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Railway Sustainability Design Guide

Wetland Design and Management Guidance Note

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Issue record

Issue	Date	Comments
0.1	June 2021	First release in advance of online edition

Reference documentation

NR/L2/ENV/122	Managing Biodiversity
NR/L2/ENV/122/01	Biodiversity
NR/L2/ENV/122/02	Habitat Management Plan
NR/L2/OTK/5201/01	Lineside vegetation inspection and risk assessment
NR/L2/OTK/5201/02	Lineside Vegetation Management Requirements
NR/L2/OTK/5201/03	Route Vegetation Management Plans
NR/L3/OTK/6202	Protecting railway assets during vegetation work
	Habitat Design and Management Guidance Note

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Contents

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1 Purpose

The lineside includes a range of wetland habitat types. Effective wetland management will contribute to safe and efficient rail operation and an increase in the natural-capital value of the lineside. This note provides guidance on:

a) Best practice wetland habitat design and management for Central, Regional, and Route management teams showcasing what good wetland habitat and biodiversity management looks like;

b) Why wetland management decisions are made in certain situations, including important considerations and implications;

c) Risks reduced by the application of this guidance note including, delays and unplanned costs from unforeseen/inadequately considered wetland and lineside constraints;

d) Benefits of the application of this guidance note including, enhanced biodiversity of the lineside, increased stakeholder confidence and improved performance relating to national biodiversity goals and the resilience of lineside wetland; and

e) Associated legislation and control documents that this document helps to achieve compliance with.

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2 Scope

This guidance note applies to Network Rail, their supply chain and third parties working on Network Rail owned land. It shows how wetland habitats within the lineside can be created and managed, supported by templates; habitat specifications; identification aids; toolbox talks; and case studies.

The guidance note complies with and supports the following documents:

a) Protecting railway assets during vegetation work (NR/L3/OTK/6202);

b) Biodiversity (NR/L2/ENV/122);

c) Lineside Vegetation Management Standards (NR/L2/OTK/5201); and

d) Habitat Design and Management Guidance Note.

This guidance note informs:

a) The production of habitat management plans; and

NOTE: *Habitat management plans are described in NR/L2/ENV/122 Module 02*

b) The production of route vegetation management plans and sectional asset plans.

NOTE: *Route vegetation management plans and sectional asset plans are described in NR/L2/OTK/5201 Module 03.*

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3 Definitions

Table 1 – Terms and definitions

Term	Definition
Algal bloom	Excessive growth of algae caused by nutrients entering the aquatic system, typically as a result of fertilizer run-off from arable fields.
Anoxic	Environment that is depleted of oxygen.
Aquatic marginal vegetation	Vegetation fringing open water often developed as a narrow (< 0.5m wide or < 0.25ha in extent) part of a hydrosere between standing water and upslope vegetation.
Biodiversity	Biodiversity is the variety and variability among all forms of life, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part.
Biodiversity Metric	A biodiversity metric devised by Natural England which assists with assessing measurable net gains in biodiversity by accounting for biodiversity losses and gains resulting from development or land management change
Biodiversity Net Gain	An approach to development that leaves biodiversity in a better state than before, abbreviated in this document to BNG.
Biosecurity	Procedures or measures designed to protect habitats and their populations of fungi, plants and animals against invasive non-native species, pests, disease or biochemical substances, which damage the health and condition of biodiversity and the environment.
Brackish	Water more salty than freshwater but not as salty as sea water.
Carr woodland	Woodland located on poorly drained soils, typically within wetland such as riverbanks.
Colonisation	Natural regeneration of plants on previously unvegetated sites.

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Term	Definition
Emergent aquatic vegetation	Plants that are rooted in the bottom of the waterbody, but their leaves and stems extend out of the water.
Eutrophication	Enrichment of water with nutrients increasing the production of algae and aquatic plants.
Habitat condition	The ecological condition of a particular habitat parcel. Condition relates to the standard of a habitat parcel relative to other parcels of the same habitat type. Habitat condition relates to Natural England's Biodiversity Metric's habitat condition scores which range from 'Poor' to 'Good' (Natural England 2019a and 2019b). Wetland habitats will vary in their ecological condition. Factors that affect the condition of a habitat include human disturbance, damage by livestock and presence of invasive non-native species (INNS).
Habitat value	A habitat's value is its relative importance in sustaining socially or ecologically significant wildlife populations and biodiversity.
Habitat mosaics	An area comprised of multiple habitat types.
Hydrosere	A plant succession which occurs in an area of fresh water such as in oxbow lakes and kettle lakes.
INNS	Invasive non-native species (INNS). Species which have been introduced into areas outside their natural range through human actions and are posing a threat to native wildlife.
Lineside	The extensive area of land that falls within the Network Rail ownership boundary.
Macrophyte	Large aquatic plants growing in or near water.
Nature based solutions	The sustainable management and use of nature for tackling socio-environmental challenges whilst providing human well-being and biodiversity benefits.
Natural capital	The world's stocks of natural assets. These include geology, soil, air, water and all living things. From this

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Term	Definition
	natural capital, people derive a wide range of services, (ecosystem services) such as food production.
Overstocking	When there are too many animals in one grazing space.
Preferred Habitat Objective	The broad process which will enable an existing habitat to be modified into the preferred habitat type. Habitat Objectives related to one of the following processes: Transform, Conserve, Restore and Enhance. This is in relation to the Habitat Management Plans (NR/L2/ENV/122 Module 2) only.
Priority habitat	Habitats principal importance listed under Section 41 of the Natural Environment and Rural Communities Act (2006).
PPE	Personal Protective Equipment (PPE) is equipment which protects the user against health and safety risks.
Protected species	Species of plants and animals afforded some level of legal protection within the UK. This includes European Protected Species listed under the Conservation of Habitats and Species Regulations 2020.
Plant litter	Dead plant material that has fallen to the ground.
Resilience	The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change.
Riparian vegetation	Vegetation that grows on the banks of rivers and streams.
Salinity	The saltiness or amount of salt dissolved in water.
Self-sown	A plant sown by itself, typically from seeds dispersed from a neighbouring plant.
Semi-natural	Habitats that have been heavily modified by human activities. Most of the UK's naturally occurring habitats are regarded as semi-natural.

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Term	Definition
Siltation	The build-up of silt on the bottom of waterbodies due to an increase in high concentrations of water-borne silt.
Soil microbes	Microorganisms that live in the soil e.g. fungi, bacteria, algae and protozoa.
SSSI	Site of Special Scientific Interest.
Stepping stones	Patches or islands of semi natural habitat which provide passage the semi natural habitat within the wider landscape for wildlife.
Submerged aquatic vegetation	Plants that grow and are completely submerged underwater.
Sustainable drainage systems (SuDS)	Approaches to manage surface water that take account of water quantity (flooding), water quality (pollution) biodiversity (wildlife and plants) and amenity.
Water table	The naturally occurring upper surface level of water present in the soil.

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4 Introduction

This document provides guidance on the following:

1. Wetland classification – how to classify wetland into sub-types to help understand the existing wetland and apply relevant best practice wetland establishment and management guidance;
2. Wetland habitat design – guidance and key considerations for the design of wetland within the lineside estate; this includes suitable site selection, soil analysis and macrophyte specification;
3. Wetland creation and establishment – guidance and key considerations on how to successfully create and establish new wetland in the lineside to maximise its biodiversity and the ecosystem services it supports;
4. Long-term management of wetland habitat – guidance, key considerations and best practice management techniques to enhance established wetland; and
5. Wetland restoration – guidance on restoring wetland which has transitioned to a higher successional vegetation community (e.g. to dense scrub).

Figure 1 – Wetland design and management guidance process

Case studies are included in section 7 to illustrate examples of best practice in the delivery of preferred habitat objectives.

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4.1 Document structure

Figure 2 shows the relationship hierarchy of the Wetland Design and Management Guidance Note and other Level 2 and Level 3 Network Rail guidance notes, manuals and modules.

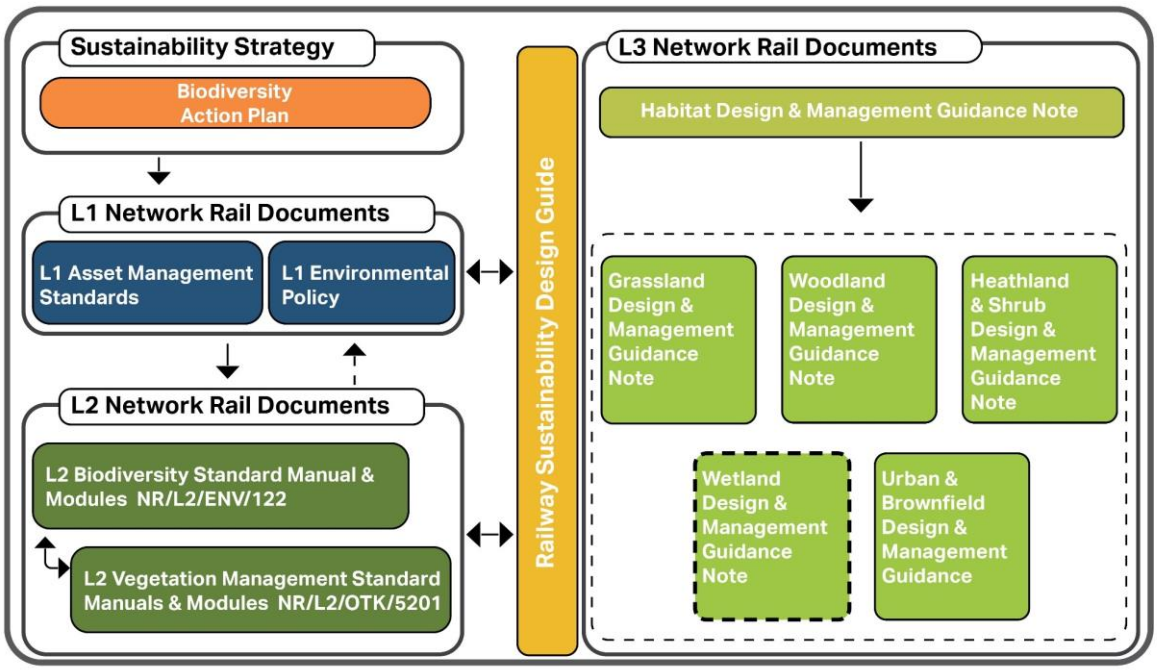

Figure 2 – Document hierarchy

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5 Wetland classification

5.1 Introduction

Network Rail has adopted the UK Habitat Classification to describe the habitats within the lineside. These are set out and described in the Habitat Design and Management Guidance Note, which defines five primary habitat types (UK Habitat Classification Level 2) according to which all land within the lineside should be classified:

- Grassland;
- Woodland;
- Heathland and Shrub;
- Wetland; and
- Urban.

***NOTE**: UK Habitat Classification documents are available at:*
https://ecountability.co.uk/ukhabworkinggroup-ukhab/

5.2 Wetland (UK Habitat classification code - F)

5.2.1 Definition

Wetland is defined as any habitat that is waterlogged, where the water table is at surface or standing water between 50% and 70% of the year.

Figure 3 – Typical wetland found adjacent to the railway

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5.2.2 Attributes

The following list of attributes are typical of wetlands:

- Predominantly found adjacent to watercourses, ponds and lakes, where the water table is high.
- Natural springs can give rise to wetland.
- Habitat which is wet at least half of a typical year; usually autumn to spring.
- Includes reedbeds and fenland, bog, wet heathland, wet grassland, swamp and marshland.
- Wetland habitat type is dependent on hydrology, soil type and the type of vegetation growing.

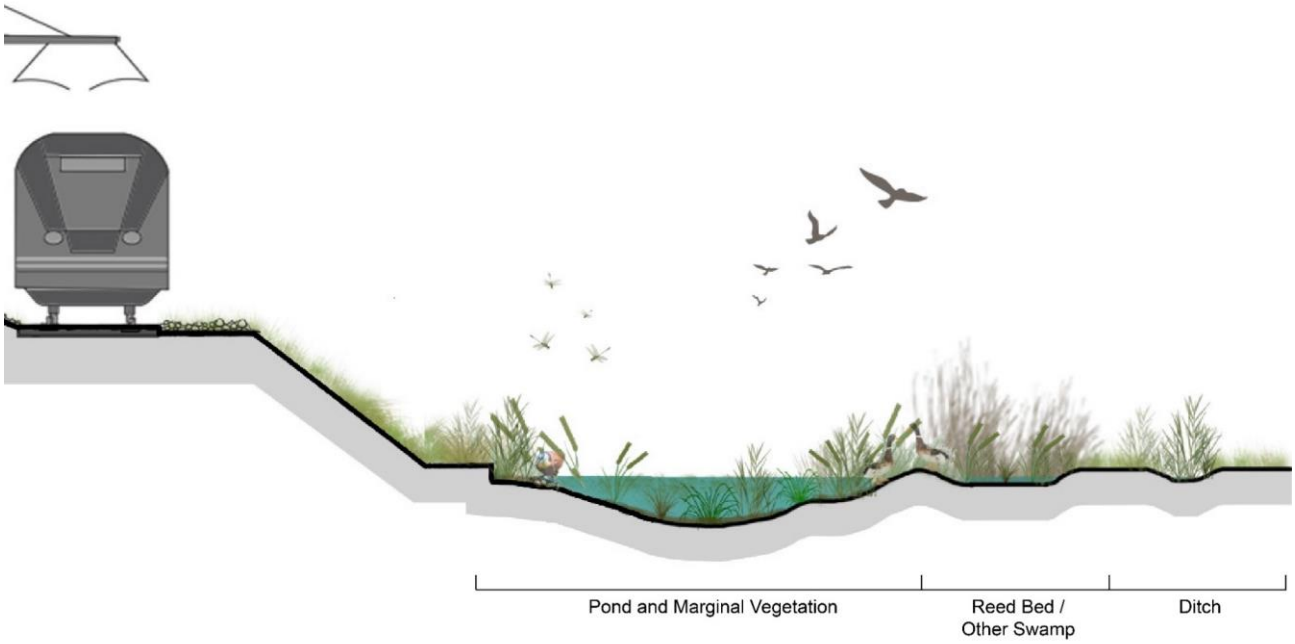

Figure 4 – Examples of typical lineside wetland habitats

5.2.3 Classifying wetland habitats

Wetland habitat is some of the rarest and most biodiverse in Britain and can be extremely sensitive to change. Where variable climate, pollution and other environmental factors influence a site, a wetland may take many years to reach good condition.

This document is focused on wetland habitats most frequently encountered in the lineside. Many of these habitats are likely to be dry during warmer months and may not obviously resemble typical wetland. Ditches, drainage features and sites with a naturally high water table are likely to be where wetland habitat is found in the lineside.

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There are also places where the railway intersects uncommon wetland habitat, such as nationally rare chalk streams. Whilst the management principles in this document are largely applicable for such habitats, where these rarer wetlands are encountered, it is recommended that a suitably qualified ecologist is consulted.

The type of wetland and the species it can support is mostly defined by the underlying water table, geology and associated hydrology. Understanding these factors is crucial to wetland creation and design, as without water, a wetland cannot be sustained.

The type of wetland habitat can influence the application of appropriate best practice guidance for wetland design and management.

Ponds are addressed separately to wetland habitats in the UK Habitat Classification but have been included within this guidance due to their similar function, design and management.

The following information should be used to further classify wetland habitat into sub-types (UK Habitat Classification, 2018).

