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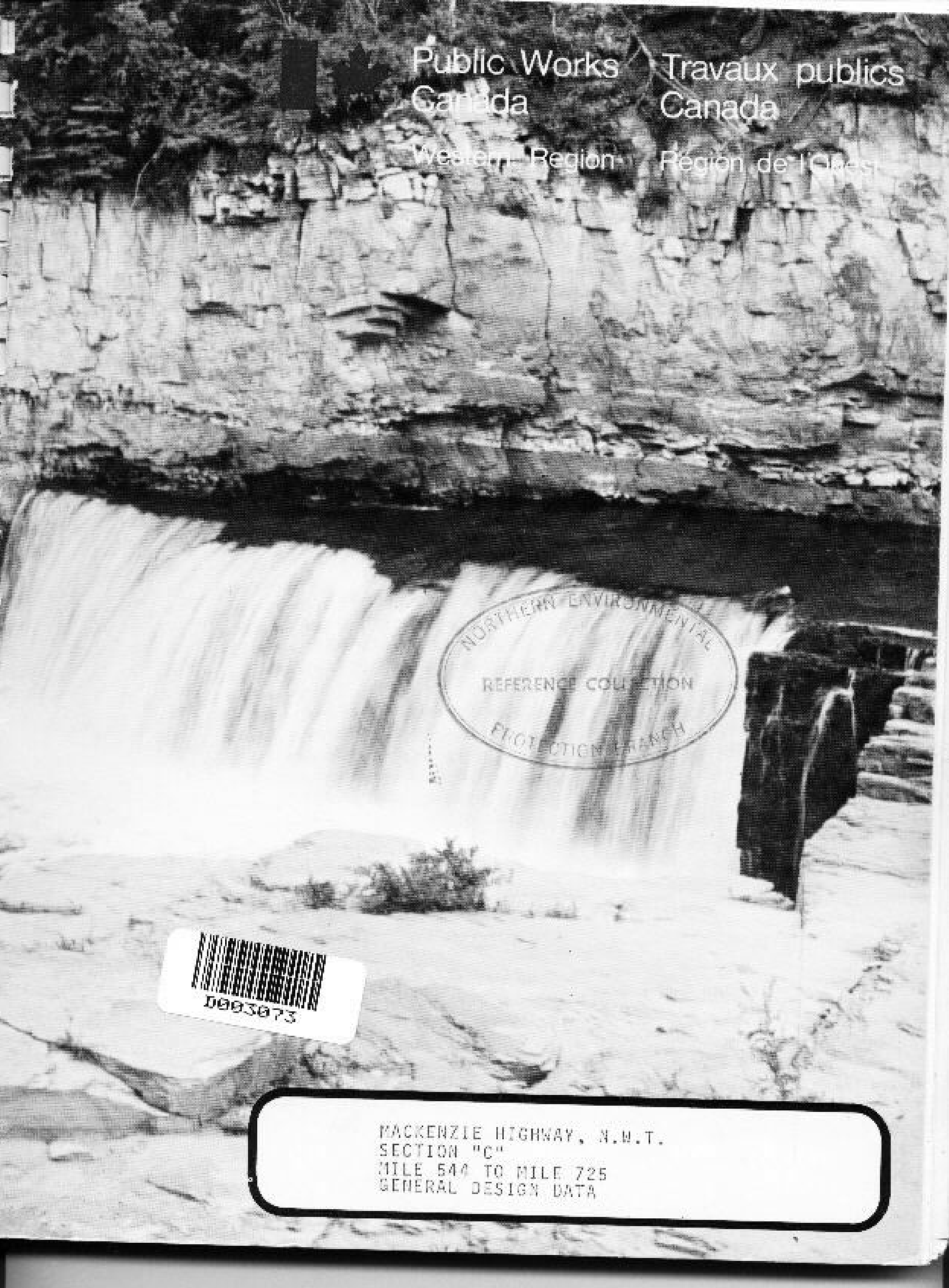

MACKENZIE HIGHWAY, N.W.T.
SECTION "C"
MILE 544 TO MILE 725
GENERAL DESIGN DATA

Government of Canada / Gouvernement du Canada

MEMORANDUM **NOTE DE SERVICE**

SECURITY - CLASSIFICATION – *DE SÉCURITÉ*
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OUR FILE – *N/RÉFÉRENCE*
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YOUR FILE – *V/RÉFÉRENCE*

DATE
February 1, 1974

TO / *À*
G. D. Reid
Ass't. Director Resources (Civil)
OTTAWA, Ontario

FROM / *DE*
F. E. Kimball
Project Manager NWT Roads
Western Region

SUBJECT / *OBJET*
Mackenzie Highway, N.W.T. - Section "C" - Mile 544 to Mile 725 - General Design Data

The enclosed report outlines general criteria which will be applied to the design of the roadway in the above-noted section.

In addition, each Design Submission will be accompanied by a separate narrative.

F. E. Kimball
Project Manager NWT Roads
Western Region
fj/hs

Encl.

MACKENZIE HIGHWAY

MILE 544 TO MILE 725

GENERAL DESIGN DATA

DEPARTMENT OF PUBLIC WORKS
WESTERN REGION
EDMONTON, ALBERTA

JANUARY 29, 1974

INDEX

INTRODUCTION

This report has been prepared to provide an outline of the general design criteria used by Department of Public Works Design Teams in preparing Preliminary and Final Design for the Mackenzie Highway. As such it is intended to provide data for various reviewing agencies in their assessment of detailed designs prepared by Department of Public Works.

This report has three main sections. The first section provides various statements and documents requested by the Mackenzie Highway Environmental Working Group (M.H.E.W.G.) in their report regarding Information Deficiencies of January 18, 1973, modified by the direction received from the Director of Engineering and Architectural Branch, I.N.A. dated December 10, 1973.

The second section contains design data published by Department of Public Works for the Design of Mile 297 to Mile 543. This information is repeated from "General Design Data Mile 297 to Mile 543" dated August 20, 1973, and from selected sections of detailed design data published during September, October and November 1973.

The third section provides additional information as requested by the Director of Engineering and Architectural Branch, I.N.A. dated December 10, 1973. This section also outlines the detailed design data which will be provided with the Preliminary Designs and the Final Designs for Mile 544 to Mile 725.

Appendix "A" contains a list of other reports published previously containing Design Data which are pertinent to this Section of the Mackenzie Highway.

IT MUST BE EMPHASIZED THAT THE DATA CONTAINED WITHIN THIS REPORT IS A GENERAL OUTLINE OF DESIGN CRITERIA AND IS NOT INTENDED TO ESTABLISH RIGID STANDARDS TO BE USED IN ALL CASES IN THE DESIGN OF THE MACKENZIE HIGHWAY. THE RESPONSIBILITY FOR THE DESIGN OF THE HIGHWAY AND ITS CONSTRUCTION RESTS WITH THE DESIGN AGENCY, THE DEPARTMENT OF PUBLIC WORKS. THE DESIGN AGENCY MUST HAVE THE FLEXIBILITY TO EXERCISE EXPERIENCE AND JUDGEMENT IN THE USE AND APPLICATION OF GENERAL STANDARDS OF DESIGN CRITERIA.

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SECTION A

SECTION A-1

GENERAL PROCEDURES FOR EXCAVATION IN PERMAFROST

The basic principle that is followed in the highway location and design is to avoid excavation in permafrost wherever and whenever possible. If, however, excavation into permafrost must be considered then the following basic principles are being, or will be used:

(i) Where the materials in question are stable during and after thaw the excavation would be carried out using a conventional sloping technique.

(ii) The use of vertical backslopes will be considered in areas of unstable soils, generally where there is a good insulating vegetation cover on the terrain. This technique has not been applied in the N.W.T. in the past but it has been used in Alaska since about 1970 with apparently favourable results. The initially indicated benefits of the technique have been (1) a self sloping, stabilizing and revegetating process utilizing the undisturbed natural vegetative cover above the vertical backslope (2) an appreciable reduction in the volume of sediments released into the ditch flow through thawing of the slope, and (3) economics of construction. A factor that must be studied with respect to the use of vertical backslopes is the possible mass stability dangers when used in very high cuts particularly during the overhang or canopy stage of stabilization.

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(iii) In areas of unstable soils where vertical cuts are undesirable for reasons such as quality of vegetative cover, sloping backslopes would be employed with the slopes and ditch bottoms being blanketed for the purpose of insulation and/or containment as well as protection against erosion. The blankets would generally consist of free draining, stable granular materials, however studies are being conducted into the possibility of incorporating quantities of other materials such as wood chips or manufactured insulating materials. The slope of the backslope and the thickness and type of blanket would be determined taking into consideration the height of the cut, the amount of ice in the materials and the stability and siltation characteristics of the backslope materials. The design objectives would be to either maintain the thermal regime of the backslope material or to confine it and hold it in place during thaw and stabilization or combinations of both.

(iv) The subgrade itself in the cut would be sub-excavated and backfilled with stable free draining granular materials to provide an insulating cover for the frozen materials underneath and/or to provide a structurally acceptable road grade. The use of wood chips or manufactured insulation is also being considered here for improved insulating capabilities. The depth to which excavation and backfill would take place at any particular location would be determined on the basis of the anticipated success of the insulating effort as well as the ice content and soil characteristics within the depth of thermal degradation that can be expected.

SECTION A-2

Culvert Icing

The problem of icing at or in culverts and small bridges is a problem that has long plagued the highway designer and maintainer. While a number of solutions to the problem have been developed over the years, unfortunately the foolproof solution, which can be applied to an icing problem in general has not been developed. Certain solutions are only effective under specific circumstances and the problem then arises in identifying and anticipating the circumstances involved at each site so that the appropriate solution can be selected or devised. It is presently felt that for the Mackenzie Highway one of the more major problems will be in the identification of streams and/or drainage courses which have potential for an icing problem and to determine the nature of the anticipated icing problem as well as the circumstances that will promote or aggravate the problem. To this end a close evaluation of existing stream crossings throughout the Yukon and N.W.T. will be undertaken. Some valuable information should also be available from an assessment of the stream crossings along the winter road to Fort Good Hope (Mile 725).

In addition to the normal icing problem which generally stops or at least is not aggravated further once the air temperature rises above a certain level, there now appears to be the distinct possibility that a somewhat different type of icing may occur within certain culverts as the result of the aggradation of permafrost up into the fill and around the culvert. The resulting problem could conceivably manifest itself quite independently of air temperature such as the freezing in the culvert of initial but small spring run-off. Critical factors in such a possible problem would logically seem to be water temperature, soil temperature immediately adjacent to the culvert and the velocity/volume of the flow. It also appears than an aggravation of all potential icing problems would be the hydraulic over-design of culverts for fishery migration reasons which generally would result in shallow flows with a low velocity during critical icing periods of the year.

To overcome or minimize problems the following are a number of the possible solutions to be used or considered by design teams. As mentioned above, the solution for each site must be determined on the basis of circumstances known to exist or than can be anticipated at the site.

(i) Proper channel design immediately upstream & downstream of the structure to ensure thatno situation is created which will increase the surface area and decrease the velocity of low flows thereby providing a potential starting point for an icing problem. This approach can be used in reverse to advantage by ponding, diking or cross-ditching in the channel well upstream to intentionally create and dissipate the icing condition before it reaches the road culvert. Such measures must, however, be used with discretion where fish use the stream in the summer.

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The use of fabric fencing upstream from the culvert is another method of accelerating and dissipating the icing condition before it reaches the road. Absorption of moisture by the fabric fence results in a self-maintaining ice dam against the freezing flow. The use of timber walls, fences, etc. upstream from the road are further variations to this approach of controlling an icing condition before it reaches the roadway.

(ii) The use of stepped culverts in larger fills which allows water to pass through higher culverts when lower culverts have been blocked by ice. Unless the top culvert is sized to carry the spring run-off flow, a closely monitored maintenance operation is required to ensure lower culverts are opened before spring breakup. Sizing the top culvert to carry maximum flow can be quite costly for streams having larger flows.

(iii) Insulating of the exterior surface of the culvert prior to installation. While no standard technique in this regard is known to exist at the present time, the principle appears to have the best potential for cases where a culvert will or may be encased in permafrost.

(iv) Draping culvert ends with a special fabric to help maintain a higher air temperature within the culvert. The flow within a culvert does not have the normal insulating protection of snow over ice that the stream outside the culvert

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would generally have and a proper draping installations helps to improve this balance. It appears, however, that the draping might have negative effects in cases where the potential icing problem would result from permafrost around the pipe.

(v) In extreme situations, re-alignment of the road location may be necessary where significant drainage improvements can be accomplished by such a move.

(vi) Wherever a serious icing problem is expected with respect to a culvert installation and even if an apparently successful solution to the problem can be incorporated into the installation, it is proposed that steam thaw lines be installed in the culvert with vertical risers so that thawing can readily and quickly be carried out if required.

