.7/15.34 = 1.7405'$

$V = \frac{1.49}{.012}(1.7405)^{.666}(.005)^{.5} = 12.70$ fps

Check

$Q = VA = 12.70(26.7) = 339$ cfs OK

Check Froude Number

$\# = \frac{12.70}{\sqrt{32.2 \times 2.67}} = 1.37$, Supercritical

$Q10 = 488/6 = 81$ cfs

$Y_n = 1.03'$, Velocity = 7.88 fps, $\# = 1.37$ Supercritical

Need riprap plunge basin to minimize erosion downstream of culvert

SVERDRUP

JOB 40477 Toyota

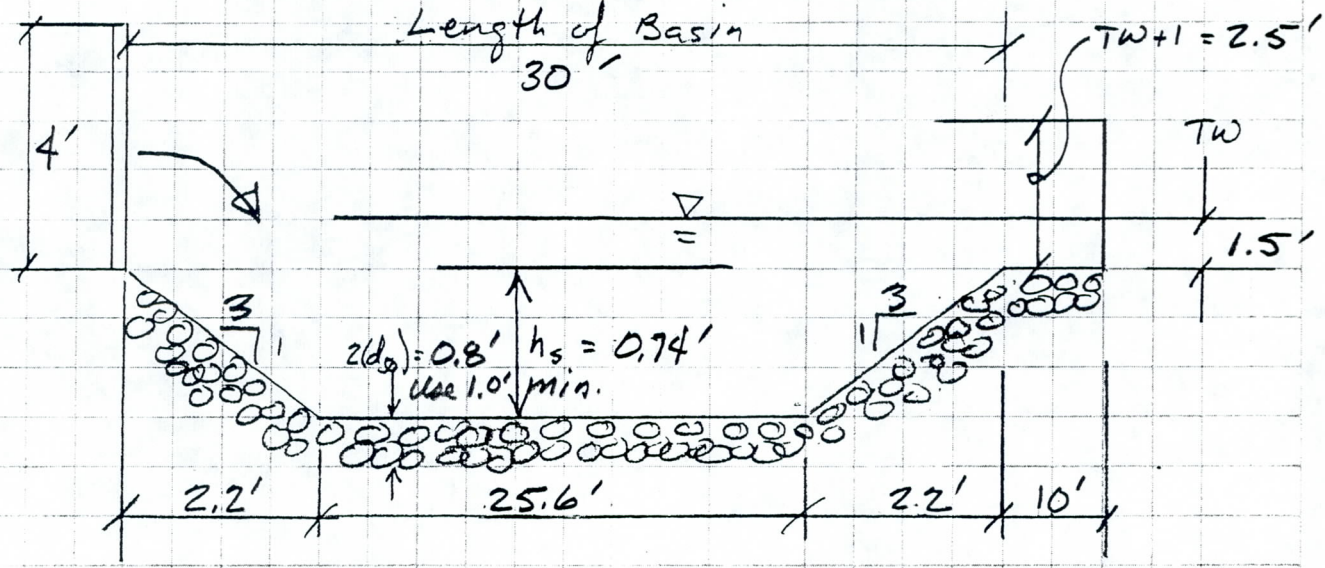
COMPUTATIONS FOR Box Culvert 60 D-6

SHEET NO. 6 OF

DATE 7/16/91

BY BDO CHKD RJT

Riprap Plunge Basin Design (Q10)



Check Rock Size (From Figure XI-2, HEC No. 14)

For $y_o = 1.03'$ $d_{50} = 4''$ or $0.33'$

$$d_{50}/y_o = \frac{0.33'}{1.03'} = 0.32 \quad , \quad F = 1.37$$

$$\frac{h_s}{y_o} = 0.72 \qquad h_s = 0.72\,(1.03') = 0.74'$$

Check $\dfrac{h_s}{d_{50}} = \dfrac{0.74'}{0.33'} = 2.24 < 4$ and > 2 ∴ OK

Length of Basin

$$10\,h_s = 10\,(0.74') = 7.4'$$

or

$$3(W_o) = 3(10) = 30'$$

Use 30'

Culvert 60 D-6

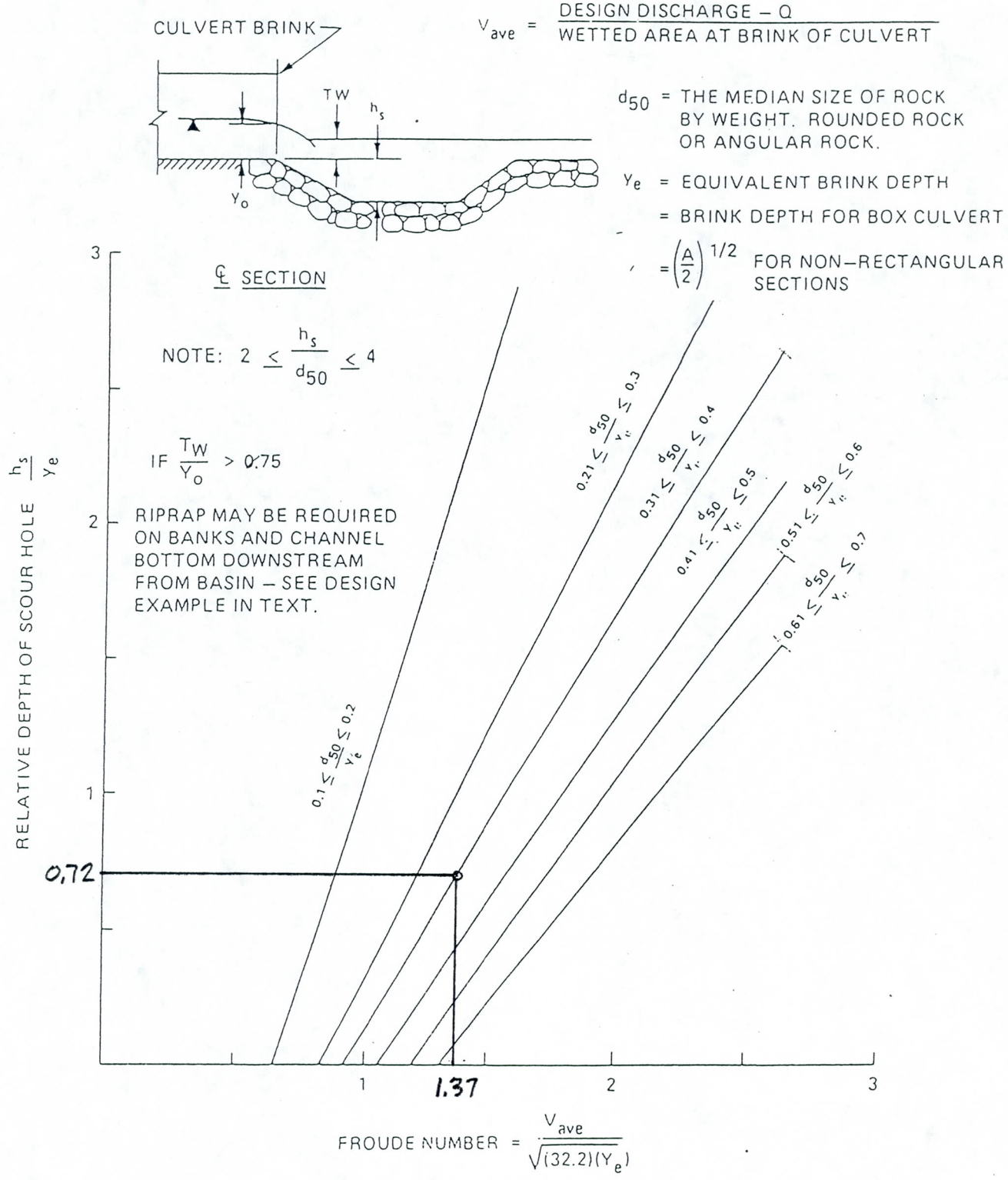


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

$TW/Y_o = \frac{1.46'}{1.03'} = 1.42 > 0.75$ ∴ Check downstream riprap lining for channel protection.

Utilize figure XI-3 for existing average velocity along channel. Compute equivalent circular diameter D_e for brink area from:

$A = \pi D_e^2/4 = Y_o(W_o) = 10.3\ ft^2$

$D_e = (10.3(4)/\pi)^{1/2} = 3.62'$

From downstream cross section Q10 velocity is 2.4 fps. Culvert outlet velocity is 7.9 fps.

L/D_e	L	V_L/V_o	V_L	
10	36.2	.59	4.7	
15	54.3	.36	2.8	
20	72.4	.30	2.4	OK

∴ Need riprap lining for approximately 70 feet from the end of the culvert outlet apron.

SVERDRUP

JOB 40477 Toyota

SHEET NO. 9 OF

DATE 7/15/91

COMPUTATIONS FOR Channel Downstream of Culvert 60 D-6

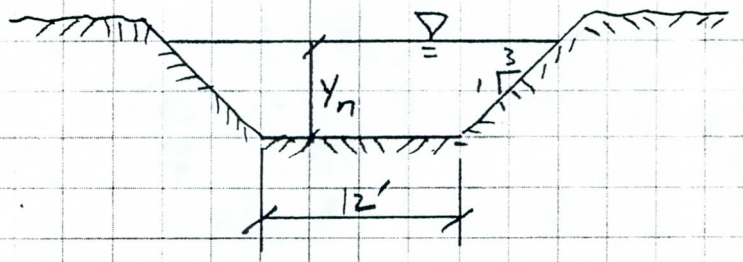
BY BDO CHKD RJT

Check depth of Flow and Velocity

$Q_{10} = 81$ cfs

$n = 0.03$

$S_o = 0.0040$ ft/ft



$Y_n \sim 1.46'$

$A = 23.88$ ft^2

$WP = 2(4.62) + 12 = 21.24$ ft

$R_h = A/WP = 23.88/21.24 = 1.1243'$

$$V = \frac{1.49}{.03}(1.1243)^{.666}(.004)^{.5} = 3.40 \text{ fps}$$

Check

$Q = VA = 3.40\,(23.88) = 81$ cfs

Check Froude Number $\quad D = A/T = 23.88/20.76 = 1.15'$

$$F = \frac{3.40}{\sqrt{32.2 \times 1.15'}} = 0.56, \text{ Subcritical}$$

$Q_{100} = 339$ cfs

$Y_n = 3.10'$, Velocity = 5.13 fps, $F = 0.62$, Subcritical

SVERDRUP

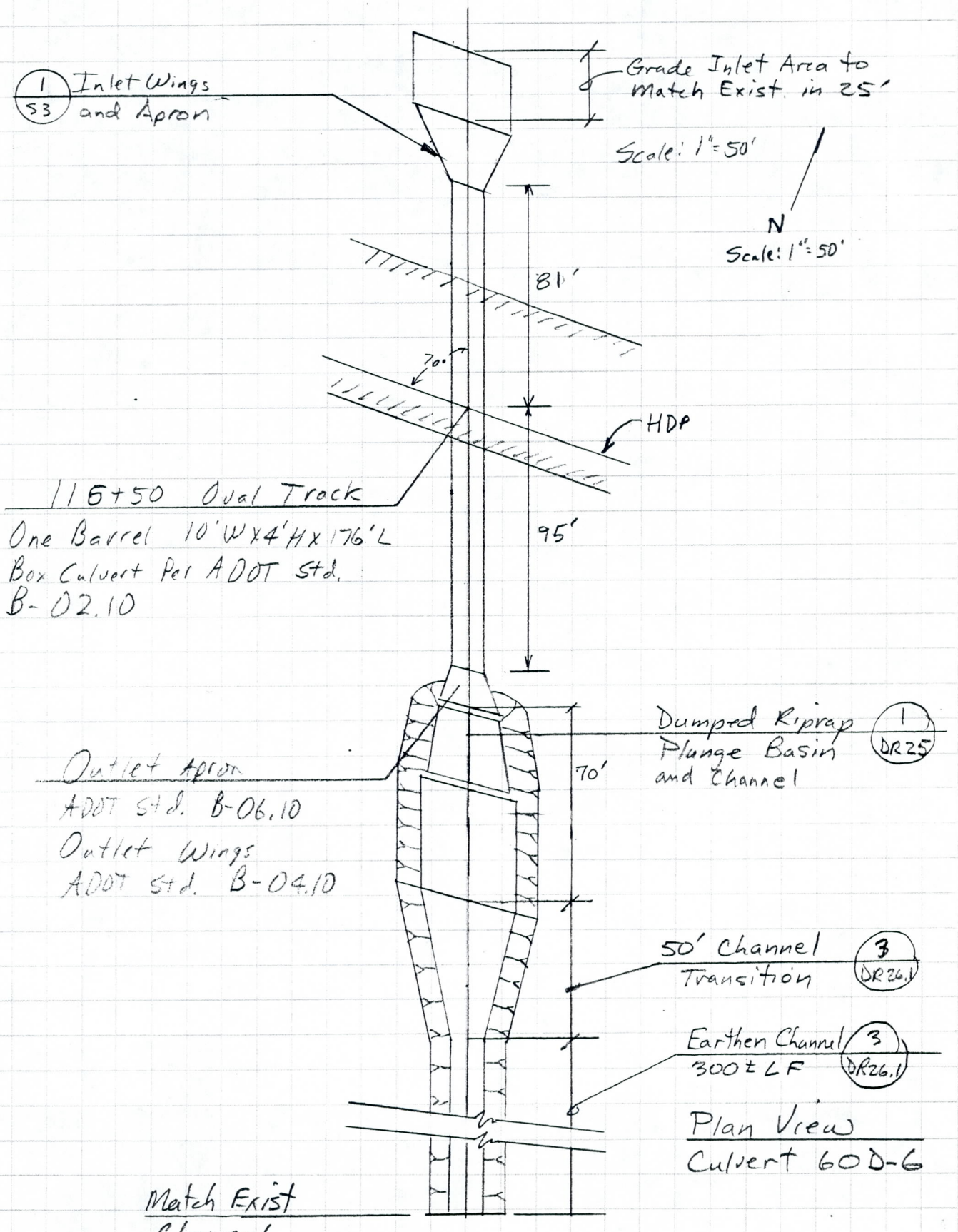
JOB 40477 Toyota

SHEET NO. 10 OF

DATE 7-20-91

COMPUTATIONS FOR Culvert 60 D-6 Plan View
HDP Sta 116+50 16A

BY BDO CHKD RJT



SVERDRUP

JOB 40477 Tayoh

COMPUTATIONS FOR Culvert Profile 60D-6 HST Sta. 116+50

SHEET NO. 11 OF

DATE 7-16-91

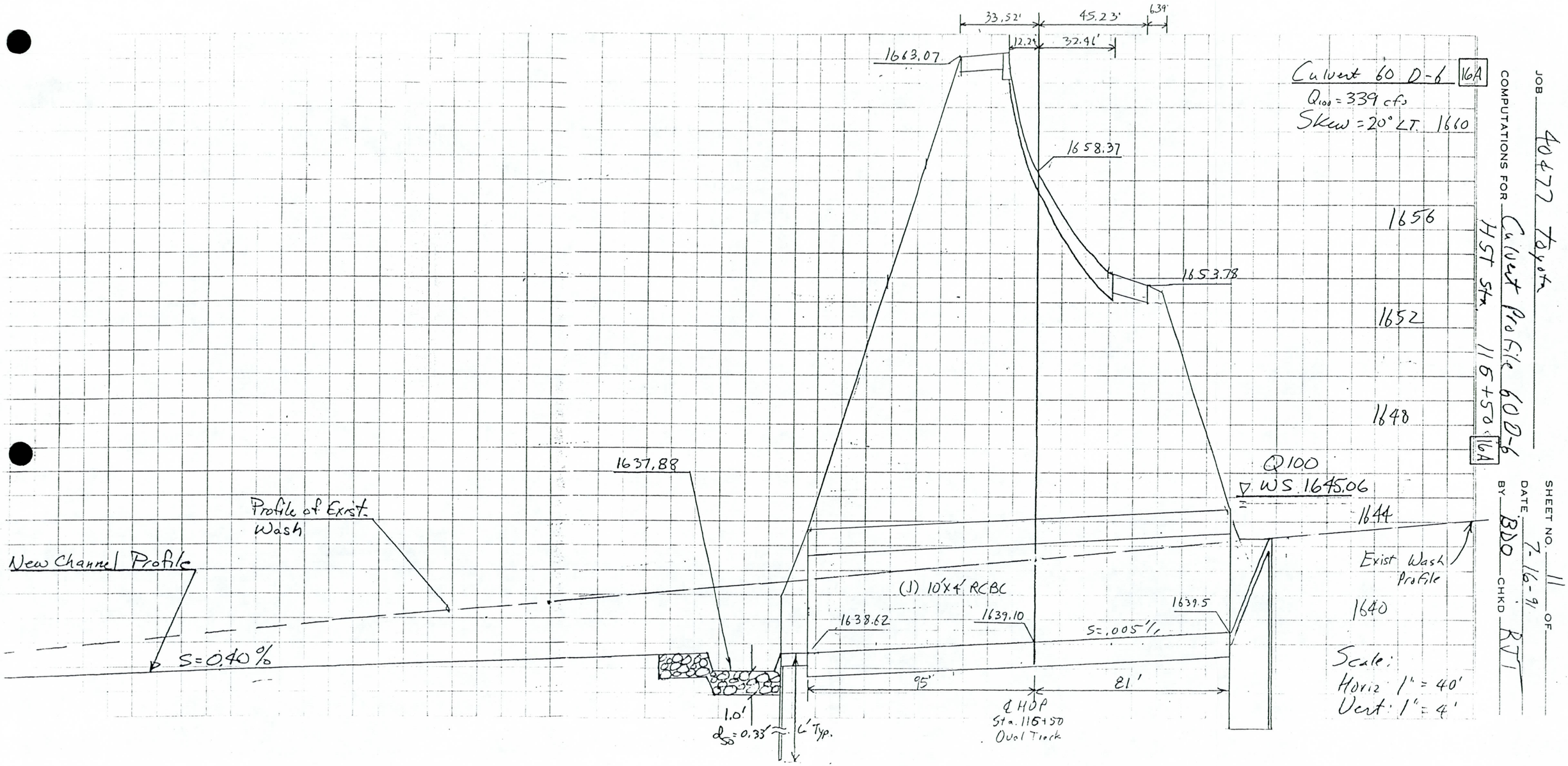
BY BDO CHKD RVT

Culvert 60 D-6 16A

Q_{100} = 339 cfs

Skew = 20° LT

16A



Scale:
Horiz 1" = 40'
Vert 1" = 4'

SECTION NUMBER TW60D6 7/10/91

Channel Slope: 0.0086 ft./ft.

CROSS SECTION DATA:

OFFSET	0	85.6	136.6	139	139.8	141	172.9	174.8	176	177.4	187.3	188.9	189.7	191.2	266
ELEV.	44	42.64	42.49	42.03	41.93	42.44	42.41	40.74	40.7	42.86	42.43	41.88	41.72	42.6	43.11
N	N/A	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.025	0.035	0.035

STAGE-DISCHARGE DATA:

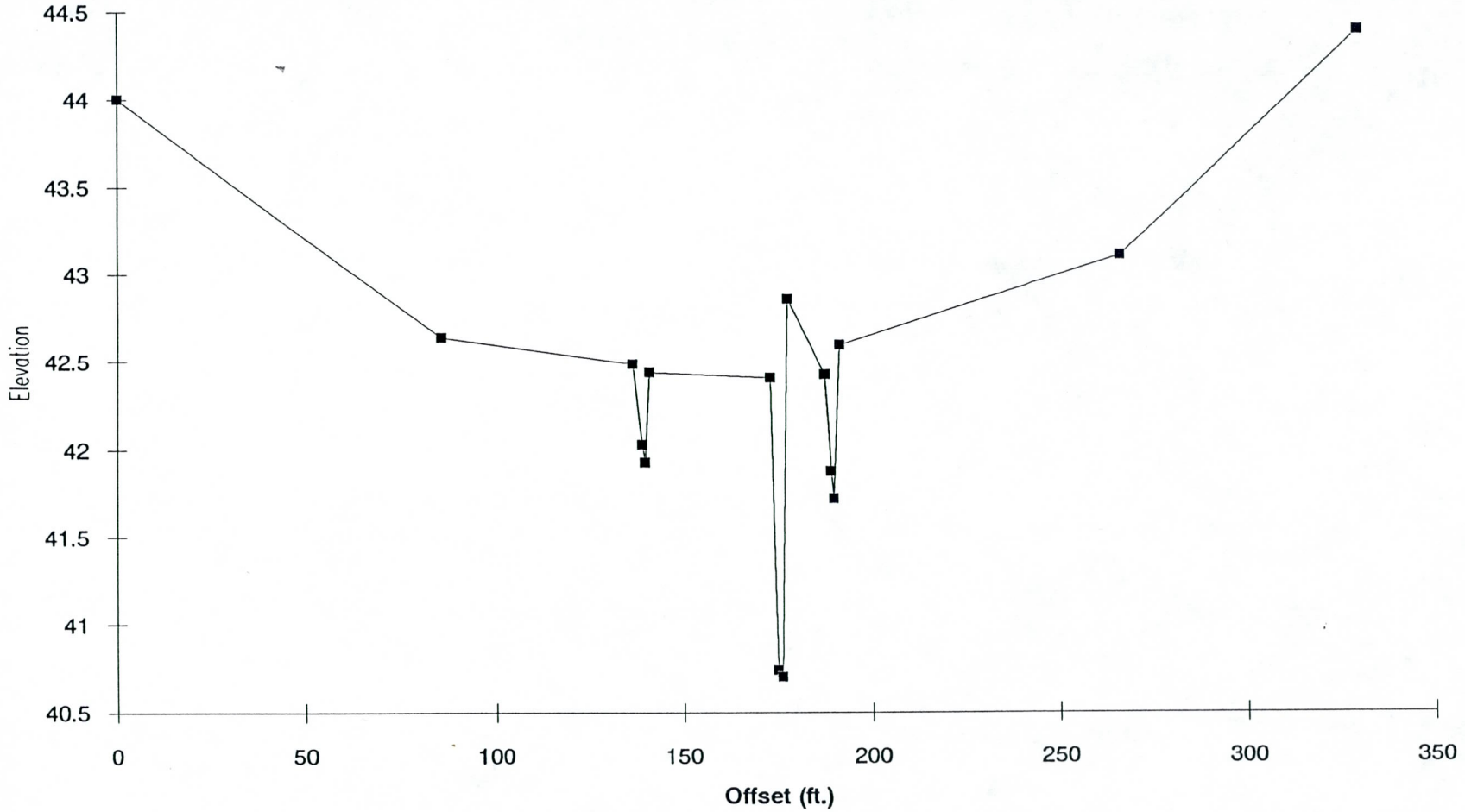
STAGE: 40.7														
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE: 40.95														
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.2	0.3	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	1	0	0	0	0	0	0
STAGE: 41.2														
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.2	0.6	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.1	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.1	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	2	0	0	0	0	0	0
STAGE: 41.45														
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	1.1	1.2	0.9	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.9	0.2	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.7	0.2	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	4	0	0	0	0	0	0
STAGE: 41.7														
WET PER.	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.2	1.2	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.2	0.3	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.0	0.3	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	1	6	1	0	0	0	0	0
STAGE: 41.95														
WET PER.	0.0	0.0	0.0	0.2	0.1	0.0	1.8	1.2	1.5	0.0	0.2	0.8	0.5	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.5	0.5	0.0	0.0	0.1	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.2	0.3	0.0	0.0	0.1	0.1	0.0
Q	0	0	0	0	0	0	2	9	1	0	0	0	0	0

SECTION NUMBER TW60D6 7/10/91

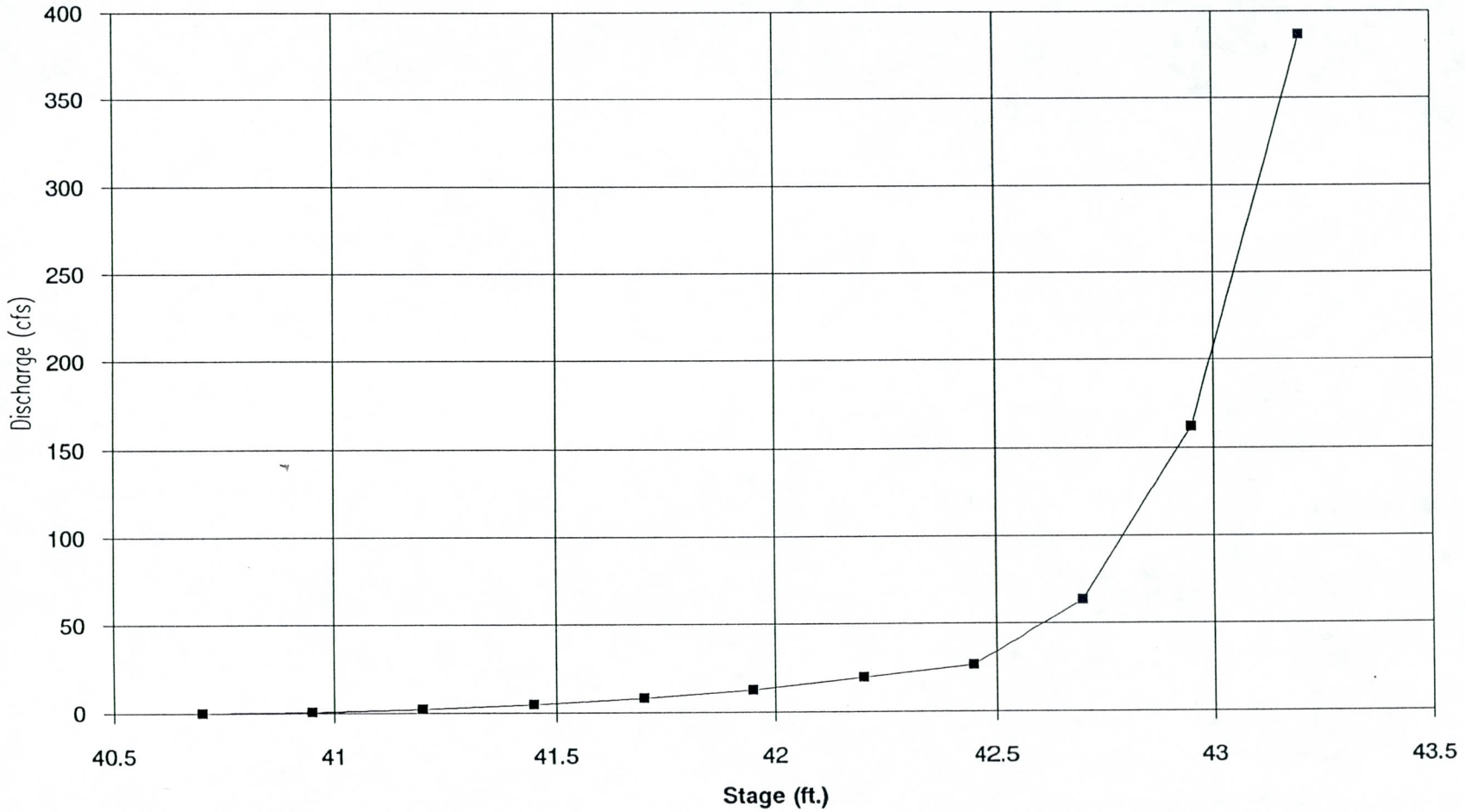
STAGE:	42.2													
WET PER.		0.0	0.0	0.9	0.8	0.7	0.0	2.2	1.2	1.8	0.0	1.0	0.8	1.0	0.0
AREA		0.0	0.0	0.1	0.2	0.1	0.0	1.2	1.8	0.7	0.0	0.1	0.3	0.2	0.0
HYD.RAD.		0.0	0.0	0.1	0.2	0.1	0.0	0.5	1.5	0.4	0.0	0.2	0.4	0.2	0.0
Q		0	0	0	0	0	0	3	13	2	0	0	1	0	0
STAGE:	42.45														
WET PER.		0.0	0.0	2.2	0.8	1.3	33.2	35.7	1.2	2.1	0.5	2.2	0.8	1.4	0.0
AREA		0.0	0.0	0.5	0.4	0.3	1.1	2.8	2.1	1.0	0.0	0.5	0.5	0.5	0.0
HYD.RAD.		0.0	0.0	0.2	0.5	0.2	0.0	0.1	1.7	0.5	0.0	0.2	0.6	0.3	0.0
Q		0	0	1	1	0	0	2	16	2	0	1	2	1	0
STAGE:	42.7														
WET PER.		3.8	54.8	57.2	0.8	1.3	33.2	35.7	1.2	2.4	6.2	7.9	0.8	1.7	16.4
AREA		0.1	7.0	8.1	0.6	0.6	9.4	11.5	2.4	1.3	0.8	1.7	0.7	0.8	1.5
HYD.RAD.		0.0	0.1	0.1	0.7	0.5	0.3	0.3	2.0	0.5	0.1	0.2	0.9	0.5	0.1
Q		0	0	9	3	0	0	21	21	3	0	2	4	0	1
STAGE:	42.95														
WET PER.		19.5	70.5	73.0	0.8	1.3	33.2	35.7	1.2	2.6	12.5	14.2	0.8	1.7	53.1
AREA		3.0	22.7	24.3	0.8	0.9	17.7	20.3	2.7	1.6	4.7	5.9	0.9	1.2	10.2
HYD.RAD.		0.2	0.3	0.3	1.0	0.7	0.5	0.6	2.2	0.6	0.4	0.4	1.1	0.7	0.2
Q		0	0	46	4	0	0	55	25	0	0	13	5	0	13
STAGE:	43.2														
WET PER.		35.3	86.3	88.7	0.8	1.3	33.2	35.7	1.2	2.6	12.5	14.2	0.8	1.7	76.5
AREA		9.9	42.3	44.5	1.0	1.2	25.9	29.0	3.0	2.0	7.5	9.2	1.1	1.6	27.4
HYD.RAD.		0.3	0.5	0.5	1.2	0.9	0.8	0.8	2.5	0.8	0.6	0.6	1.4	0.9	0.4
Q		0	0	111	6	0	0	99	30	0	0	27	8	0	0

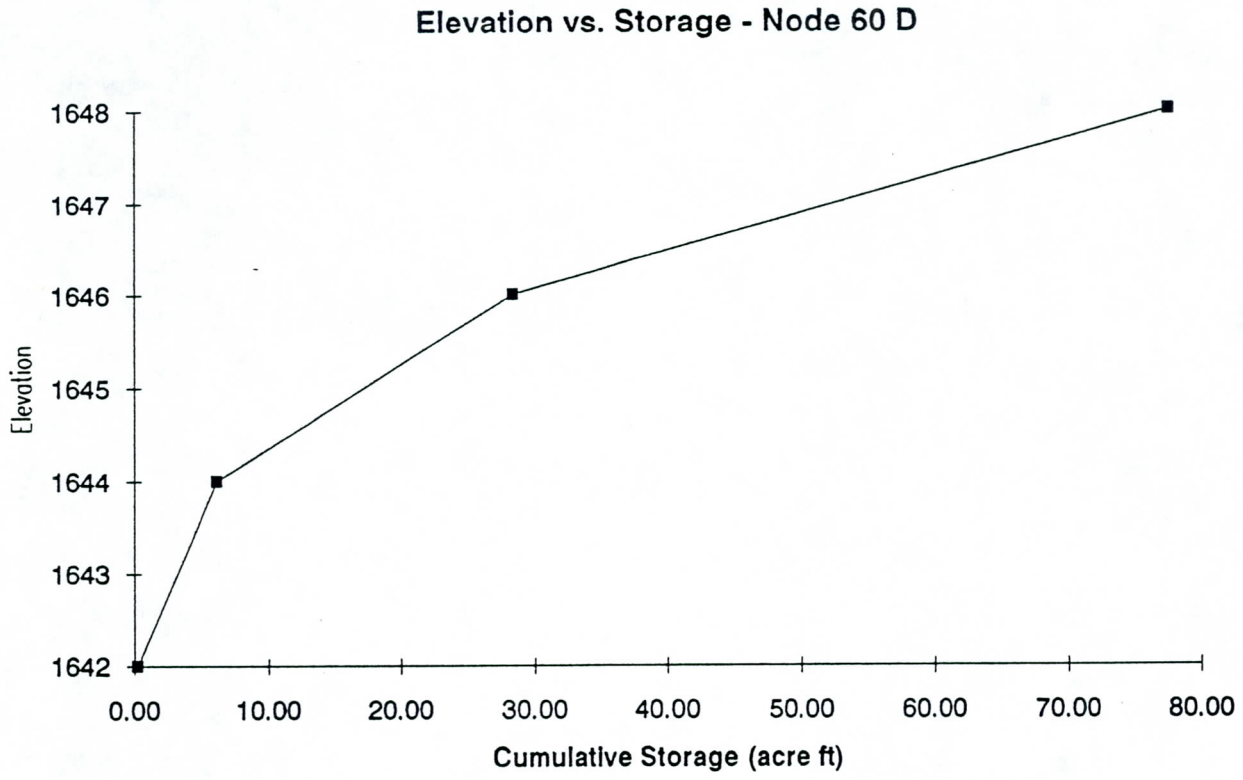
W.S. Elev.	40.7	40.95	41.2	41.45	41.7	41.95	42.2	42.45	42.7	42.95	43.2
Q	0	1	2	5	8	12	19	26	64	162	387
A	0.0	0.3	0.8	1.3	2.0	3.0	4.7	8.1	27.8	65.1	142.9
V	0.0	1.9	2.8	3.4	3.9	4.2	4.1	3.2	2.3	2.5	2.7

Cross Section - TW Cul 60 D-6



Stage Discharge - TW Cul 60 D-6




Elevation vs. Storage - Node 60 D
1648
1647
1646
1645
1644
1643
1642
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Cumulative Storage (acre ft)

SVERDR

JOB 4047 Toyota

COMPUTATIONS FOR Culvert 60 D-5 16B

SHEET NO. ____ OF ____

DATE 7/12/91

BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT: ____

STATION: 112+60, Oval Track

DESIGNER: ____

DATE: ____

HYDROLOGIC AND CHANNEL INFORMATION

2034/6 = 339 cfs

DRAINAGE AREA 10.98 sq. mils

Q_1 = 339 cfs

Q_2 = ____

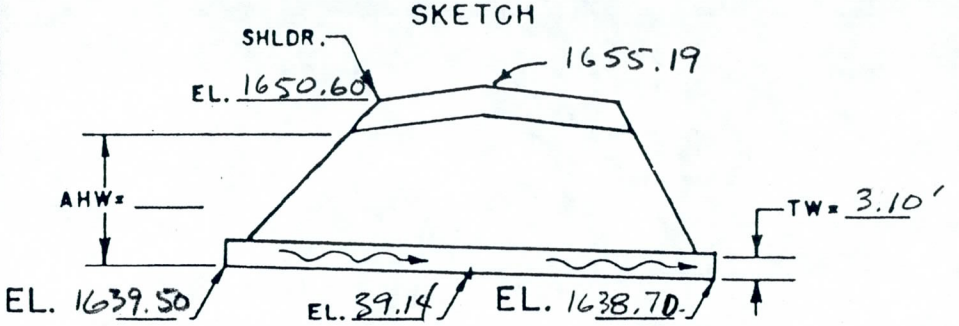
TW_1 = 2.0' Exist Channel

TW_2 = 3.10' New Channel

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY Q_{25}.
Q_2 = CHECK DISCHARGE, SAY Q_{50}) Q100

SKETCH



S_o = 0.0050 ft/ft L = 160' L/100 S_o = ____

MEAN STREAM VELOCITY = 3.3 fps

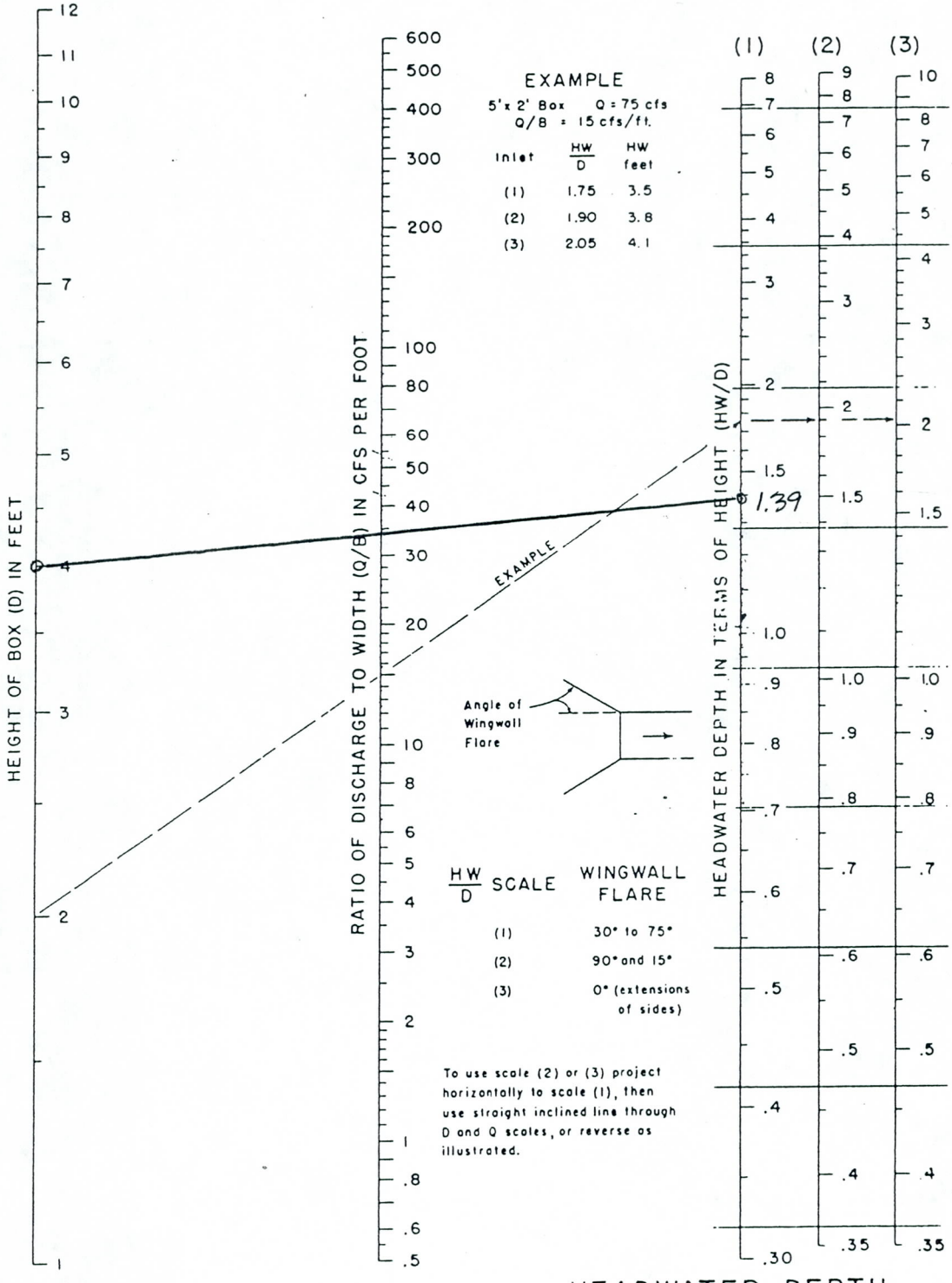
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(1) Barrel 10'x4'	Drop Inlet	339		1.39	5.56	0.2	1.75	3.30'	3.65	3.10	3.65	0.80	4.60	5.56	12.7		1645.06	Inlet Control

SUMMARY & RECOMMENDATIONS Use dumped riprap plunge basin for outlet erosion protection.

B-1

Culvert 60 D-5

CHART I

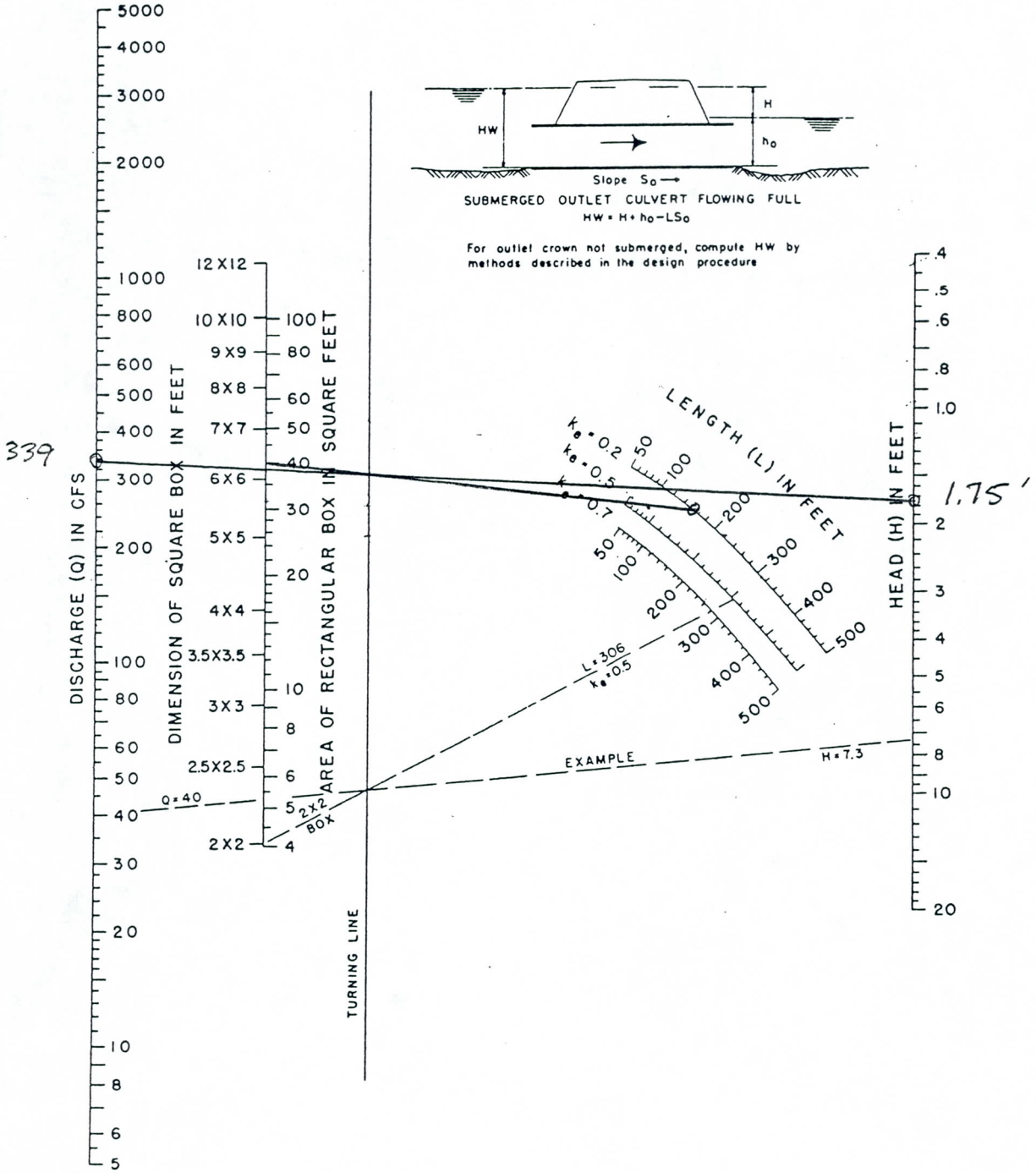


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1953

Culvert 60 D-5

CHART 8

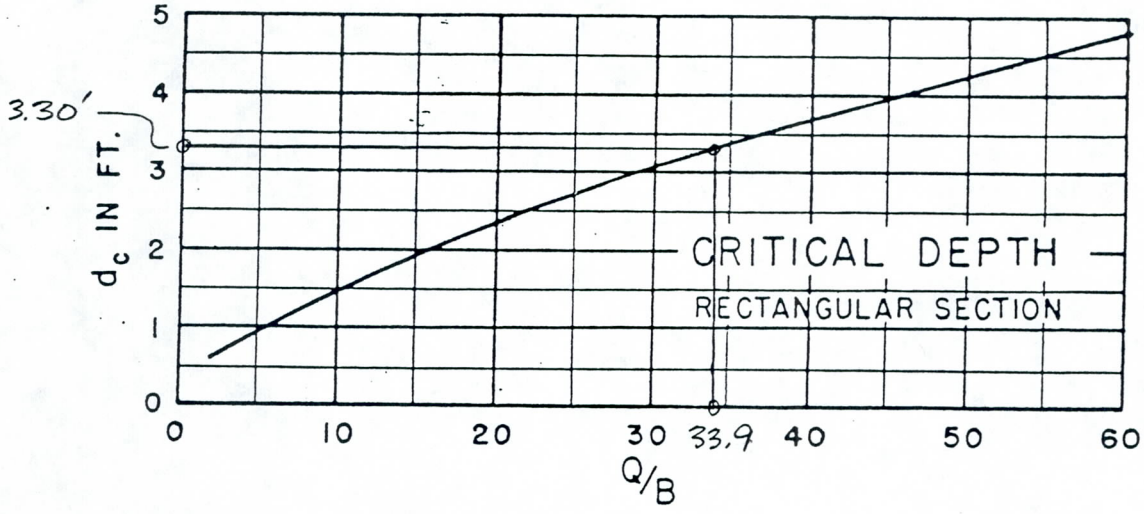


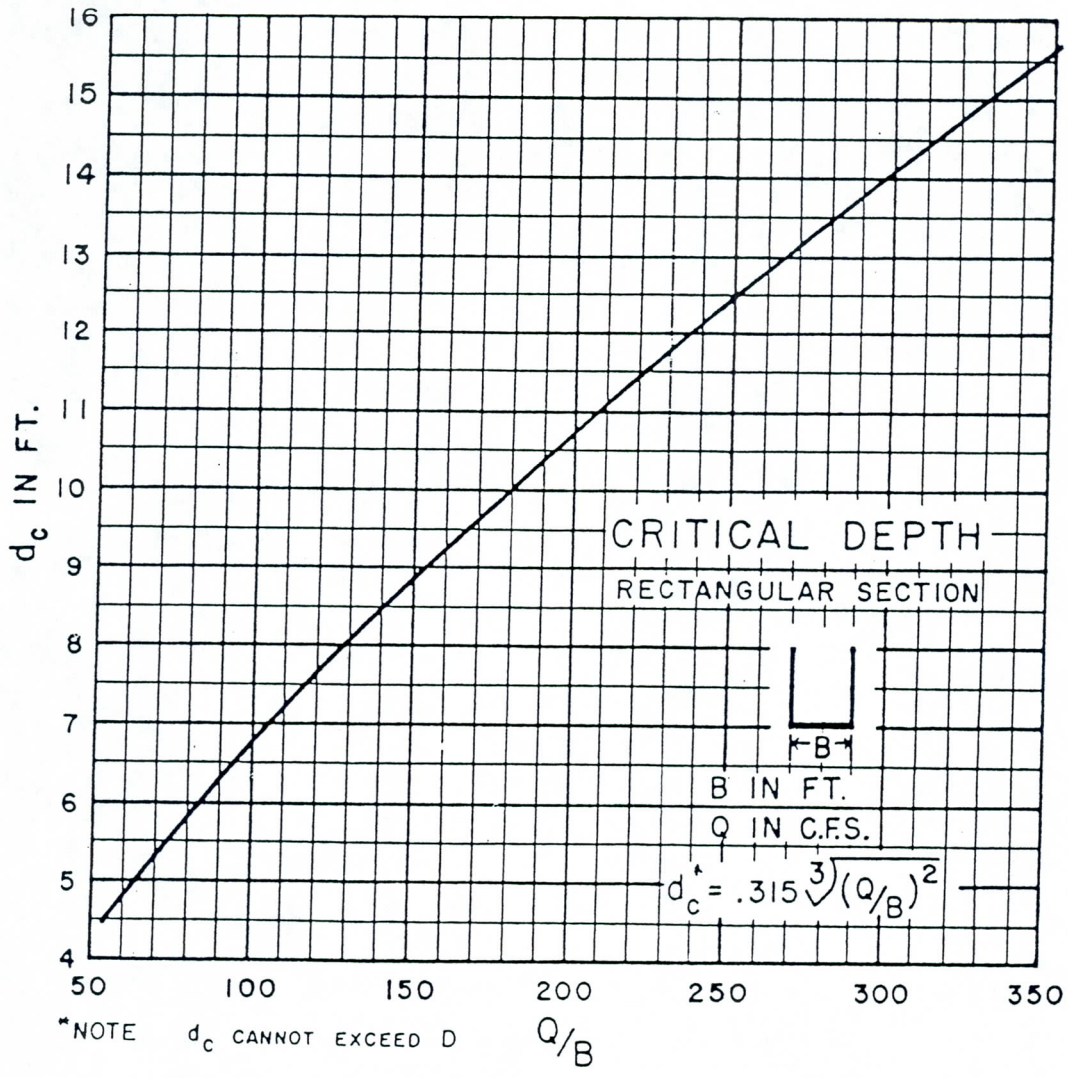
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 D-5

CHART 15





BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60 D-5

SHEET NO. 5 OF

DATE 7/13/91

BY BDO CHKD RJT

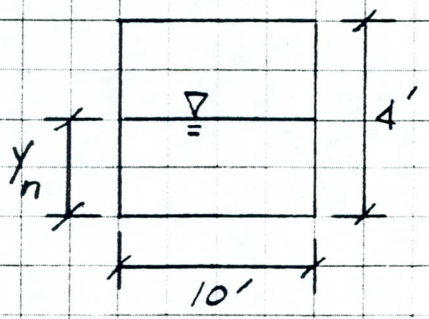
Check depth of Flow using Mannings Equation

$Q100 = 2034$ cfs, $Q = 339$ cfs/culvert

$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 2.67'$



$A = 26.7$ ft^2

$WP = 15.34$ ft

$R_h = A/WP = 26.7/15.34 = 1.7405'$

$V = \frac{1.49}{.012}(1.7405)^{.666}(.005)^{.5} = 12.70$ fps

Check

$Q = VA = 12.70\,(26.7) = 339$ cfs (OK)

Check Froude Number

$\# = \frac{12.70}{\sqrt{32.2 \times 2.67}} = 1.37$, Supercritical

$Q10 = 488/6 = 81$ cfs

$Y_n = 1.03'$, Velocity = 7.88 fps, $\# = 1.37$ Supercritical

Need riprap plunge basin to minimize erosion downstream of culvert

SVERDRUP

JOB 40477 Toyota

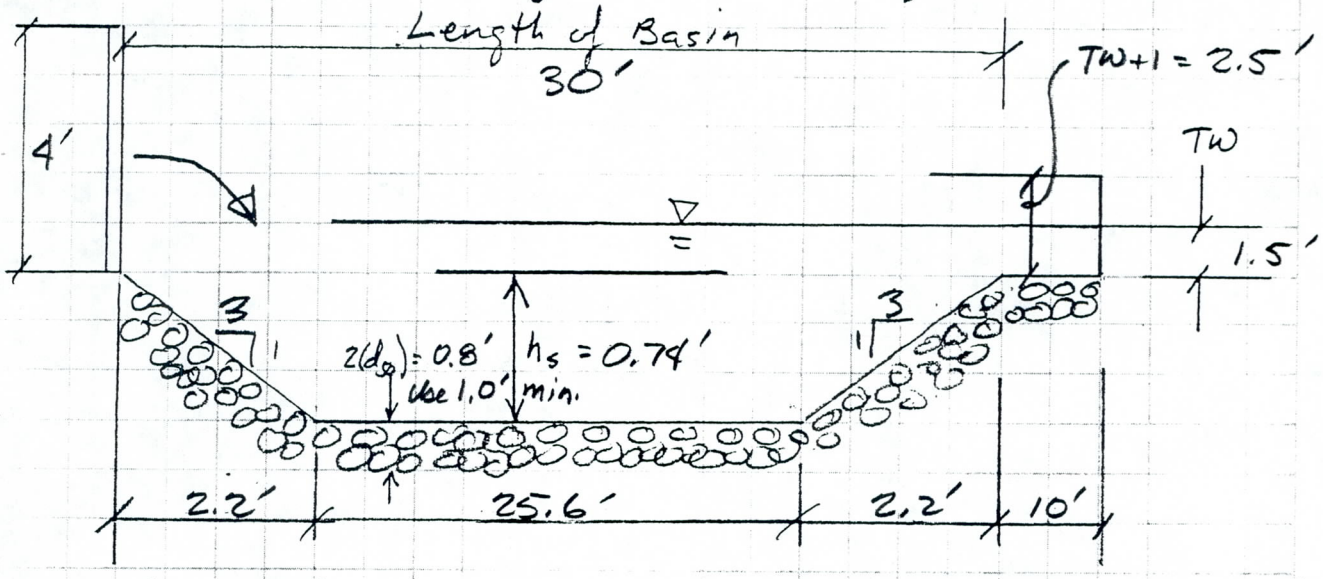
COMPUTATIONS FOR Box Culvert 60 D-5

SHEET NO. 6 OF

DATE 7/15/91

BY BDO CHKD RJT

Riprap Plunge Basin Design (Q10)



Check Rock Size (From Figure XI-2, HEC No. 14)

For $y_o = 1.03'$ $d_{50} = 4''$ or $0.33'$

$$d_{50}/y_o = \frac{0.33'}{1.03'} = 0.32 \quad , \; FF = 1.37$$

$$\frac{h_s}{y_o} = 0.72 \qquad h_s = 0.72(1.03') = 0.74'$$

Check $\frac{h_s}{d_{50}} = \frac{0.74'}{0.33'} = 2.24 < 4$ and > 2

Length of Basin

$10\,h_s = 10(0.72) = 7.2'$

or

$3(W_o) = 3(10) = 30'$

Use 30'

Culvert 60 D-5

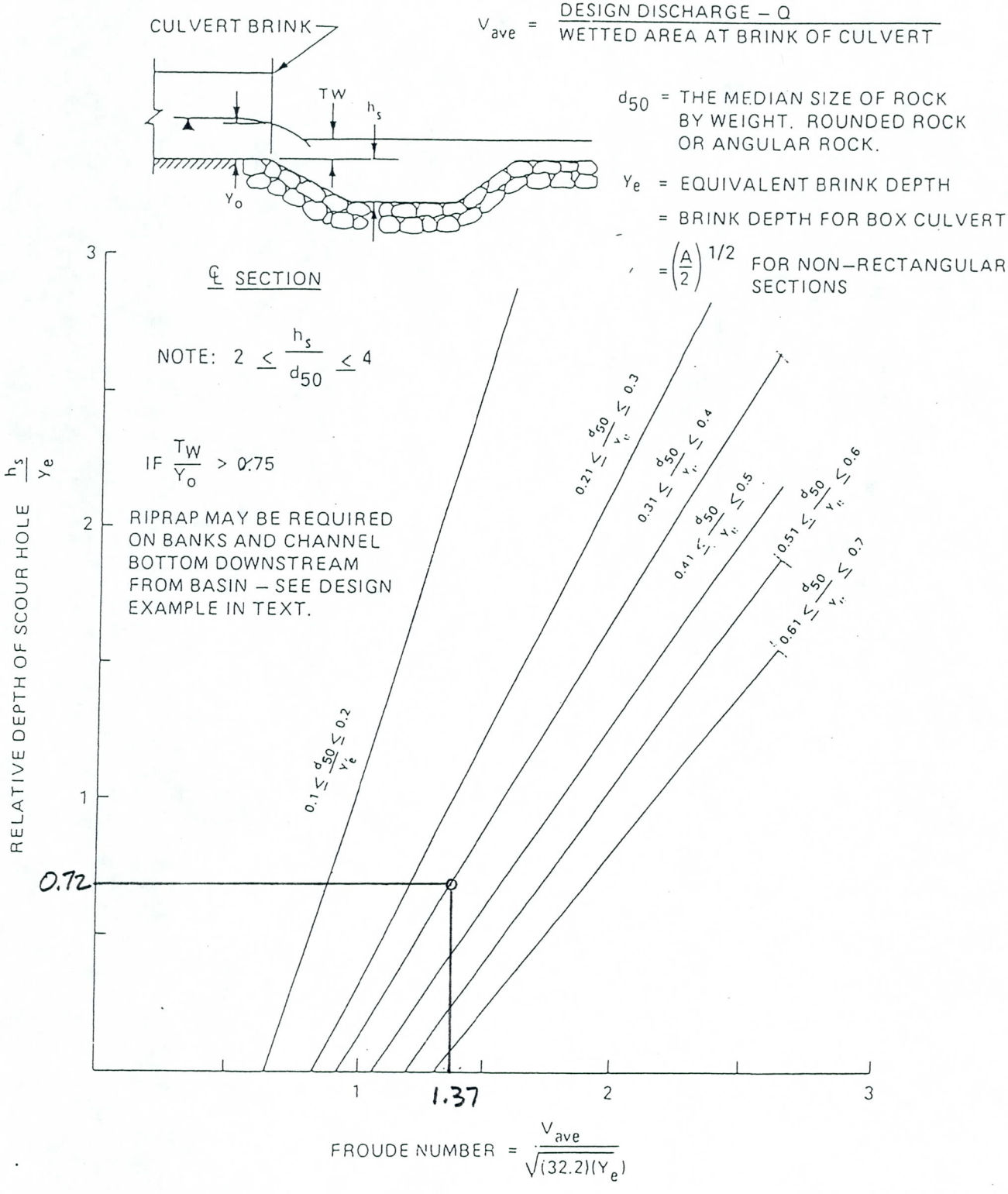


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota

SHEET NO. 8 OF

COMPUTATIONS FOR Box Culvert 60 D-5

DATE 7/15/91

BY BDO CHKD RJT

$TW/Y_o = \frac{1.5'}{1.03'} = 1.46 > 0.75$ ∴ Check downstream riprap lining for channel protection.

Utilize figure XI-3 for existing average velocity along channel, Compute equivalent circular diameter D_e for brink area from:

$A = \pi D_e^2/4 = Y_o(W_o) = 1.03(10) = 10.3\ ft^2$

$D_e = (10.3(4)/\pi)^{1/2} = 3.62'$

From downstream cross section Q10 velocity is 3.3 fps, Culvert outlet velocity is 7.9 fps.

L/D_e	L	V_L/V_o	V_L
10	36.2	.59	4.7
13	47.0	.43	3.4
14	50.7	.40	3.2

∴ Need riprap lining for approximately 50 feet from the end of the culvert outlet apron.

SVERDRUP

JOB 40477 Toyota

SHEET NO. 9 OF

DATE 7/15/91

COMPUTATIONS FOR Channel Downstream of Culvert 60 D-5

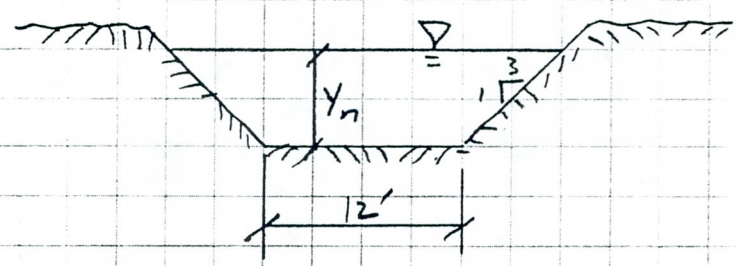
BY BDO CHKD RJT

Check depth of Flow and Velocity

$Q10 = 81$ cfs

$n = 0.03$

$S_o = 0.0040$ ft/ft



$Y_n \sim 1.46'$

$A = 23.88\ ft^2$

$WP = 2(4.62) + 12 = 21.24$ ft

$R_h = A/WP = 23.88/21.24 = 1.1243'$

$$V = \frac{1.49}{.03}(1.1243)^{.666}(.004)^{.5} = 3.40 \text{ fps}$$

Check

$Q = VA = 3.40\,(23.88) = 81$ cfs

Check Froude Number $\quad D = A/T = 23.88/20.76 = 1.15'$

$$F = \frac{3.40}{\sqrt{32.2 \times 1.15'}} = 0.56, \text{ Subcritical}$$

$Q100 = 339$ cfs

$Y_n = 3.10'$, Velocity = 5.13 fps, $F = 0.62$, Subcritical

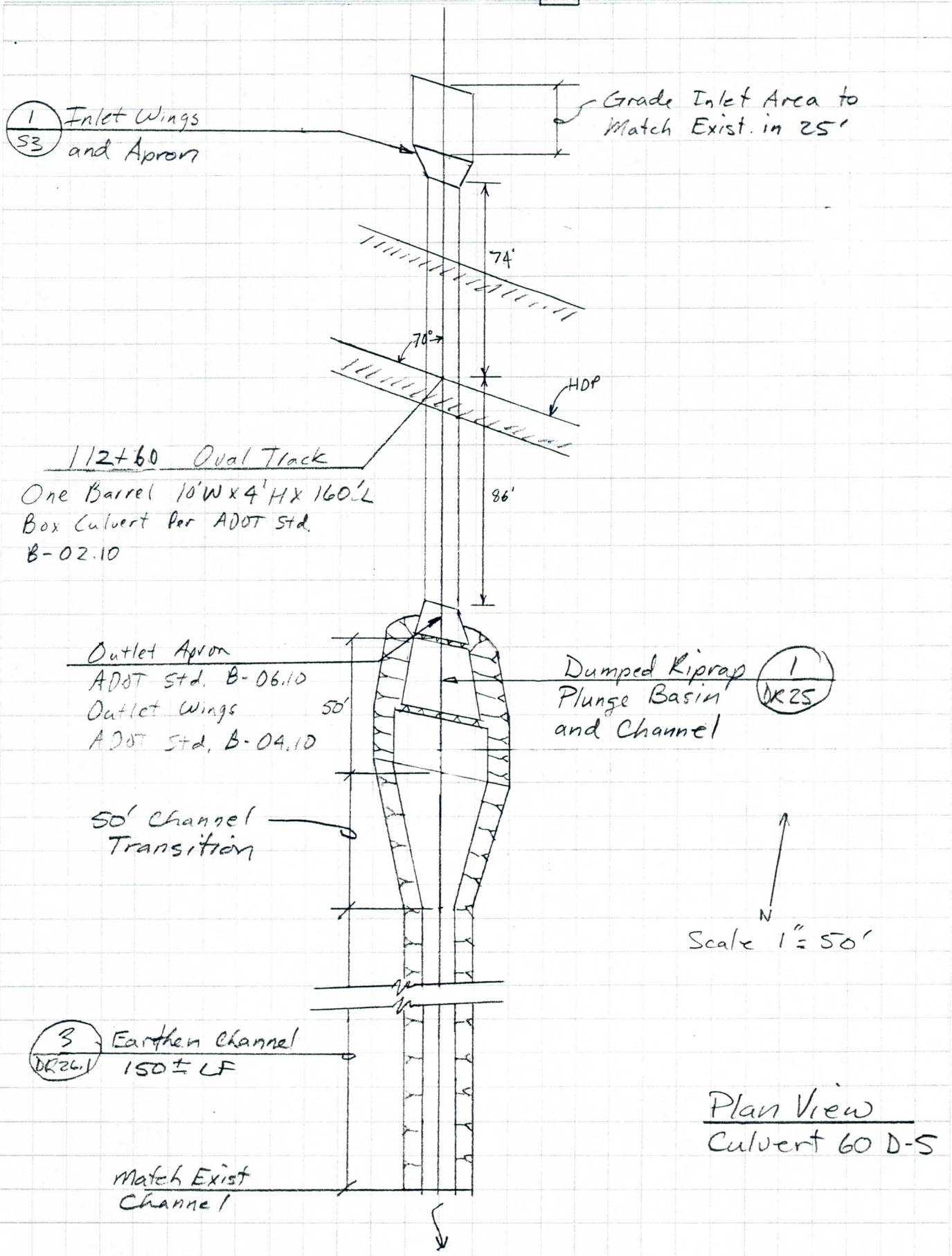
SVERDRUP

JOB 40477 Toyota SHEET NO. 10 OF

DATE 7-20-91

COMPUTATIONS FOR Culvert 60 D-5 Plan View BY BDO CHKD RJT

HDP Sta. 112+60 16B



Plan View
Culvert 60 D-5

SVERDRUP

JOB 48477 Toyota

COMPUTATIONS FOR Culvert Profile 60D-5 MST Sta 1127+60 16B

SHEET NO. 11 OF

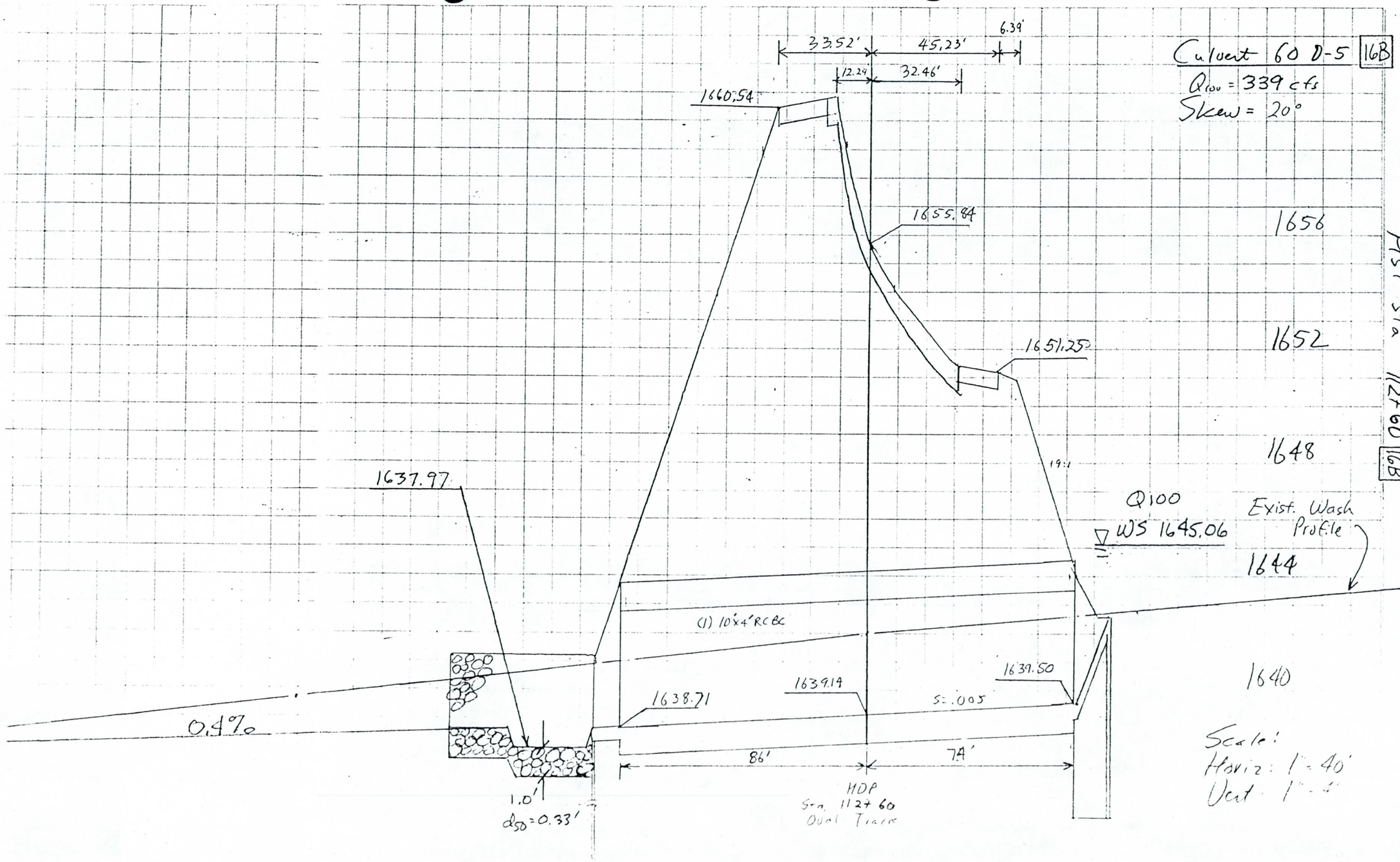
DATE 7-14-6

BY BDO CHKD RJT

Culvert 60 D-5 16B

Q_{100} = 339 cfs

Skew = 20°



Scale:
Horiz: 1" = 40'
Vert: 1" = 5'

SECTION NUMBER TW60D5 7/10/91

Channel Slope: 0.0113 ft./ft.