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F2e: Reedbeds (UK Habitat Classification Level 4)

Wetland dominated by stands of common reed (*Phragmites australis*), with the water table at or above ground level for most of the year.

Reedbeds tend to colonise areas of open water and ditches, and small areas of wet grassland and carr woodland may be associated with them.

5.2.4 Attributes

The following list of attributes are typical of reedbeds:

- Can help stabilise sediments and provide shore protection by dissipating wave energy.
- Provide shelter for wetland birds, such as reed bunting, sedge warbler, ducks and waders.
- Are common features of ditches and drainage features and can grow on damp soils, even where water is not visible above the ground for most of the year.
- Typically located on the edges of waterbodies and rivers.
- Figure 6 indicates species associated with reedbed and other swamp habitats. Common reed must dominate for the habitat to be classed as reedbed, although other species may be present.

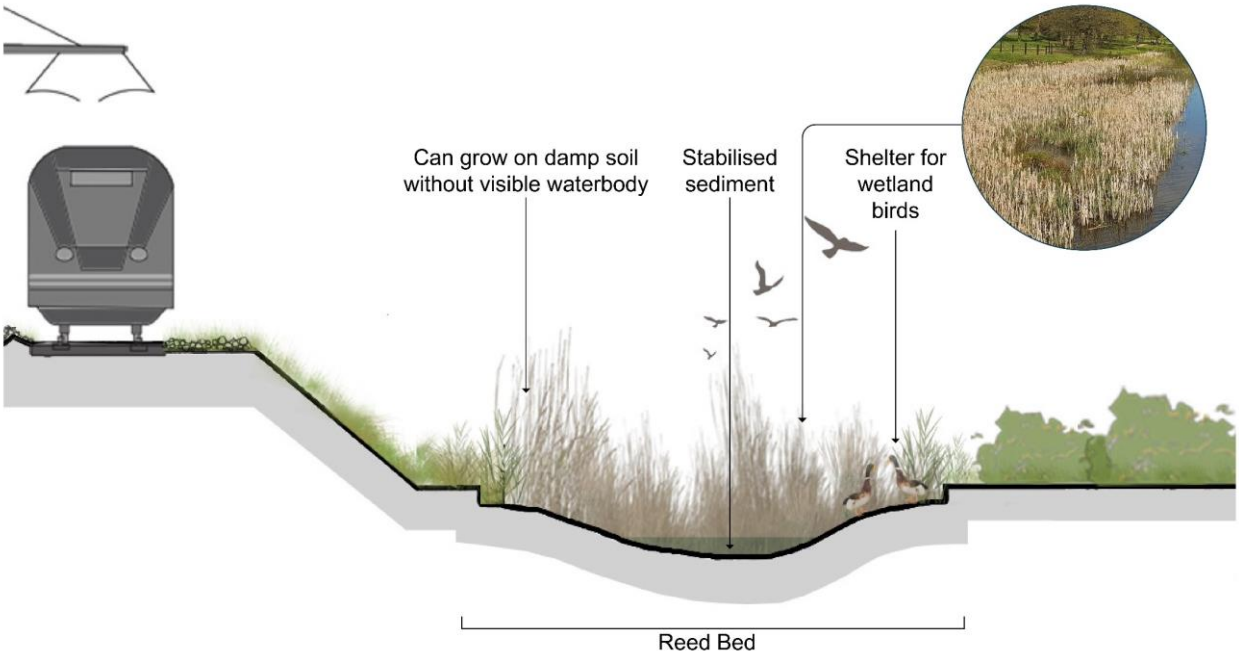

Figure 5 – Example of typical lineside reedbed habitat

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F2f: Other swamps (Level 4)

This category includes swamps other than reedbeds.

Species include reed canary-grass (*Phalaris arundinacea*) which is likely to be a constant species within this habitat type, with great willowherb (*Epilobium hirsutum*), common nettle (*Urtica dioica*), common couch (*Elytrigia repens*) and Yorkshire fog (*Holcus lanatus*).

5.2.5 Attributes

The attributes of F2f Other swamps match those provided for F2e Reedbeds (see Section 5.2.4). The difference in each habitats' classification relates to the species present within the plant community.

Figure 6 illustrates typical species found within other swamp habitat. Where common reed dominates, the habitat is likely to be classified as a reedbed.

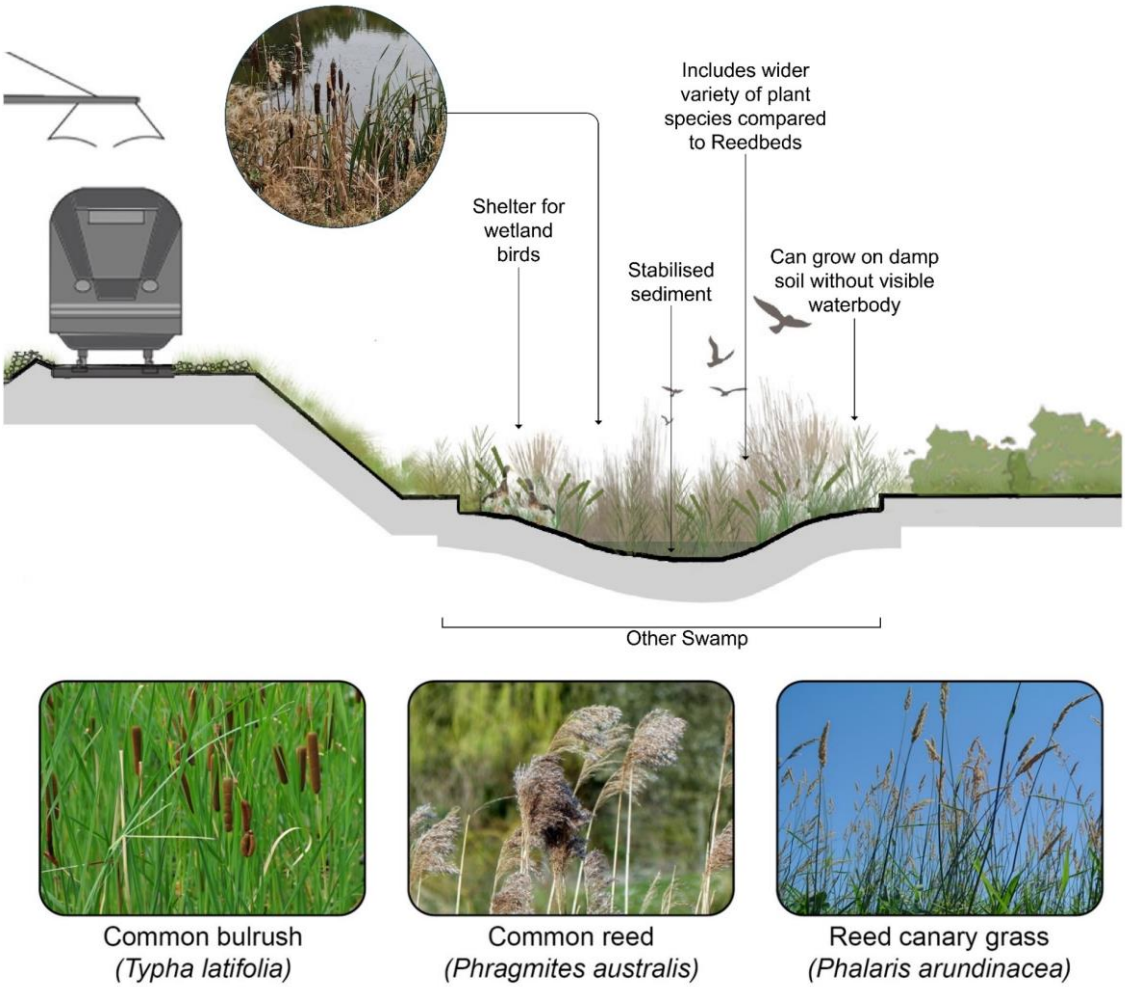

Figure 6 – Example of typical lineside other swamps habitat

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F2d: Aquatic marginal vegetation (Level 4)

Vegetation fringing open water often develops as a narrow (< 0.5m wide or < 0.25ha in extent) part of a hydrosere between standing water and upslope vegetation.

Species include valerian (*Valeriana officinalis*), great willowherb, (*Epilobium hirsutum*), meadowsweet (*Filipendula ulmaria*), hemlock water dropwort (*Oenanthe crocata*), marsh woundwort (*Stachys palustris*) and purple loosestrife (*Lythrum salicaria*).

5.2.6 Attributes

The following list of attributes are typical of aquatic marginal vegetation:

- Aquatic marginal plants grow around the margins of open water where the water is shallow. For example, adjacent to ponds, streams and rivers.
- It is often developed during the process of succession and forms a narrow strip between the open water and dry land (< 0.5m wide or < 0.25ha in extent).
- Aquatic marginal vegetation is characterised by vegetation growing on the inside edge of the pond.
- The marginal vegetation performs a filtration function, improving water quality.
- Native, flowering marginal vegetation attracts insects and provides shelter for wildlife, such as nesting birds.

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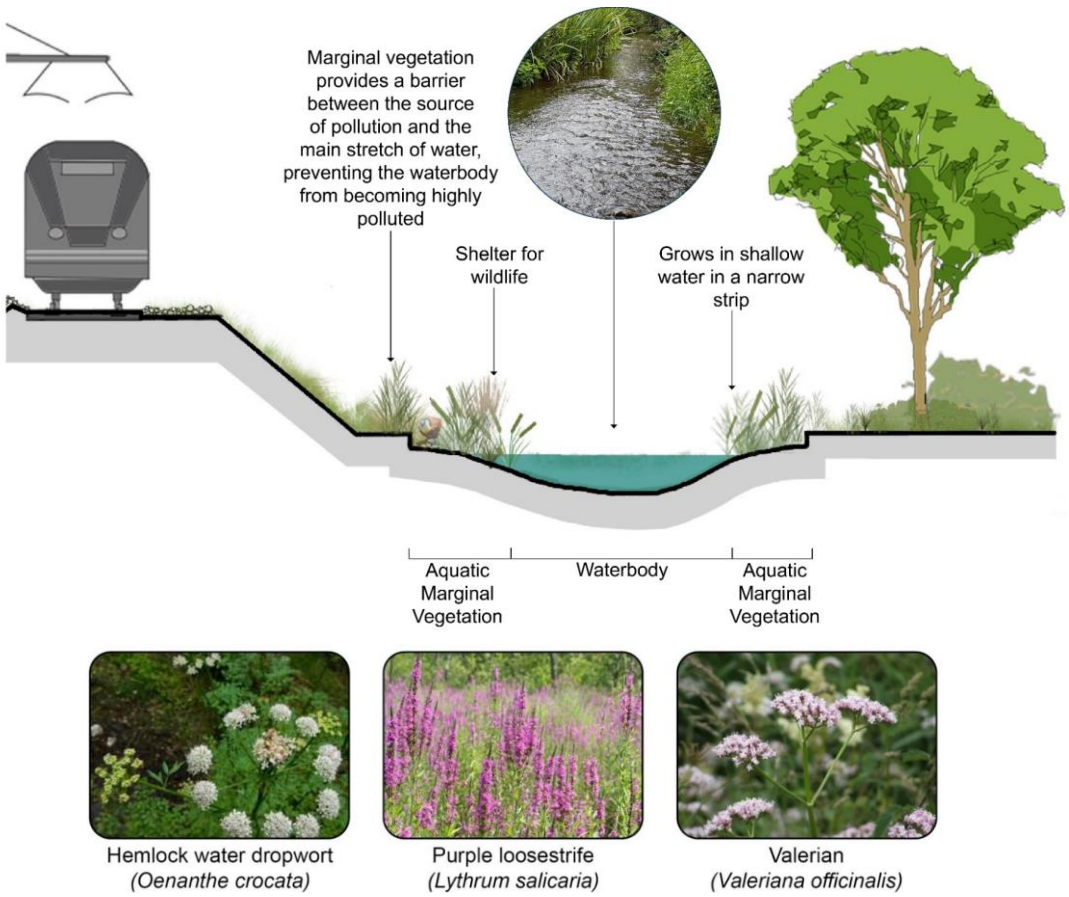

Figure 7 – Example of typical lineside aquatic marginal vegetation

R1a – Eutrophic standing waters ('Ponds')

Waterbodies that are highly productive because plant nutrients are plentiful, either naturally or as a result of artificial enrichment, characterised by algal blooms and dark anaerobic mud, rich in organic matter.

In relation to lineside habitats, eutrophic standing water will include ponds and wet ditches

5.2.7 Attributes

- The following list of attributes are typical of ponds:
- Ponds and ditches form small waterbodies that can be permanently or seasonally (temporarily) filled with standing water.
- Plant species range from those which live in deeper water, to those in marginal areas.
- Ponds and wet ditches are important for aquatic invertebrates, including damselflies, dragonflies, beetles, caddisflies, snails, water boatman and water scorpions. Dragonflies and damselflies are useful indicator species for healthy ponds (see Figure 8 for examples).

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- Provides breeding habitat for amphibians, refuge and feeding habitat for grass snakes, water voles and wetland birds.

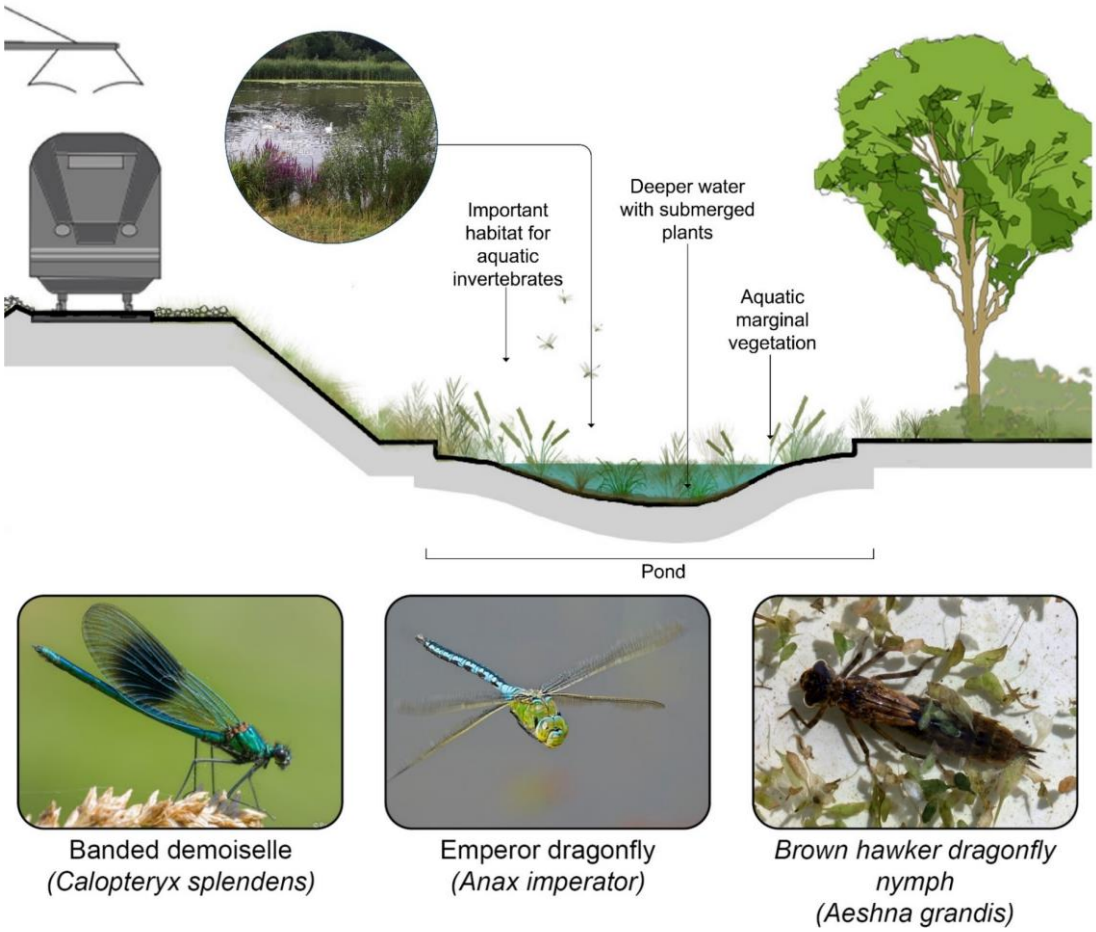

Figure 8 – Example of typical lineside pond habitat and example invertebrate species

5.3 Wetland development cycle

Figure 9 illustrates the wetland development cycle. This cycle, which applies to all wetland habitat types, progresses naturally over time. Figure 9 assists in understanding which development phase a wetland habitat is in. This can inform its future management.

