VANCOUVER ISLAND HIGHWAY PROJECT

GUIDELINES FOR ENVIRONMENTAL DESIGN OF HIGHWAY DRAINAGE

File: 2793

June 1992

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1.0 INTRODUCTION

This study and the associated designs for drainage facilities were initiated in response to the Ministry of Transportation and Highways (MoTH) desire to control the quality of runoff from highway corridors during construction and operation. These environmental design guidelines are intended to:

1. provide an understanding of the need for environmental protection measures, and
2. provide engineers and environmental specialists with design standards and recommended solutions for water quality-related surface drainage problems.

The guidelines cover the design, construction and operational phases of the Vancouver Island Highway Project. The emphasis has been on meeting the design needs of the Inland Highway from Parksville to Campbell River, however, the methods are applicable to the remainder of the Island Highway Project.

Specifically the guidelines provide:

1. Hydrologic design information.

2. Methods for erosion control during construction including a discussion of the factors affecting soil loss, methods of control and design information for appropriate temporary measures.

3. Permanent stormwater treatment facilities including rationale for their need, treatment selection process and design information for the various treatment methods such as vegetated filter areas and engineered wetlands.

4. Miscellaneous data covering drainage structures, monitoring performance of water quality facilities and restoration of stream crossing sites.

The hydrologic design in Section 2.0 includes information for sizing ditches, culverts and treatment pond outlets, including spillways. This design information includes annual precipitation, short-duration rainfall intensity data and peak unit flows based on regional streamflow data.

Section 3.0, covering erosion control during construction, discusses the factors which contribute to erosion, provides procedures for implementing soil erosion control and gives design information for important control techniques including silt fences, diversions and sediment ponds.

Recognizing that the highway will potentially generate polluted runoff during its operation and maintenance, methods designed to mitigate these impacts are provided in Section 4.0. The degree of water quality degradation is related to traffic volume, therefore the runoff treatment process selection depends on expected traffic volume and stream sensitivity at the discharge point in question. As the degree of water quality degradation increases the recommended treatment changes from the simple application of grassed medians, shoulders or ditches, as filtering media, to more sophisticated engineered wetlands.

The remaining sections cover special uses of storm drains and hydraulic energy dissipators at steep stream banks, the importance of monitoring the water quality control facilities and restoration of stream crossing sites after construction.

The five appendices provide miscellaneous background material. Included is a literature review on the effects and treatment of stormwater from highways and a rationale for the recommended levels of runoff treatment. An appendix on erosion control contains technical information on how to minimize soil loss including techniques to maximize the use of vegetation. The appendices also give information appropriate to species type and planting windows for erosion control and for planting engineered wetlands.

2.0 HYDROLOGY

2.1 General

The hydrologic parameters of importance in designing highway drainage facilities such as culverts, storm drains, water quality ponds and sediment ponds include:

- annual precipitation
- short-duration rainfall intensity
- peak daily unit flows and peaking factors.

Utilizing the methods described in Section 4.0, the mean annual precipitation determines the sizes of various treatment options, including length of grassed drainage ditches, surface area of grassed swales and surface area of engineered wetland or wetpond.

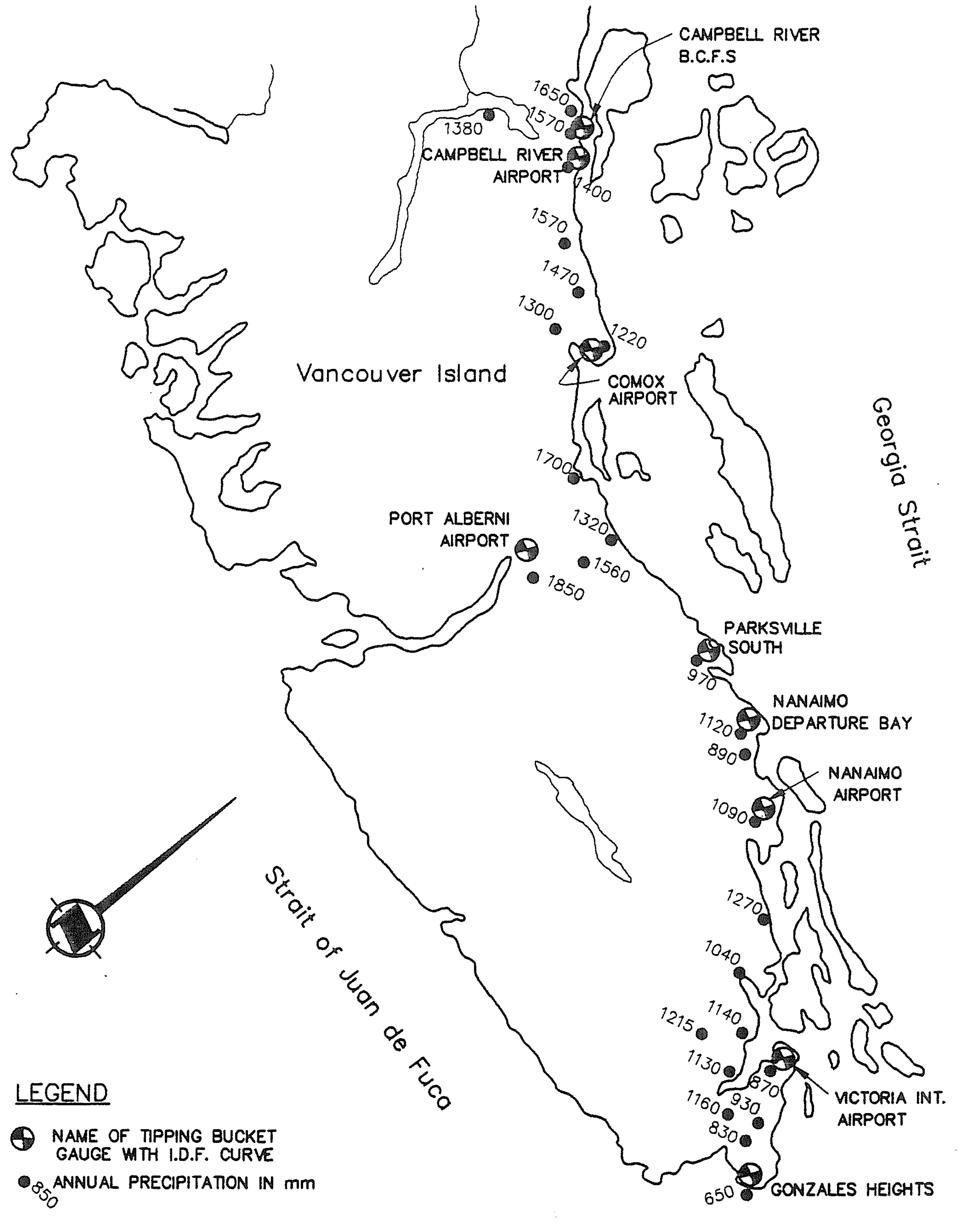
Short-duration rainfall intensity is used for highway drainage calculations with the Rational Method to determine design flows and culvert and storm drain sizes.

For larger catchments, say above 50 to 100 ha, flow estimates based on regional hydrology should take precedence over the Rational Method.

2.2 Annual Precipitation

The use of annual precipitation for the sizing of water quality facilities is relatively simple and straightforward.

Annual precipitation amounts reported by Atmospheric Environment Service (AES), Environment Canada, for various locations on the east coast of Vancouver Island along the Island Highway route, are shown in Figure 1. Interpolate as required to estimate amounts where the highway is not near a gauged location. Annual precipitation varies from a low of 650 mm at Gonzales Heights to a high of 1700 mm at Mud Bay, south of Courtenay. Typical values are 1000 to 1200 mm in the south and 1300 to 1500 mm in the north.



GAUGE SITES AND ANNUAL PRECIPITATION

FIGURE 1

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After the precipitation has been determined Figures 11 to 14 may be used to determine grassed ditch, grassed swale and engineered wetland parameters.

Everything else being equal, water treatment facilities would be somewhat larger towards the north or at higher elevations. Grassed swale and engineered wetland areas of 1% to 3% of contributory paved area result from applying the typical precipitation values to the sizing criteria.

2.3 Short-Duration Rainfall Intensity

Short-duration rainfall intensity are important in determining peak flows by the Rational Method. Other data input includes the coefficient of runoff and the contributory drainage area.

Short-duration rainfall intensity data are available from AES in summary form as Intensity-duration Frequency Curves. There are approximately nine stations with curve data along the route. Not all the curves are useful for highway drainage calculations as they do not give data points for durations less than 60 minutes. The stations with data to durations as short as 5 minutes are listed below, together with 100-year return period values for 5-, 10- 15- and 60-minute durations.

Station	100-Year Intensity (mm/h)			
	5-min.	10-min.	15-min.	60-min.
Victoria Gonzales Heights	49	35	30	18
Victoria International Airport	65	45	38	20
Port Alberni Airport	90	65	54	27
Comox Airport	82	57	45	21

For each inlet location, the appropriate duration must be determined by first calculating the time of concentration using commonly available formulae.

The considerable variation in intensity values reveals the importance of careful extrapolation between stations. None of the stations are ideally located for highway design purposes. Port Alberni Airport, which has the highest data values, is centrally located on Vancouver Island, considerably west of the highway route and well into the Insular Mountains. The other three stations are near sea level and generally east of the highway alignment. Comox Airport data are perhaps best representative of most of the route and probably only significantly conservative if applied to the Victoria area and Saanich Peninsula portions of the highway. In these southern areas, values from Victoria International Airport should be used. Figures 2 and 3 illustrate the AES Intensity-duration Frequency Curves for these two stations. These curves were last updated with 1986 data. The Highway Engineering Branch Design Manual requires return periods between 50 and 200 years for permanent structures, but more frequent intervals of 2 and 5 years are appropriate for temporary structures such as sediment ponds.

Runoff coefficients vary with the type of land use. The following values are recommended for use on the project.

Land Use	"C" Value
Pavement/gravel	0.85
Undeveloped	0.45
Construction Activity	0.60

These values are somewhat higher than frequently used for Rational Method calculations but they are intended to reflect runoff conditions during 50 to 200-year events in which infiltration and other abstractions represent a proportionately smaller effect on peak runoff (Chow, 1964). These "C" values have been approximately calibrated within the limitations of the rate of rainfall and regional streamflow data available.

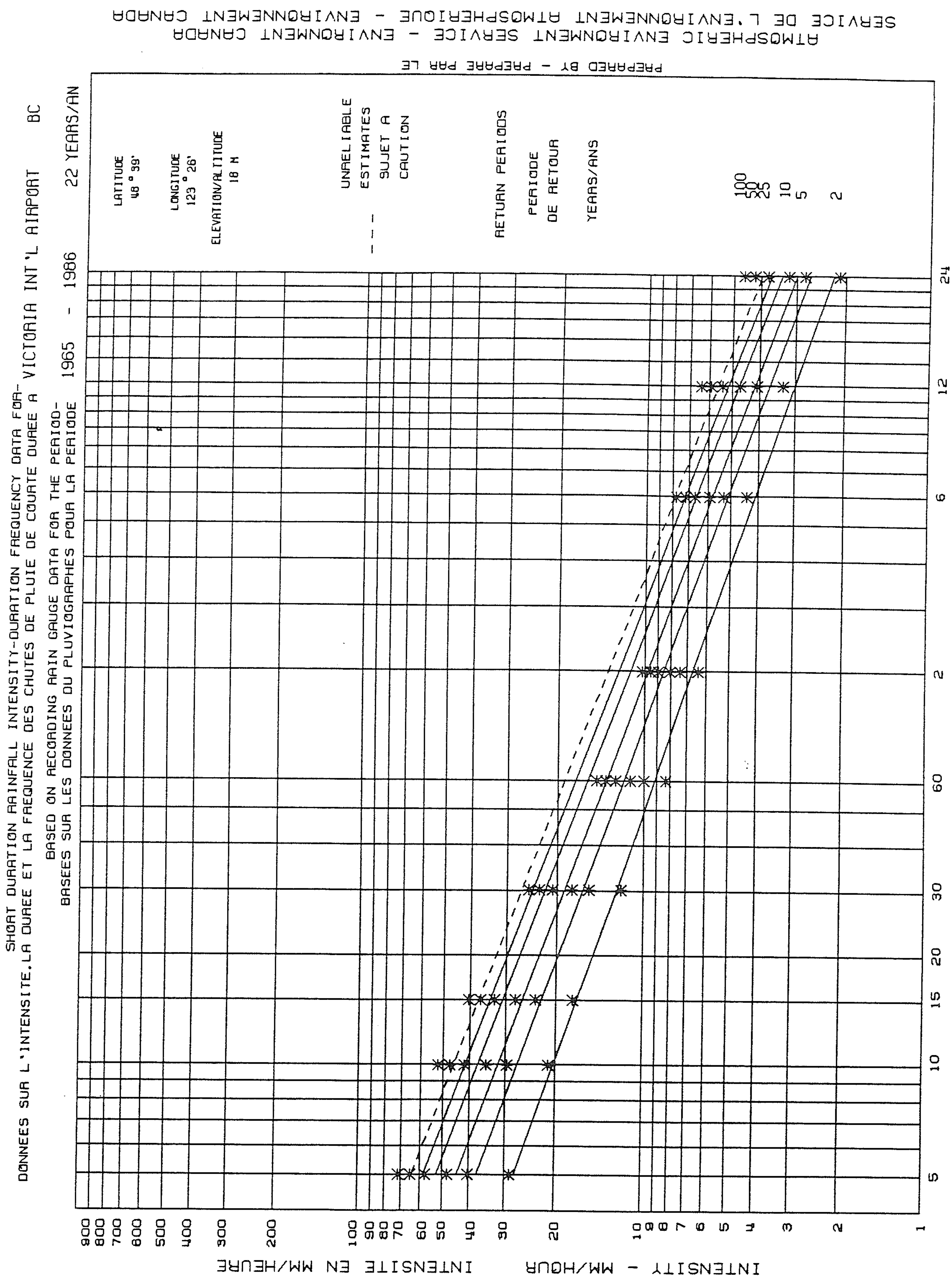

SHORT DURATION RAINFALL INTENSITY-DURATION FREQUENCY DATA FOR-
DONNEES SUR L'INTENSITE,LA DUREE ET LA FREQUENCE DES CHUTES DE PLUIE DE COURTE DUREE A VICTORIA INT'L AIRPORT BC
BASED ON RECORDING RAIN GAUGE DATA FOR THE PERIOD-
BASEES SUR LES DONNEES DU PLUVIOGRAPHES POUR LA PERIODE 1965 - 1986 22 YEARS/AN
LATITUDE 48° 39'
LONGITUDE 123° 26'
ELEVATION/ALTITUDE 18 M
UNRELIABLE ESTIMATES
SUJET A CAUTION
RETURN PERIODS
PERIODE DE RETOUR
YEARS/ANS
100 50 25 10 5 2
PREPARED BY - PREPARE PAR LE
ATMOSPHERIC ENVIRONMENT SERVICE - ENVIRONNEMENT CANADA
SERVICE DE L'ENVIRONNEMENT ATMOSPHERIQUE - ENVIRONNEMENT CANADA
5 10 15 20 30 60 2 6 12 24
MINUTES HOURS HEURES
DURATION DUREE
900 800 700 600 500 400 300 200 100 90 80 70 60 50 40 30 20 10 9 8 7 6 5 4 3 2 1
INTENSITY - MM/HOUR INTENSITE EN MM/HEURE

FIGURE 2

SHORT DURATION RAINFALL INTENSITY-DURATION FREQUENCY DATA FOR- COMOX AIRPORT BC
DONNEES SUR L'INTENSITE.LA DUREE ET LA FREQUENCE DES CHUTES DE PLUIE DE COURTE DUREE A

BASED ON RECORDING RAIN GAUGE DATA FOR THE PERIOD- 1963 - 1986 24 YEARS/AN
BASEES SUR LES DONNEES DU PLUVIOGRAPHES POUR LA PERIODE

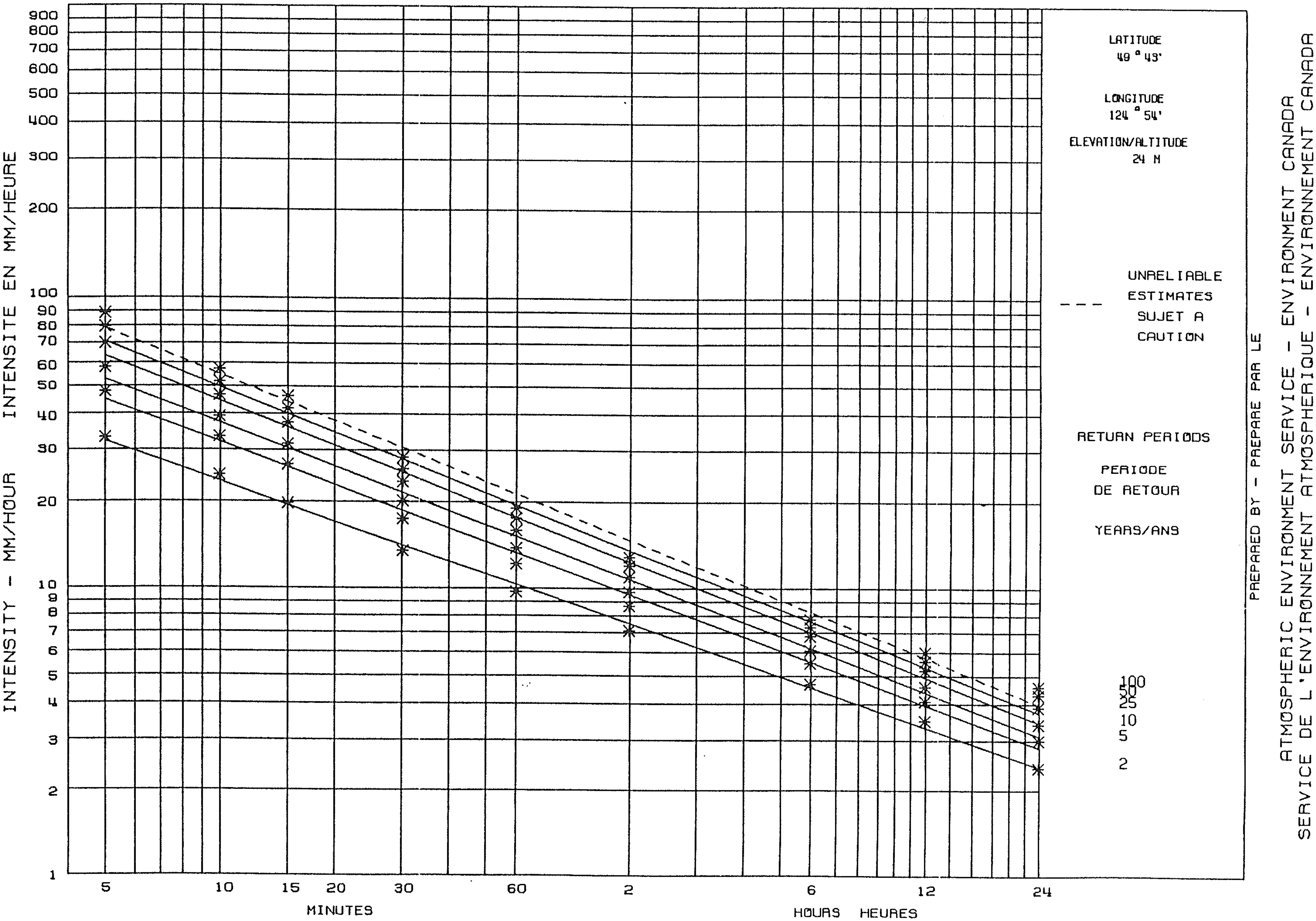
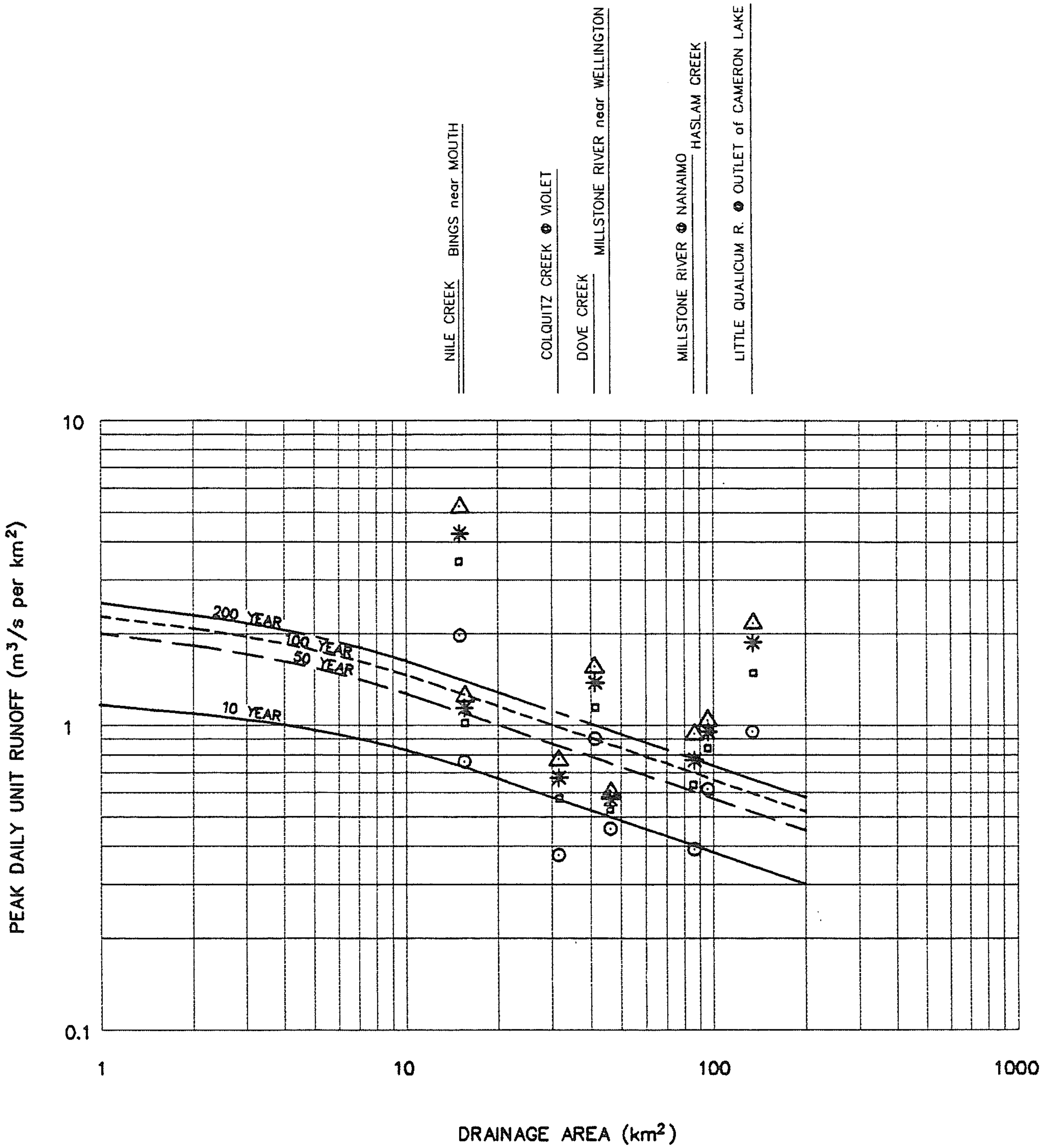


FIGURE 3

2.4 Peak Daily Unit Flows and Peaking Factors

The Rational Method can provide inaccurate peak flow estimates when applied to basins over, say, 50 to 100 ha (1 km^2). For this size of basin and larger, regional hydrology analysis should augment or supplant the Rational Method for determining design flows. Regional hydrology analysis involves the use of streamflow gauging data published by Water Survey of Canada. Using the "British Columbia Historical Streamflow Summary" and a statistical computer program prepared by Environment Canada entitled "Consolidated Frequency Analysis" (CFA 88), flood frequency analysis was completed for eight gauged streams on the east coast of Vancouver Island. The results of the analysis were plotted as peak daily unit runoff versus drainage area (Figure 4). Note that the smallest gauged streams have a catchment of approximately 15 km^2 which means there is a considerable gap in information between the Rational Method results at 1 km^2 and the regional hydrology. Nevertheless, four design curves were fitted to those points which best represent the conditions along the Inland Island Highway route. Except for major creek crossings (which should be individually analyzed), most of the highway drainage is from low-lying catchments. The low-lying catchments have lower peak unit flows than the steeper catchments, therefore the design curves have deliberately been drawn relatively low to the plotted points, rather than as an envelope to the plotted points.