CROSS SECTION DATA:

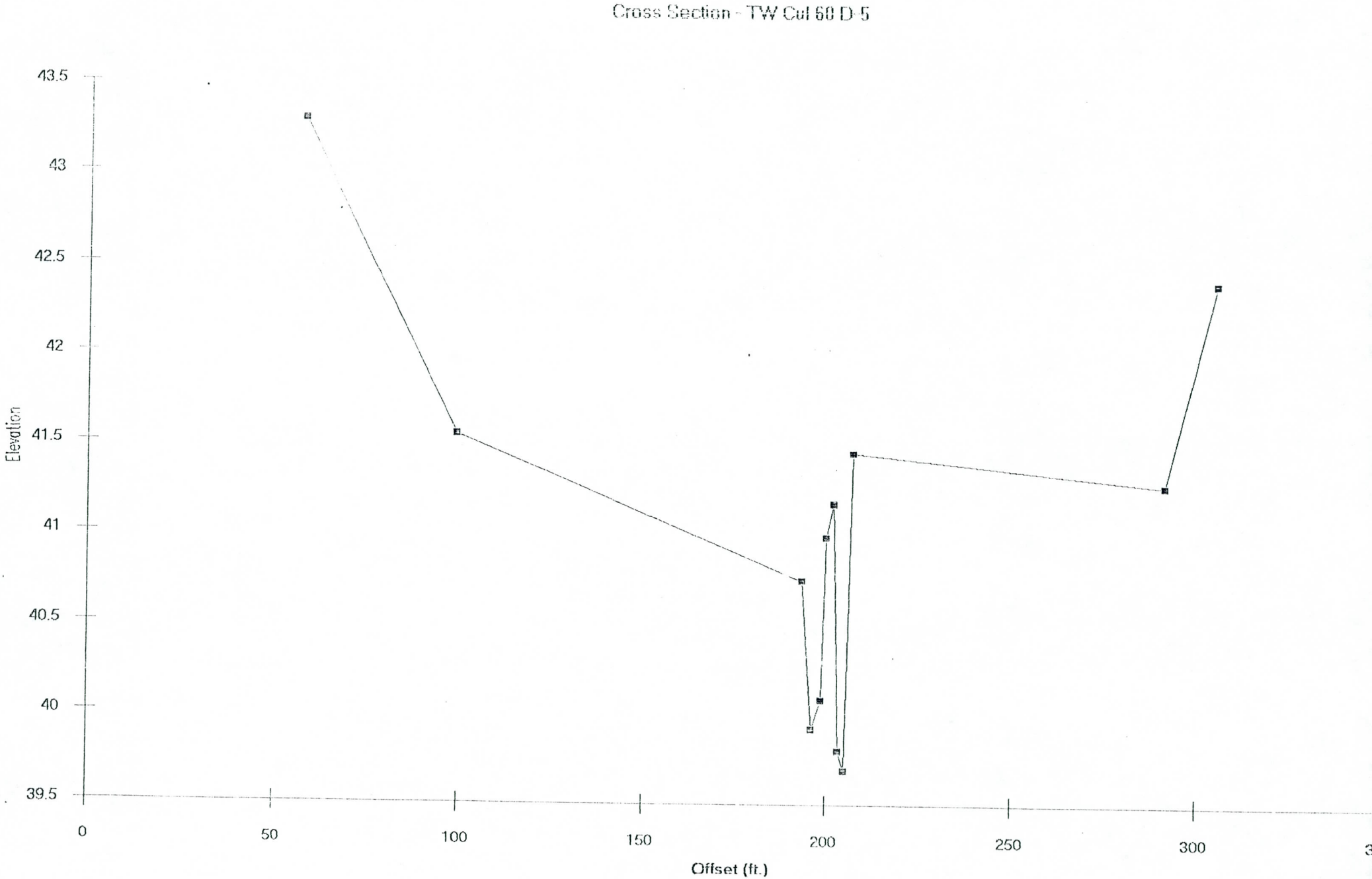
OFFSET	58	99.3	193.5	196.1	198.7	200.1	202	203.5	205.1	207.2	291.3	305
ELEV.	43.3	41.55	40.74	39.92	40.08	40.98	41.17	39.8	39.69	41.45	41.27	42.4
N	N/A	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.025	0.035	0.035	0.035

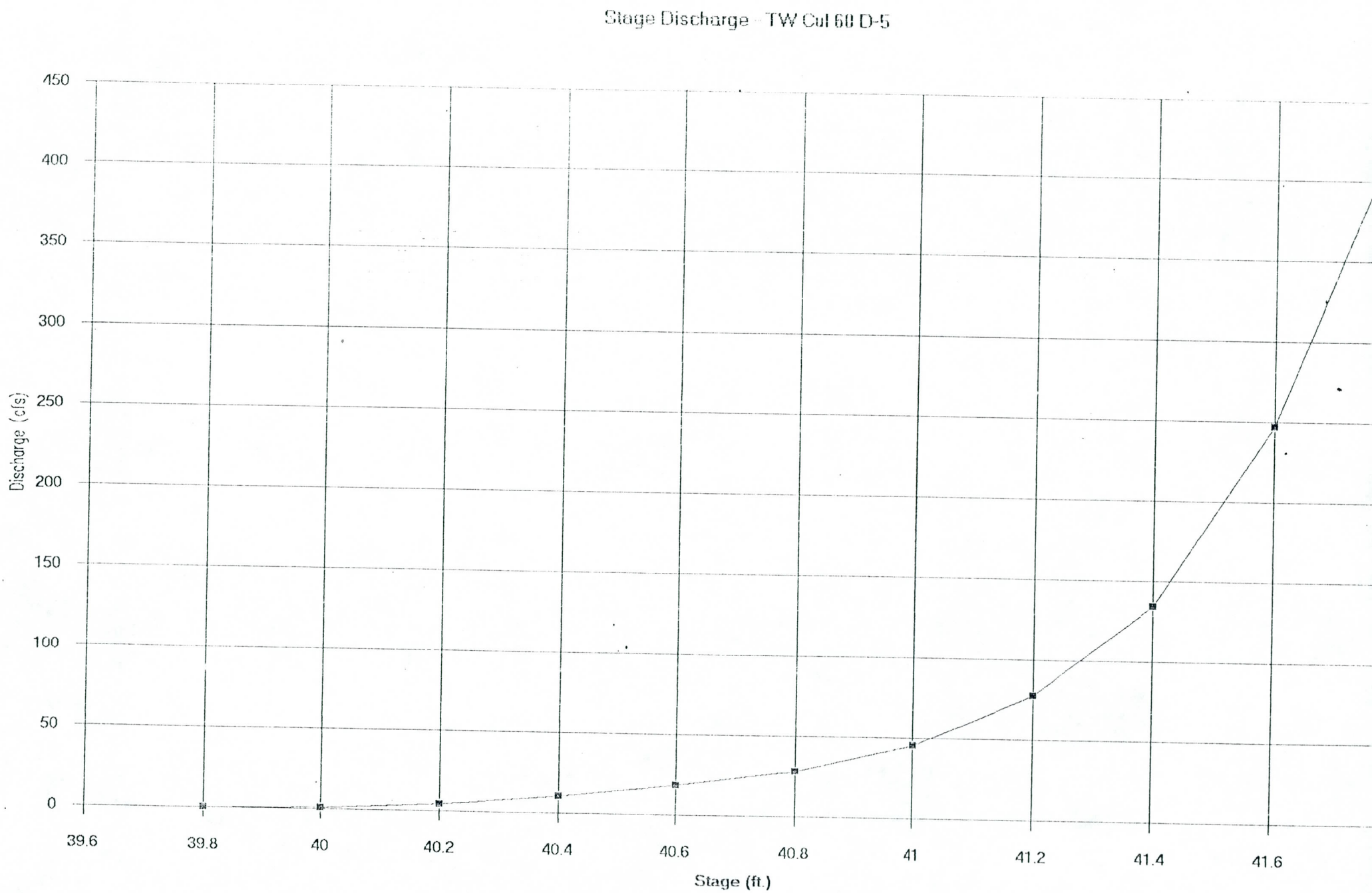
STAGE-DISCHARGE DATA:

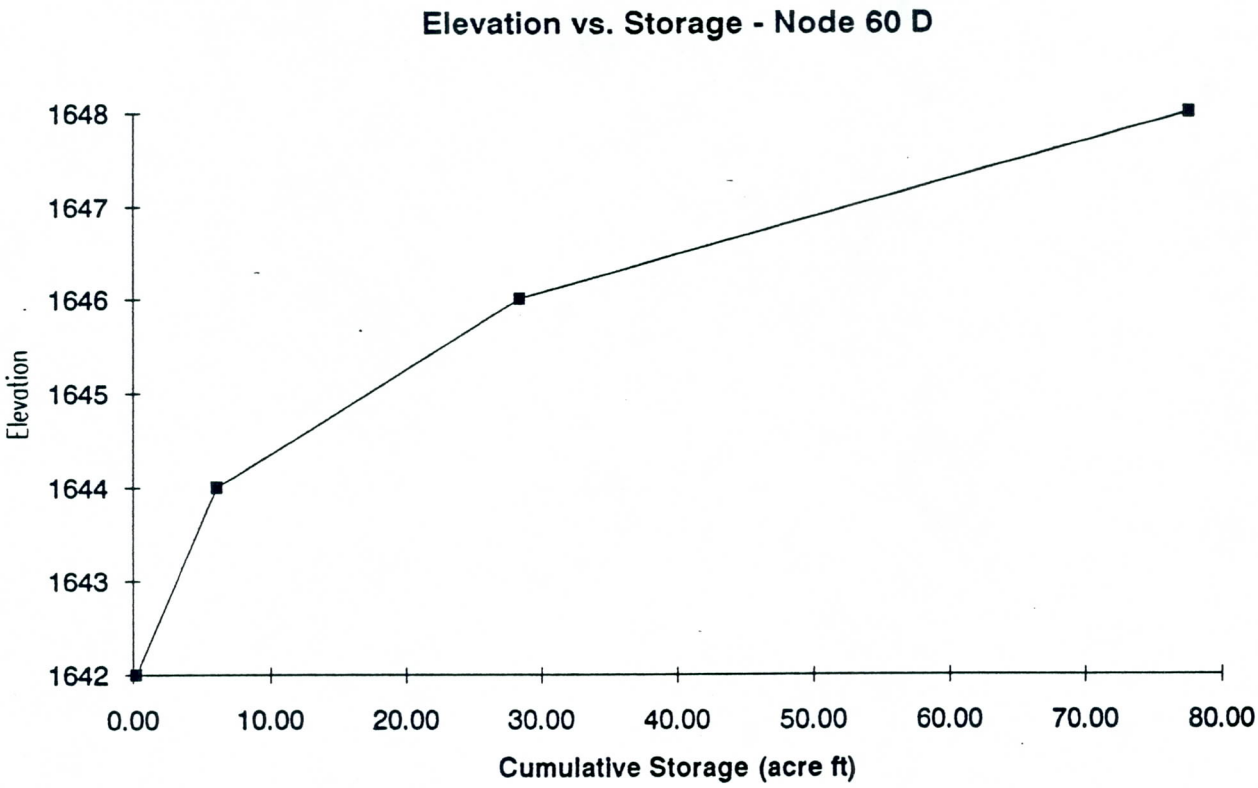
STAGE:	39.8												
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.2	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	40												
WET PER.		0.0	0.0	0.3	1.3	0.0	0.0	0.3	1.6	0.5	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.1	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	1	0	0	0	0
STAGE:	40.2												
WET PER.		0.0	0.0	0.9	2.6	0.2	0.0	0.6	1.6	0.8	0.0	0.0	0.0
AREA		0.0	0.0	0.1	0.5	0.0	0.0	0.1	0.7	0.2	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.2	0.1	0.0	0.1	0.5	0.2	0.0	0.0	0.0
Q		0	0	0	1	0	0	0	3	0	0	0	0
STAGE:	40.4												
WET PER.		0.0	0.0	1.6	2.6	0.6	0.0	0.9	1.6	1.1	0.0	0.0	0.0
AREA		0.0	0.0	0.4	1.0	0.1	0.0	0.2	1.0	0.3	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.2	0.4	0.1	0.0	0.2	0.7	0.3	0.0	0.0	0.0
Q		0	0	1	4	0	0	0	5	1	0	0	0
STAGE:	40.6												
WET PER.		0.0	0.0	2.3	2.6	1.0	0.0	1.2	1.6	1.4	0.0	0.0	0.0
AREA		0.0	0.0	0.7	1.6	0.2	0.0	0.4	1.4	0.5	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.3	0.6	0.2	0.0	0.3	0.9	0.3	0.0	0.0	0.0
Q		0	0	2	7	0	0	1	8	1	0	0	0
STAGE:	40.8												
WET PER.		0.0	7.0	9.7	2.6	1.3	0.0	1.5	1.6	1.7	0.0	0.0	0.0
AREA		0.0	0.2	1.4	2.1	0.4	0.0	0.5	1.7	0.7	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.8	0.3	0.0	0.4	1.1	0.4	0.0	0.0	0.0
Q		0	0	2	11	1	0	1	11	2	0	0	0

STAGE:	41											
WET PER.		0.0	30.2	33.0	2.6	1.7	1.9	1.8	1.6	2.0	0.0	0.0	0.0
AREA		0.0	3.9	5.7	2.6	0.7	0.7	0.8	2.0	1.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.1	0.2	1.0	0.4	0.4	0.4	1.3	0.5	0.0	0.0	0.0
Q		0	0	8	16	0	1	2	15	3	0	0	0
STAGE:	41.2												
WET PER.		0.0	53.5	56.2	2.6	1.7	3.6	5.6	1.6	2.4	0.0	0.0	0.0
AREA		0.0	12.3	14.6	3.1	0.9	1.2	2.2	2.3	1.4	0.0	0.0	0.0
HYD.RAD.		0.0	0.2	0.3	1.2	0.6	0.3	0.4	1.5	0.6	0.0	0.0	0.0
Q		0	0	27	22	0	0	6	19	4	0	0	0
STAGE:	41.4												
WET PER.		0.0	76.8	79.5	2.6	1.7	3.6	5.6	1.6	2.7	60.7	62.3	0.0
AREA		0.0	25.3	28.1	3.6	1.2	1.8	3.2	2.6	1.7	3.9	4.1	0.0
HYD.RAD.		0.0	0.3	0.4	1.4	0.7	0.5	0.6	1.7	0.7	0.1	0.1	0.0
Q		0	0	63	29	0	0	10	23	6	0	3	0
STAGE:	41.6												
WET PER.		1.2	95.4	98.1	2.6	1.7	3.6	5.6	1.6	2.7	86.8	90.9	0.0
AREA		0.0	42.9	46.2	4.2	1.5	2.5	4.2	3.0	2.2	22.3	23.0	0.0
HYD.RAD.		0.0	0.4	0.5	1.6	0.9	0.7	0.7	1.9	0.8	0.3	0.3	0.0
Q		0	0	126	36	0	0	15	28	0	0	42	0
STAGE:	41.8												
WET PER.		5.9	100.1	102.8	2.6	1.7	3.6	5.6	1.6	2.7	86.8	93.3	0.0
AREA		0.7	62.4	66.3	4.7	1.8	3.2	5.1	3.3	2.6	39.6	41.3	0.0
HYD.RAD.		0.1	0.6	0.6	1.8	1.1	0.9	0.9	2.1	0.9	0.5	0.4	0.0
Q		0	0	223	44	0	0	22	33	0	0	108	0

W.S. Elev.	39.8	40	40.2	40.4	40.6	40.8	41	41.2	41.4	41.6	41.8
Q	0	1	4	10	18	28	46	78	134	247	430
A	0.1	0.5	1.6	3.0	4.7	6.9	12.8	23.6	43.4	80.5	120.6
V	0.9	2.1	2.7	3.3	3.9	4.1	3.6	3.3	3.1	3.1	3.6


Cross Section - TW Cul 60 D-5
43.5
43
42.5
42
41.5
41
40.5
40
39.5
Elevation
0
50
100
150
200
250
300
Offset (ft.)


Stage Discharge - TW Cul 60 D-5
Discharge (cfs)
450
400
350
300
250
200
150
100
50
0
39.6
39.8
40
40.2
40.4
40.6
40.8
41
41.2
41.4
41.6
Stage (ft.)


Elevation vs. Storage - Node 60 D
1648
1647
1646
1645
1644
1643
1642
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Cumulative Storage (acre ft)

SVERDR

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60 D-4 16C

SHEET NO. ___ OF ___

DATE 7/13/91

BY BDO CHKD RVT

CULVERT COMPUTATION SHEET

PROJECT: ___

STATION: 108+50, Oval Track

DESIGNER: ___

DATE: ___

HYDROLOGIC AND CHANNEL INFORMATION

2034/6 = 339 cfs

DRAINAGE AREA 10.98 sq. miles

Q_1 = 339 cfs

Q_2 = ___

TW_1 = 2.0' Exist. Channel

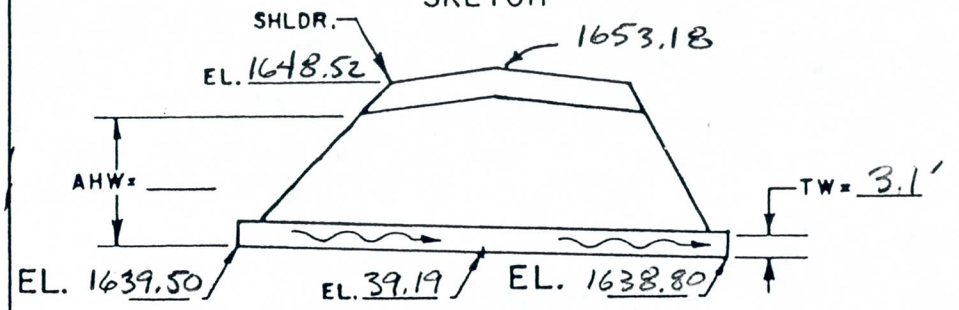
TW_2 = 3.1' New Channel

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY Q_{25}) Q100

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = 0.0050 ft/ft L = 140' L/100 S_o = ___

MEAN STREAM VELOCITY = 2.6 fps

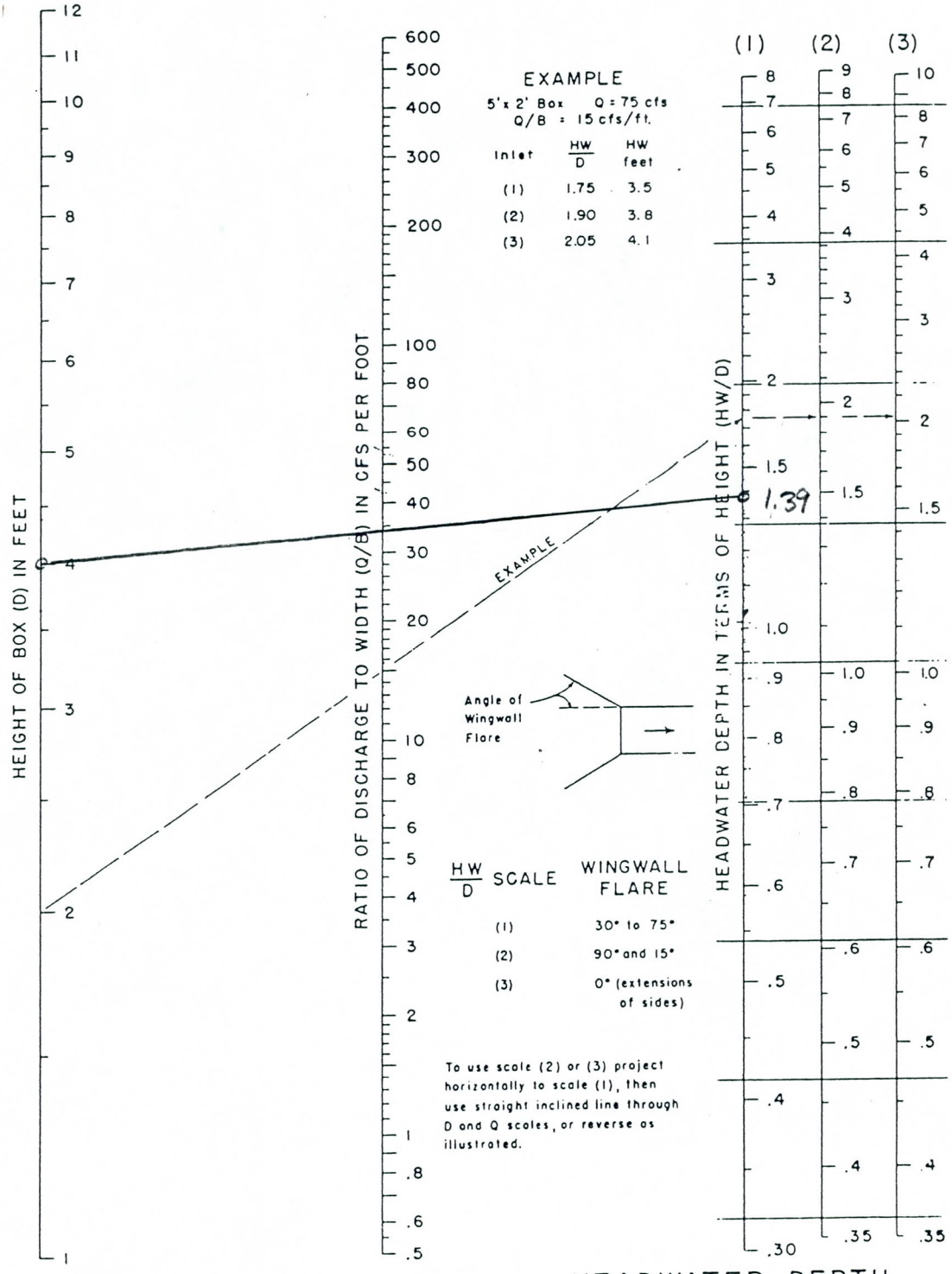
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(1) Barrel 10'x4'	Drop Inlet	339		1.39	5.56	0.2	1.65	3.30	3.65	3.10	3.65	0.70	4.60	5.56	12.7		1645.06	Inlet Control

SUMMARY & RECOMMENDATIONS Use dumped riprap plunge basin for erosion control at outlet.

B-1

Culvert 60 D-4

CHART 1

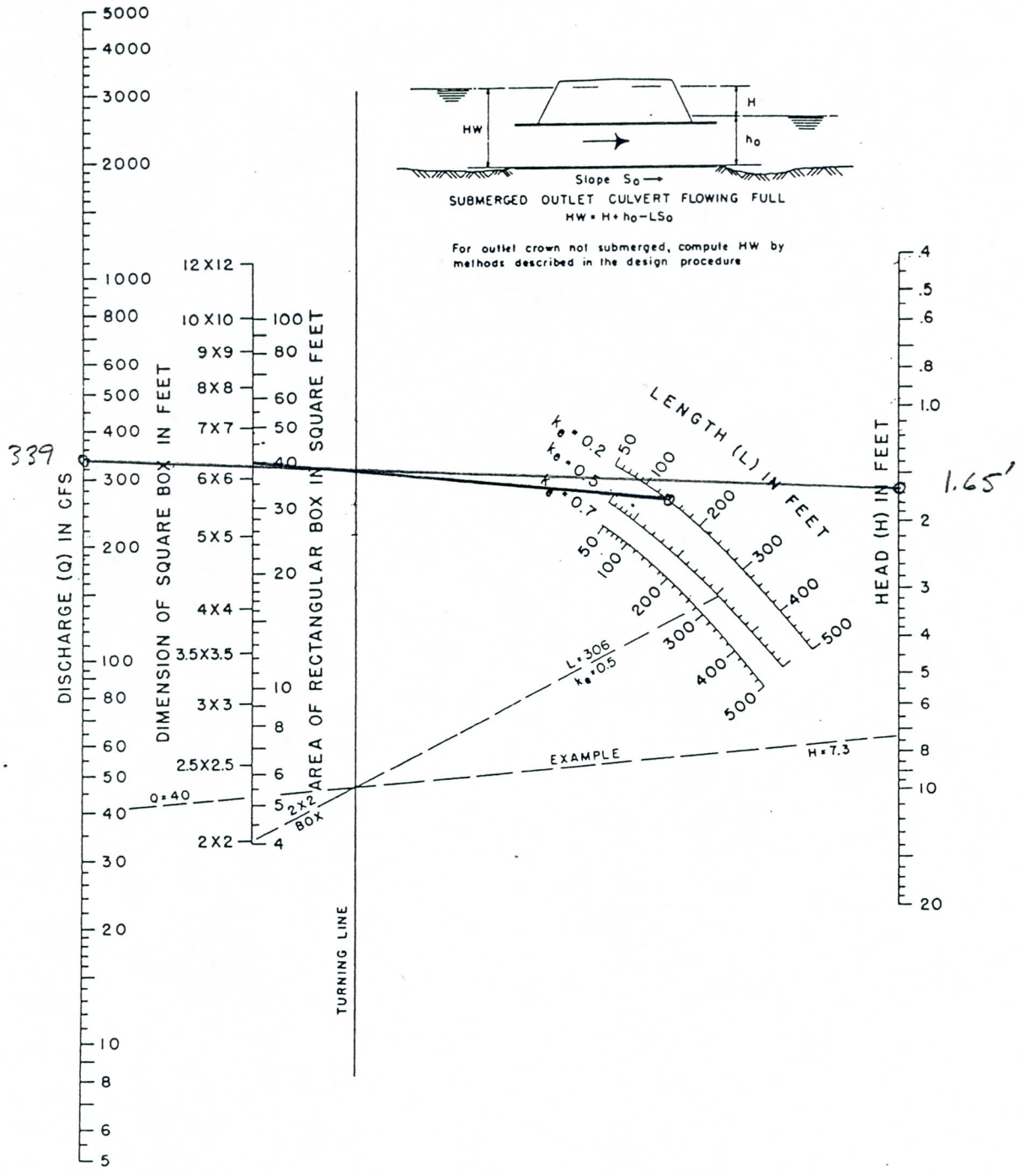


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN 1963

Culvert 60D-4

CHART 8

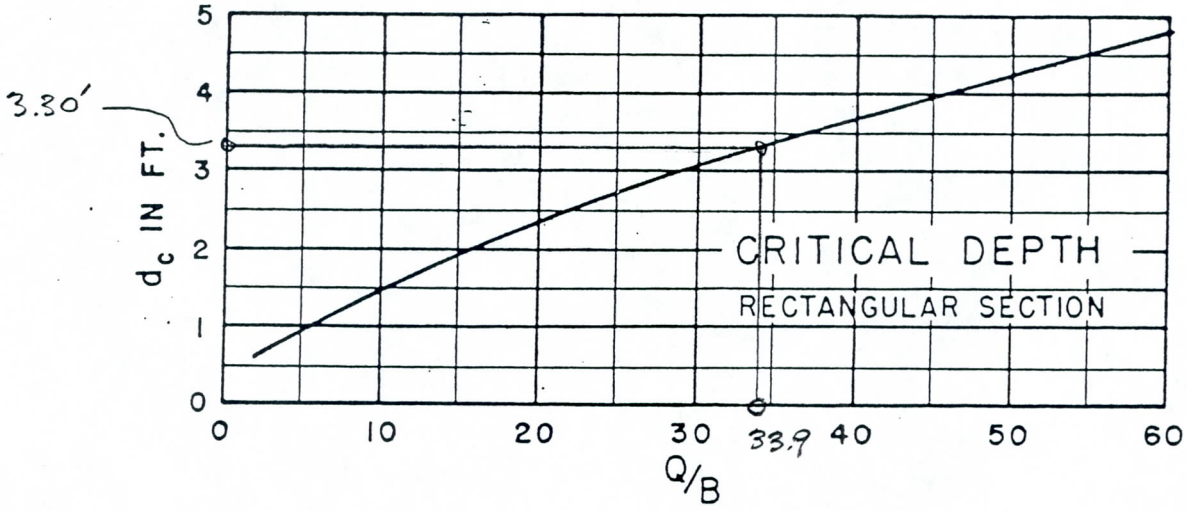


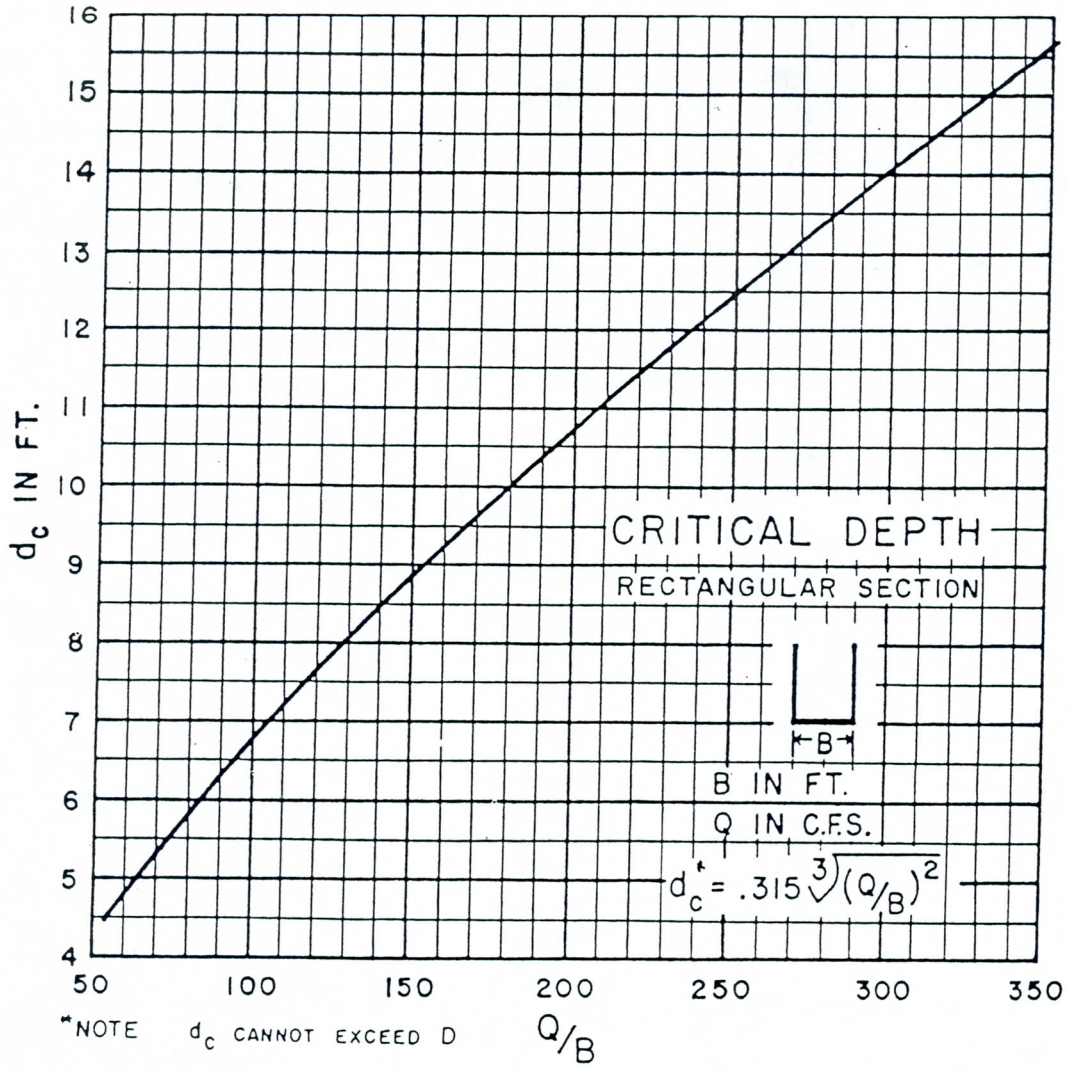
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60D - 4

CHART 15





BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60 D-4

SHEET NO. 5 OF

DATE 7/13/91

BY BDO CHKD RJT

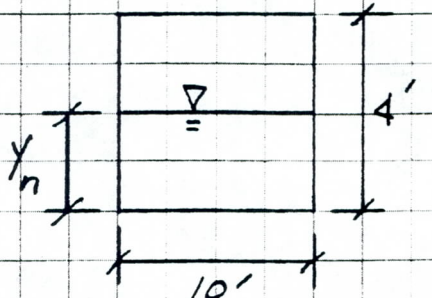
Check depth of Flow using Mannings Equation

$Q100 = 2034$ cfs, $Q = 339$ cfs/culvert

$n = 0.012$

$S_o = 0.0050$ ft/ft

$y_n \sim 2.67'$



$A = 26.7$ ft^2

$WP = 15.34$ ft

$R_h = A/WP = 26.7/15.34 = 1.7405'$

$V = \frac{1.49}{.012}(1.7405)^{.666}(.005)^{.5} = 12.70$ fps

Check

$Q = VA = 12.70\,(26.7) = 339$ cfs (OK)

Check Froude Number

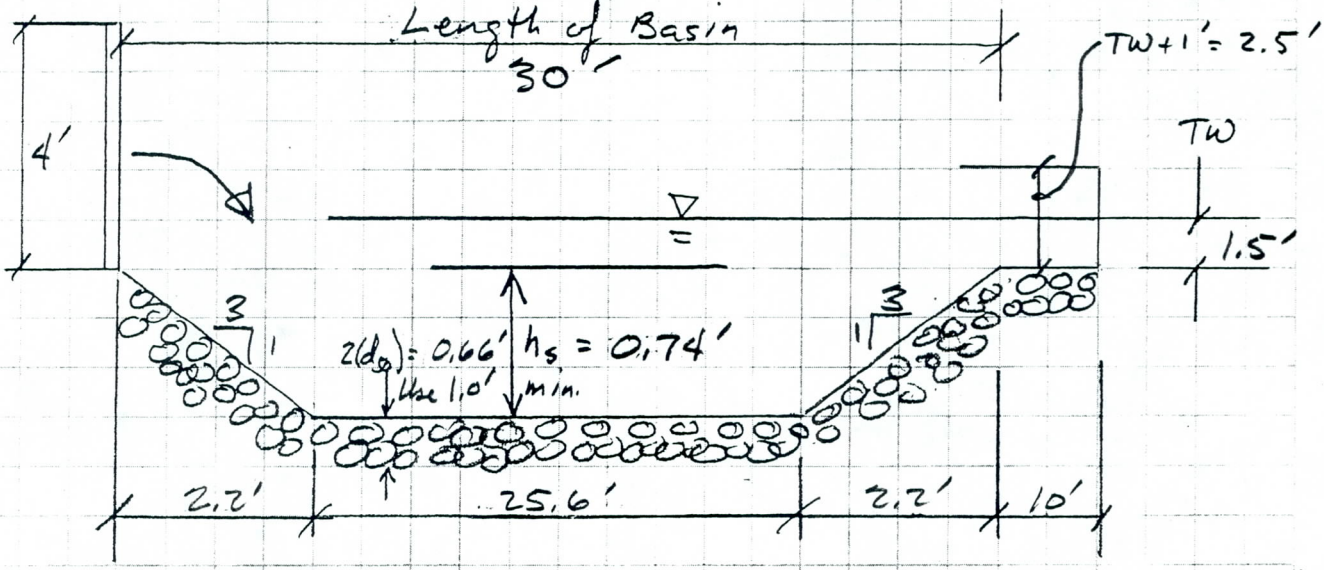
$\# = \frac{12.70}{\sqrt{32.2 \times 2.67}} = 1.37$, Supercritical

$Q10 = 488/6 = 81$ cfs

$y_n = 1.03'$, Velocity = 7.88 fps, $\# = 1.37$ Supercritical

Need riprap plunge basin to minimize erosion downstream of culvert

Riprap Plunge Basin Design (Q 10)



Check Rock Size (From Figure XI-2, HEC No. 14)

For $Y_o = 1.03'$ $d_{50} = 4''$ or $0.33'$

$d_{50}/Y_o = \frac{0.33'}{1.03'} = 0.32$, $F = 1.37$

$\frac{h_s}{Y_o} = 0.72$ $h_s = 0.72(1.03') = 0.74'$

Check $\frac{h_s}{d_{50}} = \frac{0.74}{0.33} = 2.24 < 4$ and > 2 ∴ OK

Length of Basin

$10\,h_s = 10(0.74) = 7.4'$

or

$3(W_o) = 3(10) = 30'$

Use 30'

Culvert 60D-4

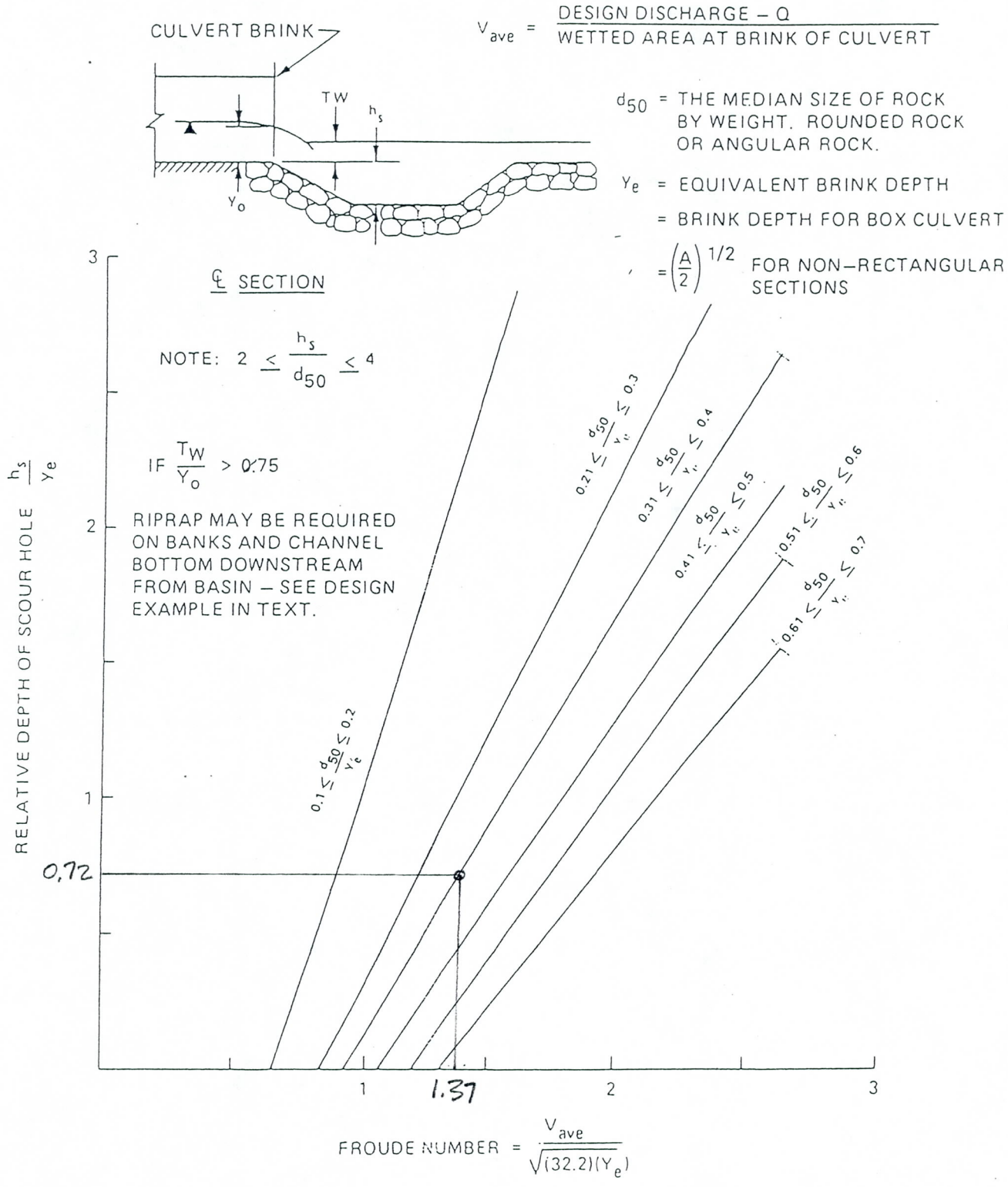


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota SHEET NO. 8 OF

COMPUTATIONS FOR Box Culvert 60D-4 DATE 7/15/91

BY BDO CHKD RJT

$TW/Y_o = \frac{1.5'}{1.03'} = 1.46 > 0.75$ ∴ Check downstream riprap lining for channel protection.

Utilize figure XI-3 for existing average velocity along channel. Compute equivalent circular diameter D_e for brink area from:

$A = \pi D_e^2/4 = Y_o(W_o) = 1.03(10) = 10.3\ ft^2$

$D_e = (10.3(4)/\pi)^{1/2} = 3.62'$

From downstream cross section Q10 velocity is 2.4 fps. Culvert outlet velocity is 7.9 fps.

L/D_e	L	V_L/V_o	V_L	
10	36.2	.59	4.7	
15	54.3	.36	2.8	
20	72.4	.30	2.4	OK

∴ Need riprap lining for approximately 70 feet from the end of the culvert outlet apron.

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Channel Downstream of Culvert 60 D-4

SHEET NO. 9 OF

DATE 7/15/91

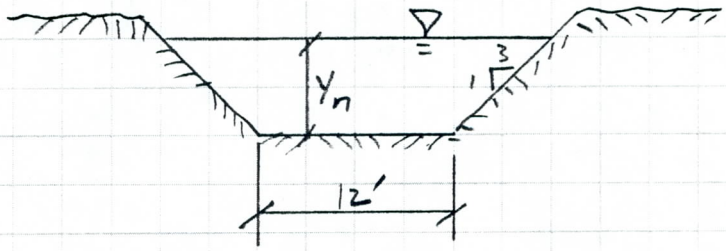
BY BDO CHKD RJT

Check depth of Flow and Velocity

$Q_{10} = 81$ cfs

$n = 0.03$

$S_o = 0.0040$ ft/ft



$Y_n \sim 1.46'$

$A = 23.88$ ft^2

$WP = 2(4.62) + 12 = 21.24$ ft

$R_h = A/WP = 23.88/21.24 = 1.1243'$

$$V = \frac{1.49}{.03}(1.1243)^{.666}(.004)^{.5} = 3.40 \text{ fps}$$

Check

$Q = VA = 3.40\,(23.88) = 81$ cfs

Check Froude Number $\quad D = A/T = 23.88/20.76 = 1.15'$

$$F = \frac{3.40}{\sqrt{32.2 \times 1.15'}} = 0.56, \text{ Subcritical}$$

$Q_{100} = 339$ cfs

$Y_n = 3.10'$, Velocity = 5.13 fps, $F = 0.62$, Subcritical

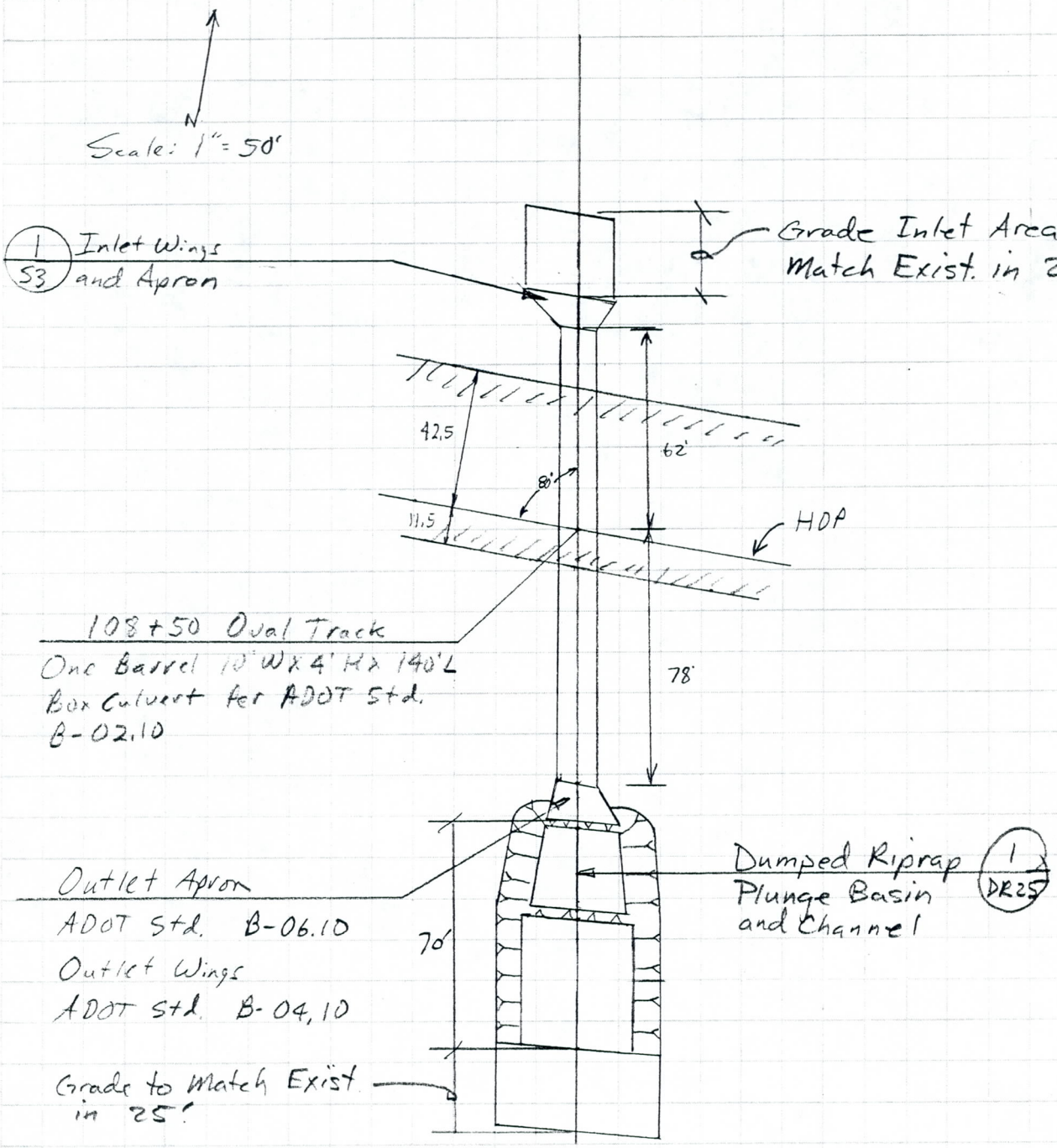
SVERDRUP

JOB 40477 Toyota SHEET NO. 10 OF

DATE 7-20-91

COMPUTATIONS FOR Culvert 60 D-4 Plan View BY BDO CHKD RJT

HDP Sta. 108+50 16C



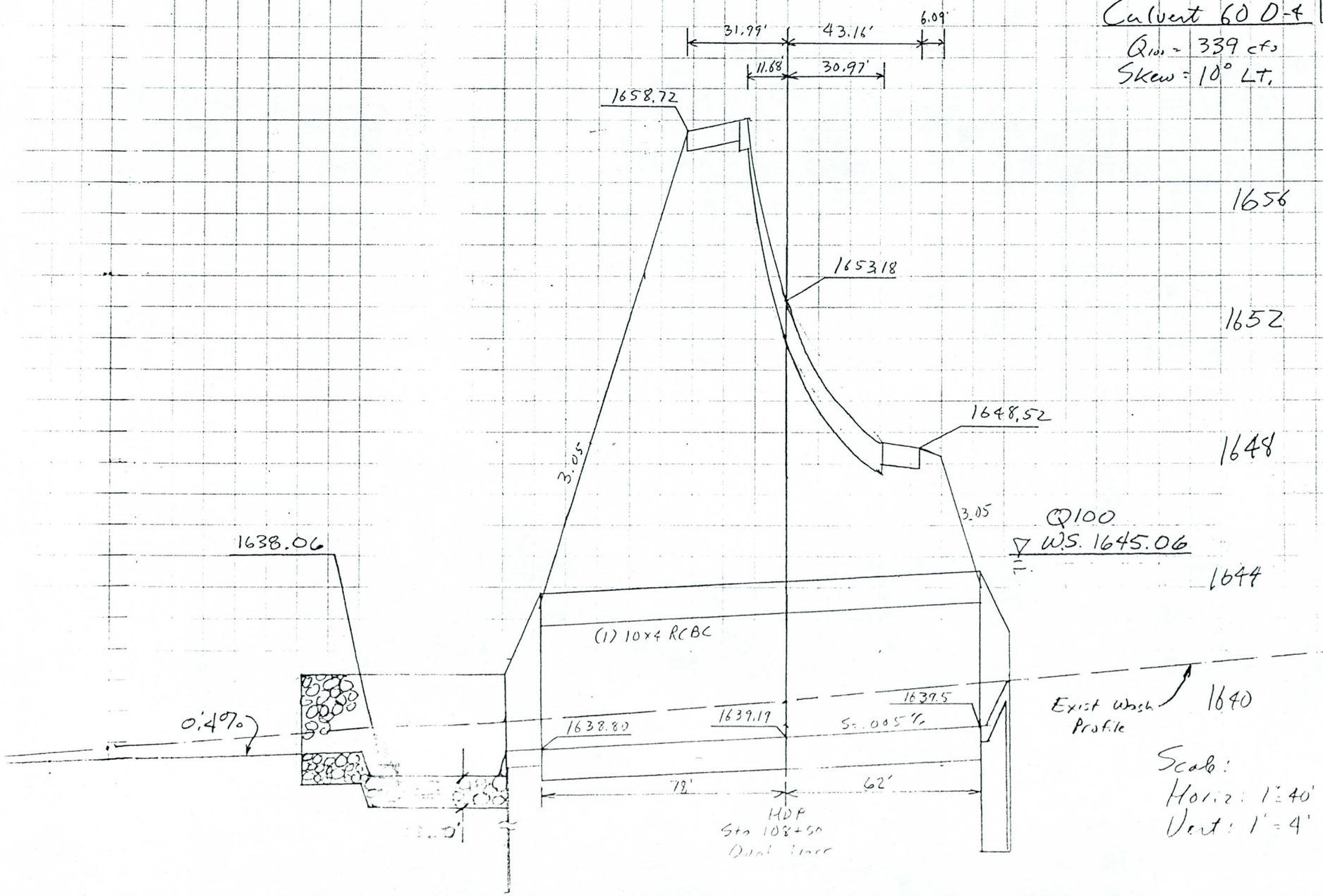
Plan View
Culvert 60 D-4

SVERDRUP

JOB 40422 Toyota SHEET NO. 11 OF

COMPUTATIONS FOR Culvert Profile 600-4 DATE 7-14-91

HST Sta. 108+50 BY BDO CHKD RVT



SECTION NUMBER TW60D4 7/10/91

Channel Slope: 0.0072 ft./ft.

CROSS SECTION DATA:

OFFSET	17.9	111.7	112.1	115.3	117.1	137.6	139.3	143	144.7	222.5	265	275	431
ELEV.	41.67	40.45	39.81	39.51	40.56	39.9	39.12	38.91	40.39	40.58	40	40	42
N	N/A	0.035	0.035	0.025	0.025	0.035	0.035	0.025	0.035	0.035	0.035	0.035	0.035

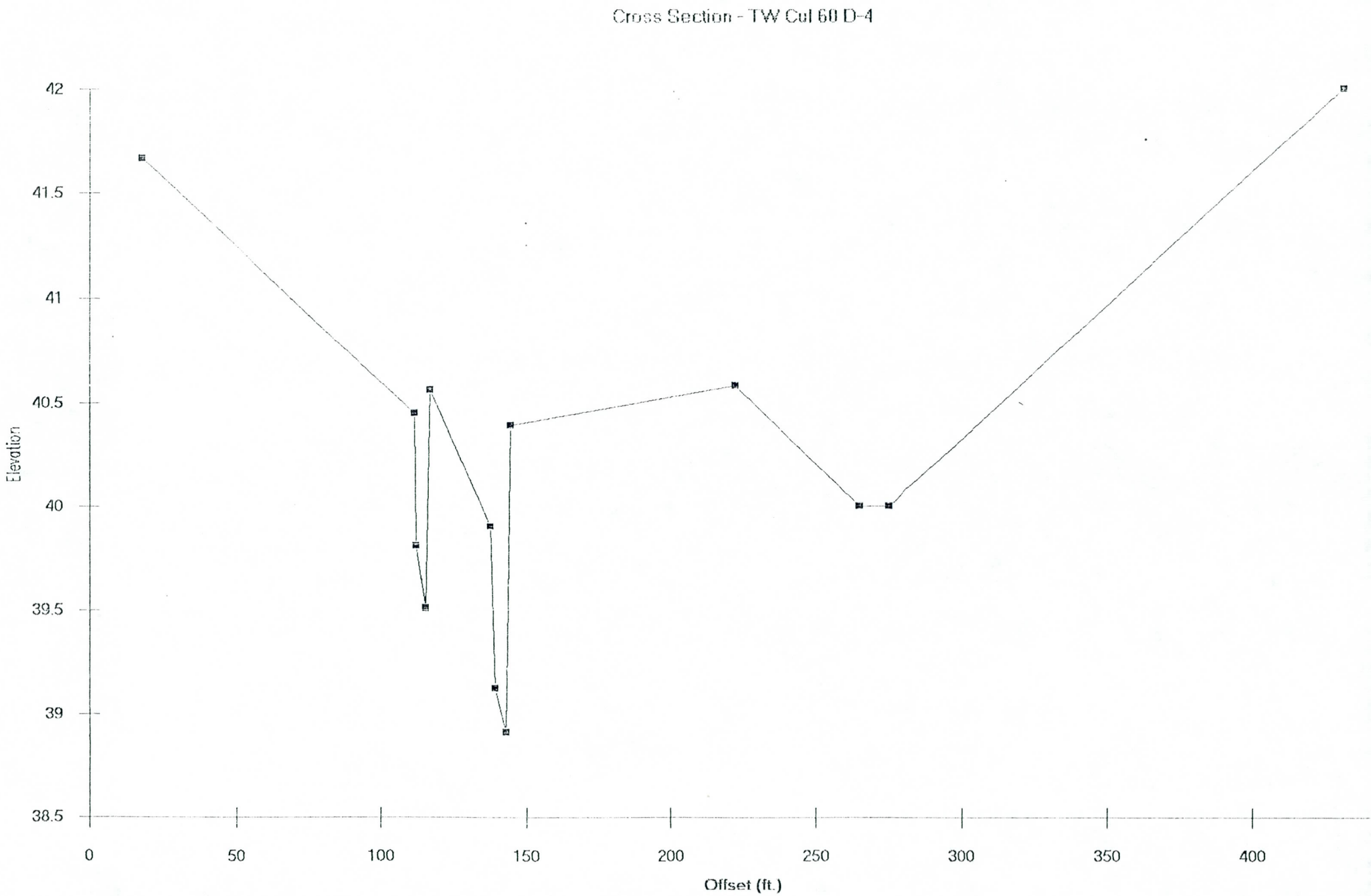
STAGE-DISCHARGE DATA:

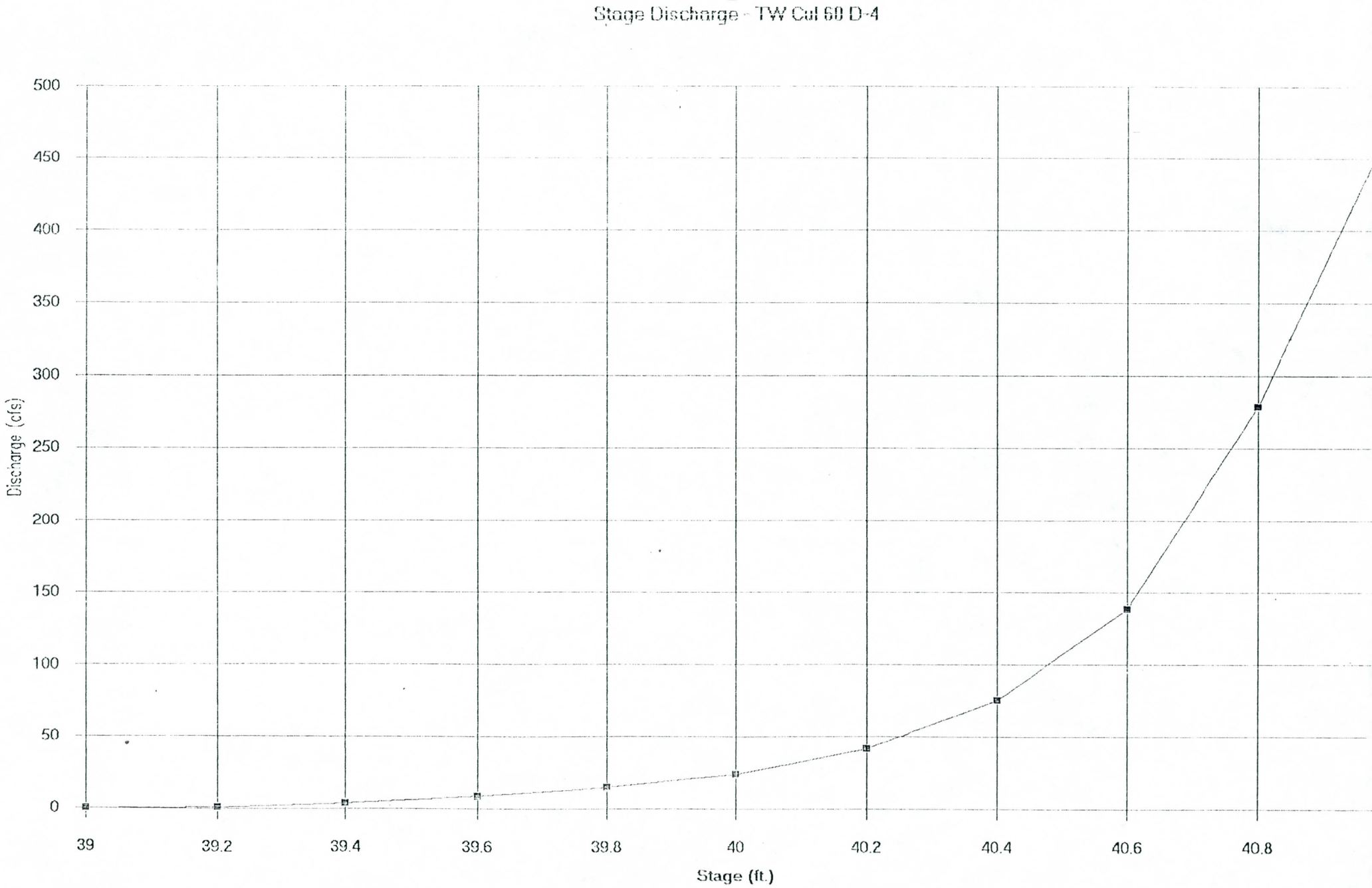
STAGE:	39												
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.1	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	39.2												
WET PER.		0.0	0.0	0.0	0.0	0.0	0.2	3.7	0.4	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	1	0	0	0	0	0
STAGE:	39.4												
WET PER.		0.0	0.0	0.0	0.0	0.0	0.7	3.7	0.8	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.1	1.4	0.1	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.2	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	4	0	0	0	0	0
STAGE:	39.6												
WET PER.		0.0	0.0	1.0	1.1	0.0	1.2	3.7	1.1	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.1	0.0	0.3	2.2	0.3	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.3	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	8	0	0	0	0	0
STAGE:	39.8												
WET PER.		0.0	0.0	3.1	3.7	0.0	1.6	3.7	1.4	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.4	0.5	0.0	0.5	2.9	0.5	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.1	0.0	0.3	0.8	0.3	0.0	0.0	0.0	0.0
Q		0	0	0	1	0	1	12	1	0	0	0	0
STAGE:	40												
WET PER.		0.0	0.2	3.2	4.2	3.1	5.0	3.7	1.7	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.1	1.3	0.2	1.0	3.6	0.7	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.1	0.3	0.3	0.0	0.2	1.0	0.4	0.0	0.0	0.0	0.0
Q		0	0	0	3	0	1	18	1	0	0	0	0

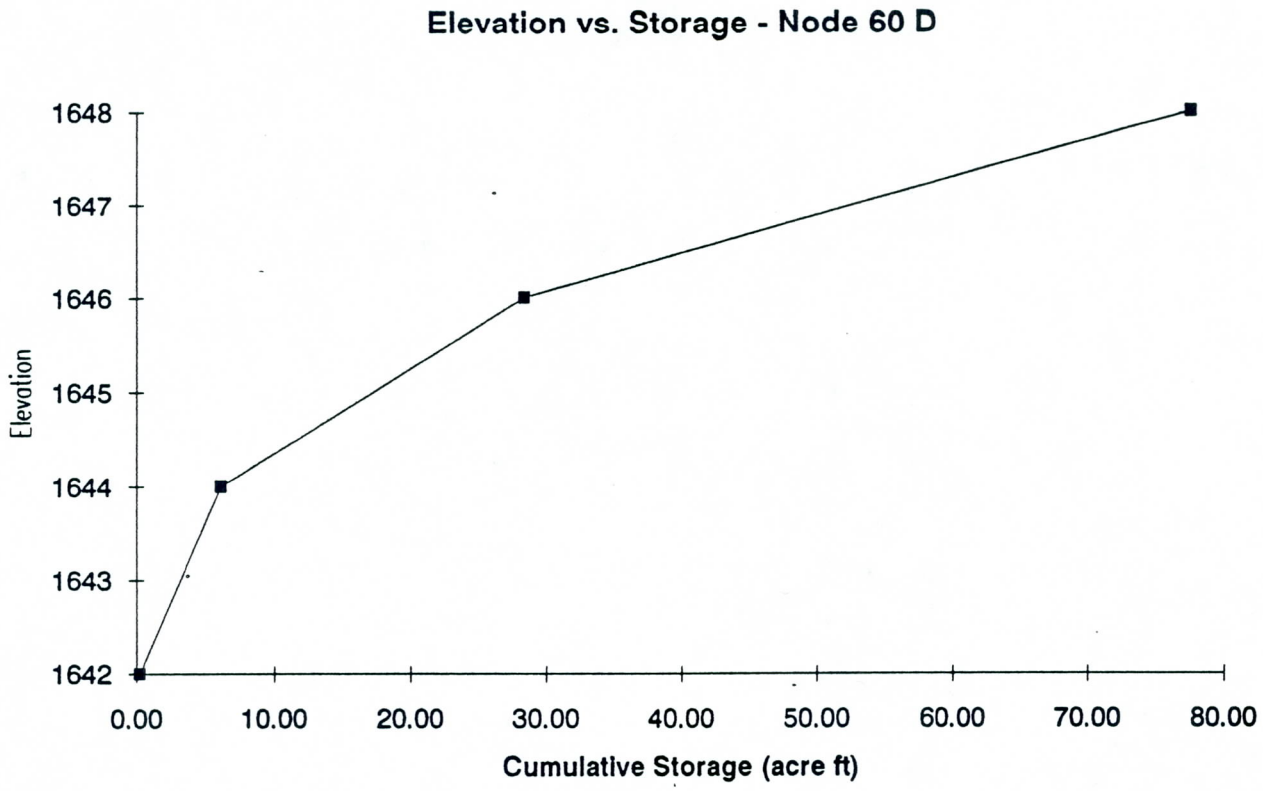
SECTION NUMBER TW80D4 7/10/91

STAGE:	40.2											
WET PER.		0.0	0.5	3.2	4.6	9.3	11.2	3.7	2.0	0.0	14.7	24.7	40.3
AREA		0.0	0.0	1.7	2.1	1.4	2.6	4.4	1.0	0.0	1.5	3.5	5.0
HYD.RAD.		0.0	0.1	0.5	0.5	0.1	0.2	1.2	0.5	0.0	0.1	0.1	0.1
Q		0	0	0	6	0	3	25	2	0	0	0	5
STAGE:	40.4												
WET PER.		0.0	0.7	3.2	5.0	15.5	17.4	3.7	2.3	6.3	29.3	39.3	70.5
AREA		0.0	0.1	2.4	3.0	3.9	5.4	5.1	1.3	1.3	5.9	9.9	16.1
HYD.RAD.		0.0	0.2	0.7	0.6	0.2	0.3	1.4	0.6	0.2	0.2	0.3	0.2
Q		0	0	0	11	0	9	32	0	2	0	0	22
STAGE:	40.6												
WET PER.		11.5	12.3	3.2	5.3	20.5	22.4	3.7	2.3	80.1	122.6	132.6	179.4
AREA		0.9	1.1	3.0	4.0	7.6	9.4	5.9	1.6	10.6	23.7	29.7	43.8
HYD.RAD.		0.1	0.1	0.9	0.8	0.4	0.4	1.6	0.7	0.1	0.2	0.2	0.2
Q		0	1	0	17	0	19	40	0	0	0	0	62
STAGE:	40.8												
WET PER.		26.9	27.7	3.2	5.3	20.5	22.4	3.7	2.3	80.1	122.6	132.6	195.0
AREA		4.7	5.0	3.6	5.0	11.7	13.9	6.6	2.0	26.5	48.1	56.1	81.1
HYD.RAD.		0.2	0.2	1.1	0.9	0.6	0.6	1.8	0.9	0.3	0.4	0.4	0.4
Q		0	6	0	24	0	36	49	0	0	0	0	163
STAGE:	41												
WET PER.		42.3	43.0	3.2	5.3	20.5	22.4	3.7	2.3	80.1	122.6	132.6	210.6
AREA		11.6	12.0	4.3	6.0	15.8	18.3	7.3	2.3	42.4	72.5	82.5	121.5
HYD.RAD.		0.3	0.3	1.3	1.1	0.8	0.8	2.0	1.0	0.5	0.6	0.6	0.6
Q		0	18	0	33	0	58	58	0	0	0	0	304

W.S. Elev.	39	39.2	39.4	39.6	39.8	40	40.2	40.4	40.6	40.8	41
Q	0	1	4	8	15	24	41	76	139	278	472
A	0.1	0.7	1.6	2.7	4.4	6.6	15.1	31.1	64.2	111.6	165.2
V	0.6	1.6	2.5	3.1	3.4	3.6	2.7	2.4	2.2	2.5	2.9


Cross Section - TW Cul 60 D-4
42
41.5
41
40.5
40
39.5
39
38.5
Elevation
0
50
100
150
200
250
300
350
400
Offset (ft.)


Stage Discharge - TW Cul 60 D-4
Discharge (cfs)
500
450
400
350
300
250
200
150
100
50
0
39
39.2
39.4
39.6
39.8
40
40.2
40.4
40.6
40.8
Stage (ft.)


Elevation vs. Storage - Node 60 D
1648
1647
1646
1645
1644
1643
1642
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Cumulative Storage (acre ft)

SVERDRI

JOB 4047 Toyota

SHEET NO. ____ OF ____

DATE 7/13/91

COMPUTATIONS FOR Culvert 60 D-3 [16D]

BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT: ____

STATION: 107+40, Oval Track

DESIGNER: ____

DATE: ____

HYDROLOGIC AND CHANNEL INFORMATION

2034/C = 339 cfs

DRAINAGE AREA 10,98 59 miles

Q_1 = 339 cfs

Q_2 = ____

TW_1 = 2.4' Exist. Channel

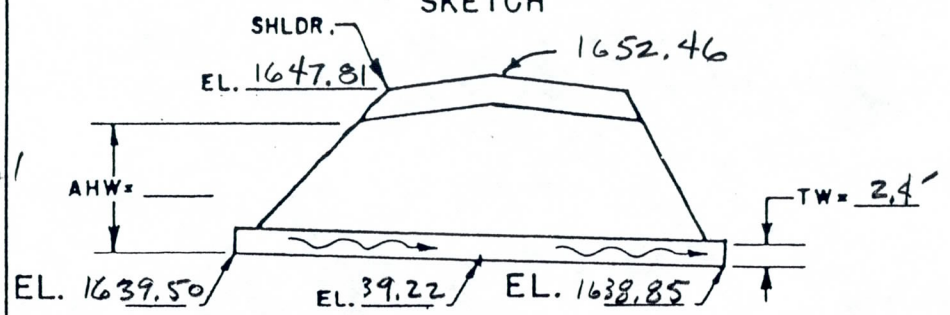
TW_2 = ____

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~ Q_{100})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050 ft/ft L = 130' L/100 S_o = ____

MEAN STREAM VELOCITY = 3.2 fps

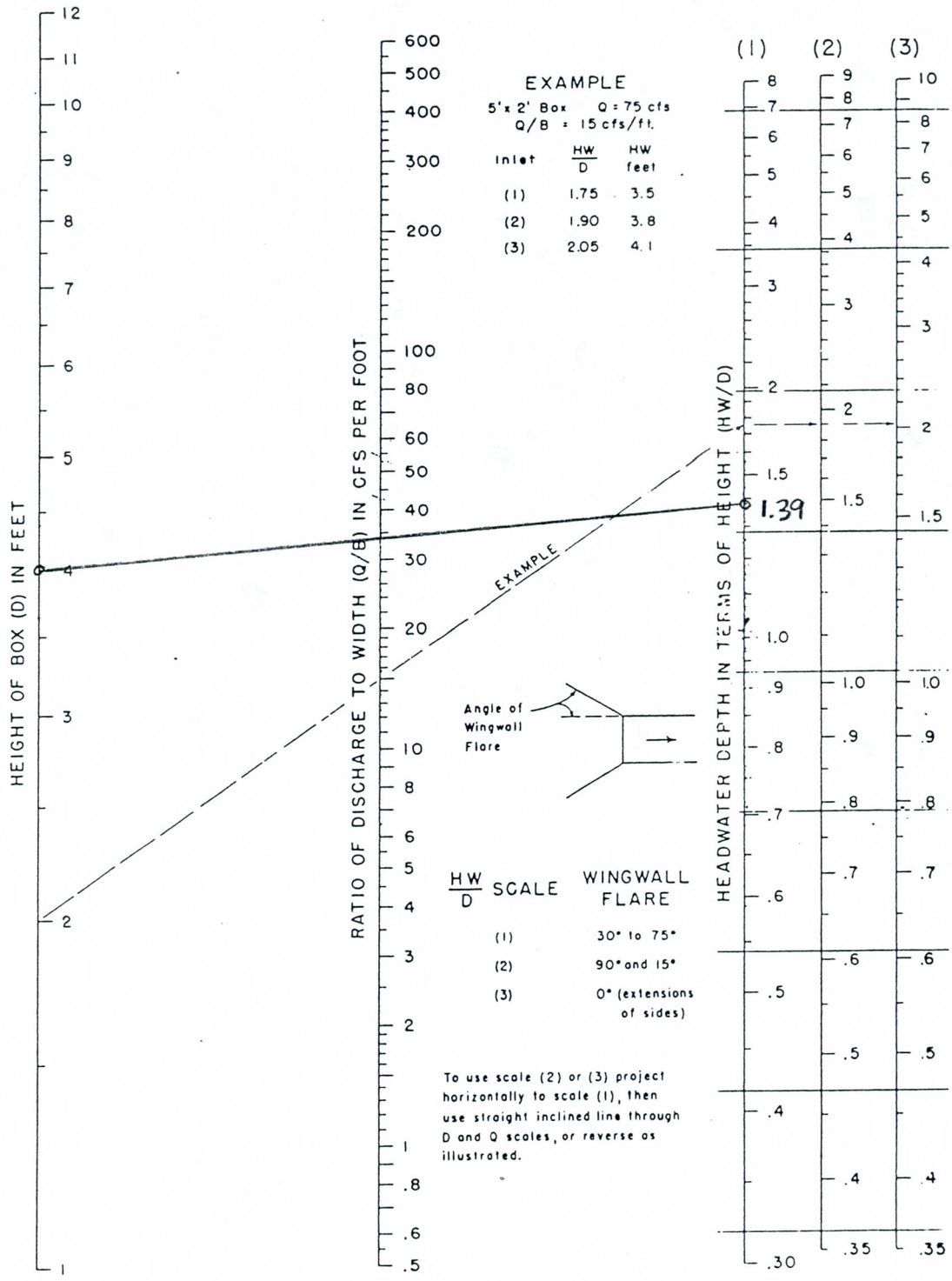
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(1) Barrel 10'x4'	Drop Inlet	339		1.39	5.56	0.2	1.65	3.30	3.65	2.4	3.65	0.65	4.65	5.56	12.7		1645.06	Inlet Control

SUMMARY & RECOMMENDATIONS Use dumped riprap plunge basin for outlet erosion protection.

