Public Works Canada
Travaux publics Canada

Western Region
Région de l'Ouest

MACKENZIE HIGHWAY, N.W.T.
MILE 628.5 TO MILE 675.4
FINAL DESIGN SUBMISSION

MARCH, 1975

Government of Canada Gouvernement du Canada

MEMORANDUM **NOTE DE SERVICE**

000017

SECURITY - CLASSIFICATION — *DE SÉCURITÉ*	
OUR FILE — *N/RÉFÉRENCE*	9305-52-300
YOUR FILE — *V/RÉFÉRENCE*	
DATE	April 18, 1975

TO / *À*: Mr. W. R. Binks
Program Manager (Civil)
Design & Construction
Ottawa, Ontario

FROM / *DE*: F. E. Kimball
Project Manager
N.W.T. Roads
Western Region

SUBJECT / *OBJET*: FINAL DESIGN SUBMISSION - MACKENZIE HIGHWAY, N.W.T.
MILE 628.5 - 675.4, MARCH, 1975

In accordance with the D.R.C.G. meeting of December 14, 1973 and subsequently as requested by the Director of Engineering and Architecture Branch, two (2) sets of design plans with varying degrees of information were developed; one for review purposes and one for contract purposes.

Review Purposes - E.W.G.

Enclosed are twenty-four (24) copies of the narrative portion of the above-noted Design Submission. Two (2) sepia mylar copies of the plans have been forwarded under separate cover.

Five (5) copies of the narrative and one (1) set of sepia mylar copies of the plans have been forwarded to Mr. C. Amos of D.I.N.A. in Yellowknife. Single copies of the narrative and a single set of prints have been forwarded to D.I.N.A. in Edmonton, D.O.E. in Edmonton and Winnipeg and K M & R in Calgary.

Contract Purposes - D.I.N.A.

One (1) set of sepia mylar copies of the design plans for the above-mentioned Submission have been forwarded to G. D. Reid for printing and distribution and one (1) set of prints has been forwarded to Mr. C. Amos of D.I.N.A. in Yellowknife and F. Janz of D.I.N.A. in Edmonton.

Items included in the Review Set of the design plans, in addition to the information included in the Contract Set of the Design Plans are:

1. Location and nature of all off-take ditches plotted on the orthomapping.

2. Cross sections of cuts and fills over fifteen feet plotted on the Plan-Profile Mile Sheets.

3. Plan shape of every borrow area and planned location of access roads by a line marking the precise boundary of the natural ground surface proposed to be disturbed.

F. E. Kimball
Project Manager
N.W.T. Roads

MACKENZIE HIGHWAY

FINAL DESIGN SUBMISSION

MILE 628.5 - 675.4

MARCH, 1975

Department of Public Works
of Canada
Western Region
Edmonton, Alberta

I N D E X

INTRODUCTION

The section of the proposed Mackenzie Highway covered by this final design submission extends from Mile 628.5 to Mile 675.4. The preliminary design for this section was previously put forward under two submissions, one for Mile 586 to Mile 631(S) submitted in April, 1974 and one for Mile 631(S) to Mile 676 submitted in May, 1974.

Since client direction has not yet been received with regard to the preliminary design submissions, specific responses are not possible in this submission. However, in the preparation of the final design and the points highlighted throughout this narrative, consideration has been given to the general nature of comments and directions provided by the client for other similar preliminary design submissions.

It is suggested that narrative portions of the preliminary design submission be reviewed in conjunction with this final design submission.

This narrative forms only a part of the final design submission, the major portion of which is contained in separate plan form.

DESIGN COMMENTS

1. Alignment

a) Horizontal

With the exception of Miles 649.3 to 650.4, 669.4 to 669.6 and 675.1 to 675.4 where revisions have been incorporated, the horizontal alignment presented is the same as was indicated in the Preliminary Submissions. The rational for the alignment revisions noted above is included in an Alignment Update Report Mile 583 to Mile 676 which is now in preparation.

b) Vertical

Four major revisions to the vertical alignment have been included. Three are at stream crossings at Miles 631.6(N), 651.2 and 659.4 where the gradeline has been lowered to reduce valley fill requirements and to reduce the bridge or culvert length. The fourth is at Mile 668 where a limestone cut has been deepened to reduce vertical gradient and to obtain additional materials thereby allowing the elimination of a previously proposed borrow pit in the area.

c) Cross-Section Types

The plan-profile mile sheets for Mile 628.5 to Mile 631 (N) have been revised to show a continuous 'B' type (wide ditch) cross-section although no change has been made to the gradeline in that area. As a result of

c) Cross-Section Types (Cont'd)

the cross slope information now available from the orthophoto mapping it is now proposed that there will be a ditch cut on the east side of the highway throughout much of this area with the exact limits of the cuts to be determined during the preconstruction survey. The ditch cut is considered a necessity for reasonable economy of construction. No erosion problem is anticipated because of the shallow cover over the bedrock in the area.

2. Drainage

a) Temporary Stream Crossings

Details of temporary crossings of streams where bridges are planned are included in the respective Phase 1B Bridge Design Submissions.

Temporary crossing for streams where culverts have been specifically designed have not been shown in this design submission as it is impossible to predict the time of culvert installation. Typically, for winter crossings a snow and ice bridge would be used as a temporary crossing while for summer crossings a temporary culvert adequately sized for the flows in question would be used.

b) Site Specific Culvert Designs

Full details of the design of culverts for all streams with a drainage area of one square mile or greater are given in the Hydrology Summary which forms Appendix 'B' to this report and on the hydrologists culvert drawings which are included in the plan package.