Best practice management techniques and associated operational considerations can be found in the following relevant sections of the document as outlined below. For best practice guidance on designing new wetland, refer to section 6.4.

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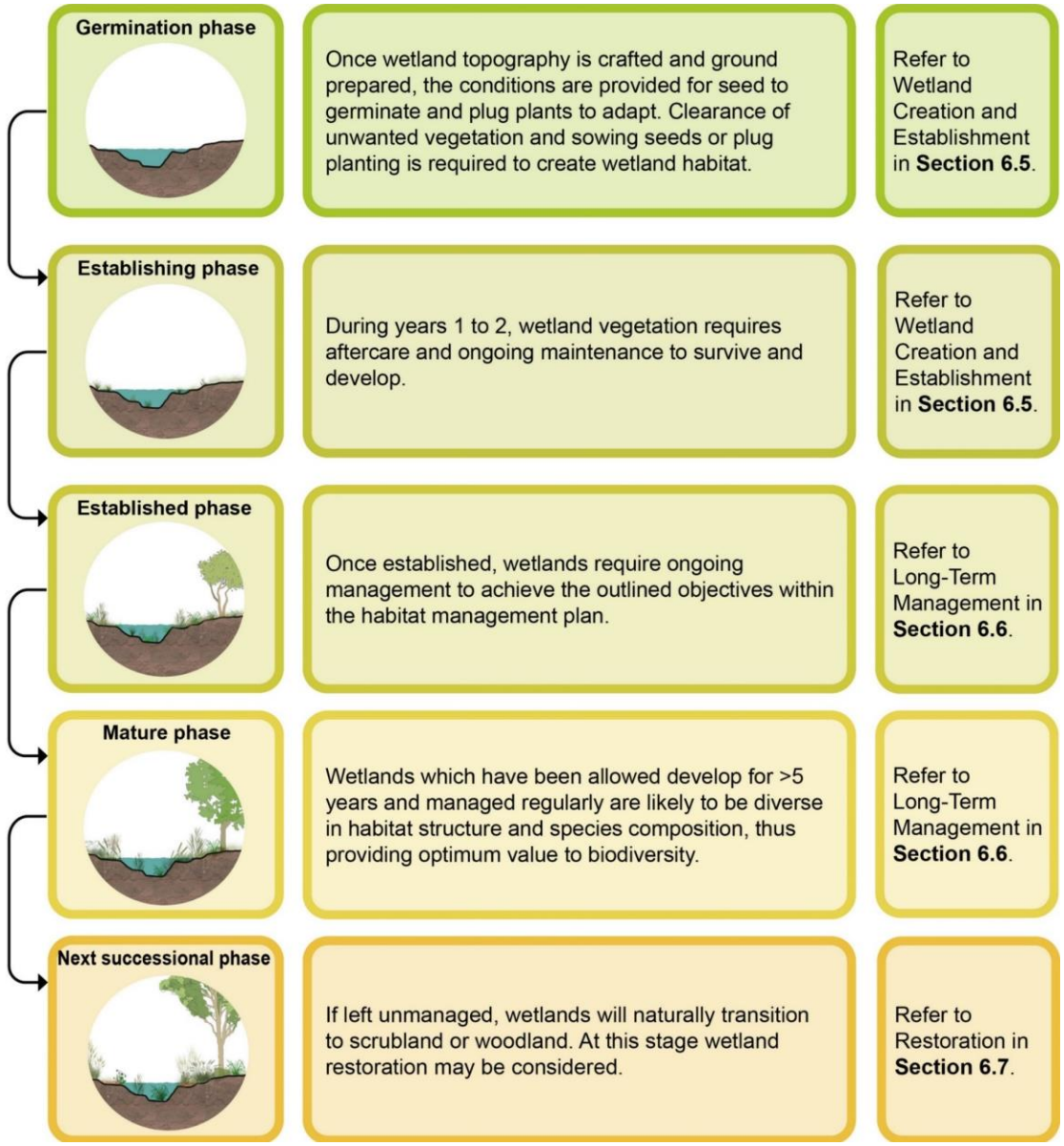

Figure 9 – Phases of wetland development cycle: applicable to all wetland habitat types

NOTE: *Anticipated costs of different stages in wetland management are addressed in the cost summary folder.*

The remaining sections within Section 5 include key design and management considerations relevant to all phases of wetland habitat development.

5.4 License requirements

This section details the legal requirements and need for licences if designated sites, protected species or priority wetland habitats are encountered.

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5.4.1 Designated sites

Sites of Special Scientific Interest (SSSI) are protected under the Wildlife and Countryside Act (1981). Certain habitat management, such as changing a grazing regime within a SSSI will require consent from Natural England, NatureScot or Natural Resources Wales.

Wetland situated within Special Protection Areas (SPA), Special Areas of Conservation (SAC) and designated Ramsar Sites may also need assessment under the UK Habitat Regulations before proceeding with works.

5.4.2 Protected species

Many species are protected under UK and European law. Protected animals most associated with wetland include great crested newt, European otter, Eurasian beaver, European water vole, grass snake, European eel, white-clawed crayfish, little ramshorn whirlpool snail and wetland birds. Protected plants most associated with wetland include floating water plantain (*Luronium natans*), fen orchid (*Liparis loeselii*), marsh saxifrage (*Saxifraga hirculus*) and slender naiad (*Najas flexilis*) (Gov.uk, 2015).

5.4.3 Protected species licenses

Where protected species may be at risk of disturbance or other harm, protected species licences may be required. A professional ecologist can advise on license requirements and appropriate mitigation. This may include consulting the following relevant government bodies prior to the implementation of wetland creation or management activities:

- Natural England: https://www.gov.uk/guidance/wildlife-licences
- NatureScot: https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/licensing
- Natural Resources Wales: https://naturalresources.wales/permits-and-permissions/species-licensing/?lang=en
- Environment Agency: https://www.gov.uk/guidance/protected-species-how-to-review-planning-applications#consult-natural-england-or-the-environmental-agency

5.4.4 Other consents

Several wetland habitats including ponds, eutrophic standing waters and reedbeds are recognised as Habitats of Principal Importance for the Conservation of Biodiversity under the Post-2010 Biodiversity Framework to meet the requirements of the NERC Act 2006. Where present within the lineside estate, management of these wetland must be prioritised. This is to ensure that management of priority wetland is programmed early due to the appropriate season for management being relatively short.

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Where fish removal / movement is required, relevant consents including fish health checks and fishing with other means other than rod and line are required. This will need to be completed by aquatic specialists.

NOTE: *Consents and permits for fisheries surveys are granted by the Environment Agency https://www.gov.uk/guidance/permission-to-move-live-fish-to-or-from-a-fishery; Scottish Environment Protection Agency Freshwater fisheries licensing - gov.scot (www.gov.scot) and Natural Resources Wales https://www.smartsurvey.co.uk/s/2D05CO/?lang=502555;*

NOTE: *Budget costs of works to specific areas or management interventions requiring statutory consent are outlined in the cost summary folder.*

NOTE: *For a full list of protected animals refer to Schedule 5 of the Wildlife and Countryside Act 1981: https://www.legislation.gov.uk/ukpga/1981/69/schedule/5.*

NOTE: *For a full list of protected plant species refer to Schedule 8 of the Wildlife and Countryside Act 1981: https://www.legislation.gov.uk/ukpga/1981/69/schedule/8*

5.5 Biosecurity

5.5.1 Invasive non-native species

Wetland associated with lineside habitat are more likely to be colonised by INNS due to transport and watercourse corridors, transmitting seed and the general greater level of disturbance that occurs. Several INNS listed on Schedule 9 of the Wildlife and Countryside Act (1981) can colonise wetland habitat. Under this Act it is illegal to plant or otherwise cause to grow any plant species listed. Examples of these are provided in Figure 11. Presence of these species may cause delay or change to the Preferred Habitat Objective.

If non-native species, listed in Schedule 9, or otherwise known to be invasive (see NOTE) are found within a site, a Network Rail ecologist should be contacted, in order to devise a plan in which the species can be removed and safely disposed of without causing spread. In this instance, the landowner is duty bound to take action to prevent spread of the species.

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Himalayan balsam
(Impatiens glandulifera)

Floating pennywort
(Hydrocotyle ranunculoides)

Curly leaved waterweed
(Lagarosiphon major)

New Zealand pygmyweed
(Crassula helmsii)

Water fern
(Azolla filiculoides)

Parrot's feather
(Myriophyllum aquaticum)

Figure 10: Example of plant INNS associated with wetland sites

American mink

Signal crayfish

Figure 11: Example of animal INNS associated with wetland sites

NOTE: *Refer to Schedule 9 of the Wildlife and Countryside Act (1981) and gov.uk guidance for a full list of invasive non-native species: https://www.legislation.gov.uk/ukpga/1981/69/schedule/9 and https://www.gov.uk/guidance/invasive-non-native-alien-plant-species-rules-in-england-and-wales#list-of-invasive-plant-species*

NOTE: *Refer to https://www.gov.uk/guidance/prevent-the-spread-of-harmful-invasive-and-non-native-plants for information on removing invasive and non-native plants.*

5.5.2 Pests and disease

Pests and diseases associated with wetland habitats are diverse and prevalent across many locations in the UK.

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Examples include:

- **Filamentous algae**: microscopic plants that form colonies. The colonies link together and form thread filaments. Filamentous algae usually grow on hard surfaces (including submerged surfaces), and when become lose, form floating mats.
- **Nuttall's waterweed**: waterweed that grows completely submerged and can grow up to 3m long.
- **Lemna:** free-floating plant (also known as "duckweeds") that grows rapidly.

Filamentous algae

Nuttall's waterweed

Lemna

Figure 12 – Example of pests and diseases associated with wetland habitats

By implementing proactive biosecurity measures, the risk of introducing or spreading wetland pests and diseases can be reduced.

This can be achieved by:

- Referring to government guidance on the requirements for plant passports, quarantining affected planting stock, removing diseased vegetation and reporting suspected pest and disease attacks (Defra, 2020);
- Planning, monitoring and reporting of concerns to identify issues through the UK Plant Health Information Portal: https://planthealthportal.defra.gov.uk/
- The use of locally prevalent species sourced from plants grown within the UK (Natural England, 2007); and
- Establishing biosecurity protocols on site, for example regular cleaning of equipment with disinfectant..

NOTE: *For more guidance on species selection refer to Section 6.4.*6

NOTE: *Anticipated costs of INNS management are addressed in the cost summary folder.*

NOTE: *Anticipated costs of disease management are addressed in the cost summary folder.*

5.6 Reintroduced species

The reintroduction of indigenous species, which have become extinct within the UK, or within a local area, is starting to be considered more widely as a mechanism to restore or rewild Britain's landscapes.

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Eurasian beavers are native to Britain but were hunted to extinction in the 16th century. More is now understood about their ability to modify wetlands in a way which benefits other wildlife. For example, by felling trees and creating dams, beavers can help prevent downstream flooding and create habitat for other wetland species, such as amphibians and fish. To date, beavers have been reintroduced into the Scottish Highlands, western England and Kent, as part of landscape scale restoration projects, with more reintroductions planned for other regions.

Where they have been reintroduced, beavers can occasionally dam up culverts. Where this occurs an ecologist should be consulted to determine whether remediation works are required. Typically, where beaver created wetlands are present within the lineside, such habitat should be retained providing it does not pose a health and safety risk to the railway, given the value to biodiversity the habitat provides.

NOTE: *Beavers were provided European Protected Species status in Scotland in 2019. The removal of mature beaver dams in Scotland must be undertaken under licence from Nature Scot: https://www.nature.scot/professional-advice/protected-areas-and-species/protected-species/protected-species-z-guide/protected-species-beavers. If a dam is found on site, an ecologist must be consulted to determine the need for a licence if the dam must be removed.*

Figure 23 – Eurasian beaver, gnawed wood and dam

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6 Wetland Design and Management

6.1 Introduction

This section provides guidance on:

- General considerations related to the design and management of wetland;
- The design of new wetland habitat;
- Maintenance required to establish new wetland habitat;
- Long-term management of wetland habitat; and
- Restoration of wetland habitat.

Each section includes practical guidance and makes reference to tables in the cost summary folder to understand the budget costs of carrying out work.

NOTE: *Professional expertise should be sought to throughout the process. For example, an experience ecologist should be consulted to determine the Preferred Habitat Objective and objectives set out in the site Habitat Management Plan. In addition, landscape advice should be sought where design, implementation, and management advice are needed.*

6.2 Habitat management plans

In addition, Network Rail's requirements for Habitat Management Plans are set out in NR/L2/ENV/122 Module 02.

According to the Habitat Design and Management Guidance Note, Habitat Management Plans should incorporate Short to Long-term objectives. Objective periods for wetland differ in relation to other habitats, due to a differing development cycle (see Section 5.7). Objective periods for wetland are likely to be as follows:

- *Short-term* (year 0 to 5);
- *Medium-term* (year 6 to 15); and
- *Long-term* (year 15+).

NOTE: *Refer to NR/L2/ENV/122 Module 02 for information on the requirements for Habitat Management Plans.*

NOTE: *Management objectives should be reviewed against data collected via monitoring (see Section 6.6.3.).*

6.3 Ecosystem services and design considerations

As outlined in the Habitat Design and Management Guidance Note, an initial site appraisal can help identify ecosystem services present and the potential to expand the range provided by the lineside. This will help inform decisions on whether wetland is the preferred habitat for the site and how wetland is designed or managed.

Wetland within the lineside can provide a range of ecosystem services. These include:

- **Biodiversity**: supports a wide range of species which provide further ecosystem services such as pollination;

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- **Habitat connectivity:** networks of habitat enhance permeability of the landscape for species, greater genetic viability and increased resilience;
- **Water regulation**: can reduce the rate at which water meets waterbodies and watercourses; reducing the occurrence of flash flooding downstream;
- **Water filtration**: aquatic and marginal vegetation can act as a filter to pollution and agricultural runoff, cleaning fresh waterbodies.
- **Carbon sequestration:** carbon sequestration of wetland provide benefits including improved health and protection against climate change;
- **Health and wellbeing:** access to semi-natural habitats provides physical and mental health/wellbeing benefits to people;
- **Landscape integration**: can improve lineside aesthetics and integrate the landscape with the wider setting.
- **Nutrient and contaminant removal:** wetland promotes biogeochemical reactions that remove nutrients and contaminants, such as pollutants, from water.