B-1

Culvert 60' D-3

CHART I

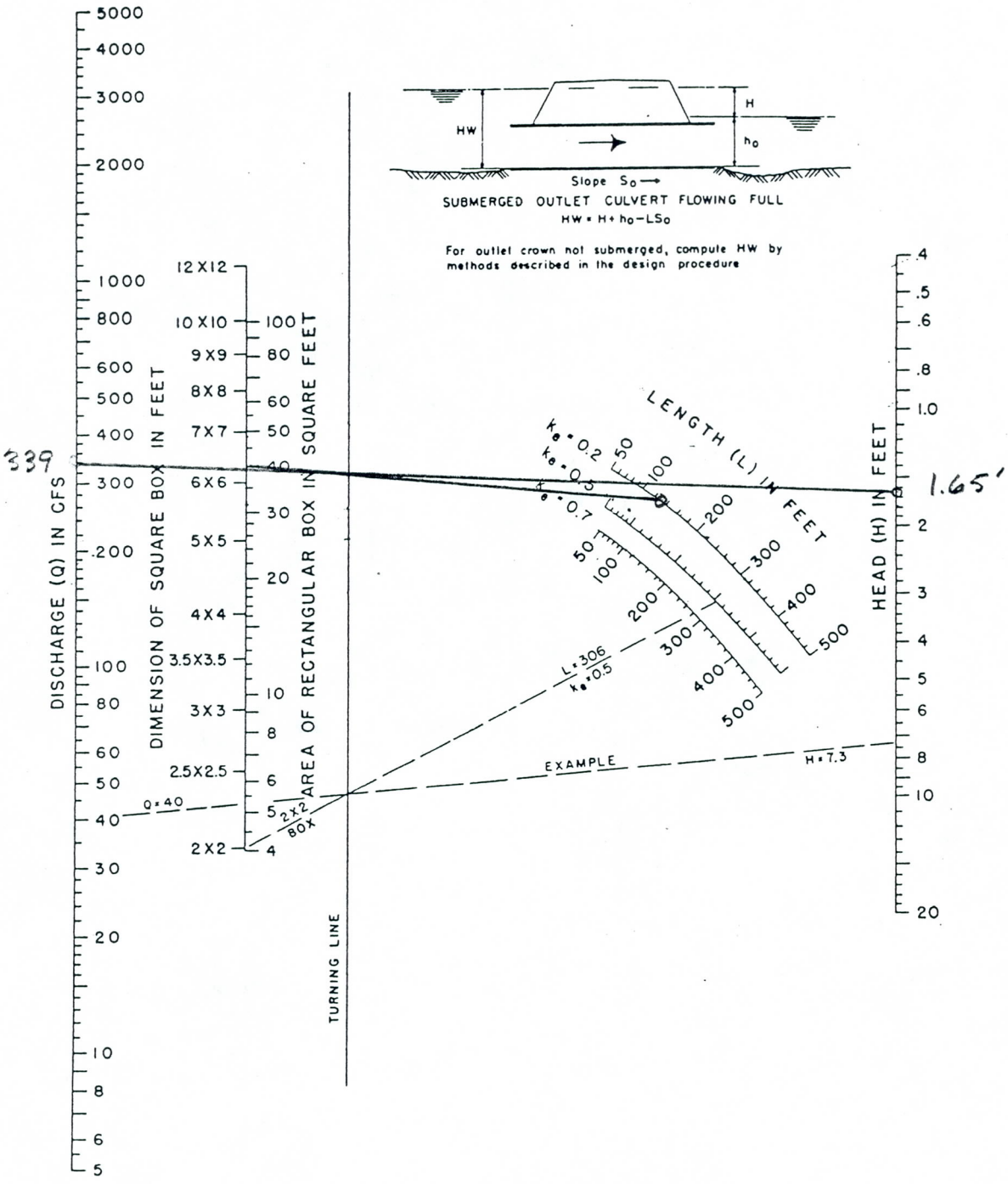


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 D-3

CHART 8



339

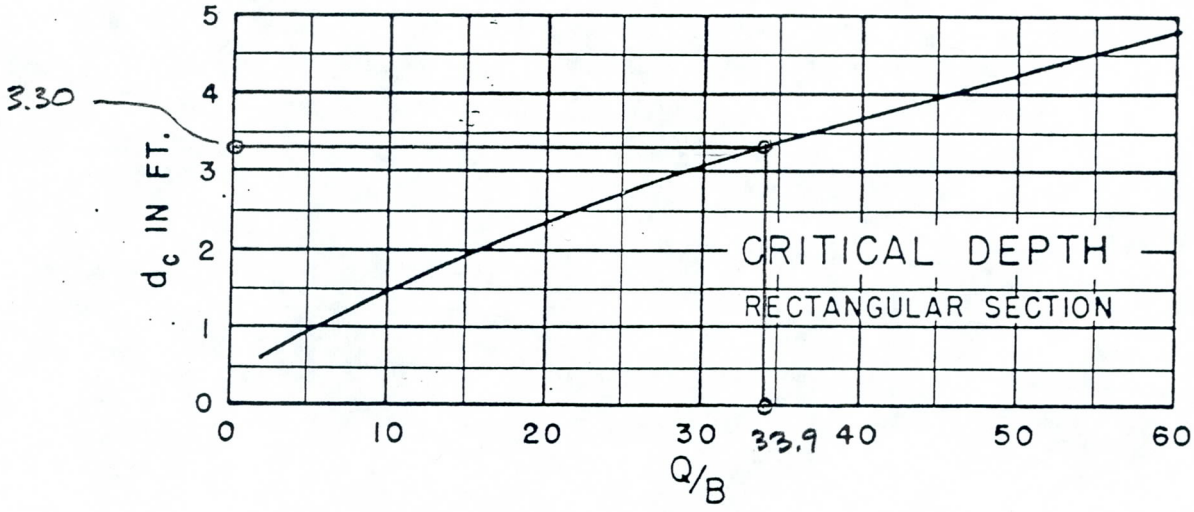
1.65'

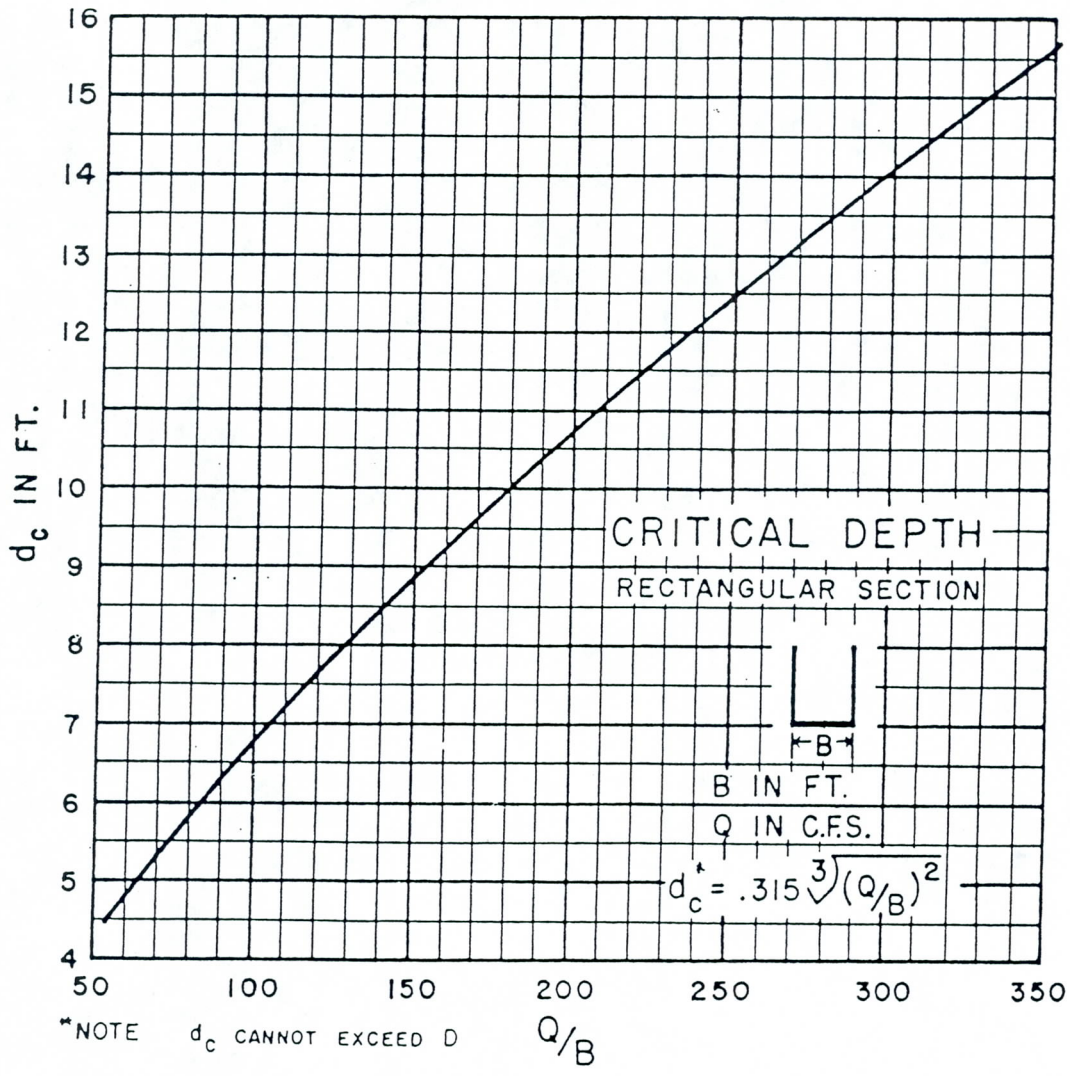
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 D-3

CHART 15





*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota SHEET NO. 5 OF

COMPUTATIONS FOR Culvert 60 D-3 DATE 7/13/91

BY BDO CHKD RJT

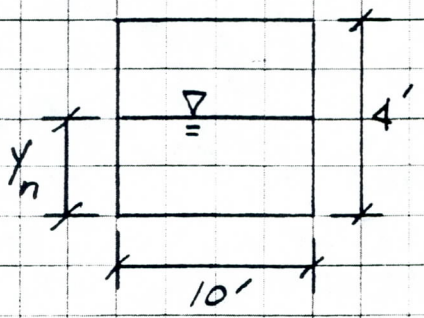
Check depth of Flow using Mannings Equation

$Q100 = 2034$ cfs, $Q = 339$ cfs/culvert

$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 2.67'$



$A = 26.7$ ft^2

$WP = 15.34$ ft

$R_h = A/WP = 26.7/15.34 = 1.7405'$

$V = \frac{1.49}{.012}(1.7405)^{.666}(.005)^{.5} = 12.70$ fps

Check

$Q = VA = 12.70(26.7) = 339$ cfs (OK)

Check Froude Number

$\# = \frac{12.70}{\sqrt{32.2 \times 2.67}} = 1.37$, Supercritical

$Q10 = 488/6 = 81$ cfs

$Y_n = 1.03'$, Velocity = 7.88 fps, $\# = 1.37$ Supercritical

Need riprap plunge basin to minimize erosion downstream of culvert

SVERDRUP

JOB 40477 Toyota

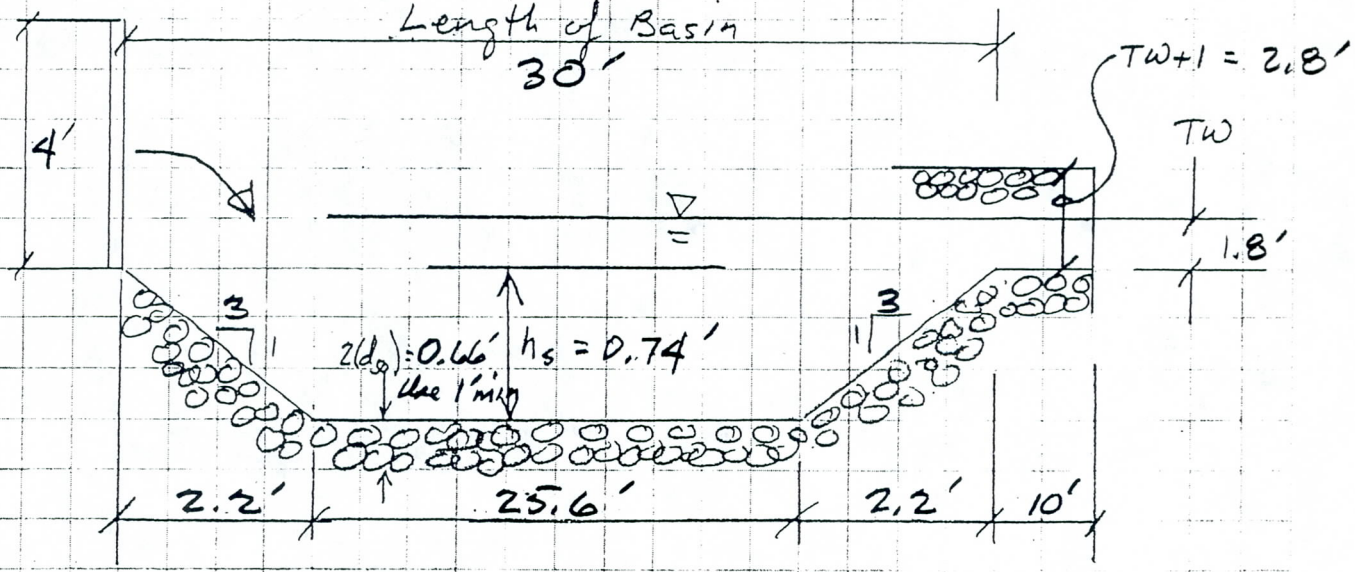
COMPUTATIONS FOR Box Culvert 60D-3

SHEET NO. 6 OF

DATE 7/13/91

BY BDO CHKD RJT

Riprap Plunge Basin Design (Q10)



Check Rock Size (From Figure XI-2, HEC No. 14)

For $y_o = 1.03'$ $d_{50} = 4''$ or $0.33'$

$$d_{50}/y_o = \frac{0.33}{1.03} = 0.32 \quad , \quad F = 1.37$$

$$\frac{h_s}{y_o} = 0.72 \qquad h_s = 0.72(1.03') = 0.74'$$

Check $\frac{h_s}{d_{50}} = \frac{0.74}{0.33} = 2.24 < 4$ and > 2 ∴ OK

Length of Basin

$10\,h_s = 10(0.74) = 7.4'$

or

$3(W_o) = 3(10) = 30'$

Use 30'

Culvert 60 D-3

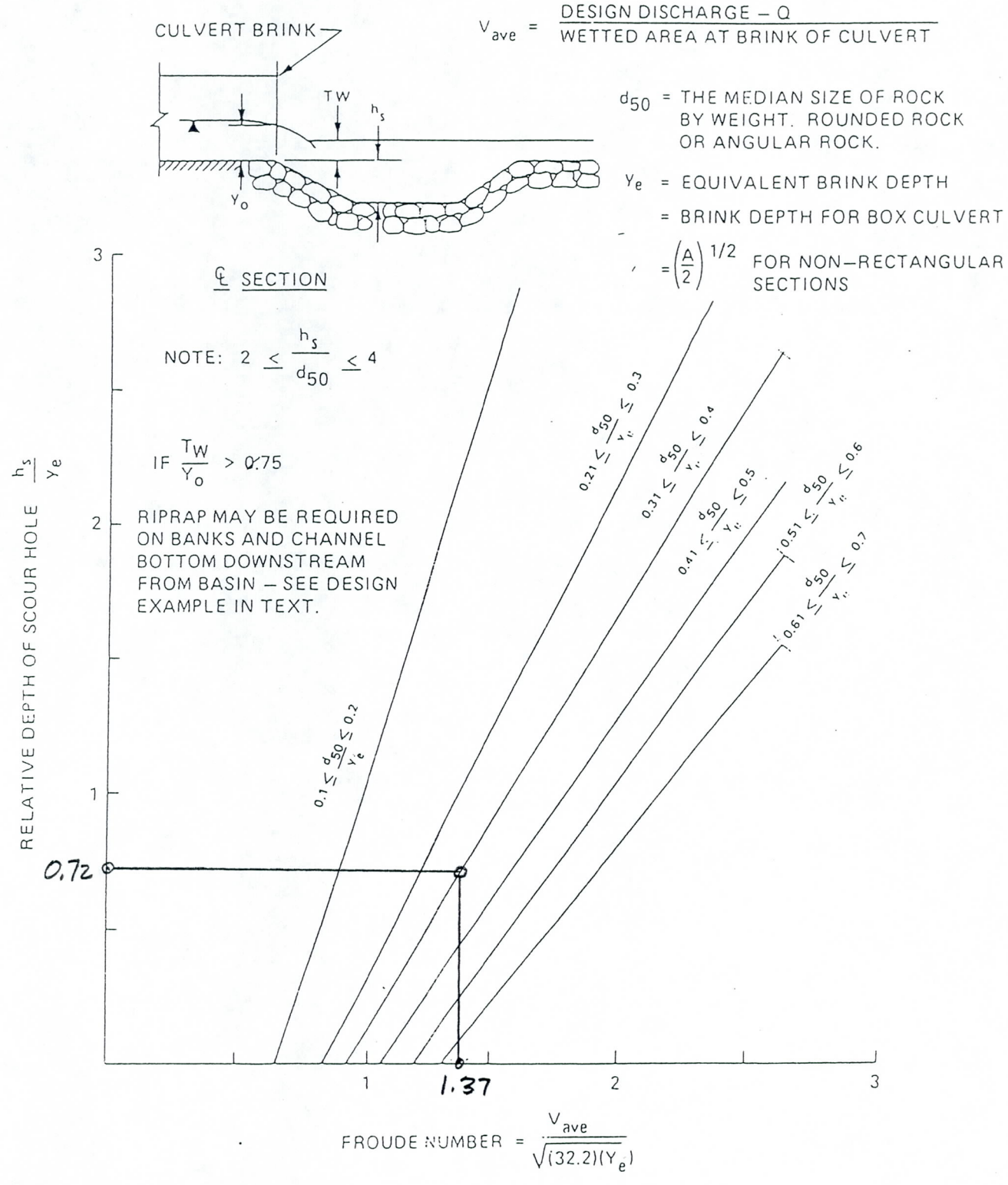


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Box Culvert COD-3

SHEET NO. 8 OF

DATE 7/13/91

BY BDO CHKD RJT

$TW/Y_o = \frac{1.8'}{1.03} = 1.75 > 0.75$ ∴ Check downstream riprap lining for channel protection.

Utilize figure XI-3 for existing average velocity along channel. Compute equivalent circular diameter D_e for brink area from:

$$A = \pi D_e^2/4 = Y_o(W_o) = 1.03(10) = 10.3$$

$$D_e = (10.3(4)/\pi)^{1/2} = 3.62'$$

From downstream cross section Q10 velocity is 3.3 fps. Culvert outlet velocity is 7.9 fps.

L/D_e	L	V_L/V_o	V_L	
10	36.2	.59	4.7	
15	54.3	.36	2.8	
14	50.7	.40	3.2	OK

∴ Need riprap lining for approximately 50 feet from the end of the culvert outlet apron.

SVERDRUP

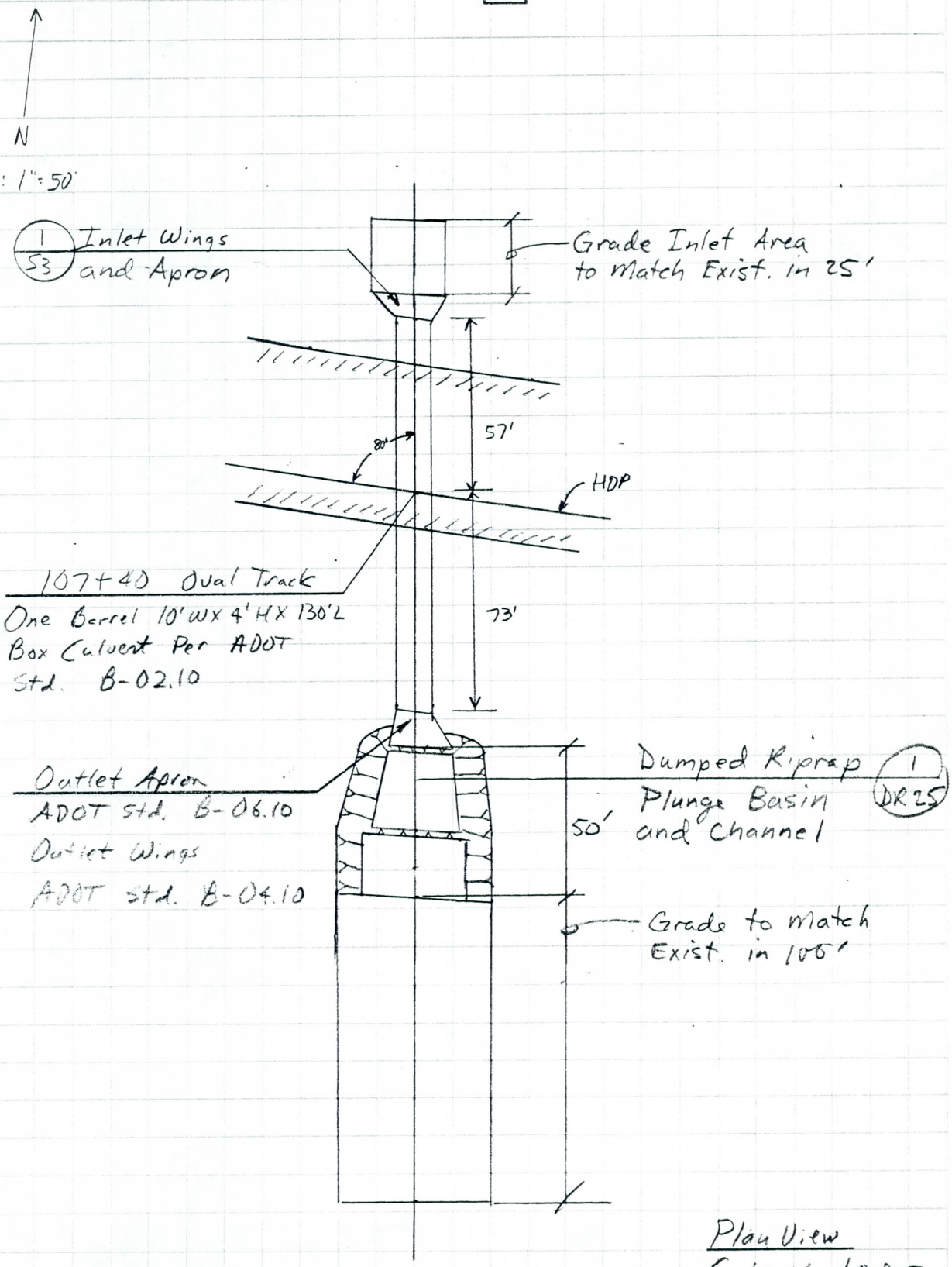
JOB 40477 Toyota

SHEET NO. 9 OF

DATE 7-20-91

COMPUTATIONS FOR Culvert 600-3 Plan View
HDP Sta. 107+40 16D

BY BDO CHKD RJT



Plan View
Culvert 600-3

SVERDRUP

JOB 4047 Toyota SHEET NO. 10 OF

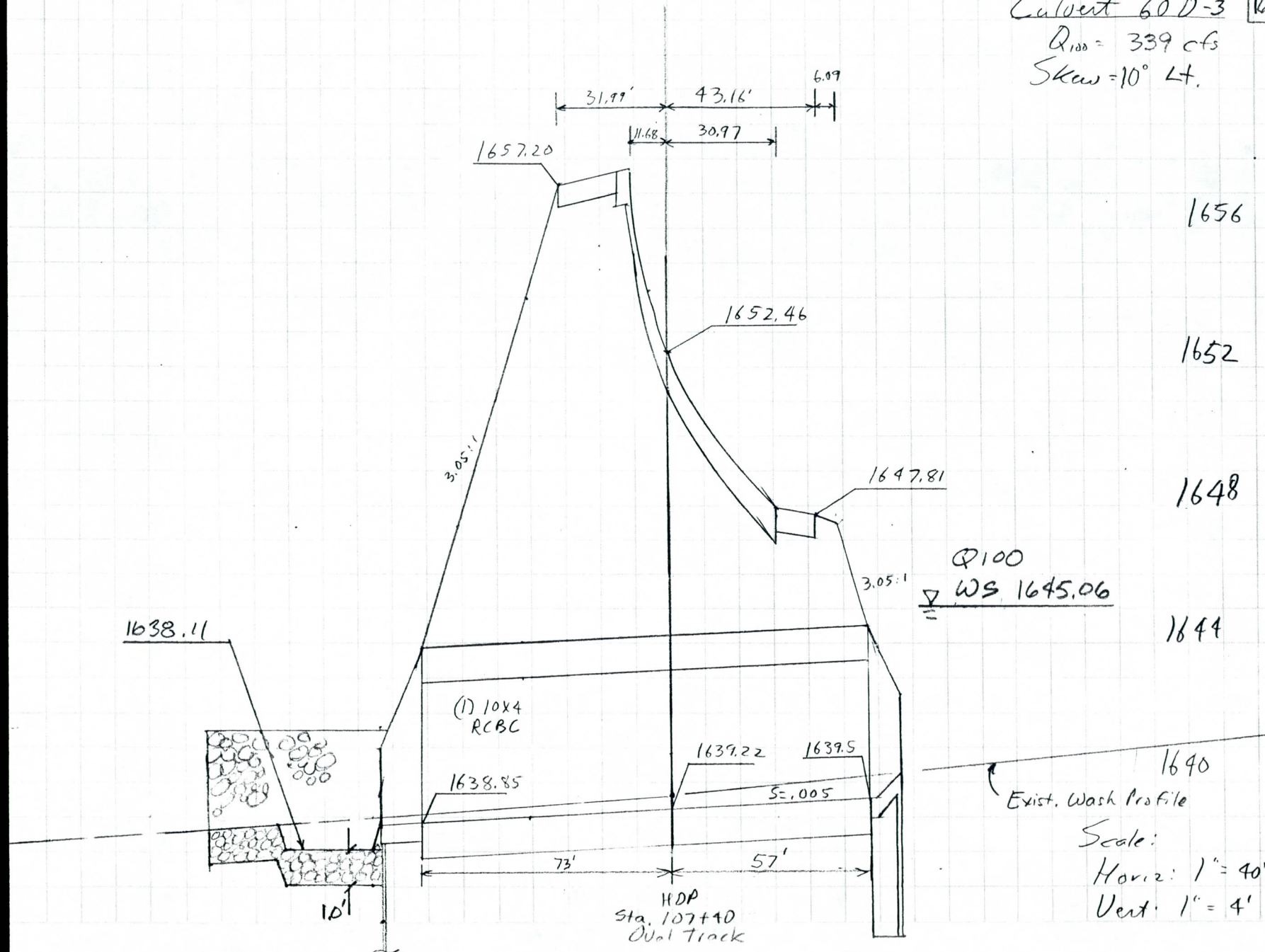
COMPUTATIONS FOR Culvert Profile 60 D-3 DATE 7-14-91

HST Sta 107+40 BY BDO CHKD RJT

Culvert 60 D-3 16D

Q_{100} = 339 cfs

Skew = 10° Lt.



SECTION NUMBER TW60D3 7/10/91

Channel Slope: 0.0078 ft./ft.

CROSS SECTION DATA:

OFFSET	20	167.7	259.6	262.3	267.3	269.8	361	362.2	363.2	369.4	450
ELEV.	41.7	40.41	40.15	38.05	38.46	39.67	39.8	39.56	39.73	40.01	41.7
N	N/A	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.025	0.035	0.035

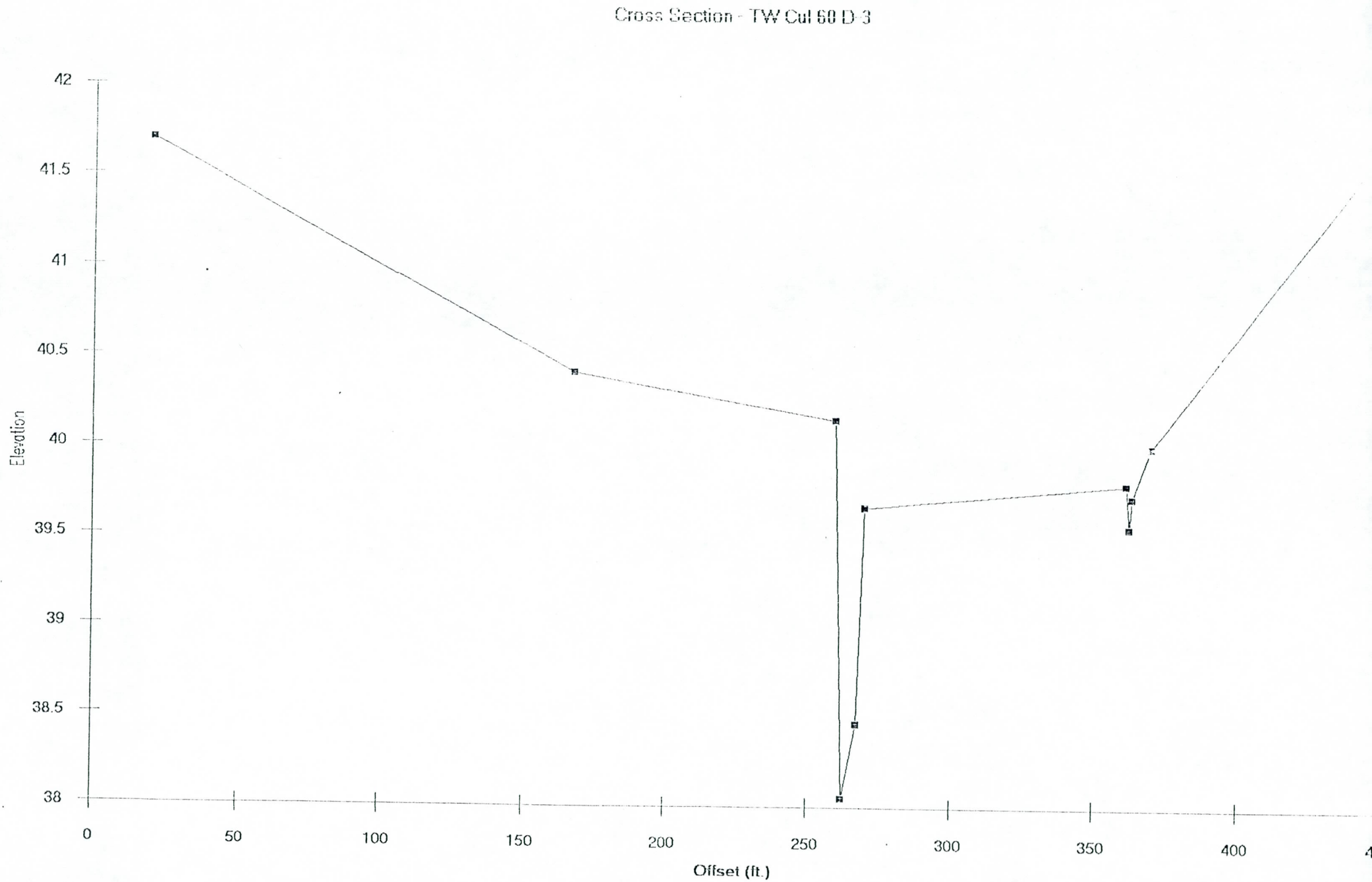
STAGE-DISCHARGE DATA:

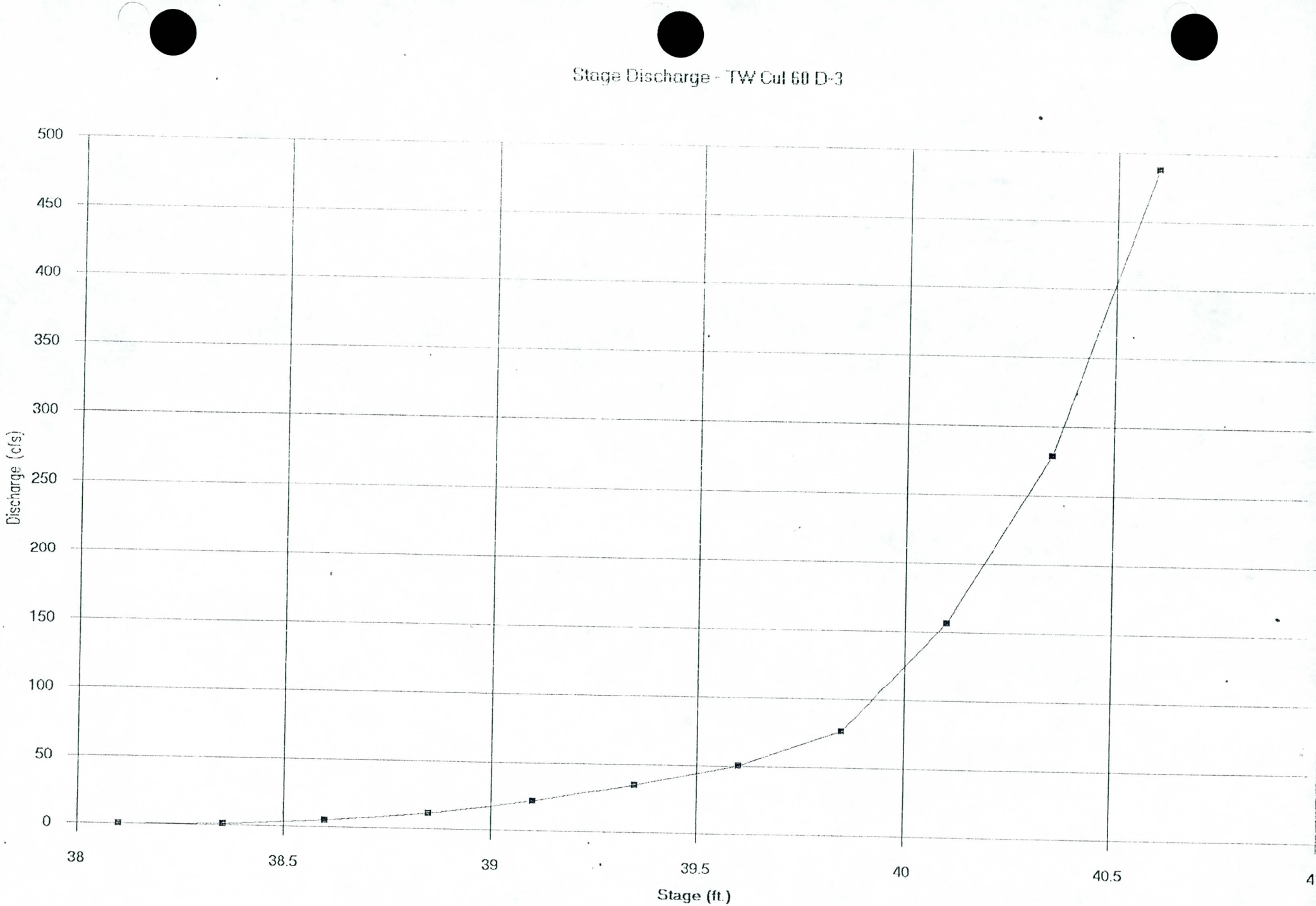
STAGE:	38.1											
WET PER.		0.0	0.0	0.1	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	38.35												
WET PER.		0.0	0.0	0.5	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.1	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	1	0	0	0	0	0	0	0	0
STAGE:	38.6												
WET PER.		0.0	0.0	0.9	5.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.2	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	4	0	0	0	0	0	0	0	0
STAGE:	38.85												
WET PER.		0.0	0.0	1.3	5.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.4	3.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.3	0.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	1	11	0	0	0	0	0	0	0	0
STAGE:	39.1												
WET PER.		0.0	0.0	1.7	5.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.7	4.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.4	0.8	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	1	20	1	0	0	0	0	0	0	0
STAGE:	39.35												
WET PER.		0.0	0.0	2.1	5.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.1	5.5	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.5	1.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	3	31	2	0	0	0	0	0	0	0

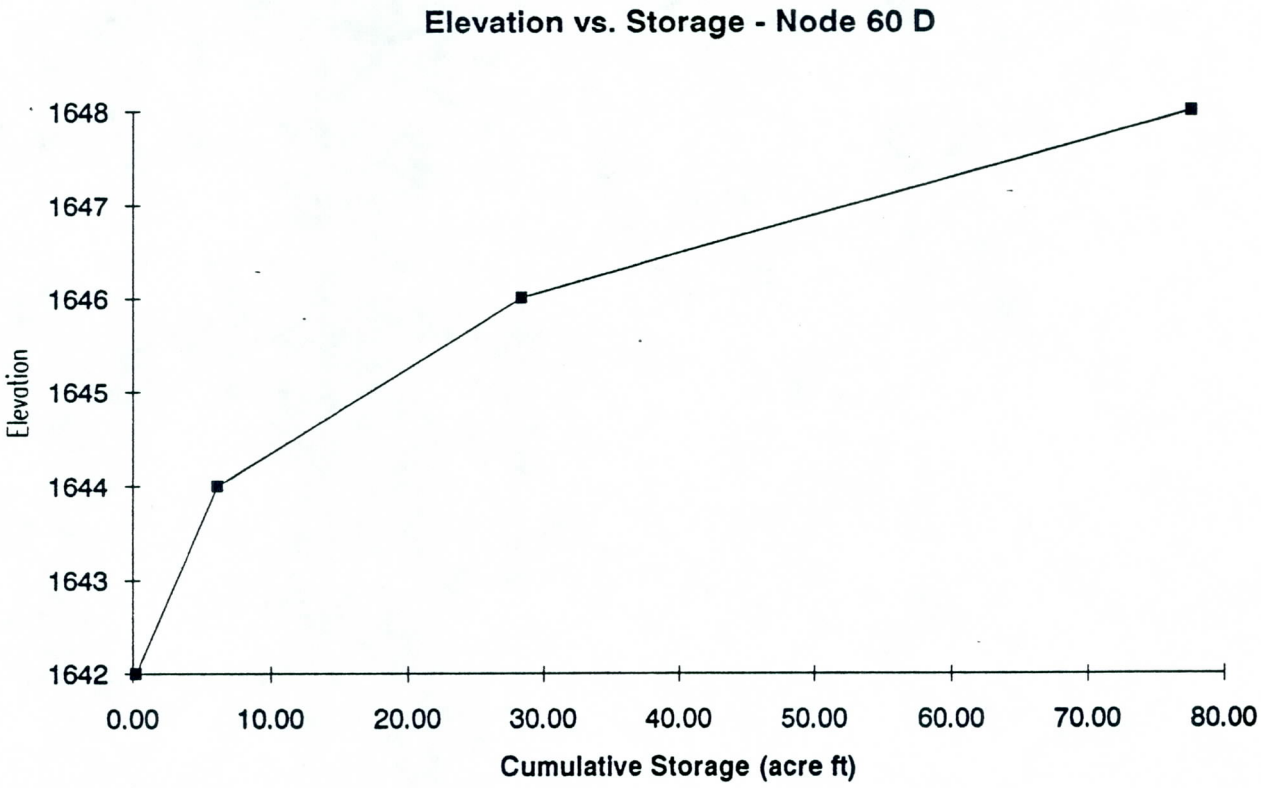
SECTION NUMBER TW60D3 7/10/91

STAGE:	39.6											
WET PER.		0.0	0.0	2.5	5.0	2.6	0.0	0.2	0.2	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.5	6.7	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.6	1.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	4	43	3	0	0	0	0	0	0	0
STAGE:	39.85												
WET PER.		0.0	0.0	2.9	5.0	2.8	94.0	95.2	1.0	2.7	0.0	0.0	0.0
AREA		0.0	0.0	2.1	8.0	2.0	12.5	12.7	0.2	0.2	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.7	1.6	0.7	0.1	0.1	0.2	0.1	0.0	0.0	0.0
Q		0	0	6	57	0	0	12	0	0	0	0	0
STAGE:	40.1												
WET PER.		0.0	0.0	3.3	5.0	2.8	94.0	95.2	1.0	6.2	10.5	0.0	0.0
AREA		0.0	0.0	2.7	9.2	2.6	35.9	36.4	0.5	1.4	1.6	0.0	0.0
HYD.RAD.		0.0	0.0	0.8	1.8	0.9	0.4	0.4	0.4	0.2	0.2	0.0	0.0
Q		0	0	9	73	0	0	72	1	0	2	0	0
STAGE:	40.35												
WET PER.		0.0	70.7	74.1	5.0	2.8	94.0	95.2	1.0	6.2	22.4	0.0	0.0
AREA		0.0	7.1	10.4	10.5	3.2	59.3	60.1	0.7	3.0	5.7	0.0	0.0
HYD.RAD.		0.0	0.1	0.1	2.1	1.2	0.6	0.6	0.7	0.5	0.3	0.0	0.0
Q		0	0	11	90	0	0	166	3	0	9	0	0
STAGE:	40.6												
WET PER.		21.8	113.7	117.1	5.0	2.8	94.0	95.2	1.0	6.2	34.3	0.0	0.0
AREA		2.1	31.5	35.5	11.7	3.8	82.7	83.8	1.0	4.5	12.8	0.0	0.0
HYD.RAD.		0.1	0.3	0.3	2.3	1.4	0.9	0.9	0.9	0.7	0.4	0.0	0.0
Q		0	0	60	109	0	0	289	5	0	25	0	0

W.S. Elev.	38.1	38.35	38.6	38.85	39.1	39.35	39.6	39.85	40.1	40.35	40.6
Q	0	1	5	12	22	35	50	76	157	278	488
A	0.0	0.6	1.9	3.5	5.4	7.4	9.6	23.1	50.4	87.5	144.9
V	0.4	1.4	2.4	3.4	4.1	4.7	5.2	3.3	3.1	3.2	3.4


Cross Section - TW Cul 60 D-3
42
41.5
41
40.5
40
39.5
39
38.5
38
Elevation
0
50
100
150
200
250
300
350
400
Offset (ft.)


Stage Discharge - TW Cul 60 D-3
Discharge (cfs)
500
450
400
350
300
250
200
150
100
50
0
38
38.5
39
39.5
40
40.5
Stage (ft.)


Elevation vs. Storage - Node 60 D
1648
1647
1646
1645
1644
1643
1642
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Cumulative Storage (acre ft)

SVERDRI

JOB 40477 Toyota

SHEET NO. ____ OF ____

DATE 7/13/91

COMPUTATIONS FOR Culvert 60 D-2 16E

BY BDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT: ____

STATION: 99+00, Oval Track

DESIGNER: ____

DATE: ____

HYDROLOGIC AND CHANNEL INFORMATION

2034/a = 339 cfs

DRAINAGE AREA 10.98 sq. miles

Q_1 = 339 cfs

Q_2 = ____

TW_1 = 2.3' Exist. Channel

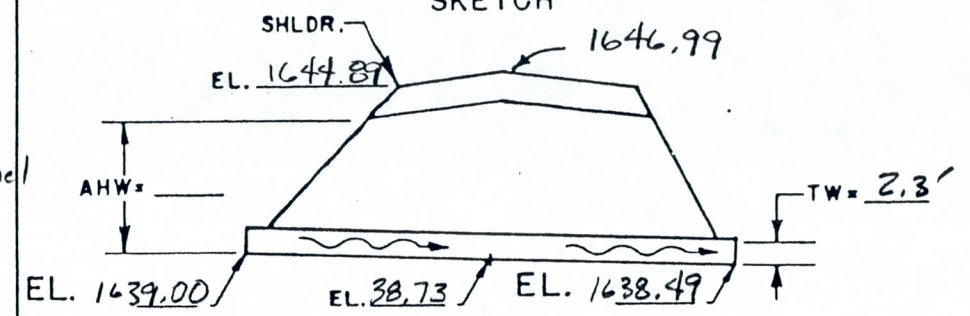
TW_2 = ____

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~ Q_{100})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .0050 ft/ft L = 102' L/100 S_o = ____

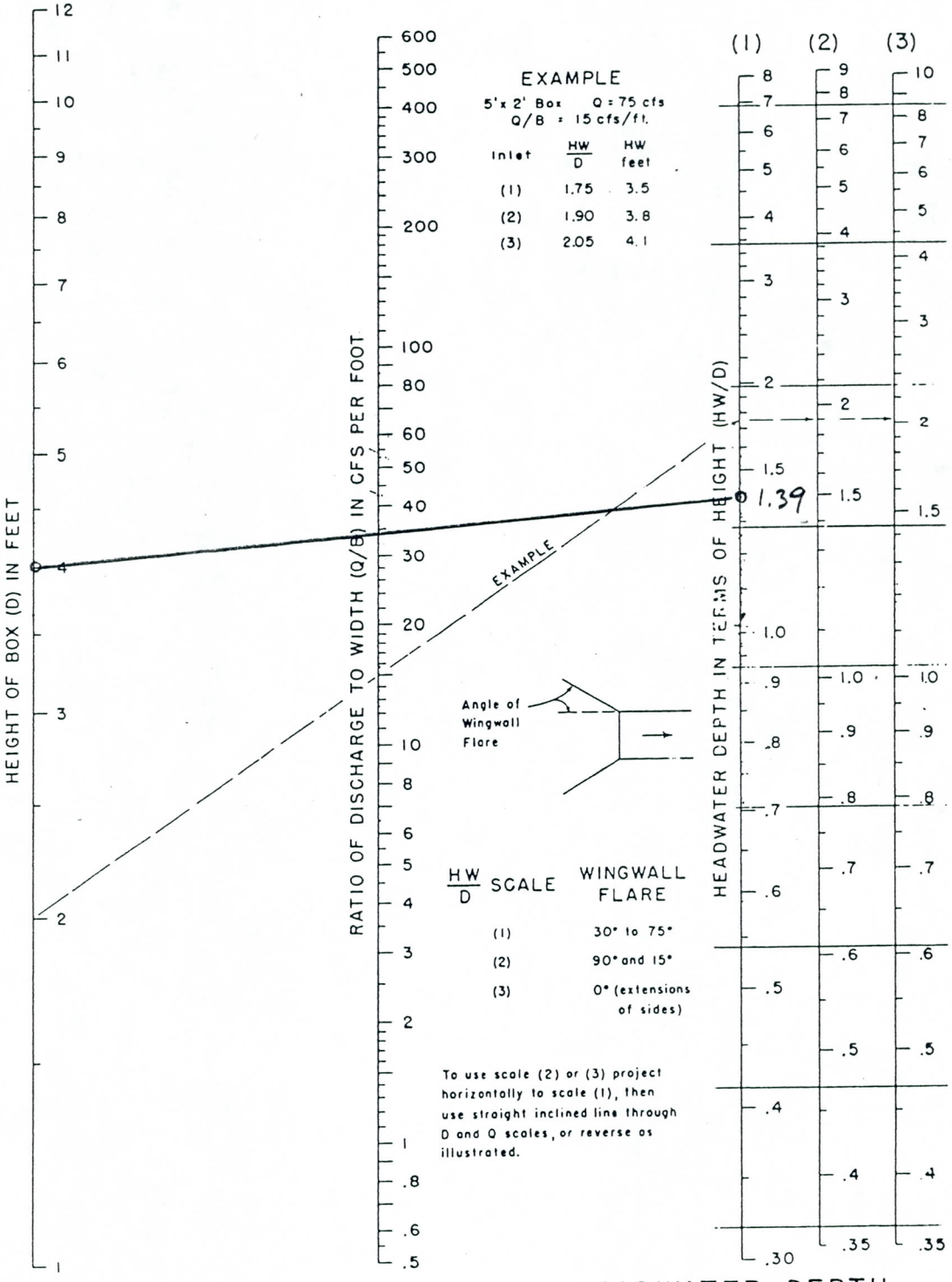
MEAN STREAM VELOCITY = 3.86 fps

CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(1) Barrel 10'x4'	Drop Inlet	339		1.39	5.56	0.2	1.65	3.30	3.65	2.3	3.65	.51	4.79	5.56	12.7		1644.56	Inlet Control

SUMMARY & RECOMMENDATIONS Use dumped riprap plunge basin for outlet erosion protection.

Culvert 60 D-2

CHART 1

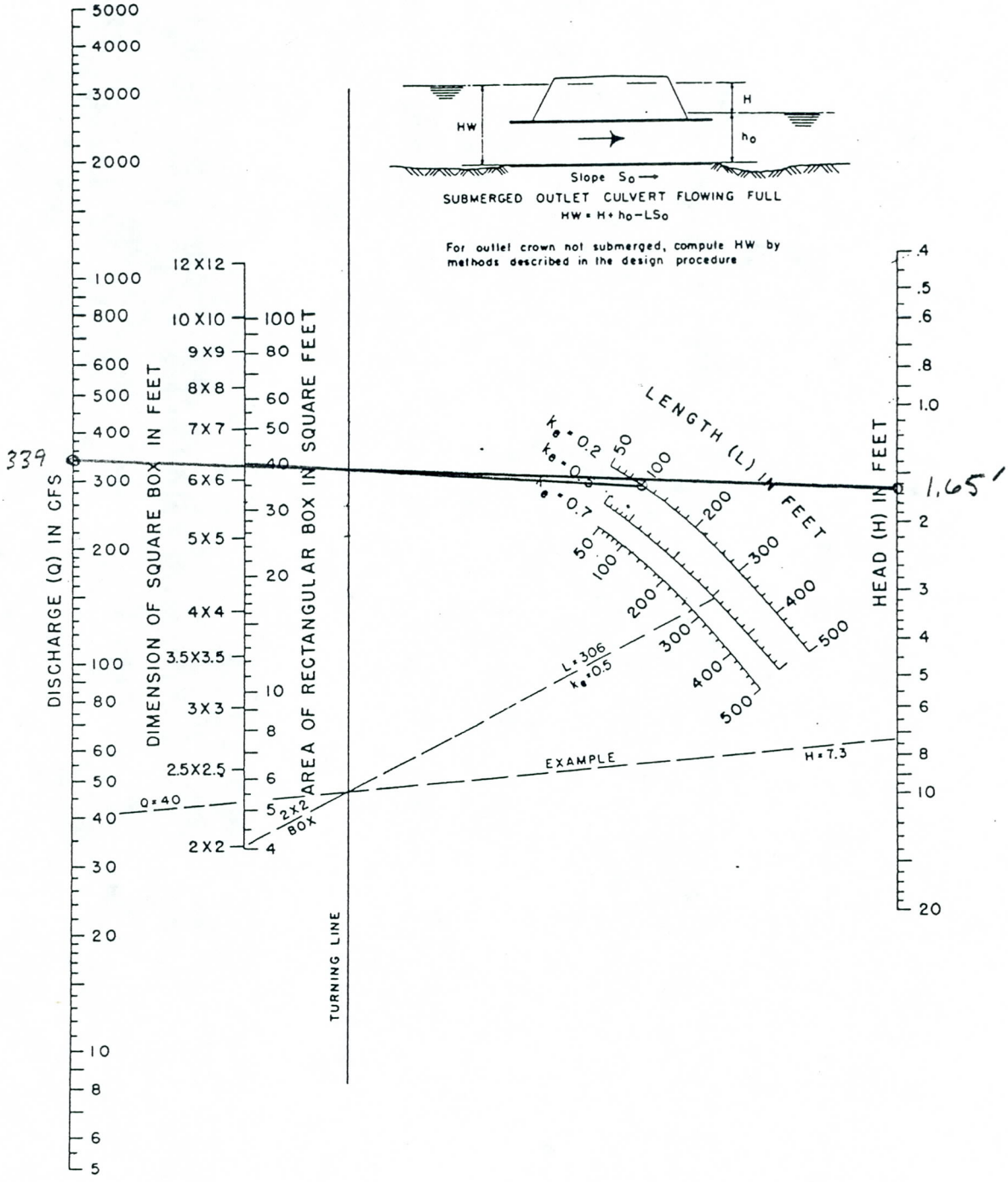


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 D-2

CHART 8

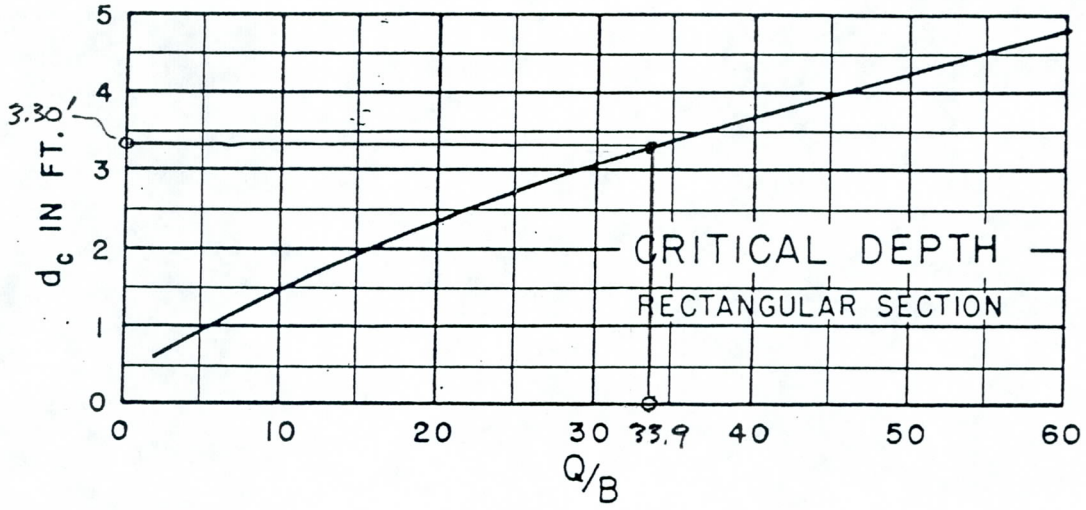


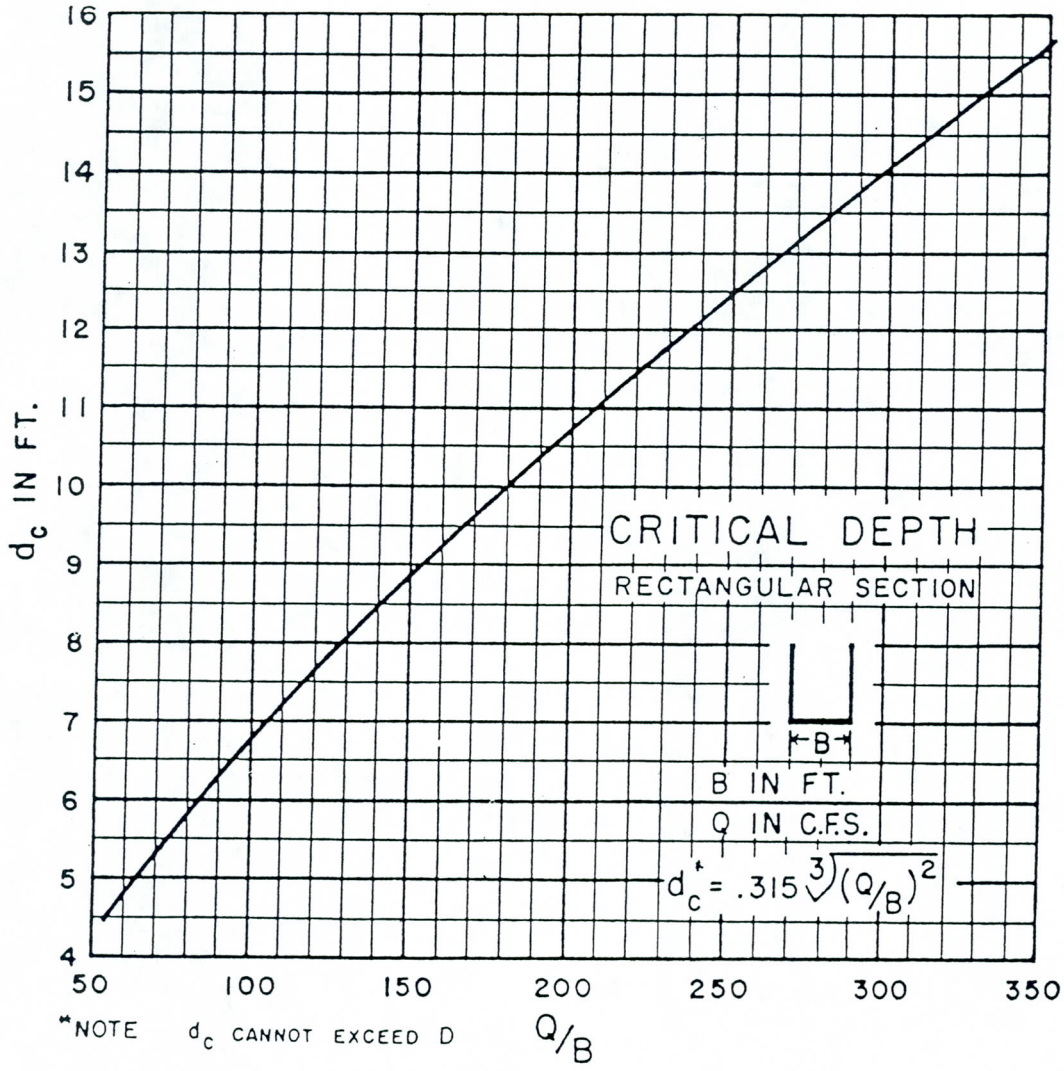
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 D-2

CHART 15





BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60 D-2

SHEET NO. 5 OF

DATE 7/13/91

BY BDO CHKD RJT

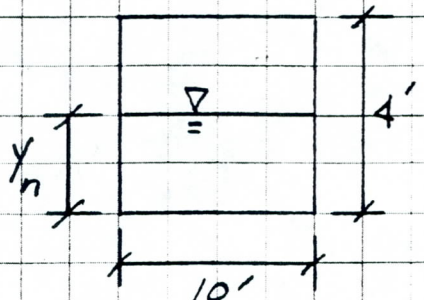
Check depth of Flow using Mannings Equation

$Q100 = 2034$ cfs, $Q = 339$ cfs/culvert

$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 2.67'$



$A = 26.7$ ft^2

$WP = 15.34$ ft

$R_h = A/WP = 26.7/15.34 = 1.7405'$

$V = \frac{1.49}{.012}(1.7405)^{.666}(.005)^{.5} = 12.70$ fps

Check

$Q = VA = 12.70\,(26.7) = 339$ cfs (OK)

Check Froude Number

$\# = \frac{12.70}{\sqrt{32.2 \times 2.67}} = 1.37$, Supercritical

$Q10 = 488/6 = 81$ cfs

$Y_n = 1.03'$, Velocity = 7.88 fps, $\# = 1.37$ Supercritical

Need riprap plunge basin to minimize erosion downstream of culvert

SVERDRUP

JOB 40477 Toyota

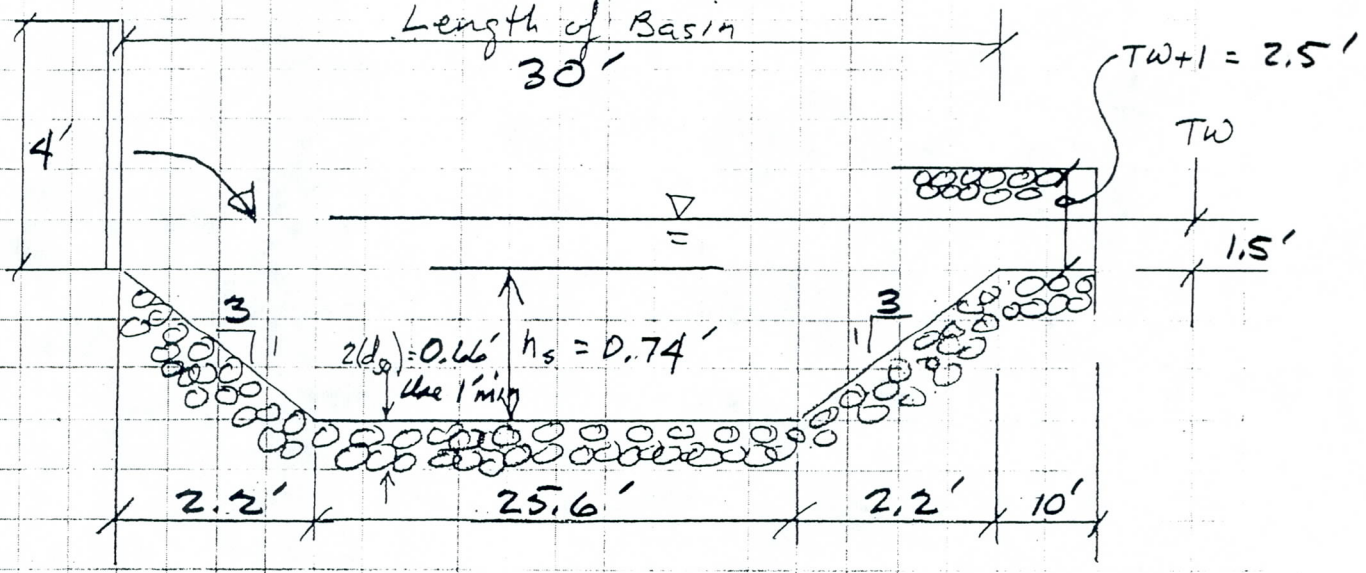
COMPUTATIONS FOR Box Culvert 60D-2

SHEET NO. 6 OF

DATE 7/13/91

BY BDO CHKD RJT

Riprap Plunge Basin Design (Q10)



Check Rock Size (From Figure XI-2, HEC No. 14)

For $y_o = 1.03'$ $d_{50} = 4''$ or $0.33'$

$$d_{50}/y_o = \frac{0.33}{1.03} = 0.32 \quad , \quad FF = 1.37$$

$$\frac{h_s}{y_o} = 0.72 \qquad h_s = 0.72(1.03') = 0.74'$$

Check $\frac{h_s}{d_{50}} = \frac{0.74}{0.33} = 2.24 < 4$ and > 2 ∴ OK

Length of Basin

$10\,h_s = 10(0.74) = 7.4'$

or

$3(W_o) = 3(10) = 30'$

Use 30'

Culvert 60 D-2

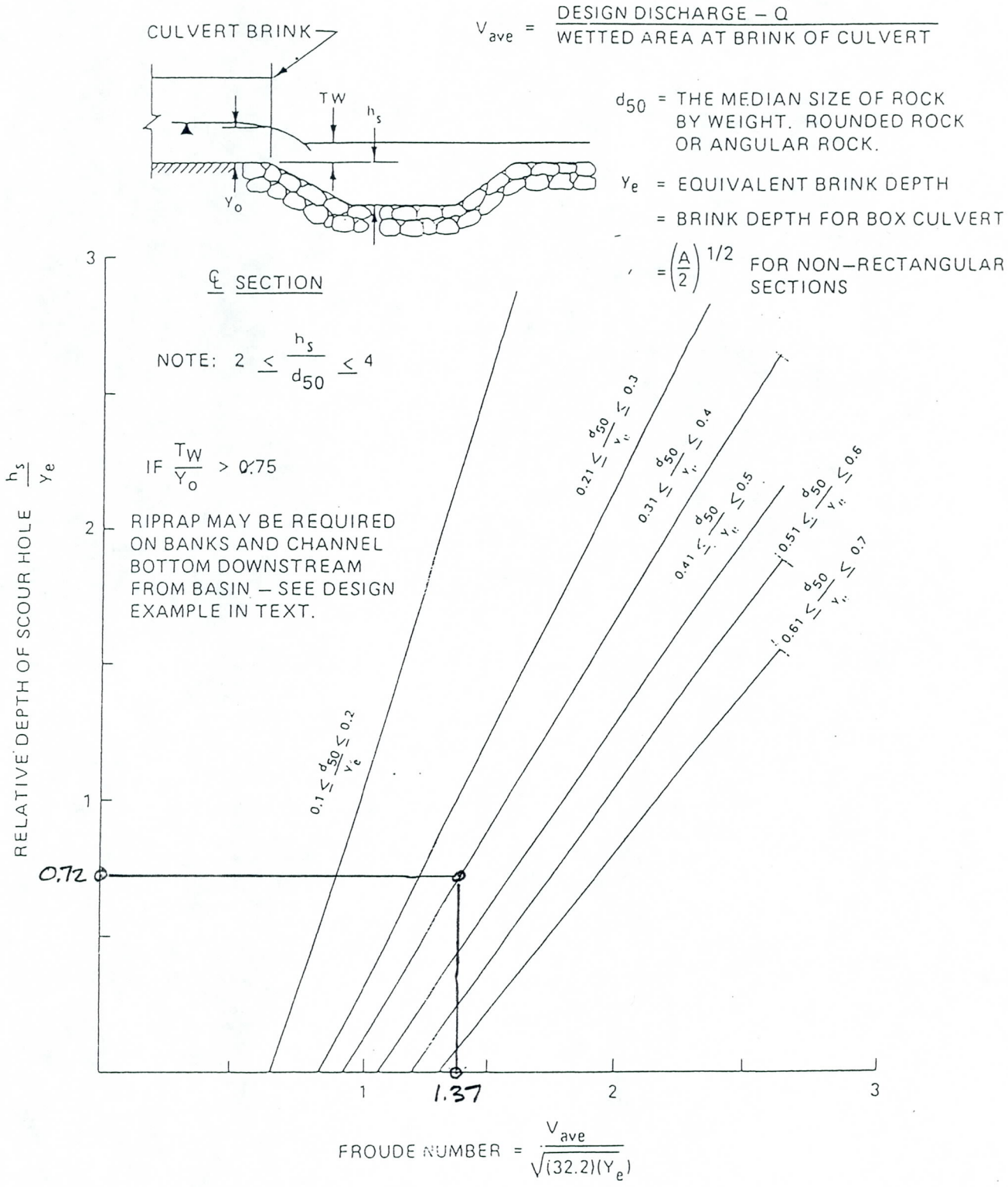


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota SHEET NO. 8 OF

COMPUTATIONS FOR Box Culvert 60D-2 DATE 7/13/91

BY BDO CHKD RJT

$TW/Y_o = \frac{1.4'}{1.03'} = 1.36 > 0.75$ ∴ Check downstream riprap lining for channel protection.

Utilize figure XI-3 for existing average velocity along channel. Compute equivalent circular diameter D_e for brink area from:

$A = \pi D_e^2/4 = Y_o(W_o) = 1.03(10) = 10.3\ ft^2$

$D_e = (10.3(4)/\pi)^{1/2} = 3.62'$

From downstream cross section Q10 velocity is 3.2 fps. Culvert outlet velocity is 7.9 fps.

L/D_e	L	V_L/V_o	V_L	
10	36.2	.59	4.7	
15	54.3	.36	2.8	
14	50.7	.40	3.2	OK

∴ Need riprap lining for approximately 50 feet from the end of the culvert outlet apron.

SVERDRUP

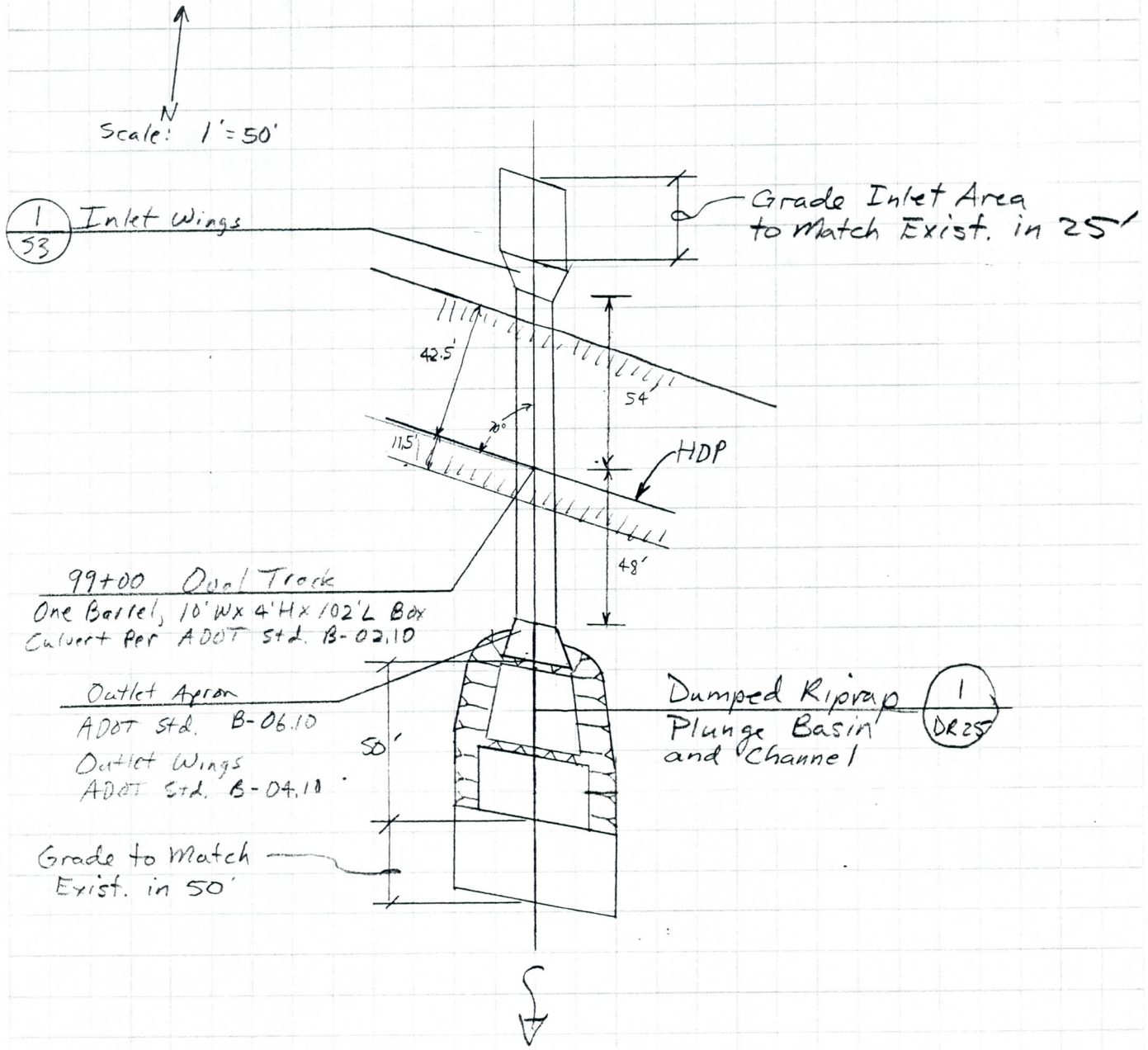
JOB 40477 Toyota

SHEET NO. 9 OF

DATE 7-20-91

COMPUTATIONS FOR Culvert 60 D-2 Plan View HDP Sta. 99+00 16E

BY BDO CHKD RJT



Plan View
Culvert 60D-2

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert Profile 600-2
MST Sta 99+00

SHEET NO. 10 OF

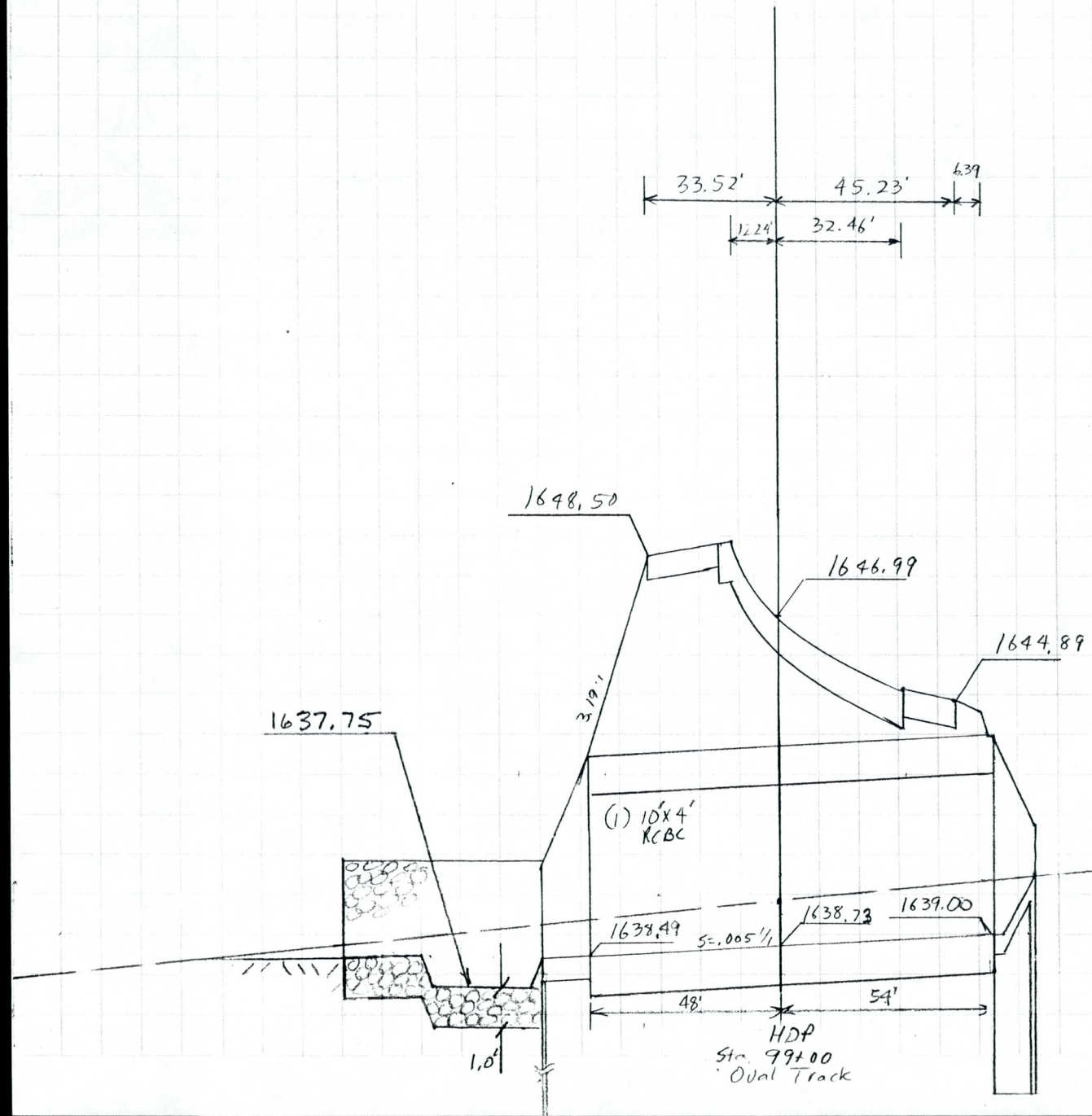
DATE 7-14-91

BY BDO CHKD RVJ

Culvert 600-2 16E

Q_{100} = 339 cfs

Skew = 20° Lt.



16E

Q100 W.S.
▽ Elev 1644.56

Scale:
Horiz: 1" = 40'
Vert: 1" = 4'

SECTION NUMBER TW60D2 7/10/91

Channel Slope: 0.0103 ft./ft.

