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Transport Infrastructure Ireland

TII Publications

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Vegetated Drainage System for Road Runoff

DN-DNG-03063
March 2015

DN Design

Standards

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For all documents that existed within the NRA DMRB or the NRA MCDRW prior to the launch of TII Publications, the NRA document reference used previously is listed above under 'historical reference'. The TII Publication Number also shown above now supersedes this historical reference. All historical references within this document are deemed to be replaced by the TII Publication Number. For the equivalent TII Publication Number for all other historical references contained within this document, please refer to the TII Publications website.

Volume 4 Section 2
Part 1
NRA HD 103/15

Vegetated Drainage Systems for Road Runoff

March 2015

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Summary:

This Standard gives guidance on how vegetated drainage systems may be used to convey, store and treat road runoff. They are described as vegetated drainage systems because they contain a significant element of vegetation and they are designed for use especially in road drainage networks. They are similar to systems described elsewhere as Sustainable Drainage Systems (SuDS). Designers should note that not all SuDS are appropriate for road use.

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VOLUME 4 GEOTECHNICS AND DRAINAGE

SECTION 2 DRAINAGE

PART 1

NRA HD 103/15

VEGETATED DRAINAGE SYSTEMS FOR ROAD RUNOFF

Contents

Chapter

1. INTRODUCTION

General

1.1 This Standard gives guidance on how vegetated drainage systems may be used to convey, store and treat road runoff. It is based on a review of recent research and practice, and a survey of a range of ponds, both wet and dry, that are fed by runoff from national roads or motorways. They are described as vegetated drainage systems because they contain a significant element of vegetation and they are designed for use especially in road drainage networks. They are similar to systems described elsewhere as Sustainable Drainage Systems (SuDS). Designers should note that not all SuDS are appropriate for road use.

Background

1.2 There is growing awareness that road runoff may, under certain circumstances, have an adverse effect on receiving waters. This has arisen both because of improving knowledge of the polluting content of road runoff and because of improved treatment of other sources of pollution. There is also concern at the possible impact that roads can have on local hydrology and therefore on flood risk. For further guidance on pollution protection and water quality refer to NRA HD 45 Road Drainage and the Water Environment.

1.3 The treatment of storm water runoff using vegetated systems is still a developing technology. It is recognised that guidance given in this Standard may therefore be overtaken by developments in current research and practice. There is also limited data on the degree of effectiveness of such systems in Ireland. However, the Standard is provided as the best available guidance because it is considered that vegetated systems, when designed, constructed and maintained as suggested in this Standard, can be used to provide a significant degree of treatment to road runoff and protection to receiving waters.

1.4 The 2015 revision of the NRA's drainage standards was precipitated by post-doctoral research carried out under the NRA's Research Fellowship Programme and mentored by the NRA's Environment Unit. This research looked at the impacts of national road drainage systems on both surface and ground water. The research concluded that the NRA's drainage standards needed to be expanded to promote the use of sustainable drainage systems and to maximise environmental benefits. A report entitled *Drainage Design for National Road Schemes – Sustainable Drainage Options* (NRA, 2014) documents this research and provides useful background reading to the NRA's drainage standards. This document is available at: nrastandards.nra.ie/latest/other-nra-documents.

Purpose

1.5 The purpose of this Standard is to provide guidance on the design of road drainage, both new and upgraded, so Designers or Specifiers may consider how vegetated systems may be incorporated in the overall drainage network and how they may be maintained. These systems can provide both treatment of the road runoff and attenuation of discharge flow rates. They may also contribute to the landscape and nature conservation value of the surrounding area. The Standard discusses how these qualities may complement each other, but also where they may conflict. This can occur because the prime function of the vegetated systems will be to protect the natural water regime into which the road runoff discharges. Maintenance of the proper operation of the systems is essential for continuing protection and must take priority. Any landscape or nature conservation value should be compatible with this function and should not inhibit the maintenance work required for the correct functioning of the system.

1.6 The Standard discusses a range of vegetated drainage systems. Many of these are in common use in Ireland, some are used for other types of non-road waste water or storm water treatment and some are in routine use in mainland Europe and the USA. The effectiveness, economy and advantages of these systems are discussed from the point of view of the Designer or Specifier. The Standard then discusses how such systems can be selected, designed, constructed and maintained in such a way that the whole drainage system, while satisfactorily performing its main purpose of removing surface water rapidly from the road, can also provide some degree of both attenuation and treatment of the flow. Such measures will thus reduce the risk of storm water either affecting the natural hydrology of the catchment area (causing local flooding) or polluting the downstream surface watercourse or ground waters.

1.7 Having first determined that some form of treatment is necessary, it is fundamental to the process of selection of systems to determine what it is that vegetated drainage systems are required to treat. The Standard shall therefore be read in conjunction with NRA HD 45 Road Drainage and the Water Environment, which provides an overview of the current knowledge of road runoff in Ireland, the factors that are believed to affect its nature and a guide to the assessment process and tools available for calculating the potential risk of pollution from routine road runoff and accidental spillages.

1.8 The selection of vegetated systems cannot be prescribed. Each situation must be considered individually as there are very many factors to be taken into account, ranging from the local landscape, geology, hydrology, climate and local river catchment and quality, to the actual or predicted traffic levels on the road, the risk of accidental spillages and the practicality of provision for maintenance. It is important that Designers and Specifiers consider the widest possible number of factors before considering what systems to incorporate. In many situations, particularly where roads are being improved, the availability of land will be a major factor in the selection process. Selection is an iterative, rather than a linear, process and is not amenable to illustration by simplified design guides, such as flow charts, to aid the choice of suitable systems. Further guidance on drainage type selection and design can be found in NRA HD 33 Drainage Systems for National Roads and NRA HA 33 Design of Earthworks Drainage, Network Drainage, Attenuation & Pollution Control.

Scope

1.9 The principles outlined in this Standard apply to all National Roads projects.

Implementation

1.10 This Standard shall be used forthwith for all schemes for the construction and/or improvements of national roads. The standard shall be applied to the design of schemes already being prepared unless, in the opinion of the National Roads Authority, application would result in significant additional expense or delay progress. In such cases, Design Organisations shall confirm the application of this Standard to particular schemes with the National Roads Authority.

2. DESCRIPTION OF VEGETATED DRAINAGE SYSTEMS

General

2.1 Vegetated drainage systems can be used as components of a drainage network to convey, store and treat water running off the road, before it outfalls to the receiving waters. They may be designed to supplement or replace conventional drainage systems. By their nature, they are part of the surrounding landscape and can contribute to the nature conservation or landscape amenity value of an area. This can be done without diminishing their primary purpose as components of the drainage system.

2.2 In a strict sense, vegetated systems are those treatment measures which employ vegetation as a primary treatment component. However, for the purposes of this Standard, systems which do not necessarily include vegetation, but may be enhanced by a vegetated component, are also considered. The systems can be considered as:

a) those that convey water, such as swales and grassed channels; or

b) those that treat water while it flows slowly through the system such as wetlands and infiltration basins; or

c) those that treat water at rest, such as ponds.

2.3 In practice there may be an overlap between these functions. These systems are described below and typical examples are shown in Figure 2.1.

Swales

2.4 Swales are wide, shallow, gently sloping depressions designed to convey water. From a treatment viewpoint their primary function is to slow the flow of water to provide filtration, and this parameter may need to be balanced with their additional attenuation functions of conveyance and water storage. They are particularly effective in controlling pollution when there is a degree of infiltration to the subgrade or where residence times are long and flow velocities are low. They can be used to reduce spillage risk by the addition of check dams, which also can attenuate the flow. Swales are well suited to areas where the road is on a gently sloping embankment as the embankment slopes can be designed to be part of the swale, and are most effective when the water flow is slowest, immediately after it leaves the road. Used in this way they could also operate as the first form of attenuation and treatment in a drainage system. Their effectiveness in removing pollutants will depend upon the detailed design. Suspended solid loadings can be reduced by up to 80% or more. Levels of soluble pollutants may not be greatly reduced, although dissolved metals can be reduced by up to 50%.

Grassed Surface Water Channels

2.5 Grassed channels are a development of swales for use as road edge channels. They differ from normal roadside channels in that the flow of water is designed to be slower, so that filtration and, to a lesser extent, sedimentation may occur as the water flows across and through the grass. Guidance on the design, construction and maintenance of grassed channels can be found in NRA HD 119 Grassed Surface Water Channels for Road Runoff.

2.6 There is no clear distinction between swales and grassed channels though historically the term swale has been used to describe a wide grassed channel. The guidance in this Standard generally relates to swales, though some of the properties of a swale may be exhibited by a grassed channel. The speed of the water along the channel is the critical factor, as a slow flow at the top of the run with good grass cover will encourage a degree of sedimentation, but if there is the possibility of faster flows from stormy conditions, re-suspension of the particles can occur. The flow in steeper sided channels tends to be less stable and such channels are harder to clean and maintain, unlike gently undulating swales which encourage smooth flows and may be mowed.

Infiltration Basins

2.7 Infiltration basins store and treat water, and can therefore provide a degree of risk reduction for both flooding and pollution downstream. They are designed to retain storm water flows and allow the water to percolate through a filter layer which may typically comprise porous material, such as gravel. The water may then be directed to a surface water outfall, or it may continue to percolate through to the groundwaters. Figure 2.2 shows a possible design with water flowing to an outfall. The shape of the basin will be determined by the land available, and for small catchments a narrow trench-like basin will be more appropriate. Infiltration Basins have the potential to remove suspended solids and reduce metal loads, but like swales soluble pollutants may not be significantly reduced. Their effectiveness in removing pollutants will depend on their design for storm flows, particularly as suspended solids are prone to remobilisation, resulting in high sediment and metal loads being discharged. As there is no effluent as such from an infiltration basin, it is not possible to measure the pollutant removal percentage. However, various research has shown that the vast majority of pollutants are retained within the top 10cm of soil and that the risk to groundwater from infiltration basins is low provided there is sufficient depth of unsaturated zone. For further guidance on groundwater protection response refer to NRA HD 45.

2.8 Infiltration basins are not suitable for retaining accidental spillages, because of the difficulty in cleaning them, and should be sited downstream of some device to contain the spillages, unless this risk is perceived to be low. They may be used to receive the ‘first flush’ flows (see paragraph 4.5) and to hold and treat these, with the rest of the flow bypassing the basin to other systems.

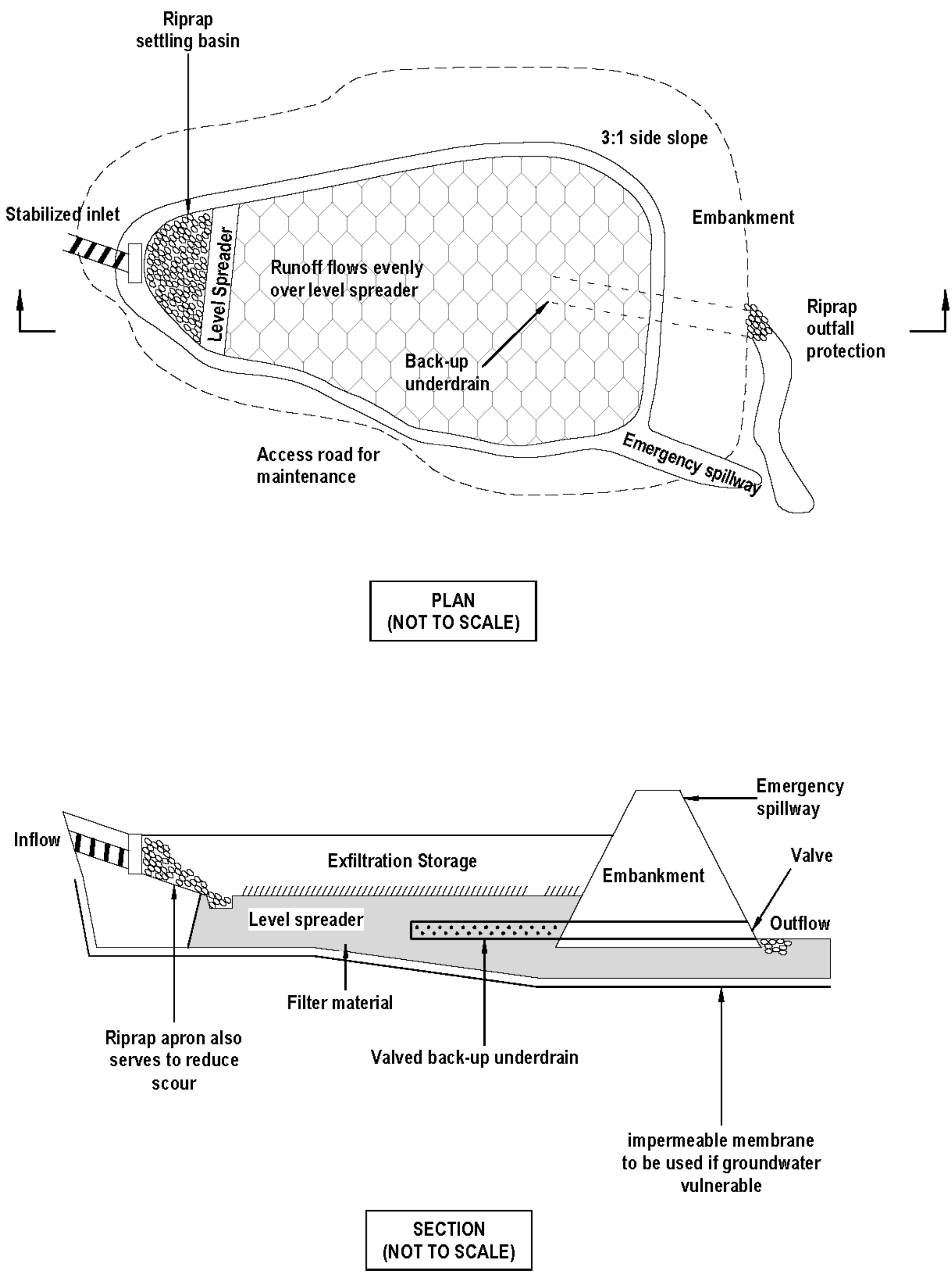
Swale / Grassed Channel

Surface Flow Wetland

Retention Pond

Sediment Pond

Figure 2.1



INFILTRATION BASIN

Figure 2.2

Wetlands

2.9 Wetlands can be defined as areas that are permanently saturated by surface water or groundwater so that they are able to support aquatic and/or semi-aquatic (emergent) vegetation such as reed swamps, marshes, or bogs, depending on the degree of saturation and inundation. Natural wetlands are of relatively rare occurrence and generally of high nature conservation value. They should not therefore be used to treat water, nor should treated road runoff be discharged into them, unless they have low nature conservation value or road runoff could provide additional water of sufficient quality and quantity. For further guidance on water quality requirements refer to NRA HD 45.

2.10 Wetlands can be categorised according to the predominant flow pathway of water through the system: either as Sub-Surface Flow (SSF) wetlands where the flow of water is primarily through the growing media and plant root zone; and Surface Flow (SF) wetlands where the primary flow is across or close to the surface of the growing medium and through the above ground parts of the plants.

Constructed Sub-Surface Flow (SSF) Wetlands

2.11 Constructed SSF wetlands are essentially basins filled with porous material through which water flows. The porous material is kept at saturation, up to an appropriate water level, and is usually planted with common reed swamp vegetation. This type of a wetland is increasingly being used to provide final treatment to municipal wastewaters and domestic sewage by removing nutrients (particularly nitrates and phosphates) through biological and chemical processes in the supporting porous media and the root zone. Provided there is a relatively long residence time (24 hours or more), the hydraulic resistance and large surface area provided by the media and the vegetation promote higher levels of adsorption, microbial degradation and biological uptake (particularly of metals) than occurs in other systems. SSF wetlands are well suited to treatment of relatively small and constant volumes of water, and have the advantage of taking relatively little space. These systems are, however, dependent on the porous medium being kept saturated and free from suspended solid loads, which rapidly clog the pores and transform them into surface flow systems.

2.12 Road run-off is markedly different from sewage effluent in both water quality and flow characteristics. Most important of these are the potentially high (peak) suspended solid loads and low nutrient loads of road runoff, and the intermittent discharge in the summer months (which may be insufficient to maintain the wetland). Hence, SSF wetlands are rarely appropriate for road runoff treatment, except possibly where soluble metals are a particular problem and a very high level of protection of sensitive receiving waters is required. Where they are used there will be a requirement for pre-treatment provisions to remove suspended solids and control structures to regulate in- and out-flow rates. Designers or Specifiers should also be satisfied as to the viability of SSF wetlands during dry periods, possibly by the provision of secondary flows through the system. They are more costly to build and require a higher maintenance input than other vegetated systems.

Constructed Surface Flow (SF) Wetlands

2.13 Constructed SF wetlands are essentially similar to the sub-surface type being permanently saturated open ended or closed basins, or low lying level ground. The growing medium material is kept at the saturation and inundation appropriate for the type of vegetation established. This type of wetland is increasingly being used to provide treatment of road runoff in the USA. They are effective in the removal of suspended solids and associated heavy metals through the physical processes of settlement and filtration. Provided there is a relatively long residence time (24 hours or more), adsorption and microbial degradation and biological uptake of metals and nutrients can occur. SF wetlands are well suited to treatment of road runoff as they are able to deal with the high suspended solid loads in road runoff. However they need to be designed so that they remain sufficiently wet in the summer months. They are relatively less costly to build but require a specialist maintenance input. Figure 2.3 shows a sketch of a typical SF wetland. Their effectiveness in removing pollutants is dependent on their design for storm flows, particularly as suspended solids can remobilise near to the outfall structure.

Ponds

2.14 Ponds may be designed primarily to attenuate flows, and are then customarily known as Detention or Retention Ponds, accepting large inflows, but discharging slowly. Alternatively they may be designed primarily to treat the water by allowing suspended solids to settle out: these are customarily known as Sedimentation Ponds. In practice they will normally perform both functions to some extent.

2.15 They may be designed to retain water at all times – particularly if there is an alternative constant water source, or if they have been engineered from existing ponds. These are sometimes known as wet ponds or Retention Ponds. Such ponds can both store water thus reducing flood risk downstream, and treat it by allowing suspended solids to settle out. The smallest particles take longer to settle out, but available evidence suggests that particles of less than 63 μm may carry more than 50% of the pollution load. Figure 2.4 shows a sketch of a typical wet pond. Ponds have a high potential to remove suspended solids, around 60%, and a potential dependent on their design for storm flows to remove metal and hydrocarbon pollutants, although their effectiveness in removing the latter two pollutant types is less. For dissolved copper the removal percentage is around 40%, and for dissolved zinc it appears to be lower at 30%. As with other treatment systems, the performance of individual systems will reflect the specific design and site characteristics.