SECTION A-3

DITCHING IN PERMAFROST

As with roadway cuts in permafrost, ditching in permafrost will be avoided wherever and whenever possible. This will be accomplished by increasing the number of cross drainage culverts to eliminate or minimize the ponding or flow of drainage water along the toe of the road fill and it may even require some localized re-alignment of the road location to take advantage of improved roadside drainage conditions. Where ditching in permafrost is unavoidable, however, in order to eliminate undesirable ponding or to improve dispersal of drainage flows, the following principles will be used:

(i) Where the materials involved are stable during and after thaw, ditching would be carried out in the conventional manner.
(ii) In unstable materials, the use of narrow vertical sided ditches would be considered with the prediction that they will stabilize themselves into revegetated swales or depressions. It is intended to experiment with some short sections of this type of ditching under current construction activities.
(iii) In materials with high ice contents, it is proposed that creation of drainage swales be undertaken by controlled disturbance to the thermal regime over the proposed ditch area, such as by tracking with a tracked vehicle. It is intended to also experiment with this proposal under current construction activities.

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(iv) Because of the general susceptibility of permafrost materials to erosion when thawed or thawing, the gradient of any necessary ditches would be kept as flat as possible. Where a gradient is unavoidably steeper than that considered safe for the material in question, or where there is the likelihood of uncontrolled thermal erosion, the ditch will be lined with granular or other suitable erosion resistant material.

SECTION A-4

EMBANKMENT PERFORMANCE OF SILT AND CLAY

Clay and silts used in construction of embankments in the N.W.T. have provided satisfacotry performance in certain situations and total embankment failures in others. The performance to be anticipated from these materials is dependent on a substantial number of variables and cannot be generalized for design purposes. Consideration must be given by the designer to each of the following for every proposed use of silt and clay in embankments.

1) The zone in which the embankment is to be constructed, i.e. non-permafrost; discontinuous permafrost, continuous permafrost.
2) The physical properties of the material.
3) The moisture content of the material.
4) The frozen/unfrozen state.
5) Ice content in the material.
6) Proposed timing for construction, i.e. winter, summer.
7) Anticipated density in the embankment.

Satisfactory performance can be expected under conditions where silts and clays having moisture contents near the optimum (plastic limit) are excavated in the unfrozen state and placed during the summer months with controlled compaction. Equally satisfactory performance can be expected from frozen high ice content silts and clays excavated in the winter months, placed in the core of large embankments and protected by an envelope of better quality material of a thickness sufficient to ensure that the silt/clay remains permanently frozen.

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Satisfactory performance subject to maintenance for differential settlement can be expected in using silt and clay in the frozen, high ice content condition placed in the winter in shallow fills and later capped or enveloped with a better quality materials. Equal performance can be expected in shallow fills constructed in the winter months using optimum moisture content clay and silt from sources subject to seasonal frost only. These fills would require later compaction and capping during summer months with the same material.

Totally unsatisfactory performance can be expected in attempting to utilize these materials in a frozen state to construct total embankment of any thickness. High embankment containing frozen silt and clay which will be subject to thaw will not provide satisfactory performance.

The designer's decision on the use of clay and silt in embankments will be influenced by the economics of obtaining more stable material. When specific severe cost alternatives become evident when all geotechnical data is available, the use of clay silts will only be proposed when its use has been validated by embankment stability analyses. Design decisions will also be influenced to a large measure by whether the available clay/silt is in a permafrost location or subject to seasonal frost only. Moisture contents in material in a seasonal frost area can be determined accurately through regular test borings. Moisture contents (ice content) determined by test borings in permafrost can be misleading if the material contains ice lenses and designers will tend to avoid use of this material except under certain conditions of enveloping with other more stable materials.

Where the designer has determined that satisfactory performance can be anticipated in the construction of embankments with silt and clay the design will proceed with the utilization of these materials. In these cases, special consideration will be given to slope angle and protection against scour and erosion. This will be necessary due to the susceptibility of these materials to small variations of moisture content when not protected by enveloping or vegetation.

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SECTION A-5

EROSION CONTROL

Erosion control in road-side ditches and on cut faces will generally be by the following methods or appropriate combinations thereof:

(i) Natural revegetation of backslopes by using vertical cuts as earlier described.

(ii) Seeding, mulching and planting of slopes with the use of items such as fabric mats or blankets for added protection in critical areas. A program of on-site experimentation into suitability of seeds and plants as well as revegetating techniques was undertaken last summer. See Section C for further information.

(iii) Blanketing slopes and ditch bottoms with stable free draining granular materials. The possible use of wood chips to retard erosion in special areas is also being considered.

(iv) Benching of cut and fill slopes to provide deposition areas for sheet flow along slopes particularly during the critical early stages of stabilization.

(v) Special dispersal areas or settling basins will be provided for ditch flow prior to its entry into aquatic habitat so as to eliminate or minimize siltation. An effort will be made to utilize depleted borrow areas for settlement of sedimentation where physically feasible and where compatible with the proposed sequential land use of the depleted borrow deposits.

SECTION A-6

CULVERT DESIGN

Due to the lack of hydrological information in the area, the determination of a 50 year flood flow cannot be carried out in the normal manner. A hydrological consultant has been retained to study drainage and run-off characteristics for the area in the hope that relationships can be developed which will permit a reasonable estimate of design flood discharge with related exit velocities. Such relationships are also being sought for small culverts as well as the larger ones.

It is recognized that the drainage design in the virgin territory in question involves considerably more investigation and reasearch than would be required in an area where drainage data is more available. It should be noted that drainage design for overland flow can only be accomplished with very accurate topographical information for the areas adjacent to the right-of-way. The airphoto mapping should permit a reasonable determination of small culvert sizes and approximations of the locations, however the actual locations will have to be established during the pre-construction survey in the field.

The extent and detail of the culvert size and flow calculations data will be provided for more major culverts. All culverts in excess of 60" diameter are being designed in accordance with guidelines

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produced by the Department of Environment - Fisheries which require that the maximum velocity through the culvert on the basis of seven days delay after the peak runoff in a 50 year return, be five feet per second or no greater than the velocity in the adjacent stream. On the basis of these guidelines, the Department of Public Works consultants, Bolter, Parish and Trimble Limited produced a full report regarding the Hydrology Study for the design of culverts from Mile 297 to 345. In addition this Consulting Engineering Firm produced a report in January 1973 entitled "Hydrology Study of Bridge Crossings Mile 297 to Mile 550, Mackenzie Highway".

It is not possible to repeat here the various design criteria used in these reports, however full distribution of the reports were made to all agencies within the Environmental Working Group. The D.P.W. consultant reports were evaluated by the Hydraulic Design Assessment Committee of the Environmental Working Group and they produced a report on May 23, 1973 which in synopsis reads as follows:

SYNOPSIS

The hydrological analysis by D.P.W.'s hydrological consultant meets the approval of the Committee. The small drainage area studies being conducted this year in a joint program by D.P.W. and the E.W.G. will be used to evaluate a more reliable delay discharge for fish passage at culvert installations.

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Culvert size and location should be specified on final design submissions for stream crossings along access roads.

The final design submissions for the 19 major culverts between Mile 305.1 and Mile 342.4 were checked by performing backwater computations. It was indicated that four of these installations will be subject to mean velocities in excess of five feet per second for the fish migration delay discharge. The designers have recommended baffles for these installations in order to facilitate fish passage. The model study being carried out by the Canada Centre for Inland Waters to determine the optimum baffle design is considered to be of top priority. The model study will be closely related to fish swimming performance studies and hydrological studies presently being carried out in the field. It is recommended that D.P.W. consider adopting the culvert backwater program developed by members of the Committee in order to reduce the rather large design costs that have been estimated. A more comprehensive analysis of the icing problem at highway crossings of streams is required in which the analysis should be directed to how the highway creates icing problems, and to how these problems can be eliminated or reduced by design.

With respect to the proposed orthophotomapping, provision should be made to extend the mapping about 4,500 feet from the centreline of the highway at stream crossings. It is strongly urged that all mapping be referenced to the Geodetic Survey of Canada

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horizontal and vertical datums in order that the final product will have a truly multiple use.

It is recommended that in the case of culvert installations in permafrost that an attempt be made to have the inlet of the culvert situated in the natural streambed.

SECTION A-7

BORROW PITS

The number of holes drilled under the geotechnical program for potential borrow areas varied from deposit to deposit depending on the nature of the land form involved and the amount of drilling that was found both necessary and feasible to reasonably define its contents. Since the geotechnical program is carried out prior to the final design process and since the amount of excavation required at each borrow site is normally determined during the final design process, it would be difficult for the driller in the field to know what level the borrow pit might be excavated to. It is, however, anticipated that there will be no difficulty in this regard as holes have been drilled well below the lower limit of materials that might be considered for use in embankments. Any requirement for an increase in the geotechnical program for borrow areas must be assessed under cost and time factors.

While a fairly descriptive proposal for the development and restoration of borrow pits can be provided in the design submission, it must be recognized that there are many variable factors involved that can result in significant changes to the actual pit development and restoration, particularly from the dimensional aspect. Typical factors or situations of this nature would be:

- variations in shrinkage factors encountered as opposed to those estimated for design;

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- variations from estimated quantities as a result of using assumed level original cross-sections for design;
- gradeline adjustments found necessary during construction;
- variations in conditions of the material in the deposit due to seasonal and climatic conditions at the time of its development; this will affect the manner in which it can be developed to a greater or lesser degree.

It is therefore, emphasized that the proposals that could be submitted for borrow pit development and restoration would be realistic only in a conceptual sense with adequate flexibility dimensionally to accommodate the many variables that are inherent in highway construction.

The procedure followed by the Department of Public Works in borrow material searches is to attempt to identify potential borrow areas with the use of airphoto interpretation. When geotechnical test drilling is carried out in the field, test holes are spotted in accordance with the airphoto interpretation. The geotechnical investigation is essentially a search for materials and for that reason 1, 2, 3 or possibly 4 bore holes are drilled in any potential borrow area. This is done with full appreciation of the fact that only a portion of those areas drilled will yield adequate borrow material. The drilling program takes into account that even where adequate material is located, other factors involving economics of various types of equipment, haul and environmental impact will further reduce the number of tested areas to the number finally utilized as borrow pits. For this reason it is not possible to carry out in the preliminary geotechnical assessment a complete delineation of exact materials within a proposed borrow area and the delineation of a frost line in various areas of proposed borrow pits.

The Department of Public Works feel that through a combination of airphoto interpretation, centreline bore holes and borrow pit drilling that sufficient information is available to prepare a final design with the designation of borrow pits for use on that contract. With the variations in borrow useage that will be caused by scheduling and by weather, further and more accurate geotechnical investigation into designated borrow pits is not warranted prior to tender call.

After award of contract and commencement of construction it is imperative that additional geotechnical information be obtained to delineate over-burden quantities, frost line and actual opening of those pits. It is the Department of Public Work's position that this information can be adequately and effectively obtained in advance of the construction of the road by travel on light-weight vehicles with drills into proposed borrow areas in advance of construction.

SECTION A-8

EFFECTS OF CONSTRUCTION ON FISH AND WILDLIFE

With regard to the effects of construction on fish, it is proposed to have all construction carried out in accordance with Land Use Regulations with specific emphasis on the provisions with respect to streams and other aquatic habitat.

Available literature and discussions with various authorities shows that the problems that construction activities might create with respect to wildlife are not clearly defined and/or understood. A proposal was obtained from an environmental consultant to study the moose densities, migration habits and susceptibility to construction activities at a cost of $85,000. The proposal was submitted for client consideration but as yet no advice to proceed or otherwise has been received.

The D.P.W. environmental consultants have been commissioned to work with Canadian Wildlife Services and Fisheries Service to review and study all available information with respect to the possible effects on fish and wildlife populations by construction activities and to arrive at a consensus regarding the effects that can be anticipated along the Mackenzie Highway together with desirable and feasible control measures and construction scheduling guidelines.

At a meeting held in Yellowknife in early June 1973 to discuss the Deficiency Report it was considered that the original response by D.P.W. was somewhat ambiguous. At that time it

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was clarified that the Department of Public Works is awaiting direction from Technical Services Branch of I.N.A. before commissioning any studies relative to construction timing. The Department of Public Works has advised its environmental consultants to confer with Environmental Wildlife Service and Fisheries Service and to study available information with respect to possible effects on fish and wildlife by construction activities. However, no full scale study will be undertaken.

With respect to the possible effect on fish, guidelines have been established by DOE Fisheries Branch which restrict construction activities in streambeds which are identified as having fish migration. This restriction is to apply during the period of fish migration for spawning. The exact times related to each stream will be determined by the DPW Environmental Consultants and information relative to the restrictions will be contained in the Department's contract documents.