3. Borrow and Waste Areas

a) Borrow Areas

Borrow sources planned for use are generally the same as shown in the Preliminary Submissions. The only change, other than the refinement of pit dimensions, is at Mile 668 where the previously planned pit has been replaced by a deepened and widened right-of-way cut. The cut is through the same limestone formation as the previously planned borrow pit adjacent to the cut.

Because of EWG Stipulations transmitted to this Department by I.A.N.D. material from the talus slopes along Brokenoff Mountain has not been scheduled for use in this submission. It must be recognized that this results in a significant disadvantage to the work from both quality and cost viewpoints.

b) Waste Areas

Excavated materials from the approaches to the stream crossings at Miles 631.6(N) and 651.2, to a large extent, are not expected to be suitable for use within the roadway embankment. Waste areas, two at Mile 631.6 (N) and one at Mile 651.2 have therefore been designated for disposal of this unsuitable material.

4. Soils

a) Sensitive Areas

Special attention will be given to the cuts on the approaches to the stream crossings at Mile 631.6(N) and 651.2 during and immediately after construction. If found necessary special measures will be taken to prevent excessive erosion and/or sloughing of the backslopes.

b) Geotechnical Information

All available centreline and relevent borrow area geotechnical information is shown on the plan-profile mile sheets. Additional geotech for the entire section from Mile 628.5 to Mile 675.4 will be obtained prior to spring breakup in 1975.

5. Archeological

The environmental consultant has not identified any archaeologically sensitive areas in this section. Normal surveillance procedures during the opening of borrow pits

5. Archeological (Cont'd)

and right-of-way cuts will be followed.

6. Effect On Wildlife And Construction Restraints

Construction scheduling restraints for the protection of wildlife are listed in Division 1, Section 2, Paragraph 3 of the Draft Specifications which form Appendix 'C' to this report. The restraints are the result of discussions with Canadian Wildlife Service and D.O.E. Fisheries.

7. Construction Details

The material from the proposed borrow pits at Mile 646.6 and Mile 653.1 will be sands which may be susceptible to erosion. Sections of highway constructed with these materials will be protected by capping with more erosion resistant materials.

SPECIAL TREATMENT FOR DITCHES

Roadway and offtake ditches are often necessary elements in highway design and construction. These ditches require the removal of the vegetative cover from their respective areas, thus increasing the potential for scour erosion. This scour erosion in highway ditches is dependent upon numerous factors including discharge, channel gradient, sediment in water, soil characteristics such as grain size, density, organic binder, cementation and ice content. Some methods used in highway construction to control or prevent scour erosion are: blanketing the ditch floors with stable, free-draining granular materials, reducing the effective ditch gradient by constructing a series properly spaced ditch checks on the ditch floor and by diverting run-off water out of the ditch onto natural vegetation by using ditch blocks.

Design equations exist for open channel flow, which relate flow velocity to the gradient and cross-sectional configuration of the channel. The Manning formula, is such an equation and is commonly employed for open channel flow calculations. The formula is as follows:

$$V=(1.486/n)\ R^{2/3}\ S^{1/2} \quad (1)$$

where V=velocity of water, in feet per second

R=hydraulic radius (water area divided by wetted perimeter)

S=slope of channel gradient, in feet per foot.

n=Coefficient of Roughness (Manning's "n")

One of the principles followed in designing the Mackenzie Highway was to avoid excavation in permafrost wherever and whenever possible. Therefore, the use of standard engineering texts for use in non-permafrost areas was considered applicable for deriving ditch lining and ditch check spacing charts for the Mackenzie Highway.

When cuts through ice-rich permafrost areas are unavoidable it is intended to sub cut and back fill with a sufficient depth of ice-free material, which would provide soil conditions similar to non permafrost areas.

The Handbook of Steel Drainage and Highway Construction Products, second Edition, 1971, lists limiting velocities for non erosion of channels. The following tabulated Manning's "n" and limiting velocities for the general soil types found on the Mackenzie Highway right-of-way are excerpts from this Handbook.

TABLE 1

Material	Manning "n"	Velocity ft./sec. For Clear Water
Fine sand	.020	1.50
Silty sand	.020	1.75
Fine gravel	.020	2.50
Stiff clay	.025	3.75
Coarse gravel Well graded gravel	.025	4.00
Cobbles	.035	5.00
Shale, hard pan	.025	6.00

Using the limiting velocities as tabulated above and Manning's formula, discharge versus gradient curves were calculated for a twelve foot wide "B" type road ditch. (See figure 2).

Ditch Lining

For a given soil type a curve in Figure 2 indicates the limiting discharge for a given gradient above which scour erosion may occur. Therefore, theoretically, by lining the ditch with an adequate depth of material selected higher in the graph scour erosion should be arrested or minimized.

Ditch Checks

As an alternate to ditch lining ditch checks, within their limits, would be adequate and possibly more economical in some areas for scour prevention.

See Figure 7 of this report for a schematic explanation of ditch check theory.

Figures 3 to 6 inclusive of this report are recommended ditch check spacing charts calculated for discharges up to 20 c.f.s. over various soil types. The derivation of these ditch check spacing charts was based on the effective gradient required for non-erosion of a soil type at a given discharge.