NOTE: *Ecosystem services of the land should be identified when fieldwork is undertaken. This should be determined by an environmental specialist, using professional judgement. Refer to the Habitat Design and Management Guidance Note, for more information on ecosystem services.*

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6.4 Wetland Habitat and Design

This section provides advice on the design of new wetland within the lineside and key considerations for implementation.

Good wetland design should seek to achieve the following:

- Maximises biodiversity whilst not impeding its primary function;
- Resilient and diverse plant species mix that enhances the biodiversity value of the habitat;
- Successful establishment;
- Combining management operations to minimise costs associated with site access and operational restrictions;
- Connections to adjacent wetland habitat to create wetland corridors, stepping stones or habitat mosaics;
- Use of nature-based solutions, such as use of willow brush matting to aid bank stability, instead of traditional engineering and management solutions; and,
- Maintain the safety and performance of the lineside.

NOTE: *The value of wetland habitats is greatly increased if they are connected and managed as part of a nature network.*

NOTE: *Anticipated costs of wetland creation are addressed in the cost summary folder.*

NOTE: *Seek advice from an experienced specialist (e.g. ecologist) where designated sites, protected habitats or species are known to be present on site.*

NOTE: *If wetland creation is being considered within an urban setting, refer to the Urban and Brownfield Design and Management Guidance Note for guidance on design and implementation for urban wetland.*

6.4.1 Operational considerations for wetland

Creating or enhancing wetland habitats in close proximity to the railway requires consideration of the key site-specific constraints to operational rail use.

Typical operational considerations for a wetland appraisal may include:

- Flooding;
- Steepness or stability of embankments and cuttings;
- Accessibility;
- Lineside width and the proximity to the line;
- Protected species or protected habitats and sites;
- Abundance of dominant shrub (e.g. bramble) on adjacent land;

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- Likelihood of the wetland acting as a catchment for rubbish and pollution; and
- Security, e.g. discouraging public access.

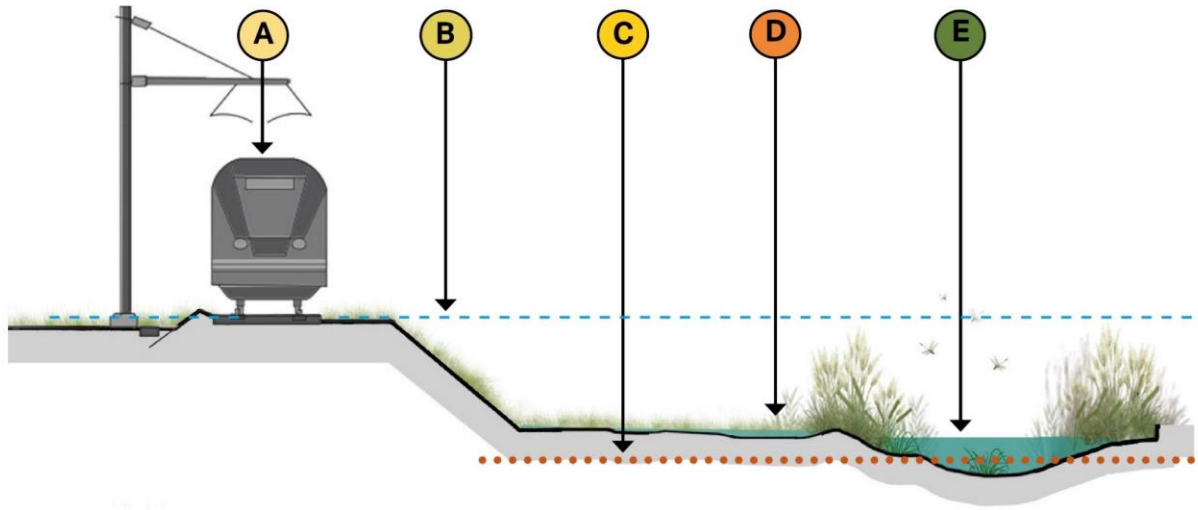
NOTE: *Refer to NR/L3/OTK/6202 Protecting Railway Assets During Vegetation Work for guidance on protecting railway assets.*

6.4.2 Site selection

The suitability of a site for wetland habitat creation should be assessed through the habitat study and site appraisal and should align with the Preferred Habitat Objective. This includes consideration of safety aspects of railway operations, habitat opportunities and constraints. Guidance on the process of recording and analysing this data is found in the Habitat Design and Management Guidance Note.

Where wetland features (e.g. ditches) are already present, the primary function should be determined (refer to Section 6.4.3.2).

However, where wetland is not present, observations made on site are likely to indicate opportunities for creating wetland habitat but may also indicate that the site is unsuitable. Some indicators of wetland habitat creation opportunities are illustrated in Figure 14. The visual indicators illustrated in Figure 15 relate to considerations which may make wetland habitat creation difficult.



A Railway line higher than adjacent lineside
Railway line should be a safe distance above proposed wetland creation to ensure if flooding does occur lineside operations are not impacted.

B Site prone to flooding
If flooding occurs regularly, additional drainage features may be required to avoid unnecessary damage and delays to the lineside operations.

C Site with high water table
Excavation in the ground will fill with water to the level of the water table.

D Waterlogged sites
Waterlogged sites and naturally occurring wetland loving plants can indicate that ground conditions are suitable for wetland creation.

E Wetland nearby
Nearby wetlands are a good indication that conditions are suitable to create new wetland within the lineside.

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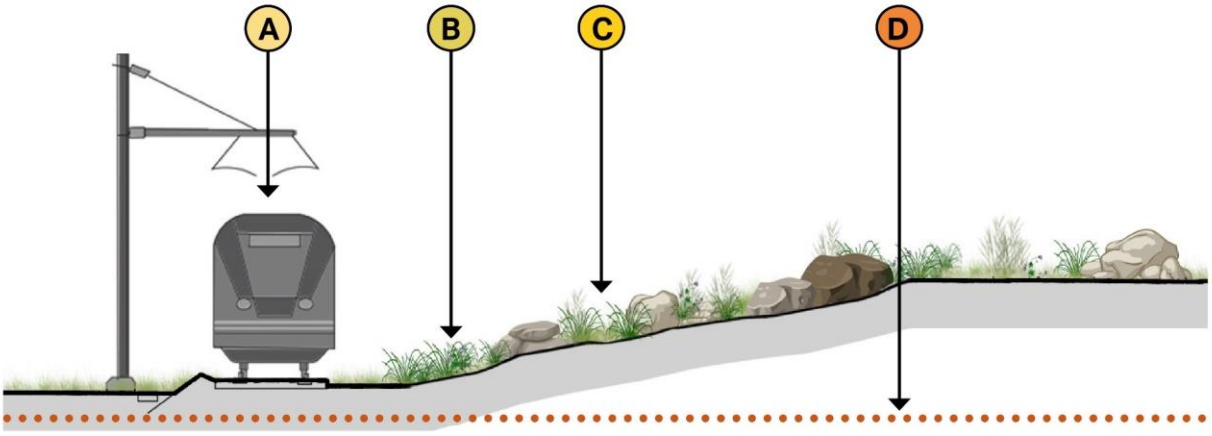
Figure 14 – Features which may indicate a site's suitability for wetland creation



A Railway line lower than adjacent lineside
To avoid damage from flooding of wetland areas, railway lines should be a safe distance above the adjacent ground level.

B Presence of INNS
INNS should be appropriately eradicated from the site prior to wetland creation being considered.

C Unsuitable site conditions
Unstable or unsafe ground conditions, such as rocky embankments, where regular safe access is not viable should not be used for wetland creation.

D Sites with low water table
Site with dry ground conditions and a low water table do not provide a suitable source of water for wetlands to thrive.

Figure 15 – Features which may indicate that a site is unsuitable for wetland creation

6.4.2.1 Connectivity

Increasing connectivity between wetland habitats can aid movement of plants, animals and resources such as water, nutrients, oxygen and carbon (Rittenhouse *et al*., 2018).

Where possible, creating ponds, ditches and areas of wetland vegetation nearby other wetland can help to provide stepping stones that create corridors for wetland species.

However, connecting waterbodies should be avoided where pollution and INNS have been identified , as this can increase environmental damage. Understanding the nature, condition and connectivity of surrounding wetland habitats is therefore essential. This can be done by taking water samples from nearby waterbodies to a laboratory for analysis and undertaking surveys to confirm and address sources of pollution, such as agricultural run-off, and INNS within the local area.

NOTE: *Refer to Freshwater Habitats Trust for more information on testing waterbodies for microbiological and chemical pollutants: https://freshwaterhabitats.org.uk/projects/clean-water/kit/*

NOTE: *when taking water samples from waterbodies, the following British Standard guidance should be following - BS EN ISO 5667-6 Water Quality. Sampling. Guidance on sampling of rivers and streams.*

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6.4.3 Hydrology

Hydrology will largely dictate what type of wetland habitat can establish on a site. The following principles are integral to understanding what wetland habitat can be accommodated within a site:

- **Water table:** different wetland habitats are adapted to establishing under different water levels, including the water table beneath the ground. On sites where the water table is permanently high, depressions or scrapes created in the ground will fill with water to the water table level (TCV Conservation Handbook). The water table should therefore be tested before a habitat is designed (see Figure 16) as part of the site appraisal stage (refer to the Habitat Design and Management Guidance Note.

  This process also indicates whether the water table is 'permanent' or 'perched'. A 'perched' water table is where clay overlays a permeable substrate such as gravel; if the clay is breached when creating a depression, the water table will drop lower. Figure 16 illustrates how a dip well can be used to determine the water table and whether water will drain or form pools when holes are dug, if it is not visible above ground; alternatively, trial holes can be dug.

  The minimum level of the water table for each wetland habitat is as follows:

  - **R1a Ponds**: water table above ground for at least four months of the year.
  - **F2d Aquatic marginal vegetation:** water table may be submerged for long periods of the year or relatively dry with damp soils.
  - **F2e Reedbeds:** water table at or above ground level for most of the year. Can appear dry for most of the year, although the water table is likely to be high (i.e. damp soils).
  - **F2f Other swamps:** water table at or above ground level for most of the year. Can appear dry for most of the year, although the water table is likely to be high (i.e. damp soils).

***NOTE**: Visibly dry soils of riparian habitats such as reedbeds, other swamps and marginal habitats can occur due to silt build up. Refer to the Environment Agency's Aquatic and Riparian Plant Management Technical Guide for more information:*
https://assets.publishing.service.gov.uk/media/6034e181d3bf7f26576beefa/SC120008-R2_Technical_guide.pdf

- **Soil type:** soils and geology dictate the rate of drainage from a site. For example, clay soils are more impermeable to water than sandy soils, making it difficult for water to drain. In addition, sandy soils are likely to be unsuitable for pond creation unless the water table is high. Whilst water may pool on clay soils more easily, they are less likely to be fed by groundwater and dry out more frequently.
- **Fluctuating seasonal water levels:** water levels naturally fluctuate according to the season and weather, directly influencing the type of vegetation that can grow.

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NOTE: *Dip wells or trial holes should be dug between autumn and spring, where possible, as the water table is likely to be at its lowest during summer.*

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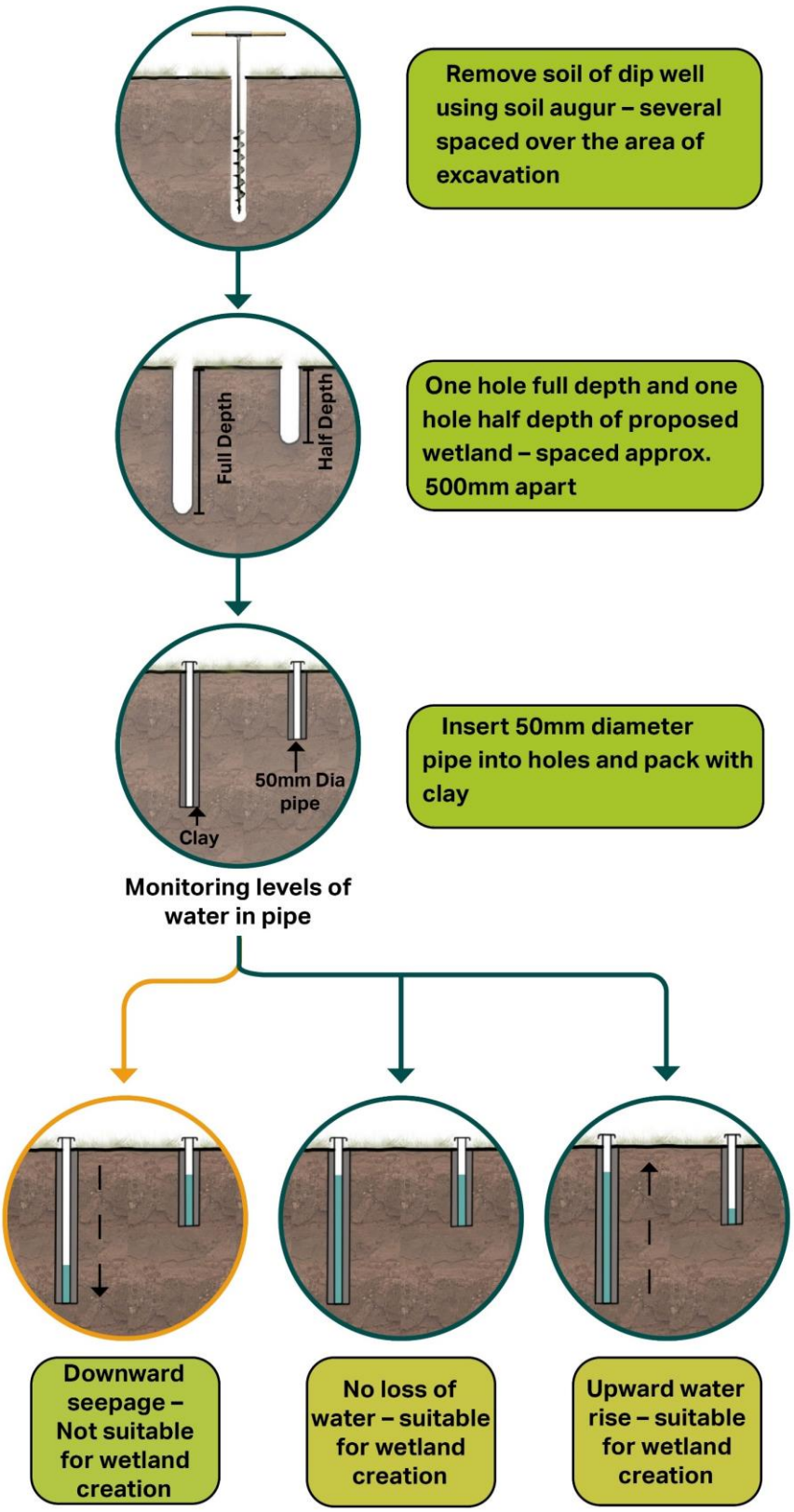

Figure 16 – Assessing ground water levels using a dip well

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6.4.3.1 Water flow

Water flow can have both positive and negative impacts upon wetland. It can oxygenate the water and allow species to colonise new areas, but it can also introduce pollutants, phosphates and nitrates and sediment resulting in siltation.

- **Connected networks:** understand whether the waterbody is isolated or part of a network of wetlands. Refer to Section 6.4.2.1 for more information.
- **Siltation and eutrophication**: where water flows between connected waterbodies or wetland, sediment and nutrients can flow downstream potentially causing issues relating to siltation or eutrophication (Freshwater Habitats, 2013). Whilst creating wetland near other wetland is beneficial for biodiversity and ecosystem services (e.g. flood prevention), ponds should not be connected to prevent these issues from occurring. Section 6.6 outlines how silt build-up and eutrophication can be rectified.