2.16 Ponds that are designed to empty after rainfall events, or to be dry for extended periods are customarily known either as dry ponds or Detention Ponds. They are usually cheaper to build than wet ponds, but they will have less effect in treating the runoff (unless they are also infiltration basins as described earlier in this chapter). Residence times are, by definition, expected to be relatively short for Detention Basins. However, for treatment purposes a minimum recommended treatment time is 6 – 12 hours. Published literature on their effectiveness for pollutant removal shows a wide variation. A problem can be short-circuiting of flow, but where this is not occurring; they can be expected to remove in the order of 50% of suspended solids. Due to short suspension time and re-suspension, they can have a low efficacy in removing small particles and a limited capacity for the removal of dissolved metals.

2.17 The ability of a retention pond to attenuate the flow will depend on its capacity, and rate of outflow. Such devices should be designed so that the natural hydrology of a catchment area is not affected by large quickly-drained areas of road. Ponds may be the most practical and effective measures for treatment of road runoff if sufficient detention time is allowed for both sedimentation and biological processes within the pool.

Hybrid Systems

2.18 In many instances, the vegetated system may be a hybrid, being neither a pure wetland nor a retention pond, but a combination of the two. These may take the form of small pools of open water within the wetland or marginal wetland associated with a pond, or other variations. These hybrids are considered to be more effective than pond or wetland systems alone. Figure 2.5 shows a sketch of a typical hybrid system.

Combinations of Systems

2.19 Designers of vegetated drainage systems often design a combined system formed of a series of components. For example in many systems the chosen design is a combination of a Pond and an SF wetland. Alternatively, at other locations, designers have used swales to reduce the suspended solid load followed by a wetland to treat the dissolved component of runoff. If the estimated spillage risk is significant (the annual probability of a major spillage incident being greater than 1%), the combined system should be designed so that spillages are contained within the swale before the flow reaches the wetland, as contamination of the swale will more easily be remedied than damage to the wetland. Control of the spillage could be by check dams, which provide automatic spillage containment, backed up by a second control system further downstream. Other systems to trap suspended solids may be used if swales cannot be designed to fit. Provided there is sufficient available land, a combination of treatment systems may be the most appropriate. Combination systems have the advantages of both SF wetlands and Ponds, and subject to design and storm flows, without their respective disadvantages. They are simpler to design, operate and maintain, and are particularly appropriate where there is a high risk of spillages. Refer to chapter 3 for indicative treatment efficiencies for combinations of drainage systems (Table 3.2).

2.20 A SF wetland could be fed from the outflow of a retention pond, which has the ability to contain spillages. In some locations additional containment measures may have to be located upstream of the wetland to provide automatic protection against minor oil spillages.

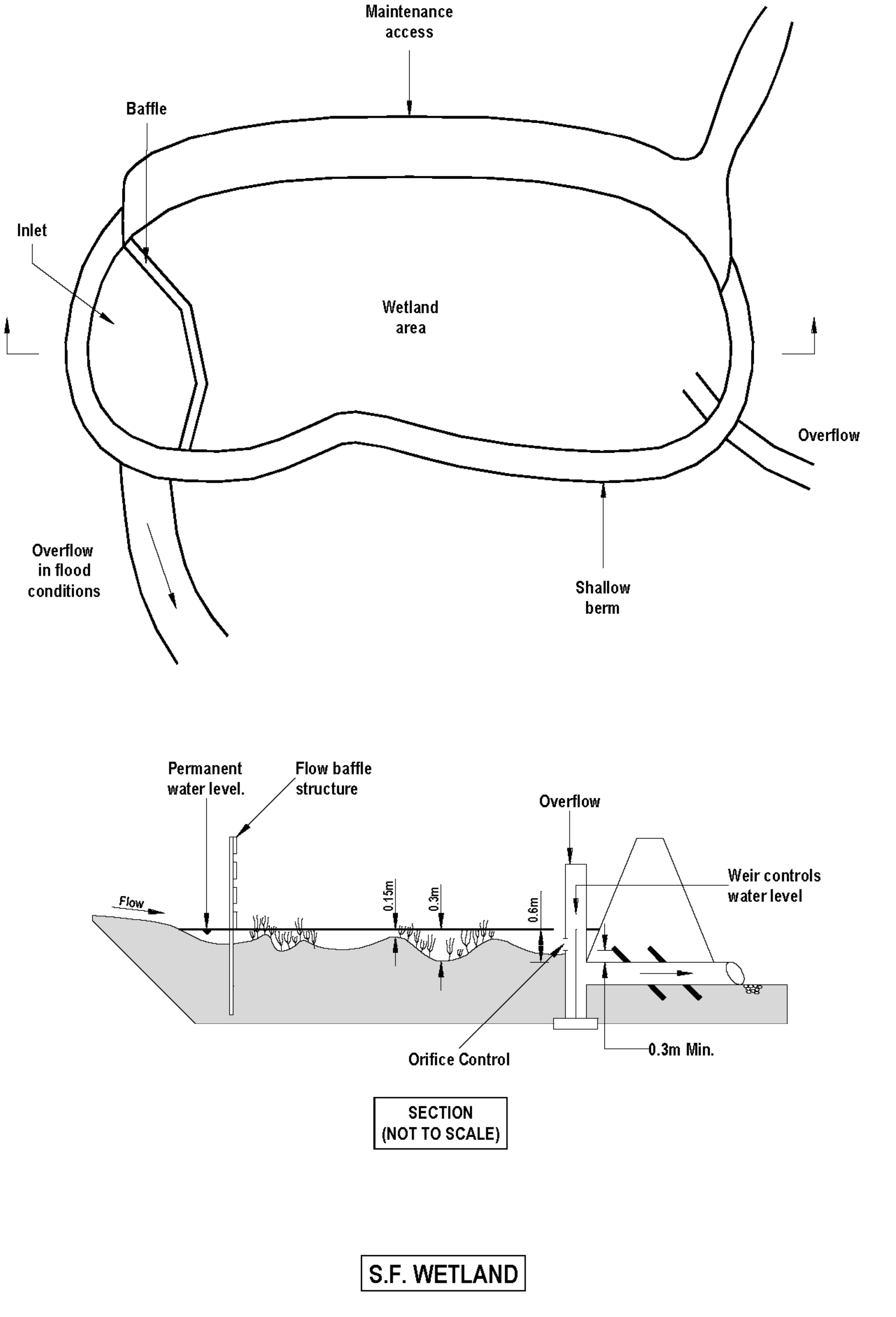

Maintenance
access
Baffle
Inlet
Wetland
area
Overflow
Overflow
in flood
conditions
Shallow
berm
Permanent
water level.
Flow baffle
structure
Overflow
Flow
0.15m
0.3m
0.6m
Weir controls
water level
Orifice Control
0.3m Min.
SECTION
(NOT TO SCALE)
S.F. WETLAND

Figure 2.3

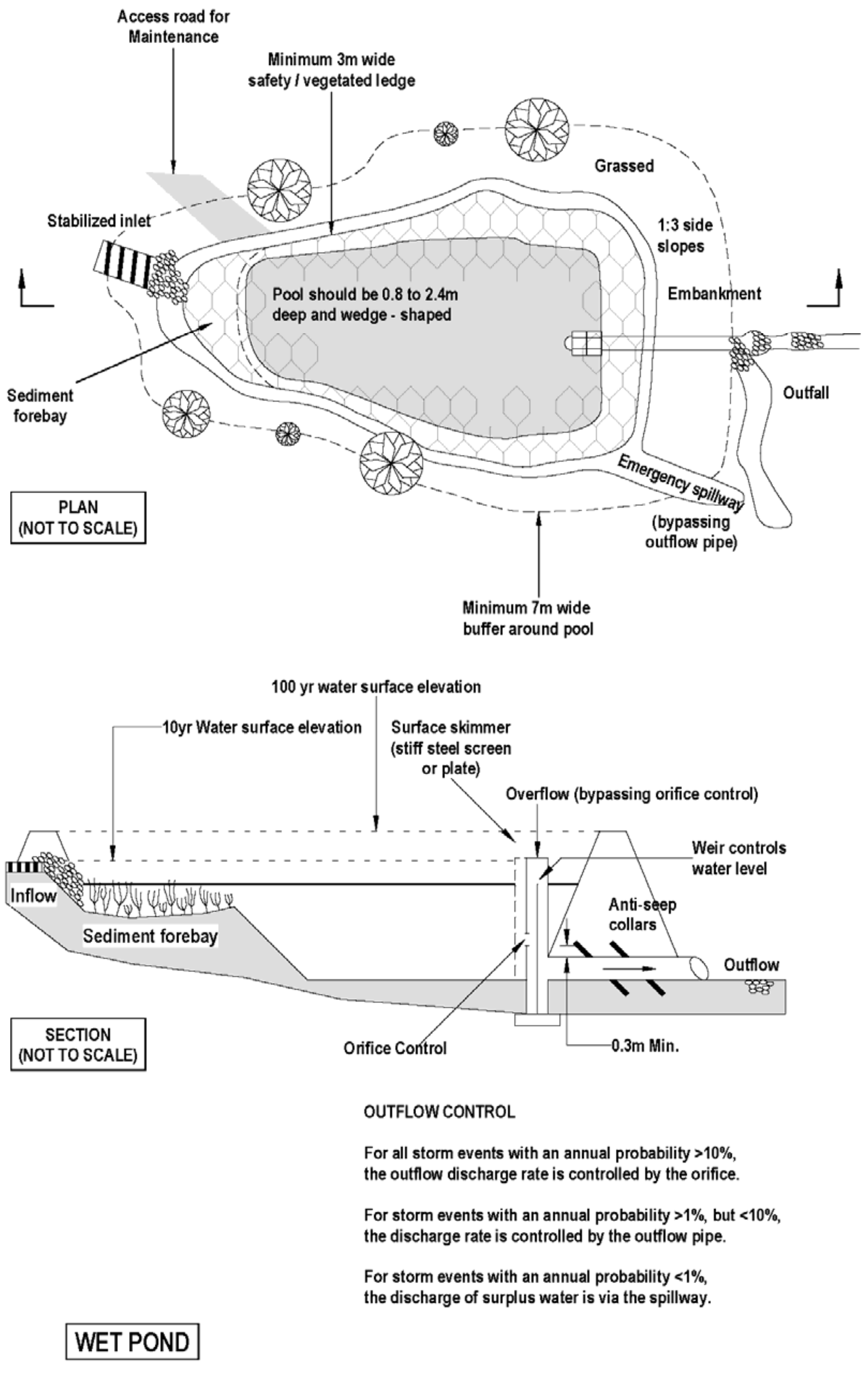

Access road for Maintenance
Minimum 3m wide safety / vegetated ledge
Grassed
Stabilized inlet
1:3 side slopes
Pool should be 0.8 to 2.4m deep and wedge - shaped
Embankment
Sediment forebay
Outfall
Emergency spillway
(bypassing outflow pipe)
PLAN
(NOT TO SCALE)
Minimum 7m wide buffer around pool
100 yr water surface elevation
10yr Water surface elevation
Surface skimmer (stiff steel screen or plate)
Overflow (bypassing orifice control)
Weir controls water level
Inflow
Anti-seep collars
Sediment forebay
Outflow
SECTION
(NOT TO SCALE)
Orifice Control
0.3m Min.
OUTFLOW CONTROL
For all storm events with an annual probability >10%, the outflow discharge rate is controlled by the orifice.
For storm events with an annual probability >1%, but <10%, the discharge rate is controlled by the outflow pipe.
For storm events with an annual probability <1%, the discharge of surplus water is via the spillway.
WET POND

Figure 2.4

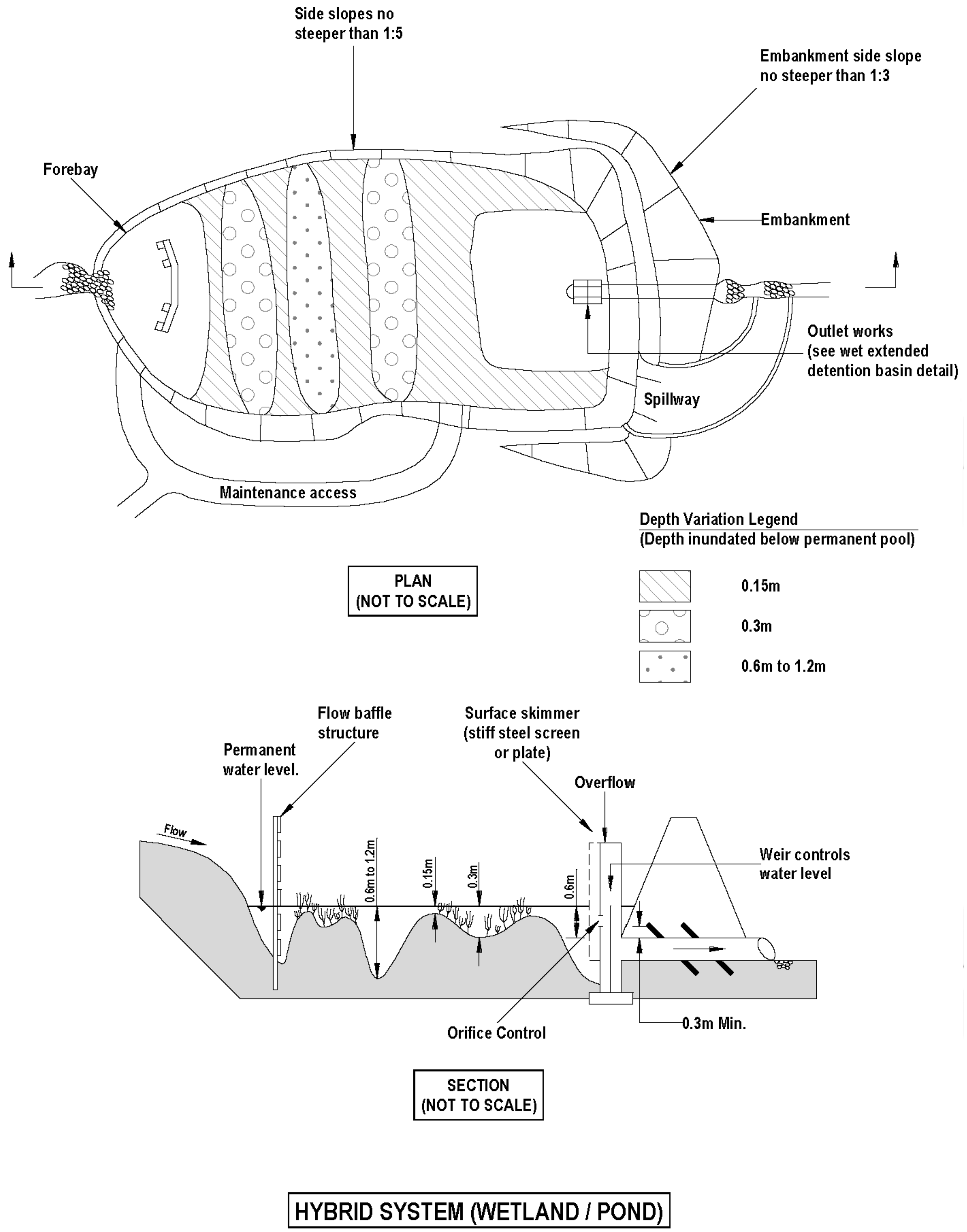

Side slopes no steeper than 1:5
Embankment side slope no steeper than 1:3
Forebay
Embankment
Outlet works (see wet extended detention basin detail)
Spillway
Maintenance access
Depth Variation Legend
(Depth inundated below permanent pool)
0.15m
0.3m
0.6m to 1.2m
PLAN (NOT TO SCALE)
Flow baffle structure
Surface skimmer (stiff steel screen or plate)
Permanent water level.
Overflow
Flow
0.6m to 1.2m
0.15m
0.3m
0.6m
Weir controls water level
Orifice Control
0.3m Min.
SECTION (NOT TO SCALE)
HYBRID SYSTEM (WETLAND / POND)

Figure 2.5

3. RUNOFF CONSTITUENTS AND TREATMENT PROCESSES

General

3.1 Although vegetated systems may be classified into the three types as described in paragraph 2.2 when their hydraulic properties are being considered, it is more appropriate to assess their role as treatment systems on the basis of the runoff constituents and treatment required. The principal constituents requiring treatment are suspended solids, heavy metals, and a wide range of organic compounds, which include oils and grease.

3.2 The most important treatment processes in vegetated drainage systems are:

a) settlement and filtering of particulate constituents;

b) adsorption of organic compounds to vegetation and soils;

c) microbial degradation and assimilation of organic compounds;

d) uptake of nutrients and metals by higher plants;

e) precipitation, bacterial oxidation and adsorption of heavy metals.

These processes, as applicable to the various types of vegetated systems, are set out in Table 3.1.

Suspended Solids

3.3 Suspended solids are the principal road runoff constituents requiring treatment because of the harmful physical effect they can have on aquatic habitats. Many of the other potentially harmful constituents of runoff (heavy metals, organic compounds) are in particulate form or attached to particles which can accumulate in the water course, leading to chronic pollution. Research (refs. 7.5, 7.7) indicates that typically more than 50% of both metal and organic contaminants associated with suspended particles are contained within the fraction finer than 63μm.

3.4 The main removal mechanism of solids by vegetated systems is due to enhanced settlement through reduced flow velocities and filtering effects (ref. 7.11). Settlement is the main process in very slowly flowing standing water as in ponds and contained types of inundated SF wetland. It is not, however, a significant process in swales, infiltration basins and those SF wetlands without standing surface water, where there is a through flow and short residence time. Settlement will be most effective in systems where there is a long residence time or where there are structures that induce particulate collisions and arrest the flow thereby promoting settlement. 24 hours is the recommended minimum duration, as described later in this chapter, and this should be exceeded where possible. The filtering process will only take place where there is a significant flow through vegetation, as in swales and grassed channels, infiltration basins, and open types of SF wetland without standing surface water. The SSF type of wetland is not an appropriate choice for the removal of solids, because of the potential to clog the substratum pores and change the hydraulic functioning of the wetland.