Due to the physical limitations of the highway ditch depth the ditch check crest is one foot above the ditch floor. A forty-foot minimum spacing of ditch checks was considered to be reasonable for construction, maintenance and effectiveness.

Discharge Determination

The Rational formula developed in 1889 by sewage engineers is probably the most widely used formula for estimating discharges. The formula is:

$$Q = CiA. \qquad (2)$$

where Q = discharge in c.f.s.

C = the run-off coefficient

i = the intensity of rainfall in inches per hour.

A = the drainage area in acres.

This approach with the following modifications was considered to be an acceptable one for small drainage areas up to about one square mile.

Bolter, Parish, Trimble, consulting engineers, have in their publication, Hydrology Study and Design of Culverts, Mile 297 to Mile 345, Mackenzie Highway, November, 1972, developed a modified Rational formula for large drainage areas in the following form: $Q_i = 26.7\ ARr\ (100 - L)\ M$ (3)

where

Q_i = maximum instantaneous discharge - c.f.s.

A = drainage area - square mile

R = rainfall in 24 hours

r = rainfall reduction factor

L = percent water loss

M = conversion factor mean daily discharge to maximum instantaneous.

Rationalizing the variables in the above formula as they are effected in the Mackenzie Valley small drainage areas the following empirical formula was developed for estimating small drainage area discharges:

$$Q = .584\ CA \quad (4)$$

where

Q = maximum instantaneous discharge in c.f.s.

C = run-off coefficient

A = drainage area in acres.

(a) - ".584" is the resultant of 26.7, R, r, M and the conversion of square miles to acres $(\frac{1}{640})$

"R" - 4 inches per 24 hours was considered a conservative estimate.

"r" - 1.0 was used since no appreciable reduction can be expected in small drainage areas.

"M" - a value of 3.5 was considered conservative for small drainage areas.

(b) - "C" - run-off coefficient is similar to (100-L). Bolter, Parish, Trimble arrived at an "L" value of 75% for large drainage areas (550 acres and greater). The accepted run-off coefficient for concrete and pavement is 0.8 suggesting a water loss of 20%. It was considered conservative to use this 20% water loss for drainage areas of 45 acres and less. Joining these limits with a porabolic curve, expected water losses for intermediate drainage areas were interpolated and converted to the following run-off coefficients:

TABLE 2

Expected run-off coefficients for small drainage areas in the Mackenzie Highway

Acres		"C"
Up to 45	-	0.80
Up to 98	-	0.65
Up to 222	-	0.50
Up to 550	-	0.25

The selection of a particular type of ditch treatment or whether it is required will ultimately rest on the experience of the resident engineer.