Further information on this subject is contained in Section B-5 and B-6 of this report.

SECTION B

SECTION B-1

PONDING AND SURFACE DRAINAGE

A. 1. Terrain Characteristics Affecting Overland Flow

There are significant variations in the terrain characteristics for the length of the Mackenzie Highway which has in turn resulted in significant variations in the requirement for drainage facilities in and along the highway.

2. Drainage Areas and Design Flows

The Departments hydrology consultant has conducted a study of the hydrology of this area and as far north as Mile 725, has identified the drainage basins and calculated design flows for the rivers and streams crossed by the alignment. The results of the work carried out to date by this firm will be presented in the following reports:

(a) Hydrology Study and Design of Culverts will be covered in all Design Submissions by the Hydrology Summary, Supplemented as required with additional Hydrology Reports.

(b) Preliminary Bridge Crossing Report, Mackenzie Highwav, Mile 550-725.

The streams dealt with in the above noted reports are those having design flows requiring bridges or culverts draining areas larger than one sq.Mi. Localized areas immediately adjacent to the alignment generate the overland flows and predominantly seasonal flows in the small gullies and water courses crossing the highway alignment. These localized flows relate to the drainage design involving culverts up to 60 inches in diameter.

The determination of drainage basins and design flows for the smaller gullies and water courses does not lend itself to the procedures used for the larger streams because of the general lack of detailed information on topography and run-off characteristics that would be necessary to isolate and quantify the relatively small and localized areas involved. During design such flows must therefore be largely established on a judgement basis assisted by airphoto interpretation, topographic mapping where available, ground reconnaissance of the drainage basin where practical and feasible, and probably most important a study of the channel or water course characteristics at the proposed crossing site to estimate volumes of historic flows. Such flow estimates can be confirmed or modified as required during the pre-construction or early construction stages of a project as more information is accumulated with respect to the localized terrain adjacent to the highway alignment.

3. Culvert Sizes and Locations

The sizing and location of bridges and culverts larger than 60 inches in diameter has been determined by the Department's hydrology consultant.

The determination of the size of culverts up to 60 inches in diameter for the small gullies and natural water courses is based on flow judgements as described above. The location of such culverts coincides with the location of the gulley or water course which is invariably obvious.

In the case of culverts required to accommodate overland flow where there is no apparent natural drainage course, the volume of flow involved is only one of many factors involved in determining the need for size and location of culverts. Using a minimum 30" diameter, the majority of these cases, the flow capacity of the culvert is not a determining factor for the installation proposed. Overland flow normally tends to migrate toward streams and natural drainage courses and remains as overland flow for only a relatively short period of time.

Figure 1 is a simplified illustration of the migration of overland flow towards natural water courses and the effect that a roadway, either with or without ditches, has on this migration. There are of course many variations in drainage patterns because of variations in terrain, slope vegetation and soil characteristics, however the principle remains generally the same.

Referring to Figure 1, it can be seen that the overland flow occurring within area a, b, c, would normally continue through area a, c, d, as overland flow and would enter the natural water course over its length from a to d. With the introduction

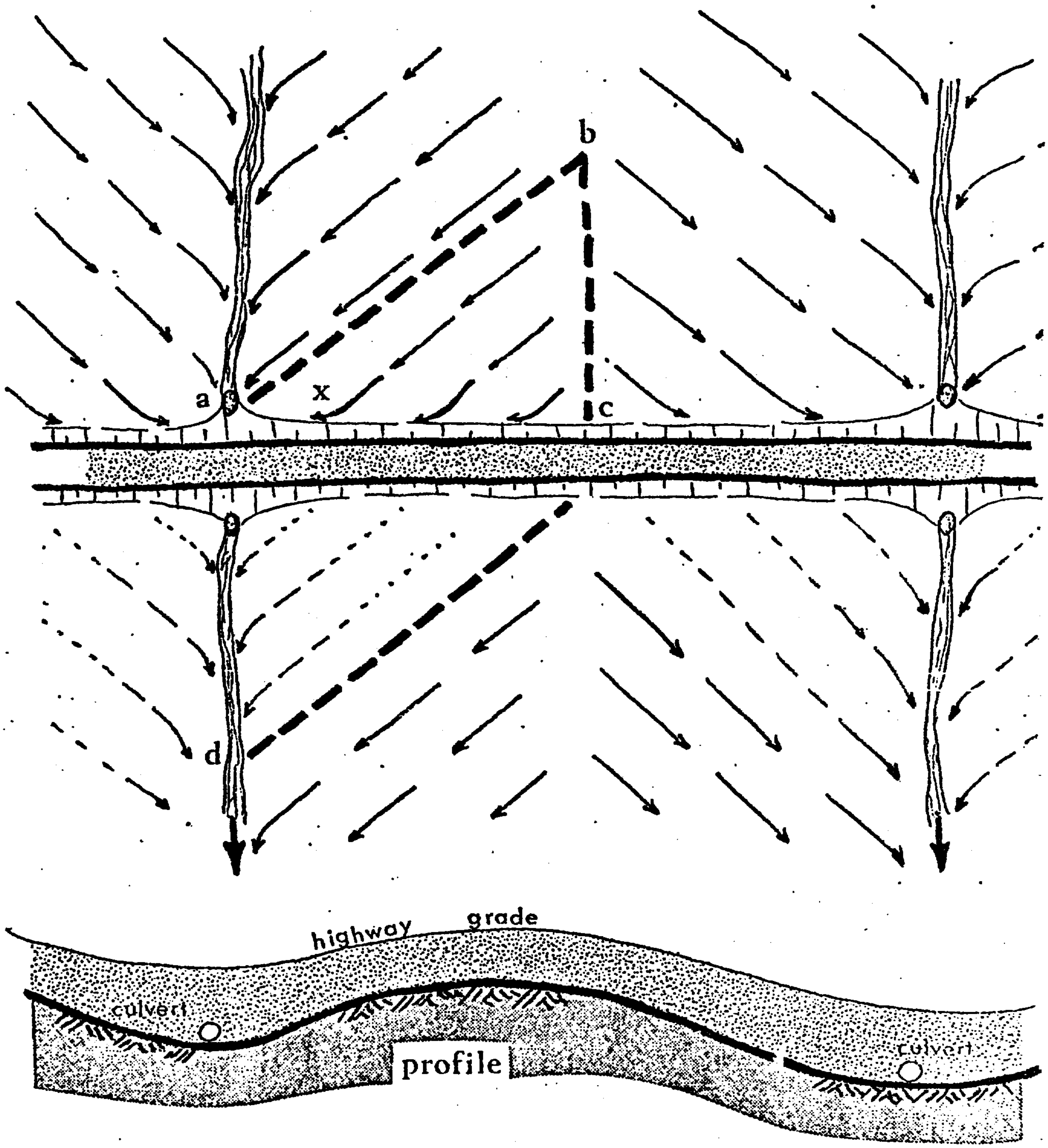

fig. I. roadway effect on overland flow

of the roadway however the overland flow from area a, b, c, is converted to channelized flow along a, c and enters the natural water course at point a. The basic effect on overland flow brought about by this situation is that the overland flow within area a, c, d is reduced to only that resulting from precipitation occurring within that area i.e. the overland flow from a, b, c would no longer flow across this area. The result on flow in the natural water course is an increase in flow volume at point a. This relatively small increase gradually diminishes from a toward d and immediately downstream from d there would be no difference from the flow that would occur without the presence of the roadway embankment. The only variation would be that change in total water volume entering the drainage course as a result of changing overland flow to channelized flow along a, c. Relative to the total flow in the natural drainage course, this discrepancy is insignificant and, in the majority of cases, so is the increase in flow that occurs between a and d.

The area of overland flow affected by the presence of a roadway in a given piece of terrain is proportional to distance a, c and angle X. These factors are controlled by surface relief and other terrain characteristics which affect drainage patterns. In cases where angle X approaches zero, the overland flow tends to migrate parallel to the roadway and regardless of distance a, c, there is a relatively minor need for, and benefit available from culverts to accommodate overland flow.

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As angle X becomes larger and depending on the length of a, c the area of overland flow affected and therefore the water volumes involved become progressively larger thereby making the need for culverts to accommodate overland flow considerably more significant.

The need for culverts along a, c is governed basically by the volume and velocity of flow that is channelized along a, c together with the capability of the materials through which flow occurs to withstand such flows within acceptable limits of scour, erosion and/or siltation. The critical factors in this relationship are the area and runoff characteristics of area a, b, c, the gradient along which channelized flow will occur between a and c, and the erodibility of the materials along which flow will occur between a and c whether this be through an excavated ditch or over undisturbed naturally vegetated terrain. The gradient along which the channelized flow will occur is readily available from site survey information. The erodibility of the materials can also be readily predicted from geotechnical information and information on surface vegetation along the edges of the right-of-way. The area of overland flow affected and the related runoff characteristics are however not readily available during the design stage of a project as indicated above. It is therefore normally accepted practice to make a best estimate of the requirement for smaller culverts during the design phase of a project and to confirm or modify the requirements during the pre-construction and early construction stages of the project

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as more detailed information becomes available on localized areas of terrain immediately adjacent to the highway. It is again pointed out that normally the culvert capacity is not the governing requirement for the number or location of culverts provided for overland flow and consequently there is a very conservative safety factor on the capacity of such culverts.

In cases where the anticipated channel flow adjacent to the roadway is not compatible with the gradient and erodibility of the materials involved, the drainage solution can be applied to one or more of the three basic factors involved as follows (refer to Figure 1):

(a) The channelized flow volume can be reduced by the introduction of one or more culverts between a and c. Depending on the dispersal that can be provided at the exit of such culverts, this tends to offset the reduction in overland flow within area a, c, d. By deposition of suspended sediments in areas of undisturbed terrain it also reduces the siltation that might enter the natural water courses.

(b) The gradient of the channelized flow can be reduced to reduce flow velocities. This approach has limited application on contiguous roadside ditches.

(c) The erosion resistance of the materials can be improved by using granular linings, rip rap, erosion blankets, revegetation, etc. Ditch checks can also be included in this type of solution, however it should be recognized that the net effect of ditch checks is basically a reduction in ditch gradient.

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It is a general design policy that drainage water will not be carried along the roadway for distances of more than 1,000 feet. This does not necessarily mean that this automatically becomes the maximum spacing between culvert installations. In certain types of terrain it is frequently possible to disperse drainage water away from the roadway on both sides of the roadway without any culvert installations.

4. Ditches

Longitudinal ditching is used where typical cross section types "A" or "B" are identified on the plans. Wherever possible such construction is only carried out in frost free or thaw stable areas where there would be no undesirable effects as a result of changes to the thermal regime brought about by the ditching.

In terrain areas where a minimum of disturbance to the underlying terrain is mandatory, particularly where an ice rich permafrost condition is known to exist, the construction involves a cross section type which avoids ditching. Where some ditching is unavoidable to eliminate undesirable ponding that cannot be handled in any other manner, special ditching techniques are proposed which are described in some detail in the Chapter dealing specifically with ditching in permafrost terrain.

Whether or not ditching is used along the roadway in diverting and channeling flow into natural drainage course has no significant effect on the total volume of water that eventually finds its way into the drainage course. By referring to Figure 1 it can be seen that the total flow in the natural drainage course downstream from point "d" would remain essentially the same before and after road construction with the only difference being a reduction in ground water in isolated areas. Some increase to flow volumes would occur between "a" and "d" however this normally is also insignificant relative to total flow in the water course.

B. Design Criteria

1. Volumes of Surface Drainage

The procedures followed in determining the drainage areas and volumes of drainage have been outlined above. As is normal practice, the design of small culverts is subject to confirmation or modification during the pre-construction or early construction phases of the project as more information becomes available on the localized terrain immediately adjacent to the roadway.

2. Subsoil Conditions at Culvert Sites

Avoiding disturbance to highly erodible soils at culvert locations during culvert installations will have little or no beneficial effect in improving their resistance to scour during peak culvert flows particularly in the area of the outlet. The removal of such materials to some depth and replacement with scour resistant materials is a normally accepted procedure that has proven itself through years of application.

3. Additional Geotechnical Information

Geotechnical information in addition to that shown on the design

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submission has been obtained during the winter of 1972/73. The geotechnical information available is generally adequate to determine the erosion potential of materials affected by the drainage design and to avoid detrimental changes to the thermal regime of any existing permafrost.

4. Control of Ponding by Ditching

In terrain areas where construction involving an "A" or "B" cross section is feasible and such is employed, many of the ponding areas upslope from the road are connected and drained by the contiguous roadside ditch. It is also possible in many cases to vary the depths of such ditches to further improve their effectiveness in controlling ponding. It is considered that where terrain and soil conditions are such as to permit this basic type of roadway construction, there will be no abnormal detrimental effects from controlling potential ponding by way of the contiguous roadside ditch.