CROSS SECTION DATA:

OFFSET	47.5	127	138.3	138.9	139.8	141.5	163.5	166.1	168	238.6	300	
ELEV.	40.96	39.65	38.31	37.95	37.85	38.37	38.81	38.38	39.16	40.42	42	
N	N/A	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.035	0.035	0.035	

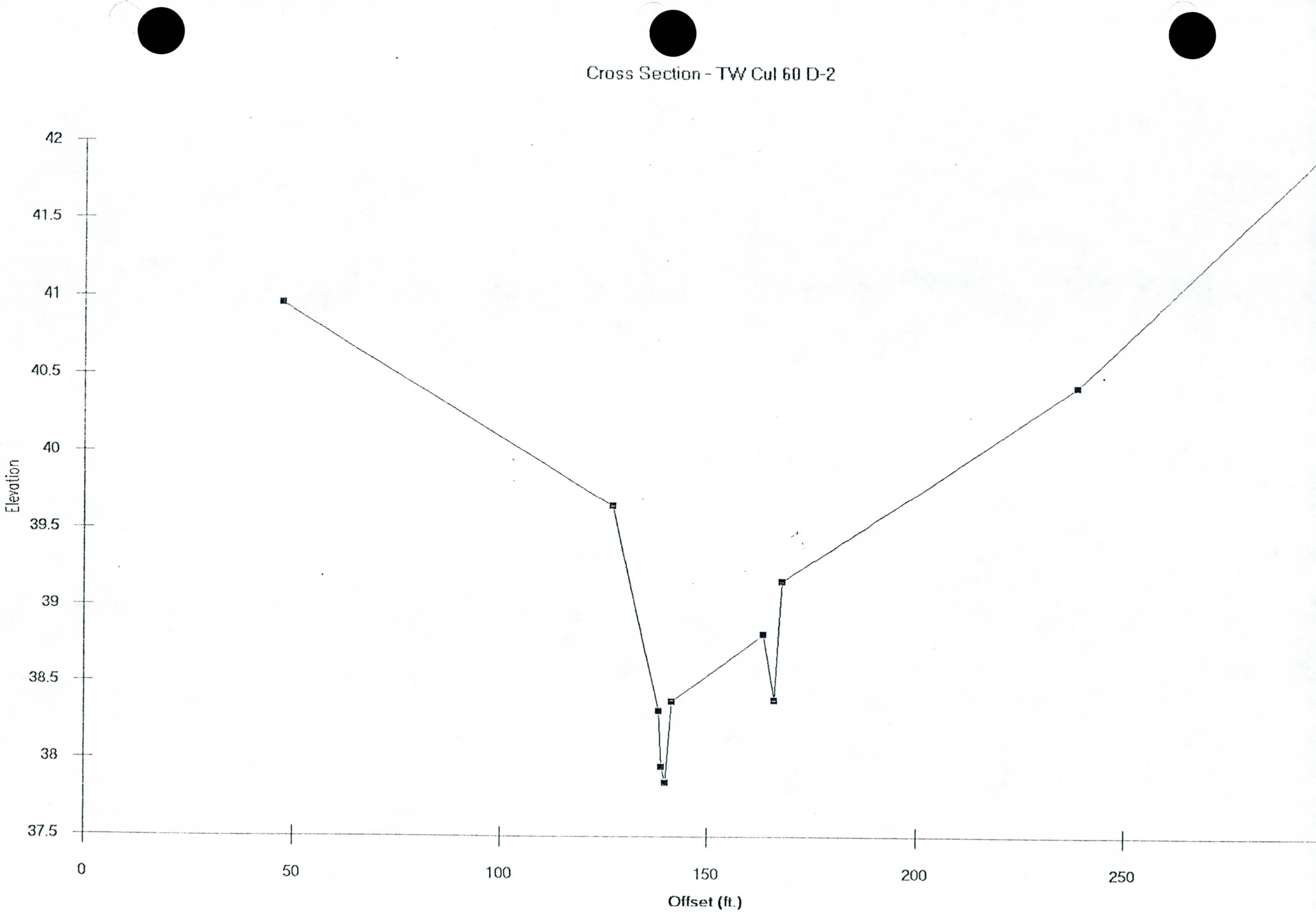
STAGE-DISCHARGE DATA:

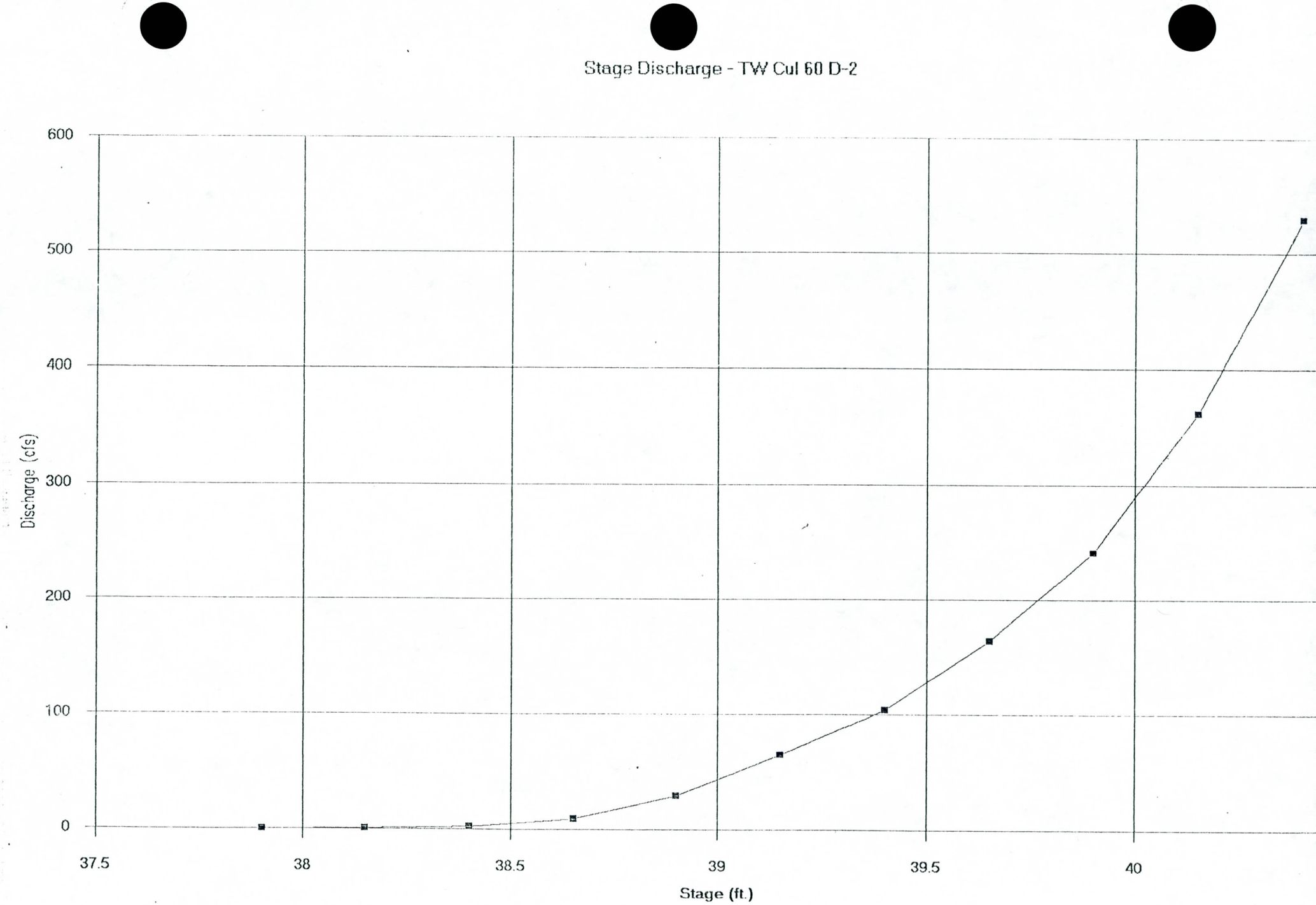
STAGE:	37.9											
WET PER.		0.0	0.0	0.0	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	38.15												
WET PER.		0.0	0.0	0.4	0.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	1	0	0	0	0	0	0	0	0
STAGE:	38.4												
WET PER.		0.0	0.8	1.5	0.9	1.8	3.3	0.1	0.2	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.2	0.5	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.1	0.5	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	2	0	1	0	0	0	0	0	0
STAGE:	38.65												
WET PER.		0.0	2.9	3.6	0.9	1.8	15.8	1.7	2.4	0.0	0.0	0.0	0.0
AREA		0.0	0.5	0.8	0.7	0.9	2.9	0.2	0.3	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.2	0.2	0.7	0.5	0.2	0.1	0.1	0.0	0.0	0.0	0.0
Q		0	0	1	3	0	4	0	0	0	0	0	0
STAGE:	38.9												
WET PER.		0.0	5.0	5.7	0.9	1.8	23.8	26.4	27.8	0.0	0.0	0.0	0.0
AREA		0.0	1.5	1.9	0.9	1.3	8.2	9.0	9.3	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.3	0.3	1.0	0.8	0.3	0.3	0.3	0.0	0.0	0.0	0.0
Q		0	0	4	5	0	0	0	19	0	0	0	0
STAGE:	39.15												
WET PER.		0.0	7.1	7.8	0.9	1.8	27.8	26.4	28.4	0.0	0.0	0.0	0.0
AREA		0.0	3.0	3.6	1.1	1.8	14.1	15.5	16.3	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.4	0.5	1.2	1.0	0.6	0.6	0.6	0.0	0.0	0.0	0.0
Q		0	0	9	8	0	0	0	48	0	0	0	0

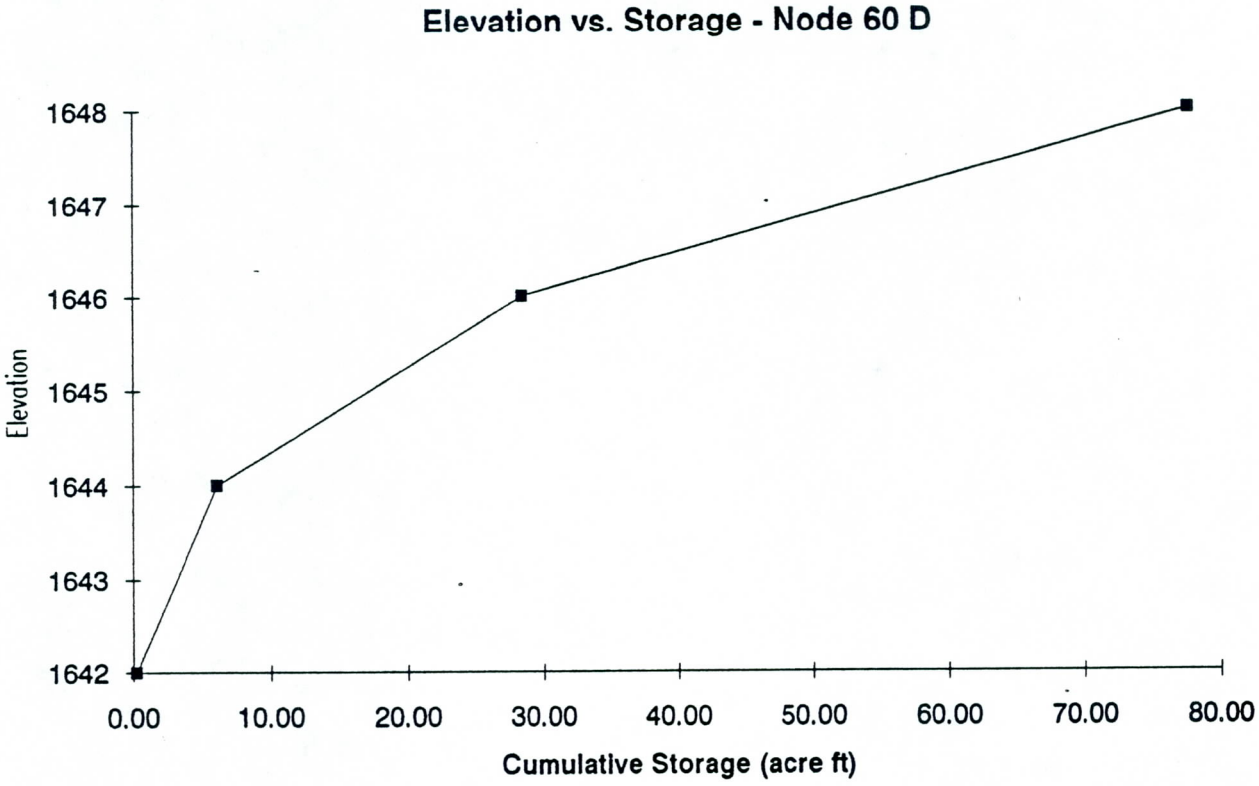
SECTION NUMBER TW60D2 7/10/91

STAGE:	39.4											
WET PER.		0.0	9.3	10.0	0.9	1.8	23.8	26.4	28.5	41.9	0.0	0.0	0.0
AREA		0.0	5.0	5.8	1.4	2.2	20.0	22.1	23.3	24.9	0.0	0.0	0.0
HYD.RAD.		0.0	0.5	0.6	1.5	1.2	0.8	0.8	0.8	0.6	0.0	0.0	0.0
Q		0	0	17	11	0	0	0	0	76	0	0	0
STAGE:	39.65												
WET PER.		0.0	11.4	12.1	0.9	1.8	23.8	26.4	28.5	55.9	0.0	0.0	0.0
AREA		0.0	7.6	8.5	1.6	2.6	25.9	28.7	30.4	37.1	0.0	0.0	0.0
HYD.RAD.		0.0	0.7	0.7	1.7	1.5	1.1	1.1	1.1	0.7	0.0	0.0	0.0
Q		0	0	29	14	0	0	0	0	122	0	0	0
STAGE:	39.9												
WET PER.		15.2	26.5	27.2	0.9	1.8	23.8	26.4	28.5	69.9	0.0	0.0	0.0
AREA		1.9	12.3	13.4	1.8	3.0	31.9	35.3	37.4	52.7	0.0	0.0	0.0
HYD.RAD.		0.1	0.5	0.5	2.0	1.7	1.3	1.3	1.3	0.8	0.0	0.0	0.0
Q		0	0	36	17	0	0	0	0	188	0	0	0
STAGE:	40.15												
WET PER.		30.4	41.7	42.4	0.9	1.8	23.8	26.4	28.5	84.0	0.0	0.0	0.0
AREA		7.6	20.8	22.0	2.0	3.5	37.8	41.8	44.5	71.9	0.0	0.0	0.0
HYD.RAD.		0.2	0.5	0.5	2.2	2.0	1.6	1.6	1.6	0.9	0.0	0.0	0.0
Q		0	0	61	21	0	0	0	0	280	0	0	0
STAGE:	40.4												
WET PER.		45.5	56.9	57.6	0.9	1.8	23.8	26.4	28.5	98.0	0.0	0.0	0.0
AREA		17.1	33.1	34.5	2.3	3.9	43.7	48.4	51.5	94.6	0.0	0.0	0.0
HYD.RAD.		0.4	0.6	0.6	2.5	2.2	1.8	1.8	1.8	1.0	0.0	0.0	0.0
Q		0	0	106	25	0	0	0	0	398	0	0	0

W.S. Elev.	37.9	38.15	38.4	38.65	38.9	39.15	39.4	39.65	39.9	40.15	40.4
Q	0	1	3	9	29	65	104	164	241	362	529
A	0.0	0.4	1.2	4.7	12.1	21.0	32.0	47.1	67.9	96.0	131.3
V	0.5	1.8	2.2	1.9	2.4	3.1	3.2	3.5	3.6	3.8	4.0


Cross Section - TW Cul 60 D-2
42
41.5
41
40.5
40
39.5
39
38.5
38
37.5
Elevation
0
50
100
150
200
250
Offset (ft.)


Stage Discharge - TW Cul 60 D-2
600
500
400
300
200
100
0
Discharge (cfs)
37.5
38
38.5
39
39.5
40
Stage (ft.)


Elevation vs. Storage - Node 60 D
1648
1647
1646
1645
1644
1643
1642
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Cumulative Storage (acre ft)

SVERDRI

JOB 4047 Toyota

COMPUTATIONS FOR Culvert 60 D-1 16F

SHEET NO. 1 OF

DATE 7/13/91

BY EDO CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 94+70, Oval Track

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

2034/6 = 339 cfs

DRAINAGE AREA 10.98 sq. miles

Q_1 = 339 cfs

Q_2 = ____

TW_1 = 1.7' Exist. Channel

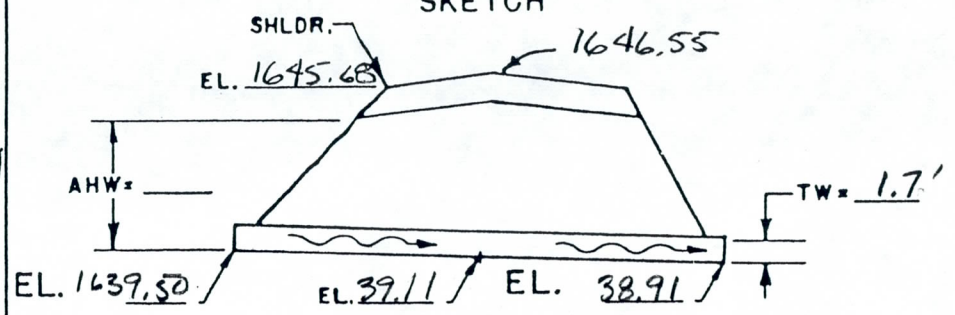
TW_2 = ____

Peak Outlet Discharge

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~ Q_{100})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = 0.0050' / L = 118' L/100 S_o = ____

MEAN STREAM VELOCITY = 3.3 fps

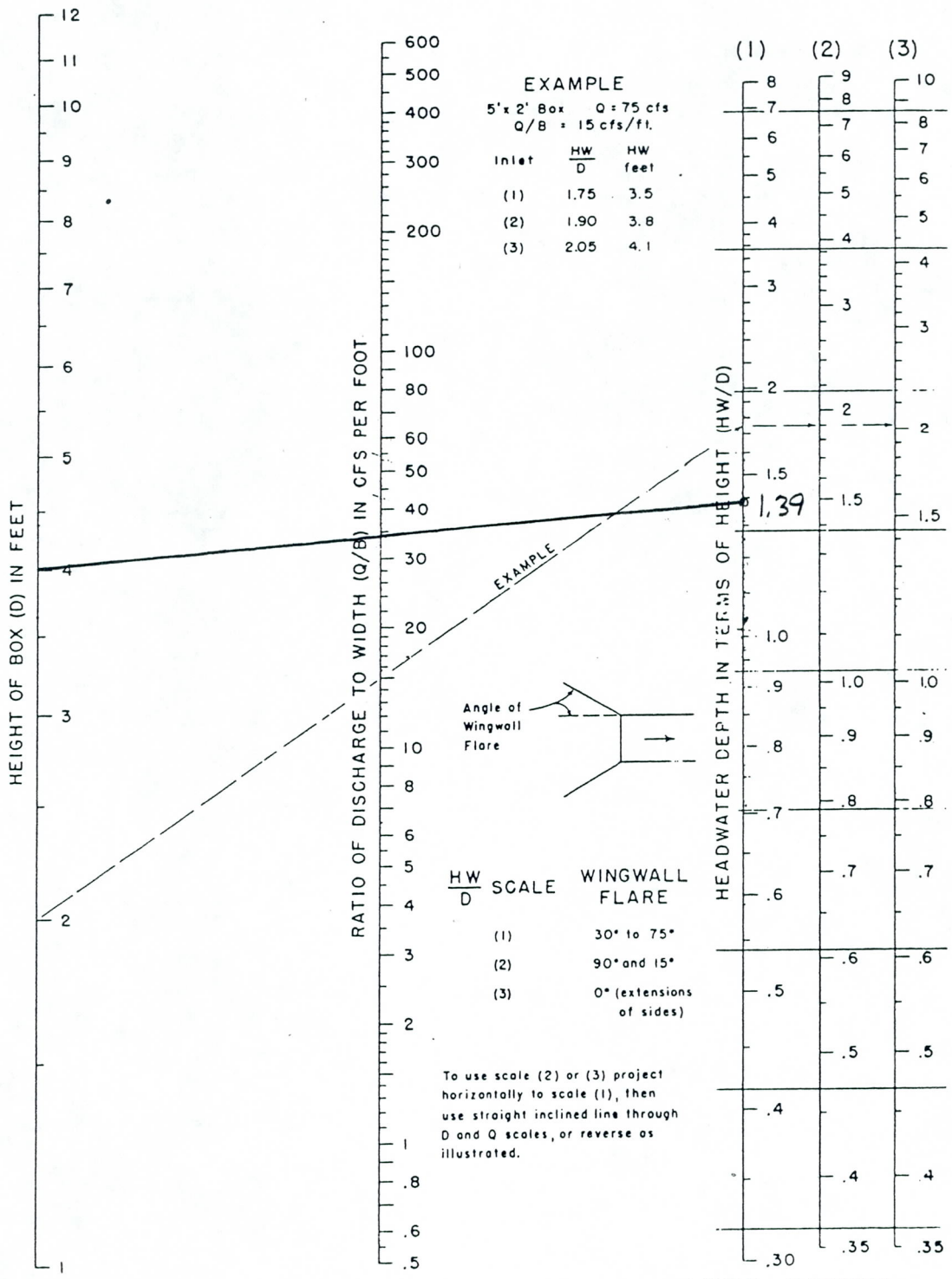
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
(1) Barrel 10'x4'	Headwall	339		1.39	5.56	0.2	1.65	3.30	3.65	1.7	3.65	0.59	4.71	5.56	12.7		1645.06	Inlet Control

SUMMARY & RECOMMENDATIONS Use dumped riprap plunge basin for outlet erosion protection.

B-1

Culvert 60 D-1

CHART 1

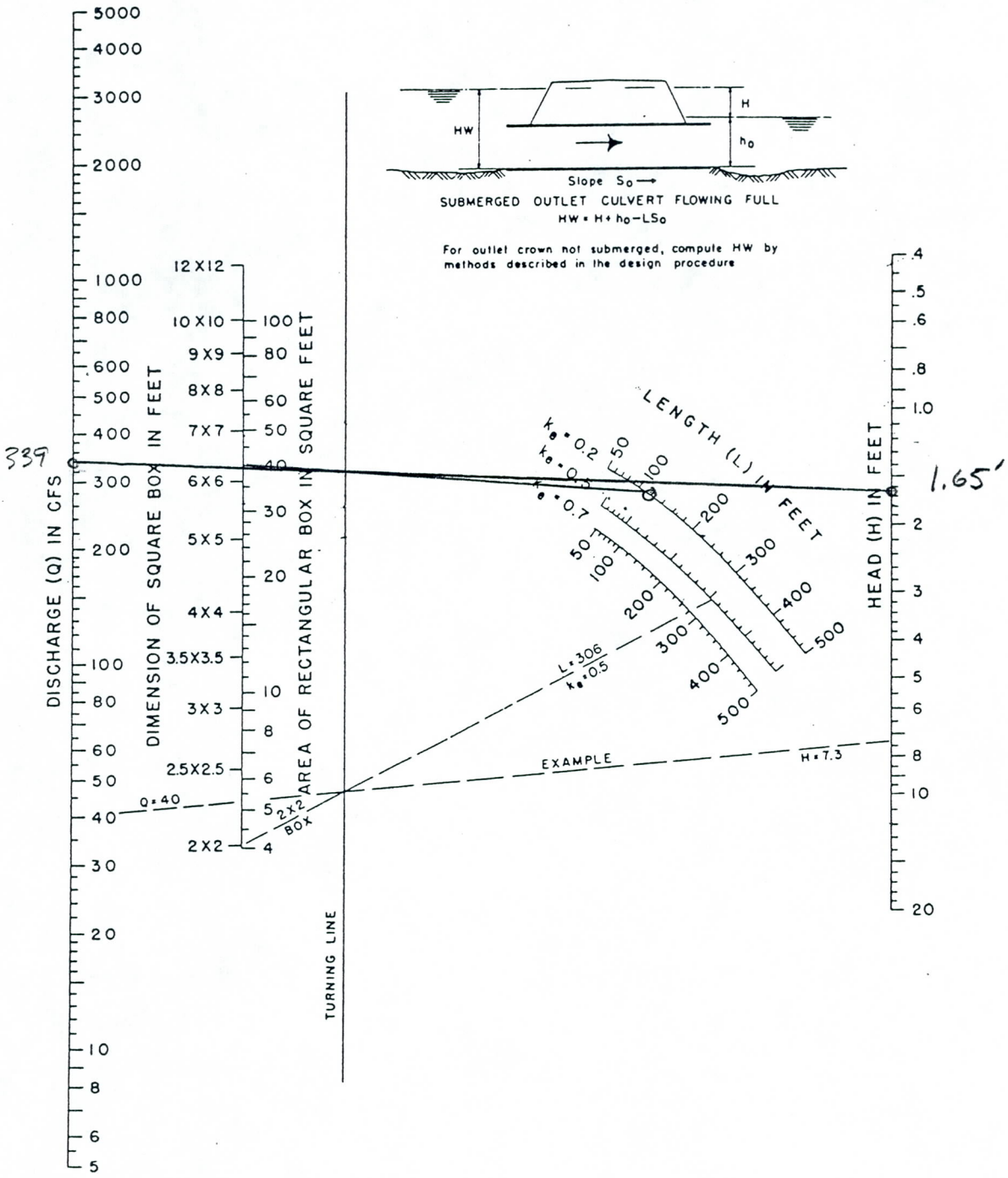


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1953

Culvert 60 D-1

CHART 8

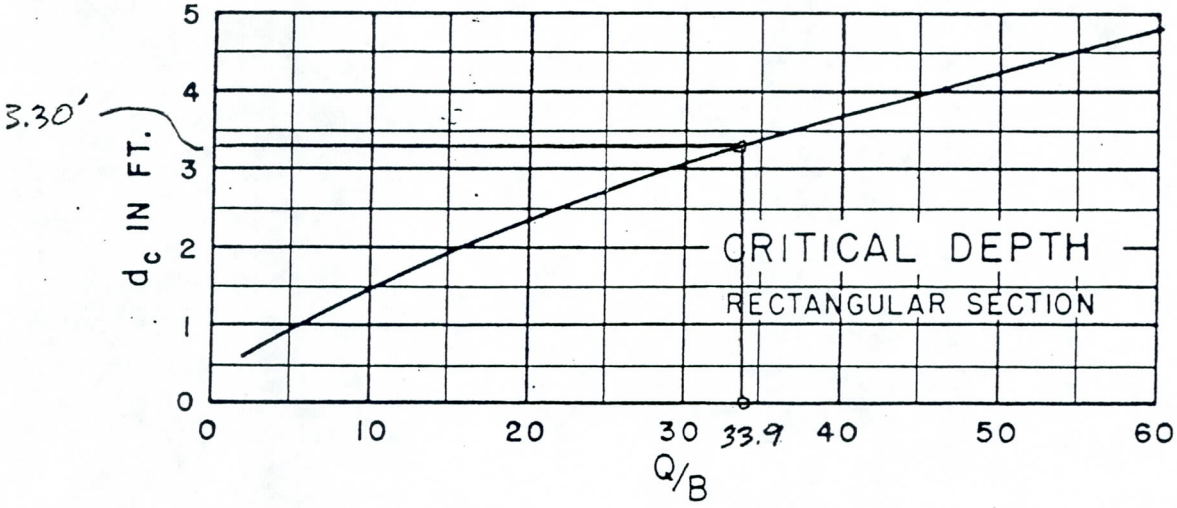


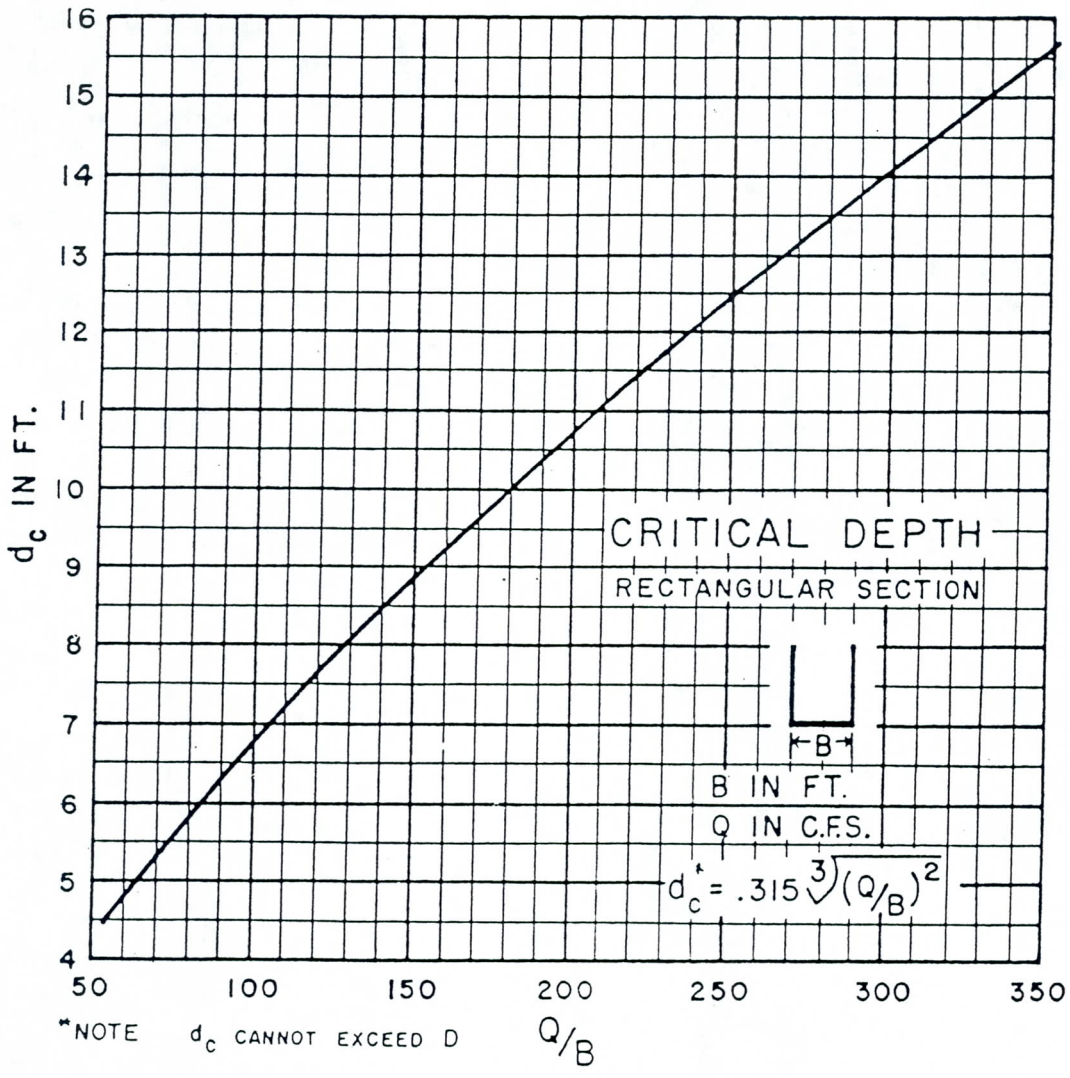
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

Culvert 60 D-1

CHART 15





BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert 60 D-1

SHEET NO. 5 OF

DATE 7/13/91

BY BDO CHKD RJT

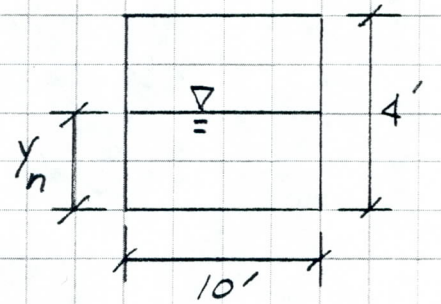
Check depth of Flow using Mannings Equation

$Q100 = 2034$ cfs, $Q = 339$ cfs/culvert

$n = 0.012$

$S_o = 0.0050$ ft/ft

$Y_n \sim 2.67'$



$A = 26.7\ ft^2$

$WP = 15.34$ ft

$R_h = A/WP = 26.7/15.34 = 1.7405'$

$V = \frac{1.49}{.012}(1.7405)^{.666}(.005)^{.5} = 12.70$ fps

Check

$Q = VA = 12.70\ (26.7) = 339$ cfs (OK)

Check Froude Number

$\# = \frac{12.70}{\sqrt{32.2 \times 2.67}} = 1.37$, Supercritical

$Q10 = 488/6 = 81$ cfs

$Y_n = 1.03'$, Velocity = 7.88 fps, $\# = 1.37$ Supercritical

Need riprap plunge basin to minimize erosion downstream of culvert

SVERDRUP

JOB 40477 Toyota

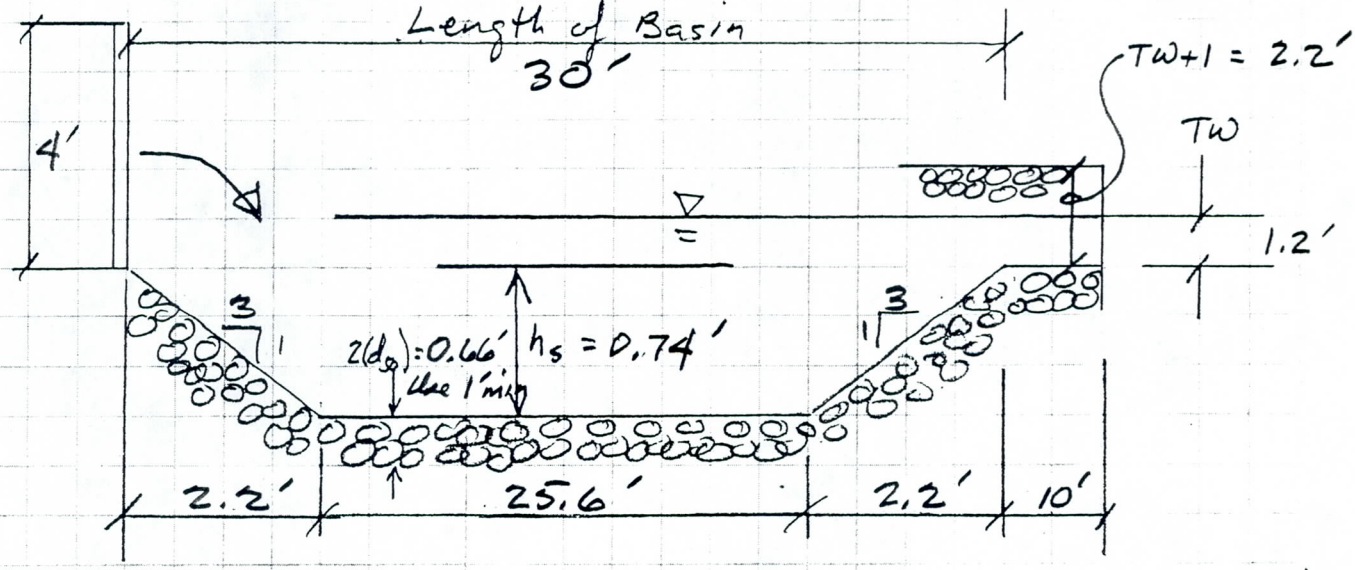
COMPUTATIONS FOR Box Culvert 60D-1

SHEET NO. 6 OF

DATE 7/13/91

BY BDO CHKD RJT

Riprap Plunge Basin Design (Q10)



Check Rock Size (From Figure XI-2, HEC No. 14)

For $y_o = 1.03'$ $d_{50} = 4''$ or $0.33'$

$$d_{50}/y_o = \frac{0.33}{1.03} = 0.32 \quad , F = 1.37$$

$$\frac{h_s}{y_o} = 0.72 \qquad h_s = 0.72(1.03') = 0.74'$$

Check $\frac{h_s}{d_{50}} = \frac{0.74}{0.33} = 2.24 < 4$ and > 2 ∴ ok

Length of Basin

$10\,h_s = 10(0.74) = 7.4'$

or

$3(W_o) = 3(10) = 30'$

Use 30'

Culvert 60 D-1

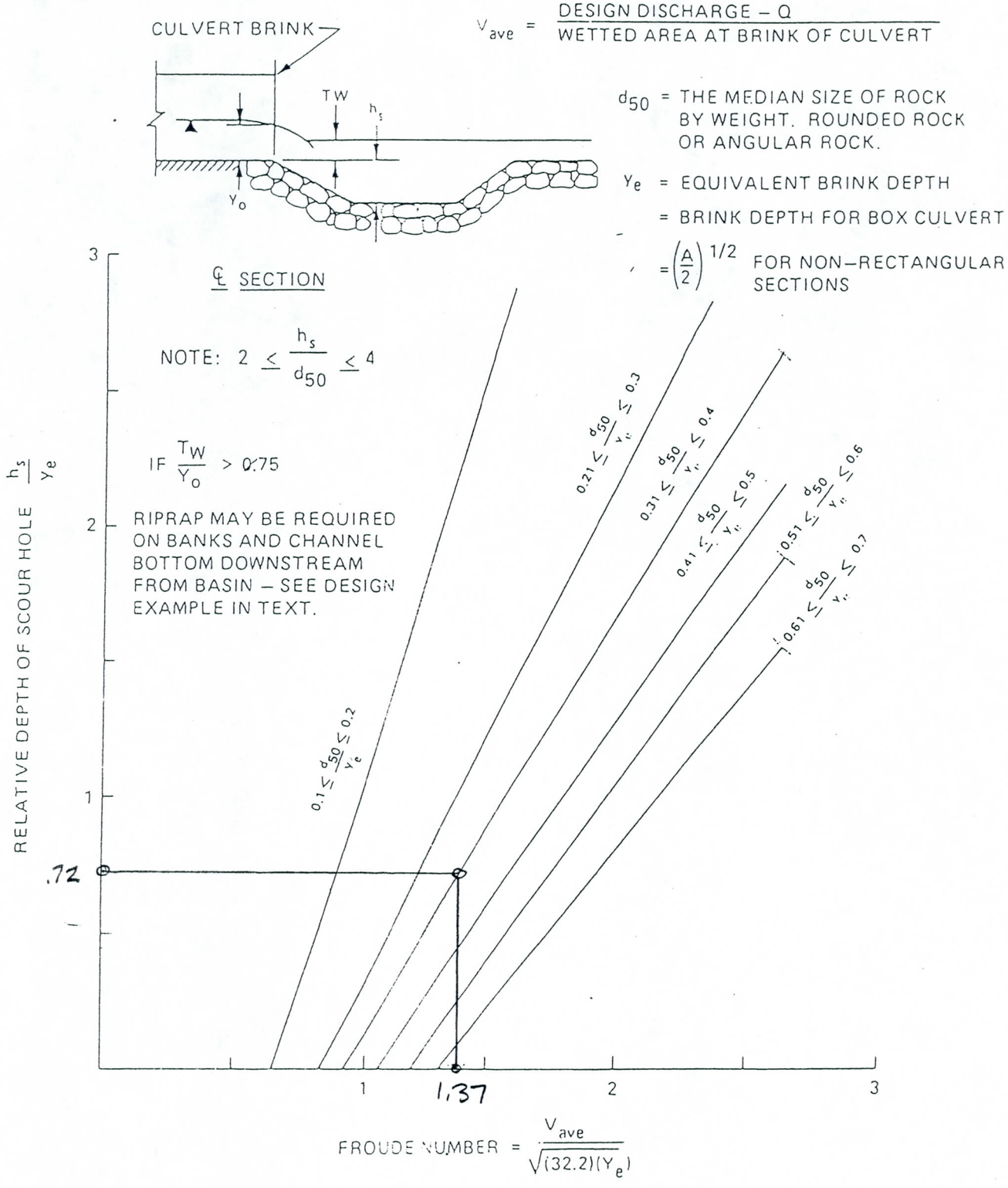


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota SHEET NO. 8 OF

COMPUTATIONS FOR Box Culvert 60D-1 DATE 7/13/91 BY BDO CHKD RJT

$TW/Y_o = \frac{1.2}{1.03} = 1.17 > 0.75$ ∴ Check downstream riprap lining for channel protection.

Utilize figure XI-3 for existing average velocity along channel. Compute equivalent circular diameter D_e for brink area from:

$A = \pi D_e^2/4 = Y_o(W_o) = 1.03(10) = 10.3\ ft^2$

$D_e = (10.3(4)/\pi)^{1/2} = 3.62'$

From downstream cross section Q10 velocity is 2.5 fps. Culvert outlet velocity is 7.9 fps.

L/D_e	L	V_L/V_o	V_L	
10	36.2	.59	4.7	
15	54.3	.36	2.8	
20	72.4	.30	2.4	OK

∴ Need riprap lining for approximately 70 feet from the end of the culvert outlet apron.

SVERDRUP

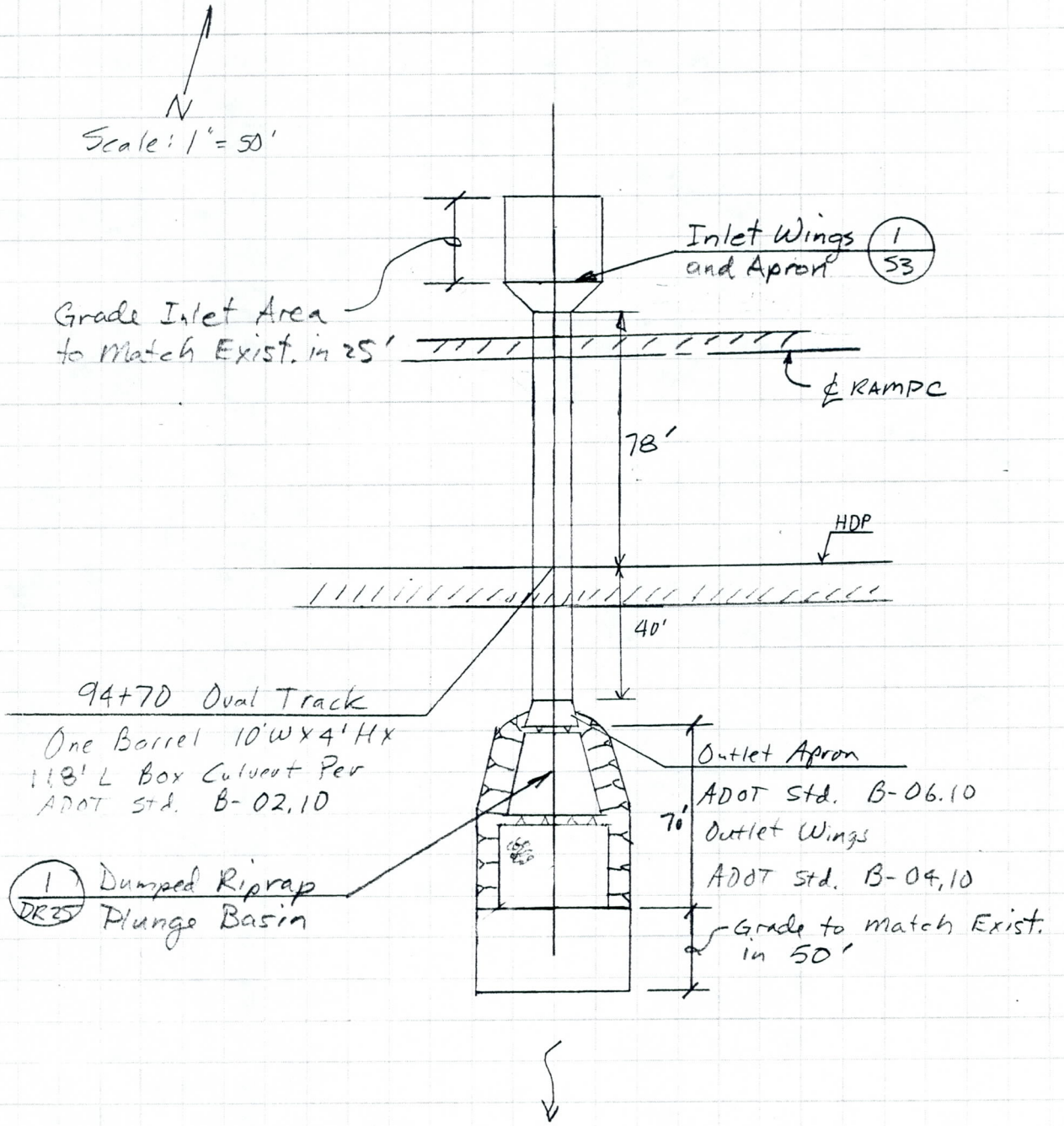
JOB 40477 Toyota

SHEET NO. 9 OF

DATE 7-20-91

COMPUTATIONS FOR Culvert 60 D-1 Plan View
HDP Sta 94+70 16F

BY DFP CHKD RJT



Plan View
Culvert 60 D-1

SVERDRUP

JOB 4077 Toyota SHEET NO. 10 OF

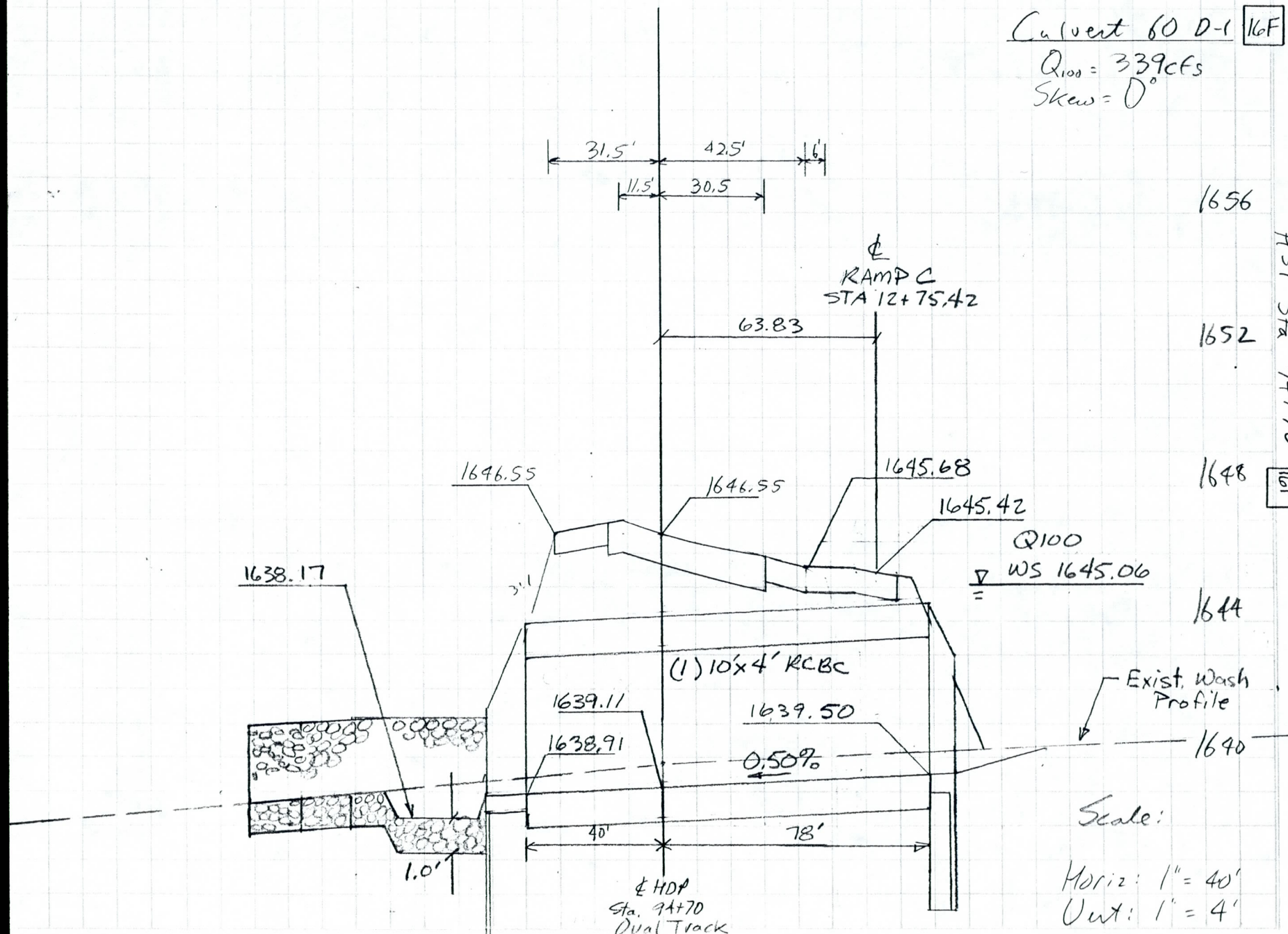
COMPUTATIONS FOR Culvert Profile 60 D-1 DATE 7-14-91

HST Sta 94+70 BY DFP CHKD RJT

Culvert 60 D-1 16F

Q_{100} = 339cfs

Skew = 0°



Scale:

Horiz: 1" = 40'

Vert: 1" = 4'

SECTION NUM[redacted] TW60D1 7/10/[redacted]

Channel Slope: 0.0082 ft./ft.

CROSS SECTION DATA:

OFFSET	40	87.5	143.7	159.9	160.5	161.6	164.1	179.6	180.4	183.4	185.5	222.2	223	224.5	226
ELEV.	42.4	40.65	40.34	38.56	38.14	38.26	39.21	38.79	38.37	37.99	39.4	38.81	38.43	38.37	39.27
N	N/A	0.035	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.025	0.025	0.035	0.035	0.025	0.025

STAGE-DISCHARGE DATA:

STAGE:	38														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	38.2														
WET PER.		0.0	0.0	0.0	0.1	0.6	0.0	0.0	0.0	1.7	2.1	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	38.4														
WET PER.		0.0	0.0	0.0	0.5	1.1	0.4	0.0	0.1	3.0	3.8	0.0	0.0	0.8	0.8
AREA		0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.7	0.8	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	1	0	0	0	0
STAGE:	38.6														
WET PER.		0.0	0.0	0.4	1.1	1.1	1.0	0.0	0.5	3.0	4.1	0.0	0.4	1.5	2.0
AREA		0.0	0.0	0.0	0.2	0.4	0.2	0.0	0.1	1.3	1.5	0.0	0.0	0.3	0.3
HYD.RAD.		0.0	0.0	0.0	0.1	0.4	0.2	0.0	0.1	0.4	0.4	0.0	0.1	0.2	0.2
Q		0	0	0	0	1	0	0	0	0	4	0	0	0	1
STAGE:	38.8														
WET PER.		0.0	0.0	2.2	2.9	1.1	1.5	0.4	1.3	3.0	4.5	0.0	0.9	1.5	2.3
AREA		0.0	0.0	0.3	0.5	0.7	0.4	0.0	0.2	1.9	2.3	0.0	0.1	0.6	0.8
HYD.RAD.		0.0	0.0	0.1	0.2	0.6	0.3	0.0	0.1	0.6	0.5	0.0	0.2	0.4	0.3
Q		0	0	0	1	3	1	0	0	0	8	0	0	0	2
STAGE:	39														
WET PER.		0.0	0.0	4.0	4.8	1.1	2.1	7.8	8.7	3.0	4.8	11.8	12.7	1.5	2.7
AREA		0.0	0.0	0.9	1.3	0.9	0.7	0.8	1.1	2.5	3.2	1.1	1.4	0.9	1.2
HYD.RAD.		0.0	0.0	0.2	0.3	0.8	0.3	0.1	0.1	0.8	0.7	0.1	0.1	0.6	0.5
Q		0	0	0	2	4	1	0	1	0	13	0	1	0	4

SECTION NU[redacted]R TW60D1 7/10/[redacted]

STAGE:	39.2													
WET PER.		0.0	0.0	5.9	6.6	1.1	2.7	15.1	16.0	3.0	5.2	24.3	25.1	1.5	3.1
AREA		0.0	0.0	1.9	2.4	1.1	1.2	3.1	3.6	3.1	4.2	4.7	5.2	1.2	1.8
HYD.RAD.		0.0	0.0	0.3	0.4	1.0	0.4	0.2	0.2	1.0	0.8	0.2	0.2	0.8	0.6
Q		0	0	0	5	6	3	0	5	0	19	0	7	0	7
STAGE:	39.4														
WET PER.		0.0	0.0	7.7	8.4	1.1	2.7	18.2	19.1	3.0	5.6	36.7	37.6	1.5	3.3
AREA		0.0	0.0	3.2	3.8	1.3	1.7	7.9	8.5	3.7	5.1	10.8	11.5	1.5	2.4
HYD.RAD.		0.0	0.0	0.4	0.5	1.2	0.6	0.4	0.4	1.2	0.9	0.3	0.3	1.0	0.7
Q		0	0	0	9	8	0	0	19	0	26	0	20	0	10
STAGE:	39.6														
WET PER.		0.0	0.0	9.5	10.3	1.1	2.7	18.2	19.1	3.0	5.6	36.7	37.6	1.5	3.3
AREA		0.0	0.0	4.9	5.7	1.5	2.2	11.5	12.3	4.3	6.2	18.2	19.0	1.8	3.0
HYD.RAD.		0.0	0.0	0.5	0.6	1.4	0.8	0.6	0.6	1.4	1.1	0.5	0.5	1.2	0.9
Q		0	0	0	15	10	0	0	35	0	36	0	46	0	15
STAGE:	39.8														
WET PER.		0.0	0.0	11.4	12.1	1.1	2.7	18.2	19.1	3.0	5.6	36.7	37.6	1.5	3.3
AREA		0.0	0.0	7.0	7.9	1.8	2.7	15.1	16.0	4.9	7.2	25.5	26.5	2.1	3.6
HYD.RAD.		0.0	0.0	0.6	0.7	1.6	1.0	0.8	0.8	1.6	1.3	0.7	0.7	1.4	1.1
Q		0	0	0	23	13	0	0	55	0	46	0	80	0	20
STAGE:	40														
WET PER.		0.0	0.0	13.2	13.9	1.1	2.7	18.2	19.1	3.0	5.6	36.7	37.6	1.5	3.3
AREA		0.0	0.0	9.4	10.4	2.0	3.2	18.7	19.8	5.5	8.2	32.8	34.0	2.4	4.2
HYD.RAD.		0.0	0.0	0.7	0.7	1.8	1.2	1.0	1.0	1.8	1.5	0.9	0.9	1.6	1.3
Q		0	0	0	33	16	0	0	78	0	57	0	122	0	26

W.S. Elev.	38	38.2	38.4	38.6	38.8	39	39.2	39.4	39.6	39.8	40
Q	0	1	4	12	25	50	97	179	299	449	627
A	0.0	0.6	2.1	4.6	9.5	20.2	38.9	64.3	92.2	121.3	151.6
V	0.2	1.2	2.0	2.5	2.6	2.5	2.5	2.8	3.2	3.7	4.1

268.7	269.8	272.1	273.9	286	340	370
38.59	38.04	38.1	38.69	39.24	42	42.4
0.035	0.035	0.025	0.035	0.035	0.035	0.035

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0	0	0	0	0	0	0	0	0	0

0.0	0.4	2.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0	0	0	0	0	0	0	0	0	0

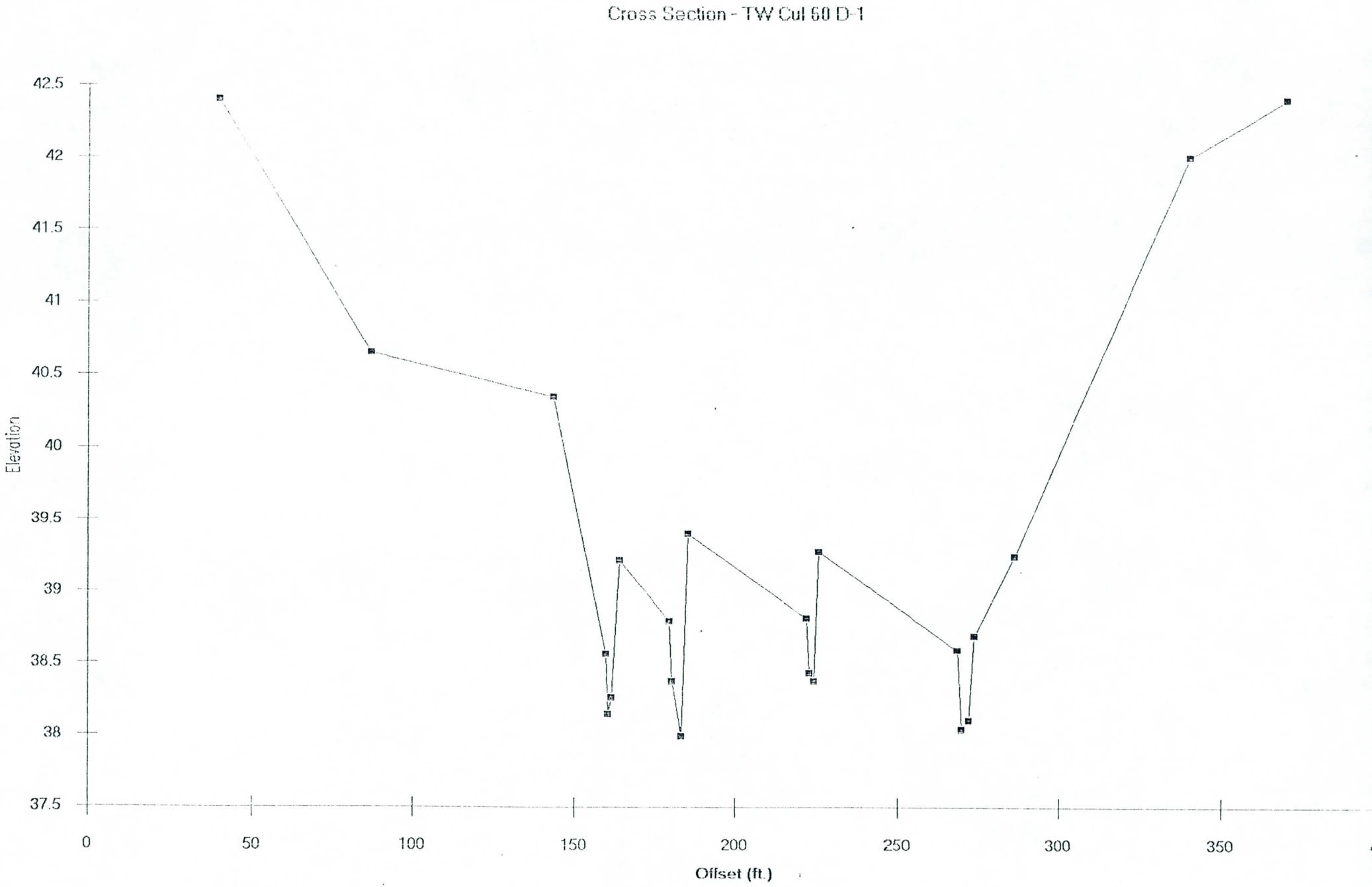
0.0	0.8	2.3	1.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
0	0	2	0	0	0	0	0	0	0

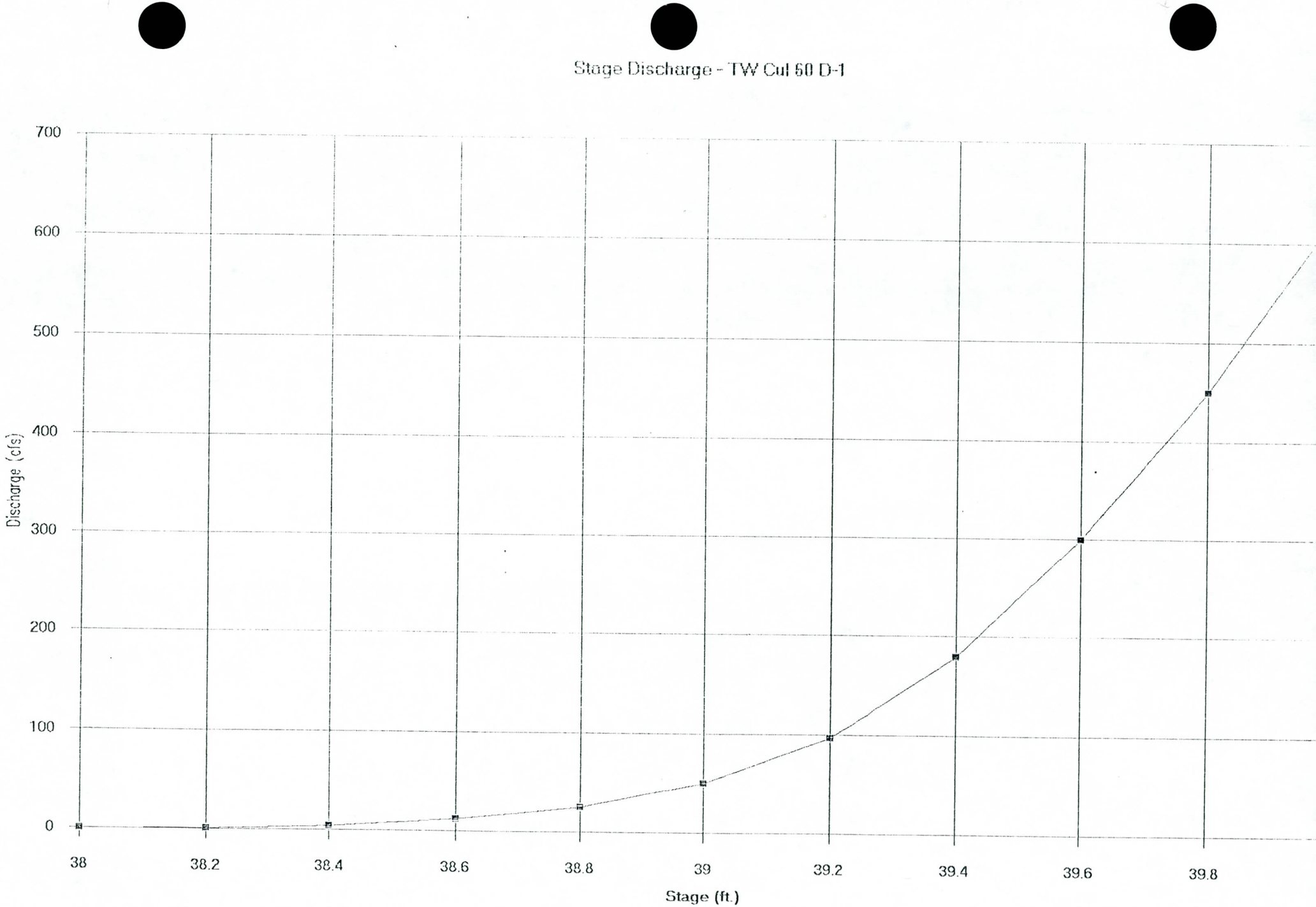
0.6	1.9	2.3	1.6	0.0	0.0	0.0	0.0	0.0	0.6
0.0	0.3	1.2	0.4	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.2	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
0	0	4	1	0	0	0	0	0	0

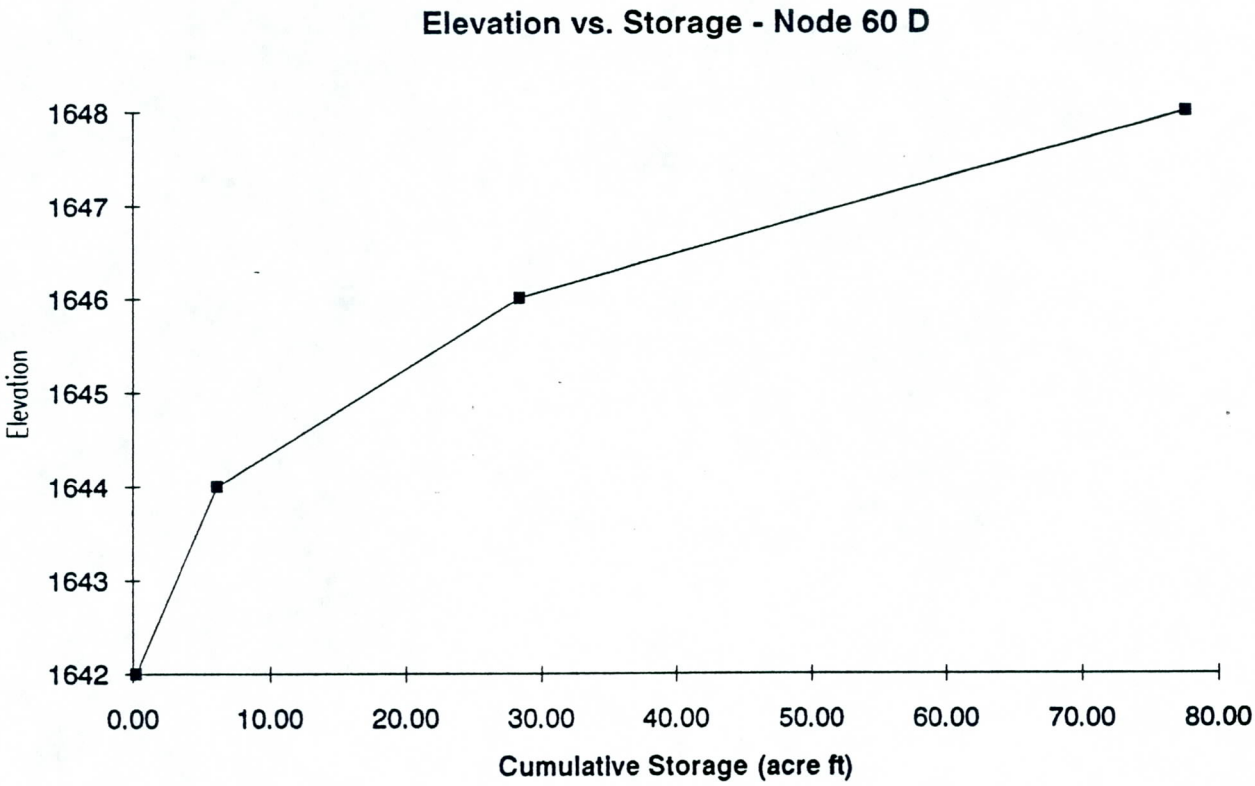
13.2	14.4	2.3	1.9	4.3	0.0	0.0	0.0	0.0	13.2
1.4	1.9	1.7	0.7	0.9	0.0	0.0	0.0	0.0	1.4
0.1	0.1	0.7	0.4	0.2	0.0	0.0	0.0	0.0	0.1
0	2	7	0	1	0	0	0	0	0

25.8	27.0	2.3	1.9	8.7	0.0	0.0	0.0	0.0	25.8
5.3	6.0	2.1	1.1	2.1	0.0	0.0	0.0	0.0	5.3
0.2	0.2	0.9	0.6	0.2	0.0	0.0	0.0	0.0	0.2
0	9	11	0	3	0	0	0	0	0

38.3	39.5	2.3	1.9	13.1	0.0	0.0	0.0	0.0	38.3
11.7	12.7	2.6	1.4	4.3	0.0	0.0	0.0	0.0	11.7
0.3	0.3	1.1	0.8	0.3	0.0	0.0	0.0	0.0	0.3
0	23	15	0	8	0	0	0	0	0
42.7	43.9	2.3	1.9	14.0	17.1	0.0	0.0	0.0	42.7
20.1	21.3	3.1	1.8	7.1	7.3	0.0	0.0	0.0	20.1
0.5	0.5	1.3	1.0	0.5	0.4	0.0	0.0	0.0	0.5
0	50	20	0	0	16	0	0	0	0
42.7	43.9	2.3	1.9	14.0	21.1	0.0	0.0	0.0	42.7
28.6	30.0	3.5	2.2	9.9	11.1	0.0	0.0	0.0	28.6
0.7	0.7	1.5	1.1	0.7	0.5	0.0	0.0	0.0	0.7
0	89	25	0	0	28	0	0	0	0
42.7	43.9	2.3	1.9	14.0	25.0	0.0	0.0	0.0	42.7
37.1	38.8	4.0	2.5	12.6	15.7	0.0	0.0	0.0	37.1
0.9	0.9	1.7	1.3	0.9	0.6	0.0	0.0	0.0	0.9
0	137	31	0	0	44	0	0	0	0
42.7	43.9	2.3	1.9	14.0	28.9	0.0	0.0	0.0	42.7
45.7	47.5	4.4	2.9	15.4	21.1	0.0	0.0	0.0	45.7
1.1	1.1	1.9	1.5	1.1	0.7	0.0	0.0	0.0	1.1
0	193	37	0	0	66	0	0	0	0


Cross Section - TW Cul 60 D-1
42.5
42
41.5
41
40.5
40
39.5
39
38.5
38
37.5
Elevation
0
50
100
150
200
250
300
350
Offset (ft.)


Stage Discharge - TW Cul 60 D-1
700
600
500
400
300
200
100
0
Discharge (cfs)
38
38.2
38.4
38.6
38.8
39
39.2
39.4
39.6
39.8
Stage (ft.)


Elevation vs. Storage - Node 60 D
1648
1647
1646
1645
1644
1643
1642
Elevation
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
Cumulative Storage (acre ft)

SVERDRUP

JOB 40[redacted]7 Toyota SHEET NO. [redacted] OF

DATE 7-[redacted]-91

COMPUTATIONS FOR Proposed Culvert 60J-1 17 BY DFP CHKD RDT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 77+70, Loop Rd. A (Brake Test)

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA

Q_1 = 241 cfs

Q_2 =

TW_1 = 1.11' *

TW_2 = 1.62' **

* Based upon D HWE from Culvert 60J-2 of 1643.20

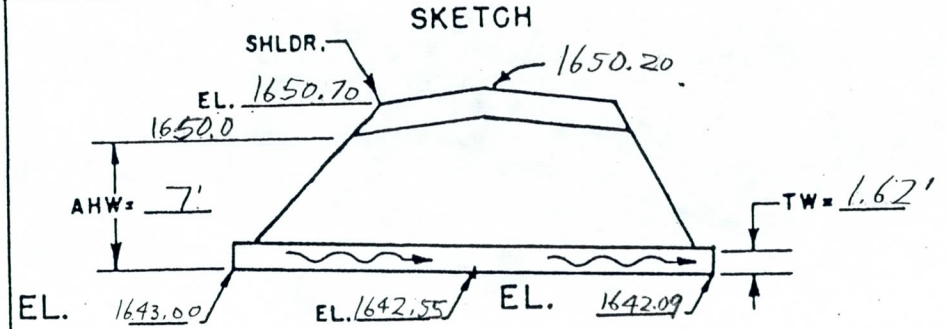
** Depth of flow in channel betw. Culverts 60J-1 and 60J-2.