Heavy Metals

3.5 As much of the metal content of the runoff is particulate, the principal removal processes within vegetated systems are the same as for the suspended solids (settlement and filtering). Precipitation and formation of metal hydroxides and other insoluble compounds can also occur in certain oxidation/reduction conditions. Vegetated drainage systems such as swales and grassed channels, SF wetlands and infiltration basins, and ponds with a vegetation cover will remove heavy metals in the particulate form either by filtration and/or by settlement. As with removal of suspended solids, SSF wetlands would not be expected to be effective in this role for the reason given in paragraph 3.4. Settlement column studies indicate that, for runoff from a single storm event, the majority of heavy metal pollutant removal occurs within the first 6 hours. Removal of copper and zinc, the two metals most likely to be present in significant concentrations, improves if there is up to 24 hours residence time (see paragraph 3.15).

3.6 Adsorption of metals to soil and vegetation, and assimilation by microbes and plant uptake of soluble metals, also take place in vegetated systems, but are considered to be of less significance than the physical processes and are reliant on a relatively long residence time. Plant uptake is dependent on active vegetative growth and microbial activity on temperature; both are likely to be significantly lower in the late autumn-winter period and metals may be released on decomposition.

3.7 Precipitation of metal oxide solids is a secondary process that removes metals from the runoff water. Insoluble metal oxides typically form under aerobic conditions in retention systems such as ponds, and are then precipitated. Aeration of water is therefore an important part of standing/flowing water systems such as ponds. Precipitation as a removal mechanism may be less in soft water and is unlikely to occur in the SSF type of wetland owing to the prevailing anaerobic conditions in the root zone.

3.8 There is now substantial evidence (refs. 7.16, 7.17) that re-mobilisation of metals may occur especially with high inputs of sodium chloride into sandy non-calcareous substrates, due to displacement of the metals by sodium ions. This is caused by the use of salt as a de-icing agent.

Organic Constituents

3.9 This group contains a wide range of chemicals. Adsorption to suspended solids and subsequent settlement is a significant removal process for oils and grease. Lighter aromatic fuel additives may volatilise prior to degradation, in which case prolonged exposure of runoff to the air is beneficial. Other aromatic compounds such as PCBs (Poly-Chlorinated Biphenyls) and PAHs (Polynuclear Aromatic Hydrocarbons) are toxic and may be more persistent, but have a tendency to adsorb to suspended solids.

3.10 As much of the organic content of the runoff is associated with particles, the principal removal processes within vegetated systems are the same as for suspended solids (settlement and filtering). Significant amounts may therefore be removed by settlement processes. Vegetated drainage systems such as swales and channels, SF wetlands and infiltration basins, and ponds with a vegetation cover will remove it in the particulate form. SSF wetlands would not be expected to be effective in this role, as the heavy particulate fractions may cause clogging of the porous media.

3.11 Biological degradation of oils and grease is relatively slow, taking several days even in ideal conditions. The biodegradation process is therefore considered to be of less significance in the removal of organic constituents from runoff than settlement. The process is likely to be of significance, however, in the in-situ degradation of accumulating material. Ponds and SF wetlands are probably the best systems for such in-situ transformation as they are more likely to support the requisite aerobic microbes.

Nutrients

3.12 Nitrogen and phosphorus are usually the primary nutrients of concern, but are not normally present in significant concentrations in road runoff, and are therefore not a major consideration for treatment where high levels of urea are applied for road de-icing. Where significant concentrations occur, uptake by vegetation and microbes in vegetated systems are likely to reduce these concentrations, but only in the growing season. The most effective system is the SSF wetland where de-nitrification of nitrates takes place under anaerobic conditions, and nitrogen and phosphate are removed by plant and microbe uptake. Vegetated systems sometimes contribute to higher nutrient discharges than are normally associated with road runoff owing to accumulation and degradation of plant material, but this should be significantly less than other sources, particularly agriculture.

Sodium Chloride and Other Dissolved Constituents

3.13 Other than heavy metals and nutrients, the significant dissolved constituent of road runoff in Ireland is sodium chloride (NaCl), applied as de-icing salt. Vegetated systems are unable to reduce concentrations of common salt to any significant extent. Sodium chloride can cause damage to vegetation, and can potentially trigger the release of accumulated nutrients and heavy metals adsorbed to the suspended solids into solution. Where use of de-icing salt is likely to be very frequent and the dilution of runoff by receiving waters is low, either the ‘first flush’ (see paragraph 4.5) should be diverted to infiltration facilities with groundwater protection or only ponds should be used.

The Importance of Residence Time and Loading

3.14 Residence time (sometimes referred to as retention time, Rt, where $Rt = V/Q$ where Q is the outflow and V is volume of the system) is the period during which the runoff is retained within the drainage system. It is probably the overall ‘key’ design parameter for all treatment systems that depend on the settlement process (e.g. ponds and SF wetlands) for removal of sediment, metals and hydrocarbons. Permanent pool storage capacity (min 10-15%), hydraulic gradient <1%, length-width ratios >3:1, uniform cross-section, flow path (zig-zag), flow arrest structures (submerged islands/weirs, vegetation across flow), and outfall structures are often cited (ref. 7.12) as important design and influencing features. Where appropriate, these apply to separate, hybrid or combination systems. Hydraulic loading has also become recognised as an important factor, where the efficiency of the treatment systems declines with increased loading. Flow rates under storm conditions are also significant in remobilisation of sediment and bypass structures are frequently recommended.

3.15 Residence times of about 24 hr are the recommended minimum, but more time is required for very fine sediment where there is reliance on ponded water alone, and times less than one hour may result in remobilisation of sediments. In these contexts, vegetated wetlands promote sedimentation and therefore appear to require shorter residence times than ponds or infiltration basins and result in relatively greater reductions in pollution loads. For those simply depending on filtration (e.g. swales), the factors that should be used to determine pollutant removal efficiency include: the maximum depth and velocity of the water, length of channel and hydraulic loading.

Table 3.1: Treatment of Road Runoff: Principal Processes in Vegetated Systems

Runoff Constituent	Swales	Infiltration Basins	SF Wetlands	SSF Wetlands	Detention/ Retention Ponds •	Sedimentation Ponds •
Suspended solids	**Filtering**	**Filtering** Settlement	**Filtering** Settlement	**Filtering**	**Settlement**	**Settlement**
Heavy metals (particulate and soluble)	**Filtering** Adsorption	**Filtering** Plant uptake Settlement Adsorption Precipitation	**Filtering** Settlement Adsorption Plant uptake	**Adsorption** **Filtering** Plant uptake	**Settlement** Adsorption	**Settlement** Plant uptake Adsorption Precipitation
Organic compounds (particulate and volatile)	**Filtering** Adsorption	**Filtering** Settlement Adsorption Biodegradation Volatilisation	**Filtering** Settlement Adsorption Biodegradation Volatilisation	**Adsorption** **Biodegradation** **Filtering**	**Settlement** Adsorption Biodegradation Volatilisation	**Settlement** **Adsorption** Biodegradation Volatilisation
Nutrients	Plant uptake	Plant uptake	**Plant uptake**	**Plant uptake**	Plant uptake	Plant uptake
Oil & grease (particulate)	**Filtering** Adsorption	**Filtering** Adsorption Settlement Biodegradation	**Filtering** Adsorption Settlement Biodegradation	**Filtering** **Adsorption** Biodegradation	**Settlement** Adsorption Biodegradation	Adsorption Settlement Biodegradation

Note: bold type indicates dominant processes

- see Chapter 2 for definitions of Ponds.

Expected Pollutant Removal Performance of Vegetated Systems

3.16 There is currently insufficient data to be able to ascribe precise treatment performances to vegetated systems under Irish conditions. The degree to which drainage systems and a combination of systems can reduce the pollution in routine runoff is illustrated in Table 3.2, which is taken from a study carried out by Moy F to determine treatment efficiencies of a range of systems. The table highlights the performance efficiencies of individual components of a drainage system as well as overall system efficiency for 5 sites in England. It will be noted that in some instances a negative efficiency was recorded within a discrete component of the system. This indicates the potential for pollutants to remobilize within component systems as a result of high velocity flows entering a system. Whilst the findings from this study are instructive the scope of the study was limited and the figures are given to indicate rather than prescribe the range of treatment efficiencies of certain systems.

Table 3.2: Indicative Treatment Efficiencies of Drainage Systems

Road	Site/Treatment Devices		% Reduction: Inlet to Outlet		
			Initial Form of Treatment	Second Form of Treatment	Total System Treatment
A34	Bypass oil separator/surface flow wetland/ retention pond	Metals	15	11	24
		PAHs	-1	99	99
		TSS	37	73	83
A34	Filter Drain	Metals	7		7
		PAHs	52		52
		TSS	38		38
M4	Oil trap manhole/Sedimentation Tank	Metals	-7	41	30
		PAHs	-30	-26	
		TSS	-19	43	33
M40	Full retention oil separator/ retention pond	Metals	19	35	48
		PAHs	13	50	57
		TSS	-9	62	58
A417	Bypass oil separator/ detention pond	Metals	27	39	56
		PAHs	4	16	22
		TSS	56	-37	40

3.17 Systems can therefore only be rated in relative terms and have therefore been classified as having low, moderate or good performance, roughly corresponding to removal efficiency categories of <30%, 30 - 60% and >60%. Because performance figures will depend on how efficiency is calculated and on the duration and intensity of the rainfall event considered, the performance guidelines in Table 3.3 apply to the relative removal from the runoff within vegetated systems that are designed for the control of runoff from rainfall events with short recurrence intervals (typically 6 months).

Table 3.3: Expected Pollutant Removal Performance of Vegetated Systems

Runoff Constituent	Swales	Infiltration Basins	SF Wetlands	SSF Wetlands **	Detention/ Retention Ponds	Sedimentation Ponds
Suspended solids and associated heavy metals	Good	Good	Good	Good	Moderate	Good
Heavy metals in solution*	Moderate-Good	Moderate-Good	Moderate-Good	Good	Poor	Poor-Moderate
Oil and grease	Good	Moderate-Good	Good	Good	Moderate	Moderate
Nutrients*	Poor	Poor	Moderate-Good	Good	Poor	Poor-Moderate

* in growing season

** very limited operational life due to rapid ‘clogging’ of wetland substratum

4. SELECTION OF VEGETATED DRAINAGE SYSTEMS

General

4.1 In considering how best to convey road runoff from the road surface, the Designer or Specifier must consider not only the requirement to ensure that water is removed as quickly as possible from the road surface, but also the effect on the local hydrology of the area and the threat of pollution to local waters. If, in designing systems to convey the runoff to the local watercourse, it is also possible to maintain or enhance the landscape or nature conservation value of the area, that will be an added benefit, but it should not be considered essential.

4.2 Opportunities for environmental benefits should be carefully considered at the beginning of the design process and the NRA Environmental Assessment and Construction Guidelines shall be applied. A review of the planning context shall be carried out to establish the presence of any international, national or local designations within, adjacent to or in the vicinity of the proposed site area. Consultation with National Parks and Wildlife Service (NPWS), Inland Fisheries Ireland (IFI), the Environmental Protection Agency (EPA), the Office of Public Works (OPW) and the local authority should be carried out. The review will indicate the relative importance of the landscape and ecology of the area, and whether it is likely that environmental mitigation will be a significant part of a road scheme. In such circumstances, vegetated systems may be particularly appropriate and the acquisition of any additional land required for them may be justified on account of the benefits they can bring. Ease of access for maintenance of the systems should also be considered early in the design process.

4.3 A detailed landscape assessment, combined with a hydrological study and an ecological survey, should be used to influence the nature, scale and location of a vegetated drainage system. This will help to secure a well-integrated system within its site context; protecting existing landscape features (natural/man-made) wherever desirable, and reflecting the character of the surrounding landscape.

Road Runoff

4.4 Designers or Specifiers shall carry out an assessment of the road runoff to be discharged in accordance with NRA HD 45. Factors that can affect its water quality include:

a) the amount of traffic, and proportion of HGVs;

b) the area of road surface drained to one outfall; and

c) the deposition from surrounding land and atmospheric sources.

The quality of runoff in urban areas has been shown to be markedly different from that in rural areas. This appears mainly due to the debris on urban roads (including oil and fuel from parked vehicles) which is washed into the drains. Air quality has also been identified as a contributing factor in the urban context.

The intensity of runoff will be affected by the climate. When intense rainfall events follow long dry periods, the build-up of pollutants on the road surface is washed off first, and the runoff from the first 10mm of rainfall is often the most seriously polluted. This is sometimes referred to as the ‘first flush’ effect of a storm. For this reason, discharges from short intense storms with long antecedent dry periods are generally more likely to pose a pollution threat than discharges from longer rainfall events which provide higher dilution.

4.5 Systems should normally be designed to treat all the water in a rainfall event but, where this is not possible, Designers or Specifiers should attempt to treat this first 10mm separately, for by so doing they will be likely to be dealing with the most polluted flow. In such situations it will be important to ensure that the time taken for the runoff to reach the outfall from the furthest point (the time of concentration) is similar for all drain runs entering any one outfall. If any one run is much longer, it will continue to discharge the more polluted ‘first flush’ for longer and separate treatment will not be readily achievable. Similarly practical limitations, such as land availability, may mean that, whilst a system can be designed to provide storage for the design event, its treatment efficiency will reduce during extreme events. In these circumstances pollutant concentrations are likely to be reduced because of the high volume of runoff related to the antecedent pollution build-up, and because dilution of the attenuated flow will be high.

4.6 Loadings of heavy metals and organic compounds (especially aromatic hydrocarbons) and sometimes suspended solids, tend to be of greater concern than loadings of nutrients and Biochemical Oxygen Demand (BOD). A high proportion of these pollutants are found to be adsorbed to the fine silt fraction of the suspended solids. By collecting, filtering and treating the fine sediment which is subsequently removed, the system will be dealing with a significant part of the runoff pollution.

Receiving Waters

4.7 Having established the likely quality and quantity of the runoff from the road, the Designer or Specifier will have to consider the characteristics of the receiving waters. These will be surface watercourses or groundwater or both. Exceptionally, they may be tidal waters.

4.8 The factors affecting the likely pollutant impact of road runoff on surface watercourses are their quality and flow. A discussion of river quality is given in NRA HD 45. The river flow determines the available dilution to the runoff. The greatest risk of pollution is in the summer, not only because of the ‘first flush’ phenomenon, but also because the river flows are then at their lowest. A generally accepted standard for measuring dry weather flows is the river flow which is exceeded for 95% of the time – this is known as the 95 percentile flow, and data on many rivers can be obtained from the EPA.

4.9 There is little evidence available to date that groundwaters have been adversely affected by road runoff, but the consequences of any pollution incident could be severe as remedial measures will be very difficult to achieve. A precautionary approach should therefore be adopted when designing systems to protect discharges to ground.

Other Factors Affecting Selection of Systems

4.10 Once the Designer or Specifier has established the design parameters for the road runoff and the characteristics of the receiving waters, the required level of treatment of the runoff, if any, can be determined, as well as the degree of attenuation required to avoid an effect on the local hydrology. In deciding what systems to select in a drainage design, the other factors may be considered in turn as described below.

The Availability of Land

4.11 This is probably the most significant factor affecting the choice of systems. For new road schemes, a suitably advanced level of drainage design is required before decisions on land acquisition are made. In certain situations, it may be necessary to consider the acquisition of additional land to achieve a better scheme in landscape, visual and ecological terms. Such a decision would be based on a review of the considerations described at the beginning of this chapter. This land may need to be acquired, or rights of access obtained for maintenance, which could impose their own constraints on the landscape.

4.12 Where land availability is limited, as for improvement schemes, vegetated systems may have to be designed to fit into the road corridor, using land within interchanges where this is suitably located. Even for these schemes, however, the possibility of acquiring extra land should always be considered where it is necessary to achieve a good standard of design. By making landowners aware of the powers available to construct road drainage, it may often be possible to obtain the necessary land by agreement. Installation of infiltration trenches and long linear ponds may be feasible if designed sympathetically. If existing ponds are available, it may be possible for these to be adapted, provided that their use for treatment is ecologically acceptable. Where land is further restricted, as it will commonly be in urban contexts, restriction of treatment to the ‘first flush’ (see paragraph 4.5) may be necessary in order to reduce the volumes to be stored and treated, and to maximise the benefit from the use of vegetated systems. The designs shown in this Standard represent an ideal to be aimed at: in restricted sites it will usually be better to design a compromise solution than not to design any vegetated system. NRA HD 33 gives guidance on how conventional drainage systems, which usually occupy less space than vegetated ones, can be designed to reduce pollution and flood risk. Guidance on the design of retro-fitted systems is given in Chapter 5.

The Climate and Rainfall Characteristics

4.13 These factors need to be considered along with the catchment area of road drained to each outfall. The climate will determine whether the area is likely to have long dry periods with occasional intense storms or whether it will have higher and more uniform rainfall. These factors, when considered with the local catchment hydrology, will enable the Designer or Specifier to determine the extent to which attenuation of the flow from particular outfalls is required. Attenuation can be achieved by large retention ponds, or infiltration basins, or by a series of smaller containment devices, possibly located in swales, and located at the top of the drainage system. The size of the pond or basin will be determined by the degree of attenuation required. Seasonal climatic and rainfall characteristics, including an allowance for climatic changes (as specified in NRA HD 33) and the availability of a base flow for irrigation, will also determine the appropriateness of selecting viable wetland vegetation. Where a base flow is used, its characteristics will have to be estimated and included in the determination of the size of retention facility.

Soil Permeability

4.14 For the purpose of selecting drainage systems, the Designer or Specifier needs to know the permeability of the natural subsoil and that used to create embankments. On permeable soils, swales, grassed channels and infiltration basins/trenches are potentially effective solutions, but consideration must be given to the percolation of water to ground and to the effects of the possible transmission of pollutants to the underlying subsoil, particularly in areas of existing contamination. The use of impermeable membranes may be necessary in some circumstances to prevent seepage to ground. They may also be necessary to maintain the quality of the treatment system. The assessment of groundwater pollution and protection requirements shall be carried out in accordance with NRA HD 45.

4.15 In areas of impermeable soils, swales will be less effective and wetlands and ponds will generally be more suitable. Retention ponds will tend to retain water, and infiltration basins/trenches will have to be constructed above the impermeable soil, using suitable granular materials.

4.16 Soils are also important in determining the stability of a vegetated system. In general, soils with a gravel, sand and clay mixture may be considered to be erosion resistant, while fine sands and silts are susceptible to erosion. Soil type thus affects the design of the system, particularly for swales and grassed channels or ditches which experience greater flows than ponds and basins etc. Velocities must either be low enough to prevent erosion, or the system must be augmented by rip-rap, sheet spreaders and concrete aprons to reduce input velocities and prevent scour.