Figure 2

LIMITING CHANNEL GRADES FOR THE DESIGN OF "B" TYPE DITCHES

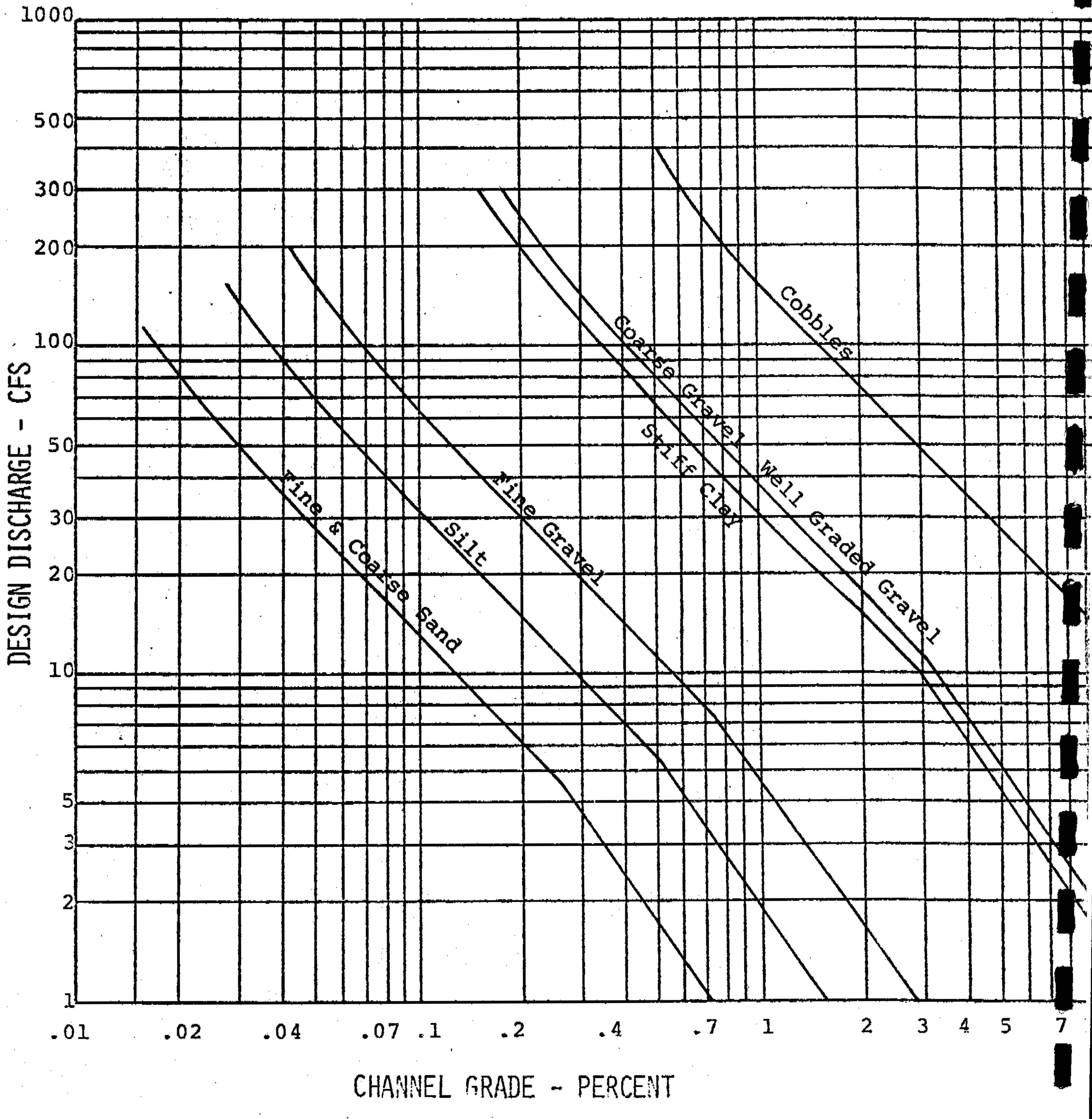

Figure 3

DITCH CHECK SPACING

(DESIGN DISCHARGE - 3 CFS)

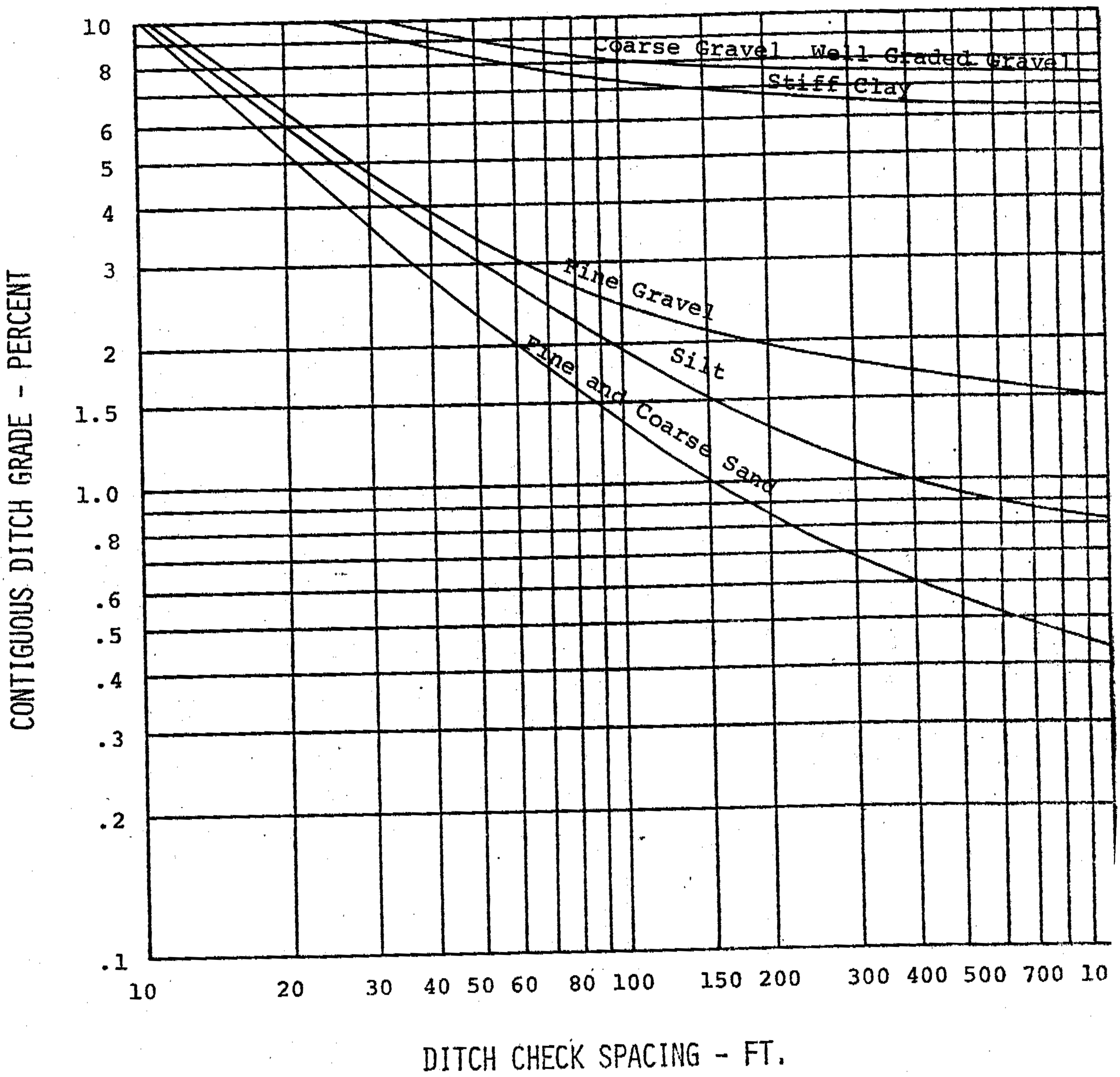

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Figure 4

DITCH CHECK SPACING

(DESIGN DISCHARGE - 5 CFS)