NOTE: *To understand how different plant species can contribute to silt build-up and for information on how to manage to prevent silt build up refer to the Environment Agency's Aquatic and Riparian Plant Management Technical Guide:*
https://assets.publishing.service.gov.uk/media/6034e181d3bf7f26576beefa/SC120008-R2_Technical_guide.pdf

NOTE: *Refer to the Environment Agency's Channel Management Handbook for more information on silt build-up and solutions to rectifying and preventing it. Solutions such as silt traps can be considered if siltation is a frequent issue:*
https://assets.publishing.service.gov.uk/media/603500cad3bf7f265b74bbb2/Channel_management_handbook.pdf

6.4.3.2 Primary function

There are two types of wetland which are likely to be encountered or created. Those which are designed as drainage features, directing water away from or beneath the railway infrastructure, and semi-natural wetland which allow drainage but primarily function as a habitat. Even if a wetland's primary function is drainage, they should be designed to accommodate as many features to maximise biodiversity as possible.

Figure 17 outlines the decision-making process which should be followed when determining the primary function of a proposed wetland. Where the primary function is drainage, Section **Error! Reference source not found.** outlines how to design drainage features for biodiversity. Where the primary function is biodiversity, semi-natural wetland is preferred. Design considerations for semi-natural wetland are discussed in Section 6.4.5.

NOTE: *The Primary Habitat Objective is determined after desk studies and data analysis is complete for a site. Refer to Habitat Design and Management Guidance.*

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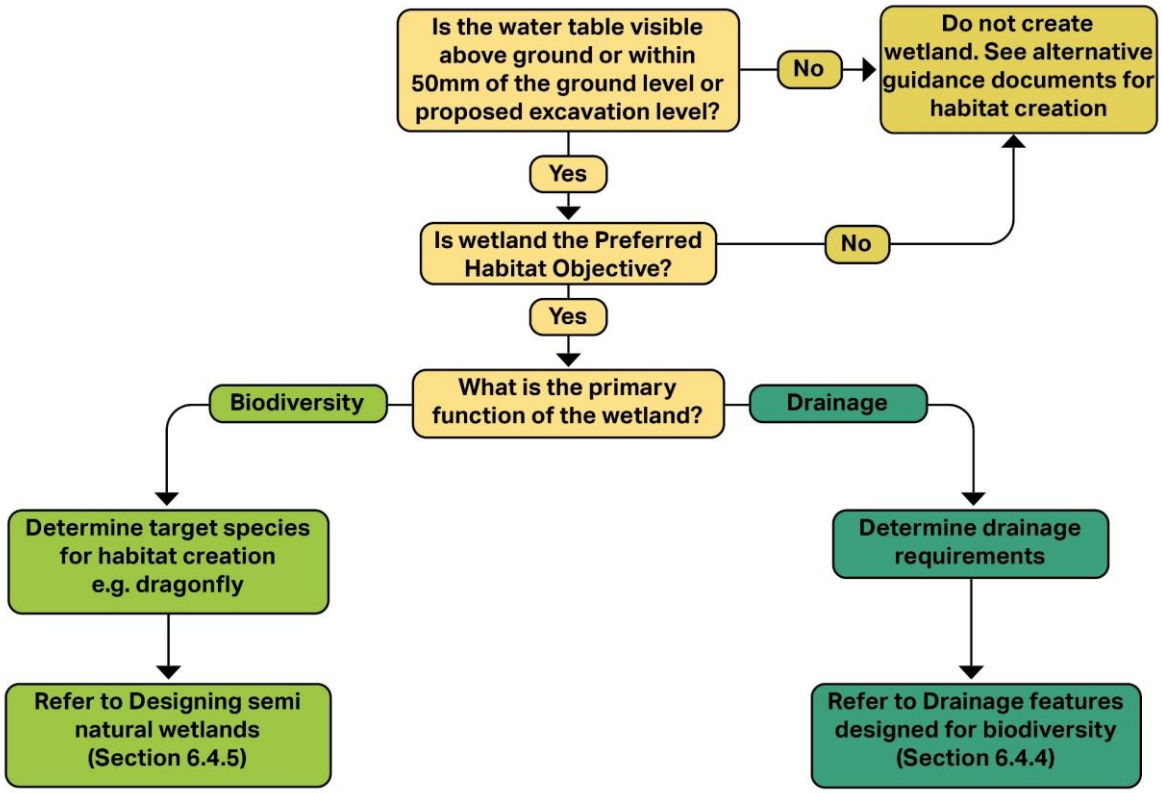

Figure 17 – Process to determine the primary function of a proposed wetland

6.4.4 Drainage features designed for biodiversity

Most wetland created in lineside spaces are likely to be required for drainage purposes. As drainage features are typically engineered solutions, they often provide low value for biodiversity. However, if designed appropriately, drainage features can offer habitats of value to a variety of wildlife. The following should be considered when designing drainage features:

- **Sustainable drainage features**: such as swales and attenuation ponds can be designed to provide effective drainage whilst benefiting biodiversity. Example are provided for bioswales and attenuation ponds in Figure 18 and Figure 19.
- **Avoiding silt build-up:** drainage features should include plant species that will avoid significant leaf fall or contribute to the accumulation of dead vegetation at the end of a season, as this can lead to silt build up and loss of drainage function.

Figure 18 illustrates a drainage feature with low growing aquatic marginal vegetation. Due to the size of vegetation, silt build-up is likely to be limited preventing drainage from becoming impeded. Semi-natural habitats, such as reedbeds can be planted around the feature. It is recommended that larger plants such as Willow and Alder are planted at least 2 metres away from any drainage features to prevent silt build-up. Section 6.6.1.1 outlines how to manage riparian vegetation.

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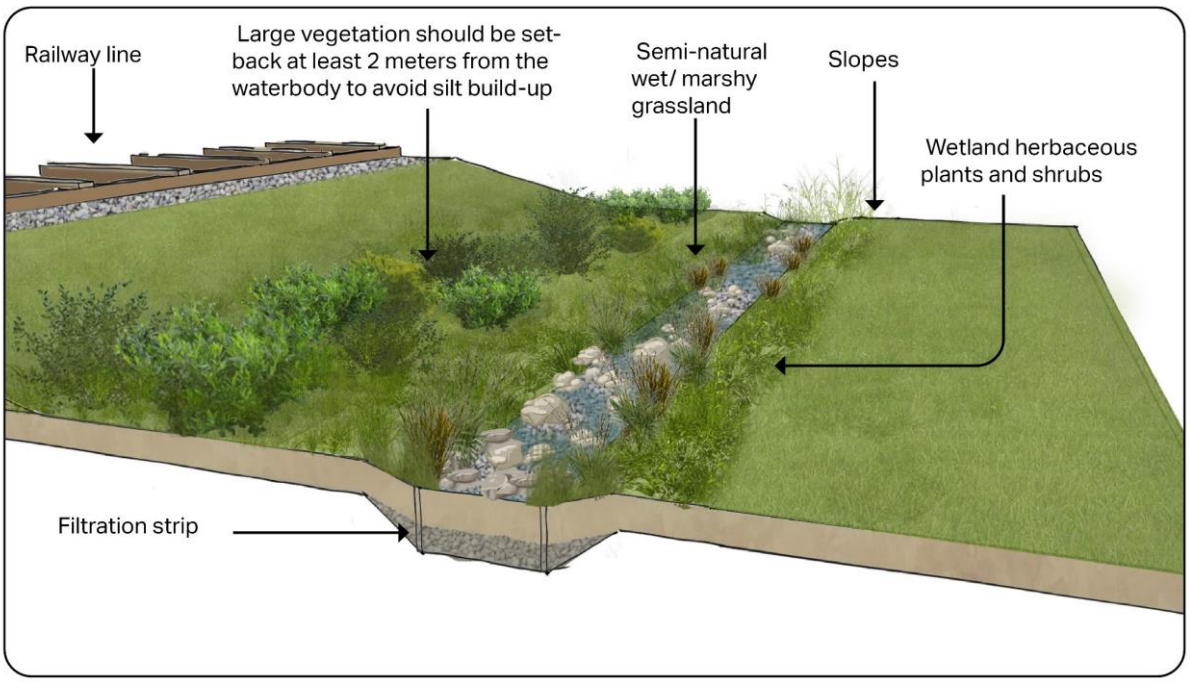

Figure 18 – Swale designed for biodiversity 'Bioswale'

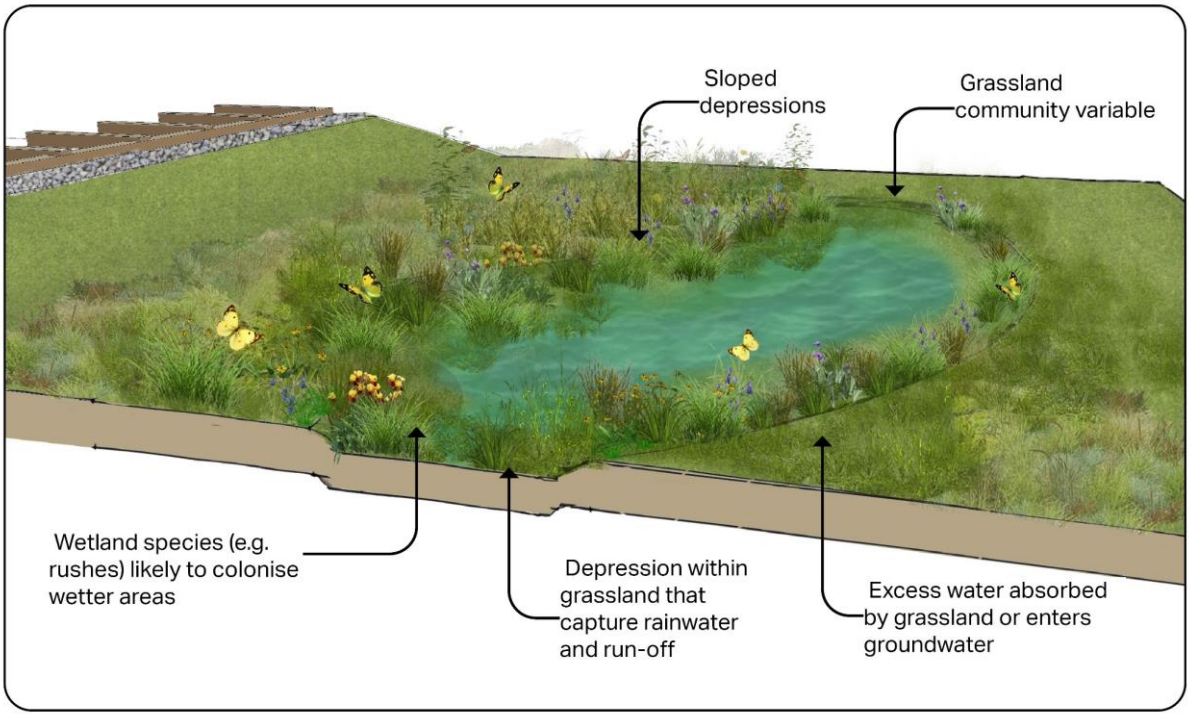

Figure 19 – Attenuation pond designed for biodiversity

6.4.5 Designing semi-natural wetland

In circumstances where wetland is the Preferred Habitat Objective and the primary function is biodiversity (see Figure 17) semi-natural wetland habitat is preferred over sustainable drainage features, as they typically support a greater range of wildlife.

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When designing a waterbody principally for biodiversity, the following features should be considered (Figure 20 illustrates some of these features):

- **Varied topography and shelfing**: structural variation in wetland allows for greater diversity of plant, insect, amphibian and fish communities to colonise in waterbodies. This can easily be achieved by varying the topography and creating a series of shelves. Where possible, include multiple shelf depths, ensuring that the shelves are no more than 25-30cm deep to encourage aquatic invertebrates (Pond Conservation, 2011), with the highest shelf no more than 6cm below the water surface to allow mammals to escape. Varying the edge profile of each shelf can also add structural diversity. Alternatively, creating reefs and ledges using stones or bricks within ponds and ditches can provide refuge for amphibians and invertebrates.
- **Water depth:** shallow waterbodies are generally better for biodiversity, as most aquatic life is found within shallow water. Where fish are not to be stocked, it is preferable to create shallow waterbodies no deeper than 20-30cm (Freshwater Habitats Trust, 2013).
- **Shallow exit slopes:** incorporating gradual, shallow slopes or "beach areas" (maximum 12^{o} angle, preferably 3^{o}) with no planting can aid animals, such as mammals and amphibians to exit the pond (Freshwater Habitats Trust, 2013). The shallow end should be orientated into the prevailing wind if possible, to allow the wind to blow across the pond and create ripples which will help oxygenate the water (see Figure 20).
- **Variety of wetland habitats:** a variety of plant communities generally leads to greater biodiversity. For example, providing a mix of marginal, submerged and emergent aquatic plants, and planting tall vegetation adjacent to the waterbody, such as trees, provides some shading and a variety of refuge spots for different plants and animals. Planting design should provide areas of different aquatic and semi-aquatic species (see Section 6.4.6).
- **Avoid using topsoil:** topsoil is likely to be nutrient rich. Nutrient rich soils can result in algal blooms in waterbodies and growth of fast-growing undesirable species such as common nettle in marginal habitats. Soils and substrates present on site should be used. Gravel and rocks can also be introduced into waterbodies to provide habitat complexity and in such cases should mimic the local soil's geology.