4.17 Although the Designer or Specifier will primarily be concerned with road runoff, there may be other watercourses affected by the road design, and groundwater levels may be close to the surface. In such situations it may be possible to use such water flows, which will probably be far less intermittent than road runoff, to provide water to wetland and pond systems to prevent them drying out.

Topography

4.18 The nature of the surrounding topography should have an influence on the choice of systems, to enable the design to be well integrated within its landscape setting. In flat areas with little or no gradients, larger systems such as wetlands or ponds may be appropriate, if suitably designed and planted, and sufficient water is available to prevent drying out. It may be possible to increase the number of outfalls, to reduce the risk of spillage at any one outfall, and design smaller features. In undulating countryside, treatment and attenuation systems will probably have to be smaller (and more frequent) to blend into the landscape. Use of ponds and infiltration basins will be possible, but swales, which require gentle, even slopes, are likely to be harder to design sympathetically. Figures 4.1 and 4.2 show indicative sections of these systems in undulating and flat landscapes.

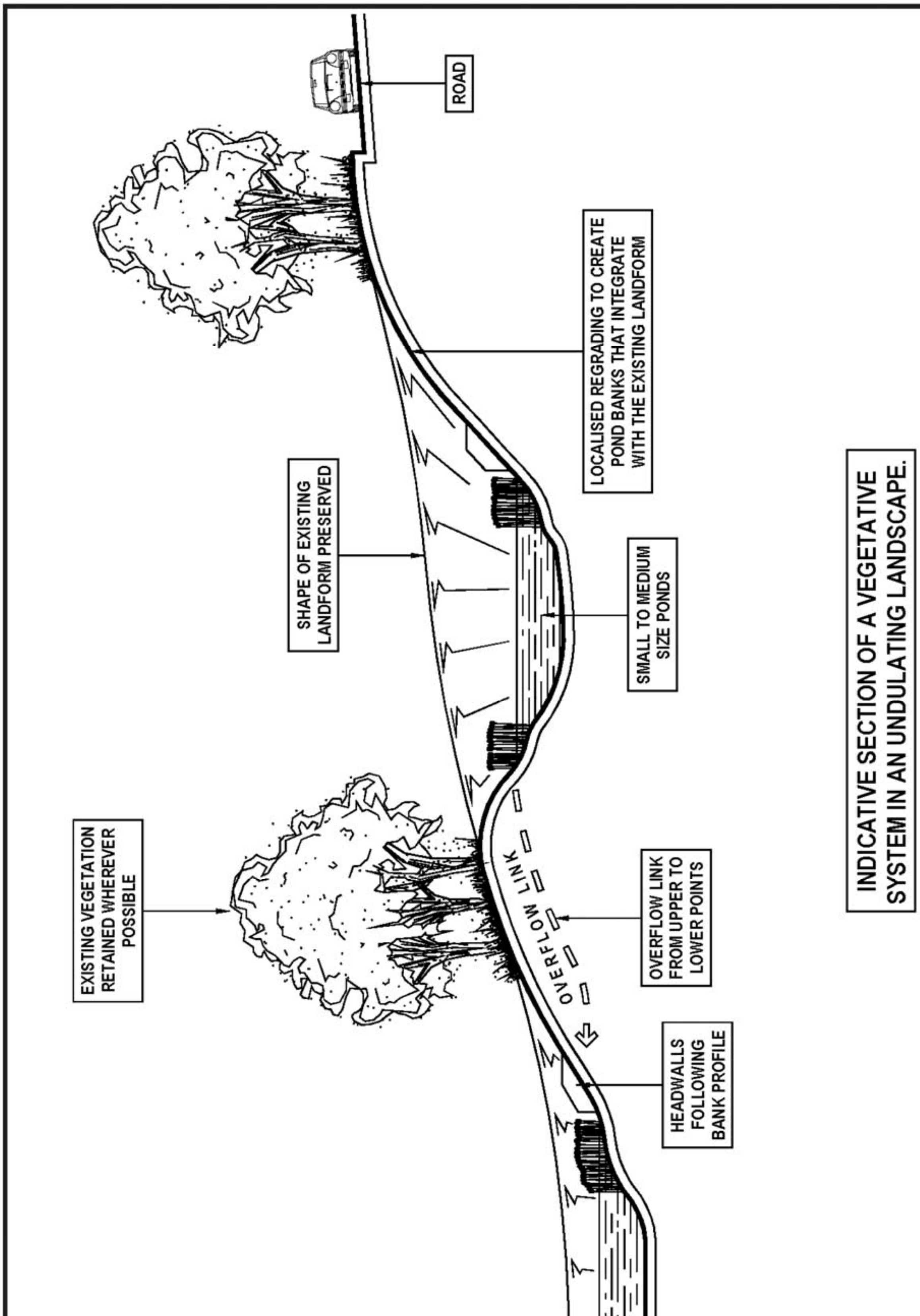
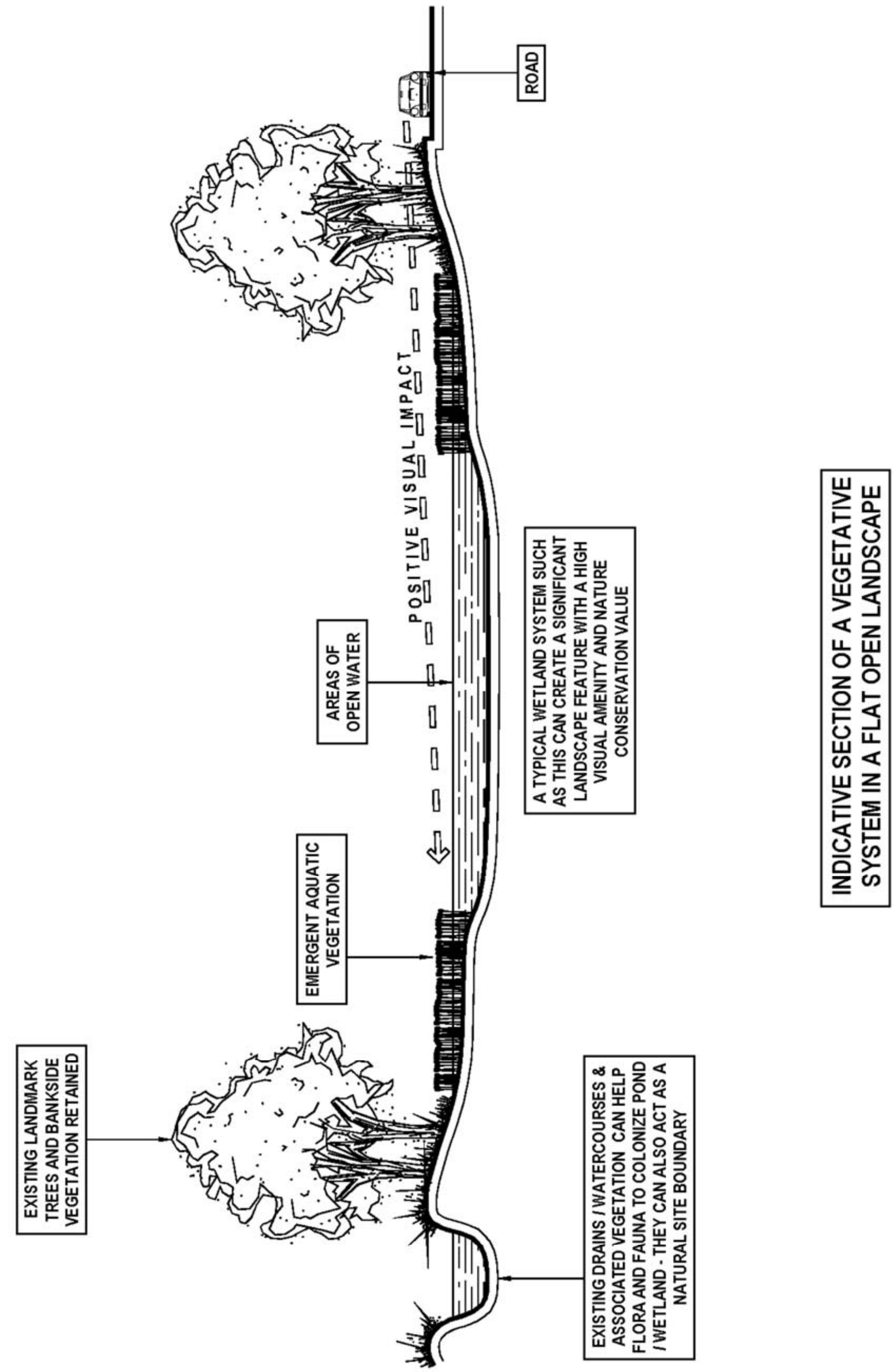

ROAD
LOCALISED REGRADING TO CREATE POND BANKS THAT INTEGRATE WITH THE EXISTING LANDFORM
SHAPE OF EXISTING LANDFORM PRESERVED
SMALL TO MEDIUM SIZE PONDS
EXISTING VEGETATION RETAINED WHEREVER POSSIBLE
OVERFLOW LINK
OVERFLOW LINK FROM UPPER TO LOWER POINTS
HEADWALLS FOLLOWING BANK PROFILE
INDICATIVE SECTION OF A VEGETATIVE SYSTEM IN AN UNDULATING LANDSCAPE.

Figure 4.1



ROAD
POSITIVE VISUAL IMPACT
AREAS OF OPEN WATER
EMERGENT AQUATIC VEGETATION
EXISTING LANDMARK TREES AND BANKSIDE VEGETATION RETAINED
A TYPICAL WETLAND SYSTEM SUCH AS THIS CAN CREATE A SIGNIFICANT LANDSCAPE FEATURE WITH A HIGH VISUAL AMENITY AND NATURE CONSERVATION VALUE
EXISTING DRAINS / WATERCOURSES & ASSOCIATED VEGETATION CAN HELP FLORA AND FAUNA TO COLONIZE POND / WETLAND - THEY CAN ALSO ACT AS A NATURAL SITE BOUNDARY
INDICATIVE SECTION OF A VEGETATIVE SYSTEM IN A FLAT OPEN LANDSCAPE

Figure 4.2

Spillage Risk

4.19 When selecting drainage systems to reduce the risk of pollution to downstream watercourses, the risk of accidental spillage must also be considered. A method is given in NRA HD 45 for estimating the probability of pollution occurring from a major spillage event. The need for spillage containment and control facilities shall be determined in accordance with the guidance given in NRA HD 45. Systems should be designed and adapted to include these measures and should usually include a method to control the discharge of any spillage at the outfall, regardless of whether designated containment provision is made. Means of control should be simple to find, readily accessible from the road and capable of being operated easily and quickly by the emergency services.

4.20 In some cases the vegetated drainage system may be used for containment but, where reinstatement would be difficult and costly, the system will have to be protected. Swales, for example, could have check dams and detention or retention ponds could have penstocks, flap valves or outlets designed to be blocked with sand bags. Wetlands could be fitted with an inlet control device to be closed in the event of spillage, or be sited downstream of a dry containment area. Infiltration basins will have to be designed downstream of a suitable containment system to collect any spillage: the main problem in this case is to ensure that clean-up of any spillages does not impair the basin’s effectiveness.

4.21 The system chosen for control of the spillage at any location should be appropriate to its estimated probability. Where this is assessed at less than 1% annually for a major spillage, methods such as check dams, booms or notch weirs will be more suitable than mechanical devices such as penstocks or gate valves, which are more susceptible to vandalism and may become ineffective through lack of use. The consequence of any spillage will determine the importance to be attached to providing some form of spillage control. In particularly sensitive areas that include designated sites, there should be some form of containment prior to the outfall, no matter how low the probability. It only takes one incident to cause considerable damage. The lower the probability of a spillage, the more appropriate it will be to design a low cost containment solution that needs little or no maintenance. Examples include dry ditches, small bermed areas or simple oil traps. Spillage risk assessment and associated requirements are outlined in NRA HD 45.

Summary

4.22 Whilst it can be seen that there are many factors which can influence the choice of vegetated systems for use in drainage systems, only certain drainage systems may be appropriate in some locations. It is, however, likely that at any one site there will be more than one solution. Also in some circumstances where flood control and spillage containment is required, more than one system may be necessary. It is therefore important for Designers or Specifiers to consider as many relevant factors as possible before deciding on a suitable drainage design.

5. THE DESIGN AND CONSTRUCTION OF VEGETATED DRAINAGE SYSTEMS

General

5.1 Attention to detail in the design and construction of vegetated systems is very important, if the benefits of water treatment and attenuation are to be fully utilised, and higher levels of overall integration with the surrounding landscape are to be achieved. The guidance below makes suggestions for good design principles, and indicates where possible problems may occur. Further details on the design and construction of these systems can be found in the referred texts in Chapter 7.

5.2 Prior to the commencement of any design, a detailed survey of the site and the adjoining area should be carried out. This would provide baseline information on the presence and nature of existing landscape features/habitats/species. Wherever possible, such information should influence the type, location and scale of vegetated drainage systems and planting to be used. All access points, including those for maintenance, should be sensitively located to fit with the flow and pattern of the surrounding landscape. Alternative surface treatments for access roads should also be considered to minimise their visual impact. The layout and surface treatment should be designed to accommodate the size and weight of the relevant maintenance plant.

5.3 Stability of the vegetated systems is paramount. As treatment depends on the integrity of the whole system, should any part of the system fail then significant reductions in performance will occur. Stability is often related to the storm events for which the systems are designed. When designing a vegetated system to cater for a particular storm event, the probability of that event should be half that used for hydraulic design, as specified in NRA HD 33. This will give an adequate factor of safety against failure of an individual system. As the most important treatment processes are settlement and filtering, a basic requirement of the design of a system is to slow and spread the flow, to encourage these processes. The hydraulic characteristics of a system will therefore be critical to its effectiveness.

Ground and Structural Stability

5.4 Designers and Specifiers must also ensure that the design of vegetated systems does not in any way prejudice the stability of embankments, cuttings or other road structures, by requiring that the systems contain the water flowing through them, and by not allowing leakage from the systems to destabilise such structures.

Soils

5.5 Central to the aims of establishing and supporting vegetated systems are the careful handling, storage and use of available soil materials on site. Special care should be taken during the excavation and placement of soil materials, to prevent damage to the soil structure and compaction of the topsoil and subsoil. Careful planning of the site works should therefore consider the timing of operations, location of storage areas and access routes. Where possible, soil materials on site should be fully utilised and a proposed scheme designed with the prevailing site conditions in mind, thereby obviating the need to import materials.

Swales

5.6 Swales are most effective in treating water when the speed of the water flow is slow. In most rainfall events this will occur naturally, but the more intense storms may lead to situations where the previously accumulated suspended solids are washed downstream. Swales should, therefore, be designed for a 5 year 24 hour event, and checked against a 10 year event. The channel velocity should not exceed 0.25m/sec, with the longitudinal slope being ideally less than 2% and no more than 6%. The flow speed should be less if the swale length is less than 120m, as an 8 - 10 minute residence time is ideal for maximum effectiveness. After 10 minutes, removal efficiency is expected to level off. Residence time is best extended by increasing flow width and length. Decreasing slope or increasing the density of vegetation would also increase the residence time but would result in greater depths due to increased impedance.

5.7 Swales should be designed without any abrupt changes in vertical or horizontal direction, so that the risk of erosion is reduced. This will also make them more attractive features and easier to maintain. Swales are best located as close to the road as possible, where flow rates are slowest. They are well suited to areas where drainage from the road flows over the edge. As it is hard to channel water from a piped flow to a swale without the risk of rivulets or channels occurring, a flow spreader, similar to that shown in Figure 5.1 should be used.

5.8 Stability of the channel is of the utmost importance and should be the primary concern in the design process. If the channel should form rivulets, the effectiveness of the swale in treating the water will be greatly reduced. A smooth sheet flow is ideal. Any design changes to improve pollutant removal (e.g. wider or longer channels) will also aid stability. Rip-rap, concrete aprons and spreaders should all be considered, particularly at the outfall of the swale to achieve an even flow of low velocity and minimise the possibility of scour. Swales work best at encouraging settlement if there is a small vertical component to the flow, caused by infiltration, and are therefore most effective if constructed in areas where the underlying material is permeable and discharge to ground can be permitted. However they must be designed to minimise the risk of water penetrating the carriageway subgrade and Designers or Specifiers must satisfy themselves that the swale will not promote slippage of the road embankment.

5.9 In certain conditions, the design of swales may obviate the requirement for a system of gullies and piped drainage with the swale discharging to a suitable collection point. They should be considered in all cases as they represent a cost effective control measure which, even if insufficient for all the treatment requirements in themselves, may provide significant primary treatment prior to secondary systems such as ponds or wetlands. Their potential for significant trapping of suspended solids may extend the periods between major maintenance for those downstream systems.

Spillage Containment

5.10 Installation of check dams will not only slow the flows but will also act as a form of automatic spillage containment for the less serious accidental spillages. Other possible controls include locations that can be blocked by sandbags, and outlets designed to retain flows. The anti-scour details mentioned in paragraph 5.7 could include a V-notch weir designed to contain the early flow and minor spillages. Although the gradient of most swales will make them unsuitable to be used to contain major spillages, it may be possible to design the lowest part of the swale with a shallower gradient and surrounded by a berm. The outlet could be a notched weir. Care will be needed in these cases to ensure that any spilt liquid cannot percolate to groundwaters, and an impermeable liner may be needed.

Integration into the landscape

5.11 Swales should be carefully integrated into the general landscape of the road, incorporating existing and proposed landscape elements such as trees or hedges as appropriate. It may be possible to design them within an interchange, or even to amend the road alignment, so that the water from the carriageway flows in swales. The optimum gradient for channel slopes is similar to that of slip roads.

Planting

5.12 The growth characteristics of the grass species are important to the effectiveness of the swales in retaining suspended solids. A dense and even sward is required consisting of species with a combination of rapid establishment and recovery, some salt tolerance and tolerance of wet conditions and periodic inundation. Species to consider are perennial ryegrass (*Lolium perenne*) and creeping bent (*Agrostis stolonifera*). Where salt tolerance is a particular requirement, salt tolerant cultivars of fescue species (*Festuca* spp.) are available. Rush species (e.g. *Juncus* spp.) should also be considered. Vegetation height should be approximately twice the depth of water to be treated and ideally 100-200mm. Shorter vegetation will not treat greater flows and taller vegetation will have a tendency to be flattened. Seeding to establish vegetation should be uniform and carried out early in the construction process as soon as soils are ready, and in the appropriate season - ideally late summer (August/September). Where quick establishment is required, turf laying would be appropriate to prevent the creation of rills, although this is more expensive than conventional seeding. Geotextiles may be employed to prevent erosion in early stages or as temporary measures in advance of seeding, but should not be relied on in the long term as they will degrade.