The gauged stations of Nile Creek and Little Qualicum River have very high unit peak flows due to a high percentage of catchment being at high elevations. Runoff from this type of catchment is not relevant to the local drainages of the Island Highway routes and so has been ignored when preparing the design curve. To obtain a peak design flow for culvert, ditch or storm drain sizing, the values obtained from Figure 4 must be peaked by the factor obtained from Figure 5. The peaking factors were determined by plotting the ratio of peak instantaneous flow to peak daily flow for the stations indicated. The slope of the peaking factor design curve has also been checked by the use of an empirical formula which relates peaking factor to catchment area.



LEGEND

- △ ——— 200 YEAR UNIT RUNOFF
- ✱ - - - - - 100 YEAR UNIT RUNOFF
- ▫ — — 50 YEAR UNIT RUNOFF
- ⊙ ——— 10 YEAR UNIT RUNOFF

PEAK DAILY UNIT FLOWS vs DRAINAGE AREA

CURVES SUITABLE FOR LOW RELIEF AREAS ON EAST COAST OF VANCOUVER ISLAND BETWEEN VICTORIA AND CAMPBELL RIVER

FIGURE 4

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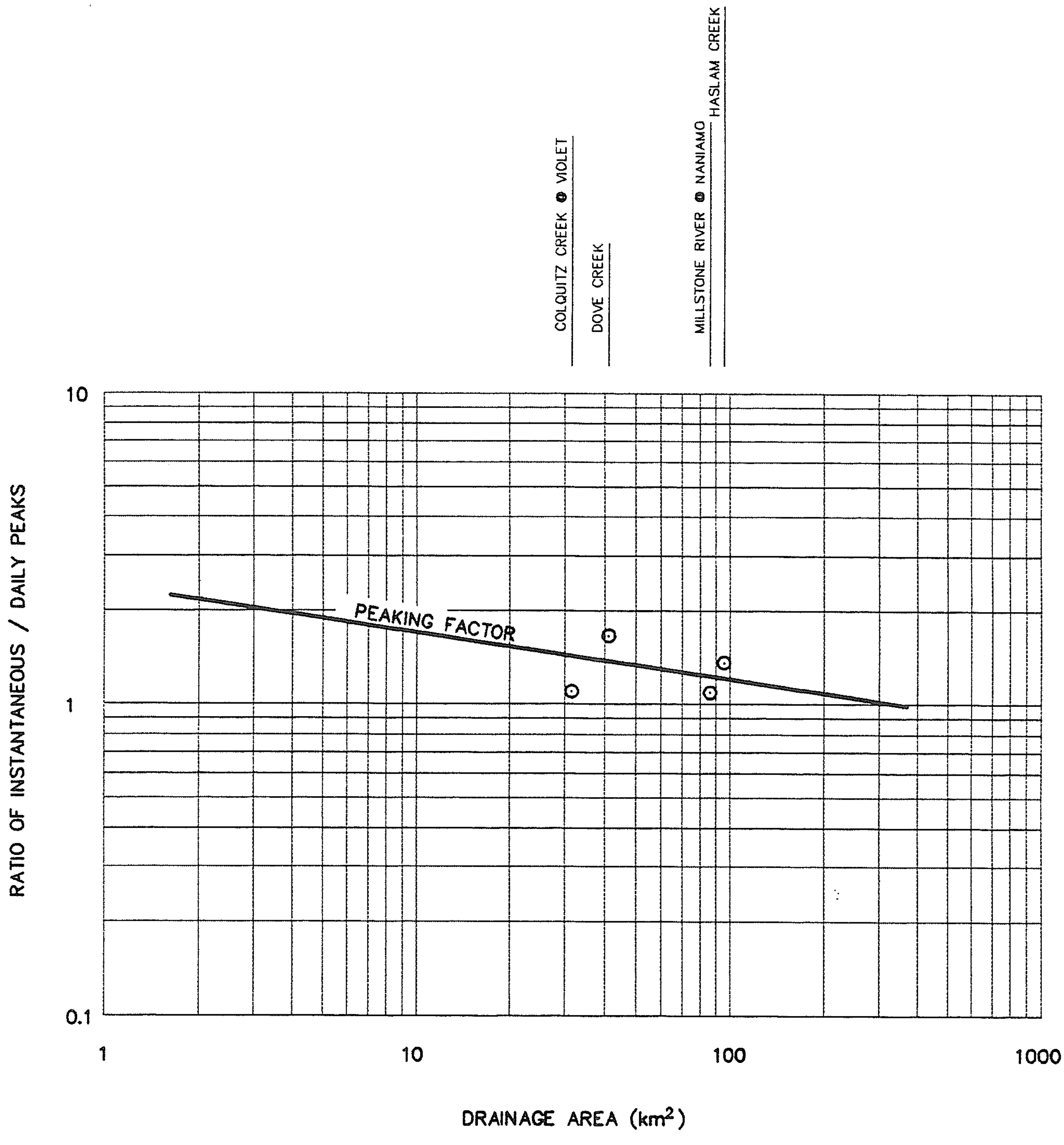


PEAKING FACTOR vs DRAINAGE AREA

FIGURE 5

3.0 CONTROLLING EROSION DURING CONSTRUCTION

3.1 General

Site erosion and subsequent downstream sedimentation during construction is of particular concern to the regulatory authorities. Whereas degradation of water quality due to highway operation, covered in the following section, may not be readily monitored, construction activity has potential for catastrophic impacts on water quality and aquatic habitat. Production of elevated levels of suspended solids (TSS) in site runoff, due to soil erosion, is a commonly understood phenomenon. Guidelines for maintaining acceptable TSS levels are in place and these levels are relatively easy to monitor.

It is important for the designer and the constructor to be aware of the potentially high flows which can arise from even relatively small rainstorms once the right-of-way has been cleared, as well as the tremendous sediment loads which can be carried by these flows due to soil loss from these bare areas. At source erosion control techniques, which include such practices as minimizing land clearing in advance of construction, revegetating bare areas as soon as possible, use of various types of diversion ditches, stabilizing ditches and travelled areas with riprap or gravel and timing the work to avoid exposing bare soil to heavy seasonal rains are essential to achieve adequate protection of receiving waters.

Generally speaking, TSS concentrations in site drainage must be maintained at a nominal increase over background or existing creek levels. For the East Coast of Vancouver Island concentrations during peak runoff conditions may be permitted to rise to 50 - 100 mg/L. For sensitive receiving environments, peak concentrations not exceeding 25 mg/L may be necessary. The Fisheries Act provides the authority under which these levels of TSS are enforced. Higher levels may be considered "deleterious" or "harmful alteration" to aquatic habitat. Charges may be laid under the Fisheries Act by federal or provincial officers. At present there is no authority to protect water quality for downstream Water Licence holders. In effect, possession of a Water Licence does not include a guarantee of water quality unless degradation is caused by specific pollutants and discharges covered under the Pollution Control Act.

3.2 Soil Erosion Potential

(Sources: Wischmeier et al [1978], Horner et al [1990] and Virginia Soil and Water Conservation Commission [1980])

The rate of soil erosion is affected by many factors, including rate of rainfall, length of sloped surface, type of vegetative or ground cover, the surface conditions of the soil and the properties of the soil itself.

The effect of each of these factors may be quantified by the Universal Soil Loss Equation (USLE). The various sources listed above illustrate the use of this equation. Total annual sediment yield may be estimated with this formula but in the short term, yield is highly variable and it is recommended sediment trapping facilities be sized on the basis of unit design information provided later in this section rather than on specific calculations of yield.

It is, however, important to understand how the various factors are affected by construction and a summary of the impacts is given below. The USLE terminology is provided in brackets after each heading.

Rate of Rainfall (Rainfall and Runoff Factor)

Rate of rainfall, of course, cannot be controlled but work activities may certainly be scheduled to avoid the fall and winter periods of greatest rainfall intensity and duration. In sensitive areas unprotected, bare slopes of erodible soil must not be allowed to stand through the rainy November to April period, otherwise significant soil loss will be experienced.

Length of Sloped Surface (Slope-Length Factor)

As slope length increases, soil loss per unit area generally increases substantially as the greater accumulation of runoff increases its detachment and transport capacities. Therefore the length of slope upstream from a stable, nonerodible channel should be held to a minimum. Deep gullying and rill erosion can be expected on steep, bare surfaces. The longer and steeper the cut or fill slope, the greater the potential for soil loss.

Vegetative or Ground Cover (Cover Condition Factor)

Undisturbed forest land typically produces 1/1000th or less soil yield than bare soil. Therefore it is imperative these bare soil conditions occur for as short a time as possible and during low intensity rain seasons. The cover condition factor may be reduced by applying various ground covers. Temporary seedings of grass typically reduce the yield to a 1/10th or 1/20th that of bare soil while permanent seedings or sod can reduce this further to 1/100th that of bare soil. Various mulches or crushed stone coverings provide a similar level of protection to that of temporary seedings (McCarthy, 1990).

Surface Condition (Support Practice Factor)

The surface condition of bare soil has a further effect on the soil loss potential of a site. The reference surface condition is an irregular loose surface having typically 150 mm of relief. A compact and smooth surface, scraped up- and downhill, increases potential erosion by 30% over the reference condition and a loose surface with a surface roughness greater than 300 mm reduces the potential loss by up to 30% from that of the reference condition. The total range in soil loss due to various surface conditions of bare soil is therefore 60%, a small difference when compared to the major impact of clearing and grubbing, but nevertheless significant.

Soil Properties (Soil Erodibility Factor)

Soils containing high percentages of silts and very fine sands having a grain size range of 0.002 mm to 0.10 mm normally have the highest erodibility factor. As the sand, clay and organic matter content of these soils increases the erodibility decreases. Soils with a high clay content are generally more resistant to detachment, but once the particles are detached they are easily transported and extremely difficult to remove from runoff. The proportion of silt and very fine sand should be noted when placing limits on the construction period, determining the relative importance of sediment trapping facilities, or designing treatments for bare slopes. The Virginia Soil and Water Conservation Commission (1980) assigns a high erodibility to soils when the factor (k) is greater than 0.36. This corresponds to soil having at least 50% silt and very fine sand, but the presence of organic matter or clay will lower this rating. If there is significant clay (say 30%) or organic matter (say 3%) present, the percentage of silt and very fine sand would need to rise to 60% to still be classified as highly erodible. An example of a form for reporting particle size analysis of soils is included as Figure 6.

Highly erodible soils should only be exposed and left bare for limited periods during the summer season when rainfalls are light, drying is good, and there is time for vegetation to be established before the heavy fall rains. As an example, the earth cut in Quadra sediments on the north side of French Creek near Parksville in the fall of 1991 proved to be extremely problematic, particularly in the fine sand and silt units of this strata (silt content in some zones exceeded 90%). In bare soil conditions these silts and sands were very easily eroded and the silts were difficult to settle, thus requiring relatively large settling basins during high runoff periods. Even after settlement the runoff was still high in suspended solids.

3.3 Soil Erosion Control

Soil erosion control should be carefully planned by implementing the four procedures listed below:

1. In planning for soil erosion control it is important to know the limits of the disturbed area and identify critical areas (by understanding the previously-mentioned factors which contribute to erosion). Appendix C - Erosion Control, identifies possible soil problems which are in addition to those discussed in Section 3.2.

2. The site should be divided into drainage areas in order to understand how erosion may be controlled locally as it is much easier to prevent erosion than to deal with sediment once it has been suspended in runoff. Methods of erosion prevention and vegetative controls for bare soil are also provided in Appendix C. These vegetative controls should be considered as a first line of defence to prevent erosion. Clear and grub the right-of-way in stages, as close to commencement of construction activity as possible. The area should not be allowed to remain bare for extended periods. On floodplains under and around bridges and culverts leave as much shrub and low ground cover as possible.

PARTICLE - SIZE ANALYSIS OF SOILS

Project: ______________________________

____

Project Number: ______________________________

Date Tested: ______________________________

Borehole Number: ______________________________

Depth: ______________________________

Soil Description: ______________________________

Cu: ______________________________

Cc: ______________________________

Natural Moisture Content: ______________________________ %

Remarks: ______________________________

SIEVE	PERCENTAGE PASSING
3"	
2"	
1 1/2"	
1"	
3/4"	
3/8"	
No. 4	
No. 10	
No. 20	
No. 40	
No. 60	
No. 100	
No. 200	

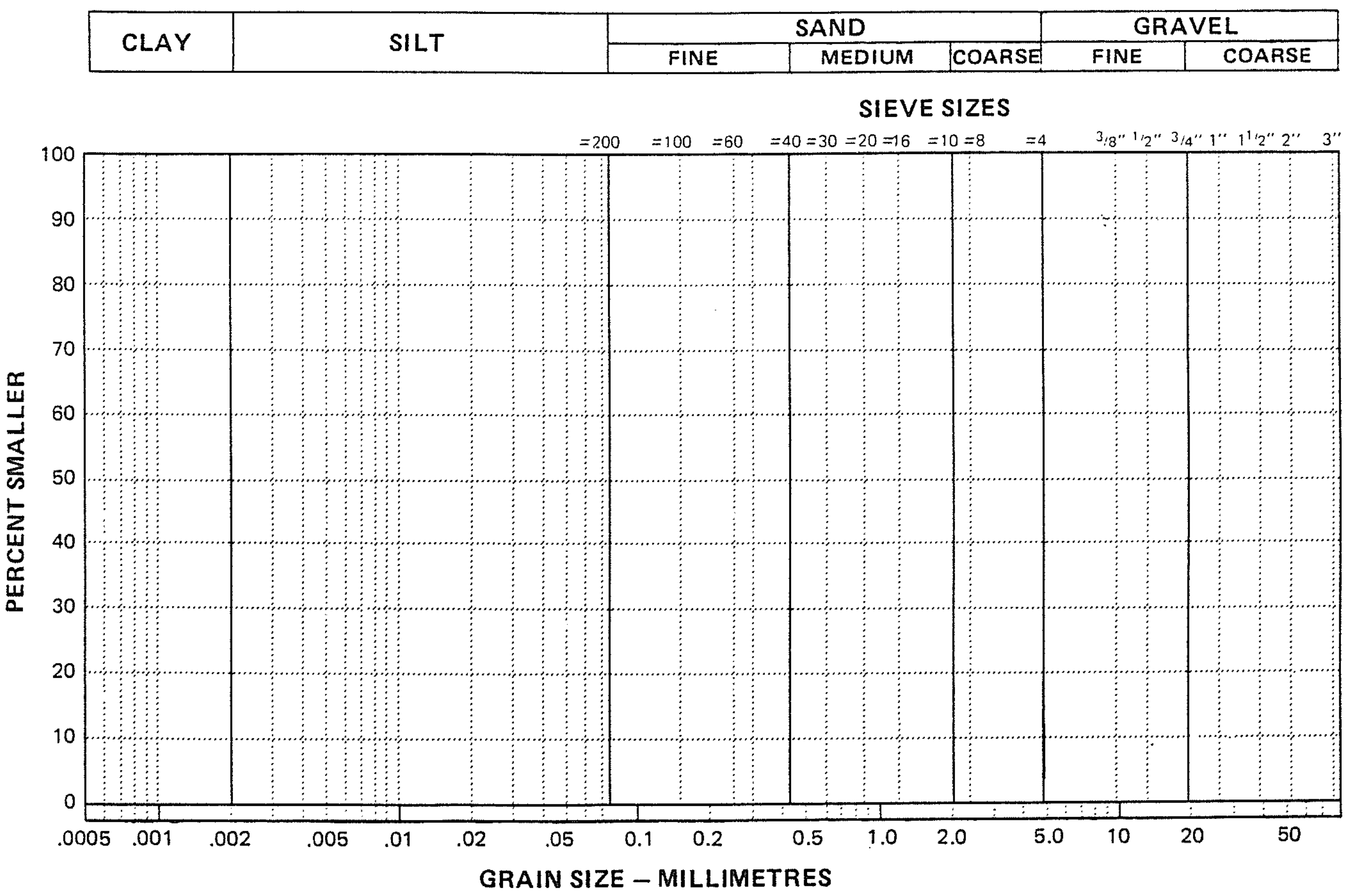


FIGURE 6

3. The second and last lines of defence to prevent sediment discharge during construction should be structural controls. These temporary measures include silt fences, diversions and sediment ponds. The design and use of these methods are described later in this Section. Structural methods to control erosion and sedimentation are more costly than source or vegetative controls and may be less efficient as well (Virginia Soil and Water Conservation Commission, 1980). Every effort should be therefore be made to limit the need for various structural controls.

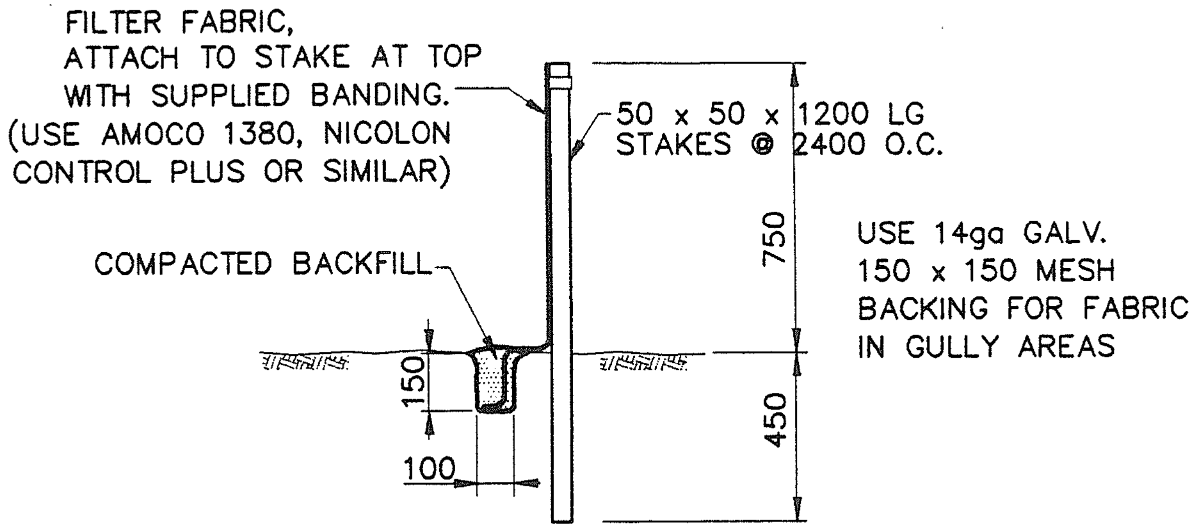
4. A final consideration in controlling sediment is good management. The Ministry's practice of placing an environmental monitor onsite appears to greatly reduce the probability of serious environmental problems but the most important management technique is timing and sequencing of the works, together with a complete design which addresses as many potential problems as possible.

3.4 Silt Fence

Silt fences are constructed of a geotextile filtering fabric supported vertically on spaced posts and are intended to filter suspended solids, slow runoff and promote settling. Recommended construction details are shown in Figure 7.

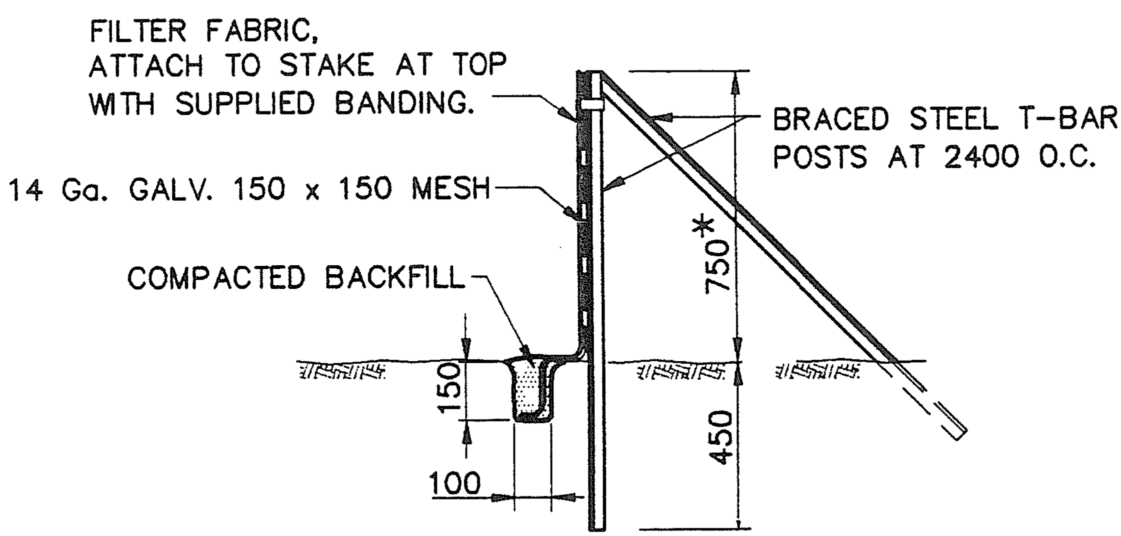
Silt fences should be used at the following locations:

- along the downhill side of rights-of-way near sensitive areas,
- toe of fill slopes where adjacent to sensitive areas,
- base of natural slopes where activity above may cause a debris slide,
- at the top of a creek bank, adjacent to construction activity,
- in sediment ponds to prevent short-circuiting of flow,
- near sediment pond outlets to prevent debris from blocking outlet and to provide an added measure of protection against discharge of sediments.



SILT FENCE MK. I

1:20 (NORMAL APPLICATIONS)



SILT FENCE MK. II

1:20 (POTENTIAL DEBRIS SLIDE APPLICATION)

FIGURE 7

A silt fence will be ineffective on silt and clay size particles as they will pass through the fabric. Horner, et al (1990) do not recommend the use of a silt fence if more than 85% (by weight) of the soil particles are silt size or smaller (i.e. not retained on #200 sieve). In these situations the use of vegetated filter strips (grassed ditches or swales), as described in Section 4.4 and in Appendix D, is suggested if there is opportunity for their growth; otherwise, trapping of silts in a sediment pond becomes the necessary last line of defence. When assessing the suitability of silt fences to retain soil particles, consideration should also be given to the imported material which will be used as fill.

Silt fences should be inspected immediately after a rainstorm and daily during prolonged storms. Ineffective silt fences should be repaired or replaced as soon as possible.

3.5 Diversions

Diversions may be used in many ways to help reduce erosion from highway construction sites. Typical applications described by Virginia Soil and Water Conservation Commission (1980) are listed below:

1. Diverting runoff from higher drainage areas away from unprotected slopes.

2. Diverting sediment-laden runoff from a disturbed area to a sediment pond.

3. Shortening the flow length along the right-of-way to divert flow to a stabilized ditch or outlet. These diversions are usually placed diagonally on the road subgrade and may divert flow to either ditch.

4. Diverting runoff originating from a bare subgrade away from an unprotected fill slope. This diversion would parallel the top of the fill slope.

Temporary diversion can be extremely beneficial in reducing erosion as long as the diversion itself does not contribute to erosion generation. In erodible soils channel flow velocities must be under 0.8 m/s or significant erosion may occur (Barfield, et al, 1981). This generally means the channel gradient should be under 1.0%. If this cannot be achieved then the channel should be either grass or riprap-lined. Small riprap, timber or hay bale check dams may also be placed in a ditch or channel to reduce its effective grade.