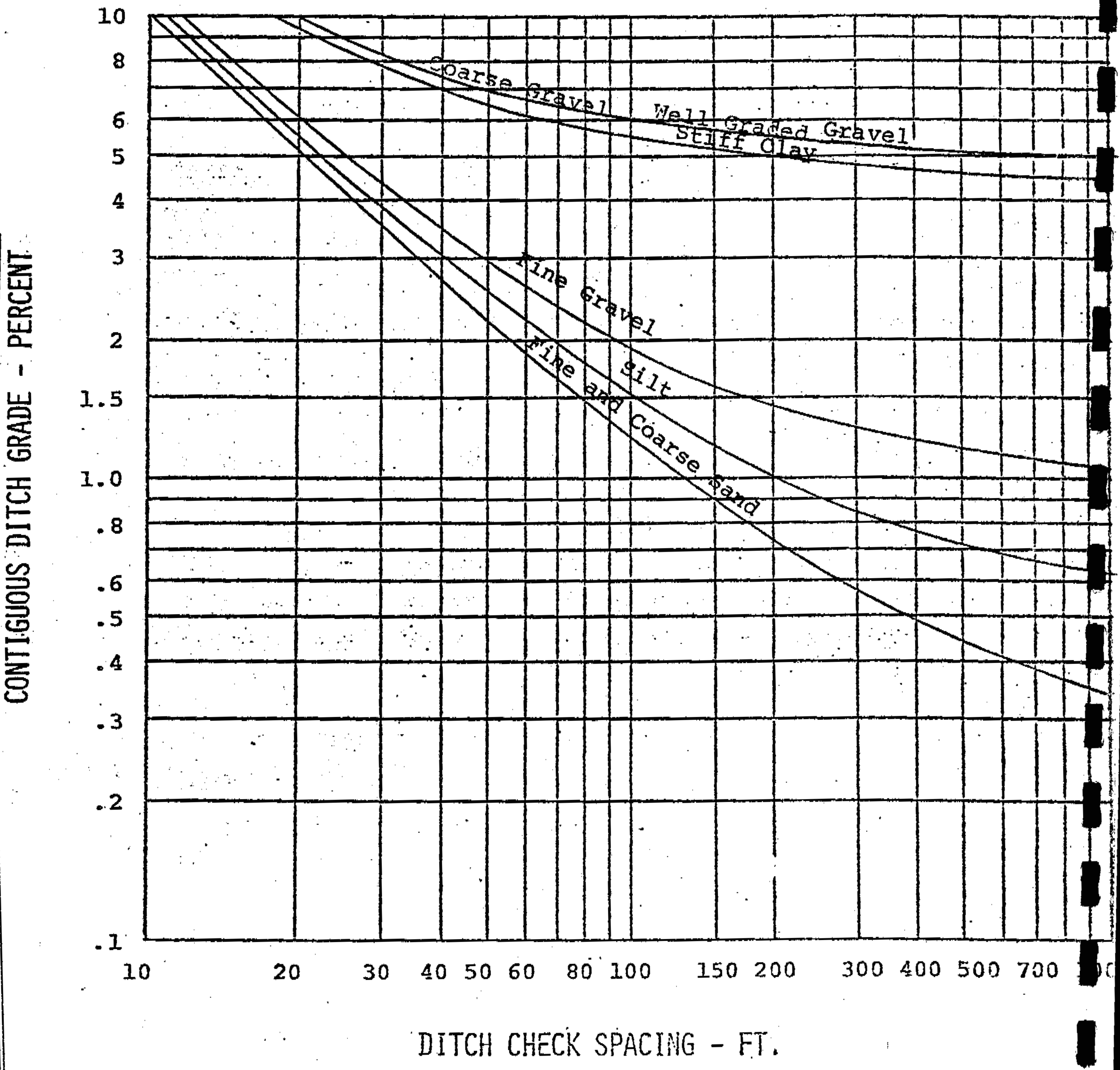

Figure 5

DITCH CHECK SPACING

(DESIGN DISCHARGE - 10 CFS)