Peak Outlet Discharge Q_{100}

(Q_1 = DESIGN DISCHARGE, SAY Q_{25})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_0 = .005 L = 182' L/100 S_0 =

MEAN STREAM VELOCITY = 2.6 ft/s

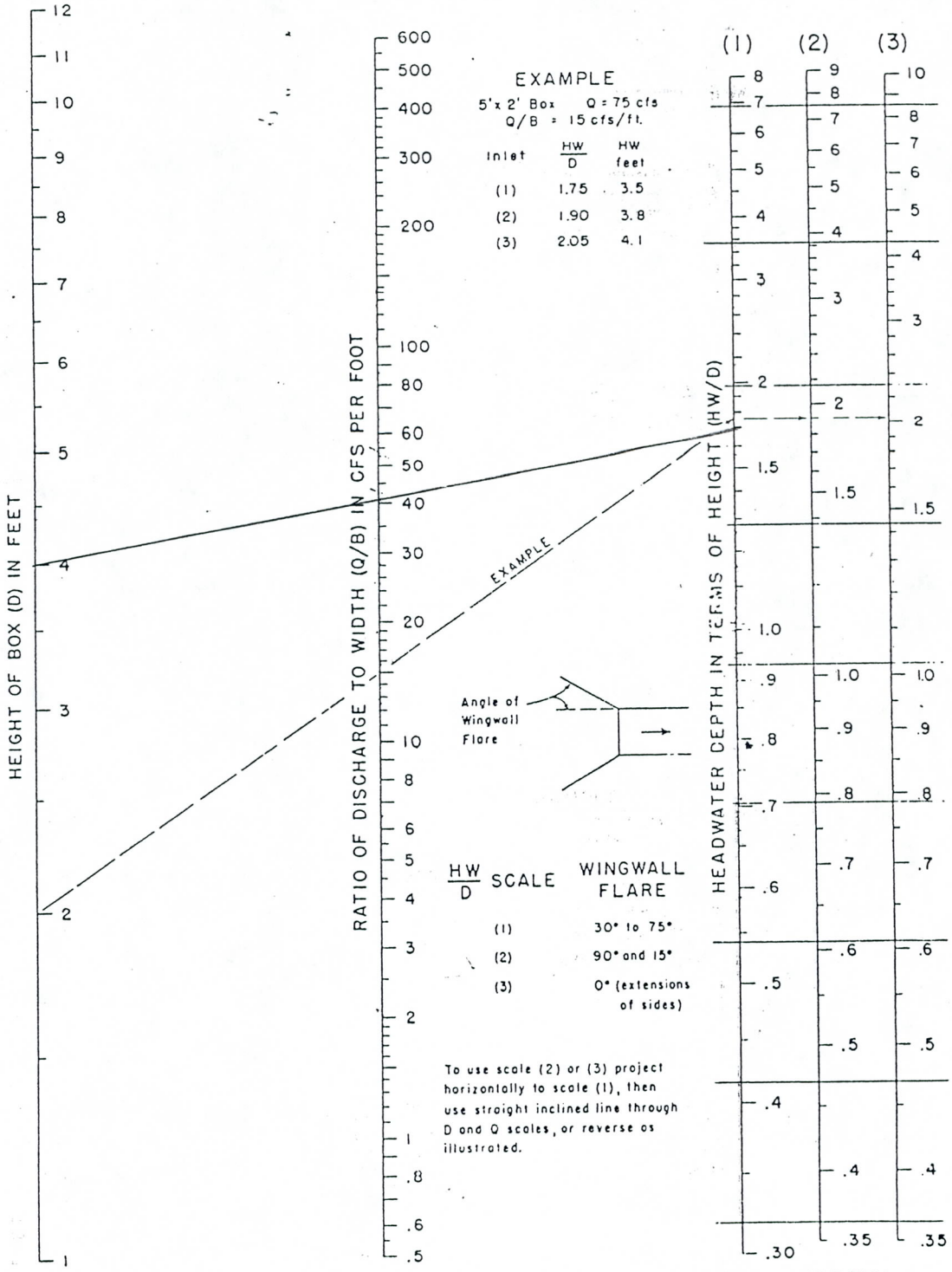
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
1 Barrel 6X4	Drop Inlet	241		1.7	6.8	.2	3.05	3.75	3.875	1.62'	3.875	.91	6.02	6.8	11.9		1649.80.	Inlet Control

SUMMARY & RECOMMENDATIONS

1/21

60 J-1 2/21

CHART I

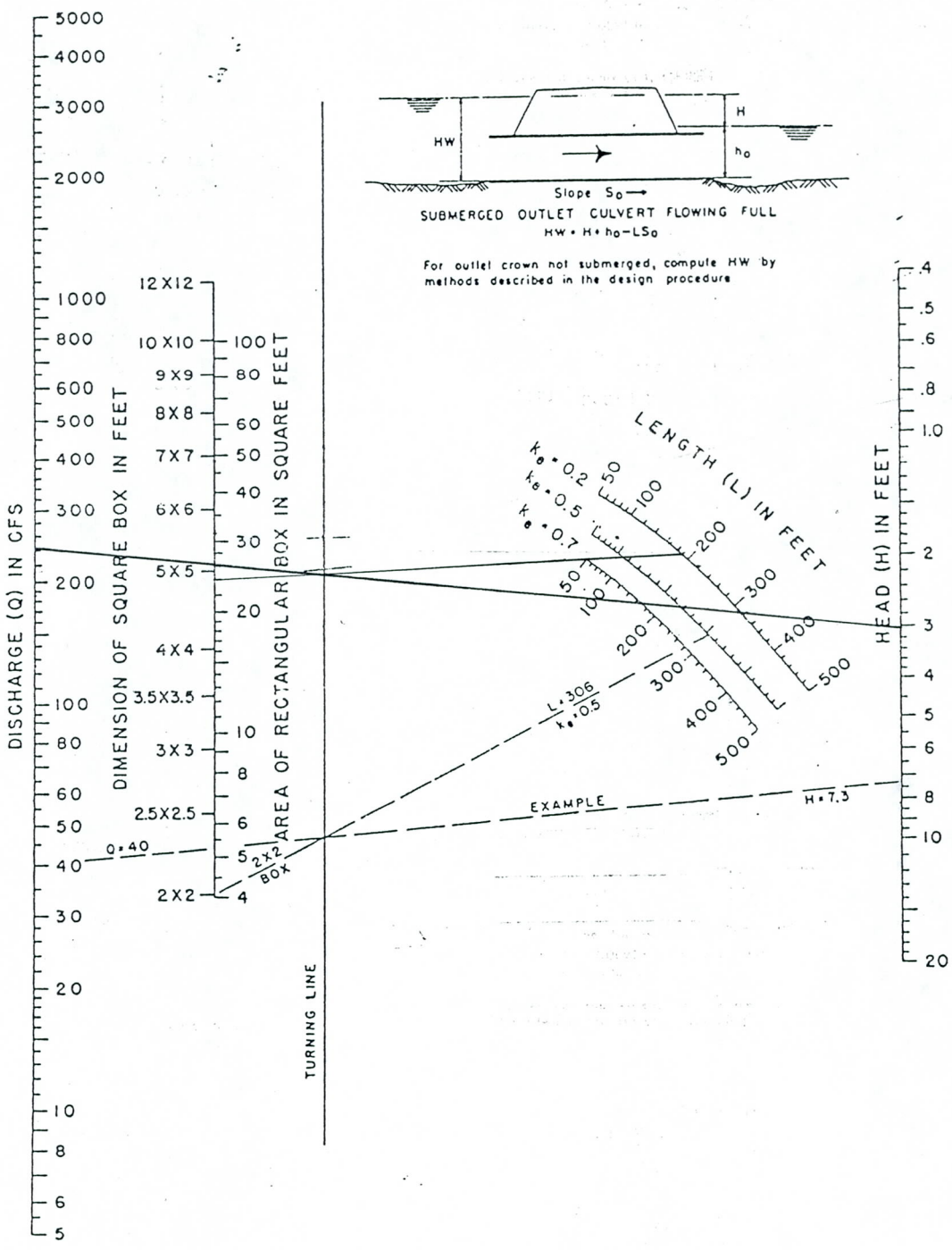


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

60 J-1 3/21

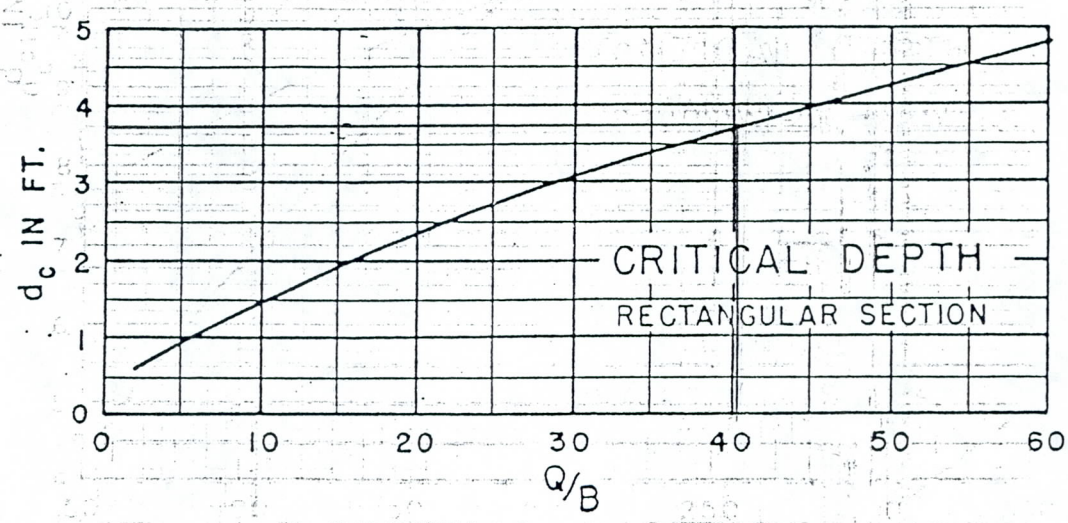
CHART 8

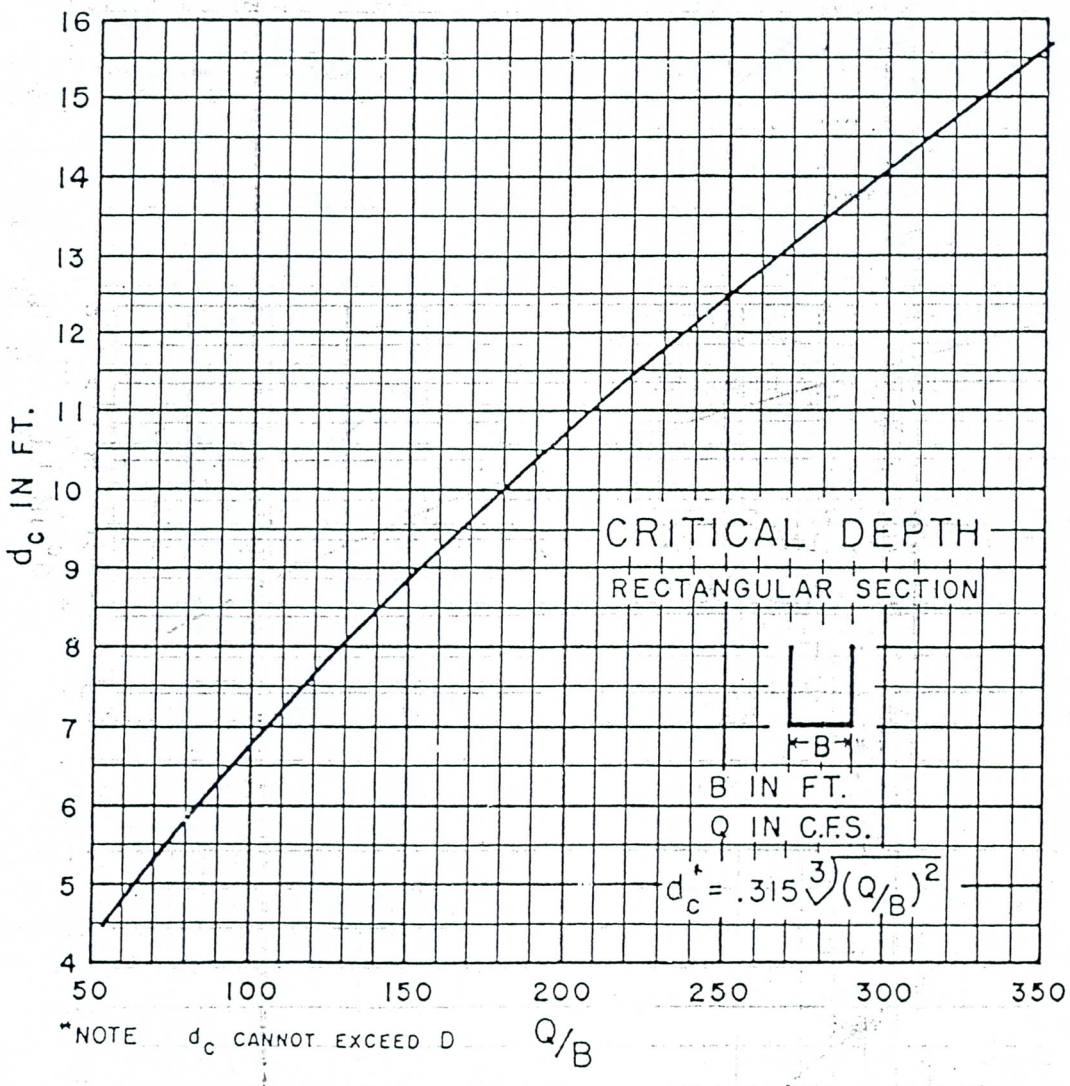


HEAD FOR CONCRETE BOX CULVERTS FLOWING FULL n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 15





*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40[redacted]7 Toyota SHEET NO. [redacted] OF

DATE 7-22-91

COMPUTATIONS FOR Proposed Culvert 60J-2 BY DFP CHKD RJT

18

CULVERT COMPUTATION SHEET

PROJECT:

STATION: HDP Stm. 78+90

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA

Q_1 = 241 cfs

Q_2 =

TW_1 = 1.0*

TW_2 = 1.36**

0.93 ***

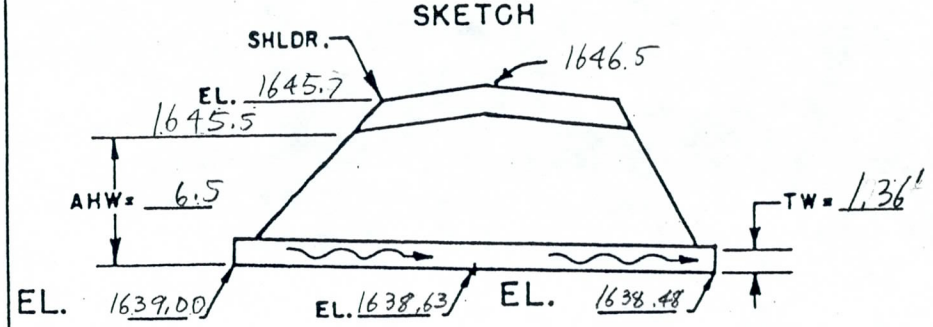
1.15 ****

Peak Outlet Discharge Q_{100}

(Q_1 = DESIGN DISCHARGE, SAY Q_{25})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_0 = .005 L = 105' L/100 S_0 =

MEAN STREAM VELOCITY = 2.6 ft/s

CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
1 Barrel 10x4	Wingwalls	241		1.05	4.20	.2	.85	2.7	3.35	1.36	3.35	.525	3.68	4.20	11.4		1643.20	Inlet Control

SUMMARY & RECOMMENDATIONS

* Derived from existing wash cross section calculations for Q_{100}

** Depth of flow in outlet channel to existing wash (Q_{100})

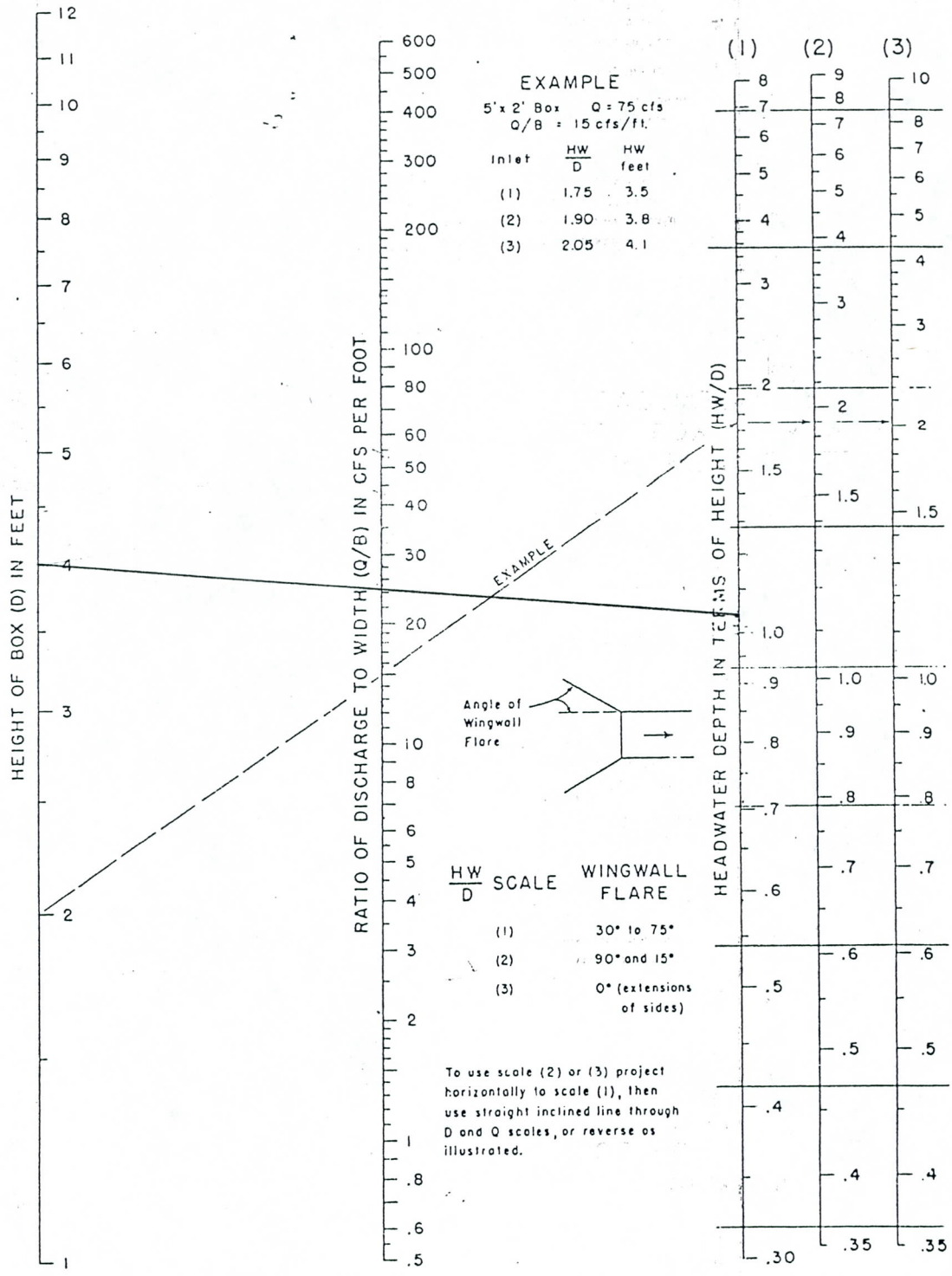
*** Derived from existing wash cross section calculations for Q_{10},

**** Depth of flow in outlet channel to existing wash (Q_{10}).

5/21

6/21

CHART I



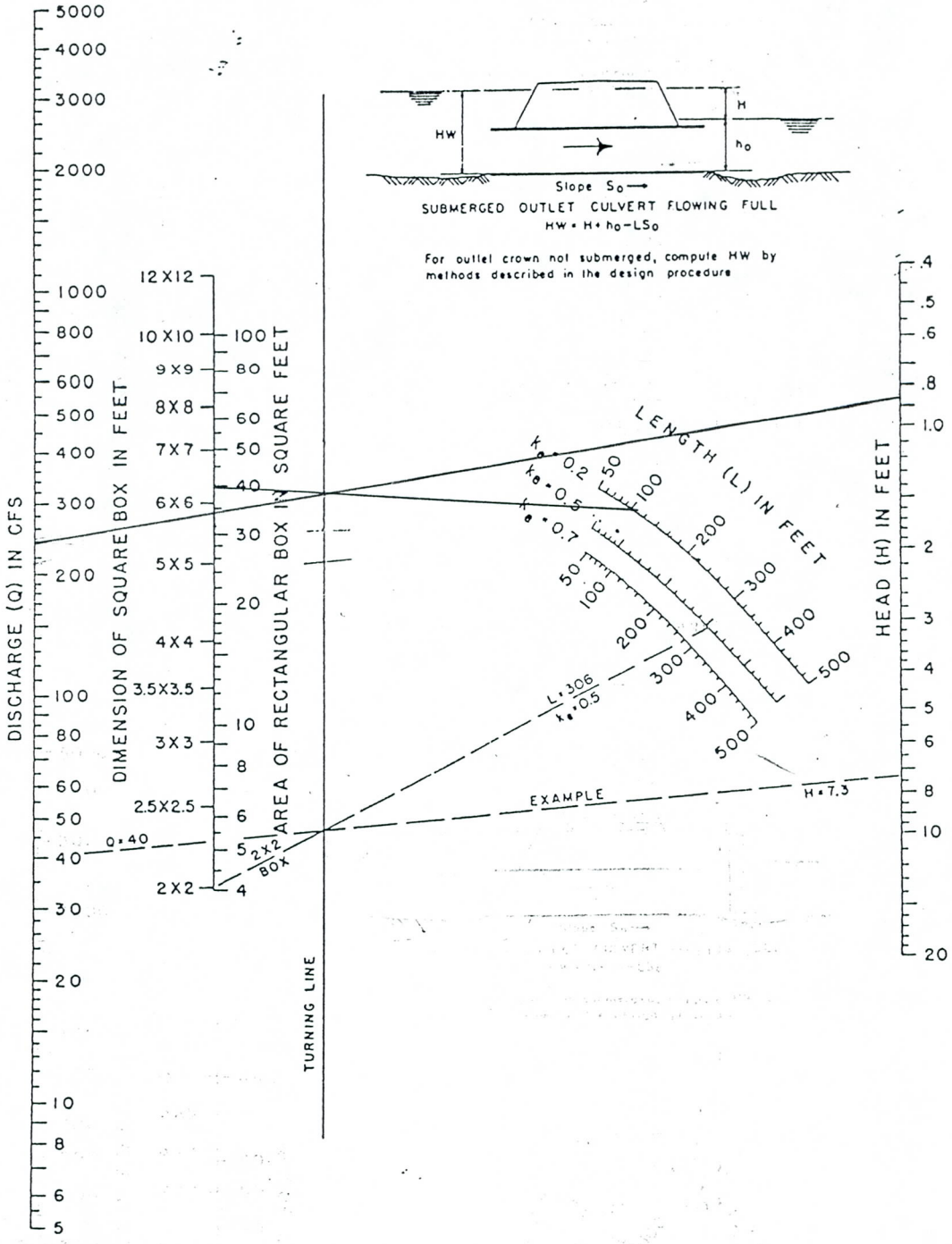
HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

60 J-2

7/21

CHART 8

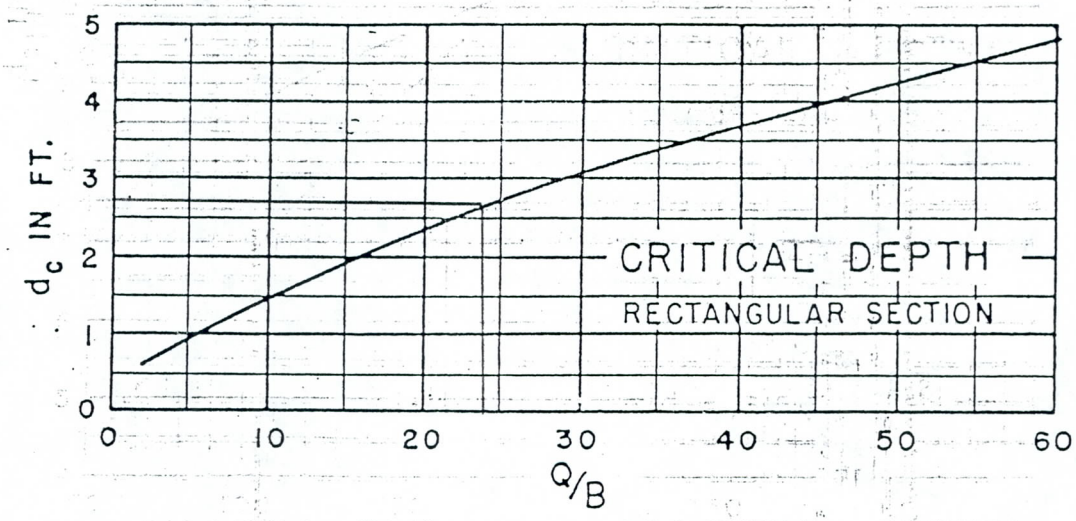


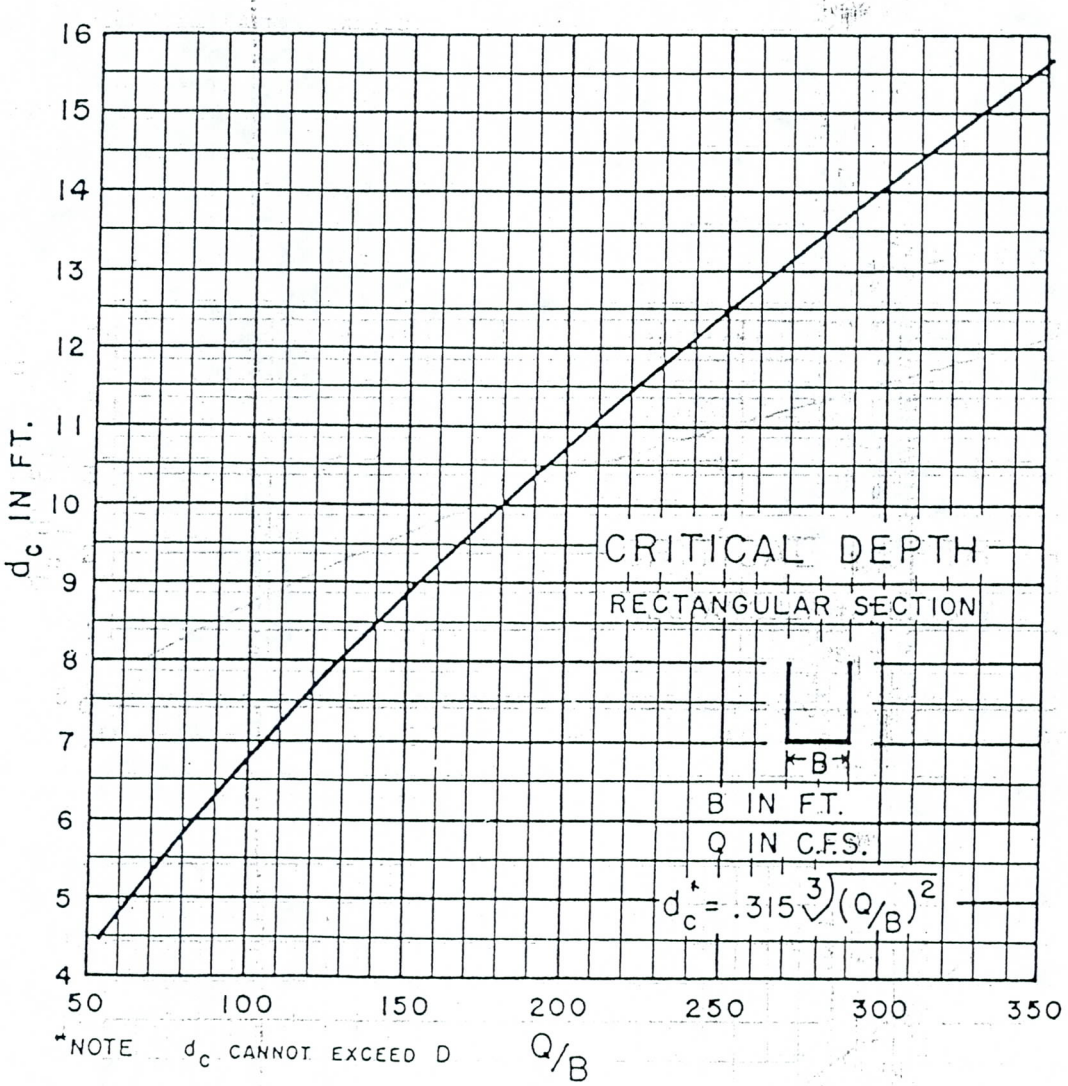
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

8/21

CHART 15





*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culverts 60 J-1 and 60 J-2

SHEET NO. 9 OF 21

DATE 7-8-91

BY DFP CHKD RJT

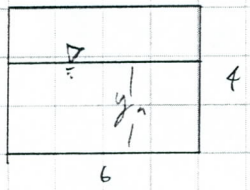
Check Depth of Flow Using Manning's Equation

Culvert 60 J-1

$Q_{100} = 241$ cfs

$n = .012$

$S = .005$



Q_{100}: $y_n = 3.37$

$V = 11.92$ ft/s

Q_{100}: $N_F = \frac{11.92}{\sqrt{32.2 \times 3.37}} = 1.15$ Supercritical

$Q_{10} = 181$ cfs

$y_n = 2.72'$

$V = 11.10$ ft/s

$N_F = 1.19$ supercritical

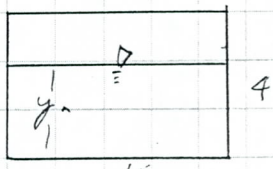
Culvert 60 J-2

$Q_{10} = 181$ cfs

$Q_{100} = 241$ cfs

$S = .005$

$n = .012$



Q_{10}: $y_n = 1.74'$

$V = 10.39$ ft/s

Q_{100}: $y_n = 2.11'$

$V = 11.41$ ft/s

Q_{10}: $N_F = \frac{10.39}{\sqrt{32.2 (1.74)}} = 1.39$

Q_{100}: $N_F = \frac{11.41}{\sqrt{32.2 (2.11)}} = 1.38$

SVERDRUP

JOB 40477 Toyota SHEET NO. 10 OF 21

DATE 7-23-91

COMPUTATIONS FOR Culverts 60 J-1 and 60 J-2 BY DFP CHKD RDT

Design Channel between Culverts 60 J-1 and 60 J-2, running Apron - Apron:

Channel Slope = $S = \frac{42.09 - .005(7) - (39.0 + .005(11))}{402.5\,(1/\cos 20°) - 97 - 75 - 7 - 11}$

$= \frac{3.00}{249.33}$

$= .0123$

Investigate using soil cement channel, $n = .02$, $S = .0123$; 10' wide bottom width w/ 4:1 side slopes. $Q = 241$ cfs.

Using Manning's Formula:

$y_n = 1.62'$ $\quad A = 26.73$ sf $\quad V = 9.02$ ft/s $\quad A/T = \frac{26.73}{22.96} = 1.16$

$N_F = \frac{9.02}{\sqrt{32.2(1.16)}}$

$= 1.48$ Supercritical

Channel Depth:

For supercritical flow under 3' prop, freeboard = $1/6\left(y + \frac{v^2}{2g}\right)$ (min) $= .48$

Channel depth = $1.62' + 0.48' = 2.10'$

Use 2.5' - This is in a cut section, so 2.5' is a minimum depth.

Taper Channel from 24' wide at outlet to 10' in 60'. At inlet to Culvert 60 J-2, taper channel from 10' to 24' in 60'

SVERDRUP

JOB 40477 Toyota SHEET NO. 11 OF 21

DATE 7-9-91

COMPUTATIONS FOR Culverts 60J-1 and 60J-2 BY DFP CHKD RJT

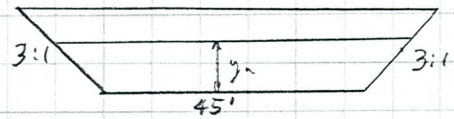
Determine Flow Characteristics Downstream of Culvert 60J-2 Plunge Basin:

Bottom Width 45', N = .03 (Untreated earthen channel) S = .004

Q = 241 cfs ⇒ Using mannings formula ⇒ $y_n = 1.36'$ $V = 3.62$ ft/s

$A = 66.54$ ft^2 $\frac{A}{T} = \frac{66.54}{53.16} = 1.25$

Natural channel velocity 210' downstream of HDP = 2.6 ft/s, which is reasonably close to our channel velocity of 3.62 ft/s.



$$N_F = \frac{3.62}{\sqrt{32.2(1.25)}}$$

$= .57$ Subcritical

Minimum channel depth for Subcritical Flow = depth of flow + 1' freeboard = 1.36' + 1' = 2.36 ⇒ Use depth of 2.5'

Since the channel downstream of Culvert 60J-2 is in a cut section, 2.5' is a minimum depth.

Determine depth of flow for Q_{10} (for plunge basin calculations only) with identical channel

Mannings formula w/ $Q_{10} = 181$ cfs yields:

$y_n = 1.15'$ $V = 3.26$ ft/s

SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Box Culvert

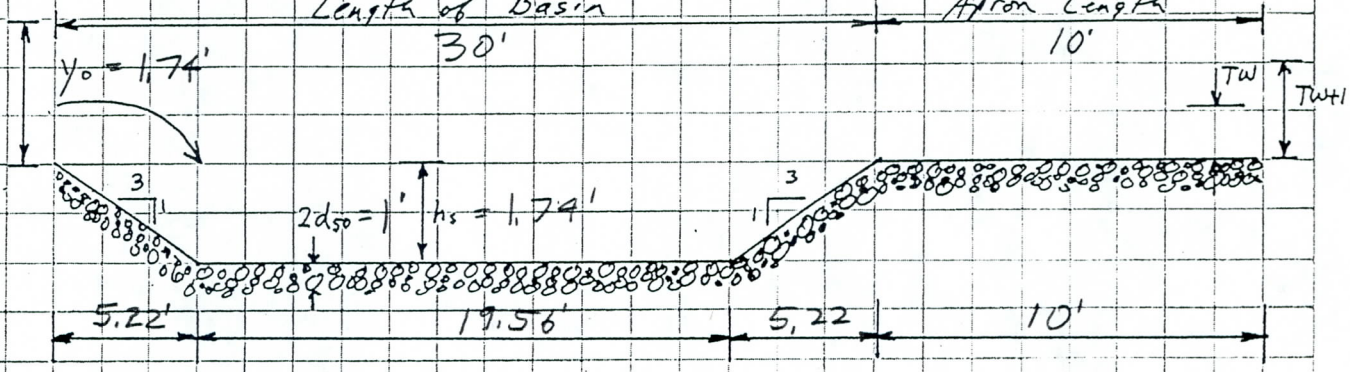
SHEET NO. 12 OF 21

DATE 8/21/91

BY DFP CHKD RJT

Top of Riprap = 3'

Riprap Plunge Basin Design (Q_{10})



Check Rock Size (From X1-2, HEC No. 14)

For y_o = 1.74' d_{50} = 6" or 0.5'

d_{50}/y_o = .29 N_F 1.39 < 3 Plunge Basin OK

h_s/y_o = 1 h_s = 1.74(1) = 1.74'

check $\frac{h_s}{d_{50}} = \frac{1.74}{0.5} = 3.48$ < 4 but > 2

Length of Basin:

$10\,h_s = 10(1.74) = 17.4'$

or

$3(W_o) = 3(10') = 30'$ Use 30'

Apron Length:

$5h_s = 5(1.74) = 8.70'$

$W_o = 10'$ use 10'

Top of Riprap:

$y_o + 1 = 1.74' + 1 = 2.74'$

Use 3'

$TW/y_o = \frac{1.15}{1.74} = .66$, < .75 ∴ no downstream riprap req'd

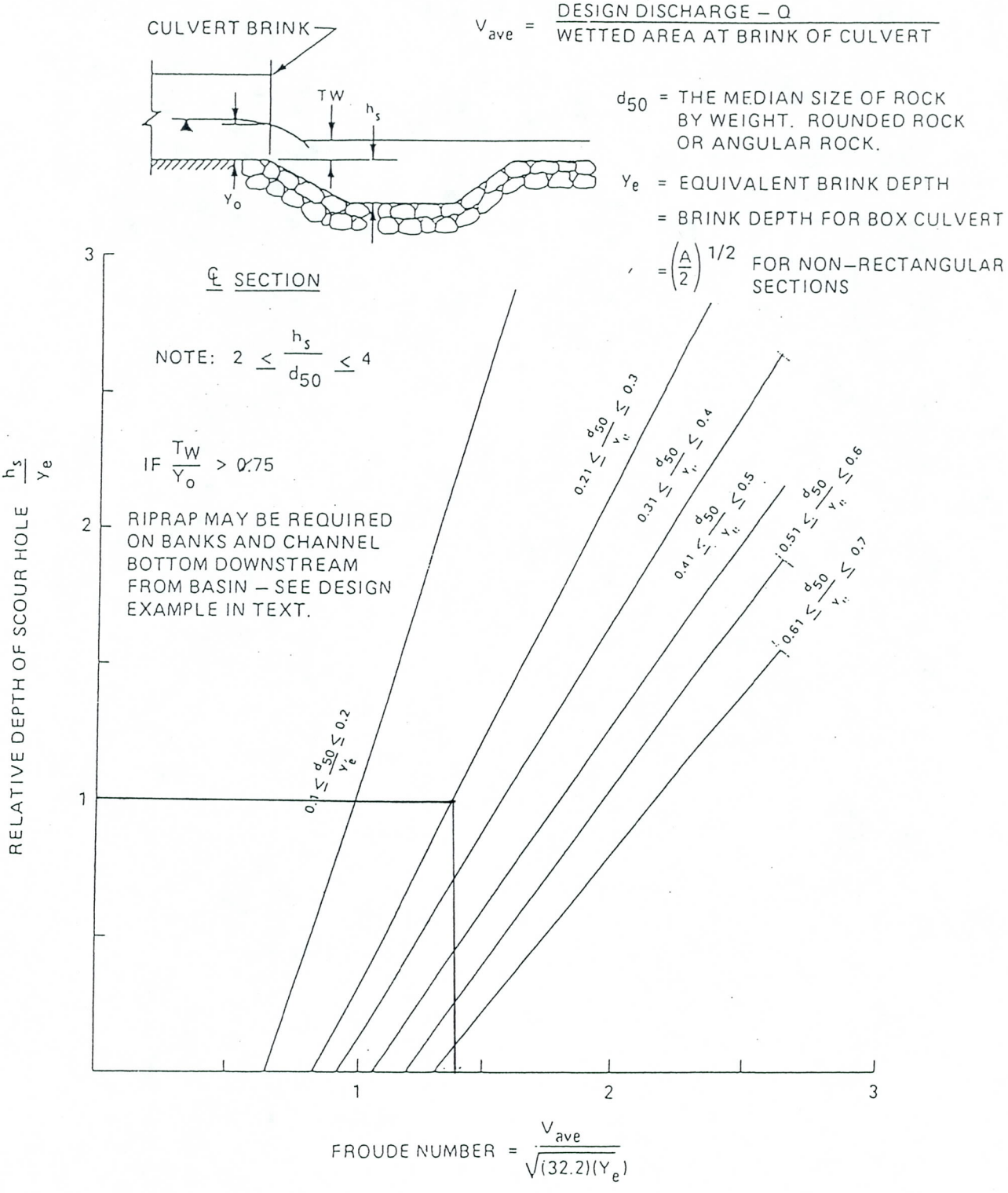


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota

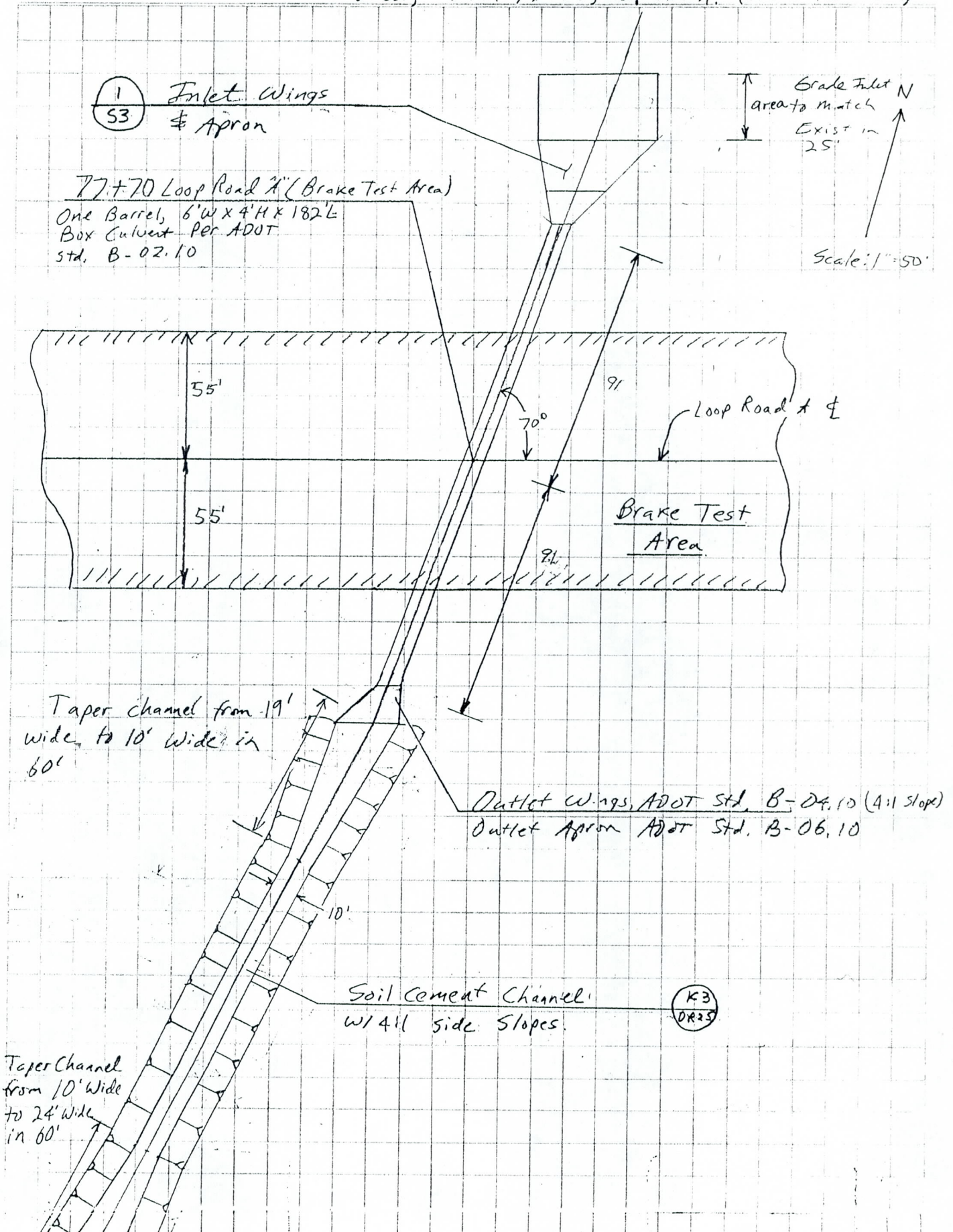
SHEET NO. 14 OF 21

DATE 6-26-91

COMPUTATIONS FOR Box Culvert 60 J-1 [17]

BY DFP CHKD KJT

Plan View, Sta. 77+70, Loop Rd "A" (Brake Test Area)



SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert Profile 60 J-1 17

Loop Road "A" (Brake Test) Sta 77+70

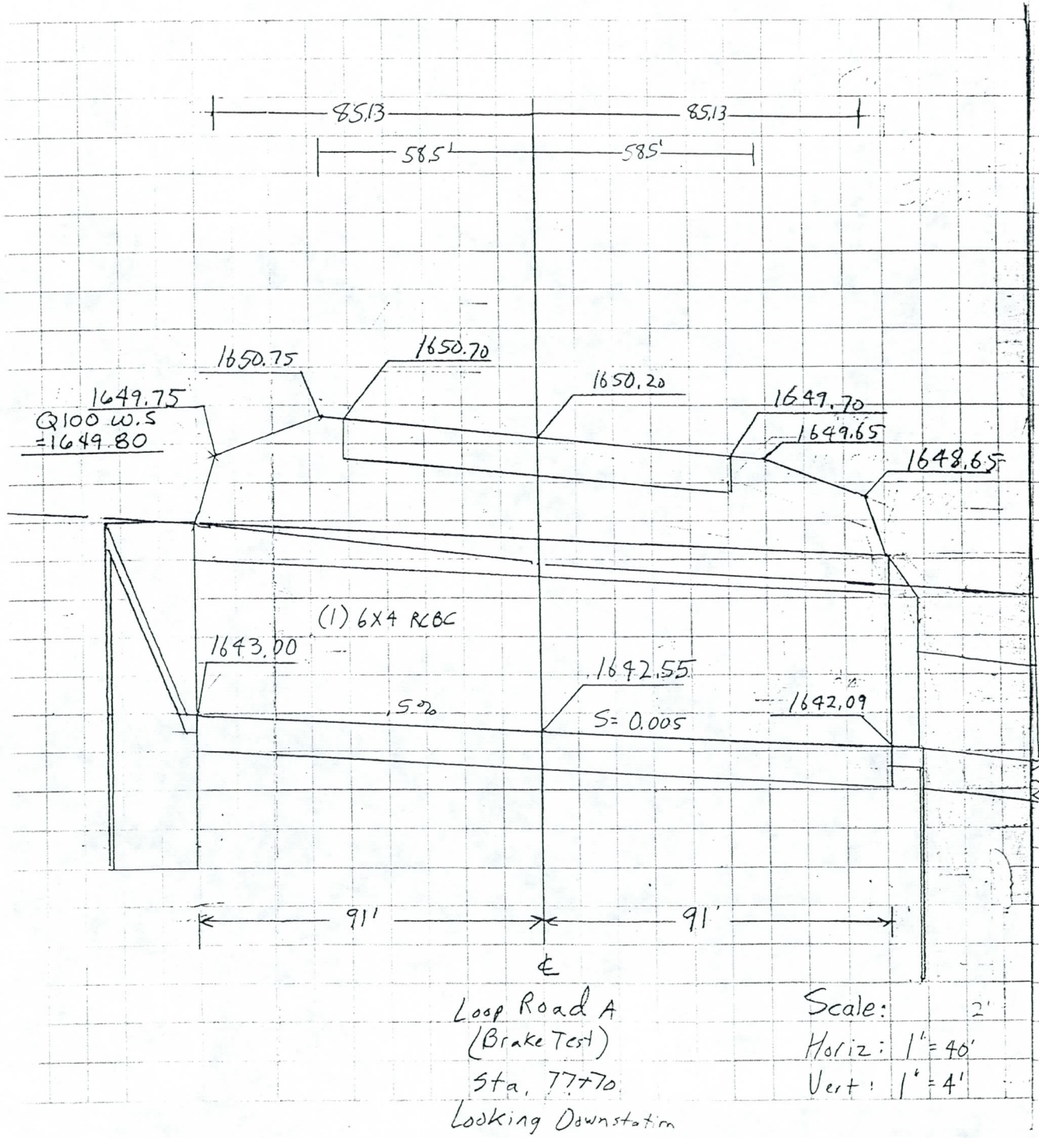
BY DFP DATE 7-8-91 CHKD RVT

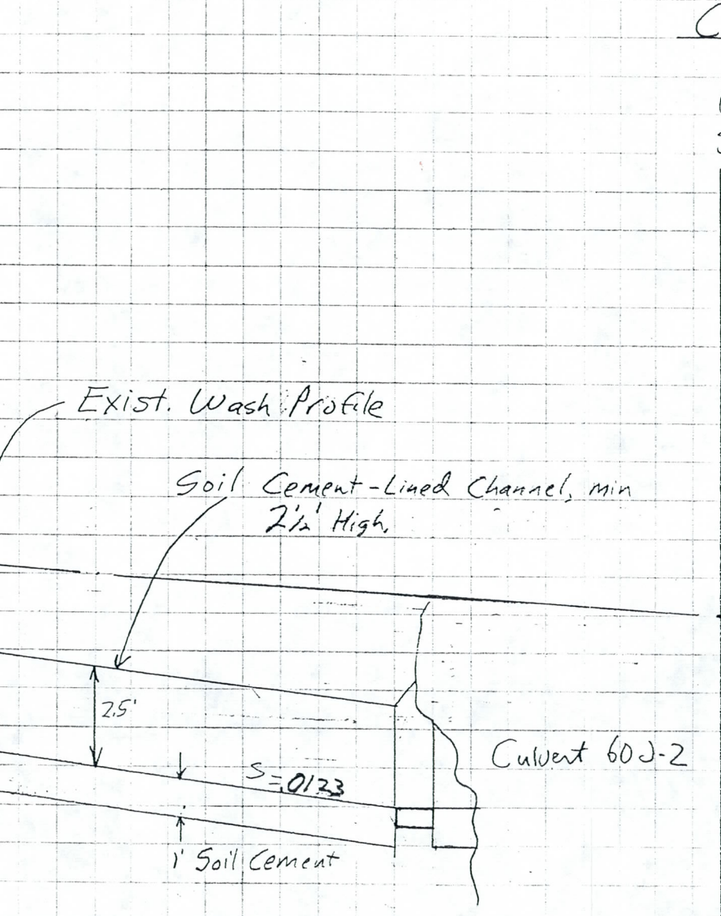
SHEET NO. 15 OF 21

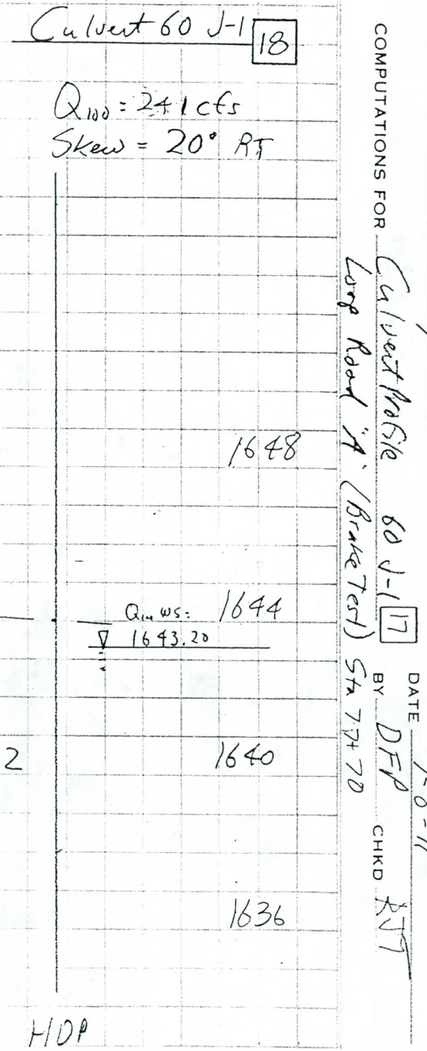
Culvert 60 J-1 18

Q_{100} = 241 cfs

Skew = 20° RT







HDP

SVERDRUP

JOB 40477 Toyota

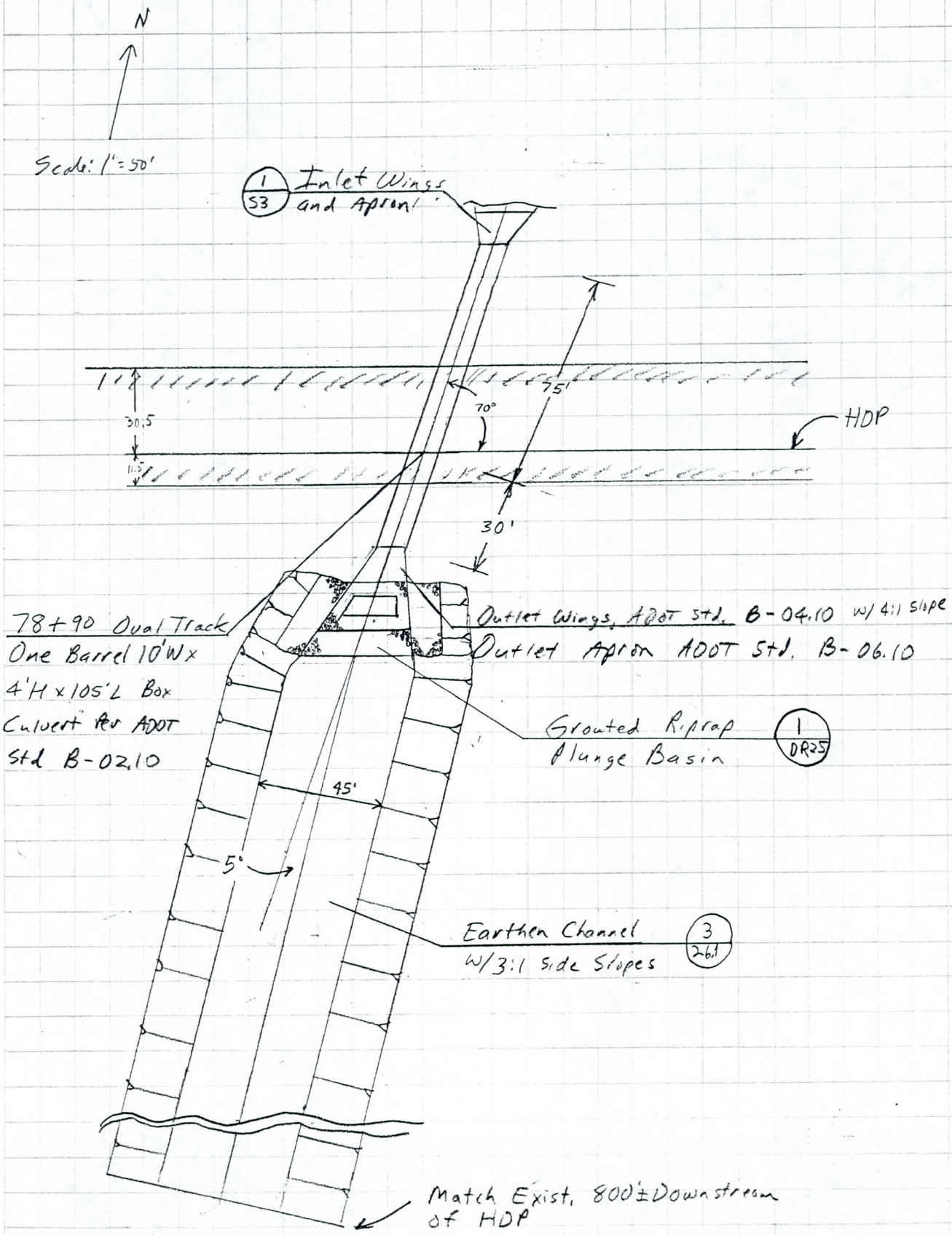
SHEET NO. 16 OF 21

DATE 7-1-91

COMPUTATIONS FOR Box Culvert 60 J-2 [18]

BY DFP CHKD RJT

Plan View, HDP Sta 78+90



1

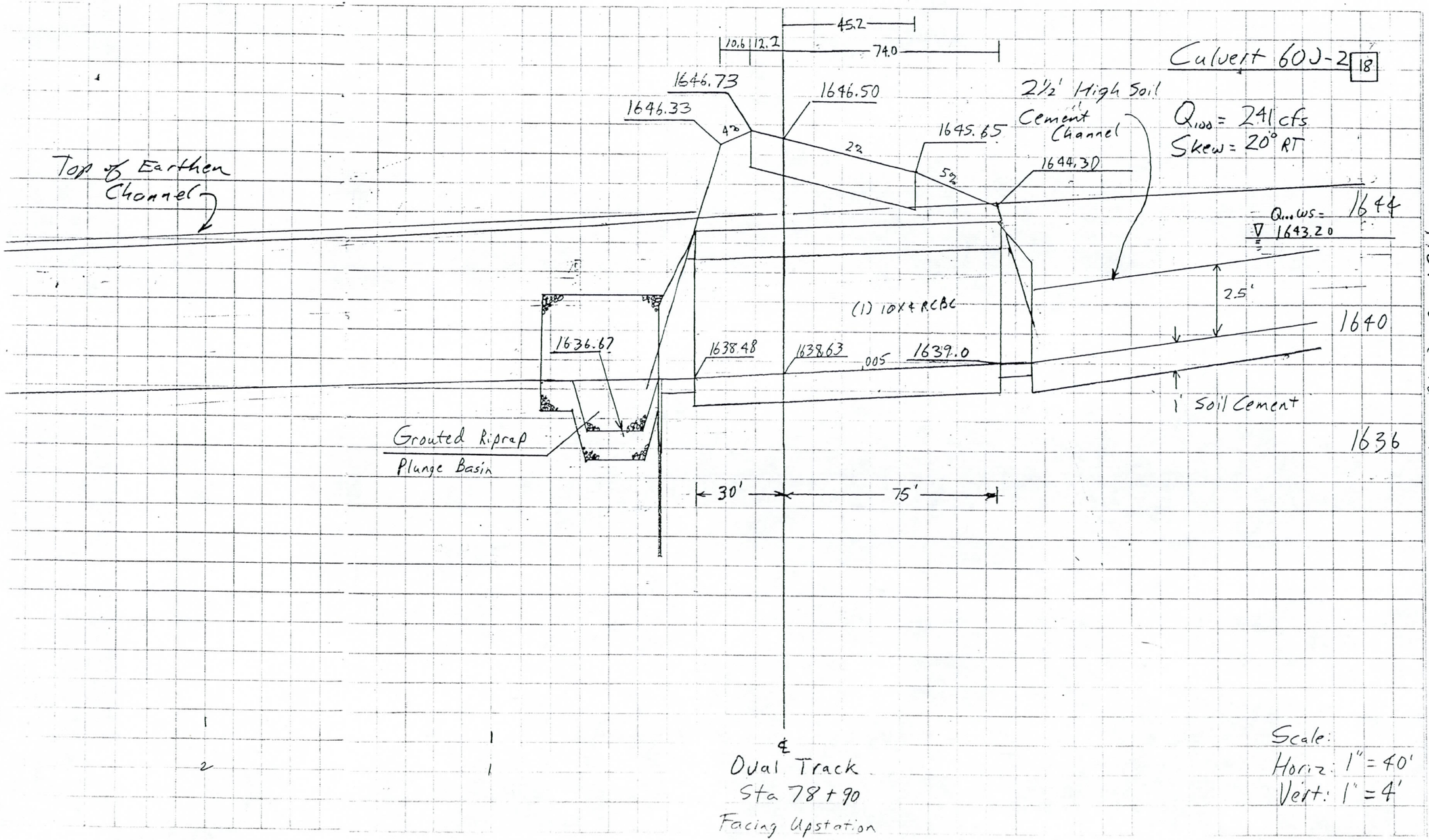
SVERDRUP

JOB 40477 Toyita

COMPUTATIONS FOR Culvert Profile 60J-2 [18] DATE 6-30-91

HDP Sta 78+90 BY DFP CHKD RJT

SHEET NO. 17 OF 21



SECTION NUMBER TW60J 6/11/91

Channel Slope: 0.0099 ft./ft.

CROSS SECTION DATA:

OFFSET	-100	23.5	69.1	72.4	73.6	75.1	121.4	213.2	410
ELEV.	43.3	41.78	42.14	41.5	41.49	41.69	42.15	42.58	43.4
N	N/A	0.035	0.025	0.025	0.035	0.035	0.035	0.035	0.035

STAGE-DISCHARGE DATA:

STAGE:	41.5											
WET PER.	0.0	0.0	0.0	1.2	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0

STAGE:	41.6											
WET PER.	0.0	0.0	0.5	1.2	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0

STAGE:	41.7											
WET PER.	0.0	0.0	1.1	1.2	2.7	3.7	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.1	0.2	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0

STAGE:	41.8											
WET PER.	1.6	2.5	1.6	1.2	2.7	13.8	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.2	0.4	0.7	1.3	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.1	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	1	0	0	0	0	0	0

STAGE:	41.9											
WET PER.	9.8	15.2	2.1	1.2	2.7	23.9	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.6	0.9	0.4	0.5	1.0	3.2	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.1	0.1	0.2	0.4	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	1	1	0	0	3	0	0	0	0	0	0

STAGE:	42											
WET PER.	17.9	27.9	2.6	1.2	2.7	33.9	0.0	0.0	0.0	0.0	0.0	0.0
AREA	2.0	3.1	0.6	0.6	1.2	6.1	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.1	0.1	0.2	0.5	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Q	2	4	1	0	0	8	0	0	0	0	0	0

12/81

SECTION NUMBER TW60J 6/11/91

STAGE:	42.1											
WET PER.		26.0	40.5	3.2	1.2	2.7	44.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		4.2	6.5	0.9	0.7	1.5	10.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.2	0.2	0.3	0.6	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Q		5	11	2	0	0	16	0	0	0	0	0	0
STAGE:	42.2												
WET PER.		34.1	45.6	49.0	1.2	2.7	49.0	59.7	0.0	0.0	0.0	0.0	0.0
AREA		7.2	10.9	12.2	0.8	1.8	14.7	15.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.2	0.2	0.2	0.7	0.6	0.3	0.3	0.0	0.0	0.0	0.0	0.0
Q		11	0	29	0	0	0	25	0	0	0	0	0
STAGE:	42.3												
WET PER.		42.3	45.6	49.0	1.2	2.7	49.0	81.0	0.0	0.0	0.0	0.0	0.0
AREA		11.0	15.5	17.1	1.0	2.0	19.6	22.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.3	0.3	0.3	0.8	0.7	0.4	0.3	0.0	0.0	0.0	0.0	0.0
Q		19	0	50	0	0	0	39	0	0	0	0	0
STAGE:	42.4												
WET PER.		50.4	45.6	49.0	1.2	2.7	49.0	102.4	0.0	0.0	0.0	0.0	0.0
AREA		15.6	20.1	22.0	1.1	2.3	24.5	31.2	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.3	0.4	0.4	0.9	0.8	0.5	0.3	0.0	0.0	0.0	0.0	0.0
Q		30	0	76	0	0	0	60	0	0	0	0	0
STAGE:	42.5												
WET PER.		58.5	45.6	49.0	1.2	2.7	49.0	123.7	0.0	0.0	0.0	0.0	0.0
AREA		21.1	24.6	26.9	1.2	2.6	29.4	42.5	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.4	0.5	0.5	1.0	0.9	0.6	0.3	0.0	0.0	0.0	0.0	0.0
Q		45	0	106	0	0	0	88	0	0	0	0	0

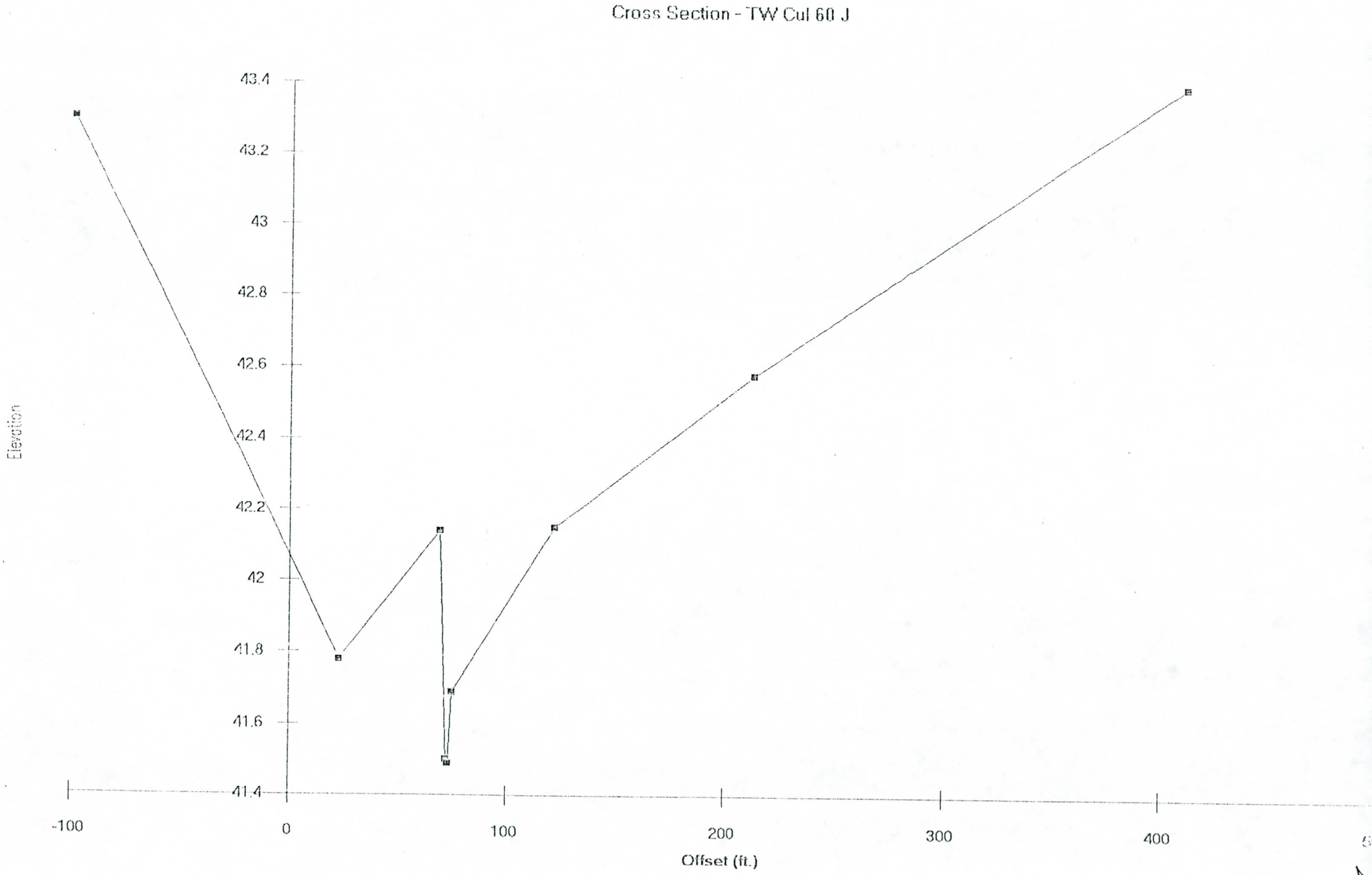
W.S. Elev.	41.5	41.6	41.7	41.8	41.9	42	42.1	42.2	42.3	42.4	42.5
Q	0	0	1	2	6	16	34	64	108	166	239
A	0.0	0.2	0.5	1.6	5.1	11.7	21.5	34.4	50.1	68.8	90.4
V	0.1	0.8	1.0	1.0	1.1	1.3	1.6	1.9	2.2	2.4	2.6

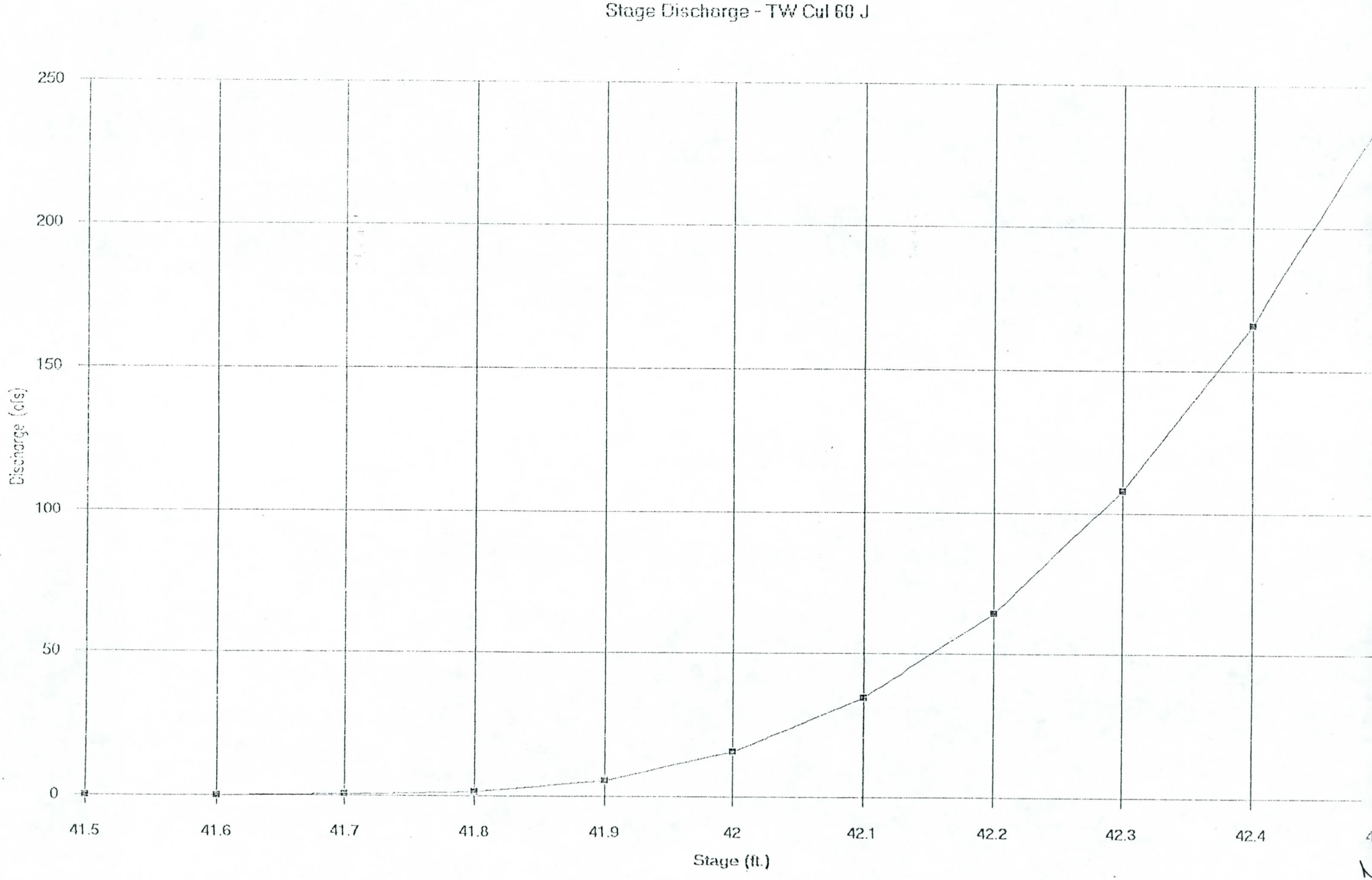
Estimated Culvert 60-2 T.W.:
Channel depth = 42.5 - 41.5 = 1.0

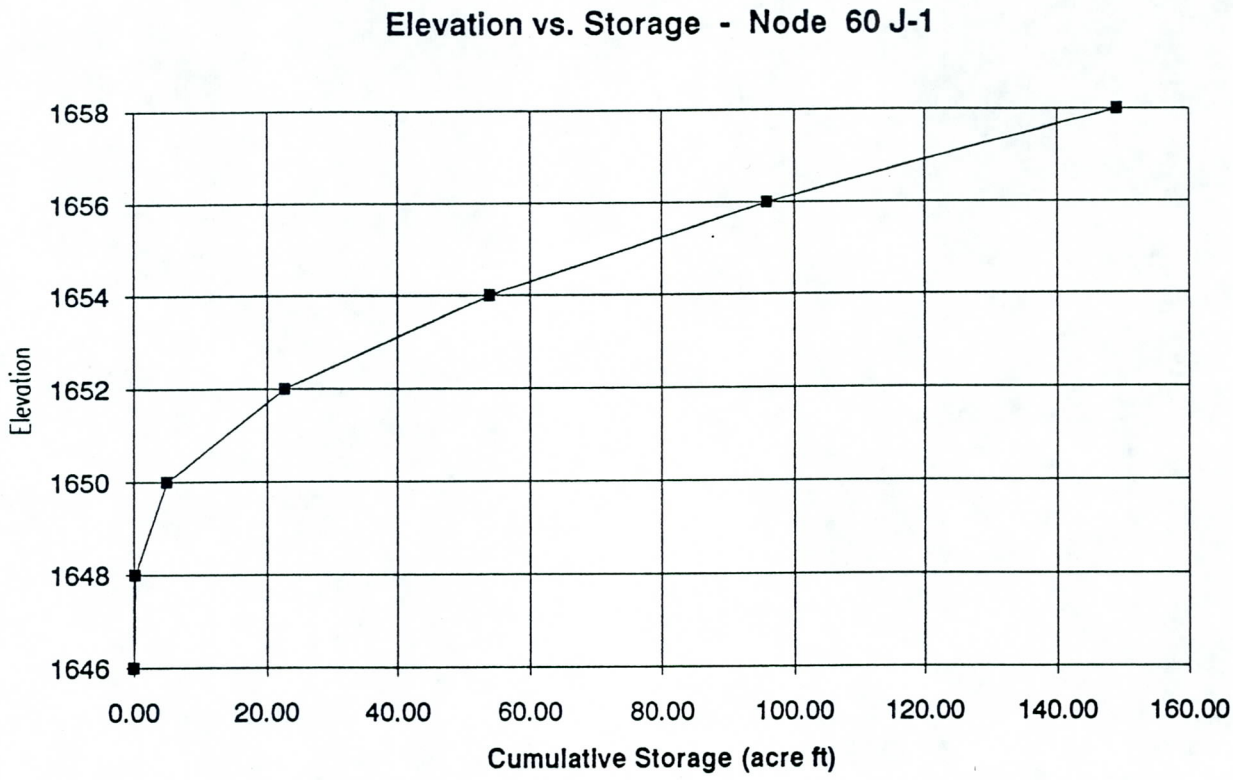
T.W. for Q_{10}:

$42.4 + \left(\frac{181-166}{239-166}\right)(42.5-42.4)$
$= 42.42$

$42.42 - 41.49 = .93'$


Cross Section - TW Cul 60 J
43.4
43.2
43
42.8
42.6
42.4
42.2
42
41.8
41.6
41.4
Elevation
-100
0
100
200
300
400
Offset (ft.)


Stage Discharge - TW Cul 60 J
250
200
150
100
50
0
Discharge (cfs)
41.5
41.6
41.7
41.8
41.9
42
42.1
42.2
42.3
42.4
Stage (ft.)