3.6 Sediment Ponds

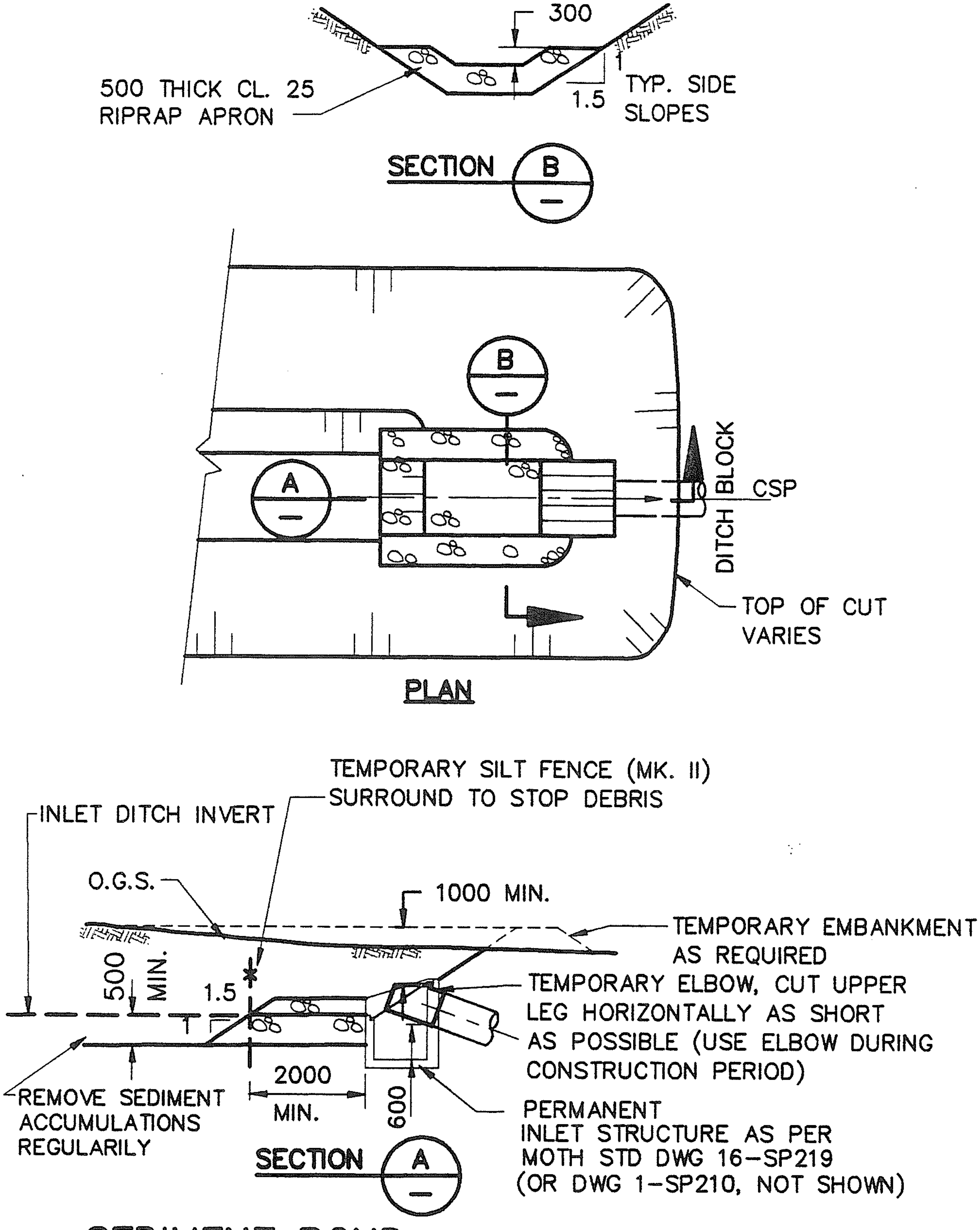
Sediment ponds represent the last line of defence against release of sediments from construction sites and therefore should be carefully designed with a network of diversions and ditches to ensure all runoff passes through the ponds. This would include runoff from waste piles and berms because these areas often remain bare over winter and may generate significant sediment. For small catchments without defined runoff channels a silt fence could alternatively provide this last line of defence. After construction is complete, these same ponds should be converted to engineered wetland areas, where these are indicated by the criteria provided in Section 4.4. Otherwise they may be filled and reclaimed.

A typical sediment pond which could be created at a permanent culvert inlet is illustrated in Figure 8. In this case the pond is created by widening and deepening the roadside ditch. The figure illustrates the use of a temporary elbow fitted to the culvert inlet. This has two purposes:

1. to deepen the pond and provide more quiescent settling and storage, and
2. to ensure discharge is skimmed from the surface where water quality is best.

Where long-term sediment trapping facilities are required it may be preferable to install a more standard vertical riser decant as detailed in many sources including, for example: Horner, et al, (1990); Barfield, et al, (1981) and Virginia Soil and Water Conservation Commission (1980).

The degree of sediment removal achieved in a sediment pond is related to its surface area. By Stokes' Law, in a basin experiencing a steady inflow and overflow, the required surface area is proportional to the overflow rate and inversely proportional to the settling velocity of the minimum particle size to be removed. Therefore, as smaller and smaller particles are settled the surface area requirements increase



SEDIMENT POND

(ILLUSTRATING HOW POND MAY BE CREATED AT PERMANENT CULVERT INLET)

N.T.S.

FIGURE 8

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rapidly. To settle fine sand (0.1 mm diameter particle) requires a pond surface area of 170 m^2 per m^3/s of flow, whereas a pond designed to remove medium silt (0.02 mm diameter) requires 4,100 m^2 per m^3/s of flow. This latter criterion for the removal of medium silt has been accepted for the Puget Sound area by the Washington State Department of Ecology and seems to represent a practical pond size to achieve. (To remove silts to 0.01 mm diameter would require a pond four times larger.) For the Island Highway the above size criteria for medium silt indicates that a pond area in the range of 1.0 to 1.5% of the catchment area would be sufficient to settle medium silt for a runoff event having a two-year return period. Smaller pond areas are often used on the assumption that over the short duration of the project such an event would not be expected, or if there are space limitations preventing the use of a larger pond.

The other major consideration in sediment pond sizing is to provide enough depth for sediment storage. Typically a minimum of 600 mm over the estimated accumulated sediment level to the outlet invert is suggested. As flow of sediment is so variable it is difficult to determine what allowance should be made for sediment accumulation. For the purposes of this work a pond depth of 1 m has been assumed to be adequate, provided construction maintenance is routine.

The following table summarizes unit flows and dimensions for sediment ponds serving less than 5 ha. It is suggested larger ponds should have a more detailed hydrologic and hydraulic analysis completed.

Table 1

Small Sediment Pond - Unit Flows and Dimensions

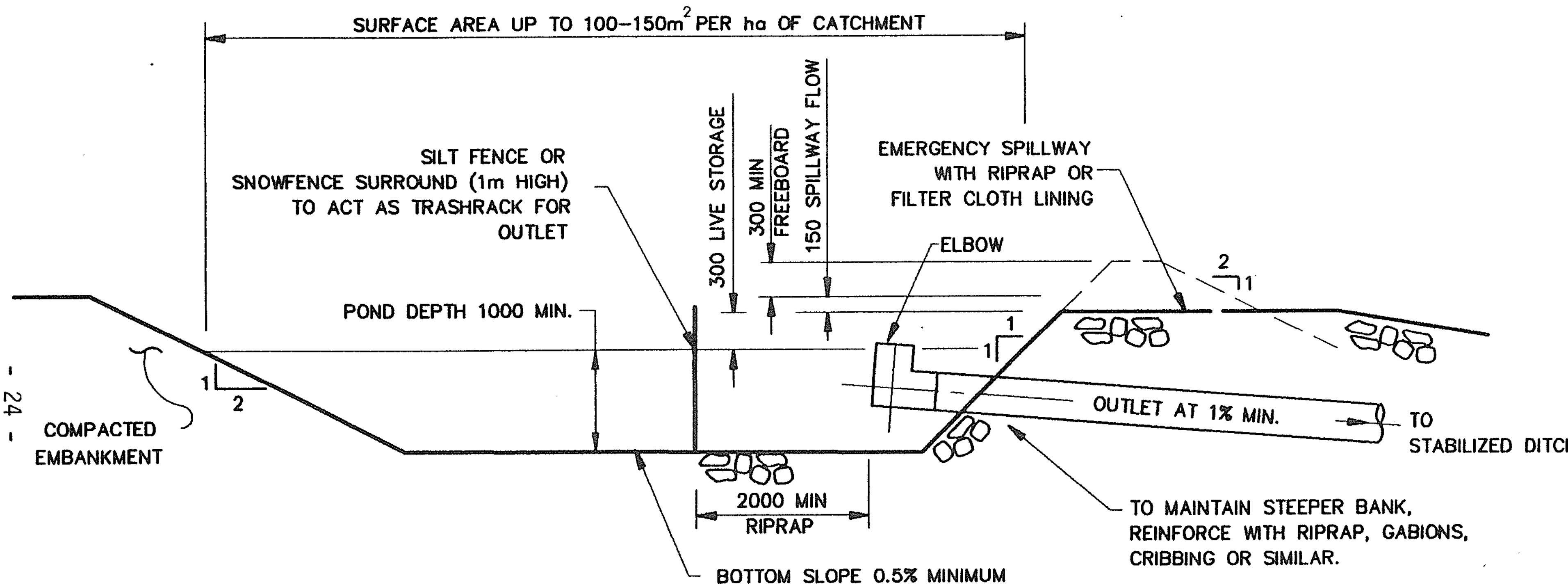
Maximum Catchment Area	-	5 ha
Design Flow	-	30 L/s per ha (2-year peak)
Surface Area	-	100 - 150 m^2/ha of catchment (1.0 - 1.5%)
Pond Depth	-	1000 mm
Outlet Pipe Diameter	-	Sized to pass design outflow under 300 mm head. Use commercial sizes available.
Emergency Spillway Design Flow	-	45 L/s per ha (5-year peak)
Spillway Width	-	Sized to pass design flow at a depth of 150 mm
Spillway Freeboard	-	300 mm

These dimensions are illustrated in Figure 9. Other design features for sediment ponds include the basin shape (the longer and narrower the better), use of baffles, embankment cross section, principal and emergency spillway design, trash racks and dewatering provisions, if needed. These features are well covered in the references already provided in this section.

3.7 Stockpiled Materials

It is important that materials for the control of erosion be stockpiled onsite during construction. Even with the best of planning there will be times when unexpected supplies of materials are required to control problem areas. The evolving phases of development will also create temporary situations, which were not foreseen at the planning stages, where special erosion control or sediment control is required.

Typical materials and suggested quantities to have on hand include silt fencing material (min. 50 m length), geotextile to stabilize small pond outlets (1 roll) and Class 10 or 25 riprap to stabilize pond outlets or ditches (30 m^3). Gravel road surfacing materials and culverts should also be available on relatively short notice. It is particularly important that the above items be available at the close of the active summer construction period in October, if not before. Hydroseeding services should also be readily available during the spring and fall planting windows.



NOTE: REMOVE SEDIMENT WHEN PERMANENT POND IS ONE–THIRD FULL

SMALL SEDIMENT POND CROSS SECTION NTS

(TEMPORARY INSTALLATION FOR CATCHMENTS LESS THAN 5 ha)

FIGURE 9

4.0 PERMANENT STORMWATER TREATMENT FACILITIES

4.1 General

Operational highway drainage is now recognized as a source of potentially polluted runoff. Pollutants originate from a variety of sources including pavement wear, tire and break wear, emissions, motor oil additives, fuels, rust, right-of-way maintenance activities and litter. Contaminants may include particulates, heavy metals, organic matter, pesticides/herbicides, nutrients and pathogenic bacteria. Most pollutants including many metals, phosphorus and organics such as pesticides are present in particulate form. Nitrogen, copper and zinc tend to be present in dissolved form. All of these can contribute to degradation of receiving water quality. Many of the streams along the Vancouver Island Highway route are particularly sensitive to changes of water quality as they are in a reasonably pristine condition. These streams provide water for domestic and agricultural use, and support significant salmonid fish populations.

Presented in Appendix A is a brief review of the literature regarding typical pollutants in highway drainage, their documented effects and methods used for treatment. Some contaminants are directly toxic to fish while others contribute to degradation of habitat. Traffic volumes greatly affect the degree of pollution caused by a highway. Below a volume of approximately 5,000 vehicles per day, significant deleterious effects of highway drainage have not been documented. Up to approximately 15,000 vehicles per day slight effects are evident. Beyond this level deleterious effects are increasingly severe. Successful prevention of pollution and effective pollutant removal is achieved by such measures as:

- traffic management (i.e. eliminating "stop and go" traffic patterns)
- litter and debris control laws and regulations
- controlled use of chemicals
- reduced use of roadside barrier or curb (uncurbed highway sections have lower pollutant loads - due to the filtering capabilities of vegetated ditches)
- infiltration systems (where soil and groundwater conditions permit)
- wet ponds, i.e. those with a permanent rather than temporary pool of water
- vegetative controls such as grassed channels, grass filter strips and overland flow
- engineered wetlands.

This report only covers the structural measures from this list, i.e. the last five items. Infiltration systems, which are potentially the most effective, are not covered explicitly as infiltration is generally a secondry benefit of the ponds and wetlands. Further design information on underground disposal of stormwater is provided by U. S. Federal Highway Administration (1980).

The selection and sizing of runoff treatment systems along a highway should be chosen in recognition of the anticipated traffic volume and receiving water conditions along the highway. Appendix B, Highway Stormwater Treatment Criteria, defines an appropriate level of stormwater treatment provided by various techniques such as grassed surfaces and engineered wetlands, and explains design criteria for facilities. As traffic volumes increase, or with increasing sensitivity of the receiving waters, the level of treatment is increased. Generally, various types of vegetative control are appropriate for low traffic volumes and low creek sensitivity. Engineered wetlands or wet ponds should be utilized for maximum protection of a stream when traffic volumes are moderate to high. While the mechanics of particulate removal are well understood and usually achieved by sedimentation processes, the rate of removal of soluble metals and organics has not been defined. Grass and wetland plant species are effective at removing soluble pollutants (Appendix B). For sensitive receiving areas, there is, therefore, a reliance on techniques involving use of sedimentation ponds which are planted with wetland species to achieve improvements in water quality (engineered wetlands).

This report addresses water quality issues related to stormwater but does not consider changes to the hydrologic regime of surface water. Conventional urban development alters the surface water regime in many ways. The increased paved area reduces infiltration and transpiration, thus increasing the volume of surface runoff. The smoother surfaces of developed areas, i.e. pavement and grass versus uneven, forested land, cause surface runoff to flow faster and thereby increase peak flows. Stormwater detention is an effective way of attenuating these effects. In highway development, however, the affected areas of the various watersheds are usually small enough, often with indirect connections to the receiving stream, that the changes to the surface water hydrograph are not significant. Therefore, detention systems are not considered necessary for this type of highway development. In an urban situation, where there is significant development or potential development, and stormwater detention is a servicing requirement, highway runoff should also be detained to the same standard as for the urban area.

4.2 Traffic Volumes

Existing and projected traffic volumes for the Inland Highway have been estimated by Ward (1989), Hamilton (1989) and Crippen (1990). Table 1 summarizes their traffic volume estimates for locations along the highway. Ward also estimated variation in traffic volume by month for existing conditions. August is the peak month. The existing ratios of the peak month to the Average Daily Traffic (ADT) for various sections were used to develop estimates of peak monthly traffic on an annual basis for the new highway.

Table 2

Average Daily Traffic (ADT) Both Ways

Location	1989 Highway 19	2014 New Highway	2014 New Highway Peak Month
Parksville North	11,400	11,726	17,000
Bowser	5,900	11,042	15,300
Union Bay	5,200	12,980	18,200
Merville	8,300	9,120	12,800
Oyster River	7,900	8,970	12,600
Campbell River	15,000	6,220	6,700
Duncan Bay	2,700	3,440	4,700

For the purposes of this work, peak daily traffic volumes which exceed 15,000 are considered to generate sufficient pollutants to warrant stormwater treatment, especially if the receiving stream is a sensitive area. Under a traffic volume of 5,000, only nominal treatment is required, even in sensitive areas. (The U. S. Federal Highway Authority (1985b) considers 30,000 vehicles per day to be the threshold volume of traffic for which runoff treatment is required for an insensitive receiving water.)

4.3 Definition of Sensitive Receiving Water

The three general types of sensitive receiving waters considered here include streams, lakes and wetlands. The following definitions are based on U.S. EPA requirements where the sensitivity of the receiving water determines the level of treatment to be applied to various effluents.

A stream or river is defined as sensitive when it provides potable water, sustains an important fishery or has highway covering more than 5% of the watershed upstream of the discharge point, regardless of the beneficial uses of the stream. All agricultural fields that receive drainage from highway ditches are deemed as sensitive.

A lake is defined as sensitive when it either has a shoreline park, is regularly used for contact recreation and recreational fishing or has highway covering more than 5% of the lake's watershed, regardless of the beneficial uses of the lake. It also includes any lake designated by scientific analysis as eutrophic or approaching eutrophic status due to human activity.

A wetland is defined as sensitive when the area of highway covers more than 5% of the wetland's watershed.

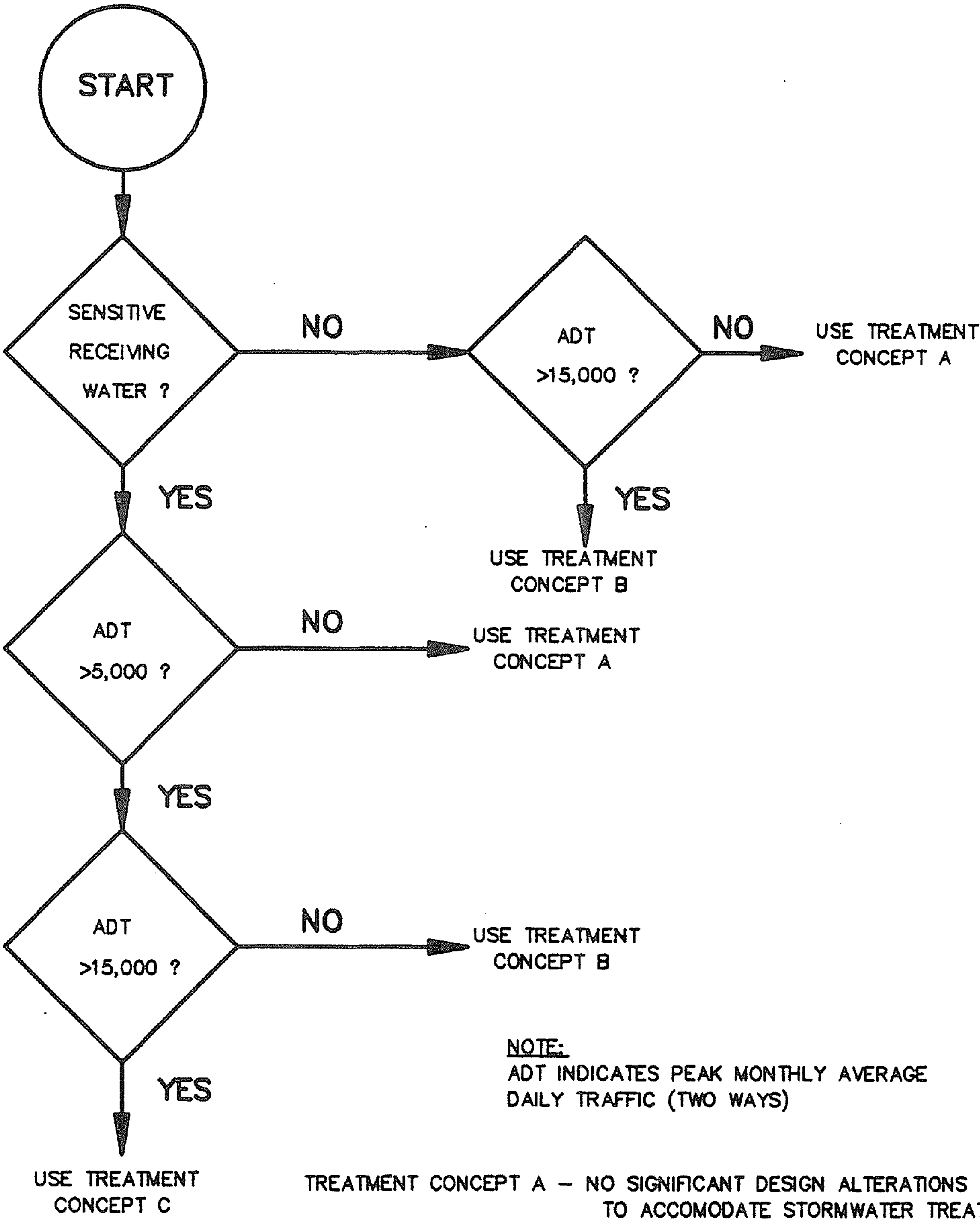
4.4 Treatment Selection Process (by G. Minton, P.E., Resource Planning Associates)

A treatment concept selection process is described in Figure 10. It uses a flow chart approach to help the user determine appropriate treatment methods for maintenance of highway runoff quality.

4.4.1 **Treatment Concept A**

Treatment Concept A represents the first level of treatment and is applicable in cases of very low traffic volumes or insensitive receiving waters. No significant design alterations need be made to accommodate stormwater treatment. Rather, the designer should rely on grassed shoulder strips, grassed medians and grassed ditches.

TREATMENT CONCEPT SELECTION PROCESS



NOTE:
ADT INDICATES PEAK MONTHLY AVERAGE DAILY TRAFFIC (TWO WAYS)

TREATMENT CONCEPT A – NO SIGNIFICANT DESIGN ALTERATIONS TO ACCOMODATE STORMWATER TREATMENT

TREATMENT CONCEPT B – ALL STORMWATER DIRECTED TO TREATMENT FACILITY

TREATMENT CONCEPT C – ALL STORMWATER DIRECTED TO ENGINEERED WETLAND

FIGURE 10

1. Grassed Median

Wherever possible the designer should attempt to drain stormwater to the median grass. There the water will either be treated by percolating down to the underlying soil or by the grass before entering a catch-basin. Percolation through the soil will normally provide the best stormwater treatment if soil and ground water conditions permit. On many sections of the new highway it may not be possible to utilize the grassed median as it is reserved for future widening and the road surfaces are sloped away from it. As use of the grassed median represents an economical way to maintain good quality runoff, every effort should be made to find a way to utilize this opportunity.

2. Grassed Shoulder Strips

As discussed in Appendix B, grassed shoulder strips may provide excellent treatment of runoff provided they are installed and maintained specifically for treatment as would be required for Treatment Concepts B or C. Normally, however, the naturally grassy area beside the roadway has too much gradient to work as a highly effective treatment area, and is not maintained for treatment purposes. However, under Treatment Concept A no particular criteria for the shoulder strip need be met and a degree of treatment will still be achieved by directing runoff to these grassy areas.

3. Grassed Drainage Ditch

Analysis in Appendix B indicates that the standard grassed drainage ditch will remove 50 to 70% of particulate pollutants. Removal is dependent on proper maintenance of the ditch as described in the Appendix. The range in removal efficiency reflects variation in rainfall characteristics along the highway and variation in expected length of drainage ditches.

Specific design criteria for these facilities is not required for Treatment Concept A.

Where the drainage from a portion of the road section cannot, without considerable redesign, be directed to a grassed drainage ditch, it may be discharged directly to the receiving water.

4.4.2 Treatment Concept B

Under Treatment Concept B the road designer should ensure that drainage from all road areas is treated prior to discharge. Generally the Ministry requires deck drains to discharge clear of the underside of the bridge. This layout minimizes drain blockage but means there is little opportunity to direct deck drainage to treatment areas. B. C. Environment and Fisheries and Oceans Canada presently have no significant concerns with discharge of bridge deck drainage directly to creeks but direct discharge could be minimized by judicious drain spacing and it is recommended that deck drains be spaced so that as much water as possible is directed away from the wetted perimeter of the creek. Provisions must be made to prevent erosion of bridge end fills and natural stream banks due to deck drainage by careful selection of drain locations and/or discharge onto protected surfaces.

The following treatment methods are appropriate to meet Treatment Concept B requirements:

- a grassed median
- a grassed shoulder strip in combination with a grassed ditch
- a grassed treatment swale at the end of the highway ditch
- an engineered wetland.

The above approaches are listed in order from least to most expensive and the designer may select from this list by progressing from one method to the next as design constraints dictate. For example, there is a negligible cost associated with use of a grassed median for treatment but the need to reserve the median for future widening and a cross fall direction away from the median would mean it cannot be utilized for this purpose. The designer would then consider the use of a grassed shoulder strip in combination with a grassed ditch.

1. Grassed Median

The use of the grassed median may be restricted by other design constraints and so will have limited application. Its use will require that the road cross fall is toward the centre median. If the roadways are crowned, drainage from the outside lanes would require another form of treatment but wherever possible this economical treatment method should be utilized.