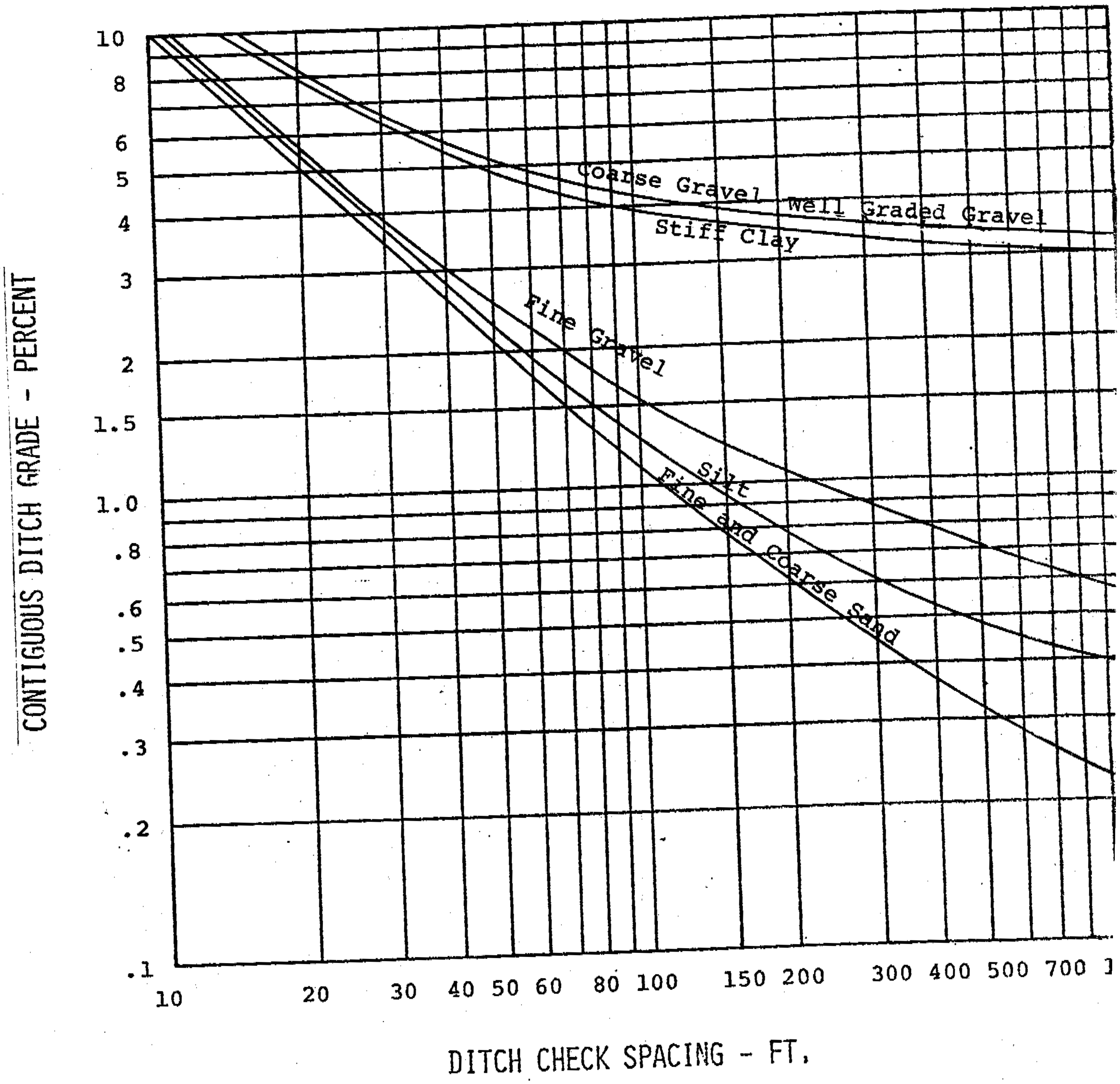

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Figure 6

DITCH CHECK SPACING

(DESIGN DISCHARGE - 20 CFS)