Elevation vs. Storage - Node 60 J-1
1658
1656
1654
1652
1650
1648
1646
Elevation
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
Cumulative Storage (acre ft)

SVERDRUP

JOB 4[redacted]77 Toyota

SHEET NO. [redacted] OF

DATE [redacted]2-91

COMPUTATIONS FOR Proposed Culvert 67 H-1

BY DFP CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 62+55 Loop Rd. "A"

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA

Q_{100} Q_1 = 2915 cfs

Q_2 =

TW_1 = 2.39'*

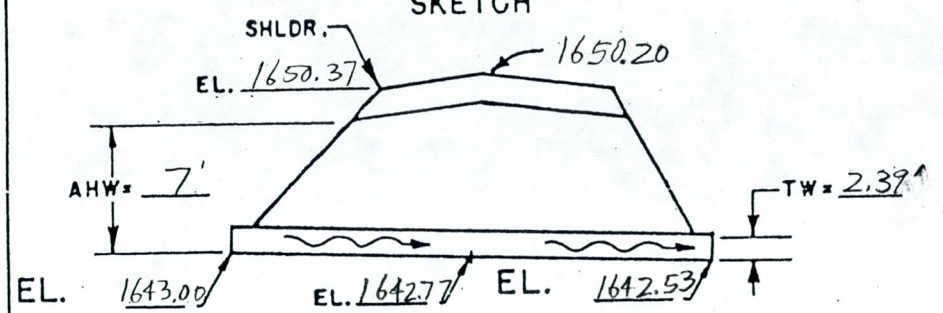
TW_2 =

*Based on DHWE from Culvert 67 H-1 (1644.92)

Peak Outlet Discharge Q_{100}

(Q_1 = DESIGN DISCHARGE, SAY Q_{25}; Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_0 = .005 L = 95' L/100 S_0 =

MEAN STREAM VELOCITY = 3.2 ft/s

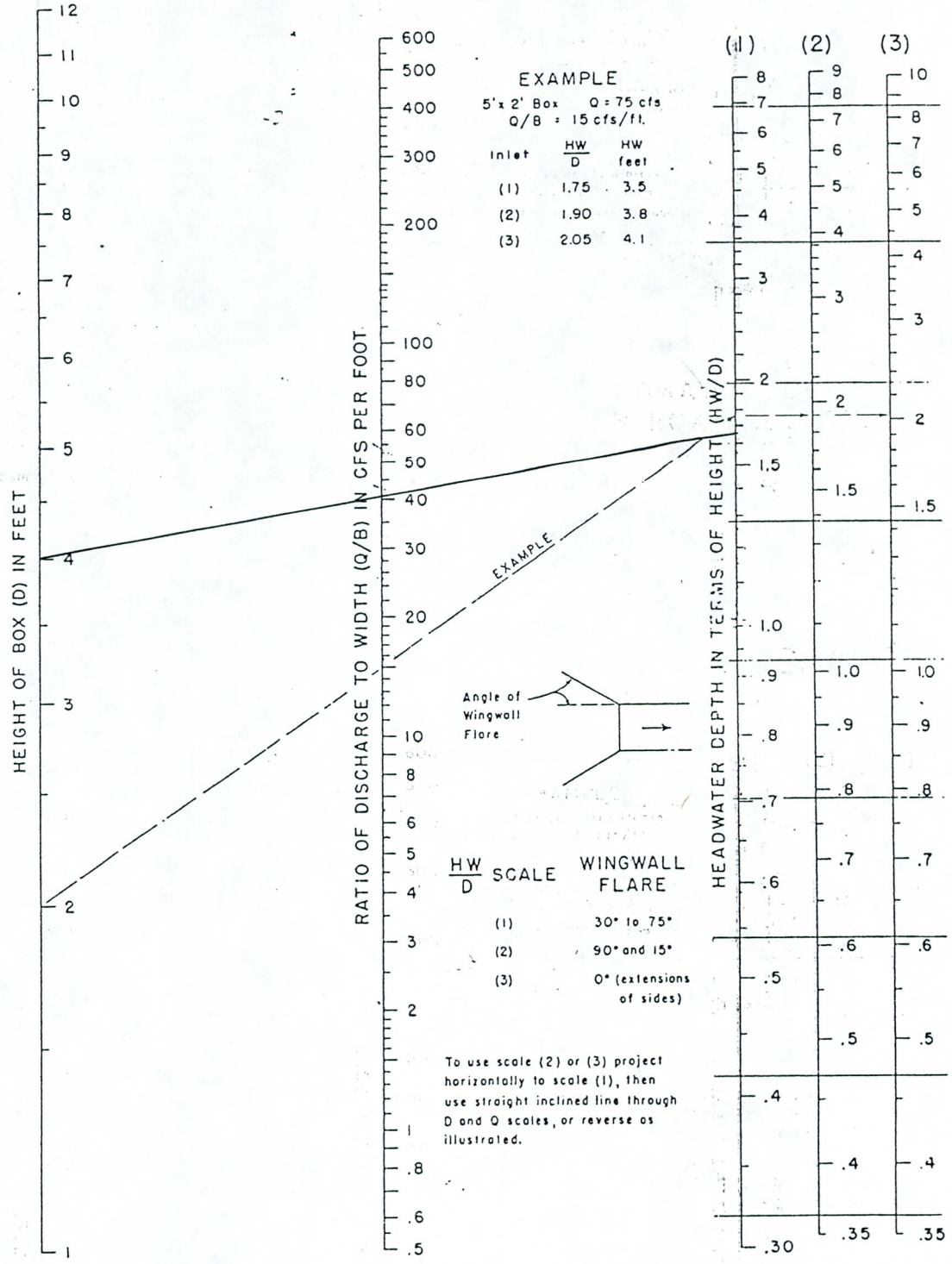
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
7 Barrel 10'x4'Rise	Drop Inlet	416		1.65	6.60	.2	2.4	3.75	3.875	2.39	3.875	.47	5.81	6.60	13.68		1649.60	Inlet Control

SUMMARY & RECOMMENDATIONS

2/20

67 H-1

CHART I

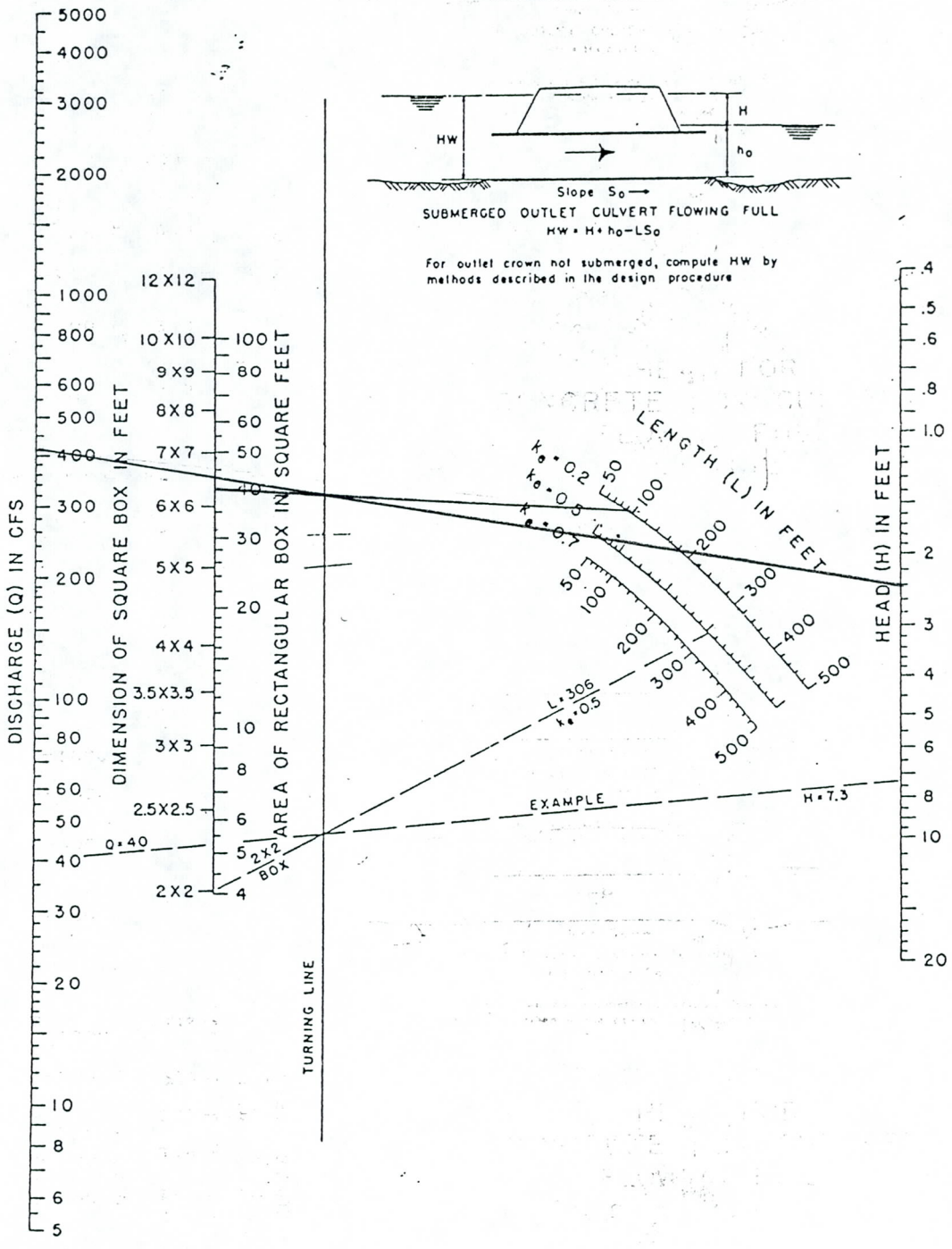


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

3/20
67 H-1

CHART 8



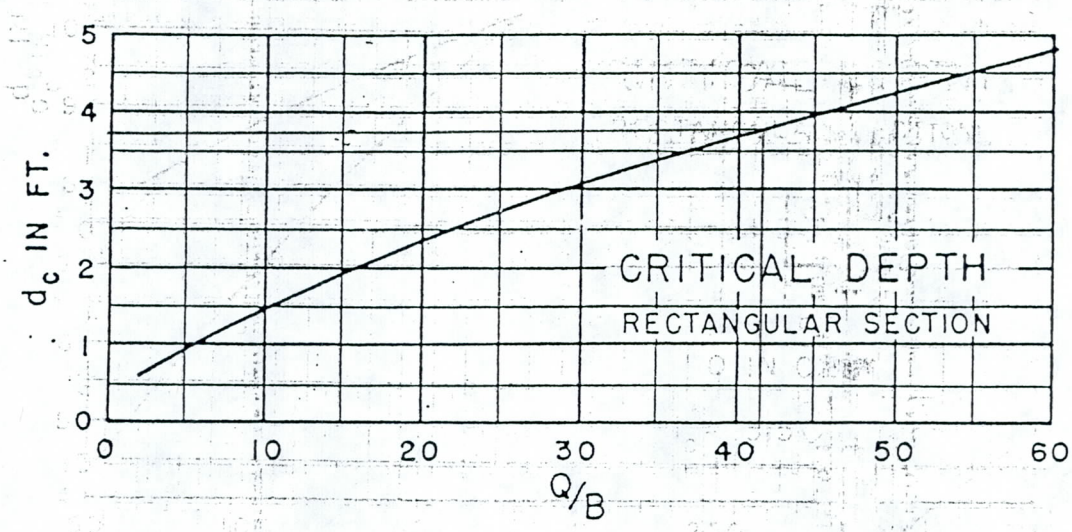
HEAD FOR CONCRETE BOX CULVERTS FLOWING FULL n = 0.012

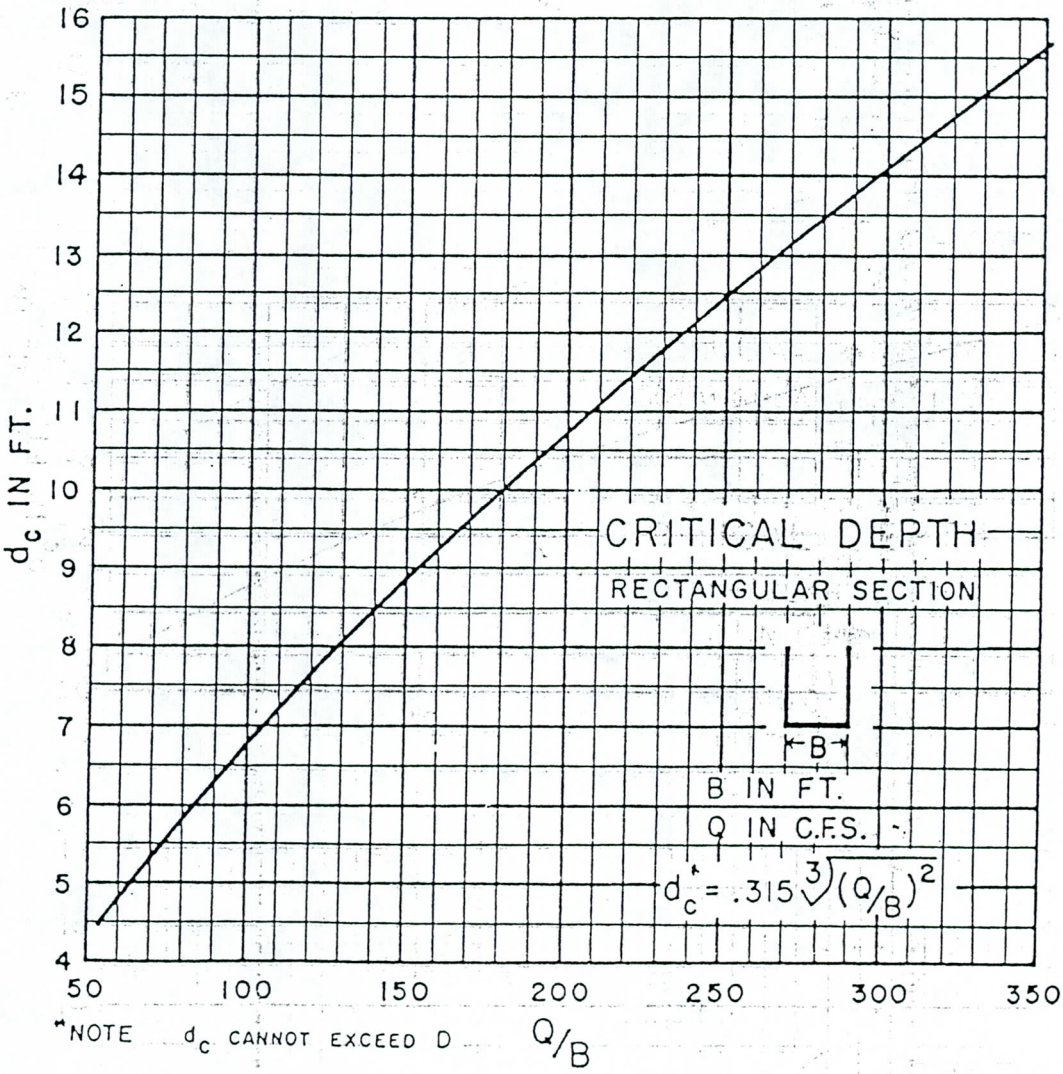
BUREAU OF PUBLIC ROADS JAN. 1963

A/20

67 H-1

CHART 15





*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 4[redacted]77 Toyota

SHEET NO. [redacted] OF

DATE 7[redacted]22-91

COMPUTATIONS FOR Proposed Culvert 67 H-2

BY DFP CHKD RVT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: HDP Sta. 61+60

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA

Q_{100} / Q_1 = 2915 cfs

Q_2 =

TW_1 = 3.57'

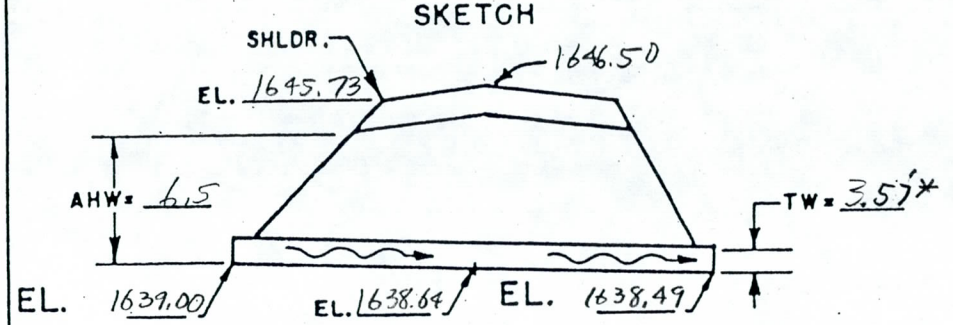
TW_2 =

Peak Outlet Discharge Q_{100}

(Q_1 = DESIGN DISCHARGE, SAY Q_{25})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_0 = .005 L = 103' L/100 S_0 =

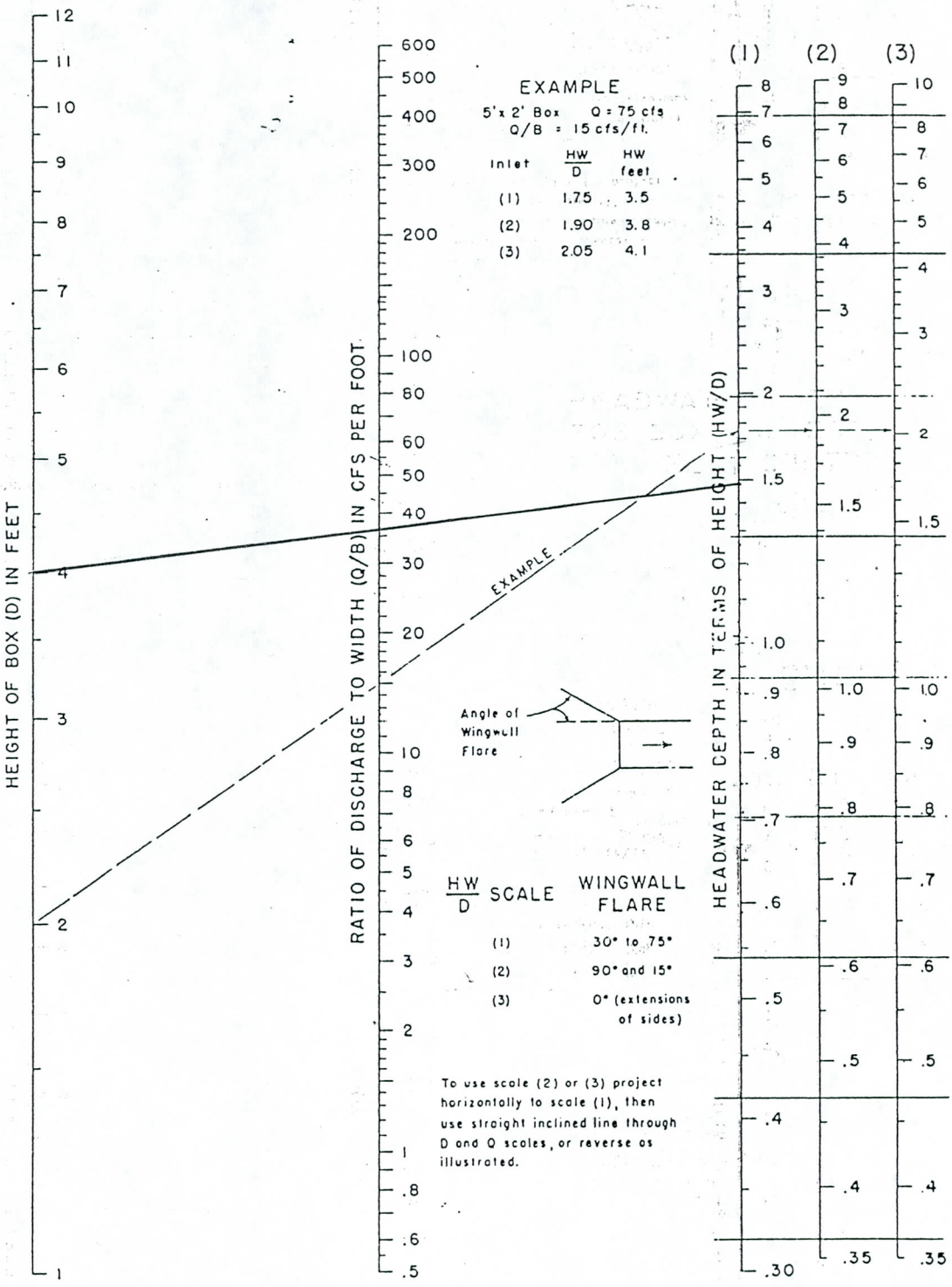
MEAN STREAM VELOCITY = 3.2 ft/s

CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
8 Barrel 10'x4'RCBC	Wingwall	364		1.48	5.92	.2	1.9	3.5	3.75	3.57	3.75	.52	5.13	5.92	12.96		1644.92	Inlet Control

SUMMARY & RECOMMENDATIONS * From Mannings Formula of proposed downstream channel.

6/20

67 H-2
CHART 1



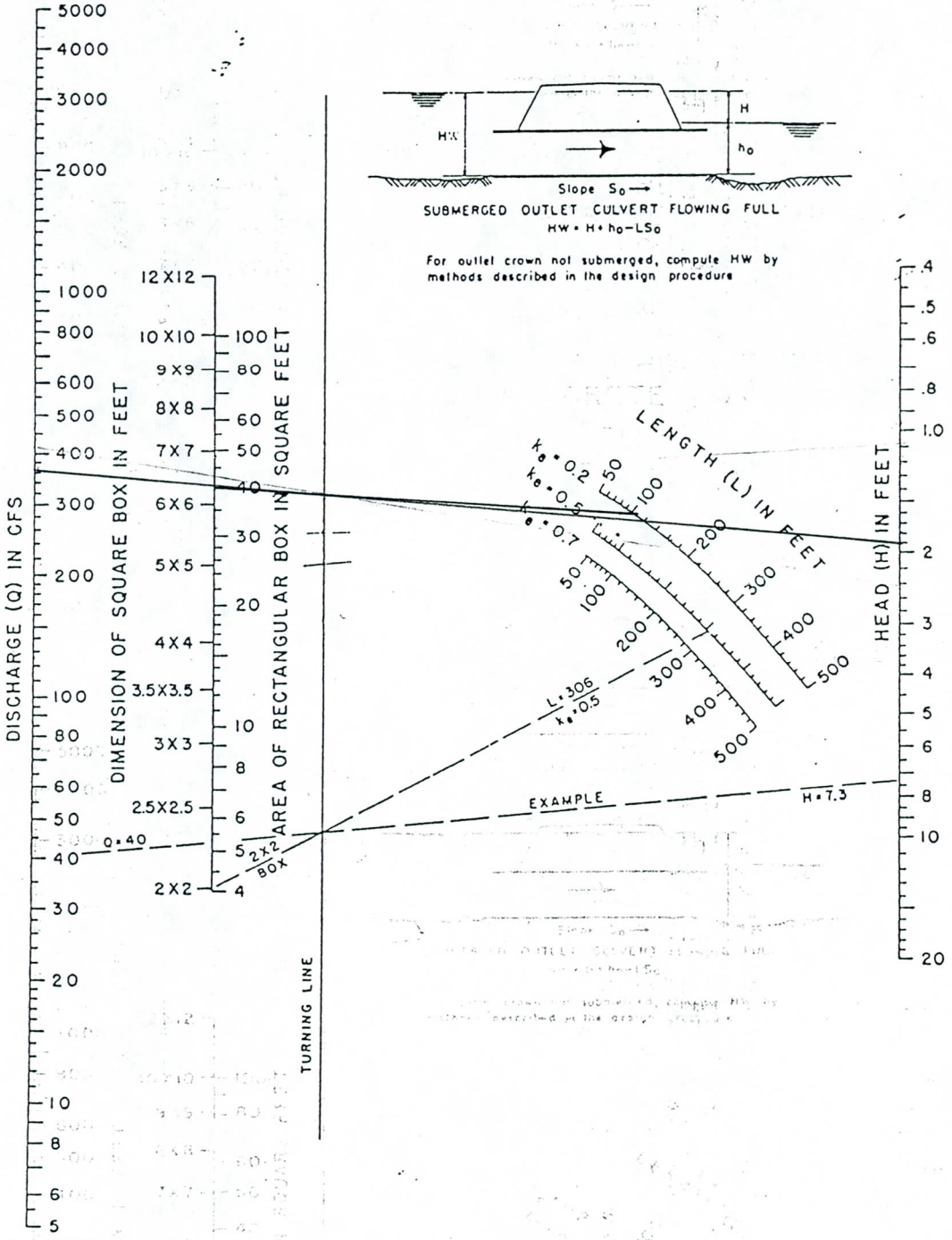
HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

7/20

67 H-2

CHART 8



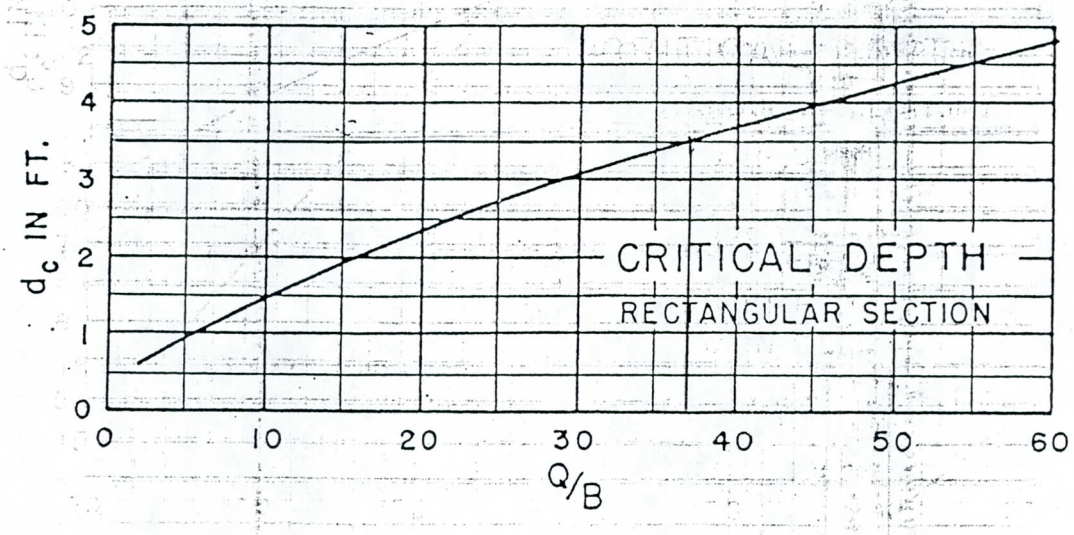
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

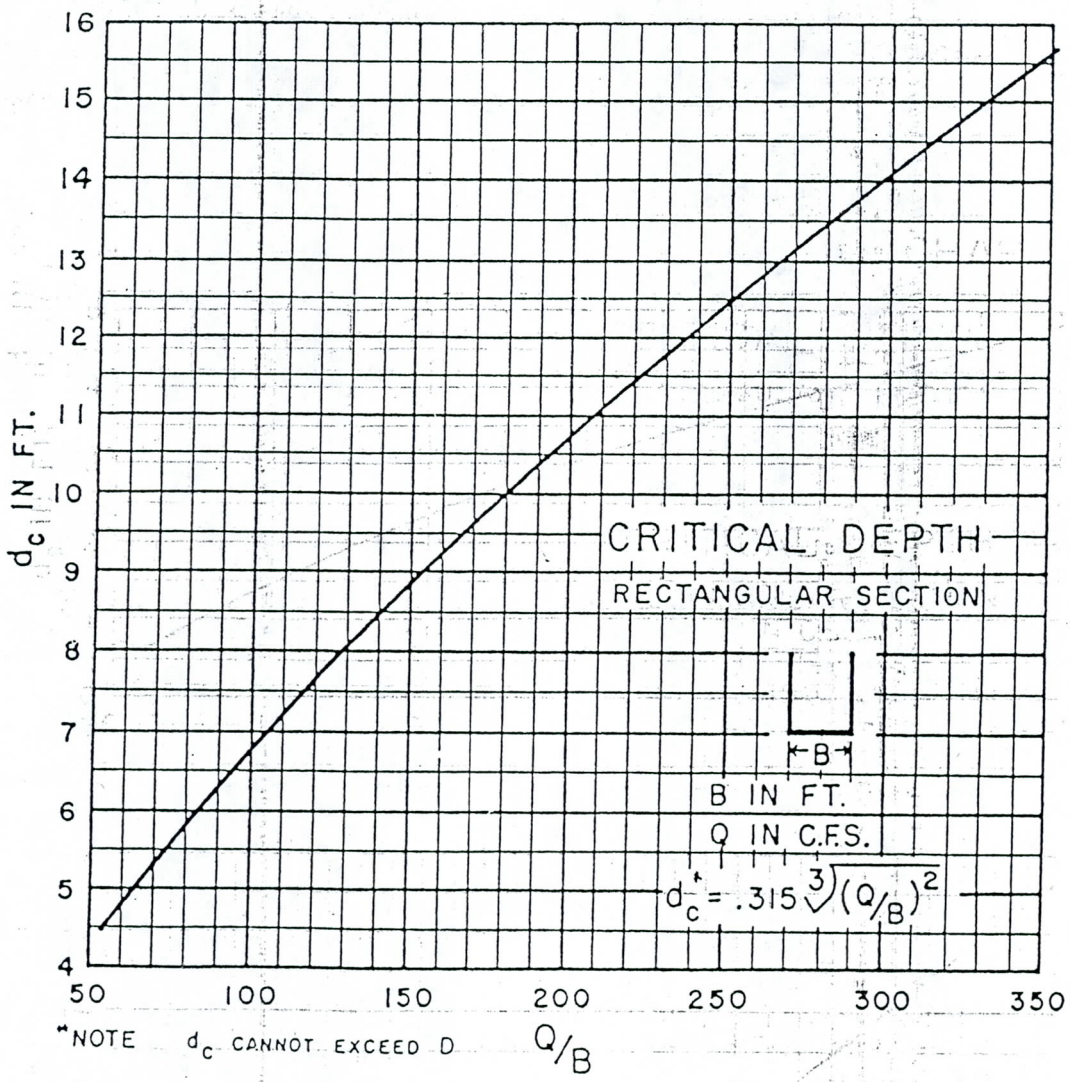
BUREAU OF PUBLIC ROADS JAN. 1963

8/20

67 H-2

CHART 15





BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

SHEET NO. 9 OF 20

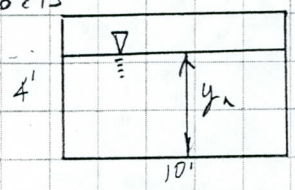
DATE 7-7-91

COMPUTATIONS FOR Culverts 67 H-1 and 67 H-2 BY DFP CHKD RJT

Check Depth of Flow Using Manning's Equation

Culvert 67 H-1

$Q_{100} = 2915 \text{ cfs}/7 = 416 \text{ cfs}$



Q_{100}: $y_n = 3.09'$, $V = 13.48 \text{ ft/s}$

$n = .012$

$S = .005$

Culvert 67 H-2

$Q_{10} = 892/8 = 111.5 \text{ cfs}$

$Q_{100} = 2915/8 = 364.4 \text{ cfs}$

Q_{10}: $y_n = 1.26'$, $V = 8.82 \text{ ft/s}$

Q_{100}: $y_n = 2.81'$, $V = 12.96 \text{ ft/s}$

Froude Nos:

Q_{100}: $N_F = \frac{13.48}{\sqrt{32.2(3.09)}} = 1.36$ supercritical

Q_{10}: $N_F = \frac{8.82}{\sqrt{32.2(1.26)}} = 1.38$ supercritical

Q_{100}: $N_F = \frac{12.96}{\sqrt{32.2(2.81)}} = 1.36$ supercritical

Investigate a channel at constant slope between aprons of Culverts 67 H-1 and 67 H-2:

$$S = \frac{1642.53 - .005(13) - (1639 + .005(9))}{\frac{(402.5)}{\cos 10^\circ} - 48 - 13 - 73 - 9}$$

$$= \frac{3.42}{265.7} = .0129 \text{ ft/ft}$$

Bottom width = 90', 4:1 soil cement treated side slopes, $n = .02$, $Q = 2915$ cfs $\Rightarrow$ Manning's gives $V = 13.44 \text{ ft/s}$, $y_n = 2.20'$, $T = 107.60'$, $A = 216.97 \text{ ft}^2$

$N_F = \frac{13.44}{\sqrt{32.2(A/T)}} = 1.67$ supercritical. For flow < 3' deep, & supercritical, freeboard $= \frac{1}{6}\left(y + \frac{V^2}{2g}\right) = .83 \Rightarrow$ Channel height of $2.20 + .83 = 3.03'$. Make side slopes 3' high. Due to high velocities, use soil cement for entire channel. Widen channel in 30' at Culvert 20 to 100' bottom width to match 8 barrel culvert inlet.

SVERDRUP

JOB 40477 Toyota SHEET NO. 10 OF 20

DATE 7-8-91

COMPUTATIONS FOR Culverts 67H-1 and 67H-2 BY DFP CHKD RJT

Design Downstream Channel from Culvert 67H-2:

Proposed channel slope = S = .002'/ft

n = .02 Q = 2915 cfs

Try a 100' wide channel w/ 4:1 side slopes, soil cement treated.

From Mannings Formula:

y = 3.57' A = 407.87 T = 128.56' V = 7.15 ft/s $N_F = \frac{7.15}{\sqrt{32.2\,(A/T)}} = .71$

Since flow is subcritical, Freeboard = $y_n + 1 = 4.57'$, use 5' for channel depth.

Widen channel from 100' wide to 150' in 120':

Check Flow w/ mannings:

S = .002 y_n = 2.84' V = 6.36 ft/s A = 458.52 ft² T = 172.72'

$N_F = \frac{6.36}{\sqrt{32.2\,(A/T)}} = .69$ Subcritical

Due to high velocities, suggest entire channel be soil cement.

A minimum length of 600' beyond the culvert discharge is necessary in order to match existing topography at the end of the channel, and provide a spread that will cause a sufficient reduction in velocity.

Cutoff Wall Design:

Per HEC No. 14, Hydraulic Design of Energy Dissipators for Culverts and Channels by FHWA, and Drainage and Design Standards for Floodplain Management Within Pima County Arizona by Pima County D.O.T. and FCD:

the downstream depth of scour is:

$$h_s = \alpha y_e (Q/y_e^{2.5})^{\beta} t^{\theta}$$

For TW 7 .50, (From Table V-1, HEC No. 14)

$\alpha = .76$, $\beta = .375$ $\theta = 0.10$ and $\gamma = 1.0$

$$\therefore h_s = .76 y_e (Q/y_e)^{.375} t^{0.1}$$

$Q = VA$ and $A = 2y_e^2$ $\therefore h_s = .76 y_e \left(\frac{V\,2(y_e)^2}{y_e^{2.5}}\right)^{.375} t^{0.1}$

where V = average velocity (ft/s) y_e = max depth (ft)
t = time duration (min)

for the 150' channel, $y_e = 2.84'$ $V = 6.36$ ft/s
$t = 35$ min

$$h_s = .76(2.84)\left(\frac{6.36(2)(2.84)^2}{2.84^{2.5}}\right)^{.375} 35^{0.1}$$

$$= 6.57' \quad \underline{\text{Use } 7'}$$

Analize Flow over Riprap beyond cutoff wall:

$n = .032$, 4:1 side slopes, 150' bottom width, $S = .002$, using Mannings:

$y_n = 3.75'$ $V = 4.71$ ft/s. Install 50' long riprap pad and install earthen channel 100' downstream of riprap, matching existing.

SVERDRUP

JOB 40477 Toyota

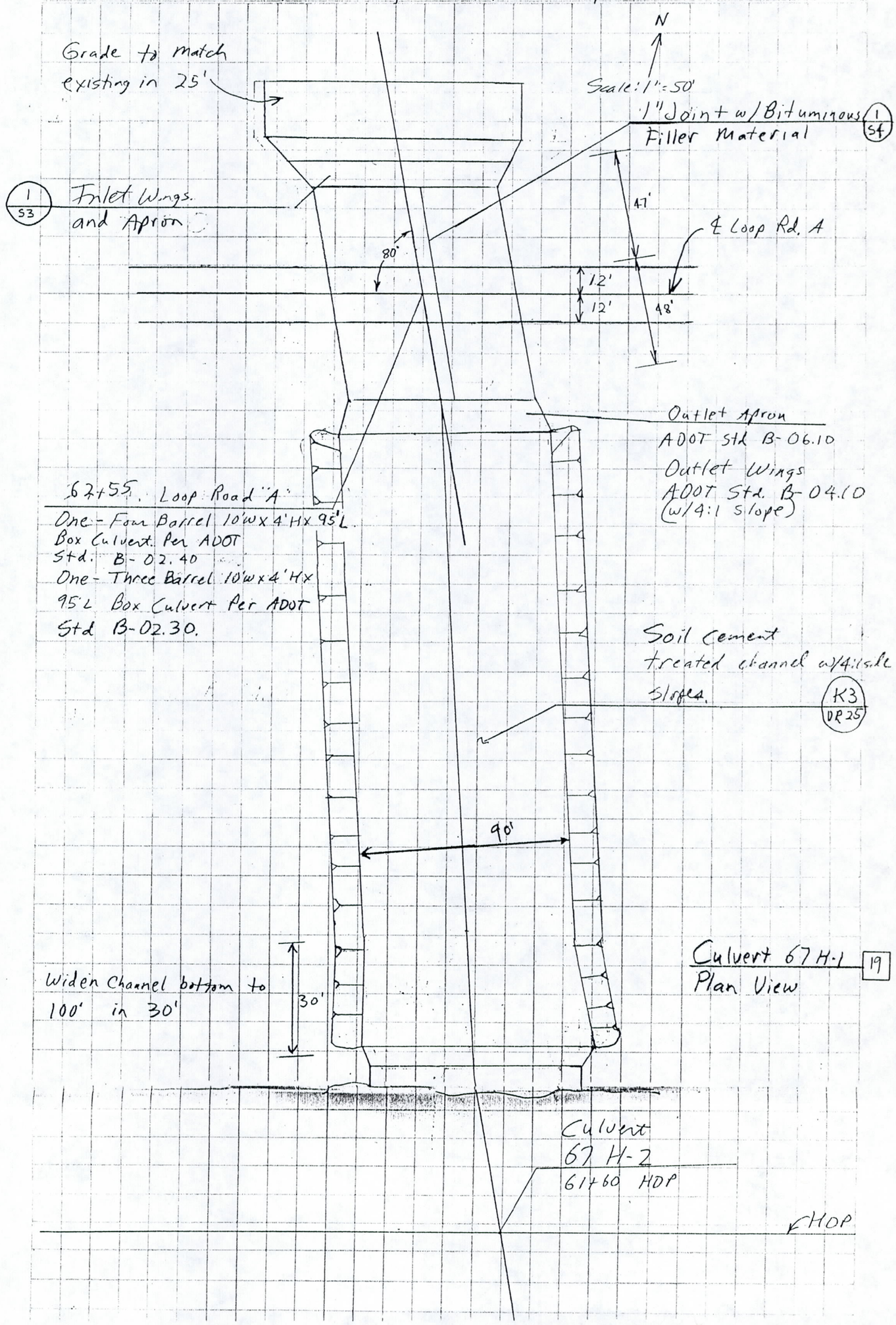
SHEET NO. 12 OF 20

DATE 6-26-91

COMPUTATIONS FOR Culvert 67 H-1 [19]

BY DFP CHKD RJT

Plan View, Sta. 62+55 Loop Road "A"



SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert Profile 67 H-1 19

Loop Rd A, Sta. 62+55

67 H-1 19 DATE 7-7-91

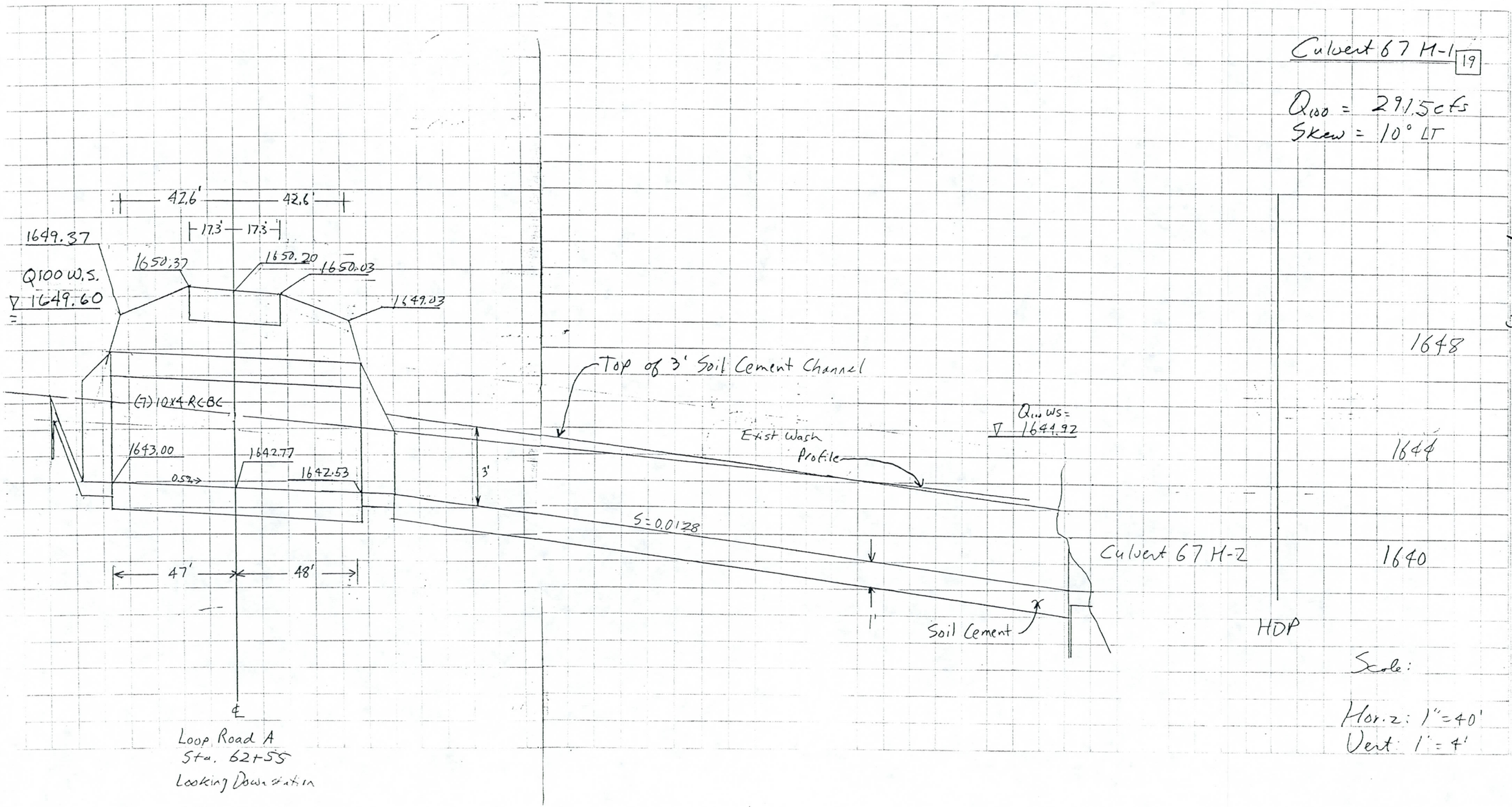
BY DEP CHKD RJT

SHEET NO. 13 OF 20

Culvert 67 H-1 19

Q_{100} = 291.5 cfs

Skew = 10° LT



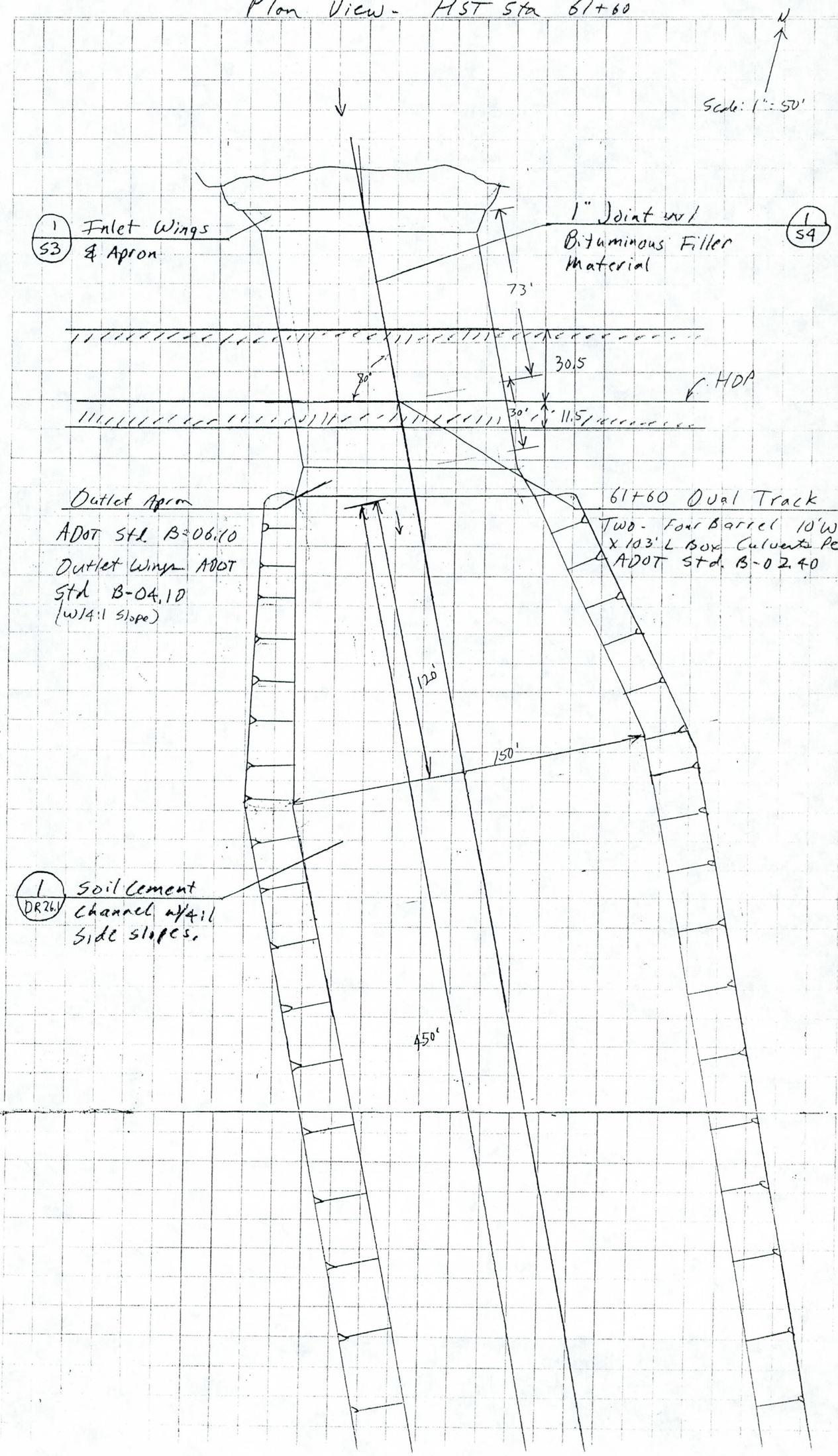
SVERDRUP

JOB 40477 Toyota SHEET NO. 14 OF 20

DATE 7-1-91

COMPUTATIONS FOR Box Culvert 67 H-2 [20] BY DFP CHKD RJT

Plan View - HST Sta 61+60



SVERDRUP

JOB 40477 Toyota

COMPUTATIONS FOR Culvert Profile 67 H-2 HDP Sta 61+60

SHEET NO. 15 OF 20

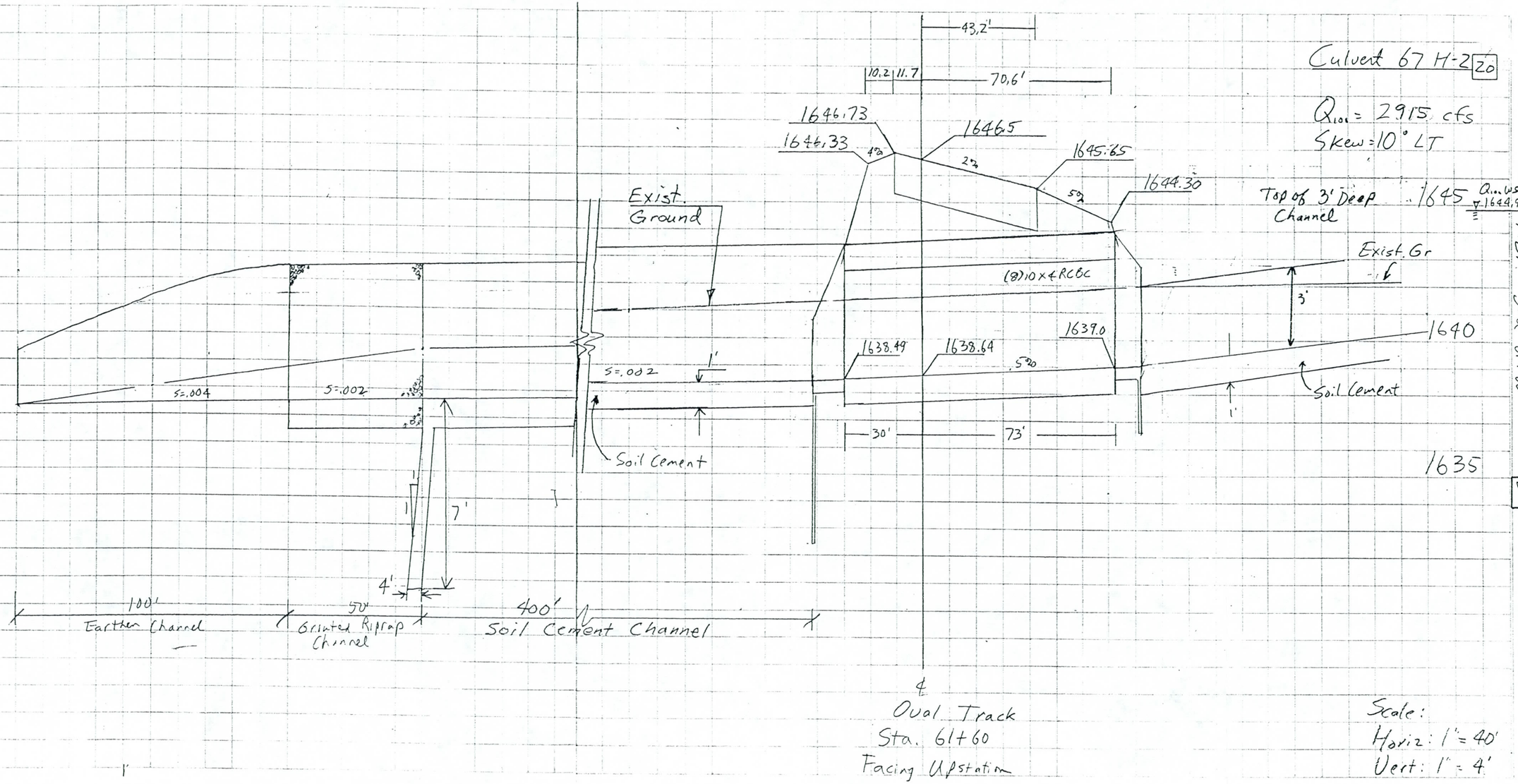
DATE 6-18-91

BY DFP CHKD RJT

Culvert 67 H-2 20

Q_{100} = 2915 cfs

Skew = 10° LT



SECTION NUMBER TW67H 6/11/91

Channel Slope: 0.0057 ft./ft.

CROSS SECTION DATA:

OFFSET	-240	-170	-140	-105	2.8	14.5	17.3	19.9	22.4	108.9	111.3	117.1	119.2	156.1	160.1
ELEV.	43.3	41.5	42.4	42	42.31	41.69	41.05	41.02	41.7	42.68	40.43	40.76	42.46	42.3	41.8
N	N/A	0.035	0.035	0.035	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.025	0.035	0.035	0.035

STAGE-DISCHARGE DATA:

STAGE:	40.3														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	40.6														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	40.9														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	5.8	0.2	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.8	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.1	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	4	0	0	0
STAGE:	41.2														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.7	2.6	0.7	0.0	1.1	5.8	0.7	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.3	3.5	0.1	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.3	0.6	0.2	0.0	0.0
Q		0	0	0	0	0	0	1	0	0	0	11	0	0	0
STAGE:	41.5														
WET PER.		0.0	0.0	0.0	0.0	0.0	2.0	2.6	1.8	0.0	1.6	5.8	1.2	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.4	1.2	0.4	0.0	0.6	5.2	0.3	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.2	0.0	0.4	0.9	0.3	0.0	0.0
Q		0	0	0	0	0	1	3	1	0	1	22	0	0	0
STAGE:	41.8														
WET PER.		11.7	21.7	0.0	0.0	2.1	5.0	2.6	2.6	11.4	2.0	5.8	1.7	0.0	0.0
AREA		1.7	3.2	0.0	0.0	0.1	1.3	2.0	1.1	1.5	1.0	7.0	0.7	0.0	0.0
HYD.RAD.		0.1	0.1	0.0	0.0	0.1	0.3	0.8	0.4	0.1	0.5	1.2	0.4	0.0	0.0
Q		0	3	0	0	0	2	7	0	1	2	36	1	0	0

SECTION NUMBER TW67H 6/11/91

Channel Slope: 0.0057 ft./ft.

CROSS SECTION DATA:

OFFSET	-240	-170	-140	-105	2.8	14.5	17.3	19.9	22.4	108.9	111.3	117.1	119.2	156.1	160.1
ELEV.	43.3	41.5	42.4	42	42.31	41.69	41.05	41.02	41.7	42.68	40.43	40.76	42.46	42.3	41.8
N	N/A	0.035	0.035	0.035	0.035	0.035	0.035	0.025	0.035	0.035	0.035	0.025	0.035	0.035	0.035

STAGE-DISCHARGE DATA:

STAGE:	40.3														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	40.6														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	3.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	40.9														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	5.8	0.2	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.8	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.1	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	4	0	0	0
STAGE:	41.2														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.7	2.6	0.7	0.0	1.1	5.8	0.7	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.1	0.0	0.3	3.5	0.1	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.3	0.6	0.2	0.0	0.0
Q		0	0	0	0	0	0	1	0	0	0	11	0	0	0
STAGE:	41.5														
WET PER.		0.0	0.0	0.0	0.0	0.0	2.0	2.6	1.8	0.0	1.6	5.8	1.2	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.4	1.2	0.4	0.0	0.6	5.2	0.3	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.2	0.0	0.4	0.9	0.3	0.0	0.0
Q		0	0	0	0	0	1	3	1	0	1	22	0	0	0
STAGE:	41.8														
WET PER.		11.7	21.7	0.0	0.0	2.1	5.0	2.6	2.6	11.4	2.0	5.8	1.7	0.0	0.0
AREA		1.7	3.2	0.0	0.0	0.1	1.3	2.0	1.1	1.5	1.0	7.0	0.7	0.0	0.0
HYD.RAD.		0.1	0.1	0.0	0.0	0.1	0.3	0.8	0.4	0.1	0.5	1.2	0.4	0.0	0.0
Q		0	3	0	0	0	2	7	0	1	2	36	1	0	0

16/20

SECTION NUMBER TW67H 6/11/91

STAGE:	42.1													
WET PER.		23.3	43.4	8.8	43.5	7.8	10.6	2.6	2.6	37.9	2.4	5.8	2.1	0.0	2.4
AREA		7.0	13.0	0.4	2.2	1.6	3.6	2.8	1.9	8.9	1.5	8.7	1.1	0.0	0.4
HYD.RAD.		0.3	0.3	0.1	0.1	0.2	0.3	1.1	0.7	0.2	0.6	1.5	0.5	0.0	0.1
Q		0	19	0	1	0	6	13	0	11	3	51	2	0	0
STAGE:	42.4														
WET PER.		35.0	65.0	35.0	142.8	154.5	157.4	2.6	2.6	64.4	2.9	5.8	2.6	23.1	27.1
AREA		15.8	29.3	7.0	33.4	38.1	41.0	3.5	2.6	24.2	2.1	10.5	1.7	1.2	2.6
HYD.RAD.		0.4	0.4	0.2	0.2	0.2	0.3	1.4	1.0	0.4	0.7	1.8	0.6	0.1	0.1
Q		0	55	0	0	0	54	20	0	41	5	70	4	0	2
STAGE:	42.7														
WET PER.		46.7	76.7	111.7	219.5	231.2	234.1	2.6	2.6	89.1	92.4	5.8	2.7	39.6	43.6
AREA		28.0	50.5	68.0	126.8	134.9	138.7	4.3	3.4	47.5	50.2	12.2	2.3	14.1	16.7
HYD.RAD.		0.6	0.7	0.6	0.6	0.6	0.6	1.7	1.3	0.5	0.5	2.1	0.8	0.4	0.4
Q		0	0	0	0	0	314	27	0	0	107	90	0	0	28
STAGE:	43														
WET PER.		58.4	88.4	123.4	231.2	242.9	245.8	2.6	2.6	89.1	92.4	5.8	2.7	39.6	43.6
AREA		43.8	75.3	103.3	194.3	206.0	210.6	5.1	4.1	74.2	77.6	13.9	2.9	25.8	29.6
HYD.RAD.		0.7	0.9	0.8	0.8	0.8	0.9	2.0	1.6	0.8	0.8	2.4	1.1	0.7	0.7
Q		0	0	0	0	0	610	36	0	0	222	112	0	0	73
STAGE:	43.3														
WET PER.		70.0	100.0	135.0	242.8	254.6	257.4	2.6	2.6	89.1	92.4	5.8	2.7	39.6	43.6
AREA		63.0	103.5	142.0	265.4	280.6	286.0	5.9	4.8	100.9	105.1	15.7	3.5	37.5	42.5
HYD.RAD.		0.9	1.0	1.1	1.1	1.1	1.1	2.3	1.9	1.1	1.1	2.7	1.3	0.9	1.0
Q		0	0	0	0	0	985	46	0	0	368	137	0	0	134

W.S. Elev.	40.3	40.6	40.9	41.2	41.5	41.8	42.1	42.4	42.7	43	43.3
Q	0	0	4	12	28	52	116	323	850	1743	3076
A	0.0	0.3	1.9	4.5	8.3	16.8	48.8	168.9	381.3	650.7	963.6
V	0.0	0.8	2.0	2.8	3.4	3.1	2.4	1.9	2.2	2.7	3.2

166.2	169.8	218.3	250	740	820
41.8	42.2	42.4	43.1	42	43.3
0.025	0.035	0.035	0.035	0.035	0.035

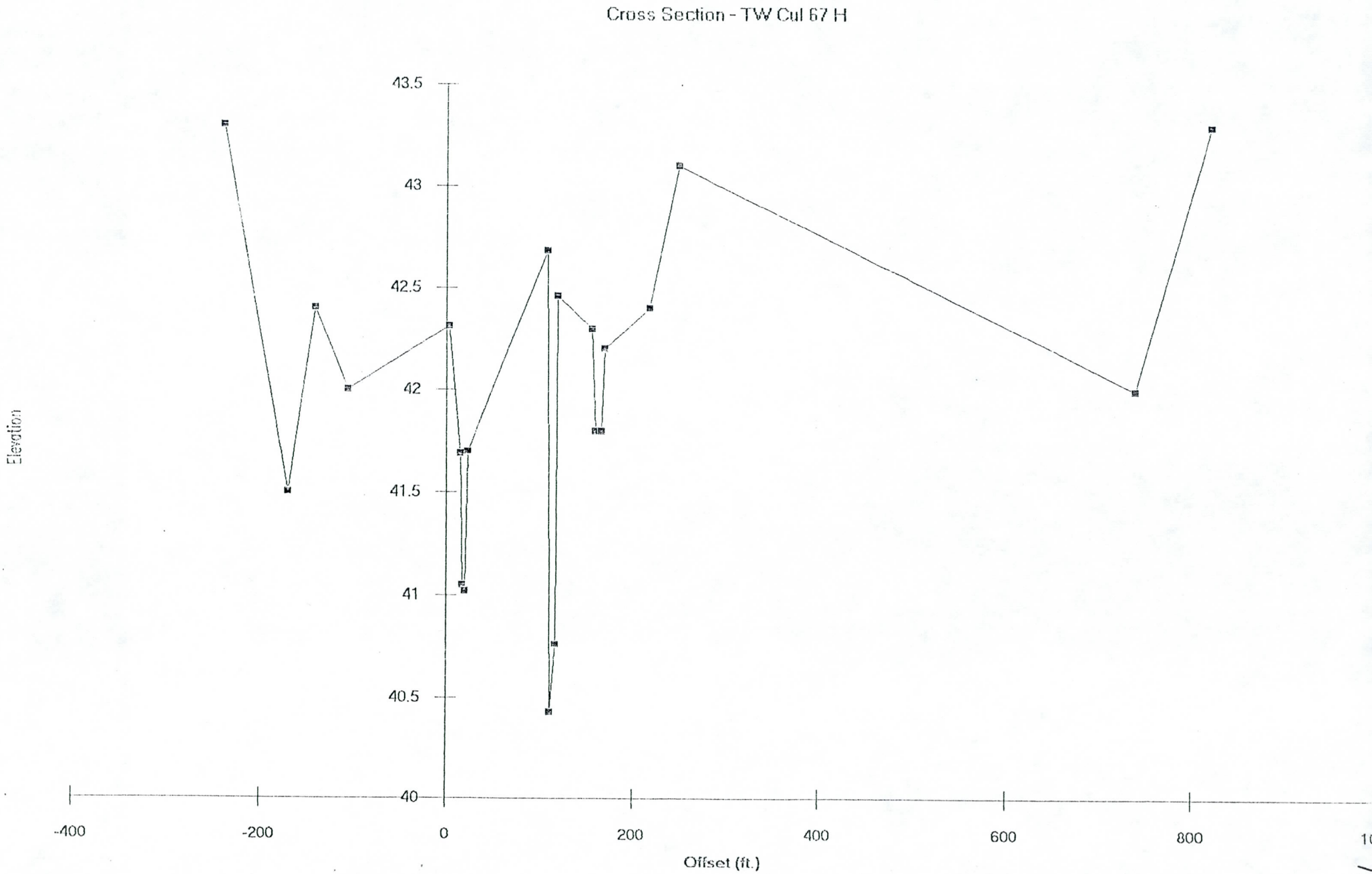
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0	0	0	0	0	0	0	0	0	0

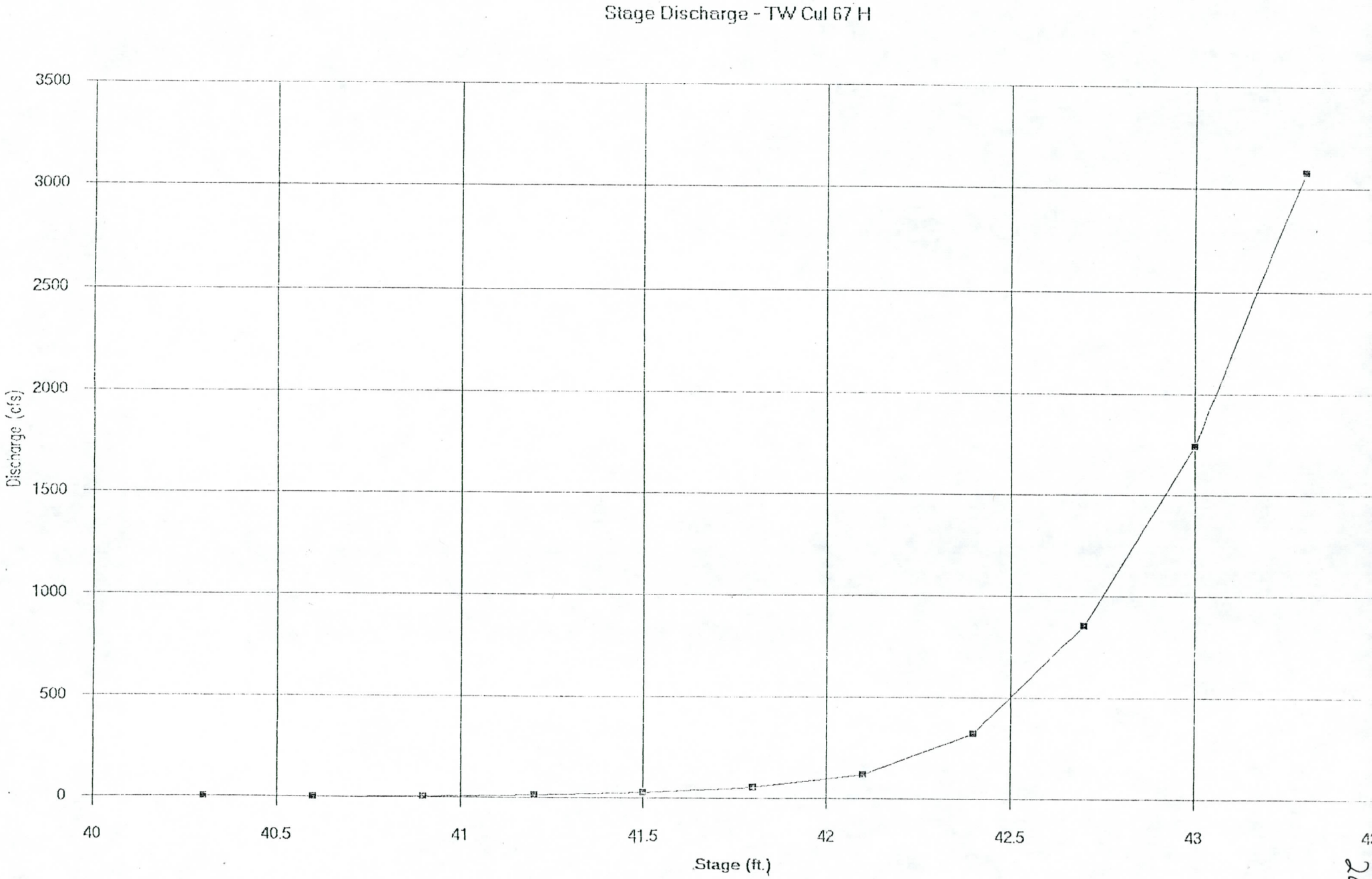
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0	0	0	0	0	0	0	0	0	0

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0	0	0	0	0	0	0	0	0	0

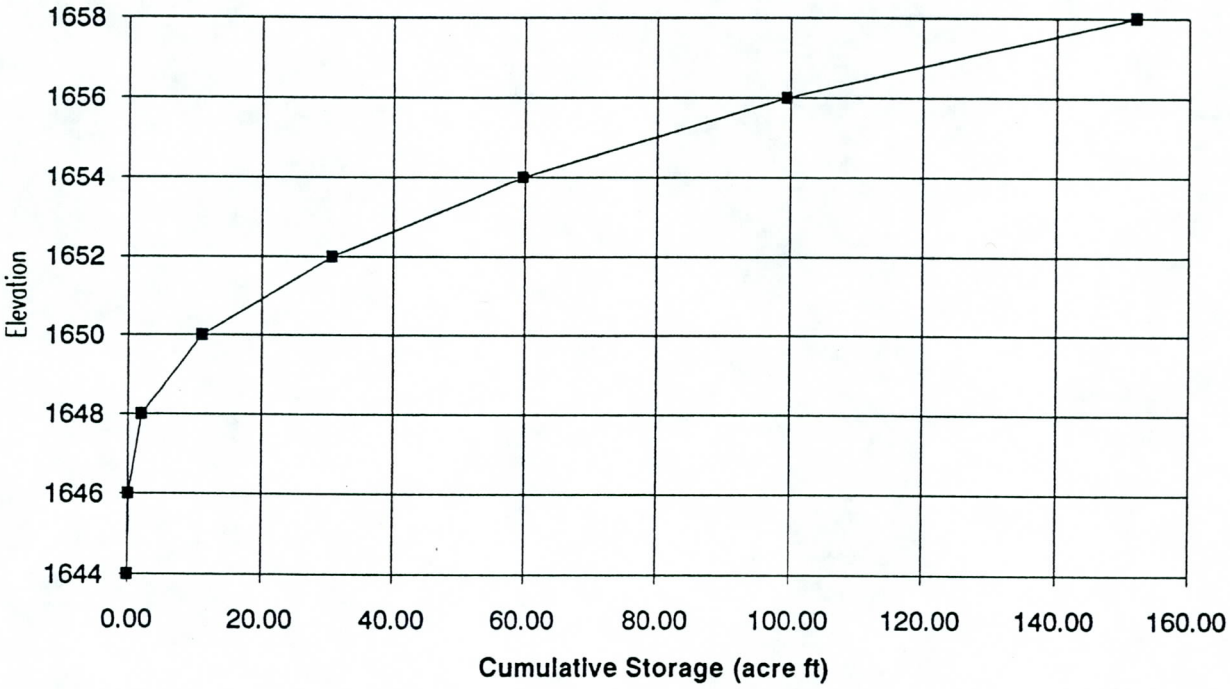
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0	0	0	0	0	0	0	0	0	0

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0	0	0	0	0	0	0	0	0	0


Cross Section - TW Cul 67 H
43.5
43
42.5
42
41.5
41
40.5
40
Elevation
-400
-200
0
200
400
600
800
Offset (ft.)


Stage Discharge - TW Cul 67 H
3500
3000
2500
2000
1500
1000
500
0
Discharge (cfs)
40
40.5
41
41.5
42
42.5
43
Stage (ft.)

Elevation vs. Storage - Node 67 H-1



SVERDRUP

JOB 4[redacted]7 Toyota SHEET NO. [redacted] OF

DATE 7-[redacted]-91

COMPUTATIONS FOR Proposed Culvert 67I-1 21 BY DFP CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: 54+15 Loop Rd. "A"

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA

Q_1 = 500 cfs TW_1 = 5.81' *

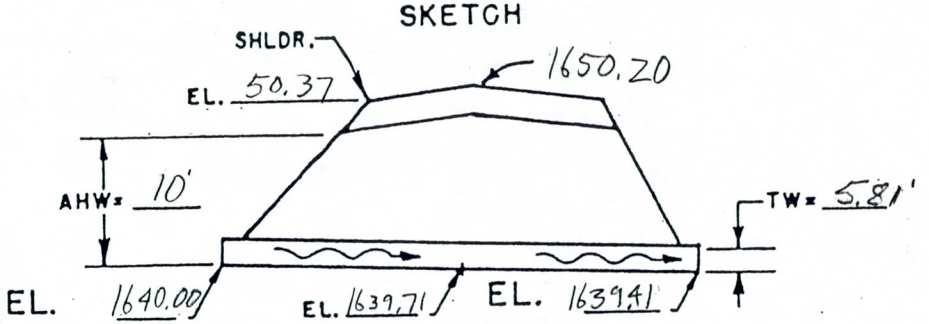
Q_2 = TW_2 =

* Based upon DHWE of 1645.22 from Culvert 67I-2.