2. Grassed Shoulder Strip/Grassed Ditch Combination

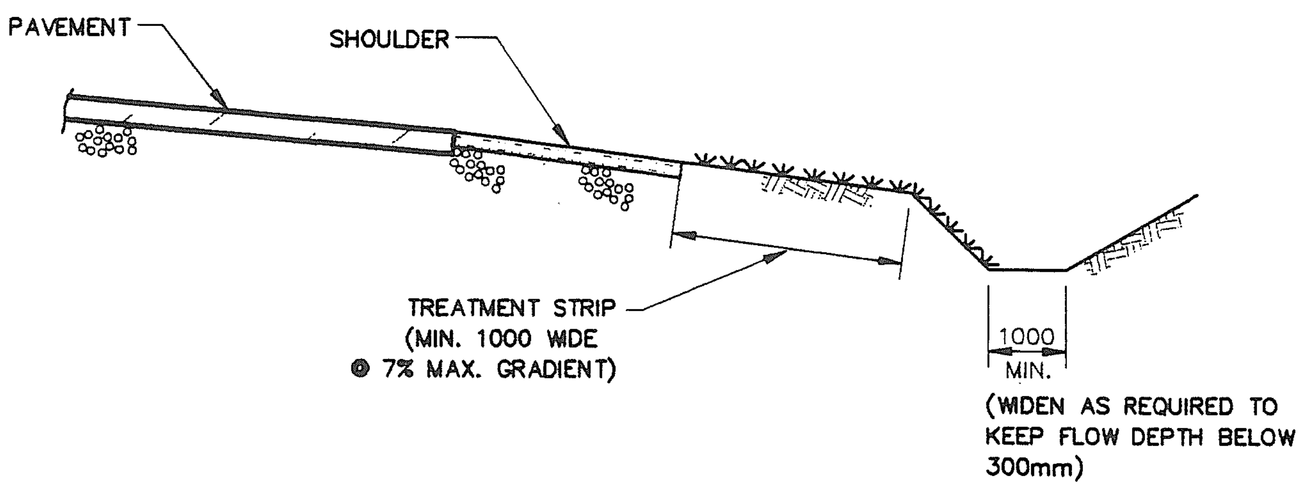
In order to use the shoulder strip/grassed ditch combination the following criteria must be met (Figure 11):

- minimum strip width of 1000 mm
- gradient not to exceed 7%
- grassed drainage ditch has standard MoTH configuration with minimum base width of 1000 mm
- allowable maximum length for effective treatment in a grassed drainage ditch varies with ditch gradient and mean annual rainfall (Figure 12). As discussed in Appendix B, grassed ditches provide treatment as long as water depth does not exceed grass height during a storm event (6-month event usually selected for design purposes), and the grass is kept short enough (i.e. between 50 mm and 100 mm for the shoulder strip and 150 and 300 mm for the ditch) so that it is not laid flat by the flowing water
- to ensure effective revegetation and a vigourous grass stand the soil of the treatment strip and ditch and grass seeding procedures must follow standard specifications as detailed in Appendix C - Erosion Control and Appendix D - Vegetated Filter Areas.

3. Grassed Treatment Swale

Where a treatment swale is used at the end of a ditch to achieve treatment, it may be sized on the basis of Figure 13 which specifies swale surface area as a percentage of the total amount of paved area which drains to the swale. Line I in Figure 13 is the standard criterion to be used in conjunction with an overlength or otherwise partially effective grassed drainage ditch. Such a swale will remove approximately 40 to 60% of the particulate pollutants in addition to a significant fraction removed by the upstream ditch. Removal by the combined system is expected to be 50 to 70%. If design conditions permit, or there is no partial upstream treatment, Line II should be used to size the grassed swale.

The shape of the swale may suit the available site, with the limitation that the minimum width be defined by Figure 14. If the swale is made wider, its length may be reduced but care is needed to ensure the flow is spread across the entire width of the swale.



ACCOMMODATING THIS TREATMENT STRIP IN THE STANDARD HIGHWAY CROSS SECTION MAY REQUIRE RELOCATING THE STRIP AWAY FROM THE SHOULDER TO PERMIT PROPER DRAINAGE OF THE FOUNDATION.

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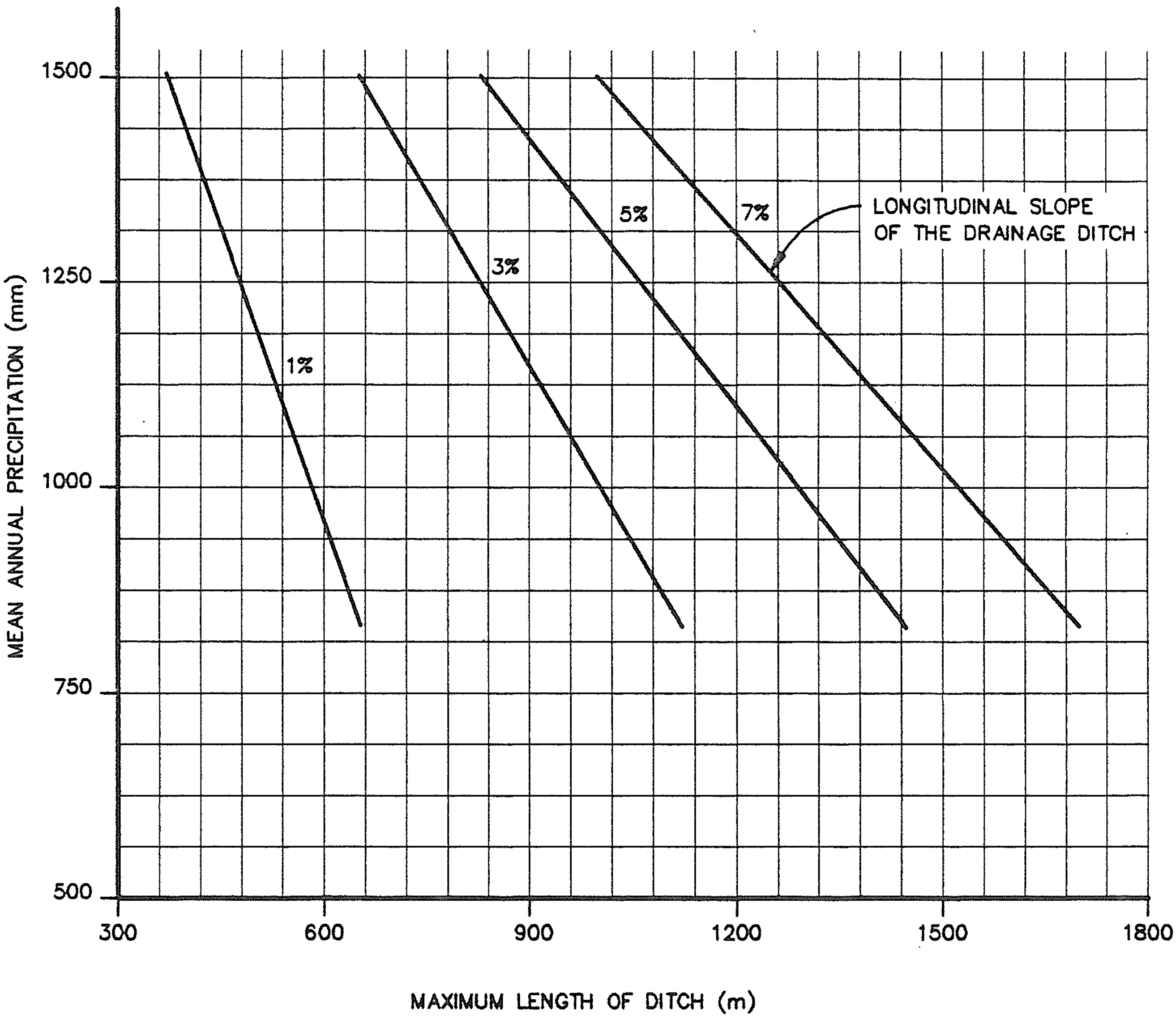
GRASS SHOULDER TREATMENT STRIP

FIGURE 11



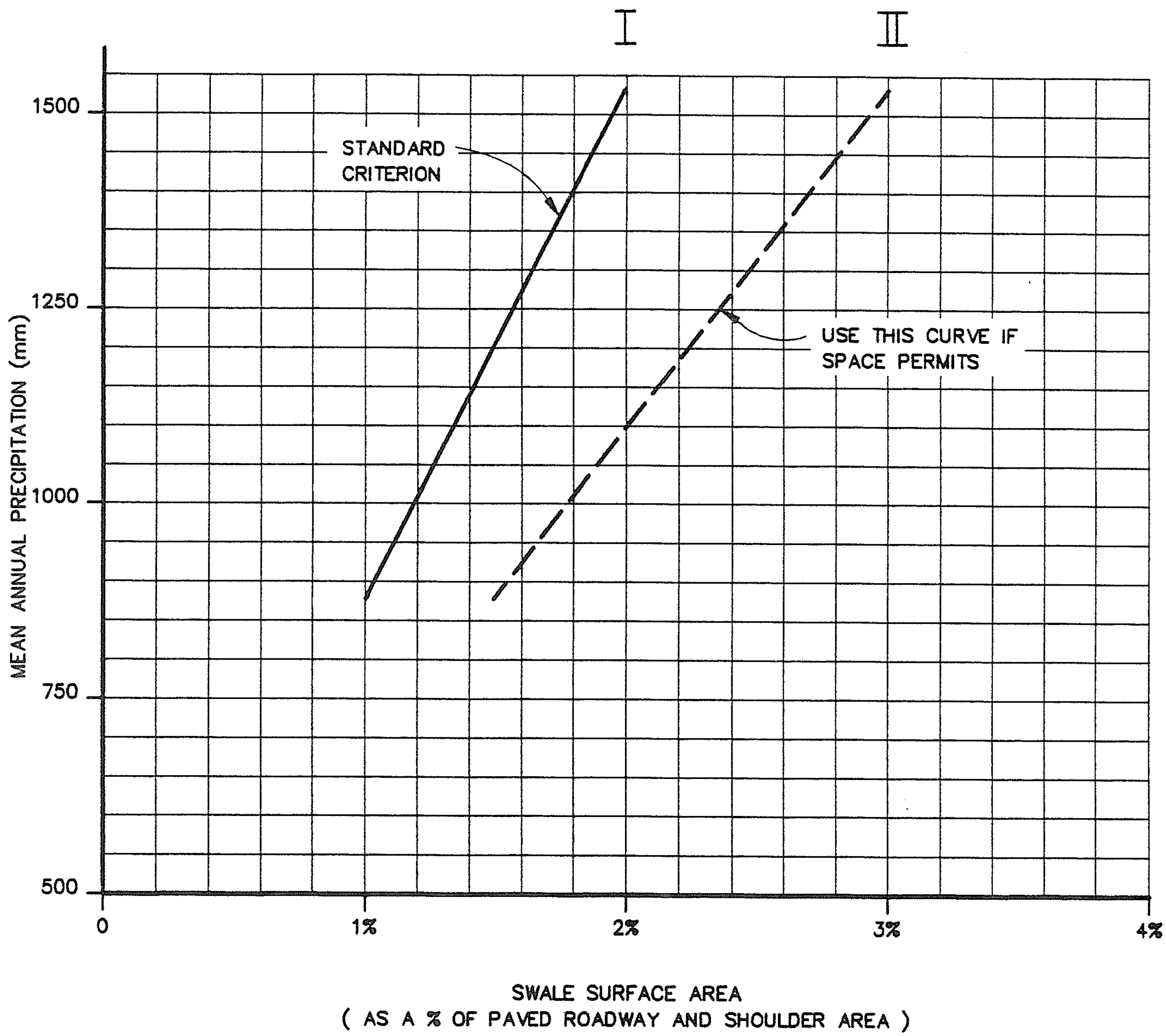
NOTE:

1. THIS FIGURE ASSUMES DITCH BOTTOM IS 1m WIDE.
   IF WIDER DITCH IS REQUIRED USE FIGURE 13, FOR GRASSED SWALES.

2. REDUCE MAXIMUM LENGTH BY A FACTOR, SAY 25–50%, TO REPRESENT IRREGULARITIES IN THE DITCH BOTTOM ie, THE PERCENT OF THE DITCH BOTTOM NOT COVERED BY A LOW FLOW.

MAXIMUM LENGTH FOR EFFECTIVE TREATMENT BY GRASSED DRAINAGE DITCH

FIGURE 12

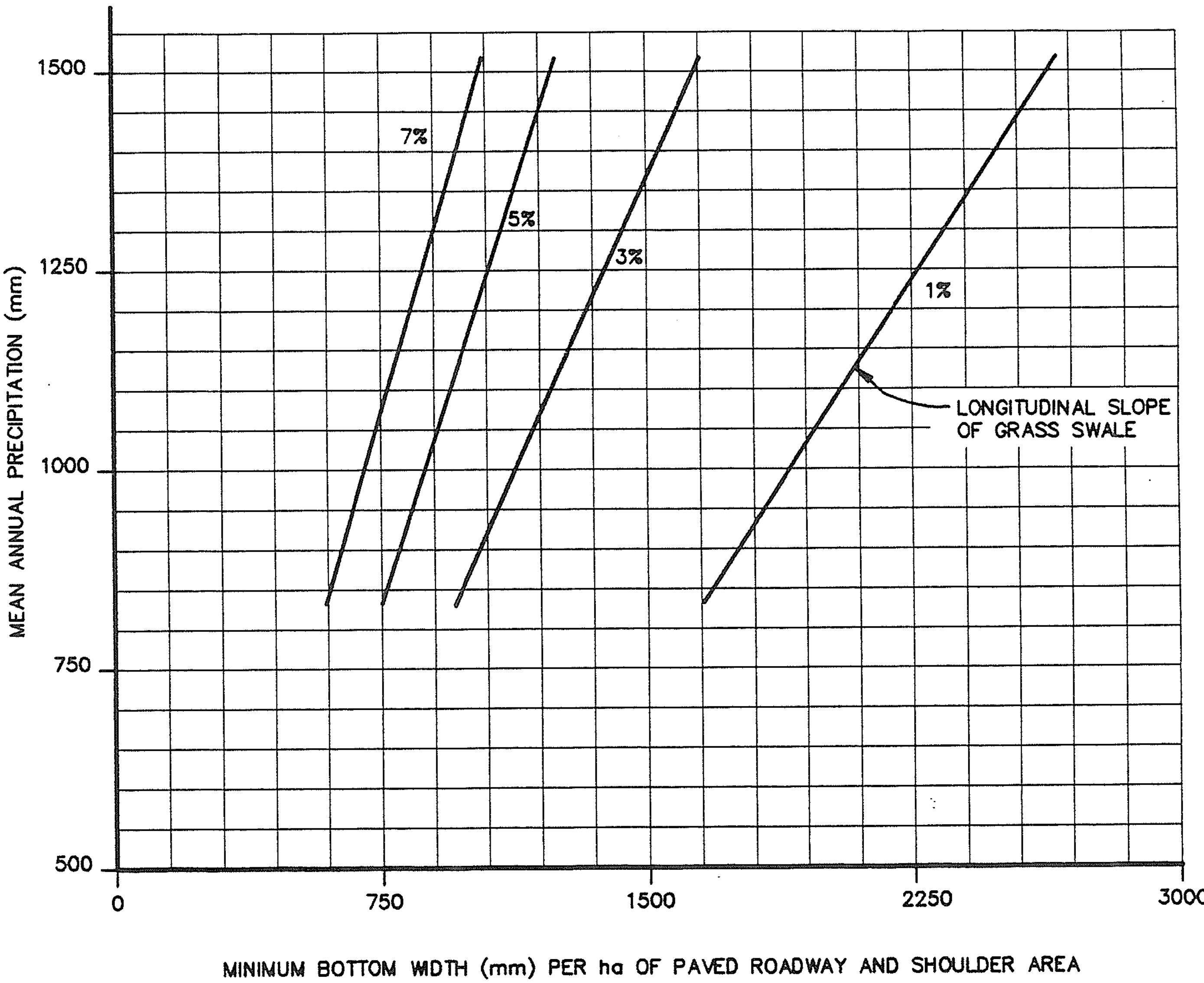


LINE I – USE WITH OVERLENGTH OR PARTIALLY EFFECTIVE GRASSED DITCH

LINE II – USE WHEN THERE IS NO PARTIAL UPSTREAM TREATMENT OR IF SPACE PERMITS

GRASSED SWALE SIZE

FIGURE 13



MINIMUM SWALE WIDTH

FIGURE 14

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KPA ENGINEERING LTD.

Further information on grassed ditches and swales regarding species selection, temporary erosion control blankets and timing of planting is provided in Appendix D - Vegetated Filter Areas.

4. Engineered Wetland

An engineered wetland is used when none of the above alternatives is practical. An engineered wetland is either a natural or excavated shallow pond in which the water level is controlled by an outlet structure and in which appropriate wetland vegetation is encouraged. In addition to sedimentation of insoluble particles, biological absorption of soluble pollutants also occurs due to the presence of the vegetation.

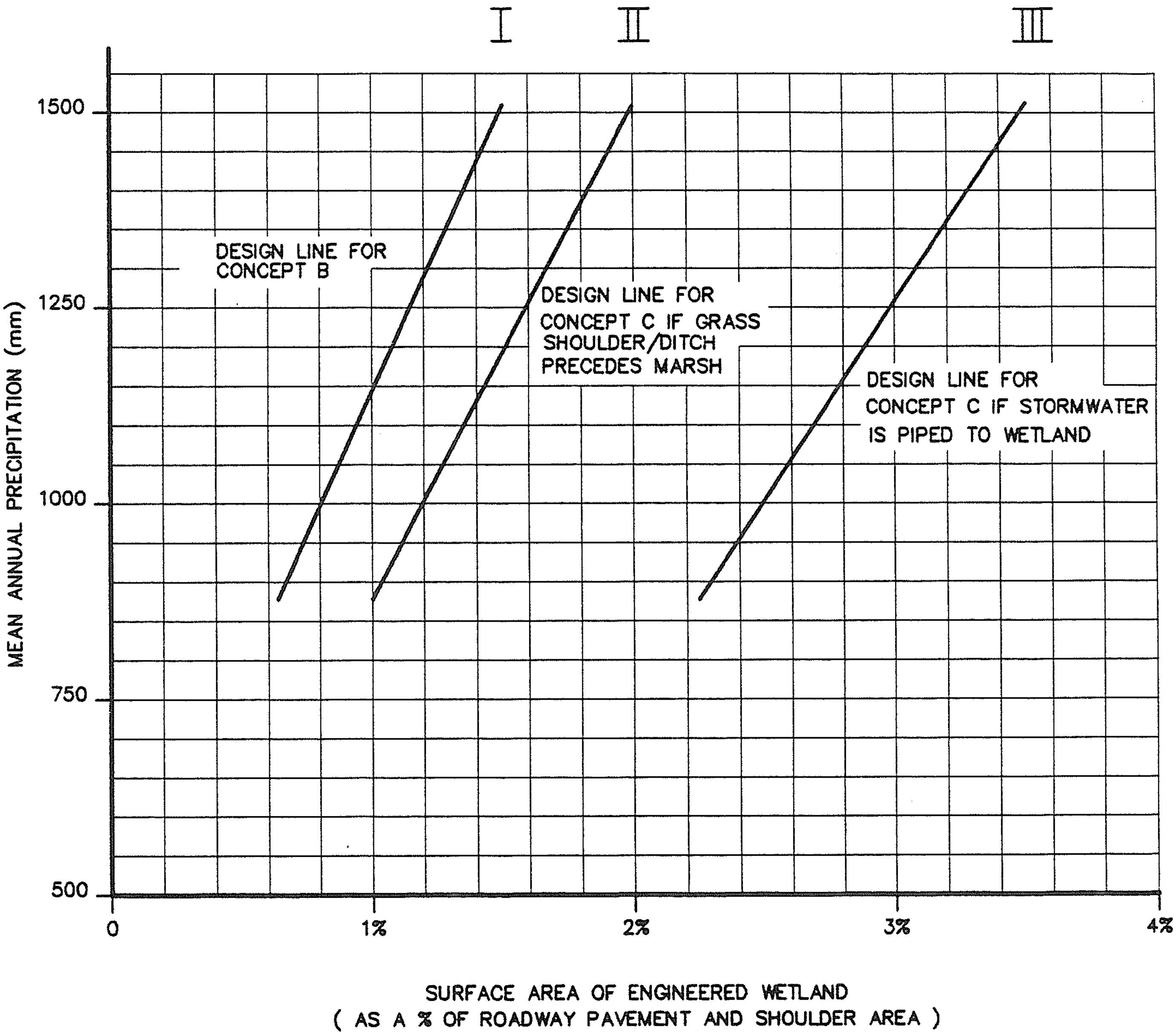
The surface area of the wetland should be determined using Line I in Figure 15.

The wetland should incorporate a deeper forebay area equalling approximately 25% of the wetland area to store accumulated sediments. The forebay should be at least 1000 mm deep and the remainder of the wetland, which will be planted, should be 250 to 500 mm deep, depending on the selected plant species.

Engineered wetlands, sized on the basis of Figure 15, are designed to treat runoff from small storm events (6-month return period as discussed in Appendix B), but they must also be designed to safely pass more severe rain events. Normal design criteria for the outlet works would be 10 - 50 years, but where the consequences of failure of the outlets or of the containment berm are serious or potentially catastrophic, the return period should be increased up to 200 years. In the latter circumstance the use of an open emergency spillway rather than conduit should be considered.

The wetlands are not designed to perform a detention function, therefore high surcharges caused by flow controlling outlets are neither necessary nor desirable.

Other design considerations include the provision of access for maintenance and removal of sediments, provision of a liner to prevent rapid infiltration of pond water, placement of substrate (topsoil) to ensure adequate rooting for the vegetation, selection of appropriate wetland species, and the potential need for an erosion control blanket to protect bare surfaces of the wetland after seeding and until vegetation is established.



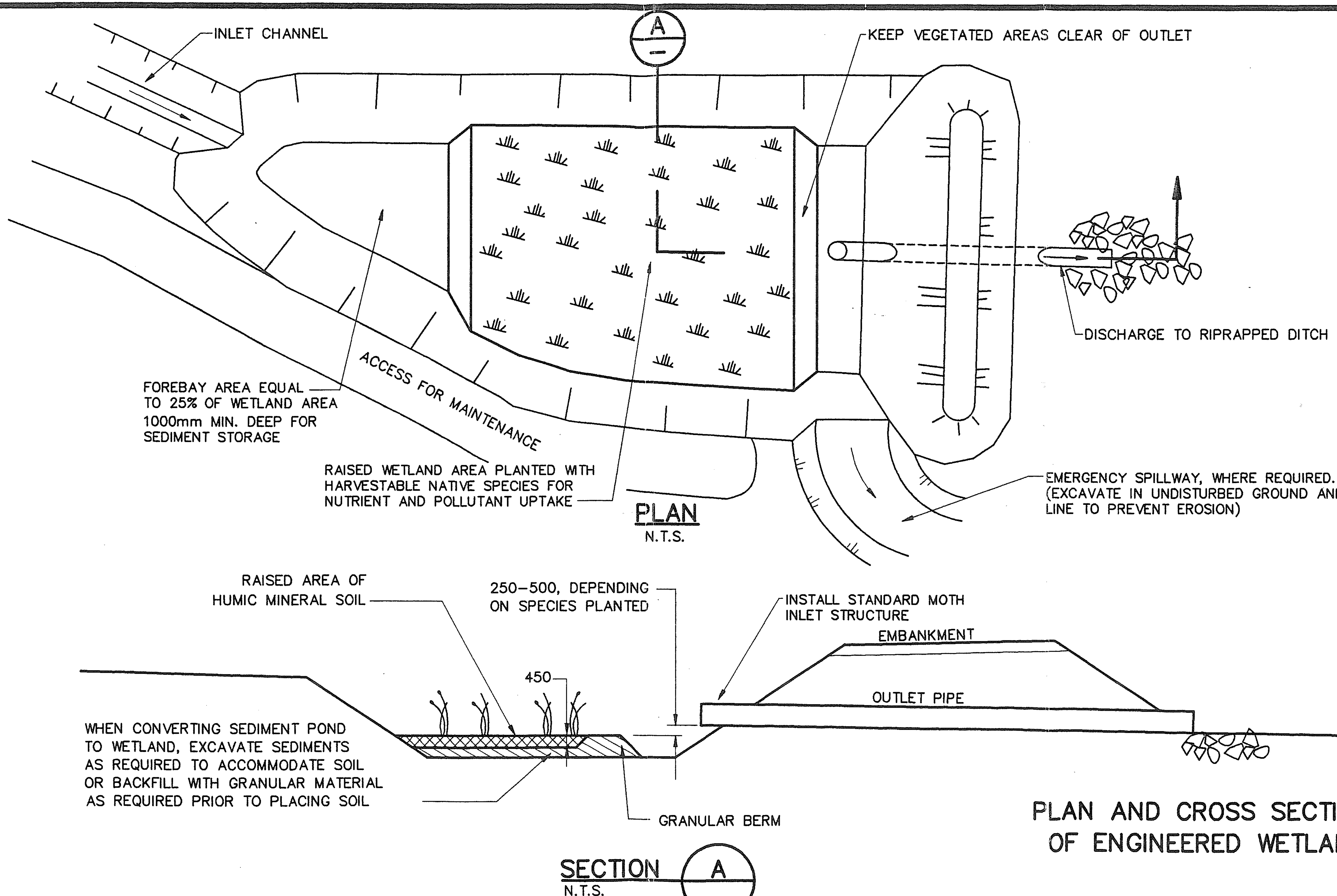
SIZING OF ENGINEERED WETLAND

FIGURE 15

Appendix E - Engineered Wetlands to Treat Highway Surface Runoff at Sensitive Sites, provides specific information for recommended monitoring of the wetland before vegetation establishment, and recommended vegetation types and planting methods. A discussion on soil types and liners is also provided. Figure 16 illustrates a plan and cross section of a typical engineered wetland.