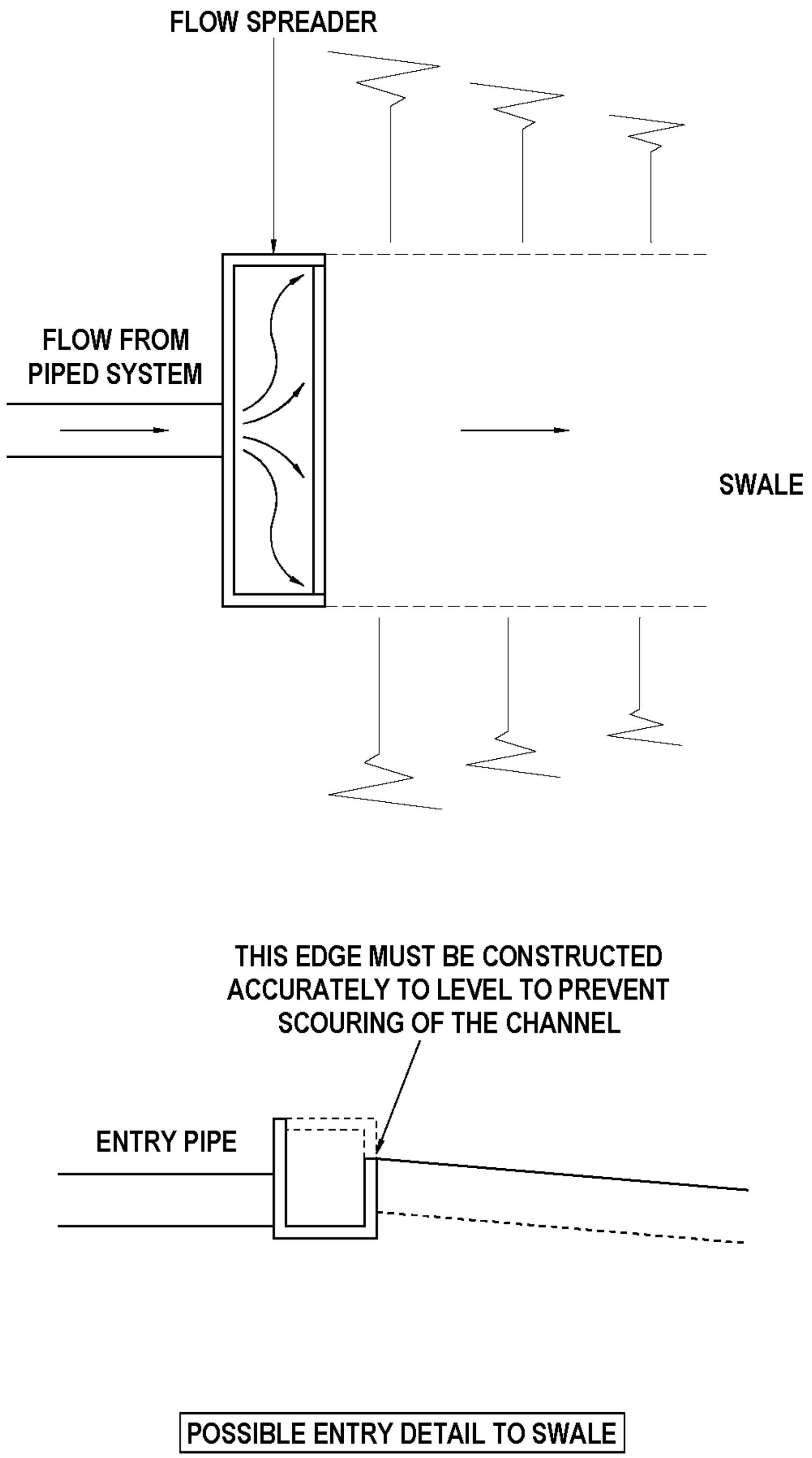

FLOW SPREADER
FLOW FROM
PIPED SYSTEM
SWALE
THIS EDGE MUST BE CONSTRUCTED
ACCURATELY TO LEVEL TO PREVENT
SCOURING OF THE CHANNEL
ENTRY PIPE
POSSIBLE ENTRY DETAIL TO SWALE

Figure 5.1

Infiltration Basins

5.13 The size of the infiltration basin will be determined by the catchment area. The basin should be big enough to accept the first 10mm of a storm, the ‘first flush’ as described in paragraph 4.5, without overtopping. The total catchment to any one basin should ideally be between two and ten hectares, with a narrow trench-like infiltration basin being used for smaller catchments. The basin must have a level base, and be located sufficiently far above the groundwater level (at least 1.5m) to ensure that the filter layer is not saturated and that water percolates through at a reasonable speed. The basin should empty within 72 hours. It should be noted that such basins may act as sources of pollutants rather than sinks if subsequent storms cause scouring of suspended solids, which are then released by overtopping to the receiving waters. It may be better to isolate the first flush in a smaller basin and use a second basin for attenuation if required.

5.14 The filter layer should consist of a free draining granular material, in accordance with Series 600 of the NRA Specification for Road Works (NRA SRW), to permit dispersal. There should be a 10 - 15% sand fraction to ensure that treatment of the water is effective. Geotextiles should be used to prevent contamination of the filter layer from either the subgrade or topsoil. The design should allow for occasional removal and replacement of the filter material. This could either be at predetermined major maintenance intervals or following an accidental spillage.

Spillage Containment

5.15 Infiltration basins and trenches are vulnerable to damage resulting from major accidental spillages. If the risk of spillage is sufficiently high to warrant the provision of containment it is best to choose another system. If that is not possible, it is preferable to use two basins as described in paragraph 5.13 above with a control system to divert the spillage into the second basin, or else to protect the infiltration basin by using a separate containment area. Filter layers can be replaced if damaged, but the operation may not always be straightforward and, if not carried out promptly, there is the risk of pollution from the spilled substance being washed out of the filter medium.

Integration into the landscape

5.16 The shape of the basin will be determined by prevailing environmental considerations, with the aim being to fit the basin into the surrounding landscape to achieve the most natural appearance. The slopes and shape of the basin should reflect those that occur locally. Where it is considered that the basins may become unattractive elements in the landscape, carefully designed low mounds, combined with planting could provide screening for passing motorists. Where possible, local materials should be used for engineering features and boundary treatments.

Planting

5.17 Vegetation types for basins, where standing water is likely for only a short duration, can be creeping bent and rush species, the same as for swales (see paragraph 5.12). Where standing water occurs for longer periods (days) wetland species such as common reed (*Phragmites australis*), reed canary grass (*Phalaris arundinacea*) and amphibious bistort (*Persicaria amphibia*) should be considered. The inlet should be designed to prevent scouring of the basin. Rip rap or flow spreaders should be included if necessary.

Sub-Surface Flow Wetlands

5.18 As stated in paragraph 2.12 above, SSF Wetlands will rarely be suitable for use in road drainage systems. Where, exceptionally, they are considered suitable, guidance on their design and construction can be found in various sources (refs. 7.6, 7.19, 7.20).

Surface Flow Wetlands

5.19 SF Wetlands are ideally located on gently sloping ground of about 0.5%, but can be on level ground or ground sloping to 1%. The required area will depend on the area drained and the level of treatment required. As a guide, they should at least be designed to treat the first 10mm of runoff without overtopping. They should be surrounded by berms with slopes of 20% or less, which are at least 0.5m above the permanent water level. The depth of water should be between 0.15 and 0.3m, and a variation in depth, as shown in Figure 2.3, will assist in creating a range of habitats to improve treatment potential. The existing sub-grade may be used for the base, but if groundwaters need protection, a liner as described in paragraph 5.40 may be needed. The inlet should be designed to produce an even flow to minimise the risk of scour: a flow spreader, similar to that in Figure 5.1 may assist, as may the use of stone pitching to stabilise the entry channel. The outlet could be a weir, or high level pipe to maintain the required water level, and to help prevent the drying out of the system. Where groundwater levels are high it may be possible to utilise ground water flows to keep the wetland moist, provided that arrangements for introducing the groundwater prevent any possibility of contamination of the aquifer by pollutants from the wetland. Ideally the wetland should be designed to overtop only exceptionally, but if this is not possible, a bypass may be needed to take flows in excess of the first 10mm stipulated above.

Spillage Containment

5.20 A SF Wetland, designed as a shallow basin, can act as an effective spillage containment facility. Outfalls will need to be designed so that spills can be contained, either mechanically, by a penstock or similar, or by emergency personnel using sandbags or booms to block a suitable channel. Although the wetland may need to be thoroughly renovated following a serious spillage, this is considered acceptable for events where the estimated probability is less than, say, 1% annually, or where the wetland is used as the second system where dual containment has to be provided. For higher probability events, the Designer or Specifier should weigh the cost of providing separate containment against the cost of renovating the wetland following a spillage, also taking into account the value and vulnerability of the receiving waters.

Integration into the Landscape

5.21 The shape and layout of SF wetlands should aim to reflect the overall pattern and scale of the surrounding landscape. Geometric shapes and steep uniform banks should be avoided where possible with side slopes generally being no steeper than 1 in 3. Smoothly flowing shapes that fit with the flow of the landform can create more natural and attractive features. Where possible, local materials should be used for engineering features and boundary treatments.

Planting

5.22 A range of vegetation is appropriate to this type of wetland and selection depends on the depth of water cover and its periodicity. For permanently full or partly inundated wetlands, reed mace (*Typha latifolia*), branched bur-reed (*Sparganium erectum*), pond weeds (*Potamogeton spp.*) and flote-grass (*Glyceria fluitans*) are appropriate. In seasonally wet parts common reed, reed canary grass and amphibious bistort are appropriate. In drier parts rush species should be considered. Establishment of aquatic and emergent species should be from planted rhizome/root stock in the spring. The grass and rush component can be sown, ideally in late summer. The extent of planting should be designed so there is vegetation across the entire flow path. Detailed planting specifications shall be developed at an early stage during the project and shall specify appropriate and sufficient plant maturity and density requirements. In hybrid systems, vegetation may be planted in strips, as shown in Figure 2.5, but this would not be appropriate in areas where there is a permanent water body. As a guide to the sizing of wetlands in relation to metal removal (particularly copper and zinc), the following removal rates, based on various studies (refs. 7.14, 7.15), could be used:

Removal of metals: gm/day/m^2	Vegetated Systems
Total Zinc	0.04
Soluble Copper	0.05

These can be used to estimate the minimum size of reed beds in wetlands where there is a reliance on vegetation related removal. This can be determined in conjunction with the detailed assessment method in NRA HD 45 as well as to assess the notional mitigation effect of the wetland on the water quality of the receiving water course. The following worked example shows how this can be done.

Worked Example

A wetland is to be designed to treat runoff from 20,000 m^2 of a road with AADT > 30,000.
From Table B.1 in NRA HD 45 Annex I, Method B, the build-up rate for total zinc is 5 kg / ha / yr.
This equals 5 x 2 x 1000 / 365 = 27.4 gm / day.
Required area of planting in wetland to remove zinc = 27.4 / 0.04 = 685 m^2.
From Table 3.1 in NRA HD 45 Annex I, Method B, the build-up rate for soluble copper is 1.2 kg / ha / yr. This equals 1.2 x 2 x 1000 / 365 = 6.6 gm / day.
Required area of planting in wetland to remove copper = 6.6 / 0.05 = 132 m^2.
The greater area is required to remove zinc, so area of planted wetland should be at least 685 m^2.

Retention Ponds

5.23 Retention Ponds are primarily designed to attenuate storm flows from the road, so that downstream watercourses are not exposed to damaging flows that can cause erosive or flooding damage. In designing ponds to attenuate flows, consideration must be given to the hydrological characteristics of the local catchment area. Generally, the peak runoff rate from a proposed development should not be increased above the peak greenfield runoff rate for all storm events up to and including the 1 in 100 year storm event. The retention pond is one such device that should be utilised to assist in adhering to this requirement. Refer to www.opw.ie/en/floodriskmanagement/ and www.opw.ie/en/fsu/ for information on catchment characteristics, flood flows, extreme rainfall depths, and other hydrological variables. Refer to www.floodmaps.ie and www.cfram.ie/pfra for information regarding flood risk. It is critical to avoid the risk of damage to habitats and species caused by the rapid discharge of runoff into sensitive receiving waters. Consultation with IFI, NPWS and the EPA should be carried out. The local authority should be consulted about both pond capacities and discharge rates at the design and environmental assessment (Phase 3 and 4 of the NRA Project Management Guidelines) phases. It is important that sufficient land is allocated to facilitate the retention pond. Maximum discharge rates may be stipulated as a condition of the consent needed for the construction of the outfall, provided that the requirement is reasonable, because such consents may not be unreasonably withheld. Control of the rate of discharge from a retention pond may be by means of a small diameter pipe, an orifice or a notched flow control device as shown in Figure 5.2. The section in Figure 2.4 shows how the outfall design can allow different discharge rates for storm events of various probabilities.

5.24 Although runoff treatment is a secondary function of retention ponds, Designers or Specifiers should take the opportunity to maximise the potential of the systems to treat runoff. By retaining storm water for a period, some treatment will be achieved by the settlement of suspended solids. The longer the residence time, the more effective will be the treatment as the smaller particles settle out last. The treatment of water may be made more effective by establishing vegetation (as described below) and designing the pond to allow a variety of plants to grow, ideally with a range of depths. Direct pathways or channels between the inlet and outlet should be avoided if possible. By retaining the runoff and only permitting a controlled discharge, the available dilution by the receiving waters will be greater than would occur without the pond. This will reduce the risk of pollution of those waters.

5.25 Retention ponds should be located within the road land so that maintenance can be fully controlled by the road authority. It may be possible to locate the pond within an interchange, or a linear pond may be necessary, running parallel to the road. Ponds can be designed to be either ‘wet’ Retention Ponds, holding water throughout the year, or ‘dry’ Detention Ponds, having a tendency to dry out in the summer months. This is most easily achieved by adjusting the invert level of the outflow pipe or channel. For wet ponds the outlet invert level should be at least 0.5 m above the pond surface, but for a dry pond it may be flush with, or less than 0.3m above, the pond level. It may be that even in a wet pond, shallower areas will dry out with a permanent body of water remaining in the deeper sections.

Spillage Containment

5.26 Retention ponds can act as effective forms of spillage containment if the outlet is designed so that the smaller flows typical of spillages and the “first flush” (see paragraph 4.5) are contained in the first instance. This could be achieved automatically by a siphon so that the outflow only operates when a certain water level is reached, or manually by a penstock. Where risk of spillage is not high (annual probabilities less than 1%), it may be more appropriate to use controls such as sandbags or a notched weir as shown in Figure 5.2. The design must allow easy access and straightforward use of the specified spillage control device. In emergencies, the quicker such devices can be used, the lower will be the risk of pollution. There is a risk that devices such as penstocks may be more susceptible to vandalism and they may deteriorate over time due to prolonged periods without use.

Integration into the Landscape

5.27 New pond landforms should aim to reflect the overall character shape and scale of the prevailing topography. They should generally aim to avoid geometric shapes with steep, uniform banks/margins. Curvilinear or indented shapes that ‘marry in’ smoothly with adjoining contours, tending to create more interesting and attractive features as illustrated in Figure 5.3.

5.28 Allowing margins to develop with vegetation where land meets water can create an area for wildlife. Where possible, side slopes to retention ponds should be in the range of 1:3 to 1:10, to allow for ease of maintenance as well as ensuring a safe environment. These side slopes should be top dressed with appropriate soil materials, as shown in Figure 5.4. Gently sloping shelves should be incorporated within ponds to provide appropriate conditions for emergent and marginal vegetation. For a given volume of storage, shallow pools are better than deep basins in terms of pollutant removal efficiency and within the land availability constraints the basin depth should be between 0.5m and 2m. For the deeper ponds, safety must be a design consideration, as discussed in paragraph 5.46.

Planting

5.29 Pond water levels are likely to vary considerably. Some ponds may be designed to become dry and others to retain some depth of water. In permanent wet parts of ponds up to 0.5m deep, flote-grass (*Glyceria fluitans*), branched bur-reed (*Sparganium erectum*), reed mace (*Typha latifolia*), common club-rush *(Schoenoplectus lacustris)* and common reed (*Phragmites australis*) are appropriate as a belt between 2 and 6m wide leaving an area of open water. In dry ponds or drier parts of ponds common reed (*Phragmites australis*), reed canary grass (*Phalaris arundinacea*) and amphibious bistort (*Persicaria amphibia*) are particularly appropriate where there are long or frequent periods of inundation. Where inundation is infrequent creeping bent and rush species may be more appropriate. Vegetation may also be planted close to the inlet to promote sedimentation. Rhizome cuttings of reed mace, common reed and bur-reed are recommended for establishment of these species. Detailed planting specifications shall be developed at an early stage during the project and shall specify appropriate and sufficient plant maturity and density requirements.

Sedimentation Ponds

5.30 The primary function of a Sedimentation Pond is to allow suspended solids to settle out of the runoff prior to its discharge into the receiving watercourse. By controlling the rate of discharge, the dilution by the receiving waters will be increased, thus reducing the pollution risk. Typically sedimentation ponds would be used where there is a high pollutant level and a high quality receiving surface watercourse or groundwater. For optimum performance the design of the pond needs to ensure a long slow flow path, providing a generous retention time, but avoiding stagnant areas. Long ponds, with the inlet at the opposite end from the outlet are ideal, as shown in Figure 5.5. The inlet should allow water to enter without scouring the pond surface, and the outlet should have a flow control device (which will mean the pond will also attenuate flows). This system is one where it may be appropriate for the 'first flush flows' (see paragraph 4.5) to be diverted, with the balance of the flow flowing to a separate treatment area (or diverted to the receiving watercourse). One way of doing this would be to use an inlet device as shown in Figure 5.6 to divert the flow away from the treatment pond once it is full. By doing this the required area of pond will be less, as it will only need to be sized to treat runoff from the first 10mm of rain. If it is possible to construct an outlet with variable control, as shown in Figure 2.4, the design should aim to detain the first inflows for the longest period and allow subsequent inflows (when the level of the pond is higher) to flow out at a quicker rate. That way runoff from most rainfall events will be detained for the maximum period.