In areas where disturbances to the terrain surface are undesirable, potential upslope ponding is controlled by cross drainage culverts wherever feasible and practical. This would basically involve the typical cross section type with the minimum amount of ditching.

In generally irregular terrain many indicated potential ponding areas or profile sags are localized conditions and are virtually eliminated by the placement of roadway embankment. Others extend a relatively short distance beyond the embankment limits and are effectively and economically eliminated by filling with regular embankment materials or with waste materials unsuitable for embankment construction. It is also a fairly frequent occurrence that the sags have drainage away from the roadway on both sides and therefore require no special action.

5. <u>Offtake Ditches and Dispersal of Drainage</u>

Regardless of ground conditions, offtake ditches are normally only excavated in cases where it is necessary to do so to remove the drainage water away from the outlet of the culvert, i.e. to eliminate ponding at the outlet. Where offtakes are constructed they will be designed in accordance with data outlined in Section A-3 of this report.

Where possible offtake ditches may be necessary in some instances, dispersal of drainage water over undisturbed natural terrain downslope from the roadway is preferred because of the resistance of such terrain to erosion and its removal of any silt load from drainage water before such water enters a drainage course. In cases where the flow upstream from a culvert is concentrated into a gulley, this gulley is usually available to pass the drainage water on the downstream side of the culvert.

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SECTION B-2

CONSTRUCTION IN SAND

In the Mile 545 - Mile 585 section, the highway passes through extensive areas of sand dunes. The situation is encountered in many short sections along the Mackenzie Highway. The sand in this area will be subject to wind erosion. It should be noted that the wind drifted sand will generally accumulate in the roadside ditches and there is little possibility of drifting off the right-of-way and the killing of the present vegetation adjacent to the roadway.

Construction problems have been encountered in the utilization of this material in maintaining a well compacted roadway. To offset this problem the first several miles of the Martin section has now been capped on the road surface with a silt-clay material approximately four inches thick. This application has been successful and has not been damaged by heavy construction traffic and will be utilized on the section 545 - 585 where material is available. Because of a continuous sand material through the section difficulties are being encountered in obtaining sufficient quantity of silt and clay. The provision of the material will involve long hauls.

The work described above for the roadway and for the shoulder slopes will protect the sand in that portion and it is expected that natural vegetation will return to the shoulder slopes very quickly. It is considered that alternate methods of prevention

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of wind erosion of the sand material in backslopes can be readily accomplished. Evidence of this is already present in excavations which were undertaken during the fall of 1972 and the winter of 1972/73 in that native growth has returned to some amount to the cut backslopes in the sand.

The accumulation of native growth into the cut backslopes is being carefully observed in conjunction with a pilot vegetation program which was implemented in August and September of 1973 by the Department of Public Works.

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SECTION B-3

HIGHWAY AESTHETICS

Discussions regarding the priority of highway aesthetics has taken place between D.P.W.'s design teams and landscape architects representing Engineering and Architectural Branch of I.N.A. It has been concluded in these conversations that the Mackenzie Highway must be classified as one which has a transportation utilization of 70% and aesthetic and recreational utilization of only 30%. Consideration of these percentages is a guiding factor on D.P.W. design teams as it relates to the overall environmental, economic, engineering and aesthetic aspects of the Mackenzie Highway.

Department of Public Works Environmental Consultants are carrying out a complete landscape architectural evaluation of each section of the highway. The format for these evaluations was contained in the preliminary design submissions for Martin and Shale. Landscape Architects of the Environmental Consultants will work with the D.P.W. Design Team and where possible the design will reflect aesthetic considerations.

On the subject of vertical form it should be kept in mind that the vertical alignment on the Mackenzie Highway will be controlled to a large measure by the existing ground topography, gradline economics and in particular the geotechnical evaluation of the permafrost conditions and moisture conditions along that alignment. For these reasons it will not be possible to always apply the freedom in design of vertical curves necessary for aesthetic purposes.

With respect to the concern for horizontal curvature, the position taken by the Department of Public Works again is that the aesthetic considerations of longer curves cannot be followed on this highway to any large measure due to the restrictions placed by other environmental concerns. Considering the intended usage of this highway continuous curvilinear alignment would represent an increased hazard to traffic while passing on the gravel surface under dust conditions. Other factors affecting the horizontal form are the I.N.A. instructions to eliminate existing clearing scars wherever possible by placing the alignment in these locations. These would include existing siesmic lines which represent long tangents and equally the C.N.T. landline which generally involves long tangents. This is not to discount the possibility of lighter curves wherever this is possible and every attempt will be made by D.P.W. design teams to fit the horizontal form to a continuity with existing terrain.

Accepted policy is that location, design and implementation of selective clearing will be done after completion of grading operations.

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Concern has been expressed relative to contour grading at the junction of cut and fill slopes. It should be noted that it is normal practice in the construction of the highway that rounding of all slopes take place as a normal part of construction activities.

Viewpoints and potential recreational areas will be delineated in the final design submission. These final design submissions should be reviewed by the Employment and Local Impact Working Group who have a sub-committee now studying viewpoint and recreational requirements along the Mackenzie Highway.

It is considered general practice to provide a screen of trees between the roadway and the borrow pits. This plus the vertical position of the pits and the roadway should reduce to a minimum any adverse visual impact from borrow pits. Since borrow pits are required as a source of material they must be located where this material can be found. There will be a minimum number of situations where there will be adverse visual impact due to construction of borrow pits and attempts will be made to rehabilitate these pits in such a manner as to reduce that visual impact. Final design submissions will outline typical rehabilitation treatments.

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SECTION B-4

FILL OVER CULVERTS

The possibility of long term effects due to permafrost aggradation in fill sections around the culvert is a major problem. The problem is aggravated by timing and scheduling of the installation of culverts. It is complicated further by construction restrictions imposed by the Department of Fisheries to ensure no adverse effects on the migration of fish during spawning periods.

Considering all other environmental aspects, it would appear that the most desirable time for the construction of culverts is during the winter months. For culverts in excess of 60" diameter sub-excavation will be required. It is anticipated that a majority of the settlement problems in culverts will be eliminated by placing a substantial bedding of good quality compacted material.

Backfill around the major culverts will be carried out utilizing best quality material compacted to 95% proctor density. The compacted backfill immediately adjacent to the culverts will have a gentle slope away from the culvert longitudinally to the highway. The remainder of the backfill will then be constructed under normal construction procedures.

For culverts less than 60" diameter, sub-excavation and backfill will be utilized in the same method as described for the culverts in excess of 60" diameter, recognizing that this is not practical in all cases since this size of culvert is placed continuously with the construction of the highway. Land Use Regulations at

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the present time prohibit the sub-excavation and disposal of material adjacent to the culvert sites. It is therefore not possible to dispose of this material without substantial delay to the construction operation. As culverts of this size are spaced generally less than 1,000 feet apart, stopping of operations to allow disposal of sub-excavated material and placement of bedding without damaging the surrounding terrain would be economically prohibitive. Experimentation has been initiated on a stretch of the Dempster Highway between Arctic Red River and Inuvik for the installation of a series of culverts where both sub-excavation and the placing of manufactured insulation will be used under the culverts. The results of this experimentation should be visually obvious in the Spring of 1974. In other locations for small culverts sizes a thin layer of bedding material will be placed over undisturbed ground. This will tend to raise the inlet of the culvert above the surrounding ground but it is assumed that permafrost degradation will be beneficial to the road in that the culvert will settle below the existing ground level at inlet elevation and will function without ponding of water after approximately two or three summers.

It will not be possible to ensure against some settlement on the culverts. The culvert design used by the Department of Public Works will take this into account by utilizing thicker gauges than normal thus increasing the safety factor against collapse due to settlement. It must be considered that on this type of road and under these type of construction and design conditions there will be some culvert failures. When these occur it will be necessary that maintenance forces be prepared to immediately replace the culvert before any substantial environmental damage results.

SECTION B-5

EFFECT ON WILDLIFE

Long term effect of right-of-way clearing, highway construction and ultimate highway use on moose is being reviewed by the D.P.W. environmental consultant and the Canadian Wildlife Service. A general consensus is that the ultimate highway use will have some effect on moose but not a substantial amount of vehicle-moose collisions. The question of increased hunter access provided by the highway is a very real problem but one which does not find a solution directly from a design agency such as the Department of Public Works. It was suggested that this potential problem was one of jurisdiction which belongs within the various regulatory bodies dealing with hunting in the Northwest Territories.

Possible damage to wetland units along the highway due to alterations in the natural drainage patterns or siltation of the area is one of the major concerns of the D.P.W. design team. Every precaution will be taken to ensure that natural drainage patterns are followed and necessary action will be taken to avoid significant siltation of wetland areas. The Department of Public Works environmental consultants are studying specific areas of potential impact on wetland areas and will identify these to D.P.W. designers. The reader is directed to Section B-1 of this report as it relates to Ponding and Surface Drainage which would effect wetland areas.

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The importance of the water fowl stopover and staging areas along the Mackenzie River has been noted by DPW environmental consultants. These consultants will advise DPW concerning any construction restrictions which should be imposed as part of contract documents for specific areas where the highway is in close proximity to the Mackenzie River and to areas of stopover and staging for waterfowl.

1. The effect of construction activity on wildlife is not well known. There is very little written on this subject in a pure objective style. Opinions, when they can be found, tend to be emotional. The recommendation of the E.W.G. that construction activity should cease from December to April in order not to disturb the moose fits into this emotional category. From past experience in building highways through moose country, most notably the Western National Parks in the Rockies, moose mortality was not noticeable. The moose frequently came into the cleared right-of-way, and although they never come closer than ¼ mile to any moving machinery, they did not appear to be unduly disturbed. This also happended frequently during the winter months when bulldozers and rock drills were the only machines working. The latter machines are extremely noisy, but apparently had little effect on nearby moose. During the summer it was common to see several of the moose feeding in a shallow pond only a few hundred yards from the edge of the highway, upon which hordes of tourists were passing.

2. "Some creatures thrive on change. There are now more moose, deer, grouse and probably even more coyotes than in Indian days. Many small mammals and birds thrive better in fields and woodlots than in the virgin forest, provided they are not poisoned by pesticides".[1] The clearing of the right-of-way (ROW) and the improvement of drainage within the ROW and adjacent forest will certainly benefit a large segment of the wildlife. "The creation of openings in the forest and the abundance of young growth following a logging operation (or the building of a highway), certainly benefit the white-tailed deer. The effects on wildlife are a mixed blessing. These same changes in habitat have pushed the woodland caribou farther back into the wilderness."[2]

3. In the pioneer days, when the population of the country was small, "the small-scale clearing of the forest actually improved the habitat of most forest species of game, and a slight pollution of lakes and streams by erosion of the land may have improved fish habitats by making available increased supplies of inorganic nutrients."[2] Thus it can be concluded that some silt carried away by streams from the ROW can be tolerated by the ecological system, and that a strict adherence to the edict of no erosion or sedimentation in the streams is unreasonable. However, nobody will argue against "increased erosion giving rise to silt laden streams no longer suited to the production of fish."[2]

4. The danger of allowing sediment to enter streams and small rivers really depends upon degree. "Excessive soil erosion and

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the transport of large quantities of coarse suspended material are detrimental, limiting light penetration in water, smothering organisms, and scouring stream bottoms."[3] Thus it may be necessary to employ a number of means to limit the transport of silt in surface runoff. The employment of silt traps, sedimentation areas (old borrow pits), ditch blocks, and flumes may be investigated. "Freshet conditions, aggravated by removal of plant cover, cause scouring and silting of stream gravels with consequent loss of eggs and fry. In these circumstances, artificial culture may be a cheaper and more practical procedure than storage-regulated flow"[3] in re-stocking an area with fish. The justification of adopting the later may be very difficult from an economic point of view, but the method should not be ruled out as a possibility.

5. "As a part of the land community, wildlife should receive consideration in all programsinvolving land use. The contribution of wildlife must be considered in aesthetic as well as economic terms, and in some cases, at least, the aesthetic values should be recognized as truly priceless."[2] In planning land use, and the Mackenzie Highway is an example of this, "Wildlife must never be separated from its environment."[1] In other words, the two must be considered as an inseparable pair in all planning. But in spite of the most careful planning, "a wildlife problem will arise when man impinges on wildlife or its habitat, or when wildlife impinges on man or his works."[2] As hard as man may try to alleviate the impact of his presence

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on wildlife, and regardless of the outcry of the environmentalists and aroused public, it must not be forgotten that "in any conflict of interest over wildlife, the future of people must receive first consideration.