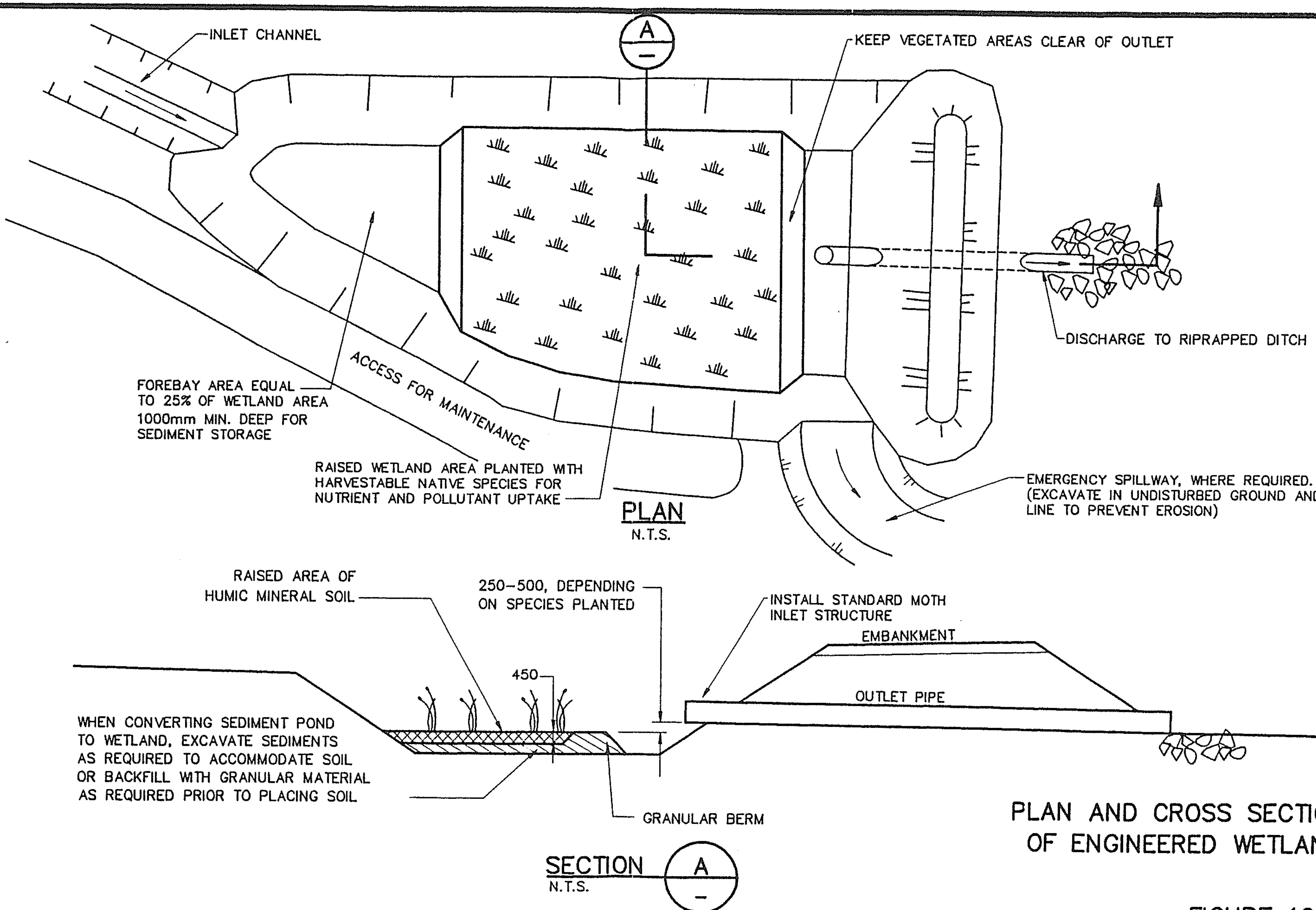
4.4.3 Treatment Concept C

Treatment Concept C is used where traffic flow exceeds 15,000 vehicles per day and drainage is to sensitive areas. In all situations an engineered wetland should be used to treat runoff from the highway and, where practical, from the bridge decks as discussed in Section 4.4.2. Lines II or III of Figure 15 provide the required surface area of the wetland. If the grassed shoulder strip/grassed ditch treatment combination as described under Treatment Concept B is in place, then Line II is appropriate. Line III is utilized when there is no "at source" treatment and the stormwater is piped directly to the wetland. Wetland areas designed from Line III are approximately twice the size of those designed by Curve II. The other criteria described in Treatment Concept B are also applicable here under Treatment Concept C.



PLAN AND CROSS SECTION OF ENGINEERED WETLAND

FIGURE 16



PLAN AND CROSS SECTION OF ENGINEERED WETLAND

FIGURE 16

5.0 STORM DRAINS AND ENERGY DISSIPATORS

5.1 General

The nature of drainage in the vicinity of creek crossings along the highway route is such that conveyance structures are required to safely carry storm flows to the creek valley bottom. Typically, an engineered wetland or sediment pond would be placed at the top of the bank and an outlet pipe would terminate at an energy dissipator in the valley. The terminal structure slows the flow velocity before discharge to the floodplain or creek and helps prevent erosion at this point.

5.2 Storm Drains

Up to gradients of 30 to 40%, normal storm drain design using buried CSP, concrete or PVC pipe is appropriate. CSP pipe joints should utilize hugger-style couplings or annular couplings with through bolts on rerolled ends. Bell and spigot connections on concrete or PVC pipe should be mechanically connected. Standard fittings are available for this purpose.

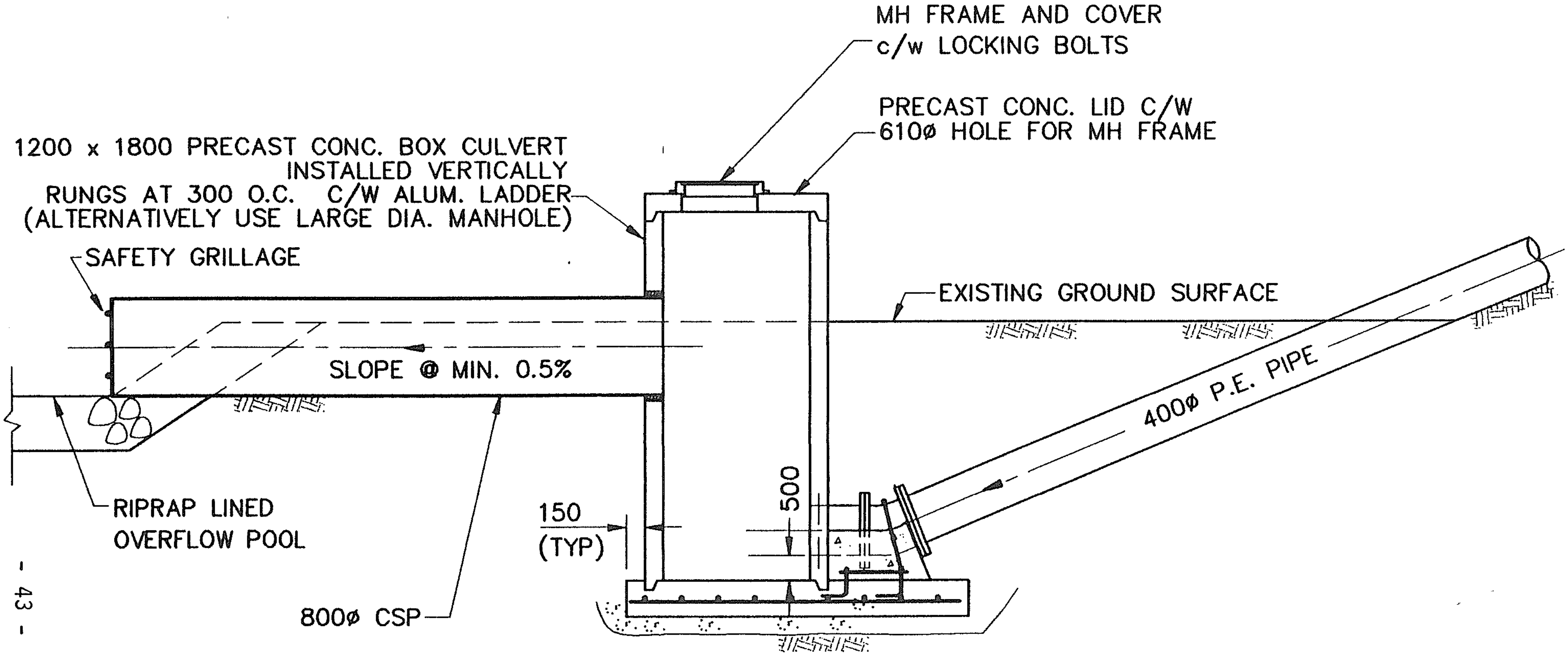
For storm drains laid on steeper grades, butt-fused polyethylene (PE) pipe laid above grade is suggested. The steeper slopes are typically near their natural angle of repose and clearing and trenching operations may make the bank unstable. Therefore, a pipe laid on the surface with minimal hand clearing may provide the best solution to conveying flow down the bank. The pipe should be laid with as much contact with the ground as possible, but the pipe may span reasonable distances, thus eliminating the need to grade the bank surface to a smooth contour.

Steeply-graded storm drains should be preceded by sediment ponds to provide sediment control as close to the highway access as possible, and to eliminate further disturbance of the floodplain. In addition, this configuration reduces wear of pipe surfaces, particularly in steel and concrete pipes, which could be a problem if sediment is allowed to travel down the pipe.

5.3 Energy Dissipators

For this project an enlarged manhole-style energy dissipator was developed. It works on the principle of dissipating the energy of the flow against water already in the manhole. Fast-moving water enters at the bottom and upwells to spill relatively slowly out the discharge pipe to a riprapped channel. This design has considerable cost savings over the more traditional impact-style of energy dissipator.

An example of an energy dissipator used at French Creek is illustrated in Figure 17. The design flow for this structure is 0.75 m^3/s.



ENERGY DISSIPATOR

FIGURE 17

6.0 MONITORING PERFORMANCE OF WATER QUALITY FACILITIES

Design of stormwater treatment facilities is still in its infancy and research in the field will refine and improve the treatment techniques presently in use.

It is suggested the permanent stormwater quality ponds be monitored to determine their effectiveness. Monitoring of inflow would help confirm the degree of water quality degradation being caused by highway operation and the appropriateness of the treatment method. Periodic sampling of the pond substrate or of the pond vegetation would indicate to what extent pollutants were being deposited in the pond and whether there is a need to harvest the pond vegetation to prevent pollutant release by winter die-off. Monitoring of outflow would determine the percent reduction in pollutants that is being achieved in the pond. The monitored constituents may include total suspended solids (TSS), metals, total organic carbon (TOC), oil and grease, and certain nutrients. A more complete list of potential pollutants is provided in Table A-1 of Appendix A. The pond outflow rate should also be measured at the time of sampling to assess settling pond performance relative to flow rate. The monitoring program should be flexible and regularly refined as the relative significance of the various parameters is determined. The pond hydrology should also be reviewed because if the pond is too wet or dry for the selected species, optimum plant growth and pollutant uptake will not be achieved.

Temporary sediment ponds should be monitored during the construction phase as it is also important to know the relative effectiveness of these facilities. TSS should be measured by grab sample at both the inlet and outlet during rainy periods, particularly during the late fall and winter months. Grain size analysis of the samples would confirm that the ponds are removing the desired fraction of suspended solids.

It would also be useful to make qualitative assessments of the degree of soil loss at critical locations to determine the effect of onsite or vegetative control measures. Rate of sediment accumulation in the ponds would assist in this assessment.

Before commencing any sampling program select a laboratory to do the analysis and determine from them the required sample volumes, sample storage procedures and any other special requirements which may be important. A trained technician may be required for some aspects of sample collection and for monitoring the pond flow rate.

Associated with monitoring the performance of the water quality facilities is the determination of an appropriate level of maintenance together with an understanding of the effects on water quality of different maintenance functions. For example, ditch cleaning operations which strip vegetation from the bottom of the ditch have a detrimental effect on water quality. Ditch excavation should be minimized, as it is only infrequently necessary to strip the vegetation and deepen a ditch for hydraulic reasons. Accumulations of sediment in ponds should, however, be removed when they represent one-half the available storage depth. Maintenance procedures with respect to wetland vegetation are not well documented but the situation will improve as experience is developed and monitoring data become available.

7.0 RESTORATION OF STREAM CROSSING SITES

In normal highway design the grade construction contract precedes the bridge construction contract. The grading contract should include the sediment ponds and all other drainage facilities and necessary stream-bank stabilization. The bridge constructor utilizes these facilities to assist in the drainage of his work areas. Upon completion of bridge construction the site should be "restored." Typical works may include conversion of the sediment ponds to water quality ponds including pond planting with appropriate species, planting of cleared floodplain areas with native stock, creating flood channels, replacing logs and stumps in the creeks to act as aquatic habitat areas, closing access roads and removing temporary bridges and ramps, all of which are intended to speed the return of the site to as natural a condition as possible. These works should form part of the bridge constructor's contract.

Advice concerning restoration of fish or wildlife habitat will be provided by biologist advisors normally retained by MoTH to assist engineering consultants responsible for highway grading and bridge design.

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ACKNOWLEDGEMENTS AND ORGANIZATION CHART

We wish to acknowledge the assistance of the many engineers and other specialists who contributed to the completion of this project. The organization chart on the following page indicates the various individuals involved and their areas of expertise.

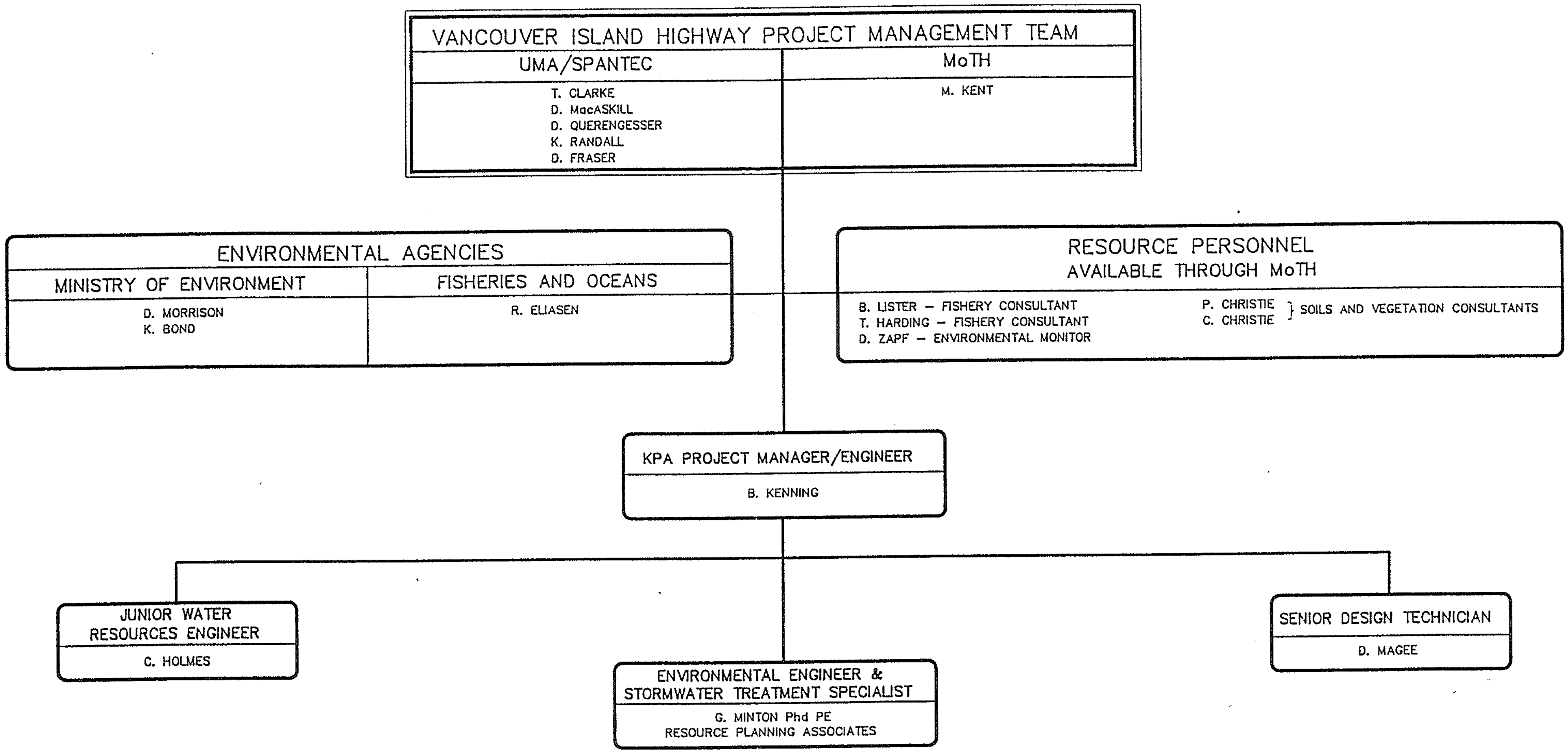
In addition to this report KPA's assignment included conceptual and detail design of drainage facilities to convey and treat drainage from the approaches to French Creek, Little Qualicum River and Kinkade Creek highway crossings. This identified work, which must be completed in the summer months, included plans for slope stabilization, drainage control and treatment and protection of work areas on the floodplain from high winter flows. This parallel work provided valuable background experience in preparation of these guidelines.

This report entitled, "Guidelines for Environmental Design of Highway Drainage," has been respectfully submitted by KPA Engineering Ltd.

PROFESSIONAL PROVINCE OF B. F. I. KENNING BRITISH COLUMBIA ENGINEER

June 25 1992

B. F. I. Kenning, P. Eng.
Project Manager



VANCOUVER ISLAND HIGHWAY PROJECT
ENVIRONMENTAL DESIGN FOR HIGHWAY DRAINAGE

ORGANIZATION CHART

KPA ENGINEERING LTD.

DATE NOV. 1991

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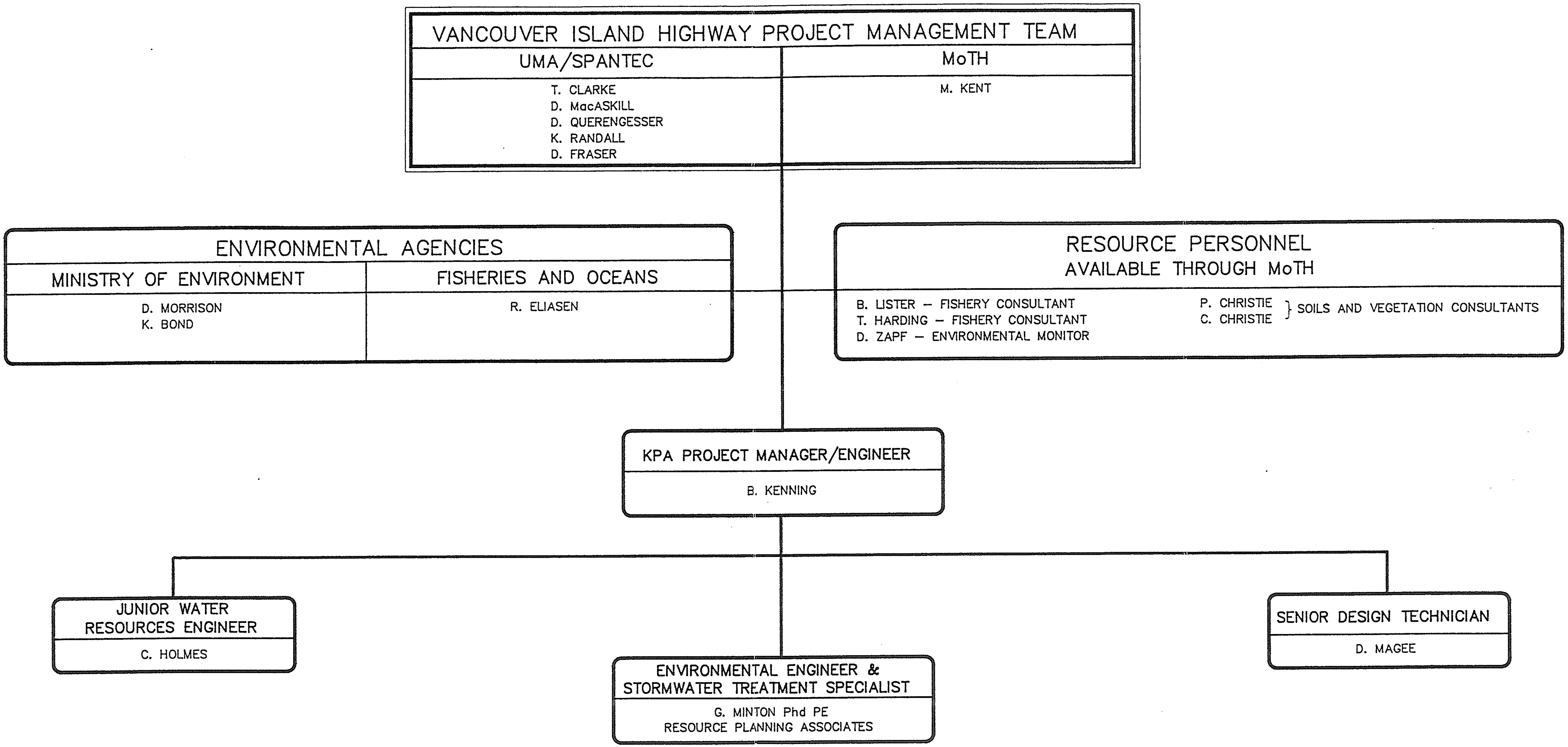

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APPENDIX A

LITERATURE REVIEW COVERING

THE EFFECTS AND TREATMENT OF STORMWATER FROM HIGHWAYS

by

RESOURCE PLANNING CONSULTANTS

SEATTLE, WASHINGTON

APPENDIX A
LITERATURE REVIEW COVERING
THE EFFECTS AND TREATMENT OF STORMWATER FROM HIGHWAYS

1. Pollutant Concentrations and Effects

The information presented below regarding stormwater pollution is drawn from research on the effects of runoff from highways in the United States by the U. S. Federal Highway Administration (see References) except where otherwise noted.

Table A-1 summarizes data obtained by the U. S. Federal Highway Administration in the late 1970s. A total of six sites were examined in Wisconsin (three), Pennsylvania (one), Colorado (one) and Tennessee (one). Average Daily Traffic (ADT) values in two directions ranged from 40,000 to 149,000, with an average of 85,000 for the six sites. The mean concentrations of most of the pollutants in Table A-1 are far above generally accepted water quality criteria (Appendix B). However, the traffic volumes far exceed that expected for the Vancouver Island Highway. As described below, research has shown a good correlation between traffic volume and pollutant quantities. Bannerman (1991) found this relationship in recent work in Wisconsin for roads with ADT values in the range of 1,000 to 8,000.

Recent research in Seattle, Washington suggests that pollutant concentrations in highway runoff may have been decreased since the completion of the work represented in Table A-1. A comparison was made of data collected from the same locations in the late 1970s and early 1980s, to data collected in the late 1980s (Merrill et al., 1989). Geometric mean concentrations of copper, lead and zinc had decreased 70%, 90% and 60%, respectively. The geometric mean concentrations obtained in recent studies for these three parameters were about 0.020, 0.050 and 0.165 mg/L, respectively. Note that these values are considerably lower than those in Table A-1. However, the comparison between geometric and arithmetic means (average), is misleading. For the same data set, geometric means will be lower than arithmetic means. The reason for the significant reduction in lead is the phasing in of lead-free gasoline. The reasons for the reductions in zinc and copper are not known. Suspended solids levels also declined by about 60%, consistent with the reductions of the metals.

Researchers for U. S. Federal Highway Administration also examined the effects of stormwater runoff on instream water quality, sediment quality (at the bottom of a lake or stream) and the biota. A summary of research where the ADT has been identified is presented in Table A-2. The results in Table A-2 suggest that minor effects are observed where the ADT is between 5,000 and 10,000, if the stormwater is passed through the grassy shoulders and ditches normally included in a rural or semi-urban highway. Bioassay effects are generally seen when the ADT exceeds the range of 20,000 to 40,000.

Stimulatory effects on algae and heterotrophic organisms at low ADT show the presence of nutrients and BOD, but at higher ADT these effects are inhibited by the high metals concentrations.

The deleterious effects observed on Rainbow trout at 50,000 ADT were not observed at the slightly lower ADT of 42,000. Despite the minor difference in ADT at these two sites, the suspended solids concentrations at the two sites were significantly different. The data in Table A-2 are for unfiltered samples. Filtering the samples from the site with 50,000 ADT eliminated the negative effect, indicating that it was a direct result of the solids on the fish gills rather than the toxicity of metals.