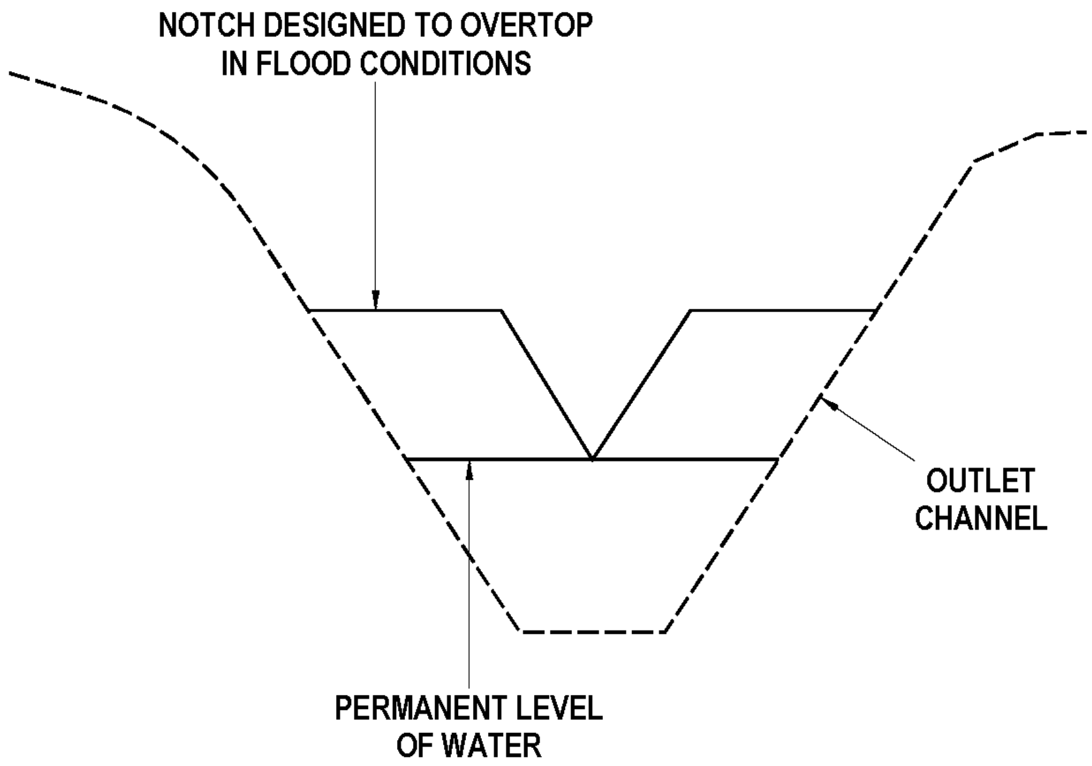
5.31 Stability of the system is essential to prevent bank erosion from overland flow and wave action. Banks slopes should be 1:3 or less. Short circuiting of the flow and increasing local flow speeds are other potential problems. Increasing pool length is an obvious way of increasing the flow path length but, if space is restricted, baffles close to inlet and outlets, islands and long or irregular shorelines are all ways of increasing the path length from inlet to outlet. Care must be taken not to cause the flow speed to increase in localised areas, as not only would this reduce the effectiveness of the system, it would also increase the risk that re-suspension of particles may occur during intense storms.

Spillage Containment

5.32 Sedimentation Ponds are well suited to containing accidental spillages in the same way as retention ponds if the outlet is designed so that, in all but very wet conditions, the spill will be retained until pumped out. The comments in paragraph 5.26 above will apply equally to sedimentation ponds.

Integration into the Landscape

5.33 Sedimentation ponds may be long and relatively narrow to increase the flow path. For this reason careful consideration needs to be given to their integration within the surrounding landscape. The shape and layout should aim to create a natural effect with a smoothly flowing outline reflecting the character of the area. Geometric shapes and steep uniform banks should be avoided with side slopes being no steeper than 1 in 3. Where possible, local materials should be used for engineering features and boundary treatments.



NOTCH WEIR OUTLET FROM BALANCING POND

Figure 5.2

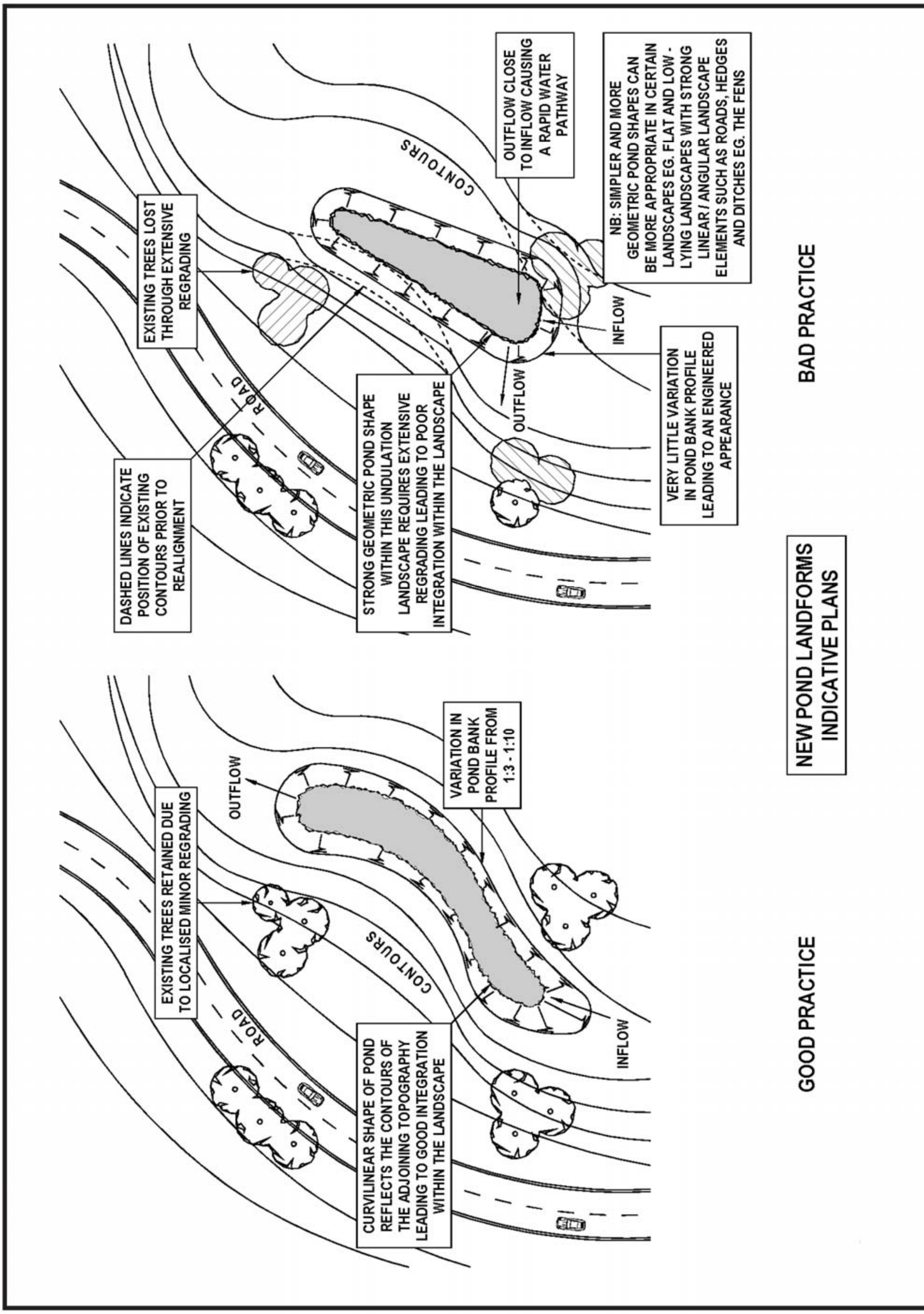

NEW POND LANDFORMS
INDICATIVE PLANS
GOOD PRACTICE
BAD PRACTICE
ROAD
CONTOURS
OUTFLOW
INFLOW
EXISTING TREES RETAINED DUE TO LOCALISED MINOR REGRADING
VARIATION IN POND BANK PROFILE FROM 1:3 - 1:10
CURVILINEAR SHAPE OF POND REFLECTS THE CONTOURS OF THE ADJOINING TOPOGRAPHY LEADING TO GOOD INTEGRATION WITHIN THE LANDSCAPE
DASHED LINES INDICATE POSITION OF EXISTING CONTOURS PRIOR TO REALIGNMENT
EXISTING TREES LOST THROUGH EXTENSIVE REGRADING
OUTFLOW CLOSE TO INFLOW CAUSING A RAPID WATER PATHWAY
NB: SIMPLER AND MORE GEOMETRIC POND SHAPES CAN BE MORE APPROPRIATE IN CERTAIN LANDSCAPES EG. FLAT AND LOW - LYING LANDSCAPES WITH STRONG LINEAR / ANGULAR LANDSCAPE ELEMENTS SUCH AS ROADS, HEDGES AND DITCHES EG. THE FENS
STRONG GEOMETRIC POND SHAPE WITHIN THIS UNDULATION LANDSCAPE REQUIRES EXTENSIVE REGRADING LEADING TO POOR INTEGRATION WITHIN THE LANDSCAPE
VERY LITTLE VARIATION IN POND BANK PROFILE LEADING TO AN ENGINEERED APPEARANCE

Figure 5.3

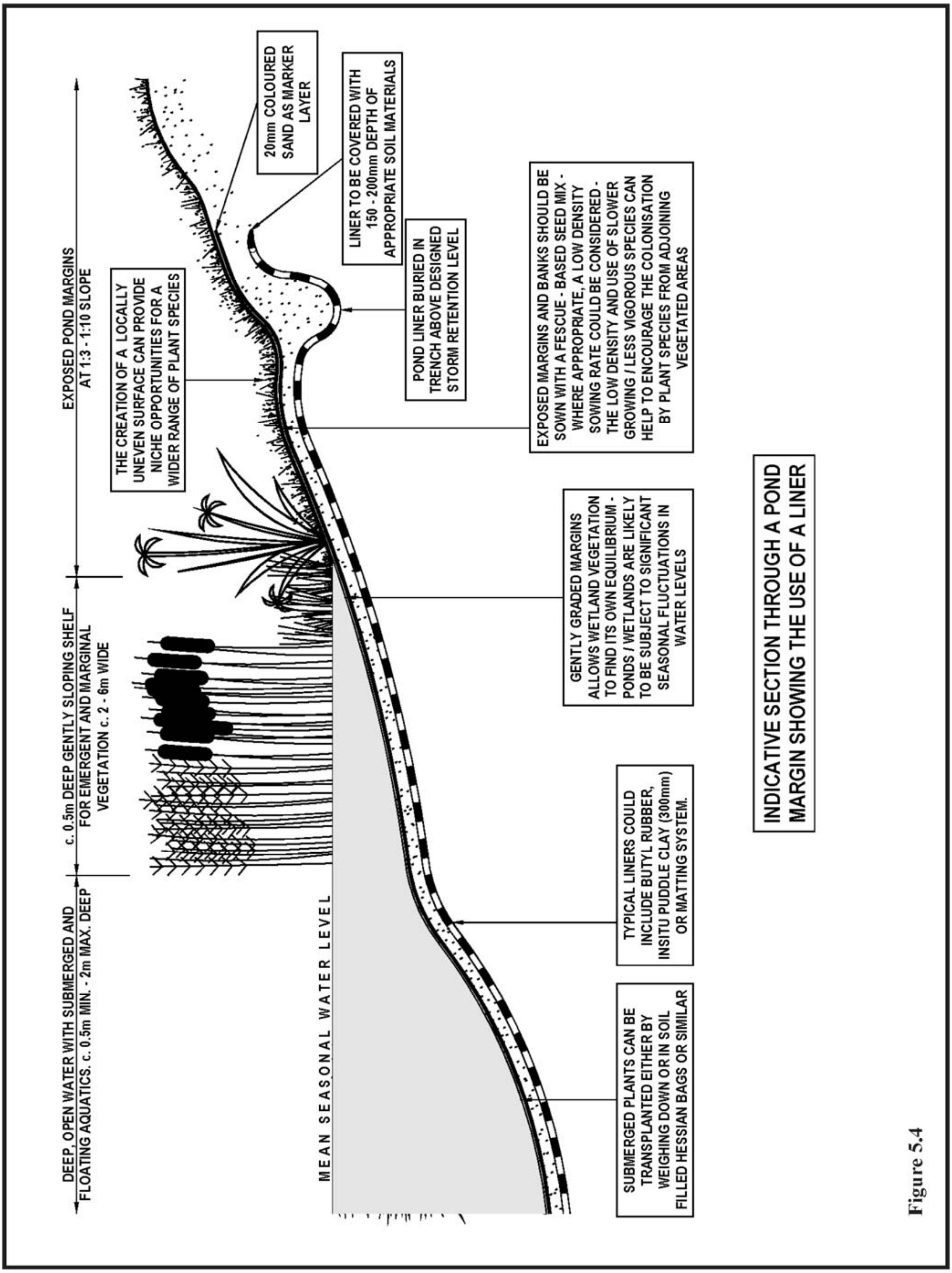

DEEP, OPEN WATER WITH SUBMERGED AND FLOATING AQUATICS. c. 0.5m MIN. - 2m MAX. DEEP
c. 0.5m DEEP GENTLY SLOPING SHELF FOR EMERGENT AND MARGINAL VEGETATION c. 2 - 6m WIDE
EXPOSED POND MARGINS AT 1:3 - 1:10 SLOPE
20mm COLOURED SAND AS MARKER LAYER
LINER TO BE COVERED WITH 150 - 200mm DEPTH OF APPROPRIATE SOIL MATERIALS
THE CREATION OF A LOCALLY UNEVEN SURFACE CAN PROVIDE NICHE OPPORTUNITIES FOR A WIDER RANGE OF PLANT SPECIES
POND LINER BURIED IN TRENCH ABOVE DESIGNED STORM RETENTION LEVEL
EXPOSED MARGINS AND BANKS SHOULD BE SOWN WITH A FESCUE - BASED SEED MIX - WHERE APPROPRIATE, A LOW DENSITY SOWING RATE COULD BE CONSIDERED - THE LOW DENSITY AND USE OF SLOWER GROWING / LESS VIGOROUS SPECIES CAN HELP TO ENCOURAGE THE COLONISATION BY PLANT SPECIES FROM ADJOINING VEGETATED AREAS
MEAN SEASONAL WATER LEVEL
GENTLY GRADED MARGINS ALLOWS WETLAND VEGETATION TO FIND ITS OWN EQUILIBRIUM - PONDS / WETLANDS ARE LIKELY TO BE SUBJECT TO SIGNIFICANT SEASONAL FLUCTUATIONS IN WATER LEVELS
TYPICAL LINERS COULD INCLUDE BUTYL RUBBER, INSITU PUDDLE CLAY (300mm) OR MATTING SYSTEM.
SUBMERGED PLANTS CAN BE TRANSPLANTED EITHER BY WEIGHING DOWN OR IN SOIL FILLED HESSIAN BAGS OR SIMILAR
INDICATIVE SECTION THROUGH A POND MARGIN SHOWING THE USE OF A LINER