6. "It is estimated that about 70% of the North American waterfowl is produced in Canada."[4] Thus the maintenance of the southern wintering grounds in the United States and Mexico bears no relevance unless the nesting grounds in Canada remain in a useable condition for waterfowl. The supply of suitable habitat for reproduction is a prime factor in determining the numbers of waterfowl. In other words, what Canada does in maintaining the nesting grounds within her boundaries will determine the fate of North American waterfowl. "The misconception that the most important waterfowl breeding areas lie in the remote Canadian north is widely held. Actually, the prairies and aspen parklands are the heart of the waterfowl breeding area. The Northwest Territories and the Yukon total 1.5 million square miles. There is thin duck population scattered throughout, with local concentrations approaching prairie densities in favourable habitat, usually in river deltas or flood plains."[4] Although every effort should be made to preserve or alter as little as possible waterfowl areas in the Mackenzie Valley, it should be kept in mind, at least in perspective, that this area is not one of the principle nesting areas for migratory waterfowl. The numbers of waterfowl fluctuate enormously with dry or wet years on the prairies. "Waterfowl have a high reproductive potential, and

their populations have a resilience which enables them to rebound quickly when water restores the habitat."[4] As the building of a highway has very little to do with the amount of water in the surrounding country, with the exception of the ROW itself, it may be concluded that the construction of a road will not alter the population of waterfowl in any appreciable amount. It may have some effect if ponds and lakes near ROW were drained, but at present the latter is not contemplated in the Mackenzie Valley.

7. The use of fences to prevent beavers from getting near culverts is not contemplated for the Mackenzie Highway. Maintenance personnel may experiment with them at a later date, but these fences will not be built during the initial construction of the highway.

The Department is hopeful that some beaver will assist in a proposed study by damming a culvert in the very near future in order that a suggested method of discouraging the damming of culverts can be tried. This suggested method is to break the beaver dam and then insert a small diameter pipe approximately 40 ft. in length with the major portion of that pipe placed into the beaver pond. Then to assist the beaver the Department would repair the break in the dam. Apparently the beaver is aware that the dam is losing water through a small diameter pipe, but is unable to find a method of blocking the inlet. Reportedly the beaver in time becomes

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discouraged and moves away to establish a home at another location. At that time the construction or maintenance crew can remove the dam and the small diameter pipe.

1) C.H.D. Clarke - "Wildlife in Perspective"

2) W.A. Fuller - "Emerging Problems in Wildlife Management"

3) P.A. Larkin - "Effect of Manmade Changes on the Environment of Fisheries"

4) W.G. Leitch - "Problems of a Mobile Resource"

SECTION B-6

EFFECT ON FISH

The Department of Public Works considers that there will be virtually no effect on fish by construction of bridges. Precautions will be taken to ensure that there is no increase in the natural velocity of the stream or any scouring as a result of the construction of river piers. Bridge designs have been submitted separately for all proposed bridges in the section.

Culvert design is based on D.O.E. Fisheries Branch guidelines at an established maximum velocity - seven days delay - on the fifty year maximum run-off of five foot per second or equivalent to the adjacent streambed sections.

It has been a basic design consideration by the Department of Public Works where hydraulic requirements for culvert sizing is 60" diameter and less the stream would be too small to support continuing fish life. It is therefore, generally not considered necessary to design for fish passage for these culverts unless specific fish sightings have been noted for the stream in question.

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SECTION B-7

GUIDERAIL

A normal practice of construction by the Department of Public Works is to have guiderails designed and erected during the surfacing contract. This surfacing contract is expected to be called to tender up to three years after the tendering of the initial grading contract. The preliminary design submissions relate to the grading portion of the work. Since some warrants for guiderails are directly related to the height of fill as it might be effected by sloping ground information which is not now available, it is not considered that guiderail design should be detailed during the design of the grading contracts.

The design of guiderails when undertaken for the surfacing contract will be governed by H.R.B. Warrants unless directed otherwise by Technical Services Branch. There is a possibility that Technical Services Branch will direct the use of Indian Affairs developed warrants for National Parks.

Full use will be made of delineators using posts with reflectors. It is considered that these provide an excellent safety marker and assist in winter maintenance operations.

Delineators will be placed during the surfacing contracts.

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SECTION B-8

SMALL CULVERT DESIGN

In the design stage it is almost impossible to accurately foresee the exact location, length, skew angle, grade, diameter and end treatment of every culvert that will ultimately be installed. The larger culverts are more obvious; the location to within ±50' is usually dictated by circumstances. This generally holds true for pipes of 48" diameter and larger. Pipes over 60" diameter are being studied by consultant engineers. Since the smallest culvert that will be installed is 30", there remains only three sizes in the grey zone of inaccurate forecasting, namely, 30", 36" and 42" diameter.

In a great many cases where culverts will be installed there will be a stream running at least during the month or two immediately following the annual disappearance of the snow. There will be indications on the stream banks if the water has been higher. A cursory examination one-half mile up and downstream will usually suffice to determine whether or not debris can be expected. When the clearing has been completed, the stripping taken care of if there is any, and the slope stakes have been placed, the drainage situation may look substantially different. A preconceived location and diameter may no longer be valid. Thus it is mandatory that the resident engineer or supervisor must be empowered to make decisions involving culverts in the field during construction. If this is the case, and it has been general highway engineering practice in this Department for several decades, it would be

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folly at the design stage to painstakingly indicate the precise location and diameter of every culvert to be placed.

The selection of a particular diameter for culverts between 30" and 60" will ultimately rest on the experience of the resident engineer. The selection will be based on his past experience, topographic maps, airphotos, airphoto mosaics, and the combined experience of his assistant resident, inspectors and instrument-men.

It may be possible that during this field study and diameter selection process, a certain stream may require a larger cross sectional area than that provided by a 60" pipe. Normally streams of this size are studied in the pre-engineering stage by consultants, but this depends on recognizing at any early design stage that a stream will require a pipe larger than 60". This may not always be the case, and hence the resident will have to deal with the problem in the field during construction. In solving this problem the resident has the option of installing twin 60" pipes side by side, or even three if necessary. The latter will carry an enormous quantity of water and should suffice to solve borderline cases which were not studied by the hydraulic consultants.

The selection of grade and elevation will be determined by the streambed profile, general cross-fall of the surrounding terrain, and ultimately the ability of the soil to resist erosion. The

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resident will also determine whether or not rip rap will be used for earthwork protection at the culvert ends as well as improving the appearance of the installation.

The end treatment of small pipes will be decided in the field by the resident engineer. The use of rip rap, scour aprons, headwalls, weirs, groynes and energy dissipators will be governed by circumstances as encountered. Not enough information exists to make these decisions now. Relative to this problem the reader is directed again to Section B-1 which deals with Ponding and Surface Drainage on which the subject of culverts under 60" diameter is dealth with in detail.

SECTION B-9

SPECIAL TREATMENT FOR DITCHES

Construction of the Highway will invariably result in some re-arrangement of the natural drainage pattern with the channelling of runoff into roadway ditches and offtake ditches.

In a normal stream channel the bed of the stream adjusts to the rate of flow with scour or deposition of material occurring until a balance is established.

In new channels such as the roadway ditches, an equilibrium will not have been established hence the potential for scour erosion exists with the possible transportation of materials into natural streams.

It is, therefore, desirable that the flow velocities of the anticipated runoff in the new channels, be controlled to prevent scouring of the exposed channel material and, failing this, that the runoff be channelled into areas where sedimentation may occur with minimal damage to the natural surroundings.

The determination of maximum allowable flow velocities at which scour will occur depends on numerous factors, including sediment in the water, soil characteristics, such as grain-size density, organic binder, cementation, ice content and other natural factors.

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The effects of runoff on the channel are dependent on:

1. Soil type and gradation.
2. Quantity of runoff.
3. Water and soil temperatures.
4. Degree of vegetation.
5. Grade of channel and discharge.

One of the principles to be followed in designing the Mackenzie Highway will be to avoid excavation in permafrost wherever and whenever possible. This should provide a material condition in cut sections comparable to conditions encountered in southern construction. Using Manning's Equation and the limiting design velocities taken from the Handbook of Steel Drainage and Highway Construction Products, Highway Task Force, American Iron and Steel Institute (See Table B.9.1), discharge vs. gradient curves were calculated for the ditch sections and general soil types to be encountered on the highway. (See Figure B.9.1). From experience and observation on southern projects and on some northern non-permafrost areas the limiting velocities as listed in Table B.9.1 are generally applicable.

<u>Ditch Lining</u>

For a given soil type a curve in Figure B.9.1 indicates the limiting discharge for a given gradient above which harmful erosion may occur. Therefore, theoretically, by lining the ditch with an adequate depth of material selected higher on the graph the anticipated erosion could be arrested or minimized. Depending on the horizontal length of the roadway ditches requiring this type of protection, economics may require some other, less costly method of curtailing anticipated erosion.

Ditch Checks

Recommended design velocities for use on the Mackenzie Highway have been tabulated by E. W. Brooker and Associates Limited and have been published in Volume I, Appendix "C" of the Mackenzie Highway Geotechnical Evaluation". (See table B.9.2).

For a given discharge on a given gradient for a particular area using Manning's Equation and Manning's "n" as listed in the above publication the velocity determined could be in excess of the recommended velocity for non-silt non-scour. Flow velocities can be reduced by constructing a series of properly spaced ditch checks across the width of the ditch. (See Figure B.9.7.)
Due to the physical limitations of the highway ditch depth it is considered practical to use an elevation difference of one foot between ditch check crests. For the purpose of general design and conservative design ditch check spacing was determined by using the recommended velocities in Table B.9.2. Based on these velocities, ditch grade vs. ditch check spacing were developed for various discharges. A forty foot minimum spacing of ditch checks was considered to be reasonable for construction, maintenance and effectiveness.

The calculation of the anticipated run-off i.e. discharge to which the ditches may be subjected can be determined, where possible, by scaling the drainage area from aerial photographs and estimating the flow using the modified rational formula developed by Bolter Parish Trimble Limited, Consulting Engineers. This modified Rational Formula was published in the Hydrology Study and Design of Culverts, Mile 297 to Mile 345, Mackenzie Highway, November 1972.

The designer's judgement in determining anticipated run-off will generally be conservatively high, for, firstly, values selected for the variables in the modified rational formula were conservative and secondly, the discharge as determined for the outlet of the ditch cut is applied to the entire cut section being considered.

By employing ditch checks, ditch lining with granular or cobble material, ditch blocks with culverts diverting water out of the ditch onto natural vegetation and by a combination of ditch checks and ditch blocks reasonable measures of roadway ditch erosion protection can be devised, until revegetation has been established. It should be recognized that the Field Construction Engineer will be required to make field adjustments based on his observation and judgement where applicable.

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TABLE B.9.1

LIMITING WATER VELOCITIES

FOR THE DESIGN OF STABLE CHANNELS

Material	Manning n	Velocity ft/sec.
Fine sand colloidal.	0.020	1.50
Sandy loam noncolloidal.	.020	1.75
Silt Loam noncolloidal	.020	2.00
Alluvial silts noncolloidal.	.020	2.00
Ordinary firm loam	.020	2.50
Volcanic ash	.020	2.50
Stiff clay very colloidal.	.025	3.75
Alluvial silts colloidal	.025	3.75
Shales and hardpans.	.025	6.00
Fine gravel.	.020	2.50
Graded loam to cobbles when non-colloidal.	.030	3.75
Graded silts to cobbles when colloidal.	.030	4.00
Coarse gravel non-colloidal.	.025	4.00
Cobbles and shingles	.035	5.00

Reference:

Handbook of Steel Drainage and Highway Construction Products.

Highway Task Force, American Iron and Steel Institute.

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TABLE B.9.2

Manning's "n" for Natural Stream Channels and Design Velocities for Non-Silt, Non-Scour Conditions for use on the Mackenzie Highway.

MATERIAL	MANNING n	RECOMMENDED DESIGN VELOCITIES (fps)
Stiff Clay	0.025	2.00
Colloidal Silt	0.025	1.00
Non-Colloidal Silt	0.020	2.00
Fine Sand	0.020	1.25
Coarse Sand	0.020	1.25
Silty Sand	0.020	1.50
Silt Till	0.025	2.00
Clay Till	0.025	2.00
Fine Gravel	0.020	2.00
Coarse Gravel	0.025	3.00
Well Graded Gravel	0.025	3.00
Cobbles	0.035	5.00
Broken Stone	0.035	3.00
Shale	0.025	4.00
Vegetal-lines	0.033	3.5 Maximum

1. Table C-1 is based on channel depths being between 0.05 and 3.0 feet.
2. Aging of channels permits velocities to be increased by 30%.
3. For vegetal-lined channels increase the given values by up to 1.5 (fps) but not exceeding maximum values given.
4. Gradients should not exceed 4 percent for any drainage course.