There are no data on runoff from highways in southwest British Columbia. Hall, et al.(1988), examined the effects of urban runoff from residential, commercial and industrial sites. The test organism was Daphnia pulex. Runoff from all the commercial and industrial sites was quite toxic. The results from the residential sites were inconsistent. Mean concentrations of copper and lead in the runoff from the commercial and industrial areas were similar or greater (sometimes significantly greater) than the concentrations shown in Table A-1. Consequently the toxic results are not surprising.

2. Experience with Treatment Systems

The U. S. Federal Highway Administration summarized the treatment practices as of 1985 (USFHA, 1985). A variety of treatment systems have been used including infiltration basins, porous pavement, grass swales and strips, wet detention ponds and engineered wetlands.

Table A-3 is a summary table from USFHA, 1985, regarding the overall effectiveness and the state of knowledge at that time. Also included in the table are "nonstructural" control practices such as sweeping and litter control. Since the USFHA summary report, other reports and manuals have been completed that indicate that stormwater can be treated effectively by vegetation systems and wet basins (Horner, 1988; Kulzer, 1989, 1990; Schueler, 1987).

Generalizations about removal efficiencies found during various research projects can be misleading as they vary greatly with size of the facility in relationship to the catchment area treated, the number and size of storms sampled and the time of year that sampling occurred.

It can be concluded that properly designed and maintained grassed filter areas and wet ponds or wetlands will remove the majority of suspended particulates. Most pollutants are primarily present as particulates including most metals, phosphorus and organics such as pesticides. Nitrogen, copper and zinc tend to be more soluble.

It has been clearly established that engineered wetlands will remove soluble metals and organics (Kulzer, 1990). However, the rates of removal cannot, at this point, be defined within the context of system design. It is known that some plant species are more effective than others. Limited data suggests that grassed filter areas also remove soluble pollutants. What is not clear is how effective the systems are during the nongrowth period when the majority of rainfall occurs on Vancouver Island.

Appendix E - Engineered Wetlands to Treat Highway Surface Runoff at Sensitive Sites also discusses the uses and effectiveness of engineered wetlands.

Table A-1
Highway Pollutants and Sources

Pollutant Groups	Examples	Sources	Parameters	Concentrations (mg/L) Average	Range	
Particulates	Dust and dirt, stones, sand, gravel, grain, glass plastics, metals, fine residues	Tire, brake and pavement wear, car exhaust, mud and dirt accumulated on vehicles	TS	1147	145	21640
			TVS	242	26	1522
			TSS	261	4	1656
			VSS	77	1	837
Heavy Metals	Lead, zinc, iron, copper nickel, cadmium, mercury	Use of leaded fuels, tire and break wear, motor oil additives, rust	Pb	0.96	0.02	13.1
			Zn	0.41	0.01	3.4
			Fe	10.3	0.1	45.0
			Cu	0.103	0.01	0.88
			Ni	9.92	0.1	49.0
			Cd	0.04	0.01	0.40
			Cr	0.04	0.01	0.14
Organic Matter	Vegetation, dust and dirt humus, oils, fuels	Vegetation, litter, animal droppings, motor fuels and oils	BOD_5	24	2	133
			TOC	41	5	290
			COD	14.7	5	1058
			Oil and Grease	9.47	1	104
Pesticides/ Herbicides	Weed Killers	Right-of-way maintenance	Dieldrin ($\mu g/L$)	0.005	0.002	0.007
			Lindane ($\mu g/L$)	0.04	0.03	0.05
			PCBs ($\mu g/L$)	0.33	0.02	8.89
Nutrients	Nitrogen/phosphorus	Fertilizers	TKN	2.99	0.1	14.0
			$NO_2 + NO_3$	1.14	0.01	8.4
			PO_4	0.79	0.05	3.55
Pathogenic Bacteria (indicators)	Coliforms	Soil, litter, excreta, bird and animal droppings	TC			
			FC			

Source: U. S. Federal Highway Administration 1981

Legend:
TS - Total Solids; TVS - Total Volatile Solids
TSS - Total Suspended Solids; VSS - Volatile Suspended Solids

Table A-2

Summary of Research on Runoff Effects

Site Average Daily Traffic (ADT)	Bioassay Response	Change in Water Quality	Change in Stream Biota	Change in Sediment Quality	Location
7,000	no[b]	-	-	-	Seattle
7,400	slight[c]	no[a]	no[a]	no[a]	Wisconsin
8,000	yes/no[d]	-	-	-	Norway
15,600	-	no	no	yes	Wisconsin
23,000	yes[e]	-	-	-	California
25,500	slight[c]	yes	yes	yes	North Carolina
42,000	no[b]	-	-	-	Seattle
50,000	yes[b]	-	-	-	Seattle
66,000	yes[e]	-	-	-	California
100,000	-	-	-	no	Florida
100,000	-	-	-	yes	Florida
185,000	yes[f]	-	-	-	California

a. water passed through grass channels and/or shoulders
b. rainbow trout
c. isopod, amphipod (Gammarus), algal (Selenastrum), water flea, mayfly, flathead minnow
d. no effect on 1-year salmon or hatching salmon eggs; stimulatory effect observed on two algal species and heterotrophic organisms (BOD test)
e. stimulated algal populations
f. inhibited algal populations.

No = no observed effect or change
Yes = observed effect or change

Source: U. S. Federal Highway Administration, 1985b.

Table A-3

Identification of Effective Management Measures

Management Measure	Particulates	Heavy Metals	Pesticides PCBs	Organic Matter Hydrocarbons	Nutrients	Pathogenic Bacteria	Comments
	Pollutant Removal Effectiveness						
1. Source Management Measures							
Traffic Regulation*	low	low	n/a	low	low	n/a	It is not possible to determine the effects of traffic regulation from the literature, however, omissions and vehicle wear are reduced where traffic is free flowing.
Litter, Debris Control Laws, Regulations*	high	high	high	high	high	high	Uncontrolled roadside dumping could contribute significantly to pollutant loads.
Controlled Use of Chemicals*	n/a	high	high	high	high	n/a	Highway agencies that emphasize training and exercise stringent control over application rates and conditions effectively reduce runoff contamination even though usual concentrations and loads are small.
2. Post Deposition Measures							
Street Cleaning*	low to moderate	low	low	low	low	low	Effectiveness is very low because most of the pollutants of concern are adhered to particulate sizes left on the roadway after sweeping.
Debris Removal, Accident/ Spill Cleanup*	low to high	n/a	low to high	low to high	n/a	n/a	The effectiveness of debris removal and accident/ spill cleanup is low in time and space because spills are infrequent. Cleanup is a locally effective management measure but the temporal and spatial potential for pollution is small.

* = inferred rating

Table A-3

Identification of Effective Management Measures

Management Measure	Particulates	Heavy Metals	Pesticides PCBs	Organic Matter Hydrocarbons	Nutrients	Pathogenic Bacteria	Comments
	Pollutant Removal Effectiveness						
Barrier Elimination*	high	high	n/a	high	high	high	Effectiveness can be inferred from studies of: 1) runoff pollutant loads from curbed and uncurbed highway sections, and 2) distribution of total pollutant loads on highway pavement surfaces from curbs and median barriers.
3. Post Runoff Measures							
Infiltration Systems	high	high	high	high	high	high	Effectiveness varies with the ratio of storage to storm runoff volume. Depth to ground water and soil characteristics are significant in determining potential for aquifer contamination. Chlorides are not reduced by filtration through soils.
Detention Basins - Wet	high	high	n/a	high	medium to high	medium to high	Efficiency varies with ratio of permanent storage to storm runoff volume.
Detention Basins - Dry	low to high	low to high	n/a	low	low	low	Efficiency varies with storage time and basin design. Pollutants deposited in basins can be resuspended and discharged during subsequent event, resulting in negative efficiency for that event.

* = inferred rating

Table A-3

Identification of Effective Management Measures

Management Measure	Pollutant Removal Effectiveness: Particulates	Heavy Metals	Pesticides PCBs	Organic Matter Hydrocarbons	Nutrients	Pathogenic Bacteria	Comments
Vegetative Controls							
a) Grassed Channels	high	high	medium	high	high	high	Efficiency varies with channel length, vegetation density, flow rate and depth, and soils.
b) Filter Strips	high	high	medium	high	high to medium	high to medium	Effectiveness varies with width of the grassed filter strip, vegetation density, soils.
c) Overland Flow	high	high	medium	high	high	high	Effectiveness is dependent on length of overland flow, vegetation density, flow rates and depths.
Wetlands	low to high	high	n/a	medium to high	high	medium	Efficiency varies with ratio of wetland storage to storm runoff volume, type of wetland, emergent vegetation, soil types. The effects on a natural wetland ecosystem are unknown but may be adverse.
Catchbasins	low	low	low	medium to low	low	low	
Filtration Systems	medium to low	low	low	medium to low	low	low	

* = inferred rating

APPENDIX B

HIGHWAY STORMWATER TREATMENT CRITERIA

by

RESOURCE PLANNING CONSULTANTS

APPENDIX B

HIGHWAY STORMWATER TREATMENT CRITERIA

1. DEFINING THE LEVEL OF TREATMENT

The appropriate level of treatment of highway runoff depends on the type of receiving water in question. For streams, high concentrations of pollutants are of concern, whereas for lakes and wetlands the primary concern is the aggregate accumulation of pollutants, particularly in bottom sediments. This problem results from the fact that the pollutants are generally not dissolved, but rather are associated with particulates that settle to the bottom.

As most discharges along the proposed highway will be to streams, approximate levels of treatment proposed in this design guide are based on reduction of deleterious concentrations of pollutants. In British Columbia there are no regulations or guidelines covering the discharge of pollutants from highways; nor are there specific receiving water criteria. Therefore, four key pollutants are presented below in Table B-1, together with receiving water quality developed by the U. S. Environmental Protection Agency (USEPA) in 1986. Also shown is the approximate percentage of pollutant that is in the particulate form. This statistic is important because although grass biofilters and engineered wetlands will remove soluble pollutants (Kulzer, 1990), it is not possible to estimate removal rates, except to state that there is greater confidence in the removal efficiency of wetlands than grass biofilters. As pollutants tend to be associated more with the fine solids, removal of 50% of the suspended solids does not translate to a 50% removal of particulate pollutants.

Table B-1 (as $\mu g/L$)

Receiving Water Quality Criteria
for
Indicated Pollutants

Pollutant	Water Quality Criteria[1]	Percent as Particulate
Lead	11 to 34	90% ±
Zinc	30 to 65	50% ±
Copper	4 to 9	40% ±
PCB	2	majority

[1] - for hardness range of 20 to 50 mg/L as $CaCO_3$

Source: USEPA (1986)

Therefore, the level of treatment needed to protect the receiving water is a function of the pollutant concentration in the stormwater, the water quality criteria and the available dilution of the inflow by stream flows.

Metals

The above criteria are compared to the mean concentrations in Table A-1; using the mean values is reasonable since the extreme values in Table A-1 are instantaneous and will be moderated substantially by the treatment device. The comparison indicates that for the metals about 90% to 98% removal is needed to achieve the receiving water quality criteria. For copper and zinc this degree of removal is not possible as approximately half of each of these constituents would be dissolved. Thus, dilution of treated runoff is important and in these examples a minimum of 10 or 20:1 dilution would be necessary to achieve the receiving water quality criteria.

Where the dilution ratio is relatively low and/or where the stream has sensitive uses, an engineered wetland should be used for treatment because of the greater confidence in its ability to remove soluble pollutants.

The above discussion is generally conservative because, as noted in Appendix A, the data in Table A-1 are from six sites whose average ADT is 85,000. The Vancouver Island Highway will experience much lower traffic volumes.

Organics

Using PCB as the surrogate organic pollutant, it appears little or no treatment is required to achieve the receiving water criteria.

Hall et al (1988) noted that in a study of 51 catchment areas, the U.S. EPA organic priority pollutants posed little risk at the levels detected in stormwater.

Required Level of Treatment

The above analysis suggests that for areas with very low traffic volumes and/or where the receiving water to highway drainage dilution ratio is relatively high (in excess of 20:1), a modest removal of roughly 50 to 60% of the particulate pollutants is a reasonable goal (Treatment Concept A in main body of report).

A goal of 70 to 80% is appropriate for areas of moderate traffic, where the watershed is sensitive, or where the dilution ratio is low (Treatment Concept B). Where traffic volumes are greater and the stream is considered sensitive, a goal in excess of 90% is needed (Treatment Concept C). Here the engineered wetland is preferred because of its ability to remove soluble pollutants.

2.0 DESIGN CRITERIA FOR TREATMENT SYSTEMS

The method used to evaluate system performance as a function of facility size is derived from USEPA (1986). The authors of that publication developed the method for wet ponds/wetlands and infiltration systems. It has been extended by Minton (1989) to grass filters by incorporating the model of grass performance developed by Tollner et al. (1976) and subsequent research under the same program. The evaluation of grass filters may be done for three distinct filter configurations: 1) the grass shoulder strip between the pavement and the roadside drainage ditches; 2) the drainage ditches that run parallel to the road; and 3) a swale placed at the end of a drainage ditch or pipe.

The USEPA method uses mean rainfall statistics which are unique to the area of interest. USEPA has developed these statistics for many areas in the United States, but none in Canada. In this analysis statistics for Seattle (mean annual rainfall of 760 mm) are used. Where mean annual rainfall differs from Seattle, the mean storm depth and intensities are increased in direct proportion to rainfall in the area of interest. For the Island Highway, annual rainfall varies from about 1000 to 1600 mm.

Grass Filters (Grass Shoulder Strips or Grass-Lined Ditches)

Pollutant removal by grass filters is effective only if the grass remains erect and the depth of flow is less than the grass height. Although the USEPA method uses mean rainfall statistics, in this case the maximum flow rate (design event) must be specified to ensure the grass is not inundated. For a given grass height, this peak rate determines the filter width for a given gradient and coefficient of friction (Manning's "n").

For grass ditches a Manning's "n" of 0.2 is recommended.

To determine the peak rate the 6-month storm is used. This is a storm magnitude which is expected to be equalled or exceeded twice in any given year. For the Western Cascade Region, all storms with a frequency equal to or greater than the 6-month event represent more than 90% of aggregate rainfall (Ecology, 1990). Considering that the facility will operate at full effectiveness for a significant portion of the larger storms, sizing for the 6-month event is reasonable. The 6-month event is about 60% of the 2-year event, therefore peak runoff rates may be estimated using the 2-year IDF curves for several weather stations along the Island Highway and a time of concentration of 10 minutes.

Grass-Lined Ditches

The performance of grass-lined ditches was evaluated for the standard highway cross-section with a 1.0 m ditch base width (1.5 m base widths are also commonly used). In order to perform effectively the ditch should be maintained conscientiously; eroded areas should be regrassed and the grass mowed regularly. Grass height should be 150 - 300 mm, with the lower height being used as the design height.

For a constant ditch width, performance will decrease as the length of the ditch (and contributory road surface) increases. Because the bottom width is held constant, there is a maximum length above which the design peak flow is exceeded.

From the methodology of Tollner, et al (1976), Figure B-1 provides the fraction of suspended solids trapped by flow-through grass-lined channels. Calculations of removal efficiency allowed for the fact that the ditch bottom cannot be constructed perfectly flat and tends to become undulating over time. Consequently, the runoff is not spread evenly across the filter during the low flows when most treatment occurs. Removal efficiency decreases gradually with increasing ditch length because, for a fixed ditch width, flow depth will become deeper and deeper as more road runoff contributes.

For two annual rainfall assumptions of 1000 and 1600 mm the removal rates for suspended solids by grass-lined ditches were calculated to be in the ranges of 60 to 70% and 50 to 60%, respectively.

Grass Shoulder Strip

For modelling purposes, grass shoulder strips are essentially a swale placed at the end of a drainage conveyance, i.e. the pavement surface. Because the runoff from the pavement per unit length is low, the Tollner model predicts that a continuous strip of grass paralleling the pavement edge need only be 300 mm wide to remove 95% of the suspended solids if water drains evenly to and through the strip. The gradient of the strip in the flow direction should not exceed 7%. A grass shoulder strip that is installed and maintained specifically for treatment therefore should be very effective. If points of erosion occur, the strip will lose its effectiveness because the water will move through the bare spot where less resistance to flow occurs. If unevenness of the longitudinal road grade causes the water to move through portions of the strip only, it will still provide substantial removal, if it is well maintained.

Grass Swale

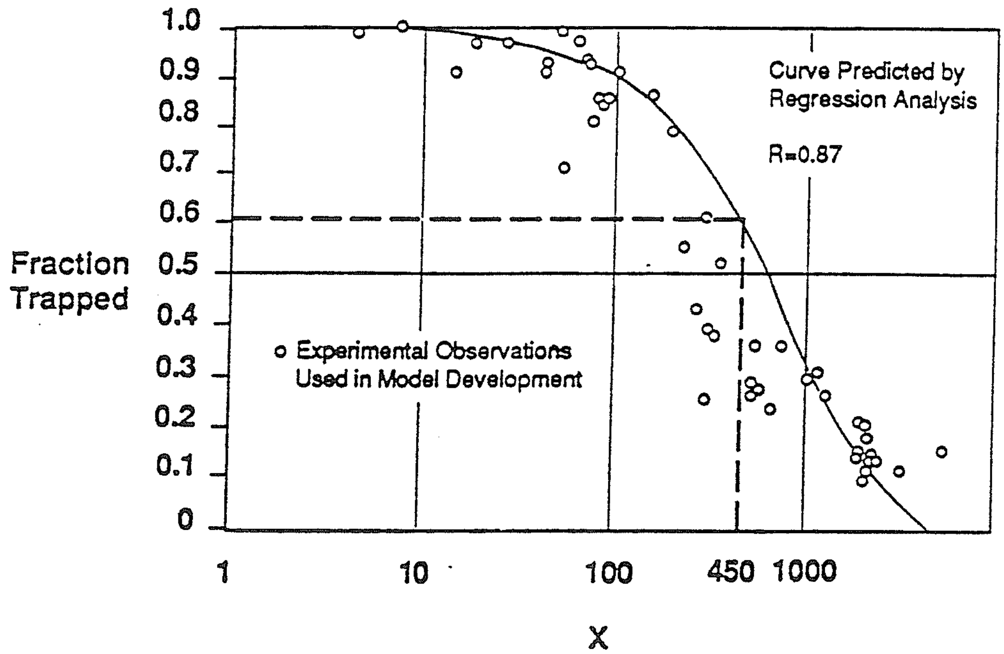
Grass swales located at the end of drainage conveyances (ditches or conduits) also provide significant treatment of storm runoff. The swale is a wide, shallow ditch and the same criteria as used for the design of grass-lined ditches would apply to swales. In this case, however, the width of the bottom of the swale is increased as required to keep the design flow depth below the 150 mm grass height.

Calculations for different conditions form the basis of Figure 13 in the main report.

Engineered Wetland

Figure B-2, (US EPA, 1986), predicts wet pond removal efficiency for varying annual rainfall and varying ratios of wet pond to impervious drainage area. The wetland will function similarly to a wet pond for suspended solids removal, but should also provide improved trapping of soluble pollutants.

A deeper forebay area for settlement of the majority of material, i.e. the larger particle sizes, should equal 25% of the total basin area. The planted wetland area of the marsh will tend to improve the settling of suspended solids during storms due to reduced short circuiting between the inlet and outlet.



$$X = \left(\frac{V_s R_s}{v}\right)^{0.82} \left(\frac{L_t W}{V_s D_f}\right)^{-0.91}$$

Fraction trapped = EXP(-0.00105X)

Where:
V_s = flow velocity through the grass
L_t = length of channel
v = kinematic viscosity
W = settling velocity of suspended solid
D_f = depth of flow
R_s = sD_f /2 with "s" being the distance between grass blades. This relationship holds when "s" is much less than depth of flow.

FRACTION OF PARTICLES REMOVED BY GRASSED LINED CHANNELS

FIGURE B–1

SOURCE : TOLLNER ET AL (1976)

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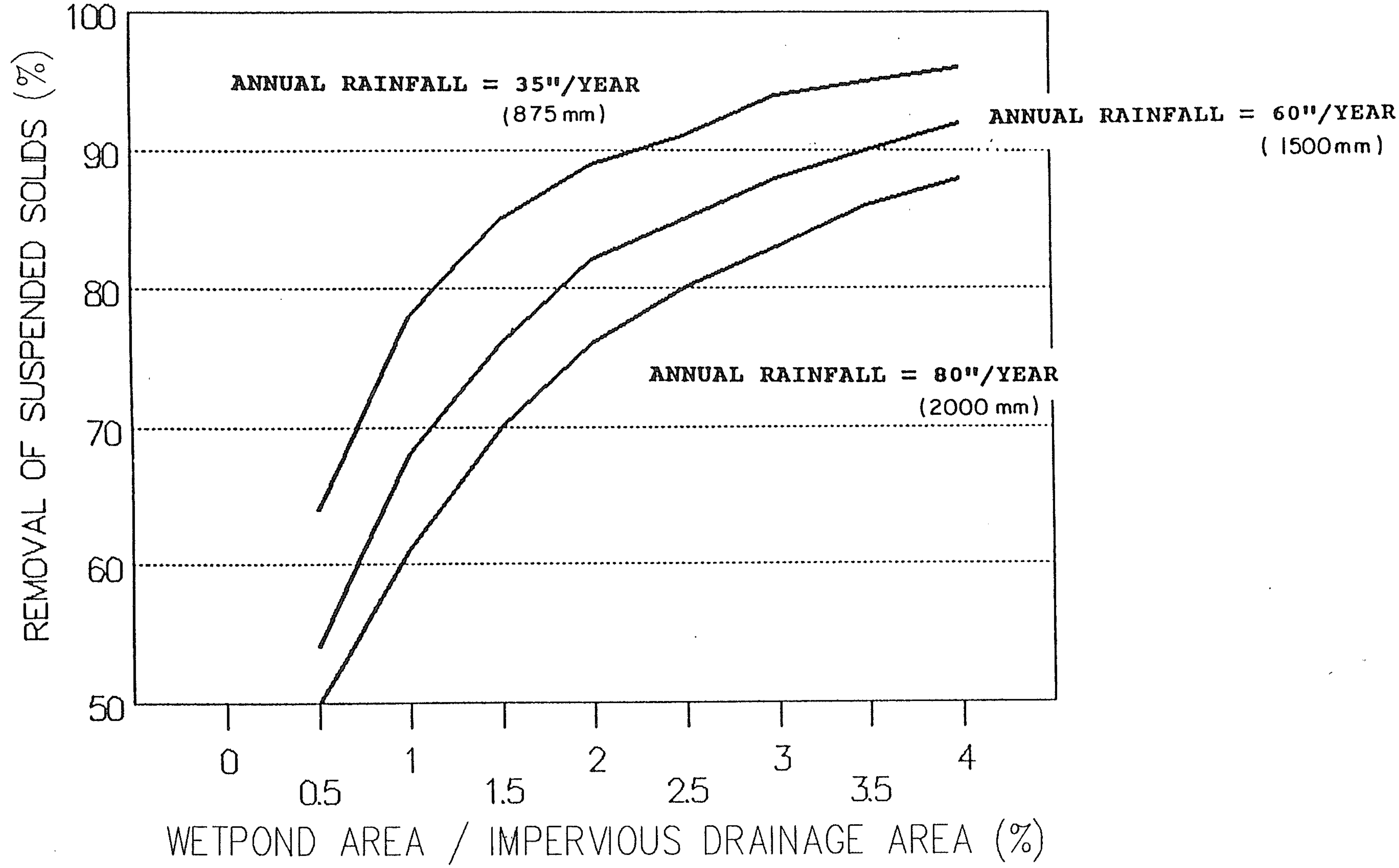

WETPOND EFFICIENCY

Source: Minton, 1990

FIGURE B-2

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APPENDIX C

EROSION CONTROL

by

TALISMAN LAND RESOURCE CONSULTANTS

APPENDIX C

EROSION CONTROL

INTRODUCTION

Highway construction impacts on soils will result from the disturbance of the original soil cover, the creation of new surfaces (cutbanks, areas of fill, and stockpiles of waste material unsuitable for construction), and from modifications affecting drainage. The main environmental concern associated with these actions is the enhanced potential for soil erosion.

The main cause of erosion and sediment loss on soils in South Coastal B.C. is surface runoff. Consequently, erosion is most likely to occur on steeply sloping terrain and on soils with slow infiltration (fine or medium textured soils, poorly drained soils, and soils containing an impervious layer). Erosion is also more likely on less cohesive, stone-free, silty to fine sandy soils, where the soil particles are more easily detached.

Table 1 summarizes soil limitations to the construction and operation of the Inland Island Highway, the problems that could result, and the generic mitigation response to minimize the potential for such problems.