Peak Outlet Discharge Q_{100}

(Q_1 = DESIGN DISCHARGE, SAY Q_{25}
Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_0 = .005 L = 118' L/100 S_0 =

MEAN STREAM VELOCITY = 6.5 ft/s

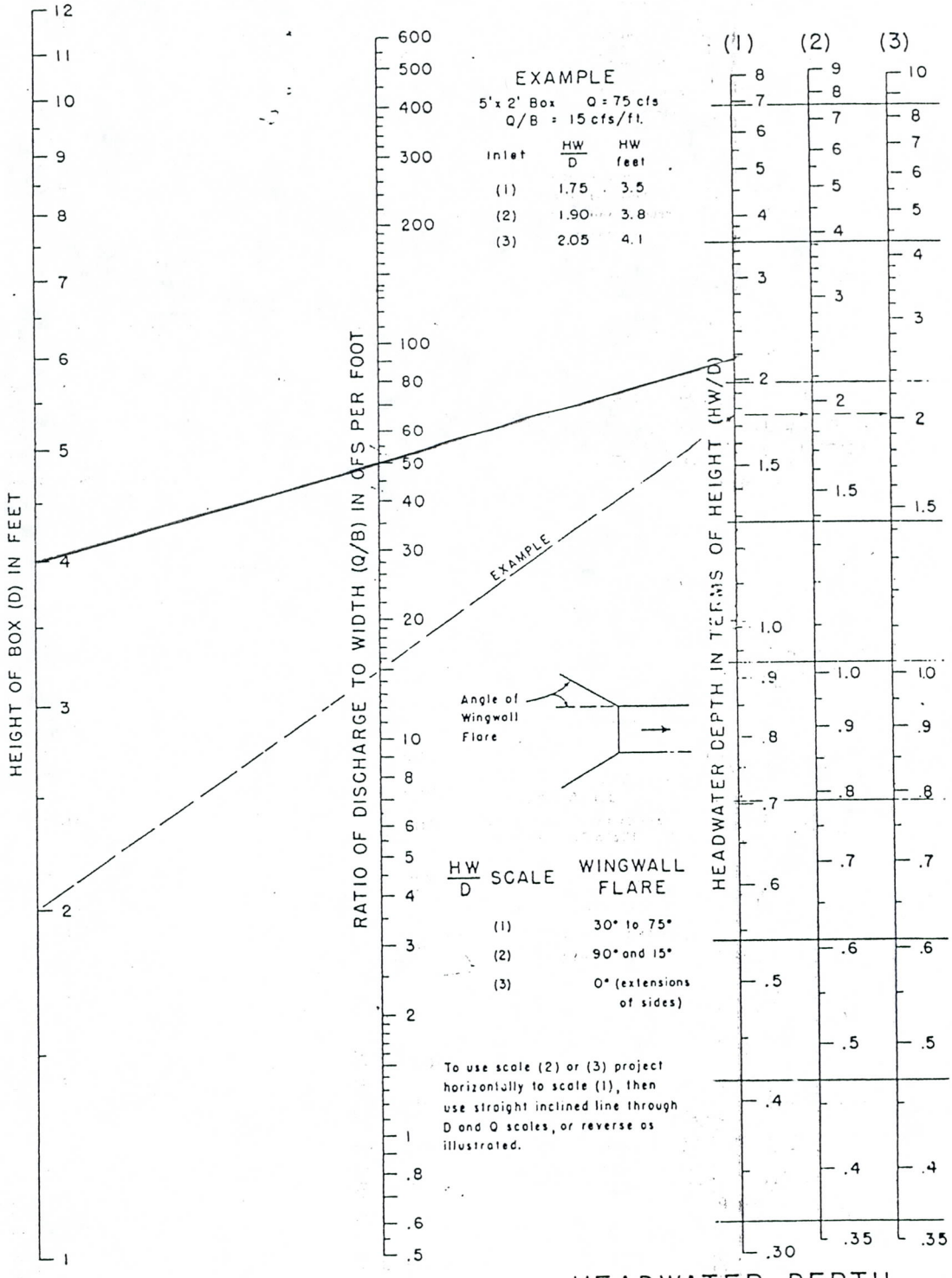
CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
1 Barrel 10'x8'Rec	Drop Inlet	500		2.18	8.72	.2	3.65	4.00	4.00	5.81	5.81	.59	8.87	8.87	12.58		1648.87	Outlet Control

SUMMARY & RECOMMENDATIONS

2/19

CHART 1

67 I-1



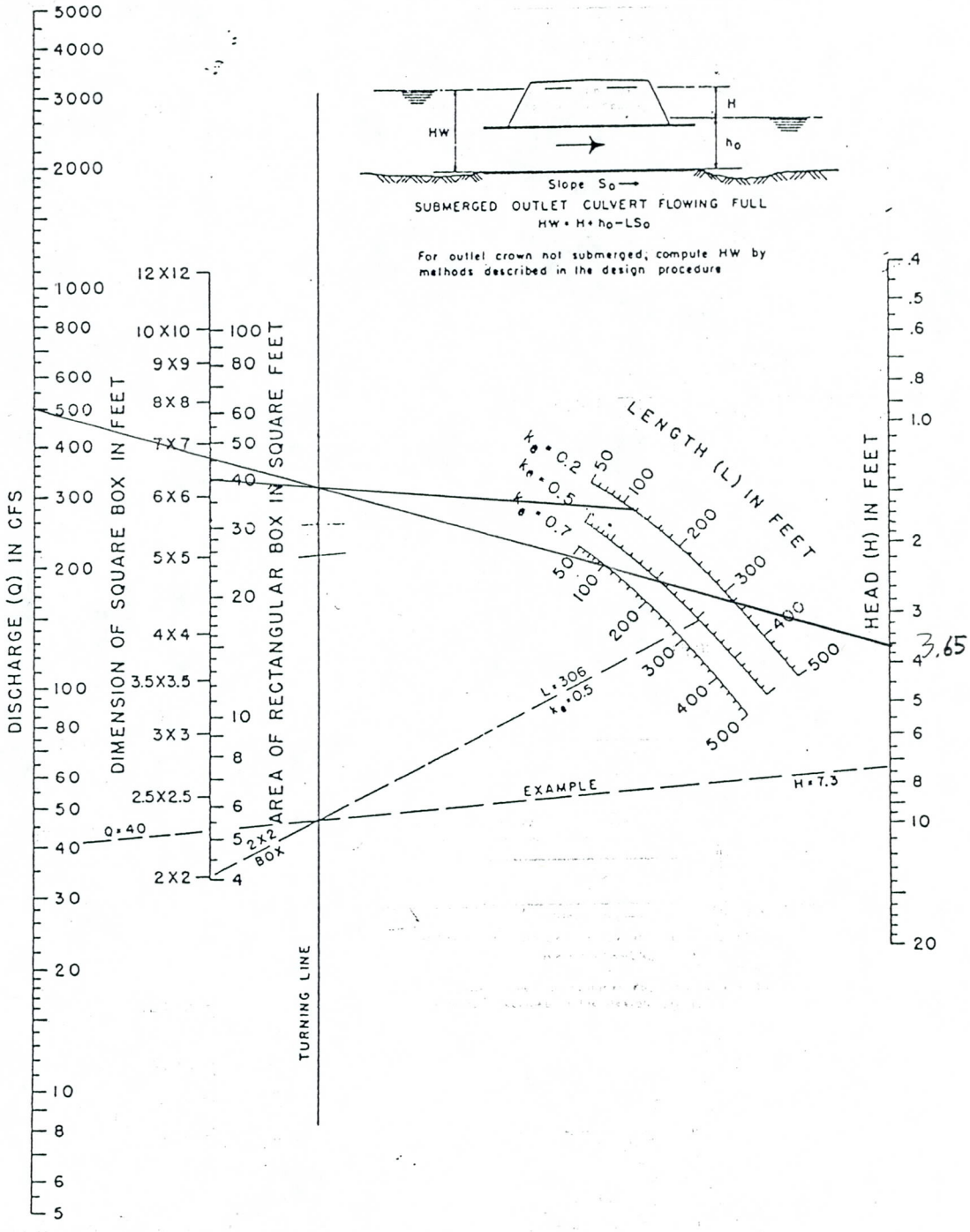
HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

3/19

67 I-1

CHART 8



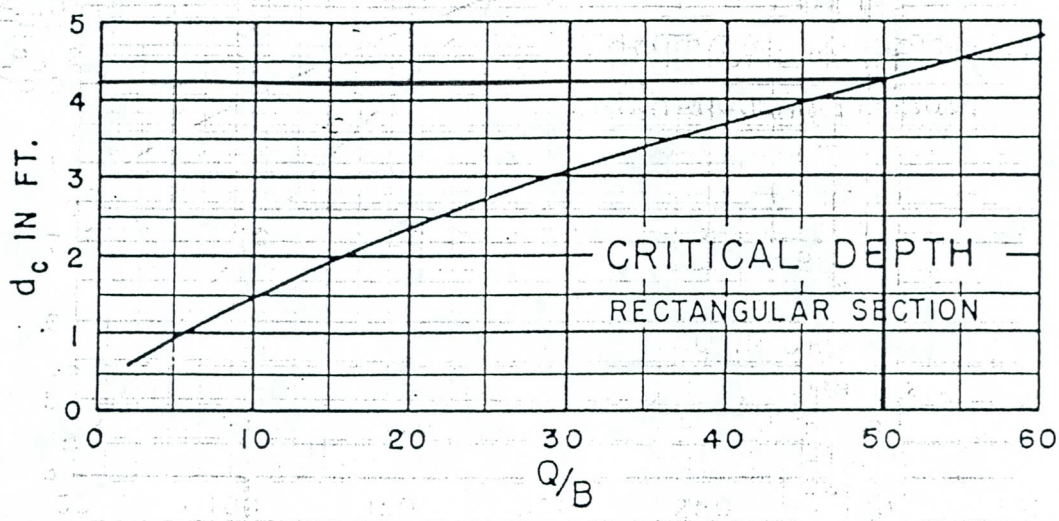
HEAD FOR CONCRETE BOX CULVERTS FLOWING FULL n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

4/19

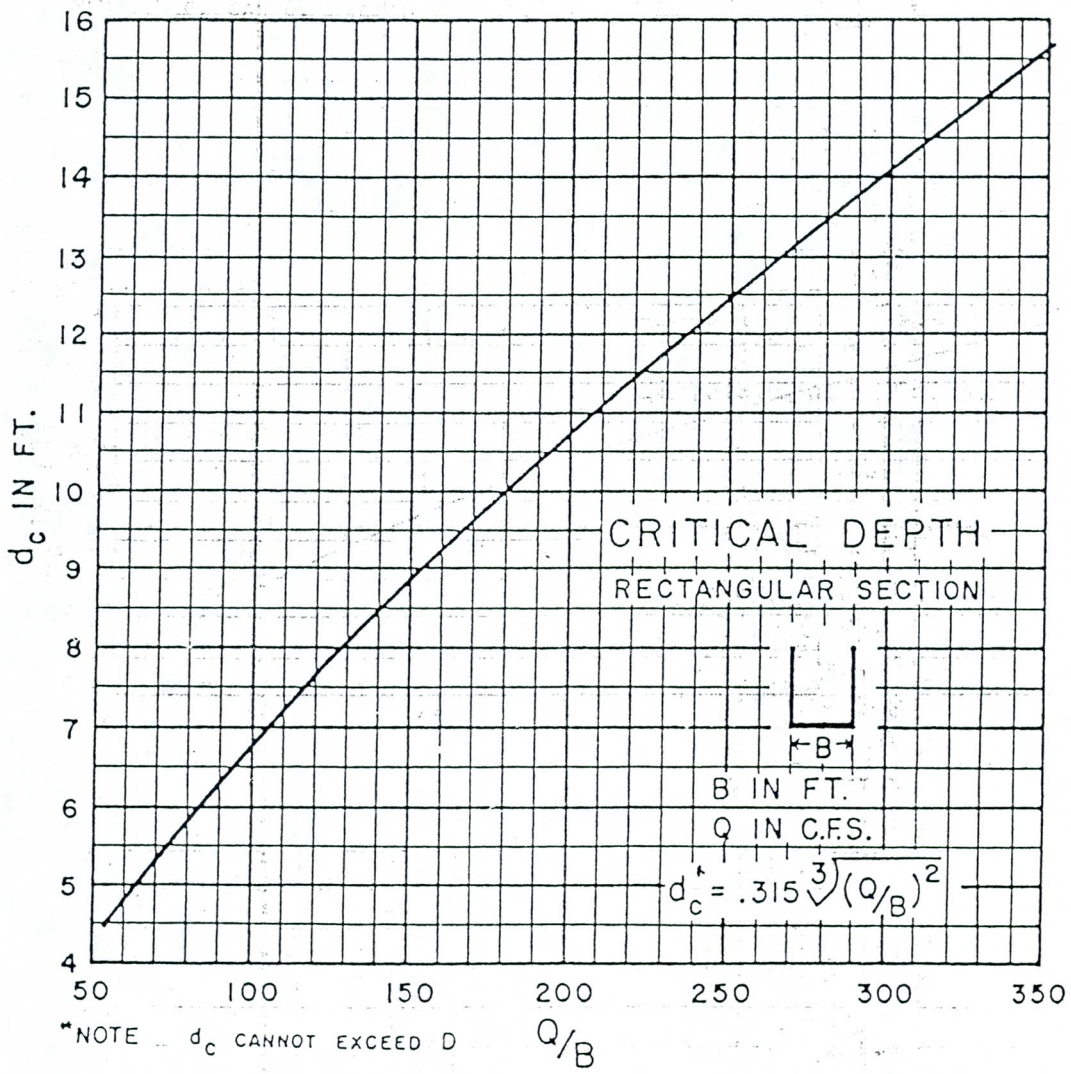
67 I-1

CHART 15



$d_c \geq D$

$\therefore d_c = D = 4.00$



BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 4[redacted]7 Toyota SHEET NO. [redacted] OF

DATE 7-12-71

COMPUTATIONS FOR Proposed Culvert 67 I-2 22 BY DFP CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT:

STATION: HDP - Sta 52+20

DESIGNER:

DATE:

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA

Q_1 = 500 cfs

Q_2 =

TW_1 = 2.34'*

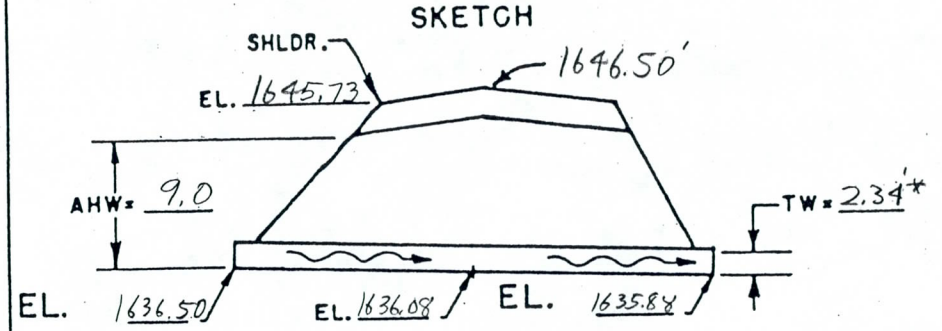
TW_2 =

Peak Outlet Discharge Q_{100}

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~)

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_0 = .005 L = 124' L/100 S_0 =

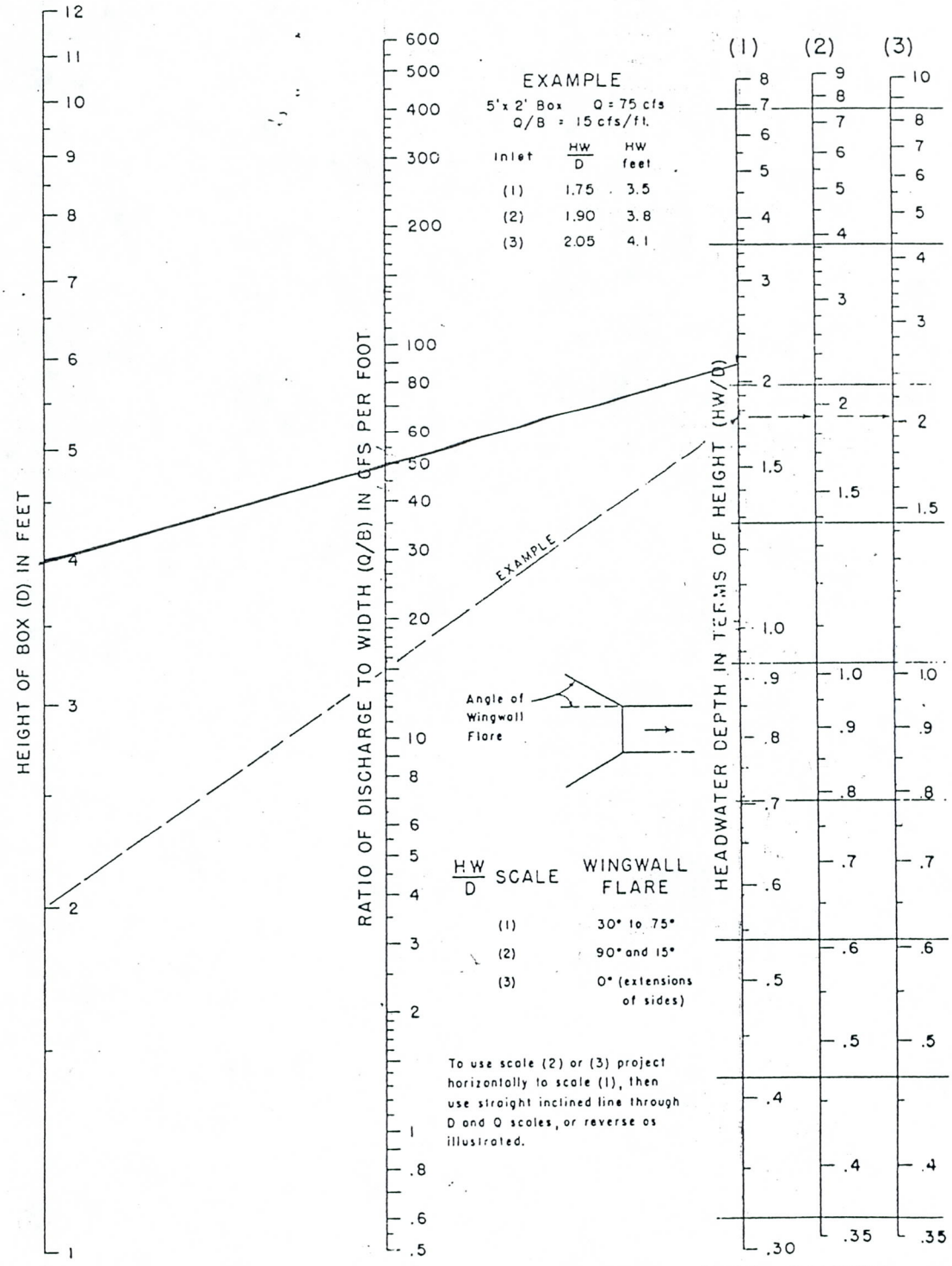
MEAN STREAM VELOCITY = 6.5 ft/s

CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
1 Barrel 10'x4' RCBC	Wingwall	500		2.18	8.72	.2	3.70	4.00	4.00	2.34	4.00	.162	7.08	8.72	14.21		1645.22	Inlet Control

SUMMARY & RECOMMENDATIONS *Used 2.34' - depth of flow in existing downstream channel.

5/14

CHART 1 67 I-2



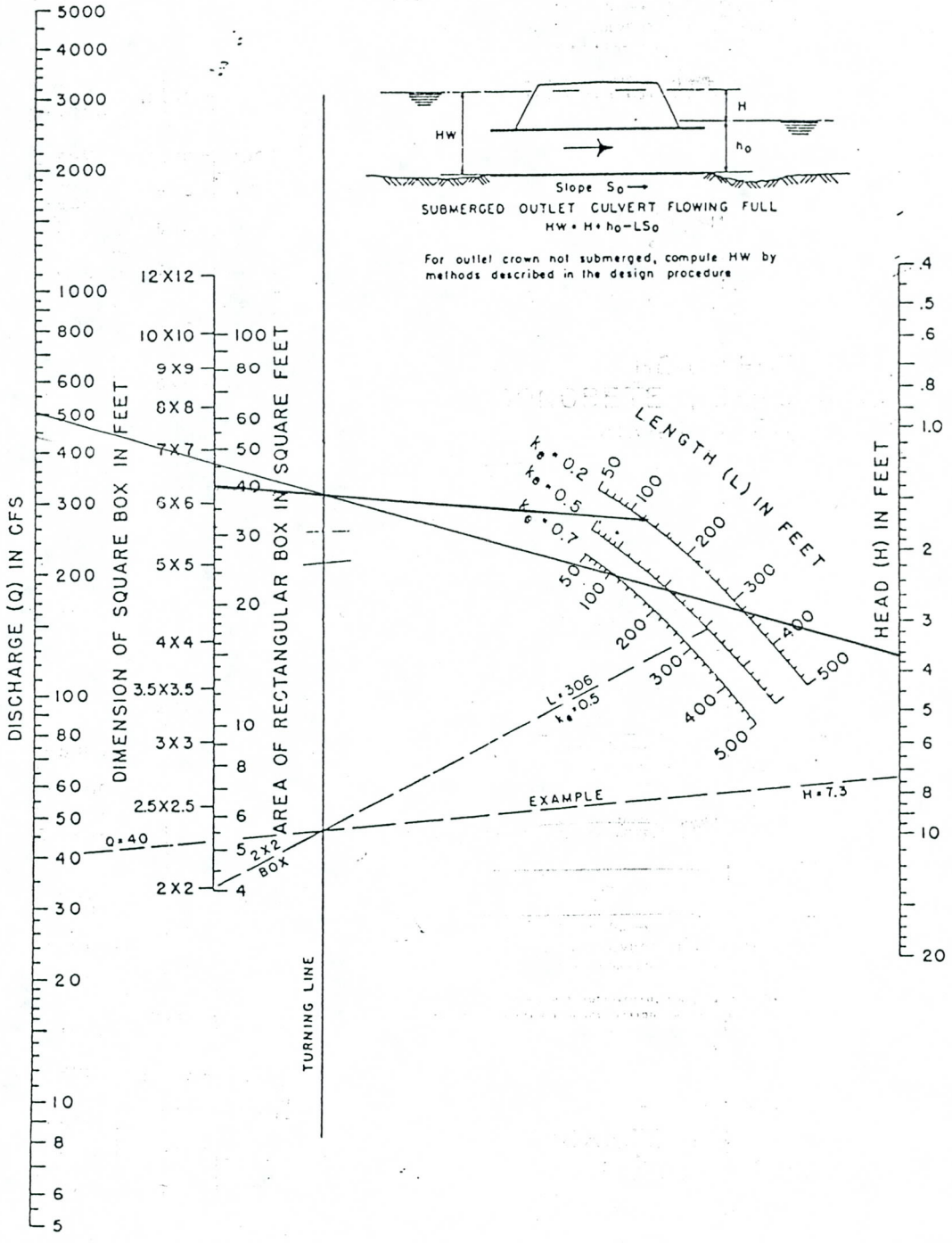
HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

7/19

67 I-2

CHART 8



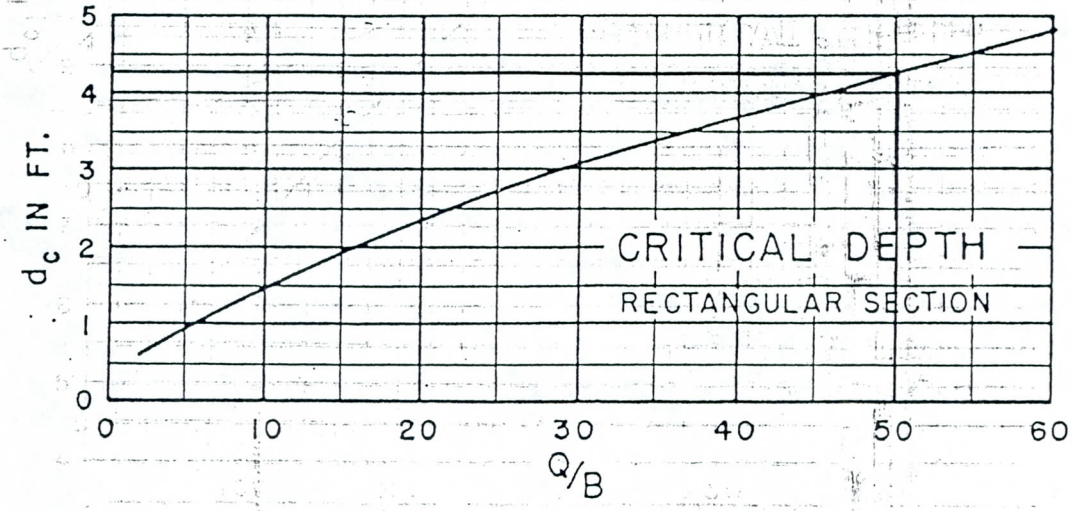
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

8/19

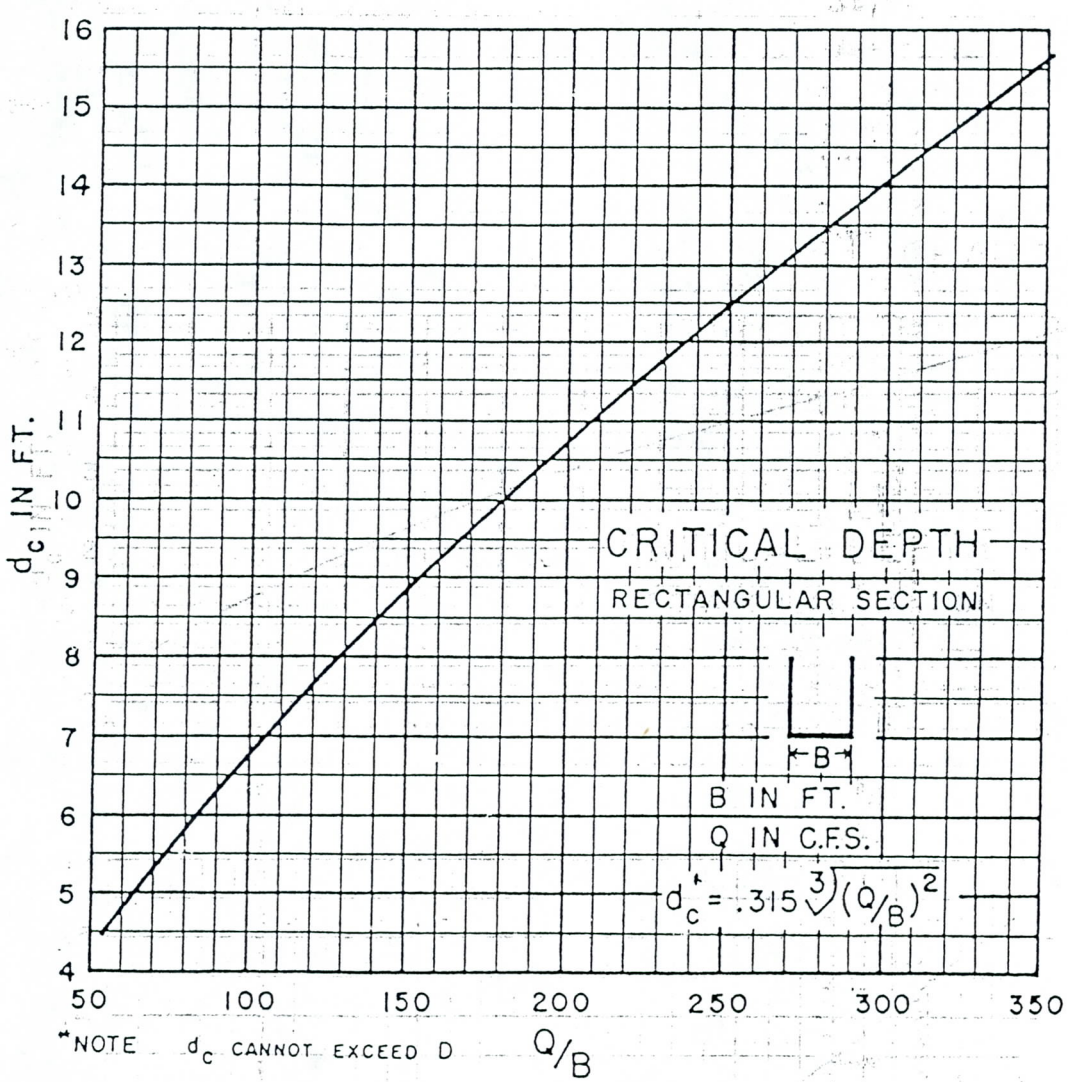
67 I-2

CHART 15



$d_c \geq D$

$\therefore d_c = D = 4.00'$



*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN. 1963

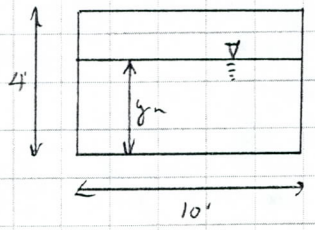
Check Depth of Flow Using Mannings Formula:

Culvert 67 I-1

$Q_{100} = 500$ cfs

$n = .012$

$S = .005$



For Q_{100}

$y_n = 3.52'$

$V = 14.21$ ft/s (from Mannings)

Culvert 67 I-2

$Q_{100} = 500$ cfs

$n = .012$

$S = .005$

Check Froude No:

For Q_{100}:

$y_n = 3.52'$

$V = 14.21$ ft/s

For Q_{100}

$N_F = \frac{14.21}{\sqrt{32.2(3.52)}}$

$= 1.33$ supercritical

So:

For Q_{100}, culvert is in outlet control. $d_c < TW > D$

$\therefore$ V based on full flow

$V = \frac{500}{10(4)} = 12.50$ ft/s

Analyze proposed channel between Culverts 67 I-1 and 67 I-2, running at constant slope between ends of aprons. Soil cement channel, 20' wide, w/ 4:1 side slopes.

$n = .02$ $\quad S = \frac{1639.41 - .005(15) - (1636.5 + .005(11))}{402.5/\cos 20° - 60 - 15 - 84 - 11} = \frac{2.78}{258.3} = .0108$

From Mannings, using a 20' channel bottom width:

$y_n = 1.85'$ $V = 9.85\ ft/s$ $T = 34.80'$ $A = 50.79\ ft^2$

$N_F = \frac{9.85'}{\sqrt{32.2(A/T)}} = 1.44$ since $N_F \geq 1.86$ and $y_n < 3'$,

Freeboard $= \frac{1}{6}\left(y_n + \frac{V^2}{29}\right) = \frac{1}{6}\left(1.85' + \frac{9.85^2}{2(32.2)}\right) = .56$

$1.85' + .56' = 2.41'$ Use depth = 2.5'

Examine Outlet Conditions of Culvert 67 I-2:

Using a 24' bottom width channel, slope of .005, 4:1 side slopes $n = .02$, $Q_{100} = 500$ cfs, mannings formula yields:

$y_n = 2.10'$, $V = 7.34\ ft/s$, $A = 68.18\ ft^2$, $T = 40.83'$

$N_F = \frac{7.34}{\sqrt{32.2(A/T)}} = 1.00$ Critical Flow

Widen channel bottom to 30' to spread flow and match existing channel.

From mannings: $y_n = 1.89'$ $V = 7.06\ ft/s$, $A = 70.85\ ft^2$ $T = 45.12'$

$N_F = \frac{7.06}{\sqrt{32.2(A/T)}} = .99$ near critical Flow

Depth of Channel:

Freeboard $= \frac{1}{6}\left(y_n + \frac{V^2}{29}\right) = \frac{1}{6}\left(1.89 + \frac{(7.06)^2}{2(32.2)}\right) = .44'$

Channel depth $= 1.89' + .44 = 2.33'$

use $\Rightarrow$ 2.5' depth of channel

Velocity at end of channel = 7.06 ft/s, which approaches existing channel velocity of 6.5 ft/s.

Cutoff Wall:

Per HEC No. 14, Hydraulic Design of Energy Dissipators for Culverts and Channels by FHWA, and Drainage and Design Standards for Floodplain Management within Pima Co. Arizona by Pima Co. D.O.T. and FCD:

the downstream depth of scour is:

$$h_s = \alpha y_e^{\beta} (Q/y_e^{2.5})^{\theta} t^{\theta}$$

For TW > .50 (From Table V-1, HEC No. 14)

$\alpha = .76$ $\beta = .375$ $\theta = 0.10$ and $\gamma = 1.0$

$$\therefore h_s = .76\, y_e (Q/y_e^{2.5})^{.375} t^{0.1}$$

$Q = VA$ and $A = 2y_e^2$ $\therefore$ $h_s = .76 y_e \left(\frac{V(2)(y_e)^2}{y_e^{2.5}}\right)^{.375} t^{0.1}$

Where V = average velocity (ft/s) y_e = max depth (ft)
t = time duration (min)

For the 30' channel, 7.06 ft/s, $y_e = 1.89'$ $t = 35$ min

$$h_s = .76(1.89)\left(\frac{7.06(2)(1.89)^2}{1.89^{2.5}}\right)^{.375} t^{0.1}$$

$= 4.91'$ use 5'

Riprap Channel:

Place a 30 wide riprap channel w/ 4:1 side slopes, slope = 0.5%, $n = .032$

$y_n = 2.45'$ $A = 97.67\ ft^2$ $V = 5.12$ ft/s $T = 49.60'$

Velocity is lower than natural stream velocity. No erosion problem.

SVERDRUP

JOB 40477 Toyota

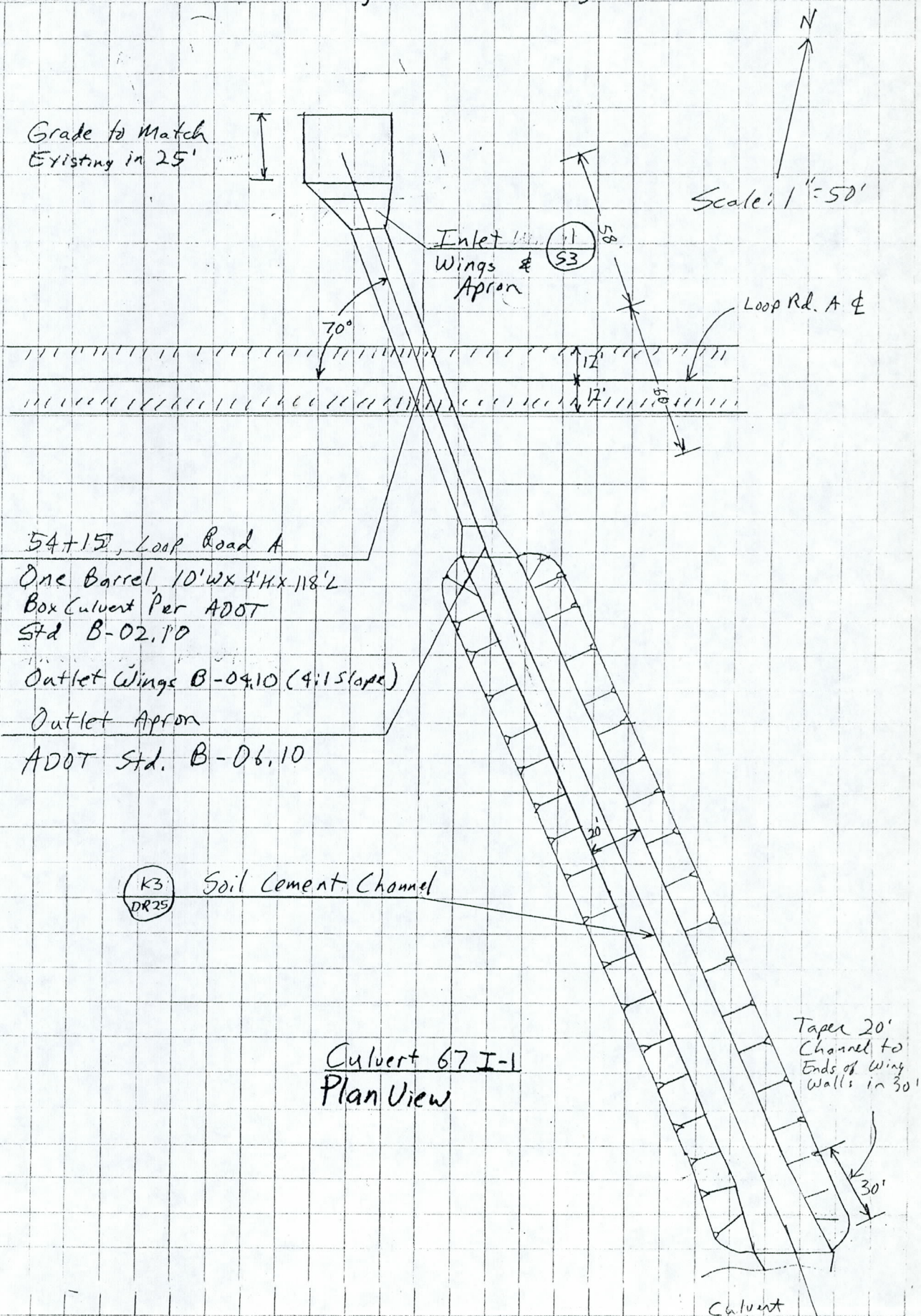
SHEET NO. 12 OF 19

DATE 6-27-91

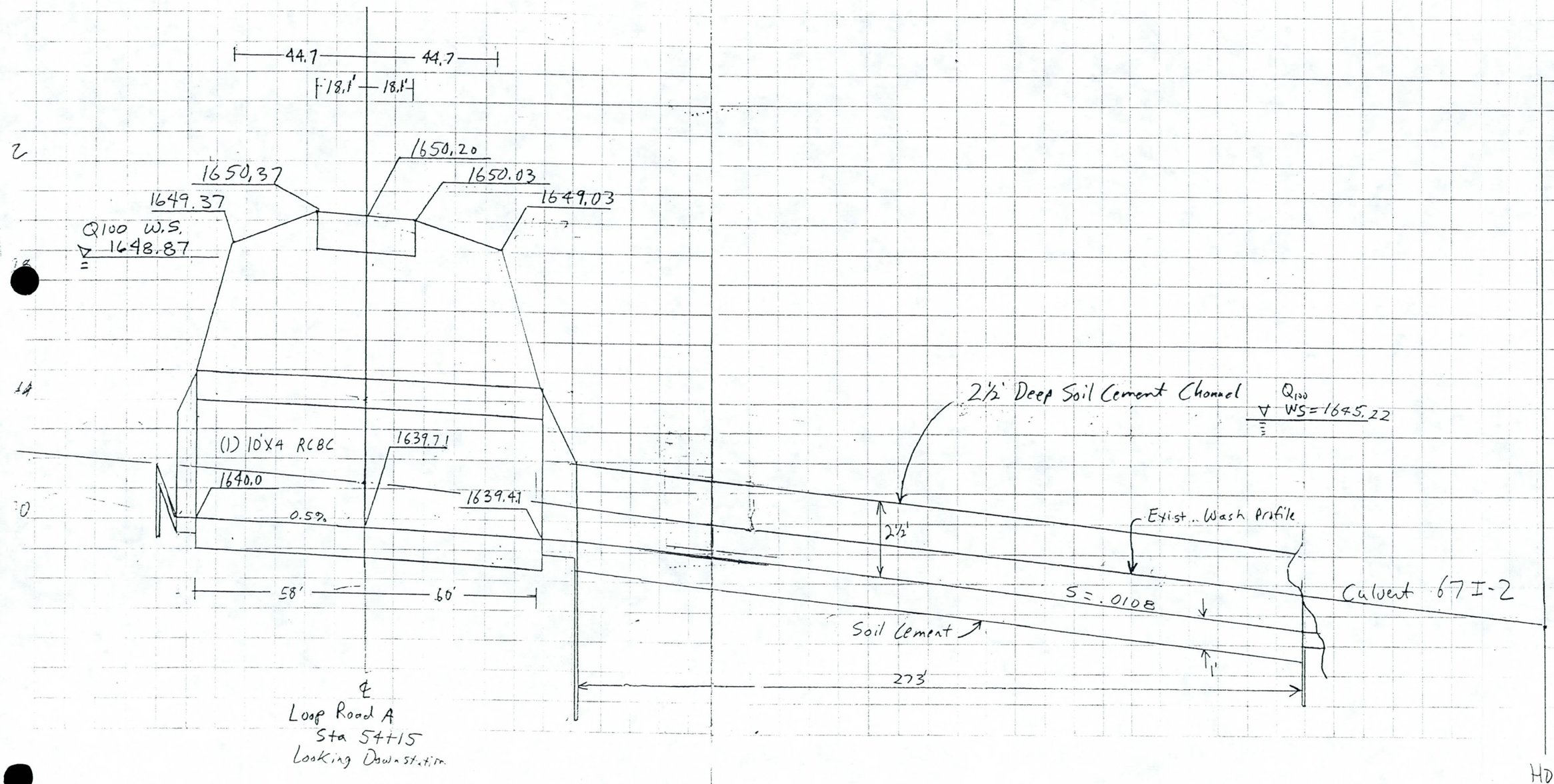
COMPUTATIONS FOR Culvert 67 I-1 [21]

BY DFP CHKD RJT

Plan View, Sta. 54+15, Loop Rd A



Culvert 67 I-1
Plan View


44.7
44.7
18.1'
18.1'
1650.20
1650.37
1650.03
1649.37
1649.03
Q100 W.S.
1648.87
(1) 10'X4 RCBC
1639.71
1640.0
1639.41
0.5%
58'
60'
℄
Loop Road A
Sta 54+15
Looking Downstation
2½' Deep Soil Cement Channel
Q100
WS=1645.22
Exist. Wash Profile
2½'
S=.0108
Soil Cement
1'
273'
Culvert 67I-2
HDP

SVERDRUP

JOB 4077.77 Toyota

COMPUTATIONS FOR Culvert Profile 67 I-1

Loop Road A Sta. 54+15 21

BY DFP CHKD RJT

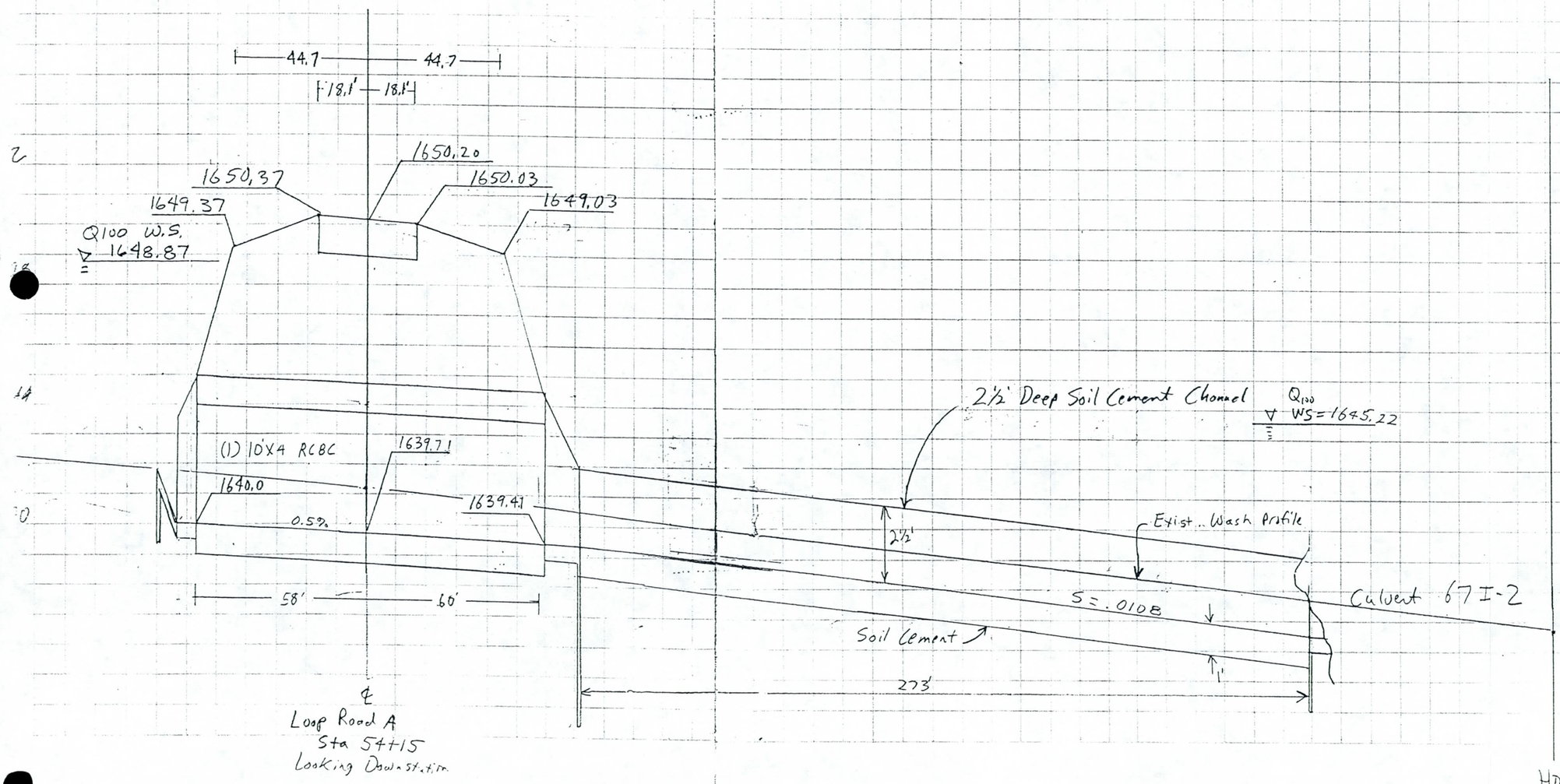
DATE 7-7-91

SHEET NO. 13 OF 19

Culvert 67 I-1 21

Q_{100} = 500 cfs

Skew = 20° LT



Scale:

Horiz: 1" = 40'

Vert: 1" = 4'

SVERDRUP

JOB 40477 Toyota

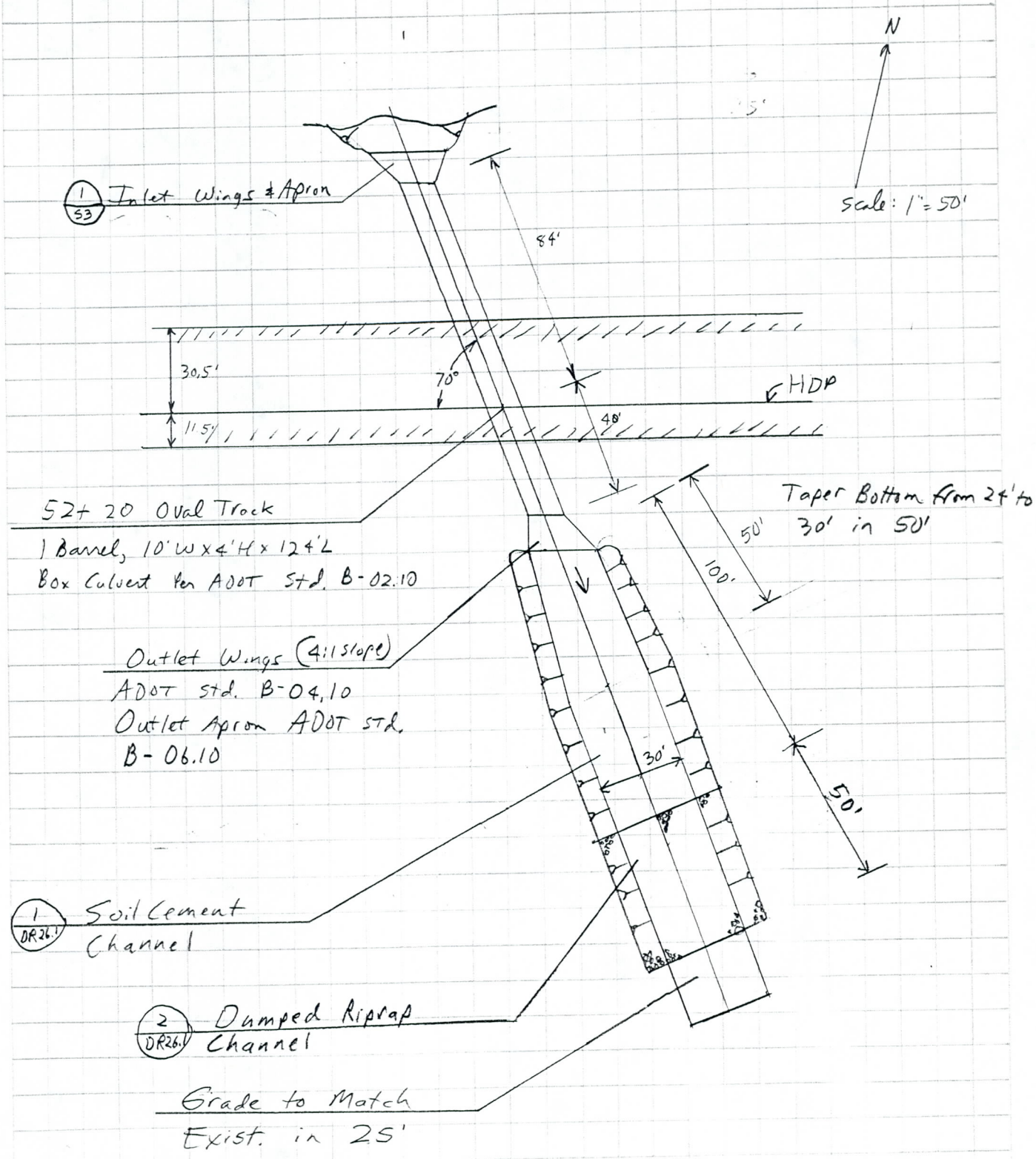
SHEET NO. 14 OF 19

DATE 7-1-91

COMPUTATIONS FOR Culvert 67 I-2 22

BY DFP CHKD RJT

Plan View, HDP Sta 52+20



SVERDRUP

JOB 40477 Toyota SHEET NO. 15 OF 19

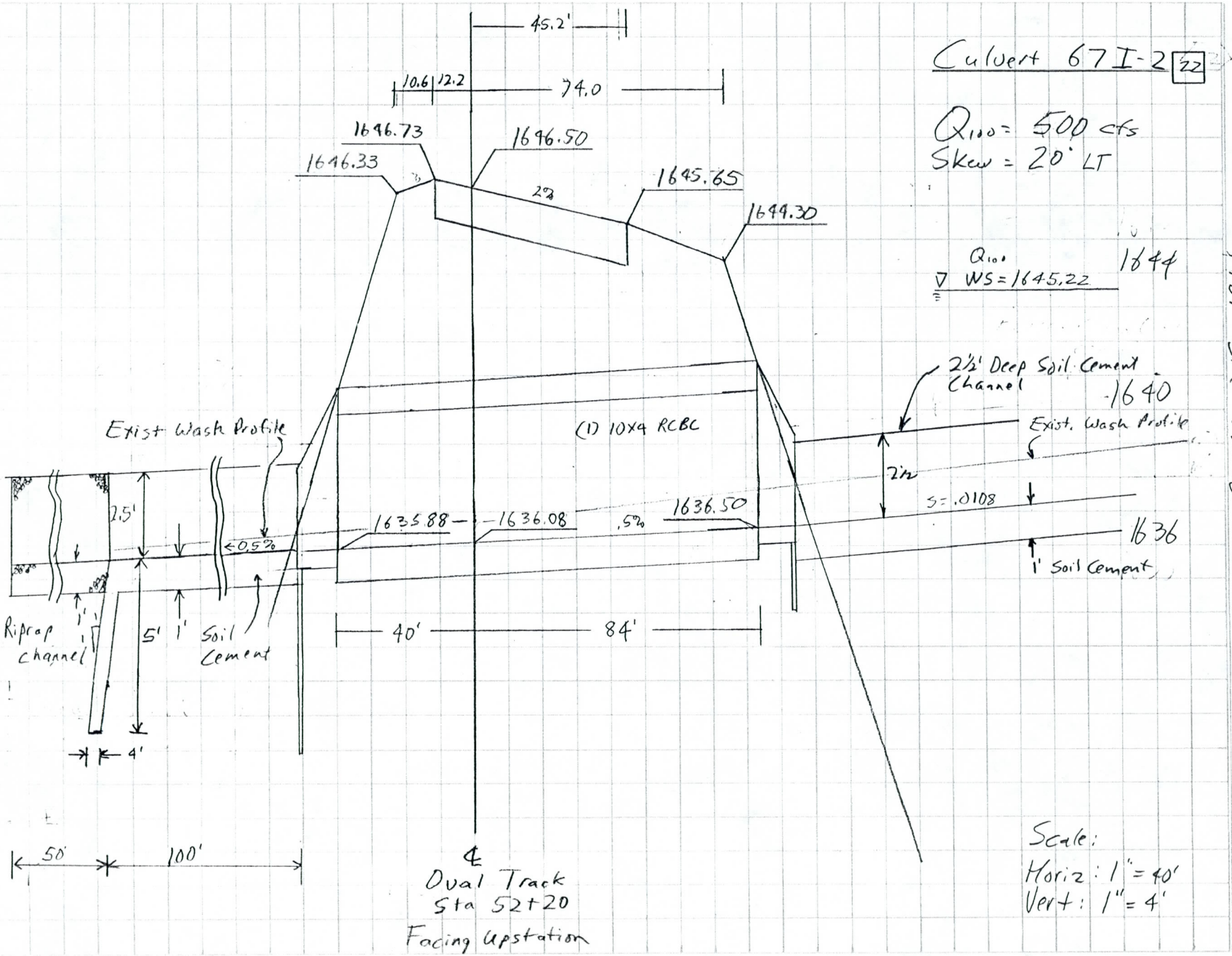
COMPUTATIONS FOR Culvert Profile 67 I-2 22 DATE 6-30-94

HDP Sta 52+20 BY DFA CHKD RJT

Culvert 67 I-2 22

Q_{100} = 500 cfs

Skew = 20° LT



Scale:

Horiz: 1" = 40'

Vert: 1" = 4'

SECTION NUMBER TW67I 6/11/91

Channel Slope: 0.0065 ft./ft.

CROSS SECTION DATA:

OFFSET	-170	-25	65	91	127.1	132.1	135.9	140.1	145.6	183.7	190	193.4	273.9	420	480
ELEV.	40.64	40.6	40	39.58	39.37	38.17	39.16	39.56	36.8	35.58	35.39	39.4	39.47	39.8	40
N	N/A	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.04	0.025	0.025	0.04	0.035	0.035	0.035

STAGE-DISCHARGE DATA:

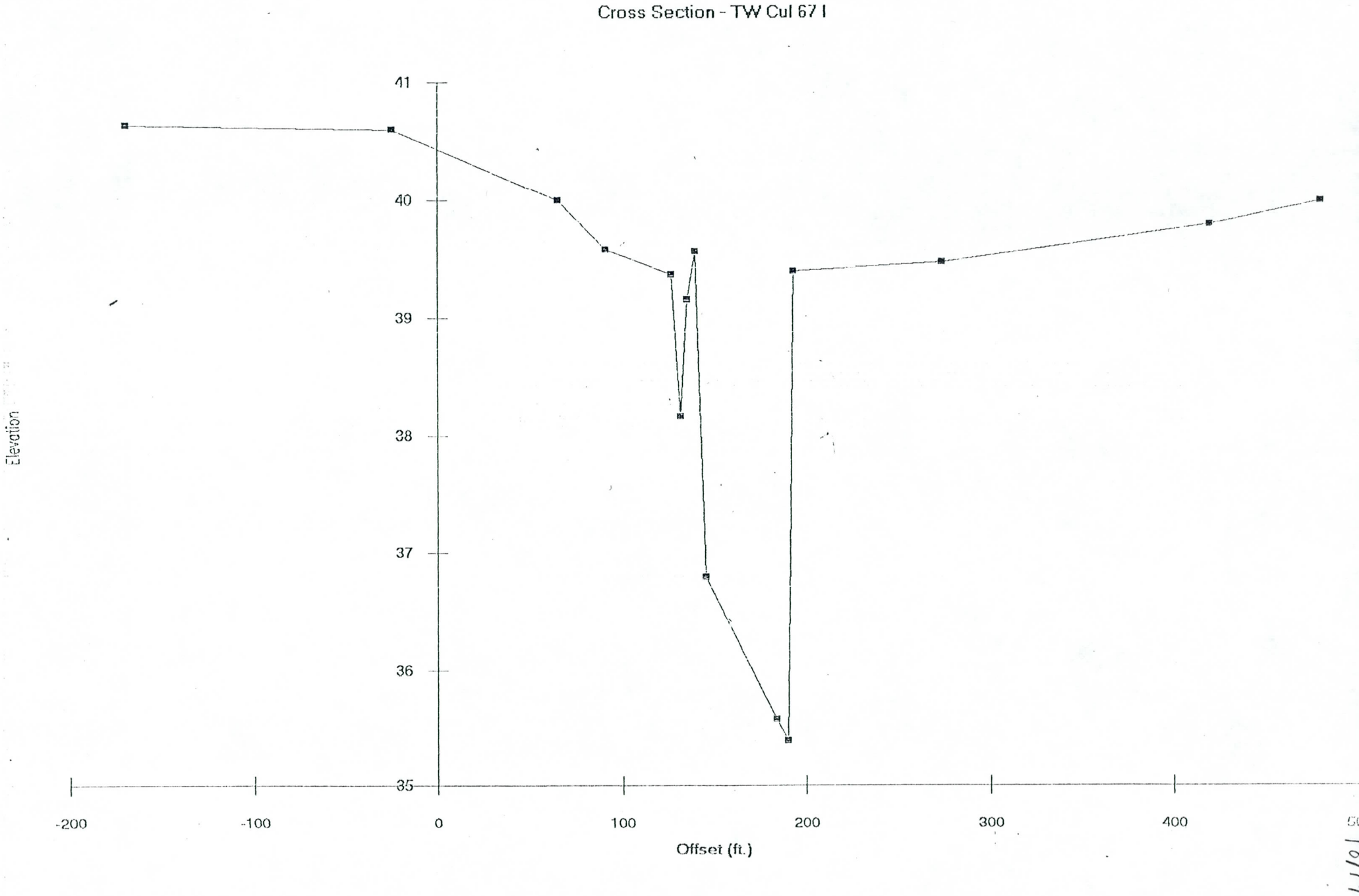
STAGE:	35.4														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAGE:	35.65														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	8.5	0.3	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.1	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	1	0	0	0	0
STAGE:	35.9														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	16.3	0.7	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	4.2	0.1	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.3	0.2	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	8	0	0	0	0
STAGE:	36.15														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8	24.1	1.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	9.3	0.2	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.2	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	23	0	0	0	0
STAGE:	36.4														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.6	31.9	1.3	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5	16.3	0.4	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.3	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	50	1	0	0	0
STAGE:	36.65														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.4	39.7	1.7	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.9	25.2	0.7	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.6	0.4	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	89	1	0	0	0

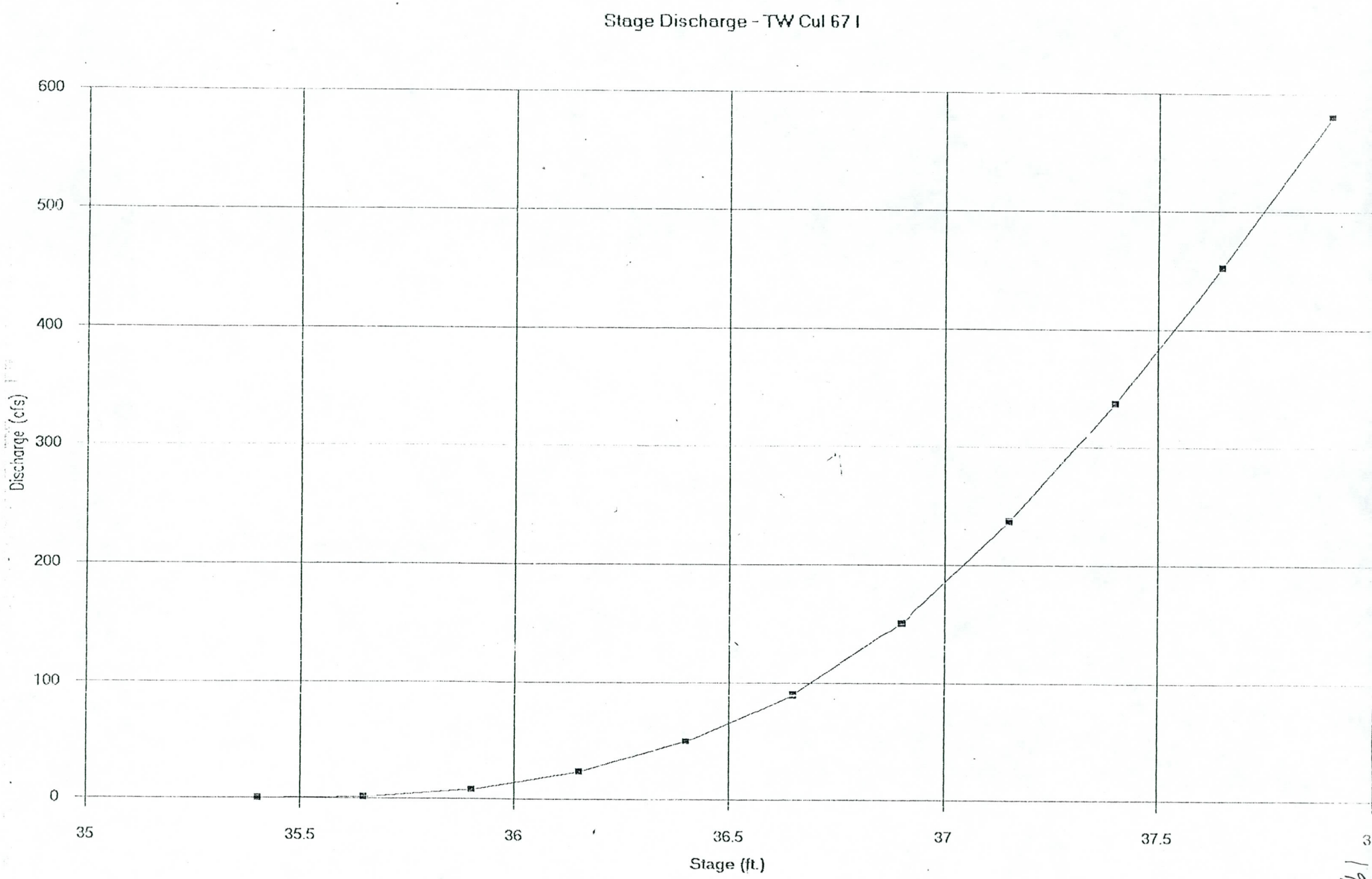
6/11/91

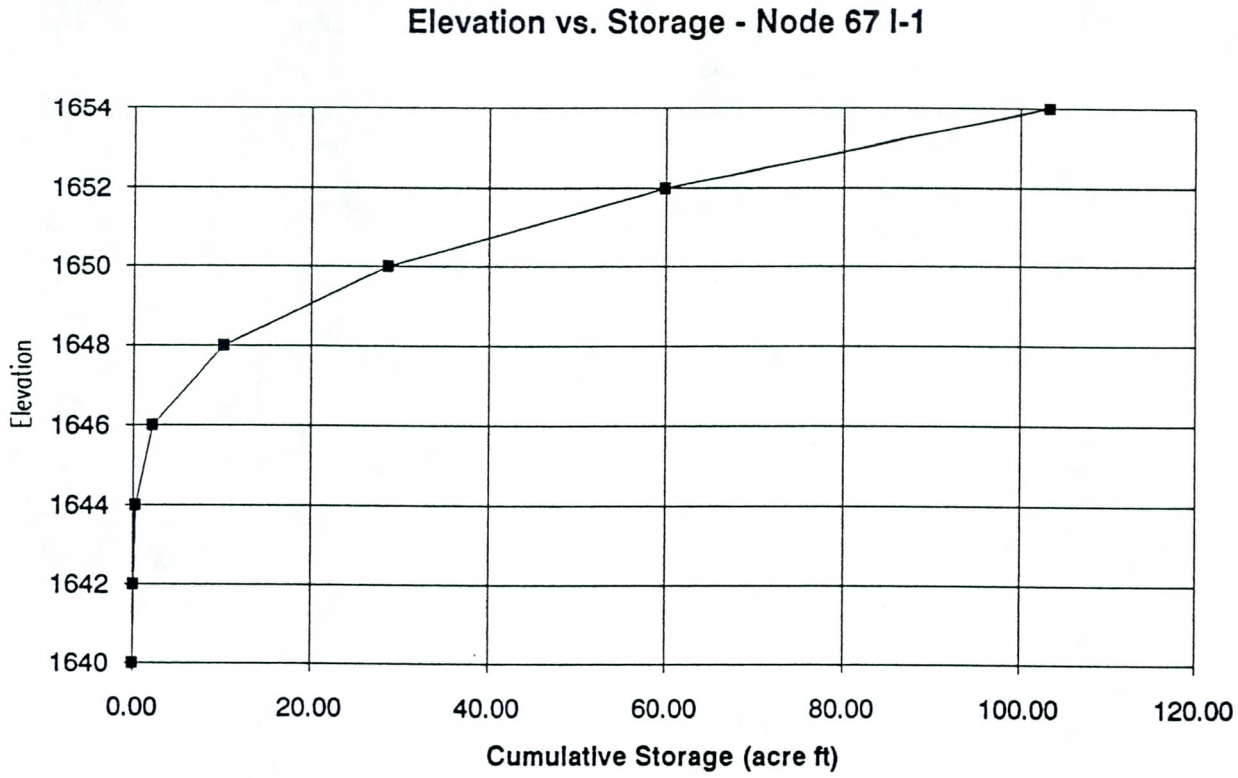
SECTION NUMBER TW67I 6/11/91

STAGE:	36.9													
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	38.1	44.4	2.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.1	36.0	1.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.8	0.5	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	150	2	0	0	0
STAGE:	37.15														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	38.1	44.4	2.3	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	36.6	47.1	1.3	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.0	1.1	0.6	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	234	3	0	0	0
STAGE:	37.4														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	38.1	44.4	2.6	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	46.1	58.2	1.7	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.2	1.3	0.6	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	0	0	333	4	0	0	0
STAGE:	37.65														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	38.1	44.4	3.0	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	55.6	69.3	2.2	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.5	1.6	0.7	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	1	0	446	5	0	0	0
STAGE:	37.9														
WET PER.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	38.1	44.4	3.3	0.0	0.0	0.0
AREA		0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	65.2	80.4	2.7	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.7	1.8	0.8	0.0	0.0	0.0
Q		0	0	0	0	0	0	0	2	0	571	7	0	0	0

W.S. Elev.	35.4	35.65	35.9	36.15	36.4	36.65	36.9	37.15	37.4	37.65	37.9
Q	0	1	8	24	50	90	151	237	338	452	581
A	0.0	1.1	4.3	9.5	16.7	25.9	36.9	48.5	60.2	72.2	84.2
V	0.1	1.2	1.9	2.5	3.0	3.5	4.1	4.9	5.6	6.3	6.9


Cross Section - TW Cul 67 I
41
40
39
38
37
36
35
Elevation
-200
-100
0
100
200
300
400
Offset (ft.)


Stage Discharge - TW Cul 67 I
600
500
400
300
200
100
0
Discharge (cfs)
35
35.5
36
36.5
37
37.5
Stage (ft.)


Elevation vs. Storage - Node 67 I-1
1654
1652
1650
1648
1646
1644
1642
1640
Elevation
0.00
20.00
40.00
60.00
80.00
100.00
120.00
Cumulative Storage (acre ft)

SVERDF

JOB 40477 Toyota SHEET NO. ____ OF ____

DATE 7-5-91

COMPUTATIONS FOR Proposed Culvert 67 J-1 23 BY DFP CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT: ____

STATION: 42+15, Loop Rd A

DESIGNER: ____

DATE: ____

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA ____

Q_1 = 313 cfs TW_1 = 2.09' *

Q_2 = ____ TW_2 = ____

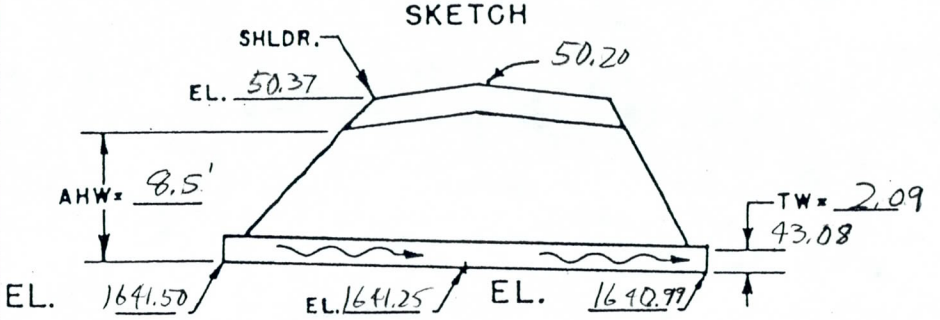
* Based upon DHWE of 1643.08 from Culvert 67 J-2

Peak Outlet Discharge Q_{100}

(Q_1 = DESIGN DISCHARGE, SAY Q_{25})

(Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_0 = .005 L = 102 L/100 S_0 = ____

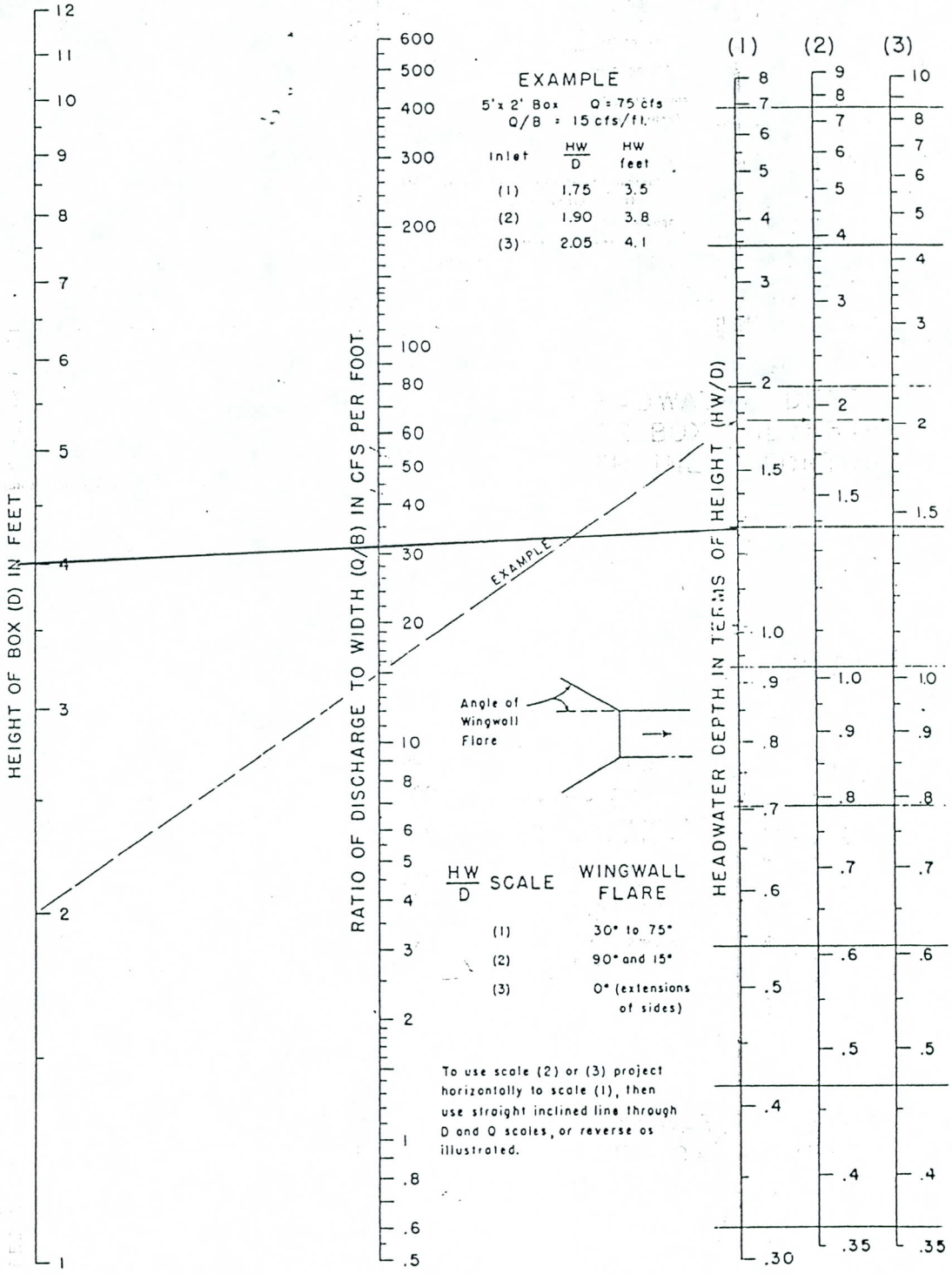
MEAN STREAM VELOCITY = 2.2 ft/s

CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			$\frac{HW}{D}$	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
1 Barrel 10'x4'	wing walls	313		1.27	5.08	.2	1.35	3.2	3.6	2.09	3.6	.51	4.44	5.08	12.38		1646.58	Inlet Control

SUMMARY & RECOMMENDATIONS

1/22

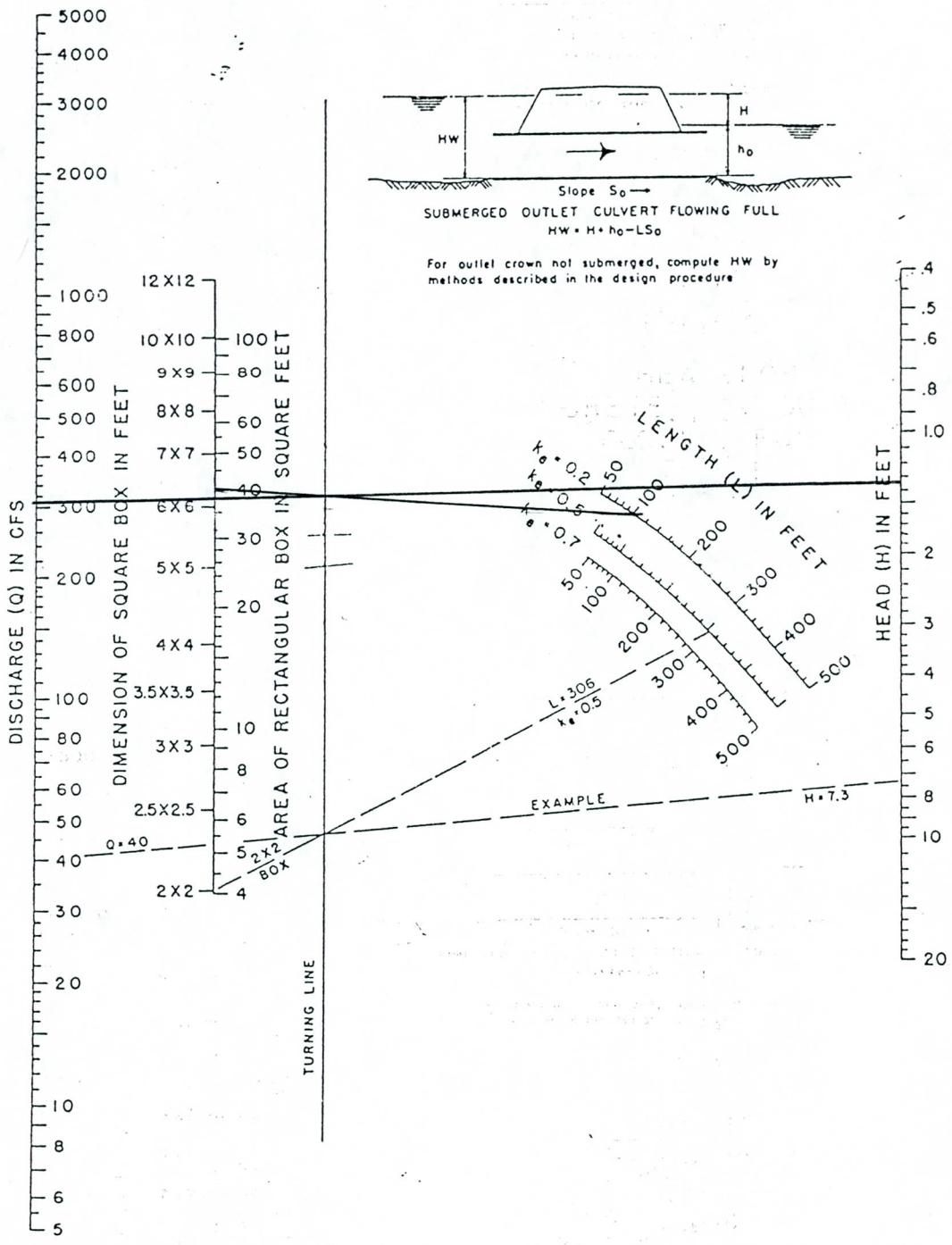
CHART I



HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

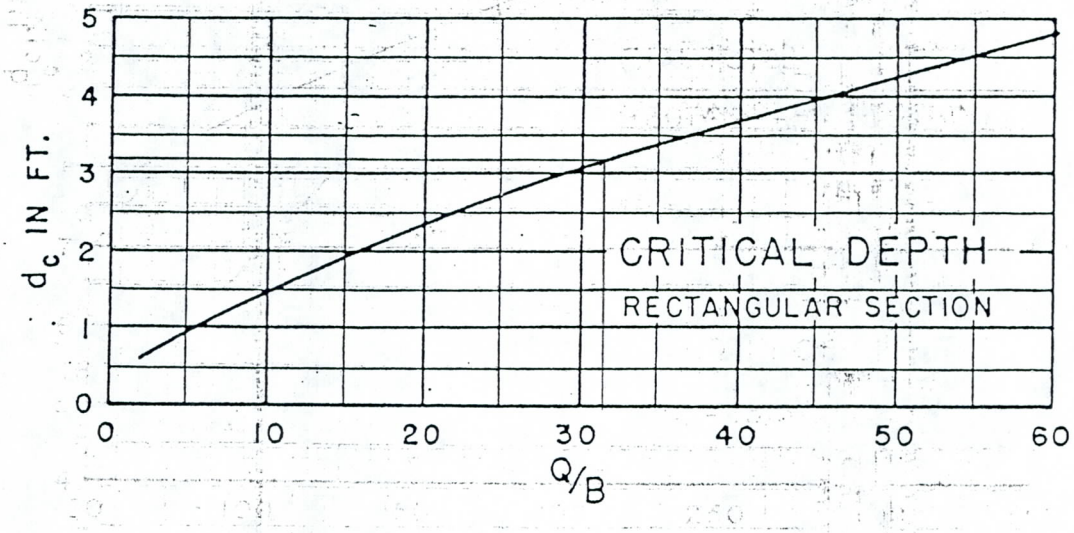
CHART 8

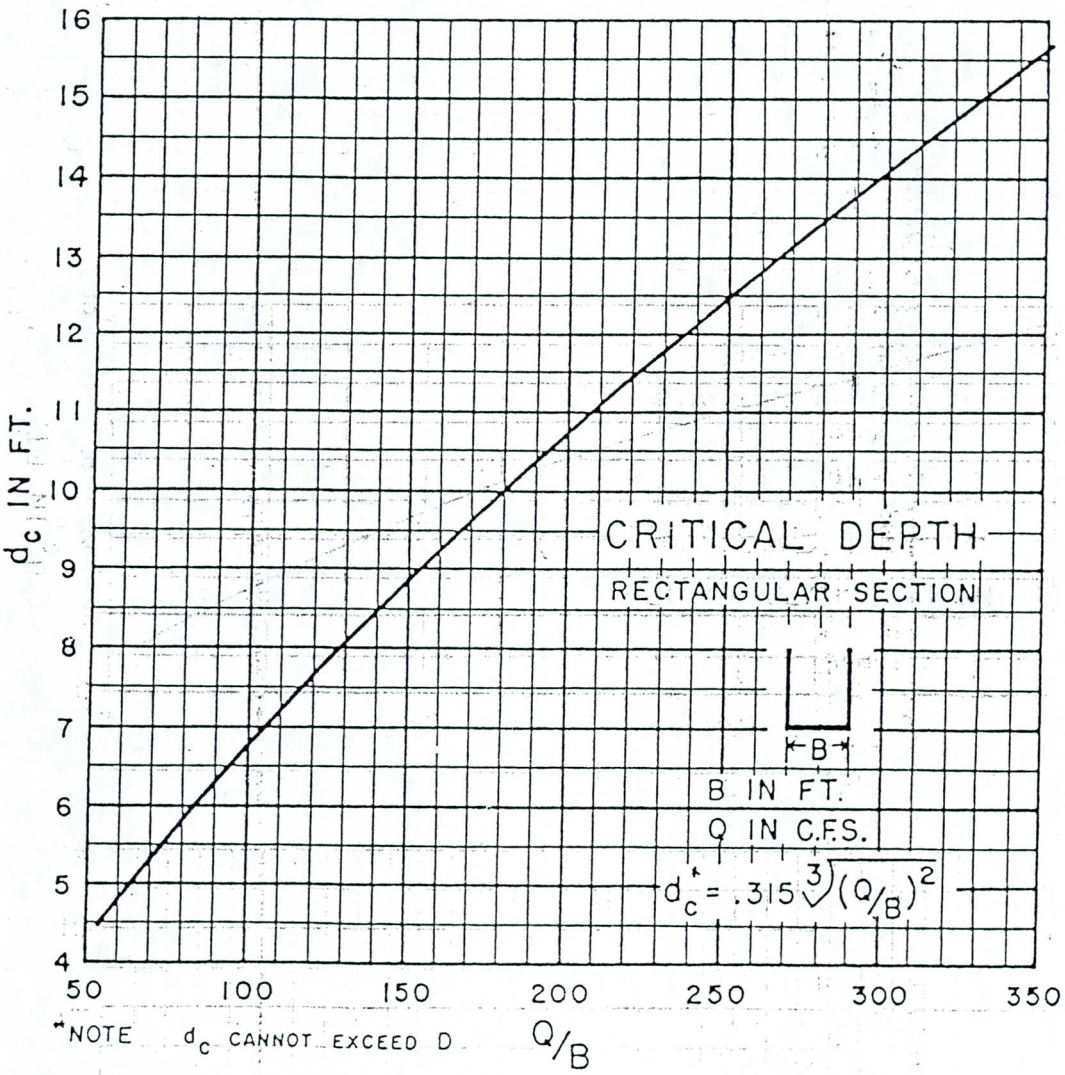


HEAD FOR CONCRETE BOX CULVERTS FLOWING FULL n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

CHART 15





BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 10477 Toyota SHEET NO. ____ OF ____

DATE 7-5-91

COMPUTATIONS FOR Proposed Culvert 67 J-2 [24] BY OFP CHKD RJT

CULVERT COMPUTATION SHEET

PROJECT: ____ DESIGNER: ____

STATION: 42+75, Dual Track DATE: ____

HYDROLOGIC AND CHANNEL INFORMATION

DRAINAGE AREA ____

Q_1 = 313 cfs TW_1 = 2.7*

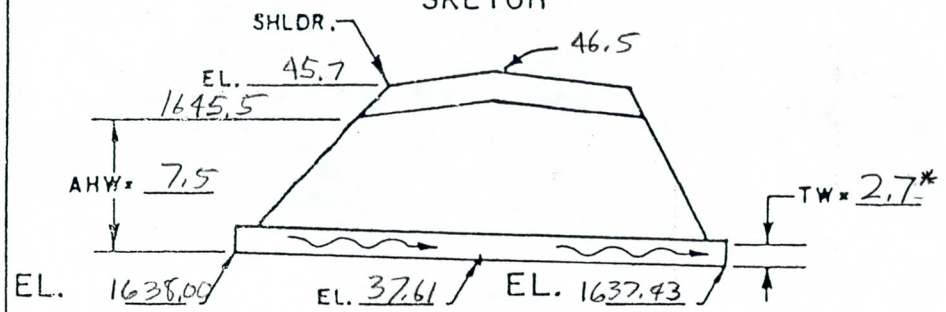
Q_2 = ____ TW_2 = ____

Peak Outlet Discharge Q_{100}

(Q_1 = DESIGN DISCHARGE, SAY ~~Q_{25}~~

Q_2 = CHECK DISCHARGE, SAY Q_{50})

SKETCH



S_o = .005 L = 115 L/100 S_o = ____

MEAN STREAM VELOCITY = 2.2 ft/s

CULVERT DESCRIPTION		Q	CAP. CHART HW	HEADWATER COMPUTATION										CONTROL HW	OUTLET VELOCITY	COST	DHW ELEV.	COMMENTS
				INLET CONT.		OUTLET CONTROL $HW = H + h_o - LS_o$												
SIZE	ENTR. TYPE			HW/D	HW	K_e	H	d_c	$\frac{d_c + D}{2}$	TW	h_o	LS_o	HW					
1 Barrel 10X4	Wingwall	313	—	1.27	5.08	.2	1.4	3.2	3.6	2.7	3.6	.58	4.42	5.08	12.38		1643.08	Inlet Control

SUMMARY & RECOMMENDATIONS * Obtained from depth of flow at existing downstream section (see p. 19/22).