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* References:

1. Seelye, E.E., 1956: Foundations, Design and Practice.

2. Handbook of Steel Drainage and Highway Construction Products. Highway Task Force, American Iron and Steel Institute.

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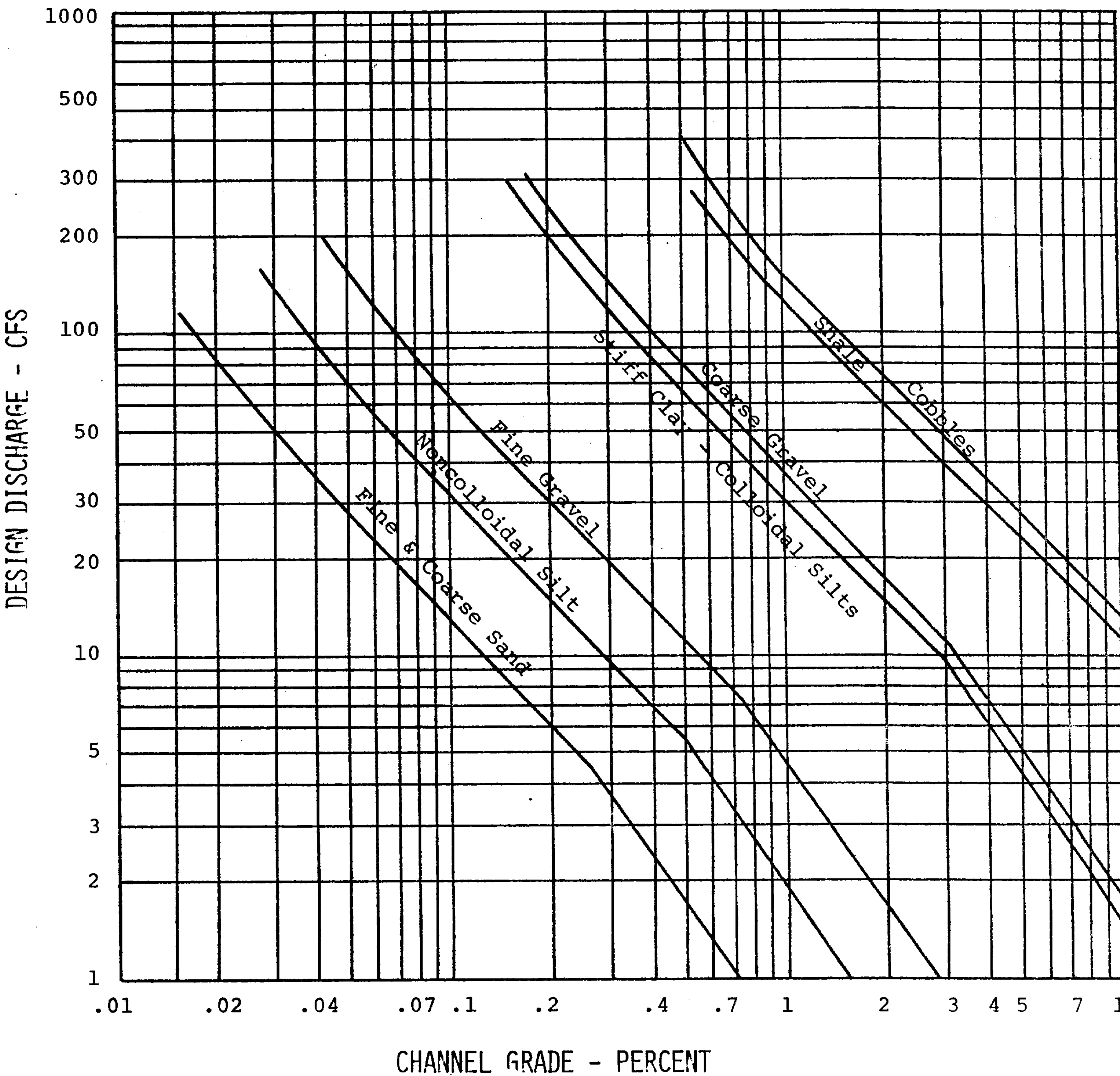
Figure B.9.1

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



Reference:
Handbook of Steel Drainage and Highway Construction Products, Highway Task Force.

Figure B.9.2

DITCH CHECK SPACING

(DESIGN DISCHARGE - 3 CFS)

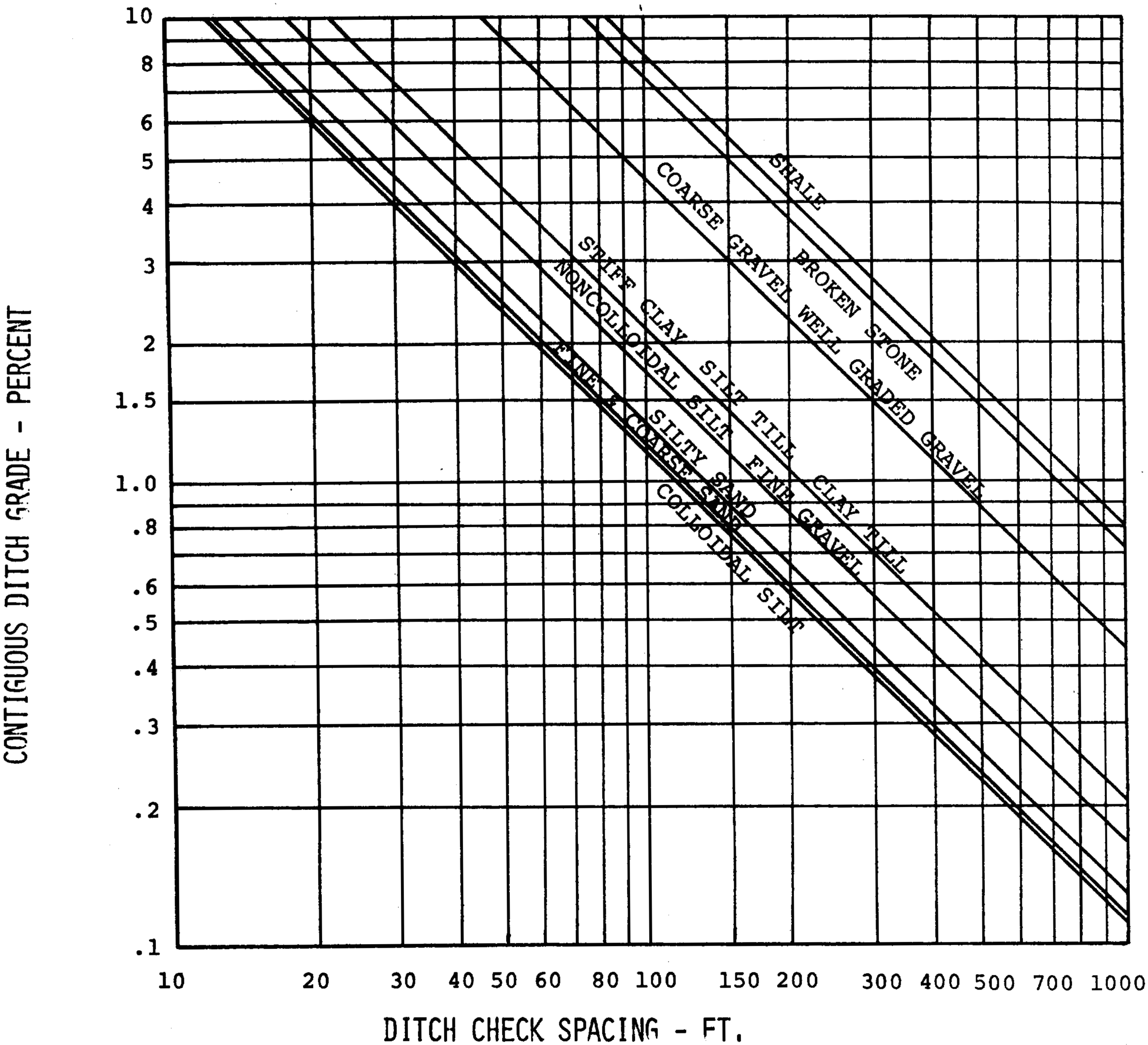


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Figure B.9.3

DITCH CHECK SPACING

(DESIGN DISCHARGE - 5 CFS)

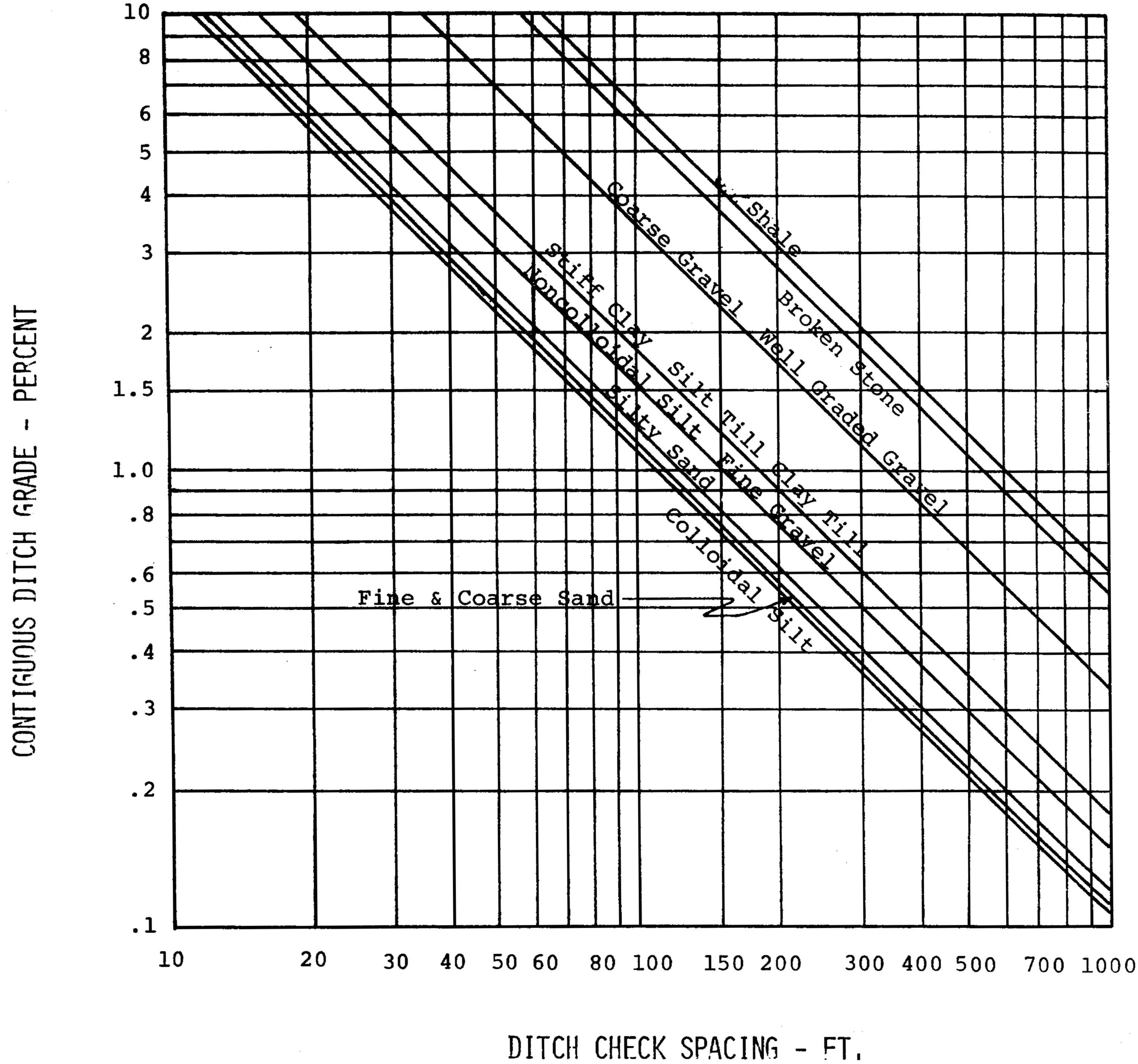

Figure B.9.4

DITCH CHECK SPACING

(DESIGN DISCHARGE - 10 CFS)