A variety of techniques are available to control soil impacts. The mitigative measures applied should take into account the type of soil, the terrain, the highway design, and the degree of protection required. In some situations, innovative, site specific measures may be required. However, for the most part, the application of one or more conventional mitigative measures will be adequate. This appendix describes conventional mitigative techniques and works commonly used to minimize soil impacts.

RETENTION OF EXISTING VEGETATION WHERE POSSIBLE

Undisturbed natural vegetation and surface litter generally provide very effective erosion protection, and thus should be retained wherever possible. For example, while it may be necessary to remove trees at bridge crossings, it may be possible to retain the shrub and herbaceous vegetation cover in the understory. In addition to providing erosion control, natural vegetation serves as a source of propagules, provides habitat diversity and contributes to site aesthetics.

MINIMIZING THE EXTENT OF DENUDED LAND

Limiting the extent of denuded land will minimize the risk and the effect of soil erosion, and will also permit rapid restoration once grading is complete. The area cleared can be limited by staging the construction and by limiting clearing to the minimum area required. Where grubbing is carried out well in advance of construction, temporary surface protection (e.g., annual grasses or mulch covers) may be required. On soils and terrain types with a high erosion potential and where valuable resources may be impacted, the risk of erosion can be limited by restricting construction to the relatively dry part of the year, from May to September.

TABLE C-1
SOIL HAZARDS, POSSIBLE SOIL PROBLEMS AND PROPOSED MITIGATION MEASURES

SOIL LIMITATION	POSSIBLE SOIL PROBLEM	EROSION PROTECTION MEASURE
fine or medium textured marine soil (sandy or clayey silt)	A. compaction and surface smearing	1. surface preparation only when water content below plastic limit
	B. slow infiltration	
coarse textured, stone-free fluvial soil (gravelly or silty sand)	C. little or no interparticle cohesion or friction, especially if gravel free	2. see B above
very stony till or glacio-fluvial soil, >40% coarse fragments	D. stoniness	3. seed and fertilizer in separate operation from mulch application or apply more seed to account for additional mortality
organic soil, off-site	E. subsidence	4. maintain existing rate and pattern of drainage
organic soil, on-site	F. release of organic acids	5. surround organics with mineral soil
impervious subsurface layer (eg., compact till, massive marine) intercepted by cut slope	G. seepage accumulation above impervious layer results in surface runoff	6. install subsurface drains above cut, with bioengineering features to protect surface along local seepage channels
poorly drained soil	H. watertable near surface for significant portion of year	7. lower watertable with ditches or subsurface drains
steep slopes adjacent to water course	I. steepness increases potential for surface runoff	8. see B above
		9. see C above
		10. install temporary sediment traps, direct runoff onto porous soils
		11. if sensitive area, limit construction to drier months
depth of rooting zone limited by bedrock	J. low moisture and nutrient retention	12. increase mulch application rate

DRAINAGE CONTROL

Soil erosion and sediment loss primarily results from surface runoff. The most effective means of reducing erosion are:

1) decreasing slope length and angles, which decreases runoff velocity;

2) constructing drains to intercept and remove runoff and seepage in a controlled manner; and,

3) timely establishment of vegetation cover on disturbed areas, cut slopes, and fill slopes.

During the construction period and the early revegetation stages, runoff and excess seepage should be diverted to stable outlets. Where runoff is a concern on slopes, terraces and interceptor drains can be constructed to minimize slope lengths and to diminish runoff velocities.

A major erosion hazard often occurs where seepage zones are intercepted by cut slopes. Many of the soils in the project area contain impervious layers, either because they have developed on stratified deposits containing fine textured or compacted layers, or because of pedogenic (soil forming) processes, such as cementation (formation of a "hard-pan"). Water movement in these soils occurs primarily as lateral seepage just above the impervious layer. Similar, localised seepage channels may occur from the piping commonly found in compacted till deposits. Where areas of high seepage are exposed in cutbanks, the resulting surface discharge may lead to erosion.

A variety of drainage structures (for example, grassed swales, ditches, and bioengineering facine or pole drains) may be constructed to remove excessive on-slope seepage or runoff. If areas of high seepage discharge are known to occur, the grading design for cut slopes should include on-slope ditches or gravel drains placed on short terraces downslope of the discharge zones.

Because they are subsurface and relatively small, the location and size of seepage layers may only be apparent when the cuts are exposed or during the first winter after the construction phase. In these situations, bioengineering techniques, both for drainage and erosion control, are often the most cost effective means of remediation. Bioengineering techniques are described in greater detail in Appendix G. Because seepage areas may not be initially apparent, it is very important that the construction budget provides for monitoring and any required remediation after the main construction phase has been completed.

VEGETATING DENUDED AREAS

The most cost effective long-term measure for preventing sedimentation is to protect exposed soil with a vegetative cover. In the short-term, the best way to do this is with agronomic species, applied by hydroseeding or by hand broadcasting with a cyclone seeder. In addition to their ready availability, rapid growth, and cost advantages, agronomic species are compatible with a variety of application methods and are adapted to a wide range of conditions.

Site Preparation

Perhaps the most important step in establishing a vegetative cover is site preparation. For example, soils with a high silt or clay content are subject to structural degradation under the heavy loading often caused by construction equipment. Care must be taken not to compact the soil or smear the surface. To maintain infiltration rates and create a good seedbed, tillage operations must be undertaken only when the soils are workable (below the plastic limit). This may limit operations, such as spreading topsoil, to the drier months. Vegetation establishment is also enhanced if the final microtopography is relatively rough, providing protected microsites. This will encourage natural plant invasion. Increased surface roughness can be created by track-walking a dry slope with a bulldozer.

Agronomic Species

Seed mixes used for this project should include perennial ryegrass (*Lolium perenne*), creeping red fescue (*Festuca rubra*), and one or more of the legumes white clover (*Trifolium repens*), alsike clover (*Trifolium hybridum*), and birdsfoot trefoil (*Lotus corniculatus*). If rapid growth is required due to late planting or site sensitivity, the seed mix should include fall rye (*Secale cereale*). For very poorly drained areas, species such as reed canary grass (*Phalaris arundinaceae*) and foxtail (*Alopercurus spp.*) should be included.

Fertilizer Rates

For most soils, fertilizer will improve plant growth. Seed and fertilizer are generally applied at rates of approximately 60 kg/ha of seed, and 125, 60, 60 kg/ha of N, P, and K. If possible, a large proportion of the N should be in the slow release form. On organic soils, which tend to have a low pH, limestone should also be applied (seed mixes and fertilizer rates should be determined in consultation with staff of MOTH Road Side Management).

Mulch

On erodible soils, hydroseeding should include an application of 1000-1500 kg/ha of mulch, both to hold the seed in place and to provide some surface protection until the plant cover is established. The mulch used should be of the woodfibre and not the paper variety. On more erosive sites, some contractors use a tackifier to hold soil and seed in place. However, there is some question as to whether tackifiers are too soluble for use in the wet conditions of South Coastal B.C.

Erosion Control Blankets

If revegetation cannot be carried out during the planting window or if a vegetative cover is, at least initially, judged to be inadequate, additional protection can be obtained with erosion control blankets. In order to be effective, erosion control blankets must be held in close contact with the surface. This requires prior treatments to smooth the surface, either by running a bulldozer up the slope or by using a grade-all. To protect the seed bed, surface treatments should only be carried out when the surface is dry.

Prior to laying the blanket, the seed and fertilizer are applied (hand broadcast or hydroseed). The top of the blanket is anchored by burying it in a trench. On the slope, the blanket is held down by pins applied at the manufacturer's specified density. According to various sources, the 6 inch pins provided are too weak and short. Alternative approaches used successfully include rebar, wooden stakes, stakes through sand bags, and 12 inch metal pins strong enough not bend when they hit a rock. Operators also suggest that it is very important to have "sufficient" overlap between the sheets.

There are a large number of blanket types available. Both Washington State and the MOTH use a clear plastic cover (6 mm poly) as a remedial measure on their most sensitive sites. In order to prevent the plastic from smothering the underlying vegetation, the cover must be removed at the end of the winter. The high cost of the plastic cover limits its use.

For less sensitive areas or situations where the blanket will be left in place, Washington State Department of Transportation uses a Superior Excelsior Blanket, constructed from wood shavings (Dr. Russ Rosenthall, pers. comm.). The MOTH has found that mixed straw/coconut fibre blankets (North American Green product SC150) perform much better than comparably low priced Excelsior wood shavings product, because the Excelsior netting degraded (Al Planiden, pers. comm.). The MOTH have also used the slightly more expensive, entirely coconut fibre mat, both on ravelling slopes and in ditches. According to Wally Smith (MOTH), the coconut fibre mat is much stronger, and unlike the wood shavings or straw products, you can walk on them, a useful feature if one intends to later plant shrubs.

North American Green recommends the straw/coconut blanket ($1.65/m^2) for 2:1 slopes and the blanket made entirely of coconut ($2.06/m^2) for 1:1 slopes. Similar products with similar specifications are also made by Bon Terra. Installation costs are $0.65-$1.00/m^2.

Extruded plastic webbing products are much stronger and much more expensive ($4-$6/m^2). These products have much greater tensile strength, and buried beneath a shallow layer of topsoil are very effective at preventing shallow failures. However, as they are not blankets, they cannot prevent surface erosion.

Stony Soils

Assuming the depth of well drained, permeable surface layers is adequate, and there is sufficient nutrient and moisture retention, hydroseeding should result in the rapid establishment of a dense plant cover. However, where the soils are shallow (for example, on rock outcrops) or stony and coarse textured, a lack of nutrient or moisture availability may limit plant growth. In these situations, higher mulch rates may be used to increase moisture retention. On stony sites, the seeding rate should be increased to allow for the lack of contact between the seed and the finer soil particles. Applying the seed and fertilizer before the mulch may also increase germination success where soils are very stony.

Where dry ravelling prevents initial grass establishment, erosion control blankets may be used to stabilize the surface.

Shrubs

In addition to herbaceous species, shrubs can be used to increase the stability of stream banks and steep slopes. Shrubs may also be used to anchor turf layers to the underlying topsoil. Methods for establishing shrubs include natural cuttings (e.g., willow), transplants or container grown seedlings. Research on mine wastes in Alberta indicates that some shrubs may be established from seed. The method selected will depend on the species and the terrain.

The use of shrubs is discussed in greater detail in Appendix F.

TRAPPING SEDIMENT ON SITE

During construction, some erosion is unavoidable and sediment retention structures will be required in sensitive areas. The most common sediment traps include sedimentation ponds, straw bale dikes, silt fences and vegetative soils filters. While straw bales have been widely used for sediment control in the past, they have been found to be relatively ineffective (Horner *et. al.*, 1990). Of the silt barrier options, monofilament geotextile fabric fences provide the best sustained performance, and may be used on slopes as well as in conjunction with sedimentation ponds (Figure C-1).

Sedimentation ponds, which may be used for temporary or long term protection, must be carefully engineered, and all structures designed to trap sediment should be regularly inspected. Silt fences have limited value for the finer soils, because they do not retain fine silt and clay particles. Similarly, the removal of suspended clay particles in sedimentation ponds require long residence periods.

Where some erosion of fine silt and clay particles will occur, the most effective means of removing the suspended particles is with vegetated soil filter areas. If the vegetation areas are designed effectively, the rate of water flow is slowed by the resistance of the plants, sediment settles out as the water infiltrates into the soil, and is bound by plant roots. Vegetative filters may be created in grassed channels or where dense herbaceous covers or litter cover porous forest soils. Design and installation specifications for ditch and swale vegetation filters are listed in Appendix D.

As stated earlier, it should be noted that controlling erosion at the source, using slope coverings, is clearly more cost effective than trapping eroded material later on.

CAREFUL TREATMENT OF ORGANIC SOILS

The main concerns with organic soils are poor drainage, susceptibility to subsidence and the potential for organic acid release. In the project area, organic soils have formed under waterlogged conditions, conditions that minimize microbial decomposition. Consequently, organic soils are sensitive to hydrologic changes. Where the highway is built close to organic soils, care should be taken to maintain the existing rates and patterns of drainage, through measures such as the installation of culverts designed to maintain surface runoff and subsurface seepage. Lowering the watertable will increase the rate of organic matter oxidation, resulting in subsidence. Raising the watertable will likely kill the existing vegetation.

Where organic soils in the RoW are removed and stockpiled prior to highway construction, the decomposition rate will likely be significantly increased. The resulting accelerated release of organic acids can adversely affect water quality. As organic acids are complexed by sesquioxides (naturally occurring soil compounds) or clay, the most effective means for preventing this is to surround the organic matter with layers of mineral soil. Steps should also be taken to separate stockpiled organic soils from surface runoff and groundwater seepage.

The main growing limitations of organic soils are poor drainage, infertility and acidity.

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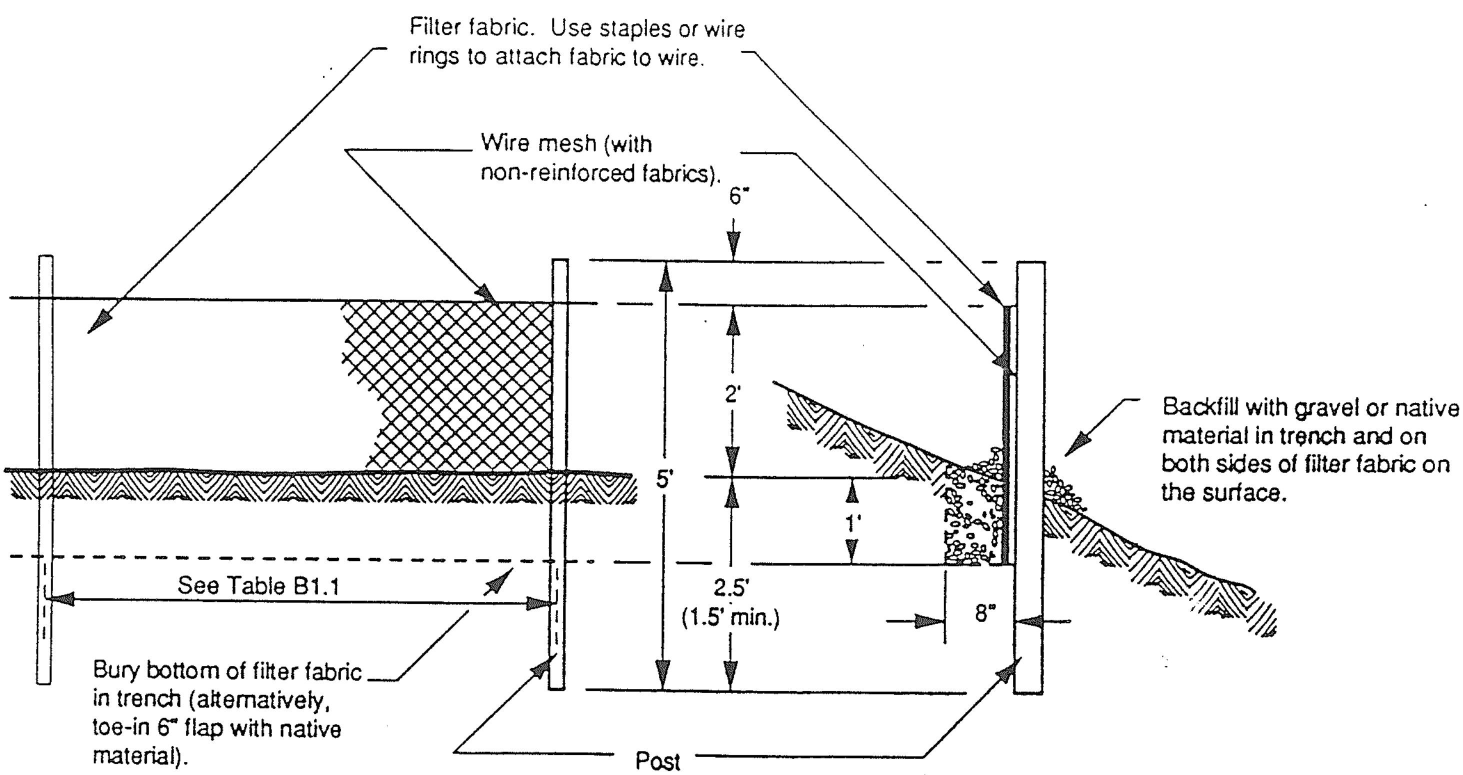

FIGURE C-1

Typical Filter Fabric Fence Detail
(from Horner et al. 1990)

APPENDIX D

VEGETATED FILTER AREAS

by

TALISMAN LAND RESOURCE CONSULTANTS

APPENDIX D

VEGETATED FILTER AREAS:
DITCHES AND SWALES

INTRODUCTION

Where highway runoff will be discharged into a sensitive watershed, and mitigation of runoff contamination is required, one of the best treatment options is the installation of a vegetated filter areas. The types discussed here are the grassed drainage ditch and the vegetated swale. Filtration of particulate pollutants is the primary treatment function.

GRASSED DITCH

Design:

Size and engineering specifications as per KPA Engineering Ltd. design.

Grass Species:

Initial provision of quick vegetative cover, followed by establishment of dense, drought tolerant, perennial turf with stiff culms (stems) is required. The following seed mix is recommended (Bob Wick, Richardson Seed Company):

50% hard fescue (*Festuca ovina*)
35% creeping red fescue (*Festuca rubra var rubra*)
10% perennial ryegrass (*Lolium perenne*)
5% red top (*Agrostis alba*)

Erosion Control Blanket:

Installation of a short-lived erosion control blanket is recommended. Grass is seeded underneath the blanket which:

- enhances plant growth through a reduction in evaporative losses and moderation of soil temperatures

- reduces scouring.

Scouring and poor grass establishment are common problems in newly established ditches and typically require several re-seedings.

Erosion control blankets manufactured by North American Green and distributed by Nilex Geotechnical Products Inc., have been successfully used by MOTH Roadside Development (pers. comm., Al Planiden, Manager). The SC125 blanket, recommended for channel linings due to its ability to withstand heavy water flow and retain soil particles, is constructed of 100% coconut fibre and heavy weight UV stabilized netting stitched together with polyester thread. The coconut fibre is degradable, but will not disintegrate for several years.

Hydroseeding:

A non-dormant application of the seed mix, with standard fertilization, is recommended in early spring or September.

Spring Seeding Window: March 1 - April 30

Early spring seeding terminates at the end of April. Later seedings will germinate, but die due to lack of water.

Fall Seeding Window: September 1 - September 30

Fall non-dormant seeding is ideal, and is recommended for construction work completed in the late spring and summer. The fall planting window is very narrow, generally from September 1st to September 30th. A growing season moisture deficit exists on the east coast of Vancouver Island, and consistent adequate moisture for germination and growth is generally not available until early September. The length of the non-dormant seeding period is limited by the first frost, as the new grasses must not be so tender that they will be killed. Weather station statistics should be checked for each watercourse. With a Dec. 1st first frost, seeding could be done as late as mid-October, however, the growth may not be sufficient to stabilze surfaces prior to heavy fall rains.

Maintenance:

The grass should be regularly mowed to maintain a 15 to 30 cm grass height in the ditch.

GRASSED SWALE

A treatment swale is a vegetated filter area located at the terminus of a highway runoff ditch. At this point the ditch, which may or may not be grassed, gently widens to create a low velocity sheet-like flow of water. This avoids channelization.

Design:

Size and engineering specifications as per KPA Engineering Ltd. design.

Installation Recommendations:

An erosion control blanket, and non-dormant seeding in the spring or fall seeding window are recommended. Refer to the installation recommendations for grassed ditches.

Grass Species:

Species recommendations depend on soil drainage conditions.

Moderately Well to Rapidly Drained Soils:

Use the species mix recommended for grassed ditches.

Imperfectly to Poorly Drained Soils:

Soils where the water table is near or at the surface for most or all of the year. Subsoils are moist for most or all of the growing season.

Swale Not in Close Proximity to a Wetland:

A monoculture planting of Reed Canary Grass (*Phalaris arundinaceae*) is recommended, only if the swale is not within seeding distance of a natural wetland. Concern is expressed that this aggressive specie not be inadvertently spread into natural wetlands where it currently is not established. Reed canary grass spreads through self-propagation and distribution by wildlife.

Reed canary grass is a tall, coarse, vigorous grass which grows in dense clumps. It is adapted to moist to wet soils, will tolerate flooding and drought, and does well on upland soil where there is adequate moisture for spring and early summer growth (Hardy BBT, 1989).

Licensed cultivars of reed canary grass are available from seed companies. However, the species can be difficult to establish from seed and may require a reseeding in the subsequent planting window. Seeding under an erosion control blanket, as recommended, will likely increase the survival rate of seedlings. Fall/spring seeding at a rate of 5 to 10 lbs PLS/ac, 1.2 to 2.5 cm deep, is recommended (Hardy BBT, 1989).

Swale in Close Proximity to a Wetland:

In this situation, the following seed mix is recommended (Don Biggins, Richardson Seed Company):

20% meadow foxtail (*Alopecurus pratensis*)
45% red top (*Agrostis alba*)
20% perennial rye (*Lolium perenne*)
15% Timothy (*Phleum pratense*)

APPENDIX E

ENGINEERED WETLANDS TO TREAT

HIGHWAY SURFACE RUNOFF AT SENSITIVE SITES

by

TALISMAN LAND RESOURCE CONSULTANTS

APPENDIX E

ENGINEERED WETLANDS TO TREAT HIGHWAY SURFACE RUNOFF AT SENSITIVE SITES

OBJECTIVE

An engineered wetland is a water management facility designed to improve the quality of highway runoff draining into sensitive areas.

FEATURES

- A flow-through system composed of a sedimentation pond followed in sequence by a man-made wetland or series of wetlands.

- Permanent water storage is relatively small. Water flows through the vegetated component as a low velocity, shallow sheet.

MECHANISMS

The majority of solids settle out in the sedimentation pond. Soluble pollutants and the remaining solids then flow to the wetland chamber, which functions as a physical, chemical and biological treatment system through:

- physical settling and filtration (Oberts & Osgood, 1991);

- chemical interaction between soil and water (Oberts & Osgood, 1991);

- adsorption (mainly ion exchange) and uptake by emergent vegetation (Chironis, 1987). The majority of pollutants and nutrients stored within emergent vegetation will become buried in the wetland bottom when the vegetation dies.

EFFECTIVENESS

- Physical settling, filtration, and chemical interactions between soil and water will occur year-round for engineered wetlands located within the coastal lowlands of Vancouver Island.

- Biological activity, the primary mechanism for the removal of soluble pollutants, occurs principally within the April to October growing season, and may be further restricted by the growing season moisture deficit of the area.

- Engineered wetlands have only a small water storage capacity. This may pose a problem, as the east coast of Vancouver Island typically gets very little precipitation during the summer. In an average year, drought may limit or halt biological activity during the months of July and August.

- Wetlands release nutrients stored in emergent vegetation during the decay component of the natural growth cycle. This typically occurs in late summer to early fall, however, the potential drying in July and August could impact the timing of the nutrient release.

RECOMMENDED POND DESIGN

(Size and engineering specifications as per KPA Engineering Ltd. design)

Sedimentation Pond

The water storage capacity of the pond should be sufficient to maintain the biological activity of the emergent wetland vegetation through the majority of the growing season.

Liner

Where the natural substrate is coarse textured and\or has high permeability, the sedimentation pond and wetland chamber should be lined with a swelling clay or a strong, impermeable, synthetic membrane to prevent rapid infiltration of water entering the pond system. Clay liners are more resistant to wildlife activity and maintenance activities, but are more difficult to install. Clay liners do not stick very well to sandy pond walls. Consequently, where sandy soils are encountered, it is recommended that the ponds be lined with a synthetic material.

Substrate

The wetland portion should be covered with a mineral topsoil, preferably with high organic matter content. Installation should be carried out when the soil is dry to avoid compaction and smearing. To create an adequate rooting depth, the soil cover should be a minimum of 40 cm deep.

The wetland should consist of one lift, with a level or slightly concave bench to facilitate low velocity, sheet flow. Given the uncertainty regarding pond hydrology, if there is the possibility of excessive flow (erosive), it may be necessary to protect the surface of the wetland chamber with an erosion control blanket, in similar fashion to the vegetated ditches (see Appendix C).

Water Flow

The design of the pond system should allow low velocity sheet flow in order to avoid channelling of the wetland substrate.

Vegetation

Year-round water levels in the pond's wetland area must be known for selection of wetland specie(s), as species adaptability will depend on the pond hydrology. Where pond hydrology is an unknown factor at the time of pond installation, it is recommended that vegetation establishment be initially attempted with a variety of species adapted to the range of possible moisture conditions. This should include transplanting cat-tail and broadcasting the seed of reed canary grass (wet soils), orchard grass (moist soils), and red fescue (drier soils).