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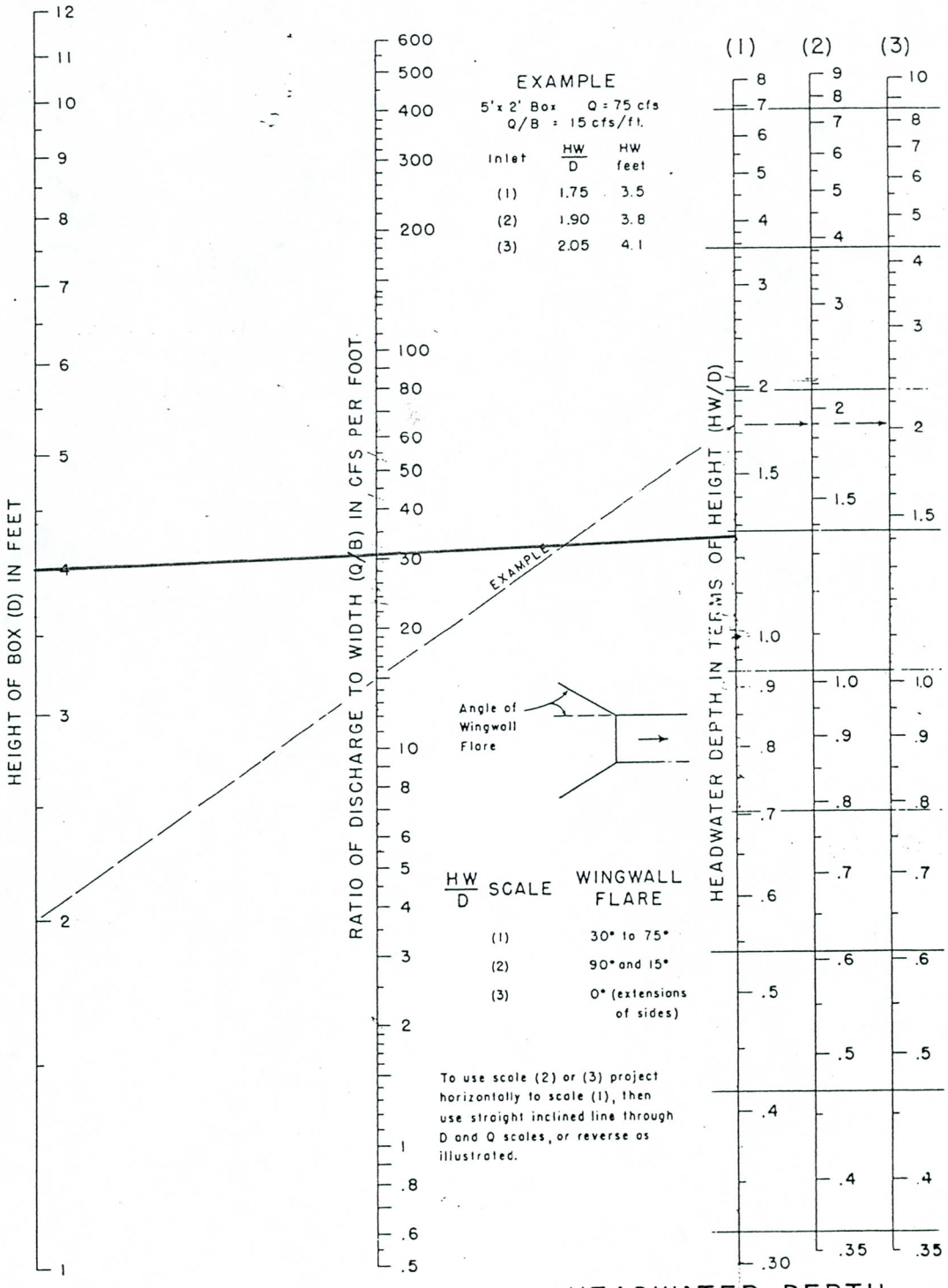
B-1

CHART I

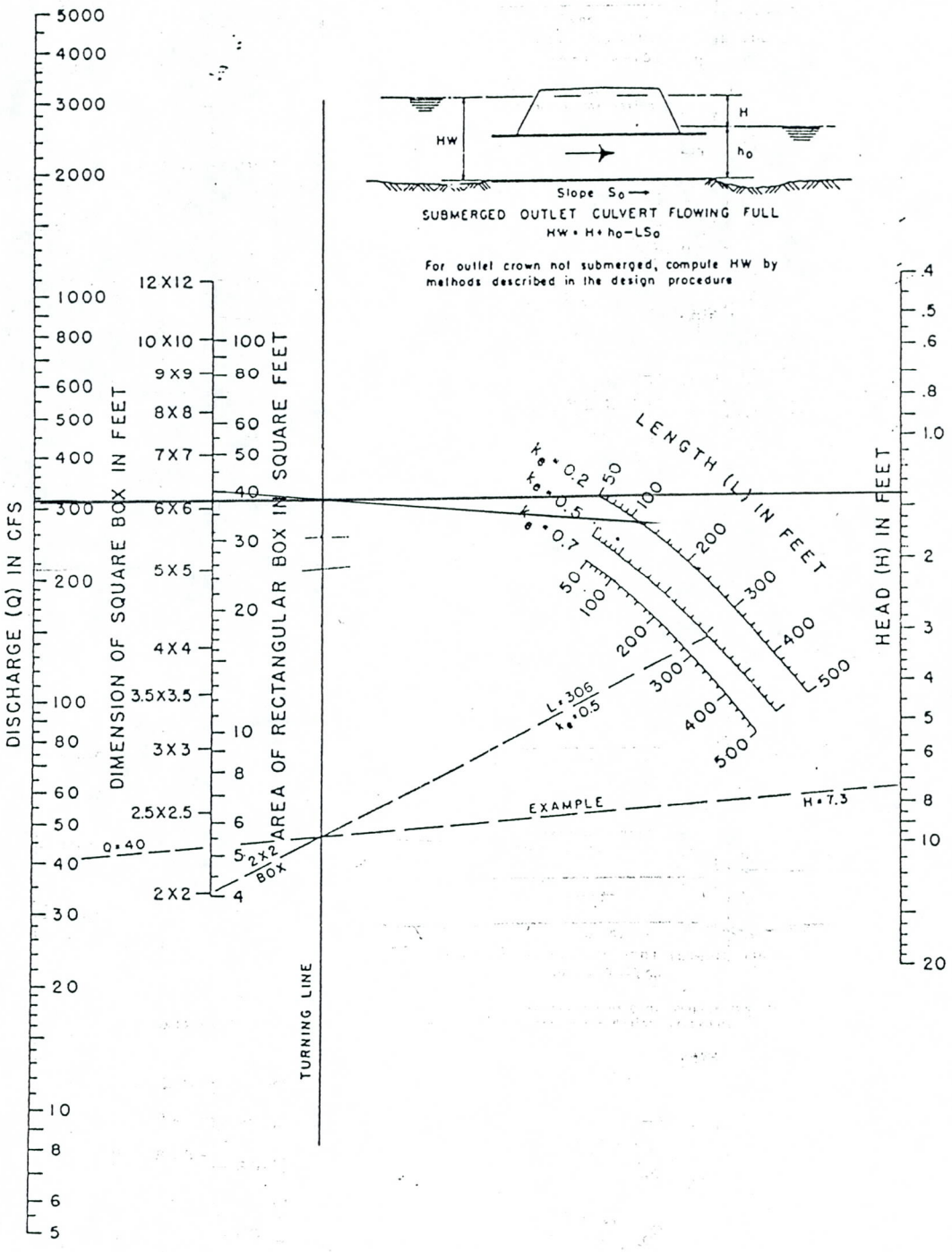


HEADWATER DEPTH FOR BOX CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

7/22

CHART 8

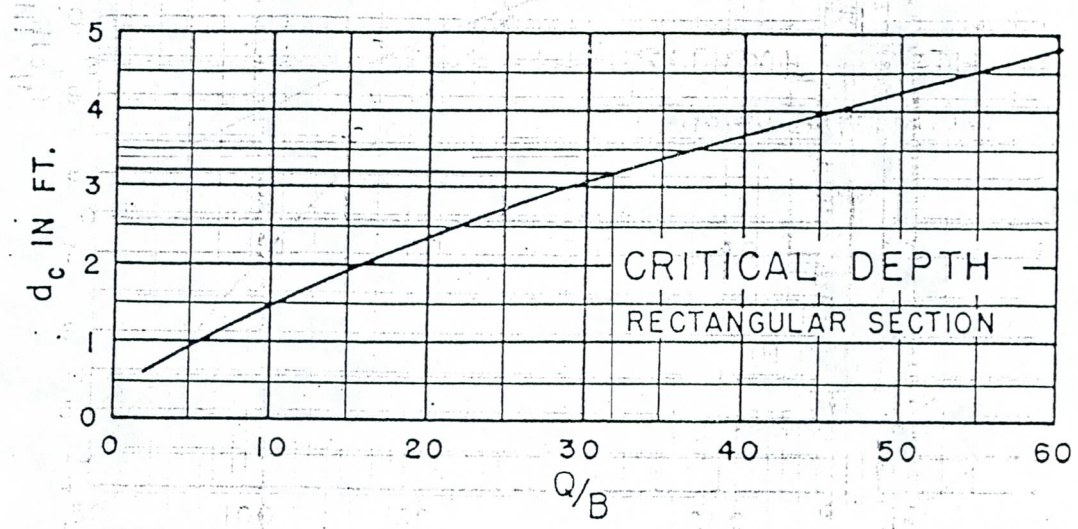


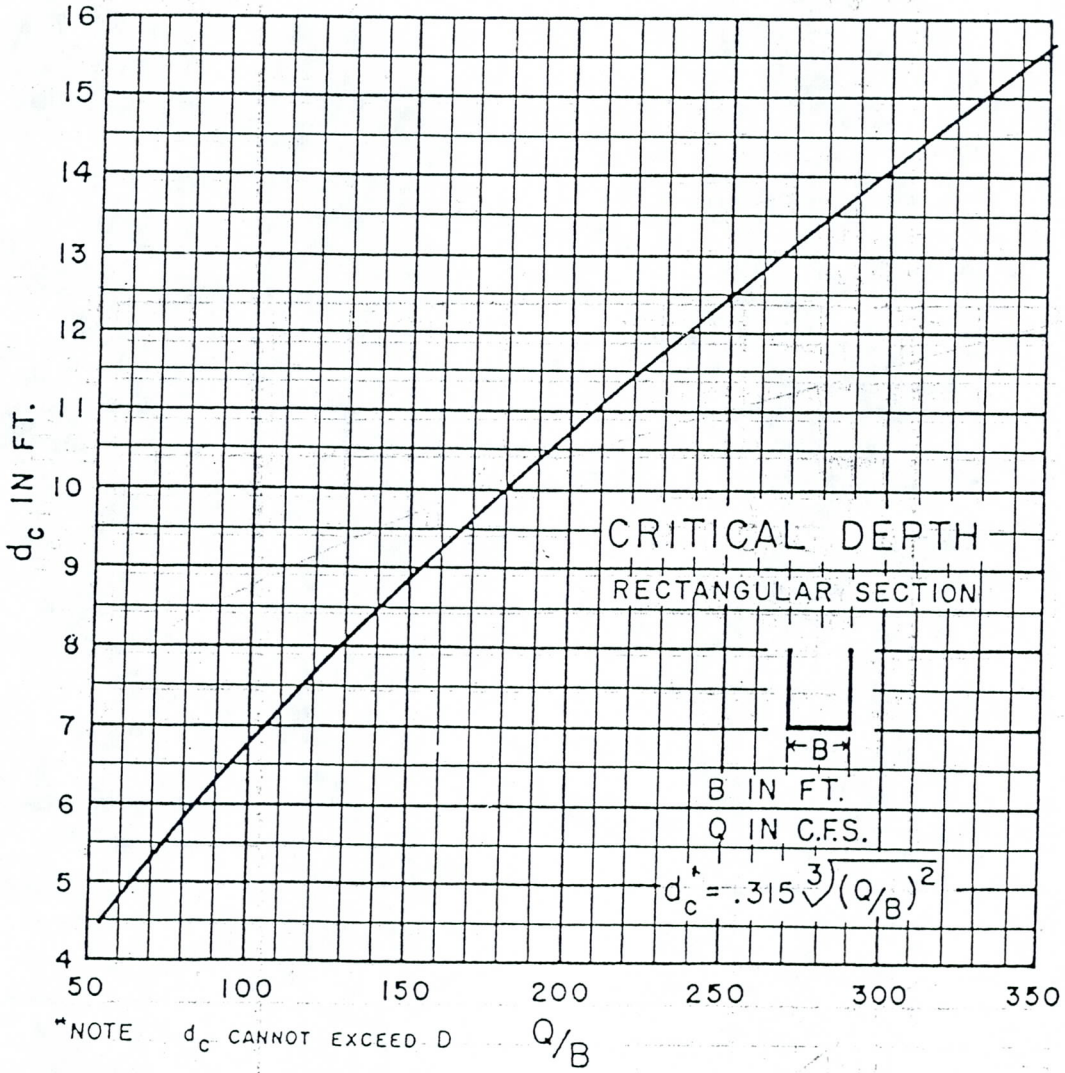
HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN. 1963

8/22

CHART 15





*NOTE d_c CANNOT EXCEED D

BUREAU OF PUBLIC ROADS JAN 1963

SVERDRUP

JOB 40477 Toyota

SHEET NO. 9 OF 22

DATE 7-5-91

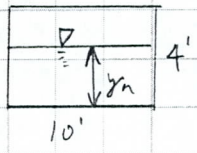
COMPUTATIONS FOR Culverts 67 J-1 & 67 J-2

BY DFP CHKD RJT

Check Depth of flow using Mannings Formula:

Culvert 67 J-1

$Q_{10} = 157$ cfs
$Q_{100} = 313$ cfs
$n = .012$
$S = .005$



$y_n = 2.53$ for Q_{100}
$V = 12.38$ ft/s

$y_n = 1.58'$ for Q_{10}
$V = 9.91$ ft/s

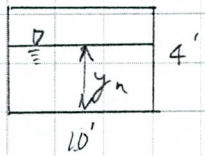
Check

$Q = VA$
$= 12.38(2.53)10$
$= 313$ OK

$= 9.91(1.58)10$
$= 157$ OK

Culvert 67 J-2

$Q_{10} = 157$ cfs
$Q_{100} = 313$ cfs
$n = .012$
$S = .005$



$y_n = 2.53'$ for Q_{100}
$V = 12.38$ ft/s

$y_n = 1.58'$ for Q_{10}
$V = 9.91$ ft/s

$Q = VA$
$= 12.38(2.53)10$
$= 313$ cfs OK

$= 9.91(1.58)10$
$= 157$ cfs OK

Froude Numbers:

Q_{10}: $N_F = \frac{9.91}{\sqrt{32.2(1.58)}} = 1.39$
Q_{100}: $N_F = \frac{12.38}{\sqrt{32.2(2.53)}} = 1.37$

Q_{100}: $N_F = \frac{12.38}{\sqrt{32.2(2.53)}} = 1.37$
Q_{10}: $N_F = \frac{9.91}{\sqrt{32.2(1.58)}} = 1.39$

All Flows for both culverts are supercritical.

Determine Slope between End of Aprons for 67 J-1 and 67 J-2:

$S = \frac{1640.99 - .005(15) - (1638 + .005(9))}{\frac{402.5}{\cos 10} - 78 - 52 - 15 - 9} = .0113$

SVERDRUP

JOB 40477 Toyota SHEET NO. 10 OF 22

DATE 7-25-91

COMPUTATIONS FOR Culverts 67J-1 and 67J-2 BY DFP CHKD RJT

Usings Mannings Formula, Analyze flow characteristics between culverts:

$Q = 313$ cfs $n = .02$ $S = .0113$ $W = 25'$; w/ side slopes of 4:1

$y_n = 1.26'$ $V = 8.27$ ft/s $A = 37.86 ft^2$ $T = 35.08$ $N_F = \frac{8.27}{\sqrt{32.2(\text{Aft})}} = 1.40$

Since $N_F < .86$ and $y_n < 3$, Freeboard $= \frac{1}{6}\left(y_n + \frac{V^2}{2g}\right) = .39$

Channel depth $= 1.26' + .39' = 1.65' \Rightarrow$ Use soil cement channel w/ minimum depth of 2'

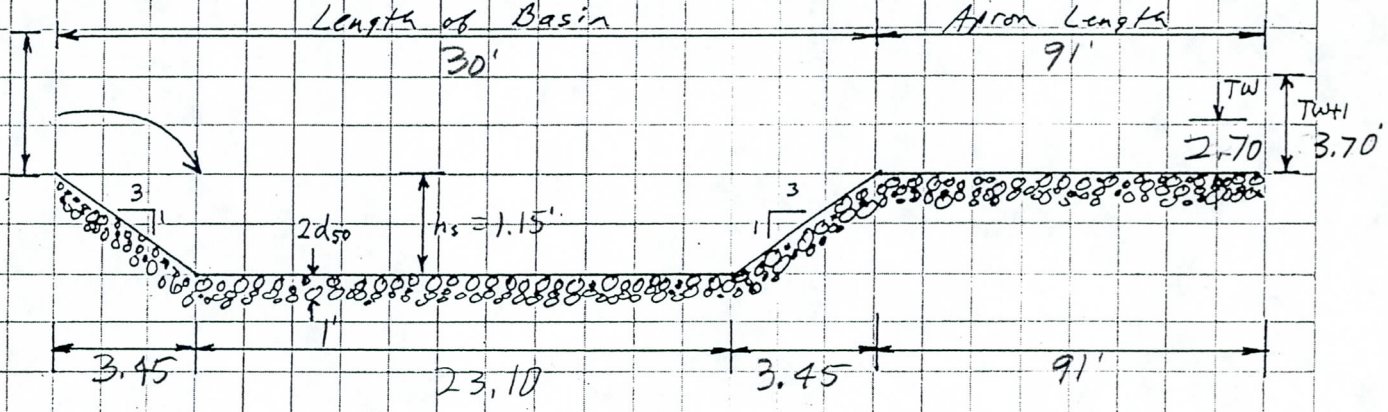
SVERDRUP

JOB 40477 Toyota SHEET NO. 11 OF 22

COMPUTATIONS FOR Box Culvert 67J-2 DATE 8/22/91

BY DFP CHKD RJT

Top of Riprap - 2.5 **Riprap Plunge Basin Design (Q_{10})**



Check Rock Size (From X1-2, HEC No. 14)

For $y_o = 1.58'$ $d_{50} = 6''$ or .5'

$d_{50}/y_o = .5/1.58 = .3165$ N_F 1.39 < 3 Plunge Basin OK

$h_s/y_o = .73$ $h_s = 1.58(.73) = 1.15'$

Check $\frac{h_s}{d_{50}} = \frac{1.15}{.5} = 2.30$ < 4 but > 2 OK

Length of Basin:

$10\,h_s = 10(1.15) = 11.5$

or

$3(W_o) = 3(10) = 30'$ Use 30'

Apron Length:

$5\,h_s = 5(1.15) = 5.75$

$W_o = 10'$

Top of Riprap:

$TW + 1 = 2.70 + 1 = 3.70$

Use 4.0'

$TW/y_o = \frac{2.7}{1.58} = 1.71$, > .75 ∴ downstream riprap req'd see Sheets 11 & 12

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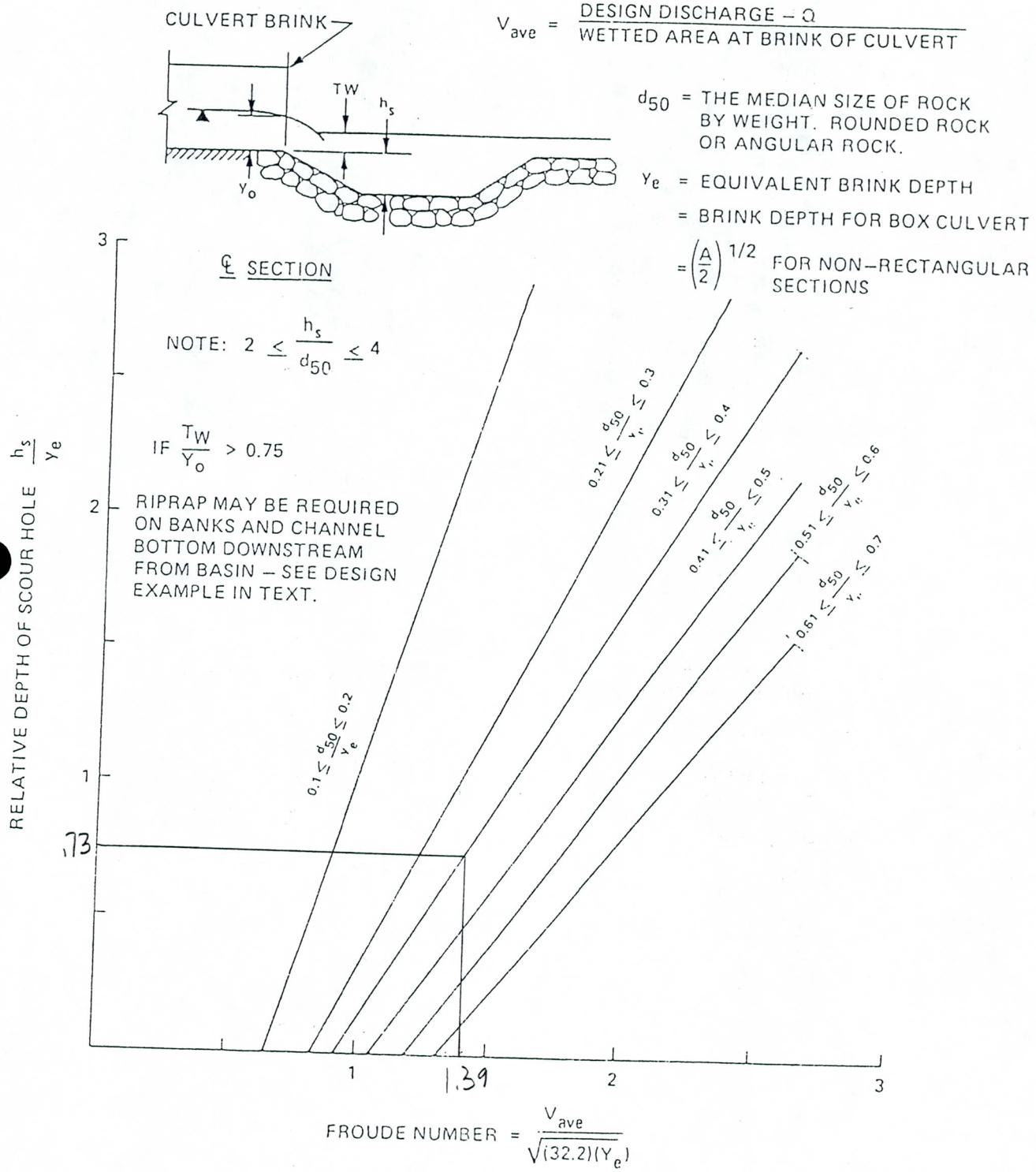


FIGURE X1–2. RELATIVE DEPTH OF SCOUR HOLE VERSUS FROUDE NUMBER AT BRINK OF CULVERT WITH RELATIVE SIZE OF RIPRAP AS A THIRD VARIABLE

SVERDRUP

JOB 40477 Toyota SHEET NO. 13 OF 22

COMPUTATIONS FOR Culvert 67L-1 DATE 7-23-91

BY DFA CHKD RJT

Utilize figure XI-3 for existing averse velocity along channel. Compute equivalent circular diameter, D_e, for brink area from:

$A = \pi D_e^2/4 = y_o (W_o) = 15.8'$ where $y_o = 1.58$ $W_o = 10'$

$D_e = \sqrt{A(4)/\pi} = \sqrt{1.27(15.8)} = 4.48'$

From Downstream cross section calculation sheets, Q_{10} velocity is 2.2 ft/s. Culvert outlet velocity = 9.91 ft/s,

L/D_e	L	V_L/V_o	V_L
27	121	.222	2.2

Use $L = 121'$

Apron Length = L - Basin Length = 121' - 30' = 91'

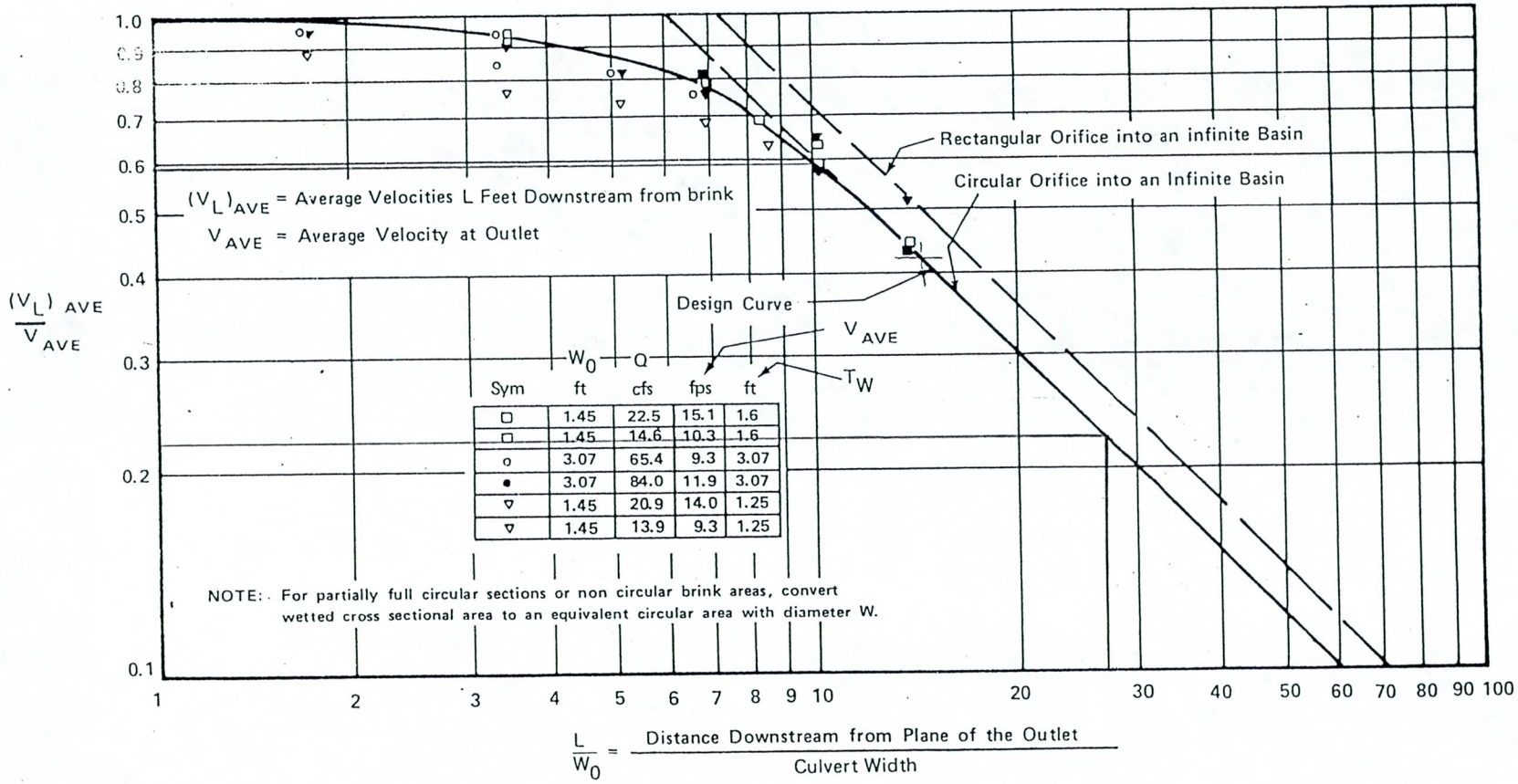


Figure XI - 3 Distribution of Centerline Velocity for Flow from Submerged Outlets from Reference XI - 2. to be used for Predicting Channel Velocities Downstream from Culvert Outlet where High Tailwater prevails. Velocities obtained from the use of this Chart can be used with Figure 2 of HEC No. 11 for sizing riprap (DO not use Figure 1 HEC No. 11, use Mean Velocity Values)

14/22

SVERDRUP

JOB 40477 Toyota

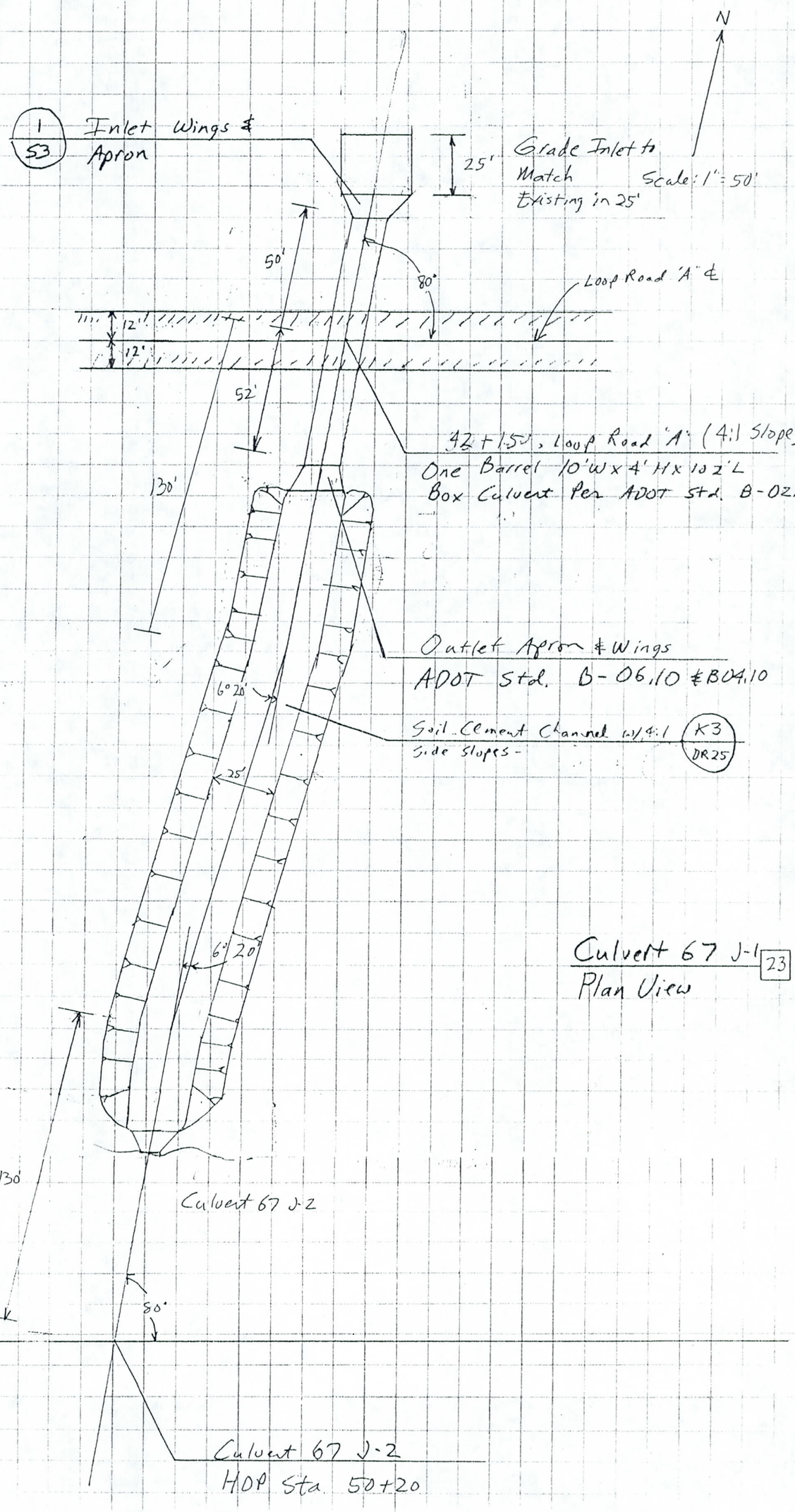
SHEET NO. 15 OF 22

DATE 6-27-91

COMPUTATIONS FOR Culvert 67 J-1 [23]

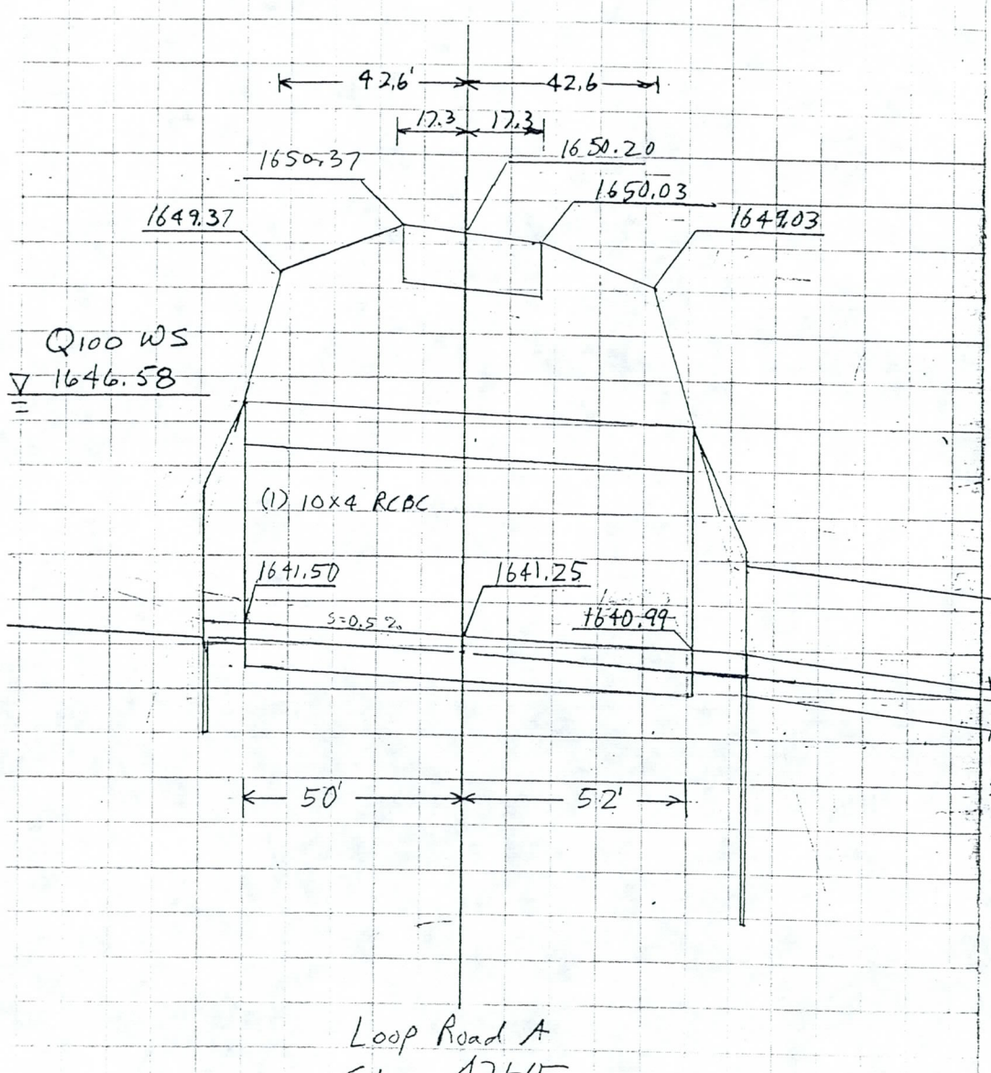
BY DFP CHKD RJT

Plan View, Sta 42+15, Loop Road "A"

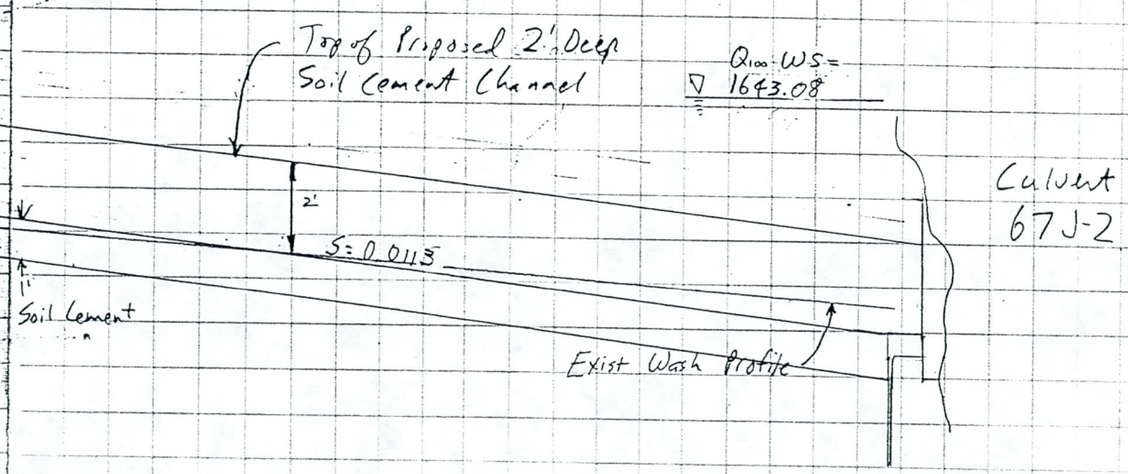


Culvert 67 J-1 [23]

Plan View



Loop Road A
Sta. 42+15
Looking Downstation



Culvert
67J-2

Culver

Q_{100} =
10° Sk

HDP

Scale:

Horiz: 1
Vert 1

SVERDRUP

JOB 40422 Toyota

COMPUTATIONS FOR Culvert Profile 67J-1 23

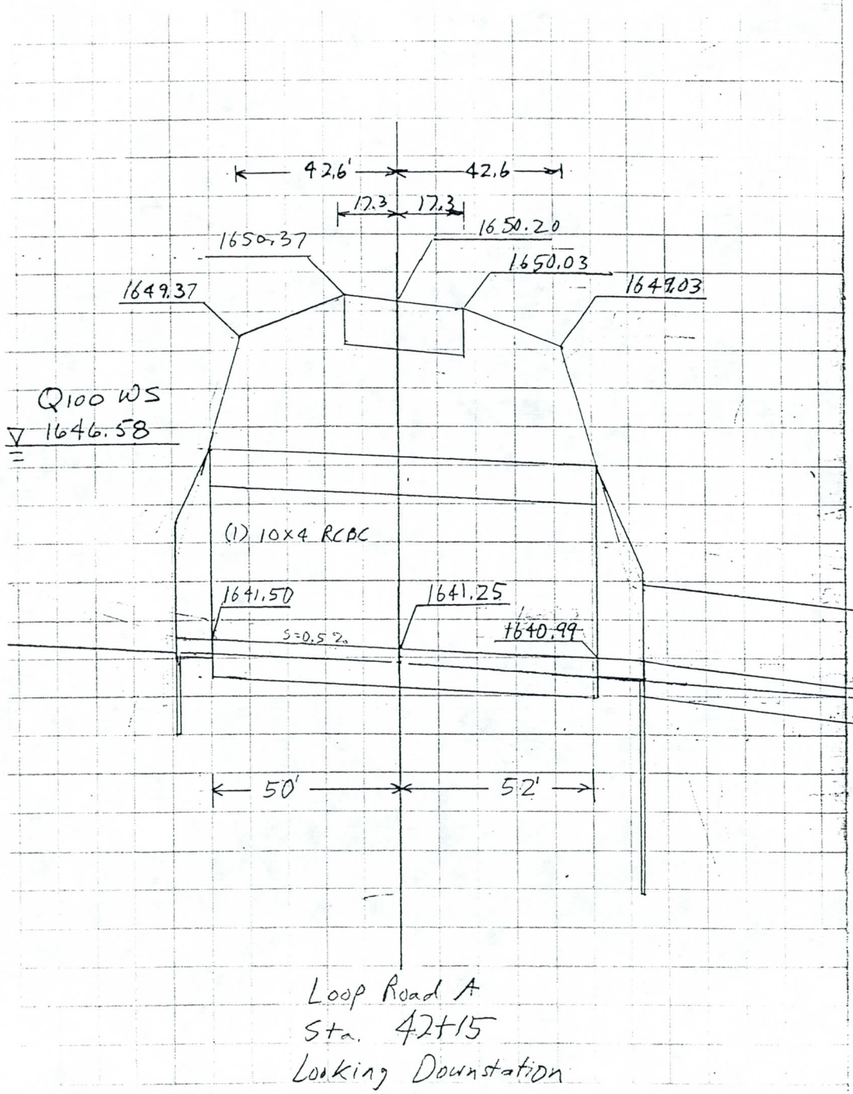
Loop Road A, Sta. 42+15

DATE 7-5-91 BY DFP CHKD RJT

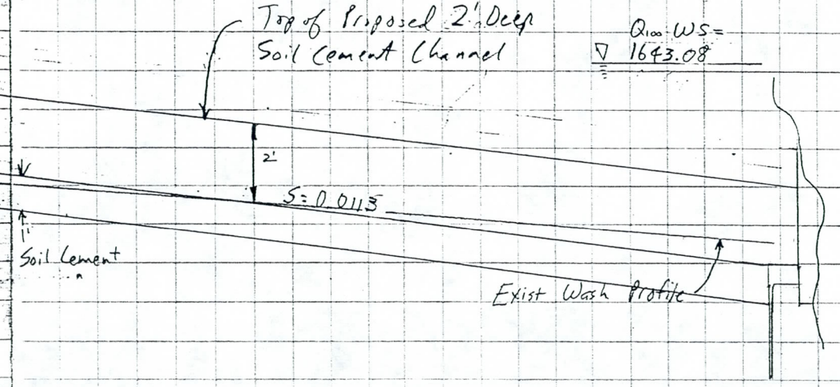
SHEET NO. 16 OF 22

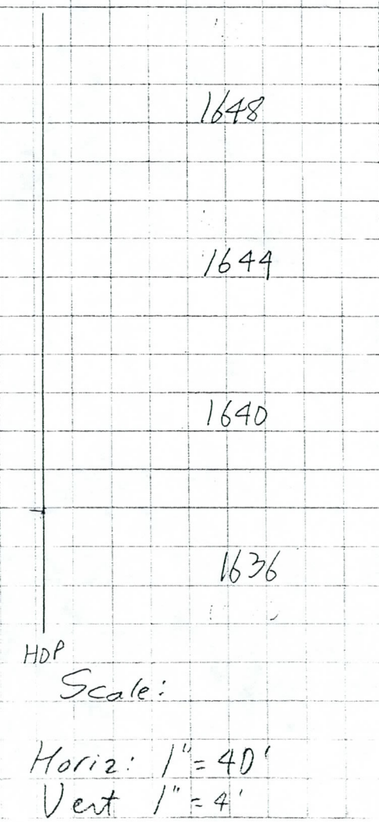
Culvert 67J-1 23

Q_{100} = 313 cfs
10° Skew RT



Loop Road A
Sta. 42+15
Looking Downstation





Scale:

Horiz: 1" = 40'
Vert 1" = 4'

SVERDRUP

JOB 40477 Toyota

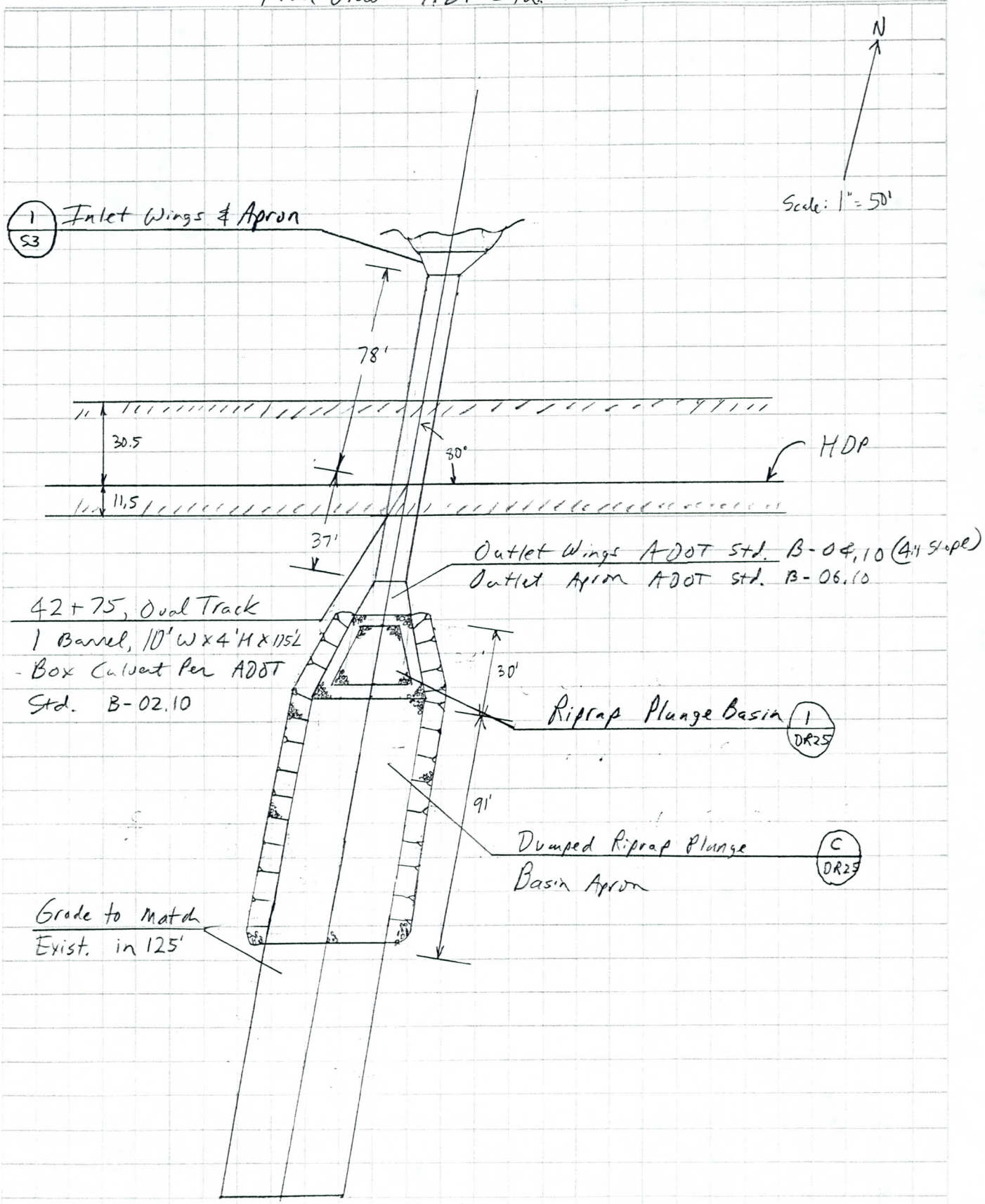
SHEET NO. 17 OF 22

DATE 7-1-91

COMPUTATIONS FOR Culvert 67 J-2 [24]

BY DFP CHKD RJT

Plan View HDP Sta. 42+75



SVERDRUP

JOB 40477 Toyota SHEET NO. 18 OF 22

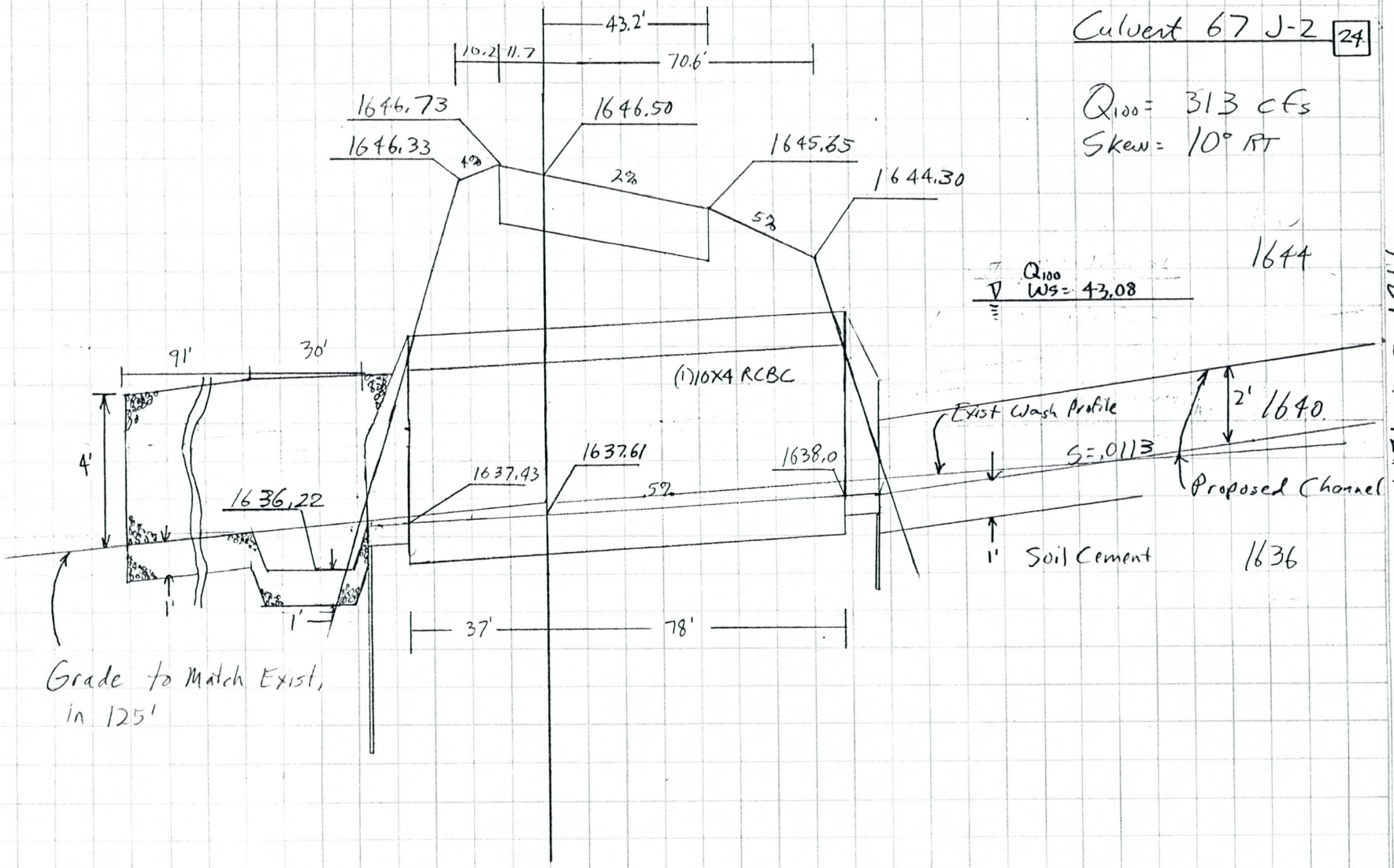
COMPUTATIONS FOR Culvert Profile 67 J-2 24 DATE 6-30-91

HDP Sta. 42+75 BY DFP CHKD RJT

Culvert 67 J-2 24

Q_{100} = 313 cfs

Skew = 10° RT



℄ Oval Track
Sta. 42+75
Looking Upstation

Scale:

Horiz: 1" = 40'

Vert: 1" = 4'

SECTION NUMBER TW67J 6/11/91

Channel Slope: 0.0097 ft./ft.

CROSS SECTION DATA:

OFFSET	0	96.1	167.4	169.7	170.7	172.1	259.4	470
ELEV.	39	38.55	38.04	36.06	36.32	37.68	38.41	38.75
N	N/A	0.035	0.035	0.035	0.025	0.035	0.035	0.035

STAGE-DISCHARGE DATA:

STAGE: 36.25														
WET PER.	0.0	0.0	0.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	0	0	0	0	0	0	0	0	0	0	0

STAGE: 36.5														
WET PER.	0.0	0.0	0.7	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	1	0	0	0	0	0	0	0	0	0	0

STAGE: 36.75														
WET PER.	0.0	0.0	1.1	1.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.3	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.3	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	0	2	0	0	0	0	0	0	0	0	0	0

STAGE: 37														
WET PER.	0.0	0.0	1.4	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.5	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.4	0.8	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	1	4	0	0	0	0	0	0	0	0	0	0

STAGE: 37.25														
WET PER.	0.0	0.0	1.8	1.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	0.8	1.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.5	1.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	2	6	1	0	0	0	0	0	0	0	0	0

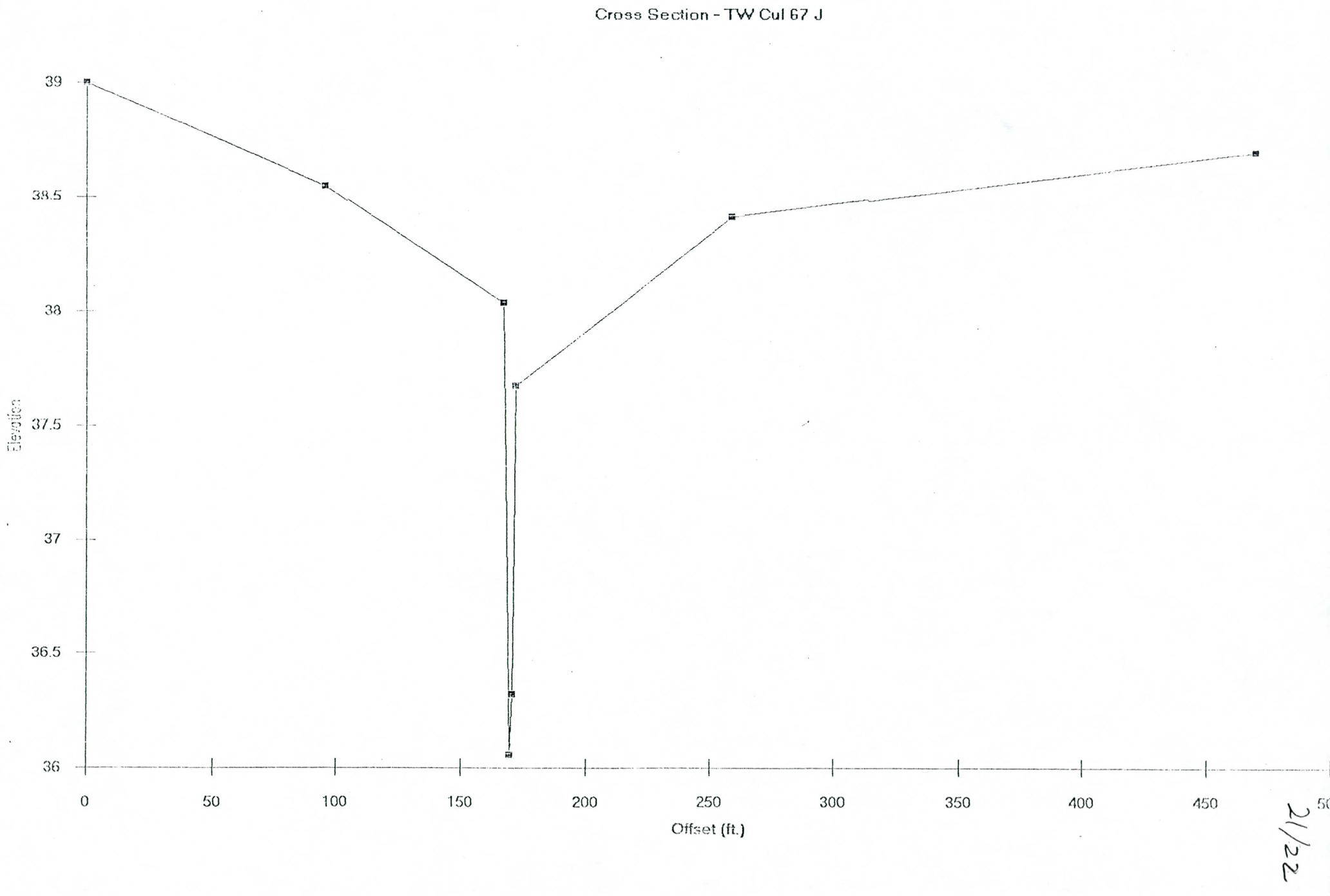
STAGE: 37.5														
WET PER.	0.0	0.0	2.2	1.0	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA	0.0	0.0	1.2	1.3	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.	0.0	0.0	0.5	1.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0	0	3	9	2	0	0	0	0	0	0	0	0	0

19/22

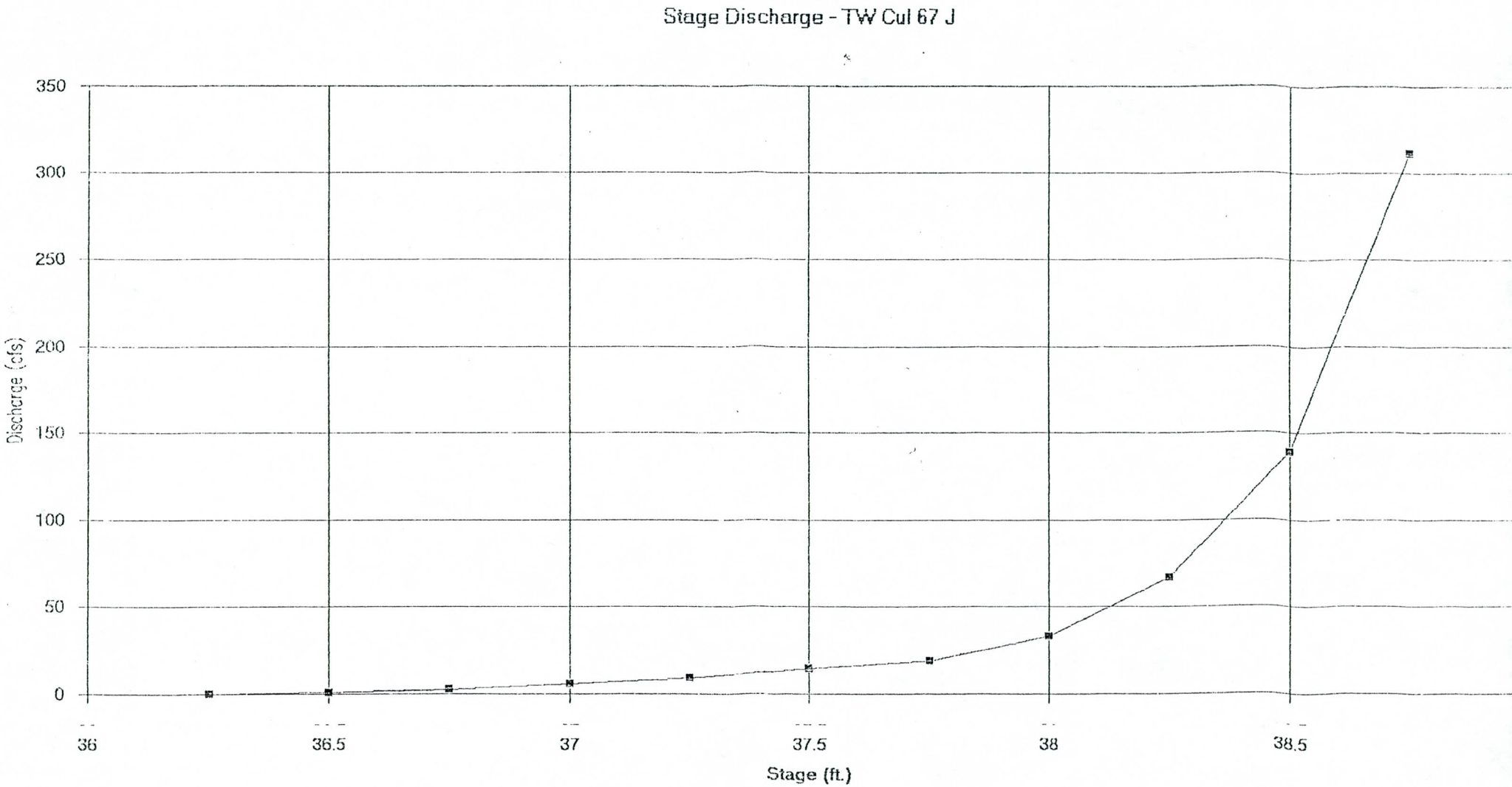
SECTION NUMBER TW67J 6/11/91

STAGE:	37.75													
WET PER.		0.0	0.0	2.6	1.0	2.0	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	1.7	1.6	1.1	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.6	1.5	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	5	12	0	1	0	0	0	0	0	0	0	0
STAGE:	38														
WET PER.		0.0	0.0	3.0	1.0	2.0	40.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	0.0	2.2	1.8	1.4	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.0	0.7	1.8	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	7	15	0	10	0	0	0	0	0	0	0	0
STAGE:	38.25														
WET PER.		0.0	29.4	32.4	1.0	2.0	70.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	3.1	5.8	2.1	1.8	21.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.1	0.2	2.0	0.9	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	8	19	0	40	0	0	0	0	0	0	0	0
STAGE:	38.5														
WET PER.		0.0	64.3	67.3	1.0	2.0	89.3	145.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		0.0	14.8	18.1	2.3	2.1	41.8	44.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.0	0.2	0.3	2.2	1.1	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	32	23	0	0	84	0	0	0	0	0	0	0
STAGE:	38.75														
WET PER.		42.7	114.0	117.0	1.0	2.0	89.3	299.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AREA		4.3	36.7	40.6	2.6	2.5	64.0	99.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HYD.RAD.		0.1	0.3	0.3	2.5	1.3	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q		0	0	84	27	0	0	200	0	0	0	0	0	0	0

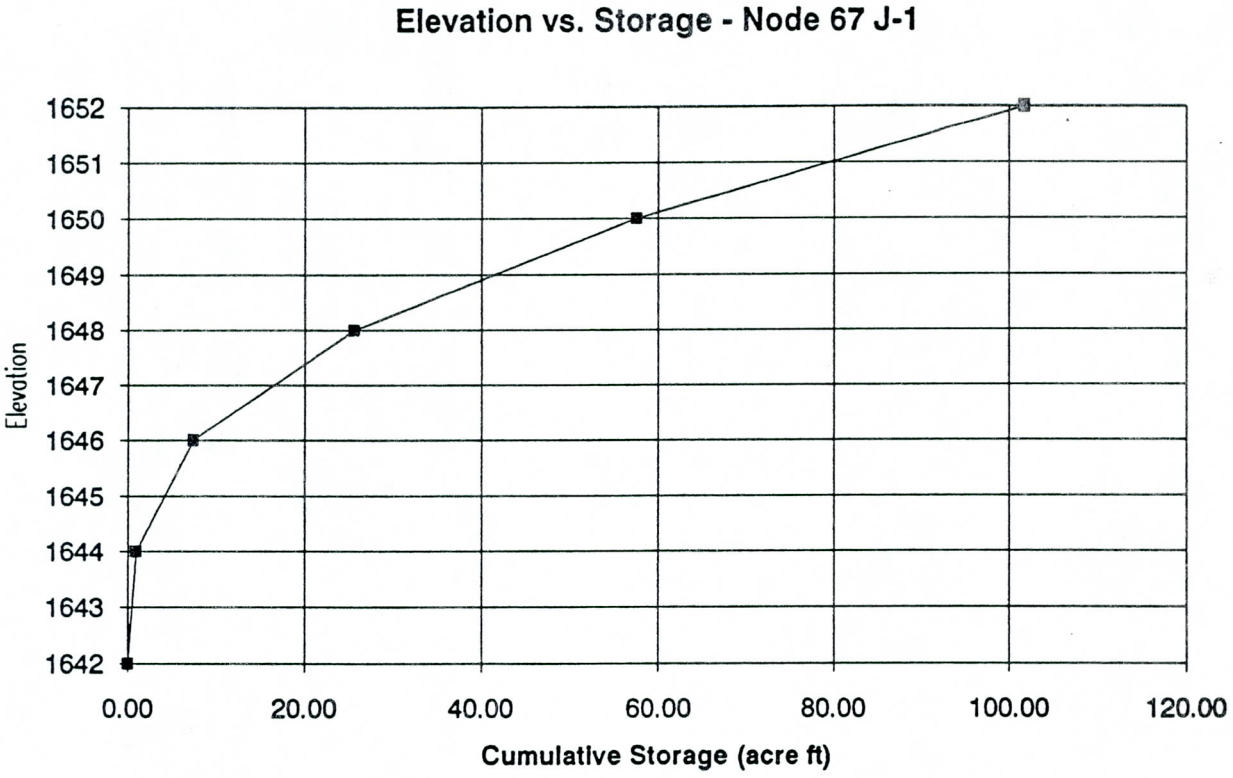
W.S. Elev.	36.25	36.5	36.75	37	37.25	37.5	37.75	38	38.25	38.5	38.75
Q	0	1	3	5	9	14	19	33	67	139	312
A	0.1	0.4	0.9	1.6	2.3	3.2	4.6	11.5	29.1	64.8	143.0
V	1.1	2.2	3.0	3.5	4.0	4.3	4.1	2.9	2.3	2.1	2.2


Cross Section - TW Cul 67 J
39
38.5
38
37.5
37
36.5
36
Elevation
0
50
100
150
200
250
300
350
400
450
Offset (ft.)

21/22


Stage Discharge - TW Cul 67 J
350
300
250
200
150
100
50
0
Discharge (cfs)
36
36.5
37
37.5
38
38.5
Stage (ft.)

22/22


Elevation vs. Storage - Node 67 J-1
1652
1651
1650
1649
1648
1647
1646
1645
1644
1643
1642
Elevation
0.00
20.00
40.00
60.00
80.00
100.00
120.00
Cumulative Storage (acre ft)