NOTE: *For information on designing ponds for wildlife, refer to the Sussex Wildlife Trust's Pond Creation & Enhancement for Landowners: https://assets.sussexwildlifetrust.org.uk/pond-creation.pdf and Freshwater Habitat Trust's Pond Creation Toolkit Sheet 4: https://freshwaterhabitats.org.uk/wp-content/uploads/2013/09/pond-design.pdf*

NOTE: *For information relating to slope, structural diversity and profile, refer to Freshwater Habitat Trust's Pond Creation Toolkit Sheet 4: https://freshwaterhabitats.org.uk/wp-content/uploads/2013/09/pond-design.pdf*

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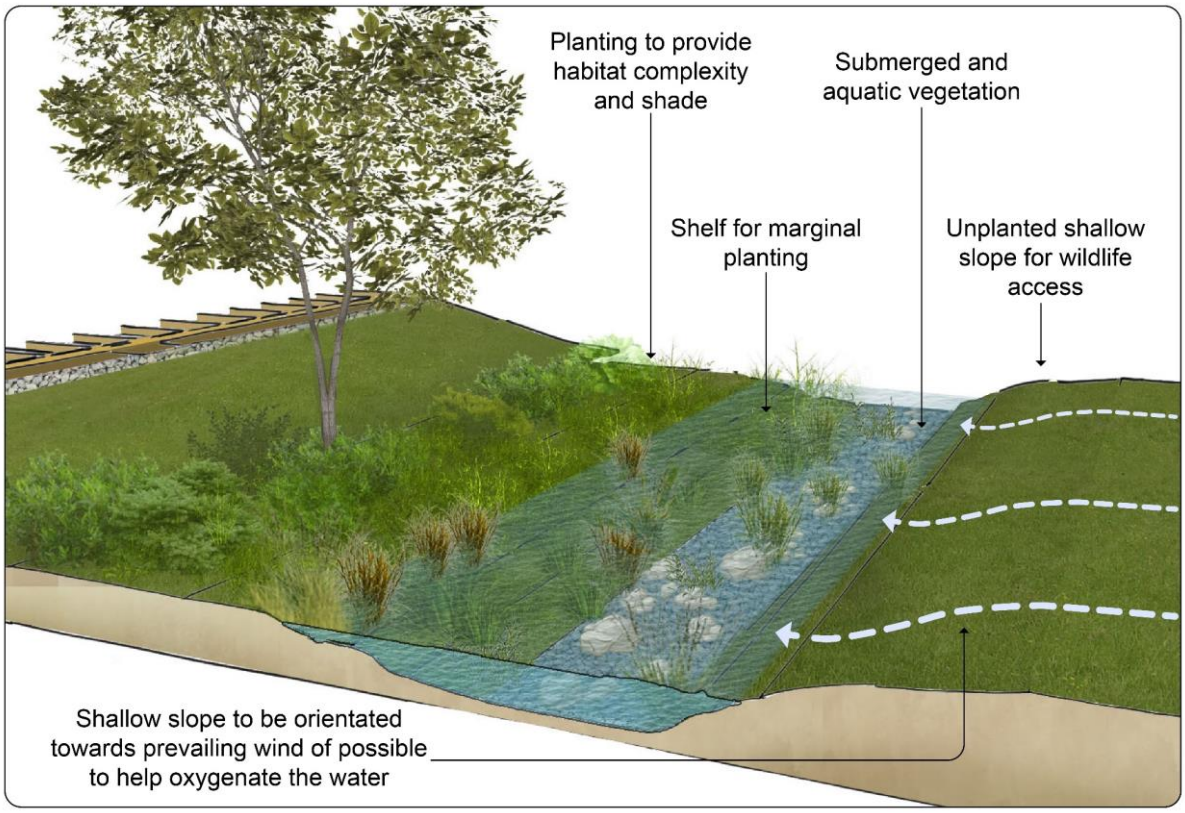

Figure 20 – Semi-natural wetland design features to promote biodiversity

NOTE: *For information of designing reedbeds for birds, refer to the RSPB's Reedbed Design and Creation Advice Note (2004)*
https://www.rspb.org.uk/globalassets/downloads/documents/conservation--sustainability/lm-advice/reedbed_design_and_establishment.pdf

6.4.6 Planting specification

The following design principles should be considered to maximise biodiversity:

- **Avoid monocultures**: plant a range of species at different planting densities. For example, plant individual plants of the same species in small groups, of three, five and seven.
- **Future operational requirements:** select species which can thrive under proposed future management associated with primary function and accessibility. For example, where a wetland's primary function is drainage, it may be more appropriate to plant species which will not overcrowd or lead to silt build-up. Alternatively, where access to a site is infrequent, selecting species which are low maintenance may be preferable.
- **Ponds:** select a range of species that provide different ecosystem functions, e.g. include submerged plants for improving habitat complexity and to oxygenate the water to ensure it does not become anoxic.
- **Species of local provenance:** ensure species planted are suited to the region or locality of Britain in which the wetland is being created. For example, a pond in

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Southern England may be planted with species adapted to a slightly warmer and drier climate compared to a pond created in Northern Scotland. Outside of urban areas, only plant species which have been recorded within 20km of the site (Freshwater Habitats Trust, 2013).

- **Planting material:** various types of aquatic plants can be sourced in different growing mediums. For example, aquatic plants can be sourced in baskets, in mats, as rhizomes, in seed form, as plug plants or in coir rolls.
    - **Plug planting:** plug planting immature plants is useful where quick establishment of a particular species is required within an existing habitat or to ensure establishment of certain species within a newly created wetland habitat. Success of establishment is highest when plug plants are selected according to the soil as detailed in Section 6.4.6.2. Irrigation is typically not needed unless planting during drought periods.
    - **Coir rolls and mats:** mats and rolls typically made of coconut fibres can be pinned or staked on the margins of waterbodies and within wetland. Coir can be pre-planted with aquatic or marginal plants (see Figure 28) and can be used to help limit the susceptibility of banks to erosion, particularly on larger bodies of water or streams. Products which incorporate plastics should be avoided.
    - **Translocating rhizomes:** planting the rhizomes of common reed plants is the most effective method of reedbed creation (Sussex Wildlife Trust, 2013). This involves cutting back reeds from a surrogate site, excavating the rhizomes and translocating them to the new wetland, where the rhizomes are planted into the soil. Over time, these rhizomes will establish into new reeds.
    - **Baskets:** certain aquatic plants may be provided in baskets. Whilst they are useful in establishing submerged and emergent plants, they are frequently made of plastic. If using baskets, where possible, remove the plastic before planting in order to prevent the plastic acting as a pollutant.

NOTE: *Sussex Wildlife Trust's note on creating reedbeds outlines how to create reedbeds using rhizomes: https://assets.sussexwildlifetrust.org.uk/create-and-manage-reedbeds-2.pdf*

- **Consider target animals:** select plants which support existing species e.g. water vole or great crested newt. Examples include:
    - **Great crested newt**: known to lay eggs on grasses, small wide-leaved and narrow-leaved submergent and marginal plants (Froglife, 2013) such as water mint (*Mentha aquatica*).
    - **Water vole:** feed on rushes (*Juncus spp*.), fools' watercress (*Apium nodiflorum*) and sedges (*Carex spp*.). They require steep grassy or muddy banks to create burrows in, or tall vegetation like reedbeds to create nests in (Sussex Wildlife Trust, 2013b).

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NOTE: *Pond Conservation's Creating Garden Ponds for Wildlife guidance outlines which vegetation and features are preferred by common aquatic invertebrate groups within ponds generally: https://freshwaterhabitats.org.uk/wp-content/uploads/2013/09/Creating-Garden-Ponds-for-Wildlife.pdf*

NOTE: *Species listed under Schedule 9 of the Wildlife and Countryside Act 1981and by the GB Non-Native Species Secretariat) should not be specified.*

Figure 21 provides examples of emergent, submergent and marginal plant species and how they relate to reedbeds, other swamp, ponds, ditches and other marginal vegetation. The species illustrated are examples only; species should be selected which are suited to the site's climatic and environmental conditions (refer to Section 6.4.9 on resilience and adaptability for more information).

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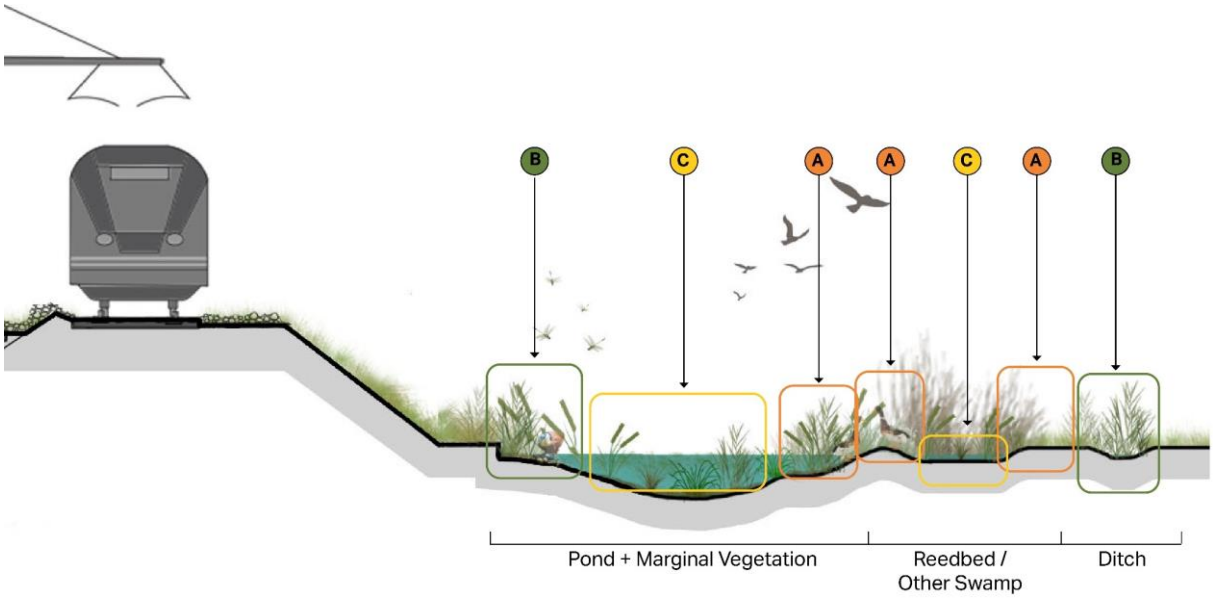
B
C
A
A
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B
Pond + Marginal Vegetation
Reedbed /
Other Swamp
Ditch

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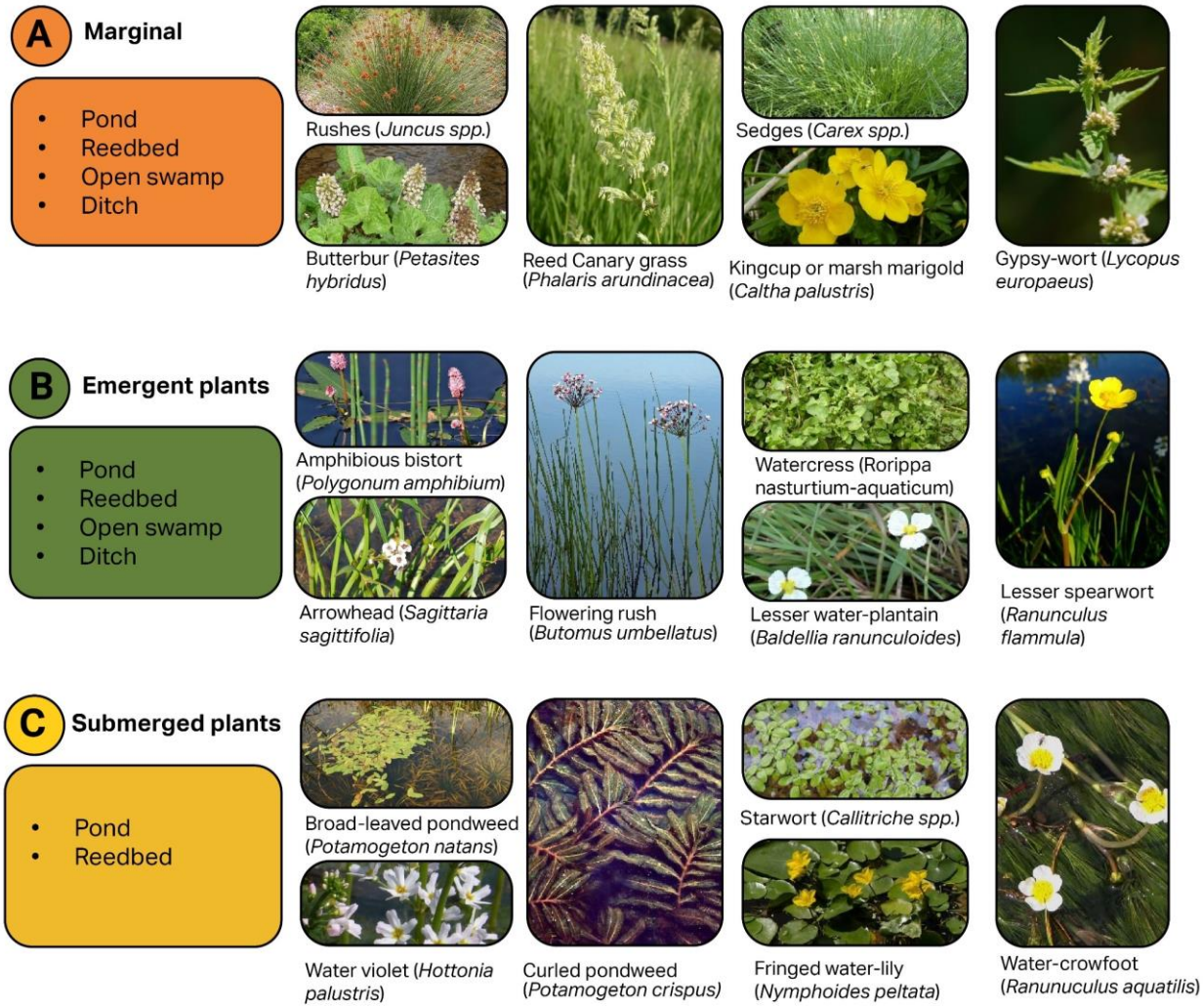

Figure 21 – Examples of wetland plant species according to habitat type

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6.4.6.1 Planting densities

When plug planting or planting rhizomes, the following densities should be considered for each wetland habitat:

- **Reedbed:** a density of 1-4 plants per square metre should be planted.
- **Other swamps:** a density of 1-4 plants per square metre if planting a combination of common reed and other species. If common reed is not specified, a density of 2-5 plants per square metre should be used.
- **Aquatic marginal vegetation:** A density of 2-5 plants per square metre should be used due to rapid growth.
- **Ponds:** A density of 2-5 plants per square metre should be used due to rapid growth.

NOTE: *Refer to the Freshwater Habitats Trust's guide on planting ponds for planting densities associated with ponds and marginal habitat* https://freshwaterhabitats.org.uk/wp-content/uploads/2013/09/Planting-Up-Ponds-FEB10_2.pdf

6.4.6.2 Soil

Soils are an important component of wetland habitats. In addition to water, the pH, soil type and nutrient levels within the soil will influence the type of wetland habitat that can establish. These properties need to be understood before designing wetland habitats:

- **Consult geospatial soil data:** open source data or maps which indicate the underlying soil type and bedrock within the location of a site. Landis' Soilscapes provides open source geospatial data which indicates the soil types and bedrock found across the British Isles. This could be used to get a broad understanding of the local soil type.
- **Take soil samples on site:** inspecting the site and taking soil samples for analysis is important to accurately determine existing soil type and pH. This can be done by taking several soil samples across a site and having them assessed within a lab which will indicate whether a site can support a neutral, calcareous or acidic wetland habitat. Plants which are known to establish and survive under the soil pH and soil type should then be selected. The pH range in which a plant species will establish can be determined by searching for each species on the Biological Records Centre's Online Atlas of British and Irish Flora's database. These are listed as 'Ellenberg – Reaction' values: https://www.brc.ac.uk/plantatlas/content/ellenberg-reaction

NOTE: *Magnificent Meadow's Advice Note on Soil Testing and Assessing Soil Texture outlines how soil samples should be taken within a site and prepared for analysis within a lab* *http://www.magnificentmeadows.org.uk/assets/pdfs/Soil_Nutrient_Testing.pdf*

NOTE: *Various companies offer soil testing and analysis which is undertaken in a lab. The Soil Association offers a list of companies which offer soil testing services:* *https://www.soilassociation.org/farmers-growers/technicalinformation/improve-your-soil/soil-testing-companies/*

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6.4.6.3 Fresh and brackish water

Brackish water may be encountered where railway lines are near to the sea, estuaries or tidal rivers. Understanding whether a waterbody contains fresh or brackish water is important, as the salinity of the waterbody influences the types of plant and animal communities that will colonise it. Brackish waterbodies tend to have fewer, but more adaptable species as opposed to fully freshwater waterbodies which often have a greater species diversity.

If the wetland is adjacent to the sea, a tidal river or an estuary, a water salinity test should be used to inform habitat selection and planting specification.

Figure 22 provides examples of species adapted to brackish water which may be found in wetland in tidally influenced areas (Environment Agency, 1995).