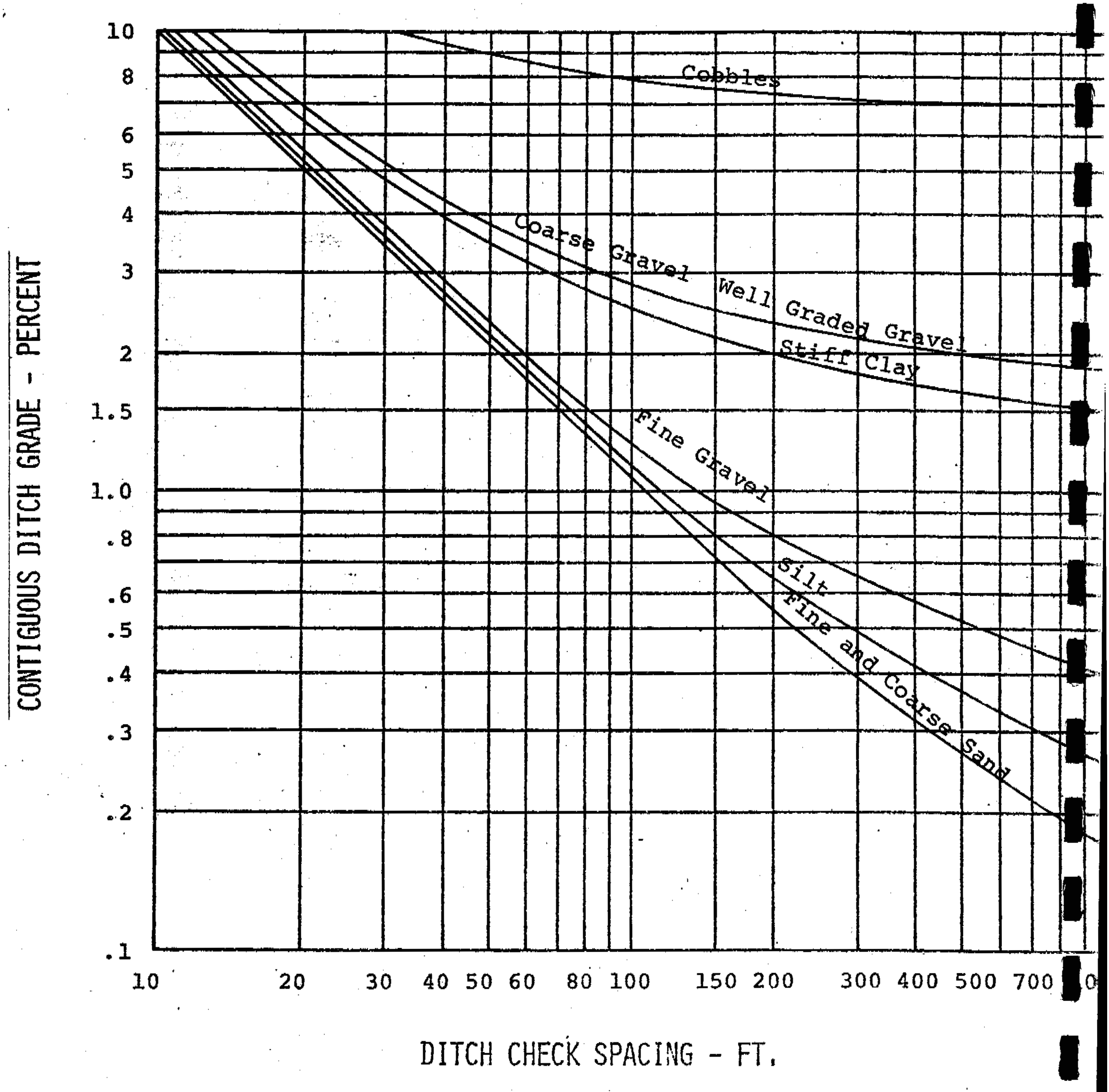
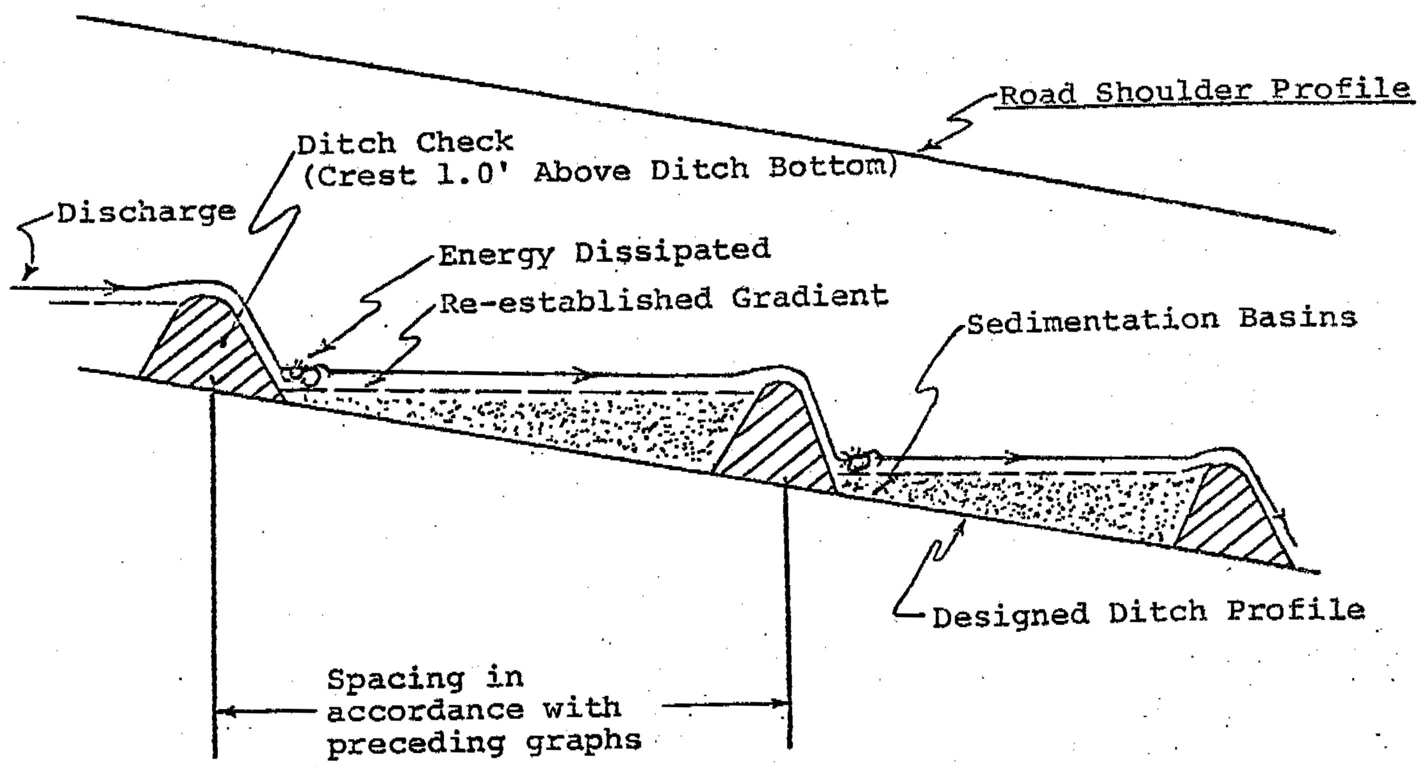


FIGURE 7

DITCH CHECKS



- The ditch checks will be constructed with non-erodible materials.