Figure 5.4

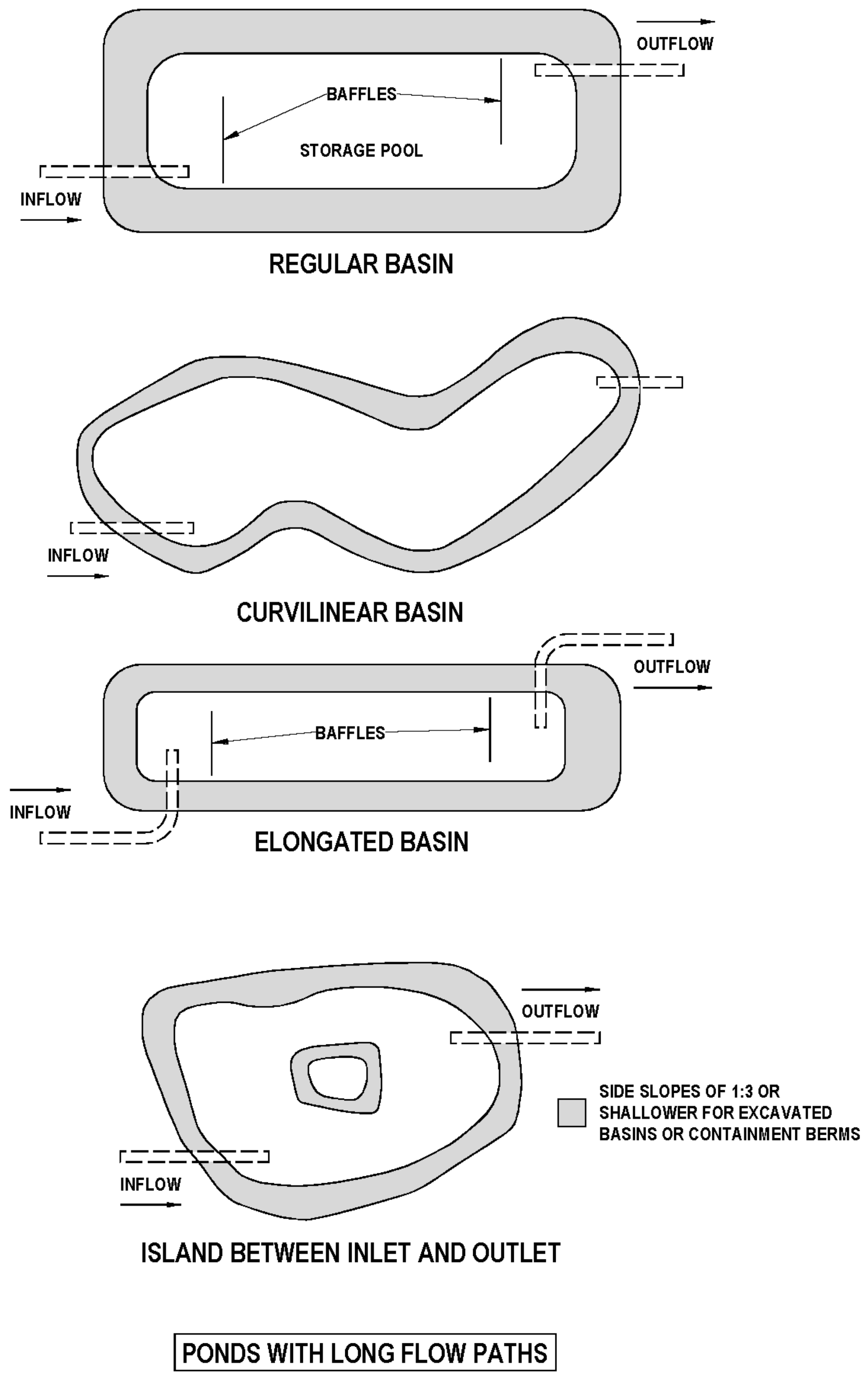
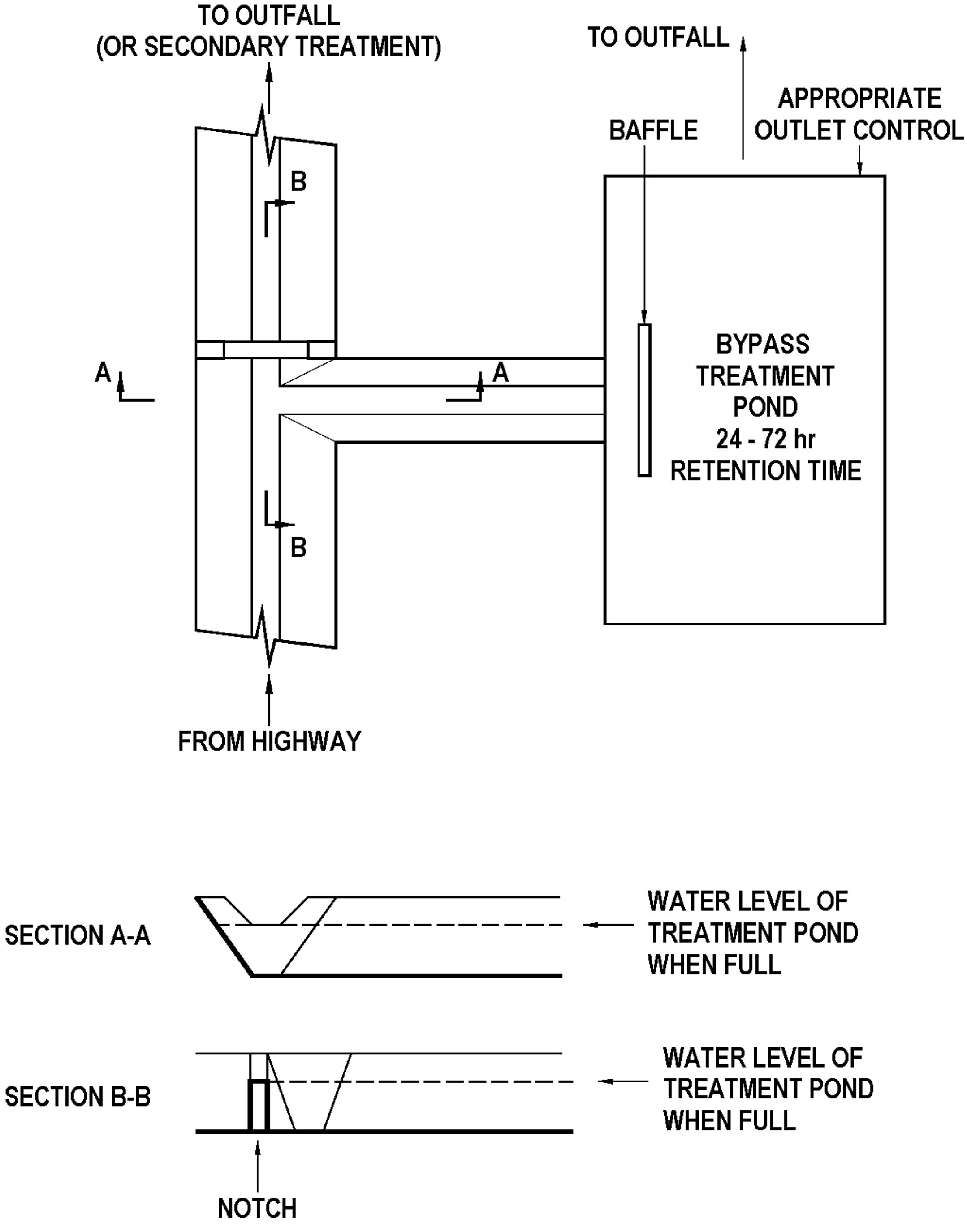

OUTFLOW
BAFFLES
STORAGE POOL
INFLOW
REGULAR BASIN
INFLOW
CURVILINEAR BASIN
OUTFLOW
BAFFLES
INFLOW
ELONGATED BASIN
OUTFLOW
SIDE SLOPES OF 1:3 OR
SHALLOWER FOR EXCAVATED
BASINS OR CONTAINMENT BERMS
INFLOW
ISLAND BETWEEN INLET AND OUTLET
PONDS WITH LONG FLOW PATHS

Figure 5.5



POSSIBLE DESIGN OF INLET DEVICE TO DIVERT
"FIRST FLUSH" FLOW TO TREATMENT POND

Figure 5.6

Planting

5.34 These ponds are designed to remain water-filled throughout the year. Here, reed mace (*Typha latifolia*), common reed (*Phragmites australis*) and branched bur-reed (*Sparganium erectum*) are appropriate as marginal species, with spiked milfoil (*Myriophyllum spicatum*), pond weeds (*Potamogeton natans* & *P. pectinatus*) and common club-rush (*Schoenoplectus lacustris*) suitable for deep water (>0.5m). The water level and supply requirements for these plant species are summarised in Table 5.1. These aquatic species can perform a limited role in uptake of soluble metals, but importantly can contribute to oxygenation of the water and enhance the processes of precipitation and biodegradation of organic material. These species can be established in bio-degradable pots/bags containing a suitable media to allow rooting into the pond sediments. Detailed planting specifications shall be developed at an early stage during the project and shall specify appropriate and sufficient plant maturity and density requirements.

Table 5.1: Water Level and Supply Requirements of Wetland and Pond Species

Species tolerant of fluctuating water levels and duration	Species requiring shallow standing water at all times	Species requiring moderate to deep standing water at all times
Phragmites australis (common reed)	*Sparganium erectum* (branched bur-reed)	*Schoenoplectus lacustris* (common club-rush)
Phalaris arundinacea (reed canary grass)	*Glyceria fluitans* (flote-grass)	*Myriophyllum spicatum* (spiked water-milfoil)
Persicaria amphibian (amphibious bistort)	*Typha latifolia* (reed mace)	*Potamogeton species* (pond weeds)

Hybrid Systems

5.35 Vegetated systems can be designed and built as a combination of two or more of the above systems. This is usually done to maximise the treatment of the runoff. One such combination could be a system containing SF wetland and a retention pond. Similarly it may be possible for an infiltration basin to act as a detention pond, with minor modifications to the design. In such cases the guidance given above for both of the above systems should be followed. Care should be taken to ensure that in creating a hybrid system the benefits of the two constituent systems are not lost.

Pre-treatment Systems

5.36 With the exception of SSF wetlands, which will only rarely be appropriate for treating road runoff, vegetated systems are considered sufficiently robust not normally to require separate pre-treatment facilities for routine runoff from rural roads. Consideration may, however, have to be given to the provision of oil separators in urban areas, or in other locations such as busy laybys where significant oil pollution is likely to occur from standing vehicles. Where spillage is assessed as a high risk (an annual probability greater than 1%), systems such as infiltration basins may need some additional protection. In many situations, it will be more economical to accept the risk of an occasional spillage and the consequential remedial cost to the system than to construct the additional facility, and this should be considered when the system is designed or specified.

Considerations for Integration into the Wider Landscape

Pond Details and Engineering Features

5.37 In many circumstances, the engineering features associated with vegetated drainage systems can have a significant visual impact on the surrounding area. In certain high profile situations where engineering features are visible above ground (e.g. headwalls or lined channels), it would be appropriate to use of local building materials to reflect the character of the surrounding area. Careful attention to detailing, for example matching stone size and jointing patterns of local walls, can create convincing and attractive features that will quickly weather and mellow. The angle of inlet/outfall header walls should follow the profile of the ground (e.g. pond margins) to reduce their visual prominence where possible. Figure 5.7 shows examples of both good and bad practice.

Boundary Treatments

5.38 Boundary treatments, such as fences and walls, can have a significant visual impact in the landscape. The use of hard ‘urban’ materials can be quite inappropriate in a rural situation. The use of local styles and materials and their careful alignment (both vertical and horizontal) should therefore be considered. The use of thorny plants, possibly combined with low fences or walls and a suitably planted narrow fringe, could also be considered as a boundary deterrent where appropriate.

Retaining Structures

5.39 Where abrupt changes in level are required within more confined areas, the sensitive use of stepped, stone-filled gabions, as shown in Figure 5.8, can be very effective. These can be quickly vegetated by spreading soil on top of the gabions and then seeding. The use of appropriate local stone within the gabions will also reflect the character of the area. A lining will be required where it is necessary to prevent passage of water through the gabions.

Pond Lining

5.40 Where the pond/wetland needs to be lined, the use of puddled clay is preferable if there is a local source available. The puddled clay should be at least 300mm thick and not be allowed to dry out, as this may result in cracking and leakage. Artificial pond liners (e.g. butyl rubber, membranes, concrete) should be well buried and designed with a shallow batter. Where butyl rubber linings and membranes are used, these should be high quality to ensure an appropriate design life and to avoid damage during maintenance operations. A marker layer of coloured sand, or other similar marker, should be installed above flexible membranes to provide an indication of their presence to avoid damage during periodic removal of sediment. A shelf should be incorporated to allow for the colonisation of the pond and its margins by vegetation. Figure 5.4 illustrates a typical pond margin showing the use of a liner.

Protection of Existing Features

5.41 Whilst considering the design and location of a vegetated system, every effort should be made to protect and retain existing features of landscape and nature conservation value. The proposals should avoid any negative effects on such features, whether natural or man-made, that contribute to the character of the system itself. Examples of such features include protected species, biodiverse habitats, landmark trees and hedgerows. In order to protect such features, a careful site survey and evaluation should be undertaken to identify opportunities and constraints and to help realise the site’s wildlife potential. A careful analysis of the landscape pattern and character should influence the general layout of a particular site and the choice of species appropriate to the locality.

Landscape Enhancement/Habitat Creation

5.42 The construction of vegetated systems can provide opportunities for enhancing the landscape and nature conservation value of the site beyond the immediate limits of the selected drainage system. The design should consider a broad variety of habitat types and landscape features in addition to those specifically related to the vegetated system. These could include:

a) **Hedgerows** – New hedges and hedgerow trees to link with and enhance existing wildlife corridors;

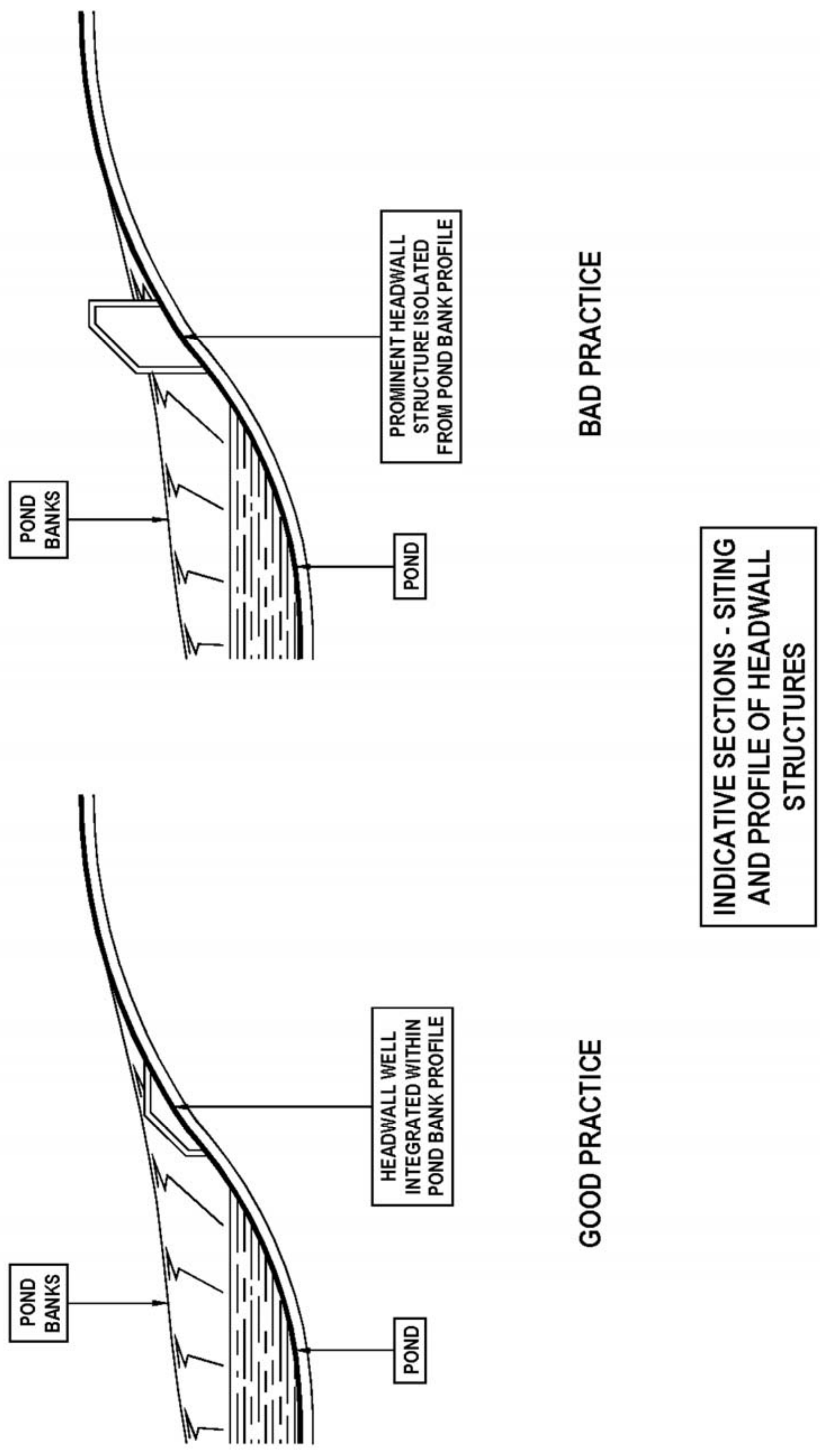
b) **Woodland areas** – New native woodland areas to reflect the surrounding landscape character and provide new habitats;

c) **Shrubs/woodland edge** – New habitats and enhancement of the surrounding area;

d) **Specimen/landmark trees** – Individual or small groups of trees to provide features within the landscape;

e) **Grassland/wildflowers** – Landscape enhancement and habitat creation;

f) **Islands –** For larger pond/wetlands it may be appropriate to incorporate islands to provide a safe refuge for wildfowl.



POND BANKS
PROMINENT HEADWALL STRUCTURE ISOLATED FROM POND BANK PROFILE
POND
BAD PRACTICE
POND BANKS
HEADWALL WELL INTEGRATED WITHIN POND BANK PROFILE
POND
GOOD PRACTICE
INDICATIVE SECTIONS - SITING AND PROFILE OF HEADWALL STRUCTURES

Figure 5.7

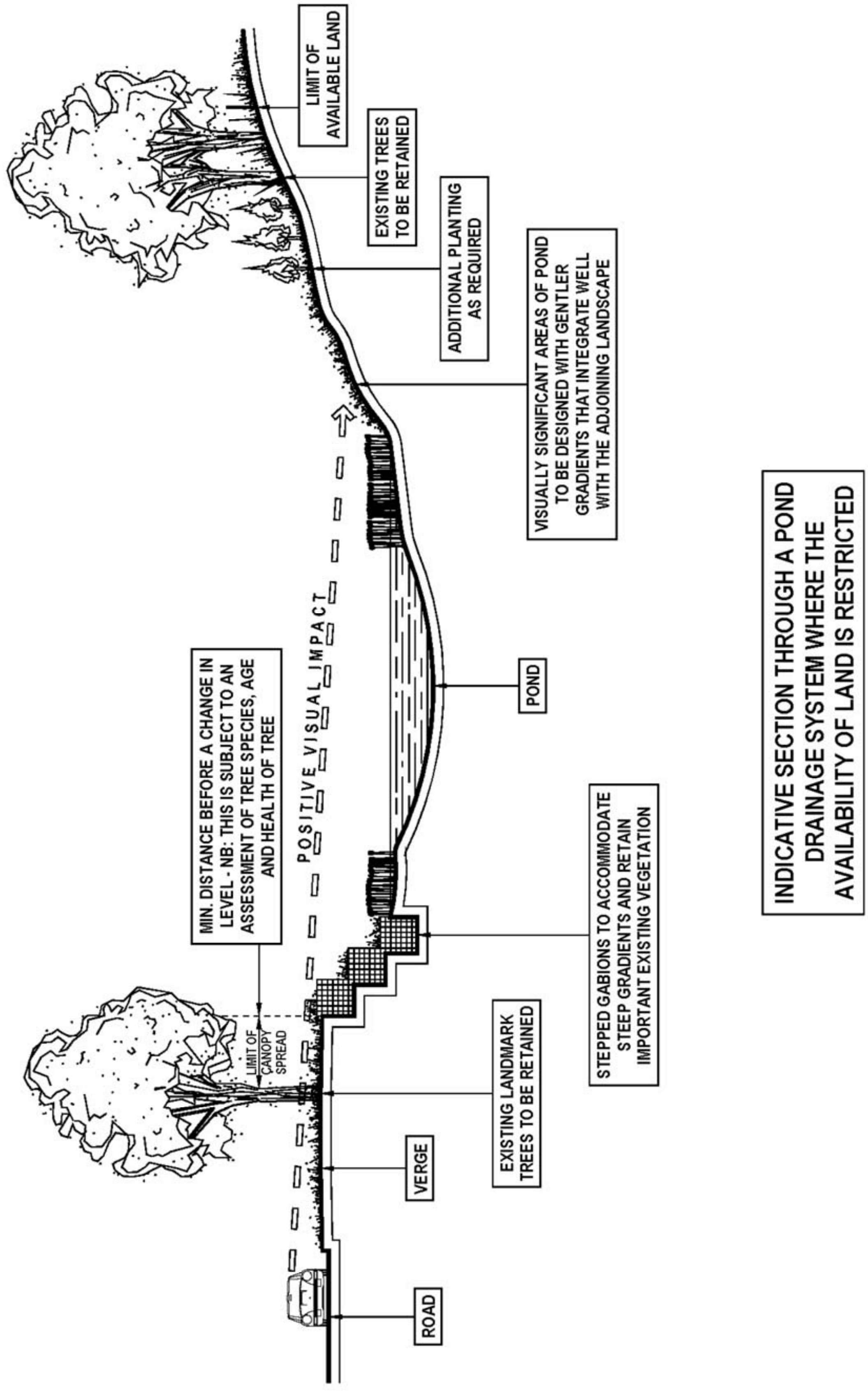

LIMIT OF AVAILABLE LAND
EXISTING TREES TO BE RETAINED
ADDITIONAL PLANTING AS REQUIRED
VISUALLY SIGNIFICANT AREAS OF POND TO BE DESIGNED WITH GENTLER GRADIENTS THAT INTEGRATE WELL WITH THE ADJOINING LANDSCAPE
POSITIVE VISUAL IMPACT
MIN. DISTANCE BEFORE A CHANGE IN LEVEL - NB: THIS IS SUBJECT TO AN ASSESSMENT OF TREE SPECIES, AGE AND HEALTH OF TREE
POND
STEPPED GABIONS TO ACCOMMODATE STEEP GRADIENTS AND RETAIN IMPORTANT EXISTING VEGETATION
LIMIT OF CANOPY SPREAD
EXISTING LANDMARK TREES TO BE RETAINED
VERGE
ROAD
INDICATIVE SECTION THROUGH A POND DRAINAGE SYSTEM WHERE THE AVAILABILITY OF LAND IS RESTRICTED

Figure 5.8

5.43 Locating a pond or wetland drainage system near an existing wetland environment/watercourse can help to encourage the rapid establishment of flora and fauna. This is further aided by retaining as much of the existing vegetation as possible (e.g. turf, trees and hedges). Professional guidance should be sought for proposals to restore or enhance existing habitats. Such proposals may overlap or be integrated with new habitat creation works, particularly marginal and wetland habitats, and often new woodland planting. Species which could be potentially invasive and cause negative impacts on surrounding features should not be used. In all cases, however, the carrying out of the maintenance of the primary functions of the drainage system must be considered and must not be prejudiced.