Under these conditions, it is very important that, for the first few years, the pond hydrology and resulting plant growth be monitored. This information will be used for the settling ponds built on other sections of the highway. For example, if flooding is year round, it may be necessary to plant cat-tail. A detailed discussion of the recommended monitoring and of the merits of different wetland vegetation is given in following sections.

Where hydrologic and soil moisture conditions cannot be determined beforehand, it is very important that, for the first few years, the pond hydrology and resulting plant growth be monitored. This information could then be used for the settling ponds built on other sections of the highway. A detailed discussion of the recommended monitoring program and of the merits of different wetland vegetation species is given in following sections.

Where soils are saturated for the majority of the year, water tolerant species such as sedges (*Carex spp.*) or rushes (*Juncus spp.*) should be planted. Where persistent ponding occurs, emergent vegetation such as cattail (*Typha latifolia*), or club-rushes (*Scirpus spp.)* should be planted.

<u>Surface Cover</u>

Given the uncertainty regarding pond hydrology, after sowing the grass seed, it is recommended that the surface of the wetland chamber should be protected with an erosion control blanket. The recommended type is the coconut fibre blanket (SC125), manufactured by North American Green and distributed by Nilex Geotechnical Products Ltd. More detailed discussions of erosion control blankets are contained in Appendices C and D.

RECOMMENDED MONITORING PRIOR TO VEGETATION ESTABLISHMENT

Year-round water levels in the pond's wetland area must be known for selection of wetland specie(s), as species adaptability will depend on the pond hydrology. The quantity of water reaching the ponds will depend on a number of factors including the infiltration rate in highway ditches. As the hydrologic characteristics are unknown at the time of pond installation, it is recommended that the water level within each of the two chambers (forebay pond and future wetland area) be monitored on a monthly basis for the first 12 months (Figure E-1). When there is no standing water in the wetland area, the moisture content of the substrate should be monitored.

<u>Cat-tail</u> (Typha latifolia) is the preferred wetland specie, and is recommended if during an average rainfall year, the wetland is flooded for much of the year, and for the remainder, the wetland substrate retains some moisture.

If the wetland substrate is dry in July and August, <u>Reed Canary grass</u> (Phalaris arundinacea) is recommended.

RECOMMENDED EMERGENT VEGETATION

<u>If the Sedimentation Pond Maintains a Moist Wetland Substrate Through the Growing Season</u>

A monoculture planting of <u>cat-tail</u> (Typha latifolia) is recommended. Cat-tail is vigourous, easily transplanted, provides a dense vegetative mass, reproduces by seed and rhizome, and has been successfully employed within engineered wetlands for the treatment of stormwater, sewage and mining

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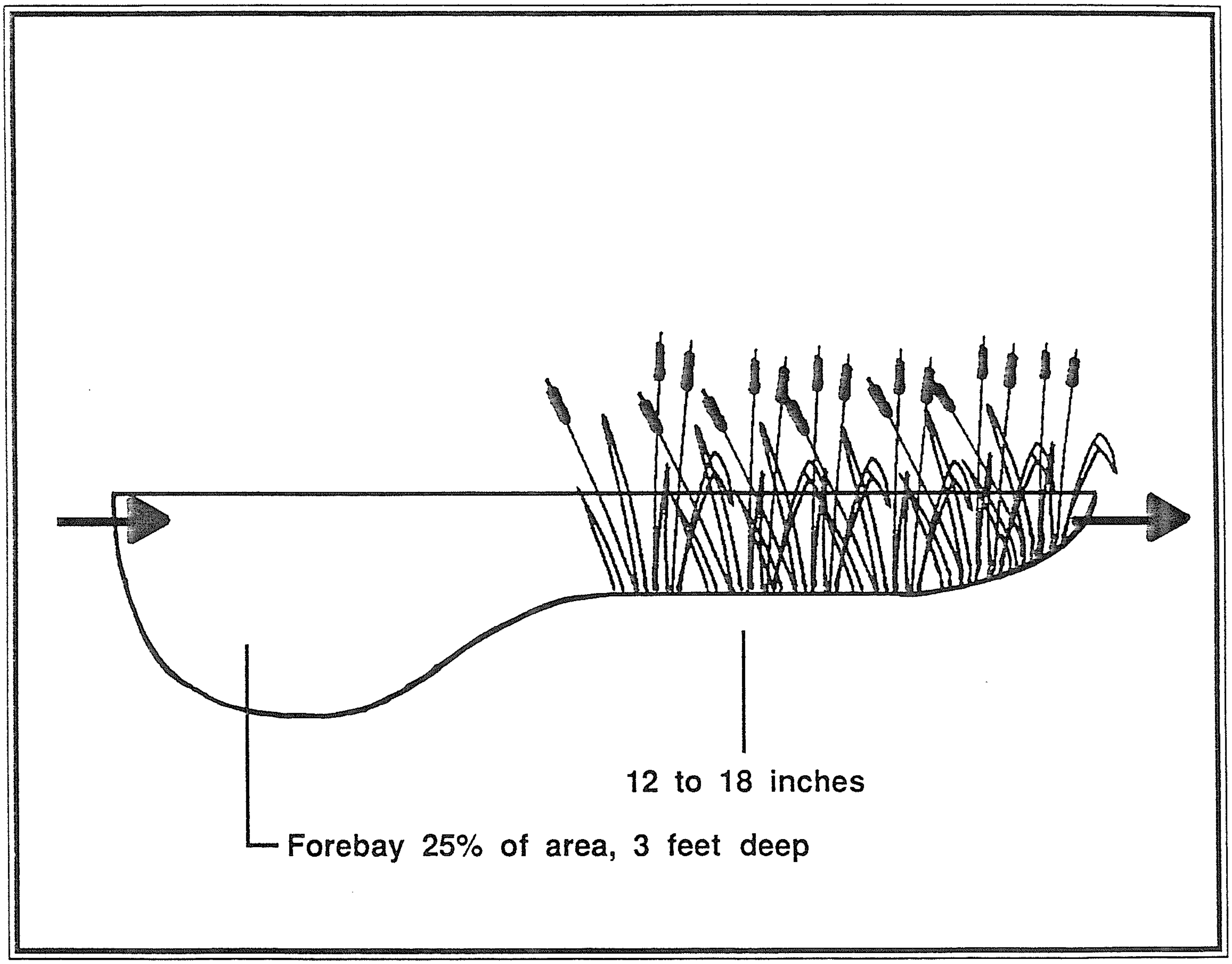

FIGURE E-1

Schematic Cross Section of an Engineered Wetland

effluent.

Cat-tail grows best in shallow slow moving water or wet floodplain soils. It will survive 1-2 months of surface drying of the substrate if the water table is within the rooting zone. Plant vigour will be negatively impacted by a lack of moisture.

Stock Procurement: Cat-tail plants should be removed from donor site(s) and transplanted to the engineered wetland in the October through March dormant season. Plants should be dug out with sufficient roots and surrounding soil to ensure survival, and to protect the roots from desiccation.

Planting Procedure: Plants should be spaced on 60 cm centers or less, and staggered in a checkerboard pattern to intercept water flow.

Nutrients: Fertilization should not be required.

The Wetland Substrate is Expected to Dry Out for One to Two Months (Typically July & August) at the End of Each Growing Season

Reed canary grass (Phalaris arundinaceae) is a vigorous sod-forming grass, adapted to moist to wet soils, tolerant of flooding and drought, which does well on upland soil where there is adequate moisture for spring and early summer growth (Hardy BBT, 1989). It is a tall coarse grass, grows in dense clumps, and is generally unpalatable to wildlife, an advantage where a synthetic membrane is to be used to line the wetland.

Planting reed canary grass is only recommended, if the engineered wetland are not within seeding distance of a natural wetland. Reed canary grass is an extremely aggressive plant and will out-compete wetland species such as cat-tail, a situation which has occurred at Swan Lake Nature Sanctuary in Victoria, B.C.. Care must be taken not to inadvertently introduce this specie to natural wetlands where it currently is not established.

Vegetation establishment: The transplantation of donor stock is recommended, however seeding is an alternative.

Transplanting Stock Procurement: Small reed canary grass clumps should be removed from donor site(s) and transplanted to the engineered wetland in the October through March dormant season. Plants should be dug out with sufficient roots and with surrounding soil to ensure survival, and to protect the roots from desiccation.

Transplanting Procedure: Grass clumps should be spaced approximately 60 cm or less apart, and staggered in a checkerboard pattern to interrupt water flow.

Seeding: Licensed cultivars are available from seed companies, however the species can be difficult to establish from seed and will likely require a reseeding in the subsequent planting window. Sow 1.2 to 2.5 cm deep. Fall/spring seeding at a rate of 5 to 10 lbs PLS/ac is recommended. (Hardy BBT, 1989).

Nutrients: Fertilization should not be required.

MAINTENANCE REQUIREMENTS

Sediment must be removed from the sedimentation pond. As sediments build up, the ability of the sedimentation pond to both treat inflowing water, and to store water to sustain the wetland vegetation through the growing season diminishes.

APPENDIX F

SPECIFICATIONS FOR SHRUB PLANTING

by

TALISMAN LAND RESOURCE CONSULTANTS

APPENDIX F

SPECIFICATIONS FOR SHRUB PLANTING

INTRODUCTION

Sensitive sites subject to erosion, for which the revegetation/erosion control prescription includes planting shrubs, include both the natural and cut and fill slopes, as well as the floodplains of all creeks.

Revegetation should be initiated in the first planting window. On the hydroseeded sites, shrub planting should be carried out in the fall or early spring. On areas that are cleared but not grubbed, shrubs should be planted in the first window following disturbance.

CONTAINERIZED SHRUBS

Stock

It is recommended that shrubs be planted as containerized stock, generally the larger the better, although availability, cost, and time constraints will be important factors in selecting stock.

Shrub Planting Window

Containerized shrubs can be transplanted anytime there is adequate moisture, typically from September through April. Polymer gel bags must be used for September transplanting to supply adequate moisture in what tends to be a fairly dry month, and are also recommended for optimal shrub survival and growth at other transplant times.

Installation Procedure

Offset planting at a density of one shrub every square meter is recommended.

1. Dig planting holes using hand tools.
2. Plant shrubs immediately after digging the planting holes to reduce drying of the backfill.
3. The hole should be slightly deeper than the pot height.
4. Put polymer-gel "tea" bags at the base of each planting hole to supply fertilizer and store water. The prescribed number of bags per shrub increases with the shrub size:
   - up to one gallon size: one pouch per shrub
   - one gallon size and larger: one pouch for each foot of height or width. This can be doubled for faster growing shrubs. Once shrubs can be measured with a calliper, use six pouches per one-half inch of calliper.

   The Gromax polymer-gel tea bags are distributed in B.C. through Matrix Industries Inc., Abbotsford, B.C. Order phone no: 1-800-745-1494 (California).

5. Thoroughly tamp the backfill to ensure good soil-root contact and eliminate air pockets.

6. Form a basin around each shrub to collect rainwater and to create space among the herbaceous vegetation.

7. If possible, water the plants.

PROCUREMENT OF STOCK

Delivery of both cuttings and containerized stock for the revegetation of sensitive sites should be arranged well in advance of the scheduled planting.

Containerized Shrubs

For the ordering of containerized shrubs:

- at least one year's notice may be required to obtain species grown from seed, and to obtain older, larger stock;
- six month's notice may be sufficient for species grown from cuttings, and if timed with seed maturity, may be sufficient for some species grown from seed;
- many, if not all, the desired species will not be available if less than six months notice is given.

The timing will depend on what the nurseries have available, the date required for seed or cutting collection, and the period necessary for maturation.

Pre-purchased Contracts

For the revegetation of those sites where there is sufficient lead time, pre-purchased contracts are recommended. These growing contracts ensure that the desired species will be available in sufficient quantities for revegetation of the sensitive sites. Growing contracts generally specify that a maintenance fee will be charged to hold stock which cannot be picked up at the contracted date due to project delays.

Cuttings

To ensure that a sufficient supply of dormant cuttings will be available for brush layering or wattling at sensitive sites:

- areas of donor stock should be identified, permission arranged, and areas flagged, well in advance; and
- harvesting contracts should be arranged well in advance.

NURSERIES

Names and addresses of nurseries prepared to contract grow native stock are provided in a report to the Ministry by C.E. Jones and Associates Ltd. titled "A Selection of Recommended Native Plant Species for Beautification of the Vancouver Island Highway Project", March 1992.

APPENDIX G

BIOENGINEERING TECHNIQUES

by

TALISMAN LAND RESOURCE CONSULTANTS

APPENDIX G

BIOENGINEERING TECHNIQUES

INTRODUCTION

Common bioengineering techniques, including wattling, brush layering and hedge brush layering dissipate water energy, trap sediments, provide local stabilization, and contribute shrubs to site revegetation. These techniques are recommended for sensitive sites where stabilization of slopes subject to seepage, surface erosion, and failure is difficult to achieve by conventional engineering methods.

Sprouting shrub species such as red-osier dogwood (*Cornus sericea*) and willow (*Salix spp.*) should be used.

Wattling uses tied bundles of dormant cuttings of a sprouting shrub specie to control erosion (Figure G-1). On steep sideslopes, trenches are dug on contour, and overlapping bundles are staked in place within each trench, and partially covered with soil.

Brush layering is similar to wattling, but employs cut dormant branches instead of tied bundles. Cut dormant branches of a sprouting shrub specie are laid in a criss-cross pattern (for stability) in trenches dug on contour. The growing tips of each branch protrude from the trench, and the cut ends are covered with soil.

Hedge brush layering is brush layering with rooted plant material interspersed with the cuttings along the terrace (Figure G-2).

HARVESTING AND INSTALLATION OF CUTTINGS: (adapted from MOTH, 1988)

- cuttings must be taken and installed during the dormant season, generally from October to March.
- donor sites must be located in the climatic vicinity of the installation site.
- readily sprouting shrub species such as red-osier dogwood (Cornus sericea) and willow (Salix spp.) should be used.
- cuttings must be taken in a dormant state, bundled at the harvest site, kept cold and moist, and installed within 48 hours of harvesting unless cold storage facilities are available. The buds must not "break" during installation.
- cutting length: approximately 0.8 meter to 1.0 meter.
- cutting diameter: minimum pencil width, preferably larger, maximum 5.0 cm thickness.
- careful handling during harvesting, transportation, storage and installation is required toprevent undue mechanical damage and desiccation.

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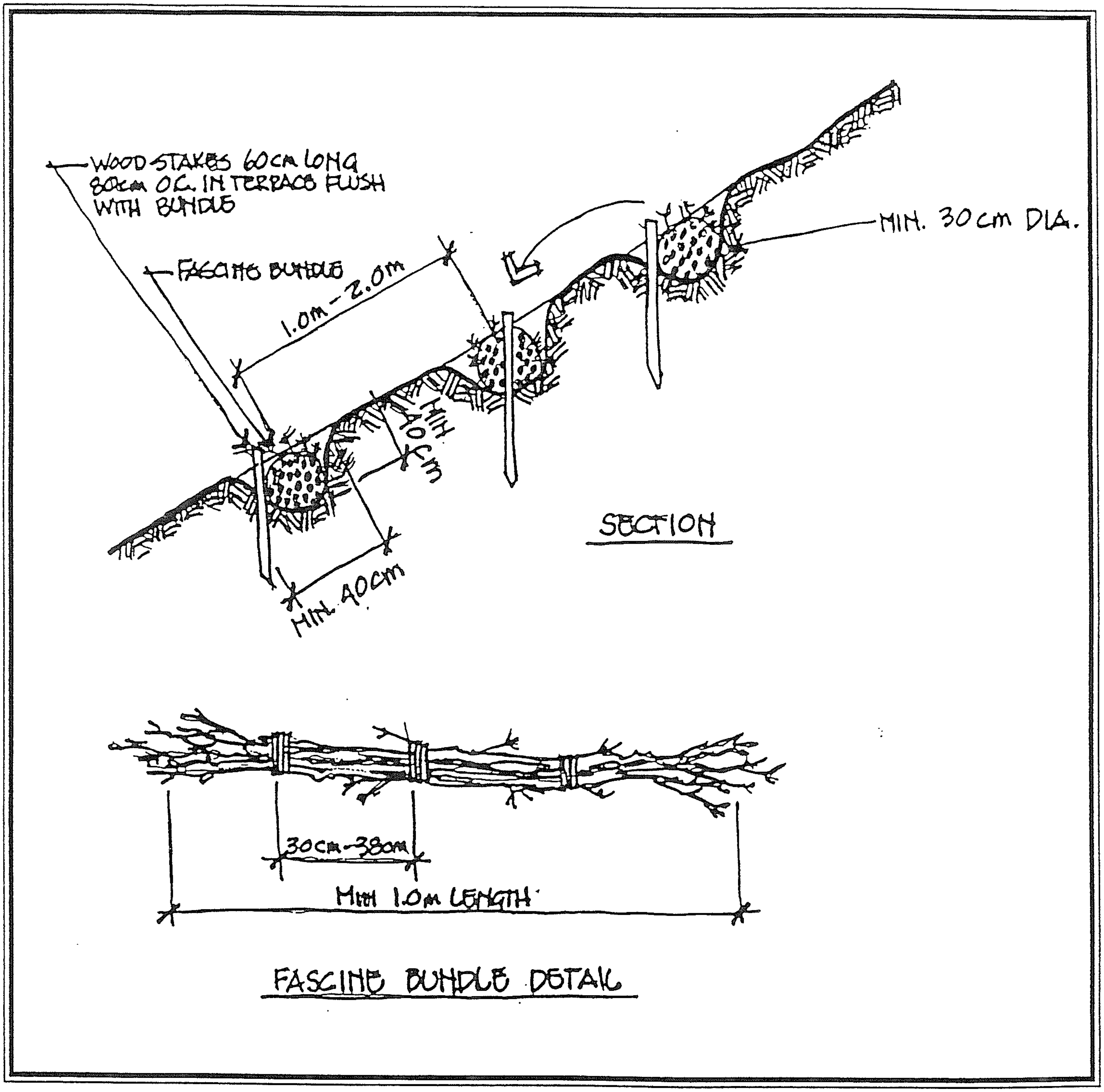

FIGURE G-1

Wattling

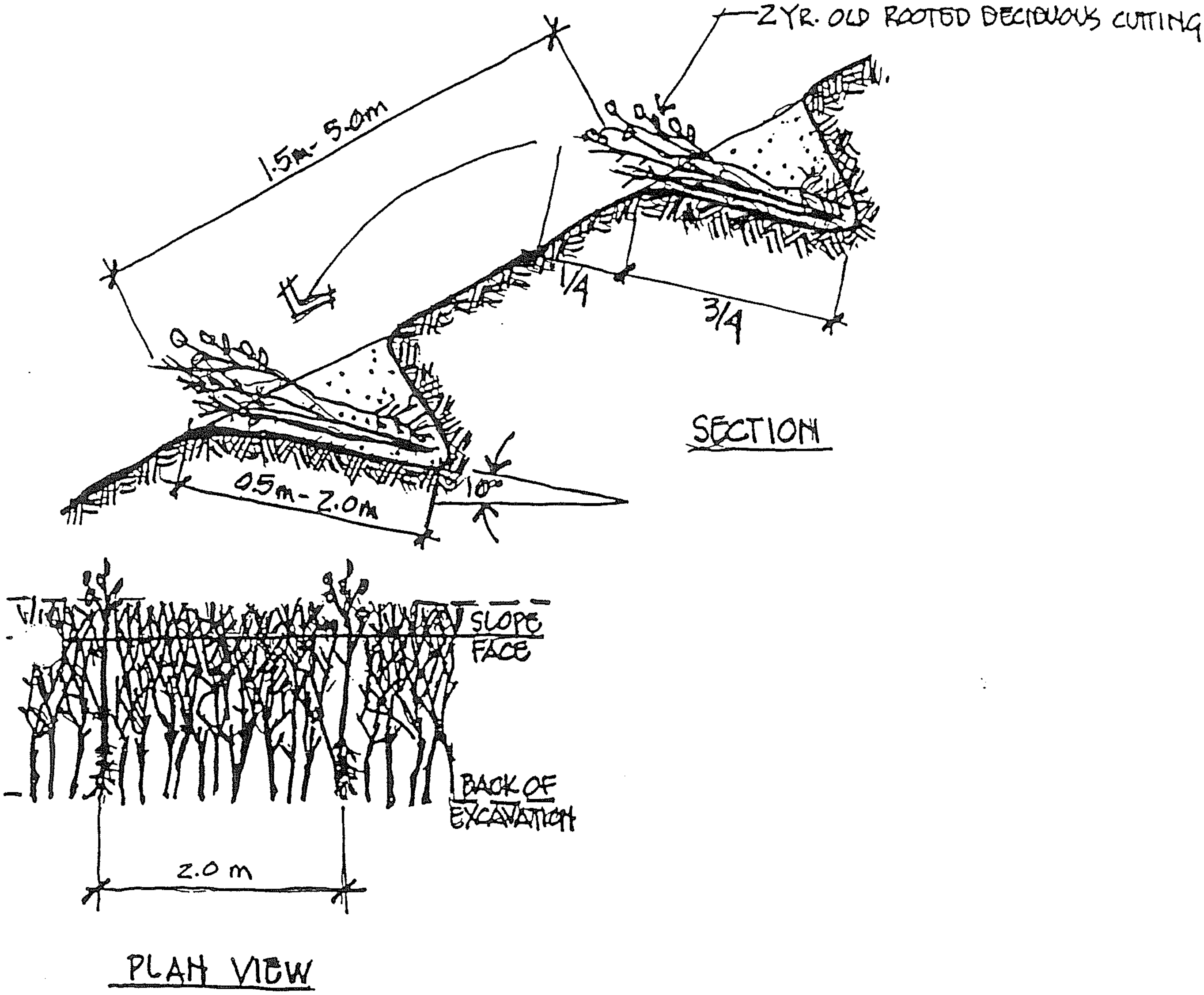

FIGURE G-2

Hedge Brush Layering

PREPARATION OF TRENCHES: (adapted from MOTH, 1988 and Leiser, 1987)

- trenches must be installed along the slope contours, and dug using hand tools.
- trenching should be started at the bottom of the sideslope area to be stabilized, and continued up the slope upon completion of each row. For ease of backfilling, toss soil upslope of trench.

Brush layering & hedge brush layering:

- each trench should be excavated to the maximum depth possible while retaining slope stability. Approximately 0.6 meters is recommended.
- trenches should be flat bottomed, and free of small to medium sized rocks or debris.
- large rocks or debris within a trench should not be dislodged, but left in place.
- trenches should be spaced so that the downslope edges of adjacent trenches are approximately 1.5 to 2.0 meters apart.

Wattling:

- each trench should be excavated to approximately half the diameter of the bundles, ie., approximately 10 - 13 cm.

INSTALLATION OF PLANT MATERIAL:

Cuttings, wattles or containerized stock should be installed and backfilled immediately upon completion of each trench.

Brush Layering and Hedge Brush Layering: (adapted from MOTH, 1988)

- place fertilizer tablets, 10 gm size of 20-10-5 analysis, down the middle and back of each trench at the rate of 4 tablets per lineal meter.
- lay cuttings in the trench in a criss-cross pattern, so that approximately 2/3 to 3/4 of each cutting lies within the trench and will be covered with soil, and 1/4 to 1/3 of each cutting will be exposed.
- use a minimum of 10 branch cuttings per lineal meter (one cutting per 10 cm).
- for hedge brush layering, place a containerized shrub in the trench every meter as well. Lay the containerized shrubs on their sides so that the stems are parallel to the cuttings.
- to backfill each trench, pull down soil from above, and firmly tamp in place with feet.

Wattling: (adapted from Leiser, 1987)

Preparation of Wattling Bundles:

- place stems alternately (ie., alternate the butts) to form a 20-25 cm bundle when compressed and firmly tied.

- securely tie the bundle every 30-40 cm with two or more wraps of heavy tying material. Use a non-slip knot.

- wattling bundles must be prepared and installed within two days of harvesting the dormant cuttings unless cold storage facilities are available.

Installation:

- lay bundles in the trenches with ends overlapping approximately 30 cm.

- stake bundles firmly in place with diagonal cut 2" x 4" wood construction stakes. Reinforcing bar may be used where the soil is too compact for wooden stakes. The length of the stakes is dependent on soil conditions, but generally ranges from 60-90 cm. Properly installed stakes cannot be moved by hand.

- stakes (vertical to the sideslope) are placed immediately below the bundles, on not more than 45 cm centers.

- stakes are placed diagonally through the bundles on not more than 75 cm centers, and also through each bundle overlap.

- to backfill each trench, pull down soil from above, and firmly tamp in place with feet. The downhill lip of the wattling bundle must be left exposed when backfilling is complete.