Soft hornwort *(Ceratophyllum submersum)*

Brackish water-crowfoot *(Ranunculus baudotii)*

Horned pondweed (Zannichellia palustris)

Figure 22 – Examples of brackish water plant species

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6.4.7 Approaches to vegetating wetland habitat

There are three main approaches to vegetating new wetland. These are:

- **Planting:** typically involves plug planting seedlings or planting submerged and emergent plants using trays, baskets or nets (Section 6.4.6. for information on planting materials).
- **Natural regeneration**: plants are allowed to naturally colonise prepared ground from surrounding areas. Whilst cheaper, habitats which establish are unlikely to be as diverse as those created by assisted creation. In most cases, wetland created using this technique will be dominated by one or two species and will take longer to reach the established or mature phase. Intensity of management post-establishment is also likely to be higher, as maintenance will be required to remove undesirable species.
- **Combined approach**: in some circumstances a combination of planting and natural regeneration may be preferable. This could include planting certain plant communities, such as those which take longer to establish, to ensure successful establishment, and allow other plant communities to naturally colonise.

6.4.8 Sourcing plant material

Successful wetland establishment is influenced by the quality of plants and requires robust procurement processes. Species listed within Schedule 9 of the Wildlife and Countryside Act 1981, and species with invasive properties should not be specified.

Plants should only be sourced from suppliers that comply with government regulations such as the Seed Marketing Regulations 2011. Before sourcing plants compliance should first be checked. If moving regulated plants within Great Britain, a UK plant passport is required; this includes all plants for planting.

NOTE: *The Seed Marketing Regulations 2011 outline requirements for suppliers of seed. See:* https://www.legislation.gov.uk/uksi/2011/463/made

NOTE: *For more information on UK plant passports, refer to:* https://www.gov.uk/guidance/issuing-plant-passports-to-trade-plants-in-great-britain#when-you-need-a-plant-passport

NOTE: *The full list of species listed on Schedule 8 can be found at:* *http://www.ukwildlife.com/index.php/wildlife-countryside-act-1981/schedule-8*

6.4.9 Resilience and adaptability

Including a diverse range of species can help increase resilience to future warmer climates and limit the damage caused by pest and disease outbreaks. Climate change means wetland is likely to be drier for longer periods of the year. Fortunately, periodically wet wetland is highly resilient, as they typically comprise species adapted to drought conditions.

The following advice should be considered when designing climate change resilient wetland:

- **When to plant drought tolerant marginal plants:** consider planting marginal plant species capable of surviving drought periods. When determining whether to

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plant drought tolerant species, consider the presence of wet soils, hydrology and requirements relating to planting specification (Section 6.4.3 and 6.4.6).

- In urban areas, it may be acceptable to plant non-native Mediterranean wetland species. Refer to the Urban and Brownfield Design and Management Guidance Note for more information.
- **When to avoid planting drought tolerant species:** including climate change tolerant species into certain habitats will alter the classification and protected species of certain habitats (e.g. reedbeds). It is recommended that such species are planted within aquatic marginal vegetation, other swamps, ponds and ditches only.

NOTE: *For more information on impacts of climate change on aquatic and riparian plants, refer to Section 2.7 of the Environment Agency's Aquatic and Riparian Plant Management Technical Guide: https://assets.publishing.service.gov.uk/media/6034e181d3bf7f26576beefa/SC120008-R2_Technical_guide.pdf*

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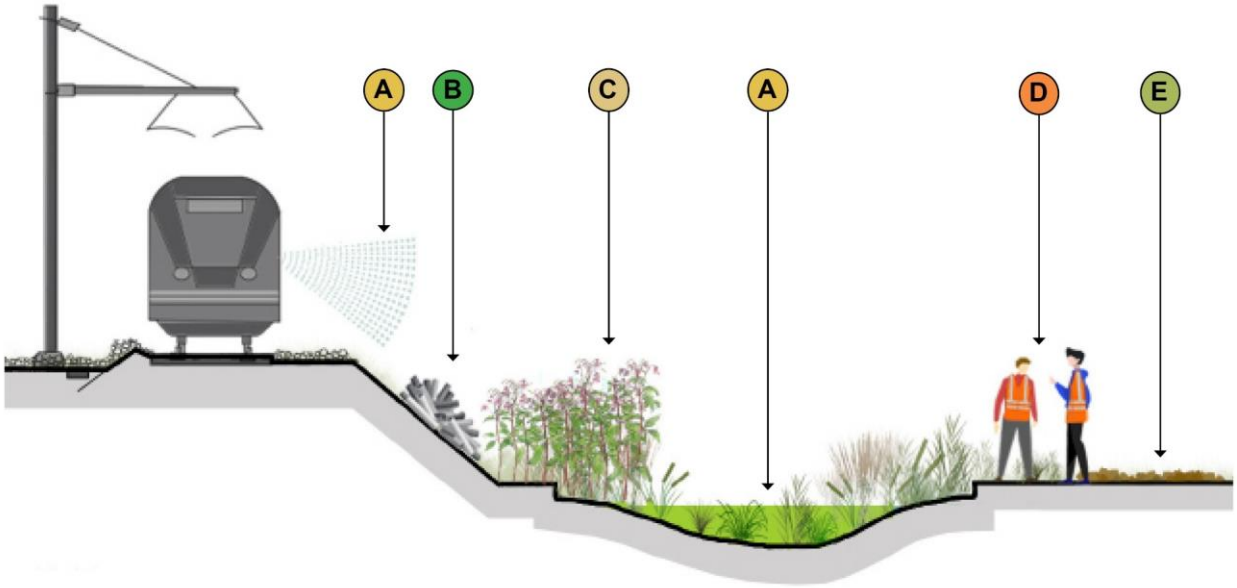
6.4.10 Protection

Wetland creation or restoration can present safety and operational risks. Some operations can also cause physical damage to wetland habitats which can be difficult to reverse. Figure 23 highlights these risks and associated protection measures.



A Pollution

Pollution from rail operations or chemicals and sewage from adjacent land may be discharged into waterbodies through run-off. This will cause eutrophication. To reduce or prevent pollutants entering the water, a buffer of dense vegetation can be created between the railway line and waterbody. If possible, proposed waterbodies should be created away from any potential source of pollution.

B Damage or destruction of habitat

Access to the lineside and use of machinery can result in physical damage to important habitats. To these habitats, clear signage and markers should be erected to indicate habitats of high distinctiveness, nature reserves or designated sites.

C Undesirable invasive species

Moving between sites without adequate biosecurity measures can spread INNS via equipment or Personal Protective Equipment (PPE) e.g. steel toe capped boots. When entering wetland habitats the UK government's 'Check Clean Dry' policy should be adhered to, to prevent the spread of INNS. All PPE and equipment should be disinfected between sites.

D Risk of drowning

Wetland habitats present a risk of drowning to Network Rail staff and the public should they enter or fall in the water. To reduce this risk, deep waterbodies should be fenced off and life buoys should be present. Signage warning of the risk should be erected.

E Poaching damage to emergent vegetation

Poaching of fresh vegetation growth by livestock and wildlife will reduce the success of plant establishment. Erecting temporary fencing around the perimeter of the wetland habitat will protect vegetation from being trampled or grazed until it becomes established.

Figure 23 – Risks and protection measures associated with lineside wetland

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***NOTE**: For information on the Check Clean Dry policy, refer to https://www.gov.uk/government/news/stop-the-spread-for-invasive-species-week*

6.4.11 Innovative and nature based solutions

There are several traditional or modern techniques which can be used as nature-based alternatives to typical engineering practices. These cost effective solutions can help reduce carbon, increase biodiversity and resilience to disasters such as flooding and climate change. Nature based solutions should be considered, where appropriate, instead of traditional hard engineering solutions.

Figure 24 indicates the main purpose of alternative nature based solutions presented in this section. For example, nature based solution A (Figure 25) is a natural alternative to lining waterbodies.

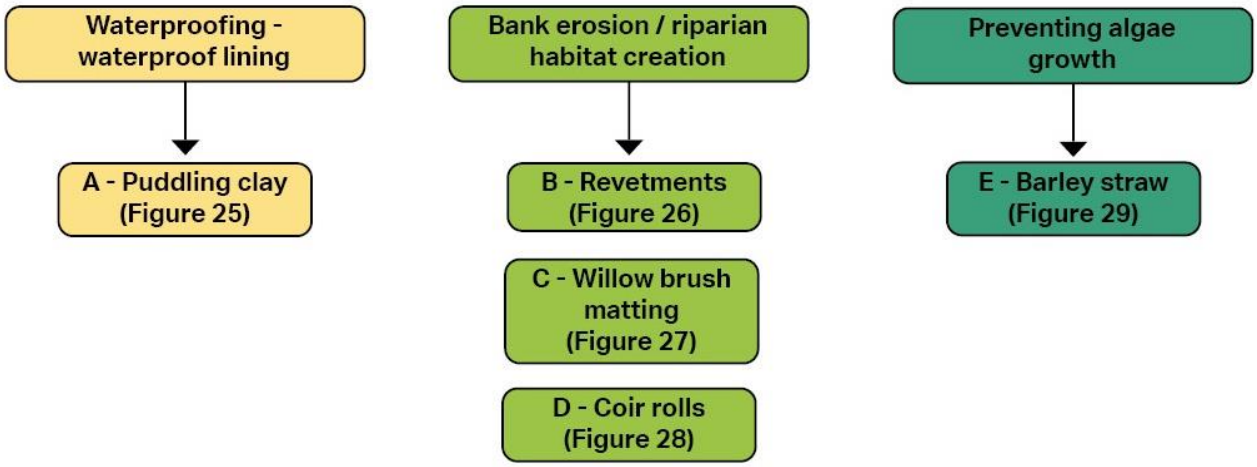

Figure 24 – Nature based solution

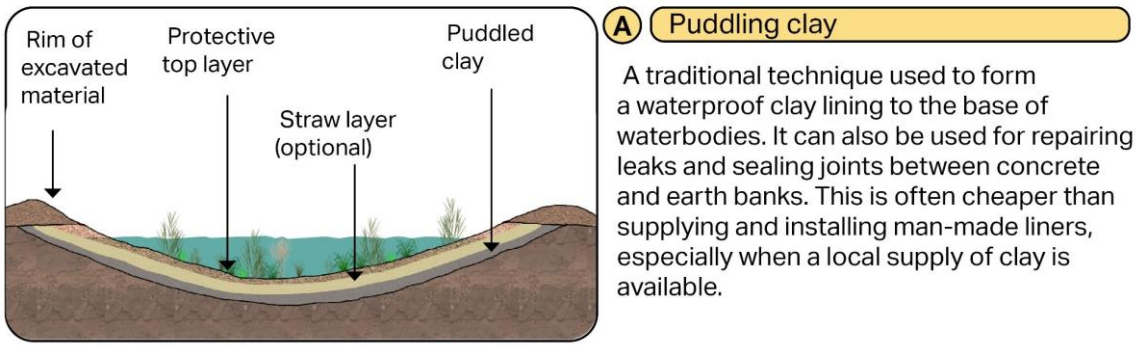

Figure 25 – Using puddled clay to line waterbodies

***NOTE**: Refer to the Canal Rivers Trust for a detailed specification for puddled clay: https://canalrivertrust.org.uk/media/library/278.pdf*

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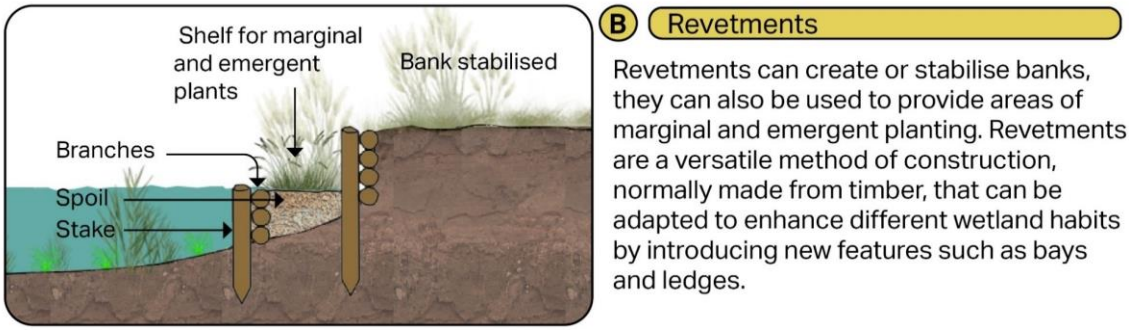

Figure 26 – Using revetments to provide bank stabilisation and marginal shelves

***NOTE**: Refer to the following document by The Conservation Volunteers for a detailed specification on revetments: https://www.conservationhandbooks.com/waterways-wetlands/banks-revetments-and-access/bank-creation-and-stabilisation/*

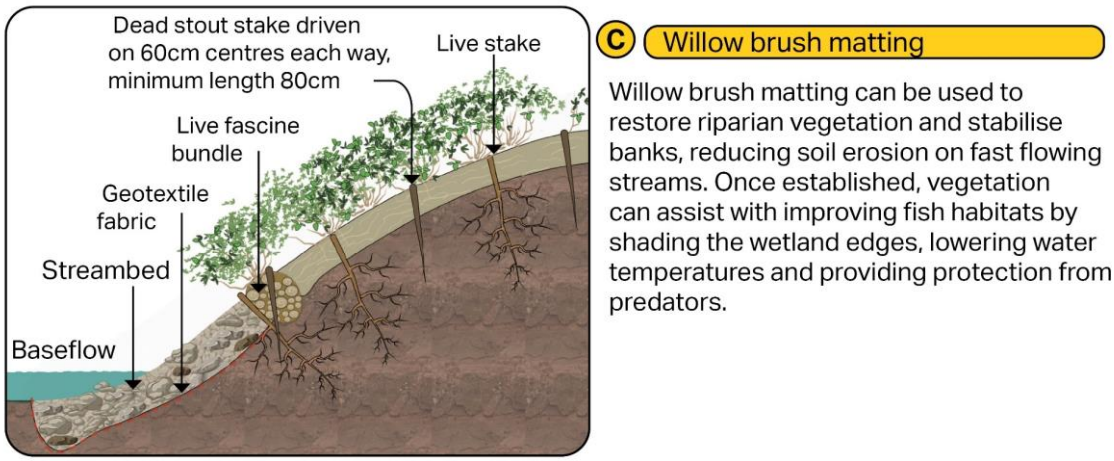

Figure 27 – Using willow brush matting to stabilise banks

***NOTE**: Refer to page 9 of the following document by Scottish Environment Protection Agency for a detailed specification on willow brush matting: https://www.sepa.org.uk/media/219450/bank_protection_guidance.pdf*

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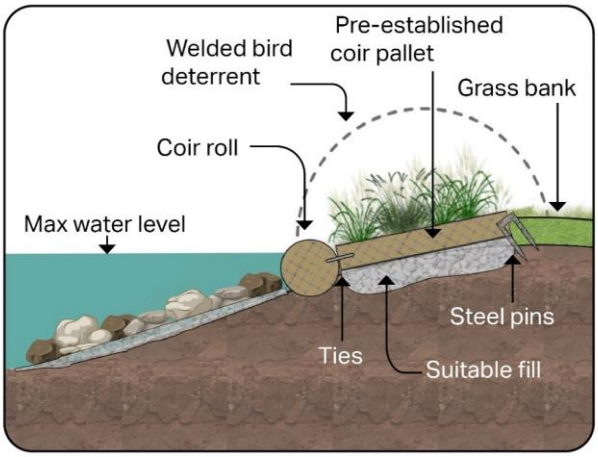
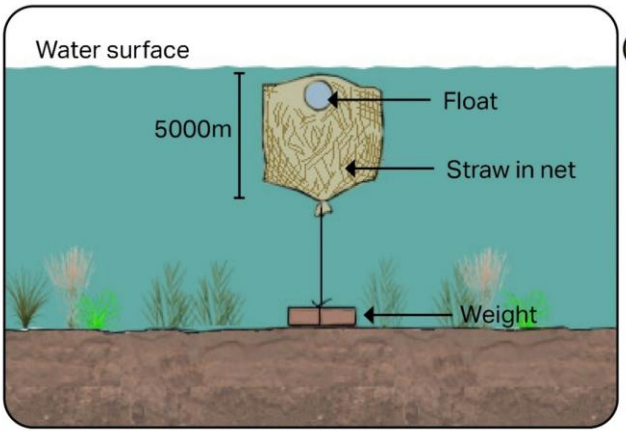


D **Coir rolls**

Rolled mats made of coconut fibres which can be pre-planted with a range of wetland vegetation, that promotes fast establishment (Sussex Wildlife Trust, 2013).