Retro-fitting of Vegetated Systems

5.44 Where space allows, existing ditches may be widened, their slopes slackened and emergent reed type vegetation introduced to create a linear system, resembling a natural stream. The principles of paragraph 5.22 should be applied. If pools and areas of reed can be incorporated, that will have added benefit. It may be possible to replace a section of piped drain with an open ditch or swale, particularly if a form of spillage containment is to be introduced. Wherever such retro-fitting of systems is proposed, the hydraulic performance of the whole drainage system should be checked to ensure this work does not increase the risk of flooding.

Health and Safety Considerations

5.45 Designers or Specifiers should be aware of the risks to both the public, road maintainers and those implementing the Contractor’s design as a result of designing or specifying vegetated systems. A risk assessment should be made at the time the systems are designed or specified. Because of their role in the treatment and control of runoff, it is recommended that there should not normally be public access to those vegetated drainage systems that may contain standing water, and boundary treatments should be designed accordingly.

5.46 Where, exceptionally, it is proposed to allow public access to a system, for amenity and recreational use, the design should ensure that water levels adjacent to the pond edge are shallow and gently graded. If deep water is unavoidable, the public should be excluded, or in exceptional circumstances suitable fencing erected to reduce the risk of persons falling into the water. Chambers, penstocks, valves and weirs should all be designed to deter unauthorised access and to avoid the possibility of the public being endangered.

5.47 Ease of access for the appropriate maintenance plant is important, not only to encourage regular maintenance, but also for the safety of the maintenance operatives. It will also aid emergency personnel in carrying out any measures to mitigate the effects of a spillage. Appropriate access to systems remote from the main carriageway is essential in all locations, and in many locations a gated access could be provided. Where systems are to be constructed adjacent to existing watercourses, a margin of about 8 metres should be allowed for maintenance and access by the riparian owner.

Establishment and Aftercare

5.48 Careful establishment and aftercare of the proposed system will be required in order to ensure the success of the scheme and its integration into the wider landscape. Set out below are some design principles that shall be considered where appropriate.

Specification

5.49 A comprehensive written specification shall be produced by an appropriately qualified professional. This shall be keyed to detailed site plans at an appropriate scale (generally no smaller than 1:500). This will cover the planting operations and the establishment and aftercare during the contract. The specification shall include a schedule of all plant material, giving species, cultivars, sizes (pot size where appropriate), numbers and densities, and shall also include details of plant handling and delivery procedures.

Defects and maintenance

5.50 The aftercare (defects and maintenance period) is critical to the success of any scheme and a maintenance period of no less than 3 years should be included. During this period, maintenance should include plant protection (shelter guards, rabbit fencing etc.), watering, weed treatment, fertiliser and replacement of failed plant material.

6. MAINTENANCE AND MANAGEMENT OF VEGETATED DRAINAGE SYSTEMS

General

6.1 Vegetated Systems are likely to require a more frequent level of inspection than conventional drainage systems, as the growth of vegetation will need to be inspected and controlled to ensure the system continues to operate as designed. For all vegetated systems a maximum inspection interval of six months is recommended, preferably at the start and end of the growing season. Further inspections should be carried out after any storm events equal to or greater than a one-year event. These are needed to check for signs of erosion or flooding, which would indicate whether the system has been affected by the storm. Advice should be sought from an ecologist, or other appropriately qualified environmental specialist, about the inspection of plants, their removal and trimming, the removal of sediment and organic material, and the maintenance of the ecological health and operation of the systems. In particular, advice should be sought concerning the potential presence of protected species and breeding birds. Consultation with IFI, NPWS, the EPA and the local authority should be carried out.

6.2 In maintaining these systems, it will be important to ensure that their primary hydraulic and treatment functions are performing satisfactorily and protecting the receiving surface watercourses or groundwater. Particular problems likely to be found include scouring of channels and the formation of rapid pathways that allow the runoff to bypass the drainage systems. Conservation of the landscape and any habitats within the systems, whilst important, must not be allowed to impede in any way the primary maintenance requirements. It may, however, be possible to adapt the programme of maintenance to minimise disruption to habitats and species. If the presence of protected species or breeding birds is suspected, consultation with NPWS, IFI, the EPA and the local authority should be undertaken before maintenance works are planned and carried out. They will advise whether a survey is needed and any special provisions required.

6.3 Accumulation of sediment and plant waste is likely to occur in these systems. When removing such debris, care must be taken to avoid damage to flexible liners below. Information should be provided to operatives on the presence and depth of liners and on the existence of any depth markers, which should be replaced if damaged. Consideration should be given to the impact that disturbance of the sediment will have on the short-term migration of fines and contaminants from the system and maintenance operations planned accordingly.

6.4 One purpose of a vegetated system is to trap and treat contaminants in roads runoff. By definition, therefore, it is an area of land that is contaminated and will require appropriate de-contamination at the end of its useful life, or whenever it becomes redundant. Consideration must be given to the disposal of sediment and plant waste as these will retain contaminants from the road runoff. Sediment and plant waste may be classified as special waste or hazardous waste and disposed accordingly. If there is doubt as to the status of the waste the advice of the EPA should be sought. In addition, sediment and plant waste is likely to require pre-treatment prior to disposal at a landfill site. This can take place either as the material is extracted or at the landfill site itself.

6.5 The disposal of special or hazardous waste is expensive and disposal facilities are limited, and the benefits of testing, screening, separation and mechanical de-watering of the sediments using mobile plant, should be considered. This not only facilitates the separation of the materials into high and low contamination levels (thereby minimizing disposal costs) but also reduces the volume and weight of any material that has to be landfilled by removing excess water. The sand and pressed cake produced shall be in a form that can be accepted by landfill sites in accordance with Landfill Directive (Council Directive 99/31/EC) and the specific waste licence conditions of the proposed receiving facility.

Management Plan

6.6 A Management Plan/ Manual should be prepared to set out a system's objectives, formulate an annual programme of maintenance operations and provide opportunities to review the behaviour of the system. This may be undertaken by inspection of the operation of the various elements of the system, by monitoring the management of pond vegetation and by follow up ecological surveys where warranted by the degree of nature conservation interest. Meaningful monitoring of water quality to determine the effectiveness of the system is a complex and costly operation and must not be specified in the management plan without the agreement of the National Roads Authority. The management plan should prescribe the various maintenance operations which may be required. Where specified operations are unable to be undertaken, for example due to adverse weather conditions, the effects should be assessed and recovery measures indicated. Properly implemented, a management plan would help to ensure the continuity and stability of a system's natural resources. Specific maintenance requirements for particular types of system are suggested below and summarised in Table 6.1. The suggested requirements in this table should be not be interpreted rigidly. As there is relatively little experience in Ireland of managing vegetated systems on roads, a proactive approach, based on local knowledge and site specific issues, is to be encouraged.

Table 6.1: Table of Inspection and Maintenance Requirements for Vegetative Systems

	Swale	Infiltration Basin	SF Wetland	SSF Wetland	Retention Pond/ Sedimentation Pond
INSPECTIONS: • Inflow/outfalls • Integrity/erosion • Debris/rubbish	Quarterly or after each major storm	Quarterly	Quarterly or after each major storm	Monthly or after each major storm	Monthly
• Build-up of sediment or invasive weeds	Annually	Twice annually	Annually	Annually	Annually
• Vegetation cover/ vigour	Monthly or after each major storm	Annually	Annually	Annually	Annually
• Check for protected species/breeding birds	Specialist advice to be sought, as described in paragraph 6.2				
ROUTINE WORKS: • Clearance of rubbish/debris	Monthly or after each major storm	Quarterly	Quarterly	Monthly or after each major storm	Quarterly
• Cutting vegetation	Monthly or after each major storm	Annual	10 year cycle and remove	1-5 year cycle and remove	5-10 year cycle and remove
• Removal of plant litter	N/A	N/A	N/A	5-10 year cycle if required	N/A
• Removal of sediment	To be determined annually	To be determined annually	To be determined annually	To be determined annually	To be determined annually

Swales

6.7 Swales are most efficient at treating water when the grass sward is dense and about 100 – 200mm long. Much shorter than that and the suspended solids in the water will not be retained; much longer and the flow of the water will be too slow or the vegetation will become flattened, although in some locations this may not affect the efficiency of the drainage. Regular mowing to 100mm will therefore be needed. This may be three or four times a season, depending on growth and the location. Appropriate machinery able to cut grass efficiently to this length will need to be selected. Grass should not be mowed when ground conditions are wet and soft as this could compact soils, create ruts and result in erosion. Removal of litter and debris will be needed on a regular basis and swales should be checked after major storm events. The effectiveness of the swales will be greatly reduced if there is a build-up of debris, as this will tend to create channels, rather than the even flow necessary for optimum efficiency.

6.8 Sediment removal may be required in particular from upstream areas of the swale and also at check dams if these are present. Long term siltation over the remainder of the swale is unlikely to be a problem, although ‘crusting’ may be observed. This should be removed mechanically and will result in subsequent need to reseed. Swales should be inspected at least four times a year for structural repairs, especially to the inlet areas and side slopes where erosion may occur. Repair should include infill, reshaping of the slopes and reinforcement if necessary. Bare areas should be reseeded and fertilised if necessary.

Infiltration basins and Trenches

6.9 To work efficiently these systems must be kept clear of debris. Signs of ponding will indicate that infiltration is not taking place and that cleaning out of the filter is needed. Litter and sediment removal will be needed twice a year. This should include a visit in late autumn if there is the possibility of leaf fall rendering the system less effective. Slopes and spillways should be checked twice annually to ensure there is no erosion, settlement, slope failure, tree growth, wildlife damage or vehicular damage.

SSF Wetlands

6.10 The maintenance of substratum hydraulic conductivity is essential in SSF wetlands and this requires regular inspection of the inflow and outflow on at least a monthly basis. The main threat appears to be clogging by silt and grease, hence the pre-treatment system, a prerequisite of this type of wetland, needs to be checked and cleaned/emptied. The design life of constructed SSF wetlands in the road situation is currently unknown, but is anticipated to be between 15 – 20 years where silt and grease inputs are minimal. After this period, the substratum may need to be replaced. Inspection should involve taking cores to establish the state of the substratum and identify clogged or severely contaminated areas. There may only be a need to replace sections of the bed.

6.11 The reed vegetation may need to be cut and the stems removed to maintain vigour and prevent the build-up of excessive vegetation litter on the surface. It is suggested that the vigour and litter build-up is reviewed annually and cutting takes place as appropriate. Cutting should be by hand and not machine in order to avoid damage to the substratum and its porosity, and it is recommended that only half the bed is cut at a time. Where replacement substratum is provided the area would be replanted.

SF Wetlands

6.12 The anticipated maintenance and inspection of SF wetlands is anticipated to be less onerous than the SSF type. It is recommended that these systems are inspected on a quarterly basis to ensure the integrity of the system, especially after periods of heavy rain. The design life of constructed SF wetlands is anticipated to be 10 or more years, depending on size and level of inputs. After this period, accumulated silts may need to be removed and any ponds may require to be dredged. These should be undertaken on a cyclic basis perhaps involving only a third or a half of the system at a time thereby ensuring there is mature vegetation to promote sedimentation while the newly planted areas are becoming established. In this type of system it is anticipated that the vegetation would not be cut. Where sediment removal is undertaken, the area would be replanted.

Ponds

6.13 Non-routine maintenance should include sediment removal from the base of the pond. The build-up of sediment will vary with local conditions, but as a guide, this operation may be needed every ten years. Sediment removal should be undertaken one third at a time to avoid removal of all vegetation.

6.14 Cutback and removal of vegetation may be required to retain the area necessary for maintenance of a permanent pool of open water and to prevent excessive build-up of organic detritus and nutrients. Periodic removal of vegetation may also increase growth rates and nutrient removal and also improve diversity of the flora when competitive species such as reedmace (*Typha latifolia)* threaten to dominate.

6.15 Consideration of vegetation removal should only be necessary at 5 – 10 year intervals for these purposes. Not all the vegetation should be removed each time. The root systems of the plants should not be entirely destroyed or removed as it will take a considerable time to re-establish. Instead roots or rhizomes may be removed in small patches to promote new root/rhizome growth. Removal should follow a cycle allowing two thirds of the vegetation to remain on each occasion in order that its treatment capacity is maintained. Removal should consist of a thinning process rather than removal of large stands of vegetation in order to avoid release of trapped pollutants and sediments and to prevent erosion. The organic detritus is also an important sink for both metals and organic pollutants. Willow, alder and birch may all become established around the pond margins and may need to be removed to prevent shading of the treatment vegetation.

6.16 Structural Repairs to the inlet/outlet and other exposed elements be undertaken as soon as damage is observed. Deterioration of these items is likely to be more rapid than usual (unless special measures were taken during construction) due to the variable water levels, which will create an aggressive environment. Areas of erosion should be filled, compacted and reseeded as soon as possible. Eroded areas near inlets and outlets may require rip-rap fill to prevent further erosion.

Management of the Vegetated System Landscape

6.17 Beyond the routine maintenance of a vegetated drainage system, there may be opportunities to manage the broader landscape around the system in the interest of nature conservation and landscape visual amenity. This could include operations such as laying mature hedges or thinning/coppicing areas of regenerating woodland. Such operations, including routine maintenance, would ideally be carefully prescribed in the form of a written management plan produced with professional guidance, commencing from initial site work through to longer-term operations for a period of approximately 10 years. Such an approach would help to avoid any potential conflicts between maintaining the effective functioning of the drainage systems with that of nature conservation and visual amenity where feasible or appropriate.

7. REFERENCES

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a) NRA Specification for Road Works (NRA SRW) (MCDRW 1)

b) Notes for Guidance on the Specification for Road Works (NRA NGSRW) (MCDRW 2)

c) Road Construction Details (NRA RCD) (MCDRW 4)

7.2 **NRA Design Manual for Roads and Bridges (NRA DMRB)**

a) NRA HD 33 Drainage Systems for National Roads

b) NRA HD 45 Road Drainage and the Water Environment

c) NRA HD 137 Hydraulic Design of Road Edge Surface Water Channels

d) NRA HD 139 Edge of Pavement Details

e) NRA HD 78 Design of Outfalls for Surface Water Channels

f) NRA HD 106 Drainage of Runoff from Natural Catchments

g) NRA HD 107 Design of Outfall and Culvert Details

h) NRA HD 118 Design of Soakaways

i) NRA HD 119 Grassed Surface Water Channels for Road Runoff

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a) HA 41 Maintenance of Highway Geotechnical Assets (DMRB 4.1)

b) HA 55 New Roads Landform and Alignment (DMRB 10.1)

c) HA 56 New Roads Planting, Vegetation and Soils (DMRB 10.1)

d) Environmental Assessment Techniques: Ecology and Nature Conservation (DMRB 11.3.4)

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7.19 Ellis J, Shutes R and Revitt D, 2003 Guidance Manual for Constructed Wetlands R&D Technical Report P2-159/TR2 Environment Agency.

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7.21 Water Services Acts 2007 – 2013.

7.22 Landfill Directive (Council Directive 99/31/EC).

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8. GLOSSARY

Absorption	Substances taken into plant, soil or other material and loosely held without binding or physical or chemical incorporation
Adsorption	(Of particles or droplets) collected, and sometimes bound, on surface of soil, vegetation or other matter
Aerobic	In the presence of oxygen (air)
Anaerobic	In the absence of oxygen (air)
Assimilation	Conversion into complex constituents of the organism
Biodegradation	Decomposition by microbes
Biological Oxygen Demand (BOD)	The rate of removal of oxygen by bacterial organisms using the organic matter in water
Precipitation	Deposition of soluble substance in an insoluble form (e.g. oxide, carbonate)
Re-mobilisation	(Of metals) change to soluble form, or displacement as ionic form, from cation exchange sites on clay minerals or organic materials
Rhizome	An underground plant stem which produces roots and shoots
Species:	
Aquatic	Plants living wholly within the body of water or directly on its surface
Emergent	Plants which are rooted in water and have parts (shoots, leaves and or flowers) which grow above the surface of the water
Marginal	Plants which live at the margin of water bodies
Semi-aquatic	Plants which are capable of living in both water and on wet land
Substratum	Subsurface material providing support for plants and/or filtering function and main pathway for water flow (usually soil or gravel)
Volatilisation	Changing of liquid to gaseous phase

9. ENQUIRIES

9.1 All technical enquiries or comments on this document, or any of the documents listed as forming part of the NRA DMRB, should be sent by e-mail to infoDMRB@nra.ie, addressed to the following:

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