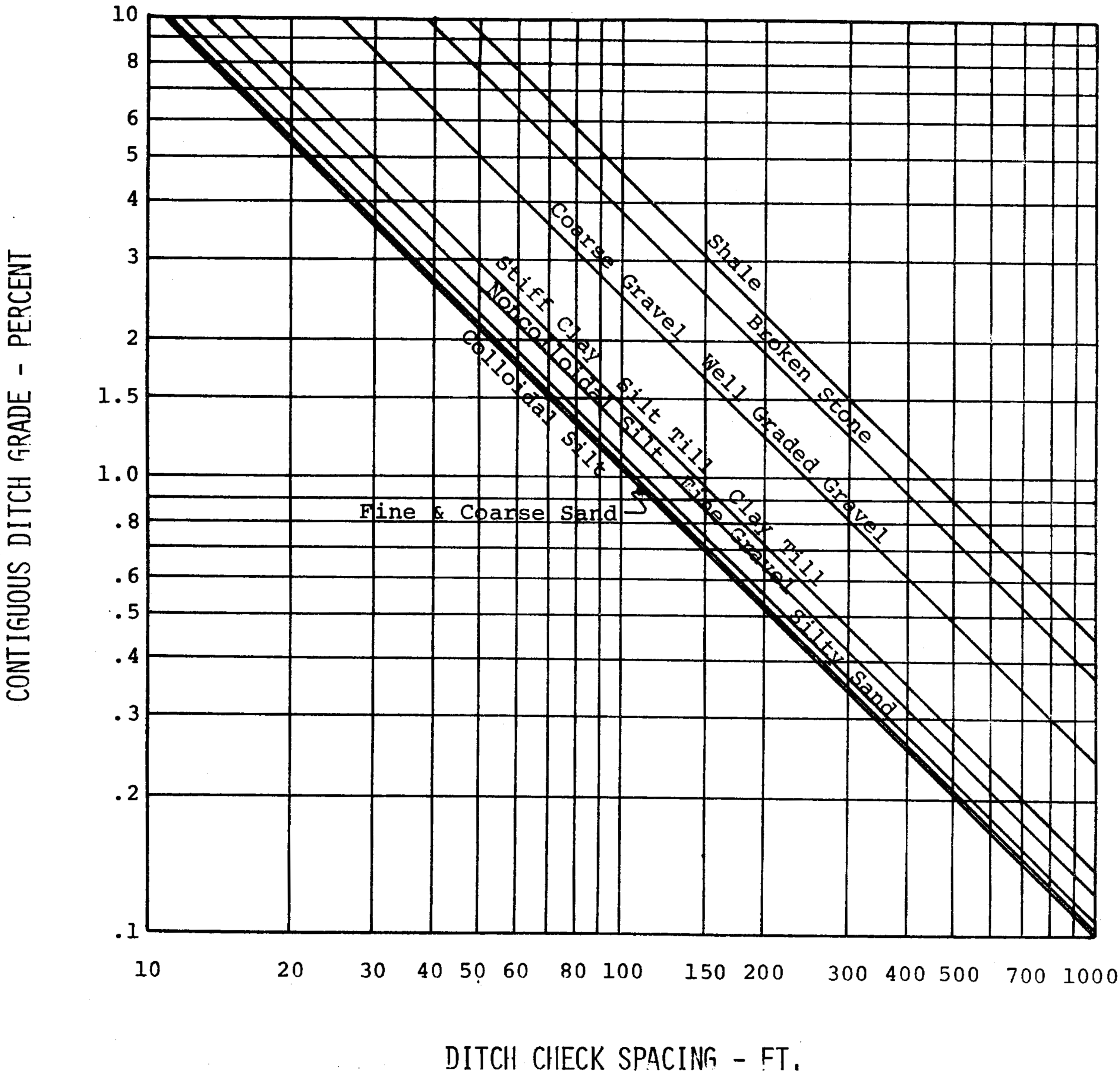

Figure B.9.5

DITCH CHECK SPACING

(DESIGN DISCHARGE - 20 CFS)

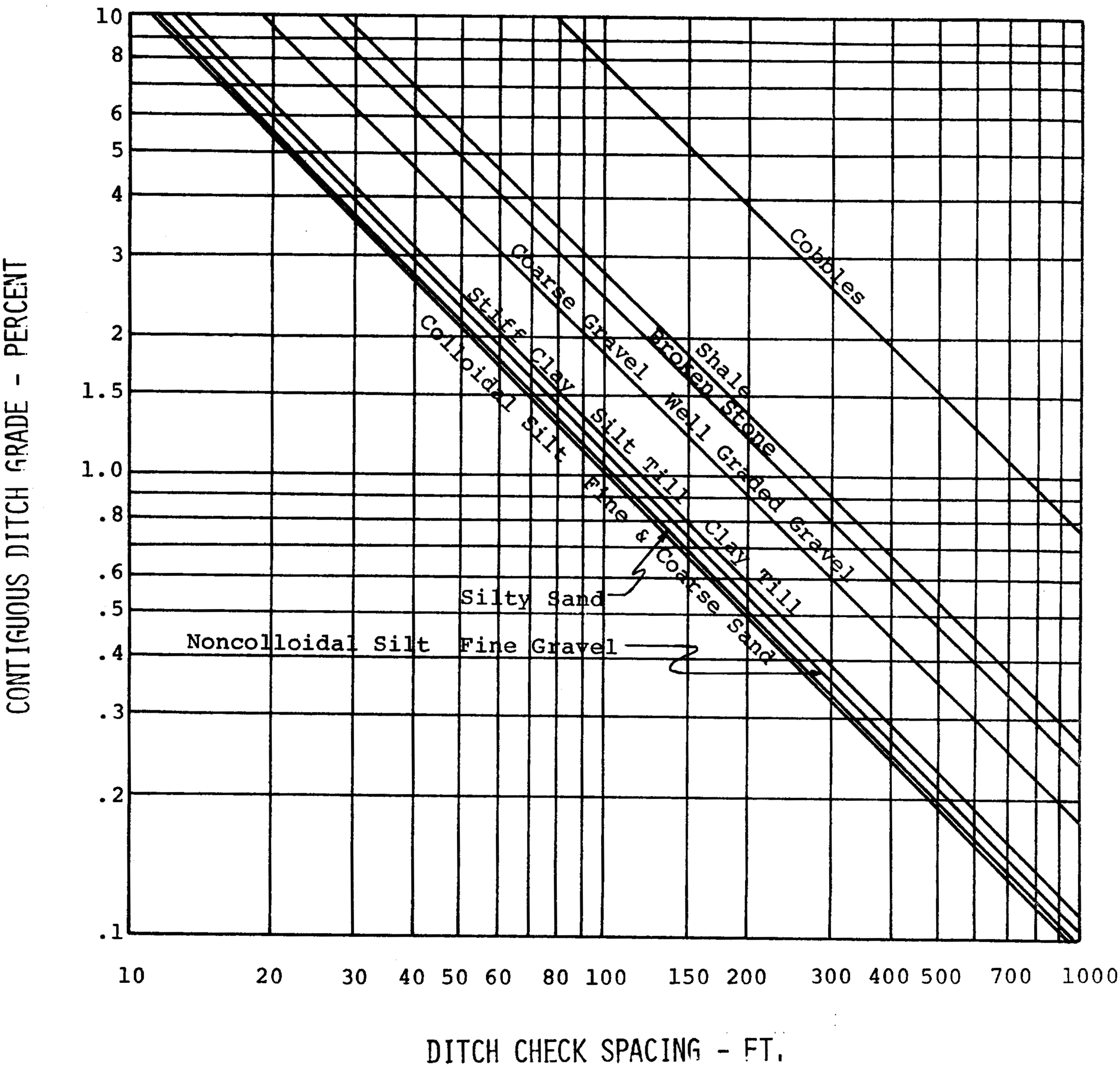

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Figure B.9.6

DITCH CHECK SPACING

(DESIGN DISCHARGE - 30 CFS)

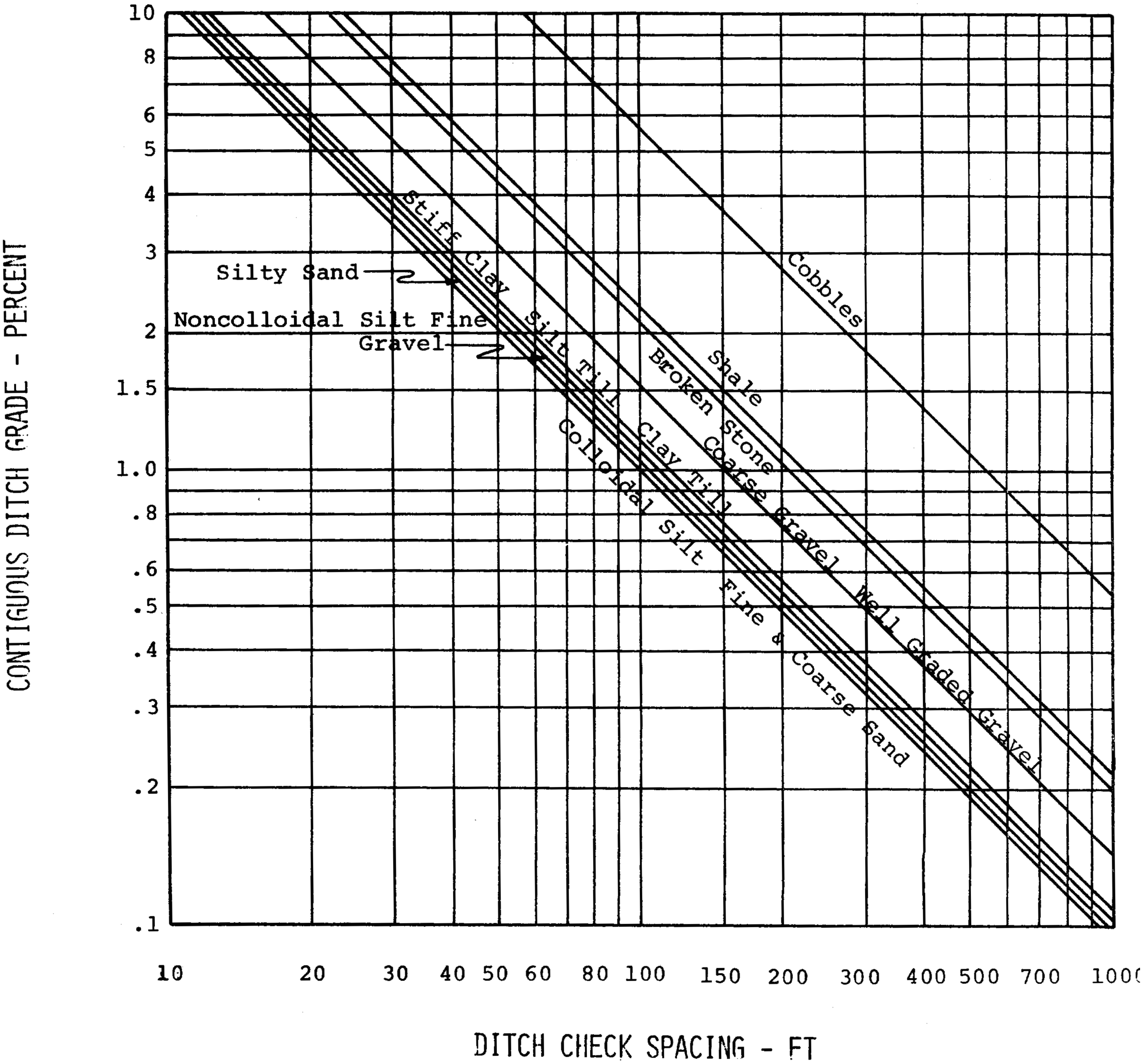
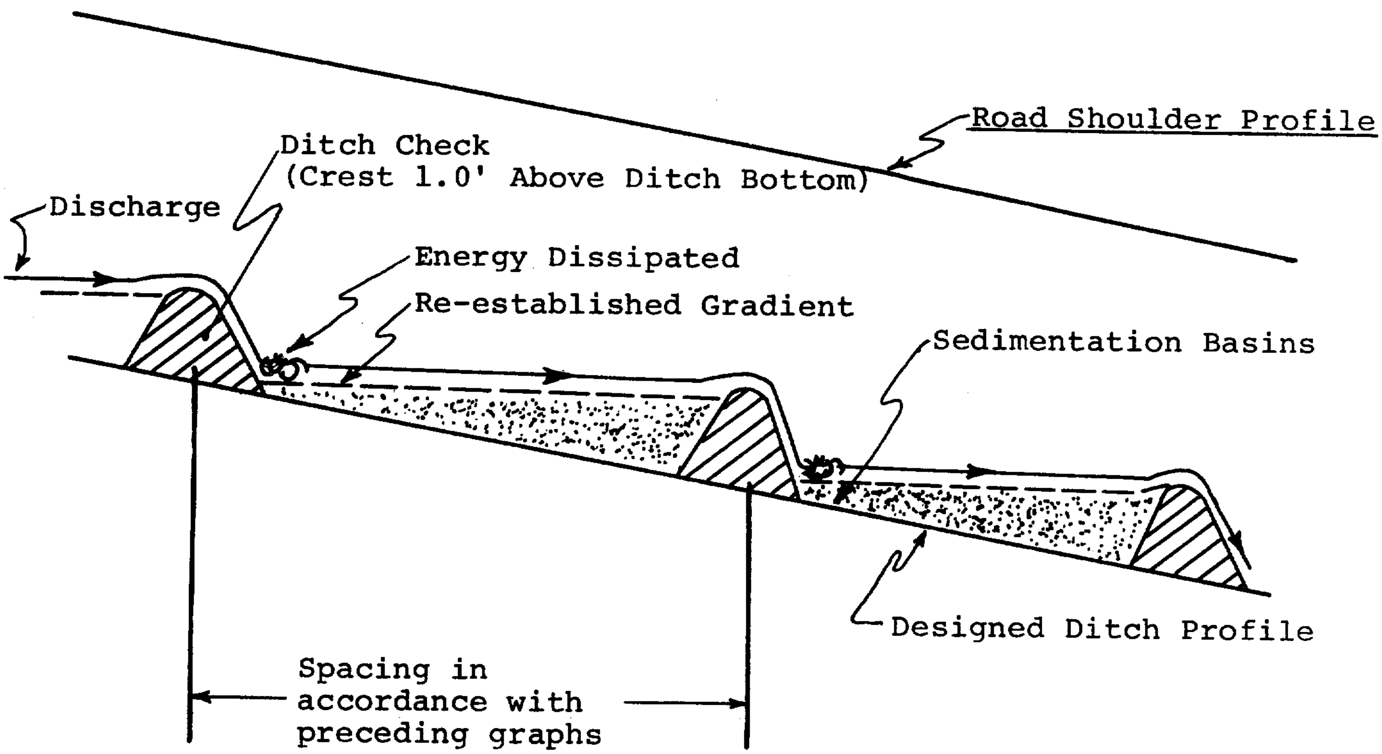