APPENDIX "B"

HYDROLOGY SUMMARY

TABLE 1

CULVERT VELOCITIES

Creek Mileage	DESIGN DISCHARGE – NORMAL DESIGN: Inlet Velocity (f.p.s.)	Maximum Velocity Inside Culvert (f.p.s.)	Exit Velocity	DESIGN DISCHARGE FOR FISH CULVERT: Inlet Velocity (f.p.s.)	Maximum Velocity Inside Culvert	Exit Velocity	FISH MIGRATION DISCHARGE – FISH MIGRATION DESIGN: Inlet Velocity (f.p.s.)	Maximum Velocity Inside Culvert (f.p.s.)	Exit Velocity
632.4(N)	10.3	14.1	7.2	-	-	-	-	-	-
633.8	8.3	10.8	6.1	-	-	-	-	-	-
634.1	12.2	19.7	11.3	-	-	-	-	-	-
636.0	9.8	11.0	5.6	-	-	-	-	-	-
637.0	9.8	13.7	6.0	-	-	-	-	-	-
638.0 △1	5.5	5.5	4.9	-	-	-	-	-	-
638.6 △1	-	-	-	5.9	5.9	3.7	Velocities in Culvert Do Not Exceed 5 F.P.S. for Discharges up to a Discharge of 50 C.F.S. At Overspill.		
642.6	N/A								
645.7	N/A								
646.9	7.0 △2 7.8 △3	7.0 △2 8.2 △3	3.4 △2 5.2 △3	- -	- -	- -	- -	- -	- -
648.5	-	-	-	7.5	7.5	7.5	2.7	2.7	2.5
651.2	14.8	16.6	13.8	-	-	-	-	-	-
657.3	- -	- -	- -	2.2 △2 4.1 △3	2.2 △2 4.1 △3	2.0 △2 3.3 △3	Velocities in Culverts Do Not Exceed 5 F.P.S. for Discharges up to a Discharge of 95 C.F.S.		

△1 Design Discharge based on Maximum Channel Capacity.
△2 Considering Beaver Dams Downstream.
△3 With Downstream Beaver Dam Removed.

TABLE 2

HYDROLOGY SUMMARY

MILE 628.5 to MILE 675.4

Part 1

MILE	632.4(N)	633.8	634.1	636.1	637.0	638.0	638.6
Drainage Area (A) Total (sq. miles)	3.3	1.2	5.2	3.5	4.0	3.1	3.0
Qhwm (c.f.s.)	105	95	327	174	265	210	85
Drainage Area (Ae) EFFECTIVE (sq. miles)	2.9	1.2	5.2	3.5	4.0	3.1	0.3
Relief (feet)	800	700	2,000	2,000	1,800	1,950	50
(100 - L) Water Retained for Run-off	0.23	0.22	0.28	0.28	0.27	0.28	0.19
Rainfall (inches in 24 hours)	3.5	3.5	4.5	4.5	4.5	4.5	3.5
M Ratio	4.05	4.18	3.87	4.00	3.96	4.04	4.8
Qe (c.f.s.)	252	103	677	471	514	422	26
Drainage Area (Alc) LAKE CONTROL (sq.mi.)	0.4	-	-	-	-	-	2.7
Relief (feet)	150	-	-	-	-	-	1,950
(100 - L)	0.2	-	-	-	-	-	0.28
Rainfall (inches in 24 hours	3.5	-	-	-	-	-	4.5
M ⚠1	2.6	-	-	-	-	-	2.6
Qlc (c.f.s.)	19	-	-	-	-	-	236
Drainage Area (Am) MUSKEG (sq. miles)	-	-	-	-	-	-	-
Qm (c.f.s.)	-	-	-	-	-	-	-
Q rational (c.f.s.) (Qe + Qlc + Qm)	271	103	677	471	514	422	262
Q design (c.f.s.)	270	105	680	470	520	210 ⚠2	85 ⚠2

⚠1 Modified M for lake control, Ref. Modified Rational Formula Mile 545 to Mile 725, February, 1974.

⚠2 This is the Assessed Maximum Capacity of the Stream Crossing. Higher Discharges from the Basin are accommodated and attenuated on the low Flood Plain to the North.

TABLE 2

HYDROLOGY SUMMARY

MILE 628.5 to MILE 675.4

Part 2

MILE	642.6	645.7	646.9	648.5	651.2	657.3	
Drainage Area (A) Total (sq. miles)	1.1	1.4	1.8	19.1	22.6	1.9	
Qhwm (c.f.s.)	90	160	110	240	1,075	70	
Drainage Area (Ae) EFFECTIVE (sq. miles)	-	-	-	-	3.0	-	
Relief (feet)	-	-	-	-	1,150	-	
(100 - L) Water Retained for Run-off	-	-	-	-	0.24	-	
Rainfall (inches in 24 hours)	-	-	-	-	4.0	-	
M Ratio	-	-	-	-	4.04	-	
Qe (c.f.s.)	-	-	-	-	311	-	
Drainage Area (Alc) LAKE CONTROL (sq.mi.)	1.1	1.4	1.8	19.1	19.6	1.9	
Relief (feet)	50	50	50	2,000	1,200	200	
(100 - L)	0.19	0.19	0.19	0.28	0.24	0.20	
Rainfall (inches in 24 hours	3.5	3.5	3.5	4.5	4.0	3.5	
M △1	2.6	2.6	2.6	2.3	2.3	26	
Qlc (c.f.s.)	51	65	83	1,478	1,155	92	
Drainage Area (Am) MUSKEG (sq. miles)	-	-	-	-	-	-	
Qm (c.f.s.)	-	-	-	-	-	-	
Q rational (c.f.s.) (Qe + Qlc + Qm)	51	65	83	1,478	1,466	92	
Q design (c.f.s.)	90	160	110	1,500	1,500	95	

△1 Modified M for lake control, Ref. Modified Rational Formula Mile 545 to Mile 725, February, 1974.