FIGURE B.9.7

DITCH CHECKS



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

SECTION C

SECTION C-1

STATUS REPORT: REVEGETATION PILOT PROGRAM

Revegetation demonstration activities for the Department of Public Works began in August, 1973, in the Fort Simpson and Inuvik areas. A report proposing the revegetation studies was prepared by D.P.W. in July, 1973 and following co-ordination with the Client, the program was started in August.

The purpose of this pilot program is to determine the exact combinations of conditions necessary to cover the disturbed terrain and minimize environmental impact.

The initial activities were staged at Fort Simpson, Mile 300 to 320 of the Mackenzie Highway and at the construction sites in the Mackenzie delta, Mile 330 - 365 of the Dempster Highway, Mile 931 - 964 of the Mackenzie. These areas in the delta introduce significant changes in climate and variation in site.

The initial activities were designed to revegetate as much as possible of the first construction section, (300 to 320) of the Mackenzie Highway and to stabilize the numerous cuts through which the Highway passes.

The variety of site conditions includes all of the basic road building methods used, turnpike, cut, fill, and

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approaches to rivers, streams, or gullies and variations in microclimes and other environmental conditions.

In each of these road types we are using the grass seeds recommended by previous studies, slope stabilization materials, natural vegetative growth and its response to artificial stimuli; and fertilizers and their affect on the seeds and areas selected.

The major land forms we are concerned with are:

a) Sand cuts
b) Silt cuts
c) Access roads
d) Roadside and offtake ditches
e) Bridge and culvert approaches
f) Damaged vegetation
g) Borrow pits

On each of these sites we are comparing results of the following test plots:

a) Seeding
b) Seeding and fertilization
c) Seeding, fertilizing and mulch
d) Fertilizing bare soil

The size of the test plots are a minimum of 10' x 40' signed and roped off to assist evaluation later.

In this pilot study we are using hand labour to maximize uniformity in the distribution of test materials. When a large scale operation is to be undertaken chippers and hydro-seeders will be necessary to produce and spread the much greater volume of material.

The following is a list of plots presently established:

PLOT NO.	SEED MIX & LBS/ ACRE	FERTILIZER N.P.K/ACRE	SOIL TYPE	LAND FORM	STABILIZATION METHOD	DATE PLANTED	MILE
1	Control plot/no seed - fertilizer or mulch						
2	A/60	60/60/60	Sand	Backslope 1/3	None	31/08/73	298.2
3	A/120	60/60/60	Sand	Backslope 1/3	"	" " "	298.2
4	A/180	60/60/60	Sand	Backslope 1/3	"	" " "	298.2
5	C/60	60/60/60	Sand	Backslope 1/3	"	" " "	298.3
6	C/120	60/60/60	Sand	Backslope 1/3	"	" " "	298.3
7	C/180	60/60/60	Sand	Backslope 1/3	"	" " "	298.3
8	A/240	60/60/60	Sand	Backslope 1/3	"	" " "	298.3
9	A/60		Sand	Backslope 1/3	"	12/09/73	299.8
10	A/120	120/120/120	Sand	Backslope 1/3	"	12/09/73	300.2
11	B/120	120/120/120	Sand	Backslope 1/3	"	28/09/73	300.3
12	C/120	120/120/120	Sand	Backslope 1/3	"	26/09/73	300.3
13	A/120		Silt	Level Seism-ic Trail	"	12/09/73	300.5
14	A/120		Sand	Backslope 1/3		12/09/73	300.95
15	B/120		Sand	Backslope 1/3	"	28/09/73	301.1
16	C/120		Sand	Backslope 1/3	"	28/09/73	301.3

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PLOT NO.	SEED MIX & LBS/ ACRE	FERTILIZER N.P.K/ACRE	SOIL TYPE	LAND FORM	STABILIZATION METHOD	DATE PLANTED	MILE
17	C/120		Sand	Backslope 1/3	Curasol AK	28/09/73	301.3
18	A/180		Sand	Backslope 1/3	None	12/09/73	301.8
19	B/180		Sand	Backslope 1/3	"	28/09/73	301.8
20	C/180		Sand	Backslope 1/3	"	28/09/73	301.9
21	A/120	60/60/60	Silt	Offtake Ditch	"	12/09/73	302.25
22	A/120	100/0/0	Sand	Backslope 1/3	Jute Mesh	12/09/73	303.35
23	A/120		Sand	Backslope 1/3	Wood Chips	11/09/73	303.5
24	C/120	100/0/0	Sand	Backslope 1/3	Wood Chips	11/09/73	303.5
25	A/120		Sand	Backslope 1/3	Curasol	12/09/73	304.8
26	A/120	60/60/60	Sand	Backslope 1/3	Curasol	12/09/73	304.8
27	A/120	100 M(urea)	Silt	Offtake Ditch		12/09/73	304.9
28	A/180	No Fert.	Sand	Backslope 1/3	Curasol AK	11/09/73	305.1
29	A/180	100/60/60	Sand	Backslope 1/3	Wood Chips & Plastic Netting	11/09/73	305.0
30	A/180	120/120/120	Sand	Backslope 1/3	Jute Mesh	11/09/73	305.0
31	A/180	100/0/0	Sand	Backslope 1/3	Straw/Plastic Net	11/09/73	305.1
32	None	None	Sand	Backslope 1/3	Curasol	08/09/73	299.8

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PLOT NO.	SEED MIX & LBS/ ACRE	FERTILIZER N.P.K/ACRE	SOIL TYPE	LAND FORM	STABILIZATION METHOD	DATE PLANTED	MILE
33	A/60	None	Silt	Backslope 1/3	None	30/08/73	
34	A/120	None	Silt	Backslope 1/3	"	" " "	
35	A/180	None	Silt	Backslope 1/3	"	" " "	
36	D/60	None	Silt	Backslope 1/3	"	" " "	
37	D/120	None	Silt	Backslope 1/3	"	" " "	
38	D/180	None	Silt	Backslope 1/3	"	" " "	
39	A/120	120/120/120	Silt	Backslope 1/3	"	" " "	
40	D/120	30/50/0	Silt	Backslope 1/3	"	" " "	
41	Creeping Red Fescue/ 120	60/100/0	Silt	Backslope 1/3	"	" " "	
42	"	120/120/120	Silt	Backslope 1/3	"	" " "	
43	"	None	Silt	Backslope 1/3	"	" " "	
44	No Seed /0	60/100/0	Silt	Backslope 1/3	"	" " "	
45	A/120		Ice Silt Flows	Backslope 1/3	"	" " "	
46	A/120	60/100/0	"	Backslope 1/3	"	" " "	
47	D/120		"	Backslope 1/3	"	" " "	
48	D/120	60/100/0	"	Backslope 1/3	"	" " "	

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In accordance with I.N.A. suggestions, the program will continue with some revisions mostly in seed variety and in demonstration plot orientation to climatic factors.

a) Size of Test Plots will be 10' x 40' divided into four (4) sections covered with the following material:

1) Wood mulch
2) Straw mulch
3) Slash
4) Nothing (control)

b) Fertilizer will be applied at the following rates per acre:

200 lbs. Urea (45%N.)
230 lbs. Triple Superphosphate (60%P.)

(Soil tests to be done for K requirements)

c) Seed Mixture (if available - if not substitutions will be made)

1)	Boreal Red Fescue	--	15 lbs.
2)	Nugget Kentucky Bluegrass	--	15 lbs.
3)	Bluejoint (probably N/A)	--	10 lbs.
4)	Slender wheat grass	--	6 lbs.
5)	Frontier Reed Canary grass	--	6 lbs.
6)	Engo Timothy	--	6 lbs.
7)	Meadow Foxtail	--	6 lbs.
			64 lbs./acre

Sites have been located for use next planting season at Mile 308 - 311.5 on the Mackenzie near Fort Simpson and several borrow and spoil sites near Fort McPherson and Inuvik.

Germination results and observations will be reported as soon as available.

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SECTION C-2

DISPOSAL OF WASTE

This section pertains to waste material as encountered on the right-of-way, in borrow areas and on haul roads during the construction process of the Mackenzie Highway.

The designed grade of the Mackenzie Highway will generally be one of the overlay type, cutting only when necessitated by gradeline continuity, economy of gradeline across deep gullied water courses, and/or to maintain recommended centreline gradients. Cutting will also be designed in areas where the geotechnical investigations indicate the materials on the highway right-of-way are suitable for construction.

Some organic waste materials are anticipated to minimal depths in cut areas containing suitable material for construction. These generally minor quantities can readily be disposed of in the side slopes of shallow fills along the toe of the side slopes of larger fills, and in minor depressions on the right-of-way.

In areas where cutting will be necessitated by gradeline requirements rather than for suitable construction material, disposal areas for this material may be required. Conceivably for some material the fore mentioned methods may apply. However, if quantities of waste are such that the fore mentioned methods

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are neither sufficient nor applicable, the waste material will be disposed of in completed borrow pits and wherever practical ensuring consideration for the environment by avoiding adverse visual impact, ensuring complete entrapment of silt in the pit and ensuring pit slope stability. Some special disposal sites other than borrow pits may be necessary however, the need for these at present appears minimal.

SECTION C-3

PRELIMINARY AND FINAL DESIGN DATA

A) The preliminary design data to be provided with each preliminary design submission will include the following narratives:

1) Overland Drainage
2) Sources of Borrow
3) Special Treatment of Ditches
4) Summarized Environmental Data
5) Additional Design Statements

B) The final design data to be provided, with each final design submission will include the following narratives:

1) Overland Drainage
2) Sources of Borrow
3) Special Treatment of Ditches
4) Summarized Environmental Data
5) Additional Design Statements
6) Stream Crossings Utilizing Bridges

APPENDIX A

This Appendix consists of reports published previsouly that contain data relative to general design and particular details as they apply to this section. (Mile 544 to Mile 725).

BOLTER PARISH & TRIMBLE	Civil Engineering Report, Mackenzie Valley Reconnaissance, Hydrological Data and Guidelines.
	Preliminary Bridge Crossing Report Mile 550 to Mile 725
BROOKER, E.W. & ASSOCIATES	Geotechnical Data, Mile 632 to Mile 725, Volumes I - XIV
DEPARTMENT OF PUBLIC WORKS	Mackenzie Highway, Mile 297 to Mile 543, General Design Data
	Alignment Update Report, Mile 500 to Mile 725.
LOMBARD NORTH PLANNING LTD	Environmental Impact Study, Mackenzie Highway, Mile 550 to Mile 725 (October, 1972)
	Field Research Report, Environmental Impact Study, Mackenzie Highway, Mile 550 to Mile 725
R.M. HARDY AND ASSOCIATES	Geotechnical Data Mile 544 to Mile 635, Volumes I - 7.
	Geotechnical Investigations, Proposed Bridge Sites, for, Jungle Ridge, Nota, Vermillion, Prohibition, Christine, Helava, Francis, Canyon Creek. 8 Volumes.