Figure 28 – Using coir rolls to promote quick establishment of wetland vegetation

***NOTE**: Refer to the following document for a detailed specification on coir rolls and pallets:*
https://www.therrc.co.uk/MOT/References/MMG_Laying_Guide_XS_Specs.pdf



E **Barley straw**

Substances given off by waterlogged and decomposing barley straw stops algal growth without damaging other wetland organisms. This technique is effective in flowing and still water and is scalable to larger waterbodies such as lakes and rivers. The reduction of algae allows emergent and submerged plants to recolonise, which in turn suppress the algae growth so the need for straw treatment declines.

Figure 29 – Using barley straw to prevent algae growth

***NOTE**: Refer to the Centre for Ecology and Hydrology for a detailed specification on barley straw:*
http://nora.nerc.ac.uk/id/eprint/19957/1/BarleyStrawtocontrolalgae.pdf

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6.5 Wetland Creation and Establishment

This section provides guidance on how to successfully create and establish wetland in the lineside to maximise its biodiversity value and ecosystem service provision. This section refers to the germination and establishing phase of the wetland development cycle.

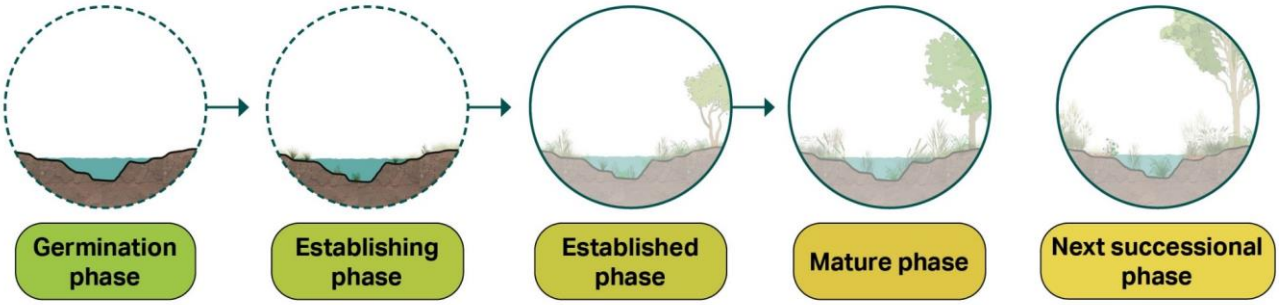

Figure 30 – Phases of wetland development cycle: applicable to wetland creation and establishment

Best practice suggests the following general wetland creation and establishment principles should be applied:

- Undertake ground preparation where necessary. This may include digging depressions, such as scrapes in the soil. This is likely to require appropriate construction plant and therefore it is important to make sure there is sufficient working space before instructing contractors;
- Undertake the most appropriate creation approach: planting or natural regeneration;
- seeding or plug planting, according to environmental and site access conditions;
- Implementing an appropriate aftercare programme;
- Remove all arisings once vegetation is cut to prevent the soil becoming more fertile or nutrients leaching into the waterbody;
- Removing dead or diseased vegetation from site to a licensed green waste recycling facility;
- Where habitat management is to be undertake on wet or soft ground, put in place protection measures such as ground protection matting and avoid using machinery which could result in a health and safety issue or damage the soil or habitat; and
- Consider risks to wetland habitats, for example flooding or drowning and implement appropriate mitigation.

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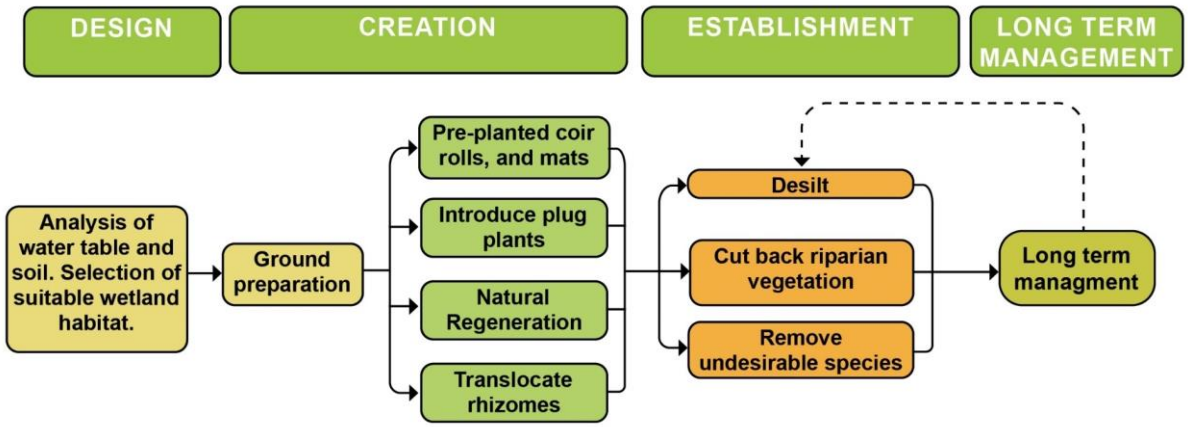

Figure 31 – Wetland creation and establishment process

Figure 31 outlines the process that should be followed when creating a wetland habitat and the subsequent actions recommended for successful establishment.

Methods and considerations relating to ground preparation, implementing creation and immediate aftercare are outlined within the following sub-sections. Management interventions and long term management are discussed in Section 6.6.

NOTE: *Seek advice from an experienced botanist where wetland creation or management advice is required or where individual botanical species advice is required.*

NOTE: *The routine maintenance schedule for wetland including when to undertake inspections is set out in the schedule folder.*

6.5.1 Implementing new wetland

The methods employed in implementing new wetland habitat will differ according to the type of wetland habitat being created. The following approaches are relevant for all wetland habitats:

1. **Excavation works:** a hole of the desired size and shape should be dug using an excavator. The hole should be dug deeper than the final desired depth if using a liner or puddled clay (TCV, 2021). For example, when using puddling clay, the first layer should be a depth of 75mm; any excavation should therefore accommodate this. Refer to Section 6.4.5 for the best depths for creating waterbodies to maximise biodiversity. Where drainage is the primary function, the depth is likely to be determined by engineering requirements. Ground works should include the creation of small islands, underwater shelves and bars.

NOTE: *For information relating to depths, angles and techniques for undertaking ground works refer to Freshwater Habitats Trust's Pond Creation Toolkit Sheet 4: https://freshwaterhabitats.org.uk/wp-content/uploads/2013/09/pond-design.pdf*

2. **Soil preparation:** soil preparation is only required when planting submerged or marginal plants. Where such plants are proposed for planting, the soil should be saturated with water before planting (RSPB, 2004).

The following sections outline different approaches that can be undertaken for the creation of different wetland habitat types.

6.5.1.1 Wetland habitat creation approaches: reedbeds

Consider the following when creating reedbeds:

- The optimum time for planting a reedbed is in June and when water levels are at or just above the soil surface.
- Consider planting only part of the site with reeds, as planting the entire site isn't always necessary. This is because reeds expand in coverage over 1-10m per year and will naturally colonise bare areas.
- In areas where wildfowl are present, consider fencing off or netting the habitat to prevent wildfowl grazing of seedlings.

NOTE: *For information regarding reedbed creation approaches refer to RSPB resource on creating and managing reedbeds for wildlife: bringing_reedbeds_to_life_tcm9-385799.pdf (rspb.org.uk)*

6.5.1.2 Wetland habitat creation approaches: ponds and ditches

Consider the following when creating a pond or ditch:

- Ensure ponds or ditches are left for two weeks before planting to allow any chemicals that enter the water emanating from creation to dissipate or evaporate.
- Emergent or submerged plants can be planted any time of the year, although are best planted when water is present (Freshwater Habitats Trust, 2013b) (see Section 6.5.2).
- Consider using excavated earth from the pond or ditch to create banks at the side of the feature to increase habitat diversity.

NOTE: *For more information regarding pond and ditch creation approaches refer to the Pond Conservation resource: Creating-Garden-Ponds-for-Wildlife.pdf (freshwaterhabitats.org.uk)*

NOTE: *For information regarding pond creation using clay refer to The Yorkshire Wildlife Trust resource: https://www.ywt.org.uk/wolds-dew-ponds/restoration*

NOTE: *For information regarding pond creation using a liner refer to The Wildlife Trust resource: https://www.wildlifetrusts.org/actions/how-build-pond*

NOTE: *For information regarding ditch creation refer to the RSPB resource: https://www.rspb.org.uk/get-involved/activities/nature-on-your-doorstep/garden-activities/digadampditchfordiversity/*

6.5.1.3 Wetland habitat creation approaches: aquatic marginal vegetation

Consider the following when creating marginal vegetation:

- A variety of aquatic and semi-aquatic perennials can be plug planted to create marginal habitat suitable for aquatic life and pollinating invertebrates.

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- Marginal plants can be planted any time of the year (Freshwater Habitats Trust, 2013b), although it is best to avoid planting during summer or during drought periods (see Section 6.5.2).
- The site can either be naturally very damp or a shallow scrape can be dug. If lining is required to sustain wet soils, a natural method, such as puddling clay, should be considered (see Section 6.4.11).

NOTE: *For information regarding approaches to planting aquatic marginal vegetation refer to The Conservation Volunteer resource: Creating and managing a patch of wet grassland - TCV Practical Conservation Handbooks*

6.5.2 Planting

The best time to plant wetland according to each habitat type are as follows:

- **Reedbeds and other swamps**: May and June (RSPB, 2004).
- **Aquatic marginal vegetation**: April to June when the water temperature is warming (RHS, 2021).
- **Pond/ditch emergent and submerged plants**: emergent plants should be planted during April and May. Submerged plants to be planted from April to June (RHS, 2021).

NOTE*: See schedule folder for appropriate seasonal sowing and planting periods.*

6.5.3 Establishment

Once planted, maintenance should be carried out to support successful establishment. The following interventions should be considered:

- **Removal of pernicious weeds:** undesirable ruderal species, such as nettles, are likely to colonise and establish quickly. If left uncontrolled, they may dominate the habitat. Pernicious weeds should be controlled, either by hand pulling, or using mechanical or hand tools if within a waterbody; this should be undertaken from the bank.
- **Establishment maintenance:** management to encourage new growth and allow the habitat to develop to the mature phase. For example, young emergent vegetation should be protected from adverse weather conditions by planting scrub or trees on the windward side to provide shelter from prevailing wind and rain. Vegetation should also be protected from grazing and disturbance from wildfowl, rabbits and livestock. This can be done by erecting stockproof fencing, or animal-specific netting to prevent wildfowl or rabbits, during the establishment phase (see Section 6.4.10).

6.5.4 Lineside management considerations

Machinery should be selected to minimise impacts on the environment and set out in RAMS. This could include use of hand tool, strimmers or mowers, opposed to large flail machines or diggers. Other factors for when choosing machinery include (TCV, 2021):

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- Access routes should be planned in advance to avoid vulnerable habitats.
- Drier, elevated areas may be required for access and storage.
- Confirm that there is sufficient clearance height and width before work is carried out.
- Ground conditions should be stable and not result in machinery becoming stuck. Ground protection mats may be required to prevent machinery sinking into soft ground and causing damage to the soil through compaction.
- The reach of the excavator arm must be sufficient for excavating and disposing of the spoil. Usually larger machines with a longer reach are more efficient, as they are capable of doing more work without moving position but may require further measures to avoid damaging the ground.
- Experienced and skilled machinery operators are vital for successfully creating wetland features in line with the proposed design. This can be established through pre-qualification questionnaires completed by potential contractors prior to formal instruction.

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6.6 Long-term Management of Wetland Habitat

This section outlines the key considerations for the management of established wetland. The guidance refers to the established and mature phase of the wetland development cycle. It should be read alongside NR/L3/OTK/6202 Protecting railway assets during vegetation work.

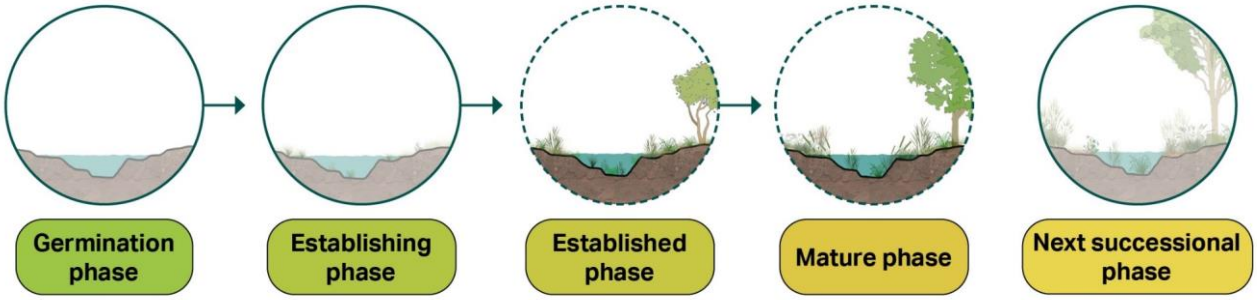

Figure 32 – Phases of wetland development cycle: applicable to long-term management of wetland habitat

Best practice suggests the following general principles should be applied in relation to the long-term management of wetland vegetation:

- Implementing a long-term management regime suitable for the site, soil, hydrology and wetland type e.g. cutting;
- Monitoring wetland to analyse changes in wetland vegetation and structure to inform future management and biodiversity net gain;
- Conserve, create and enhance structural variation within wetland; and
- Increase species diversity and species-richness.

For ponds and ditches where there is open water, best practice suggests the following principles are applied:

- Ensure riparian vegetation is managed to maximise biodiversity and protection from pollution;
- Prevent scrub encroachment or colonisation of more than 40% of the water surface by shading plants e.g. lilies (Environment Agency, 2015).

NOTE: *It is important to pro-actively liaise with owners of adjacent wetland outside of the lineside to ensure habitat enhancement opportunities are maximised and objectives are aligned.*

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6.6.1 Management interventions

Management interventions typically used to conserve or enhance established wetland differs according to the type of wetland habitat. Within in this section, habitats are grouped according to management requirements, as follows:

- **Riparian vegetation**: reedbeds, other swamps and aquatic marginal vegetation.
- **Ponds and ditches:** eutrophic standing water ('ponds').

When determining what management is required, the primary function of the habitat needs to be considered. Management undertaken for wetland which primarily function as a drainage feature may differ to those undertaken for enhancement of biodiversity. These are discussed for each habitat group below.

6.6.1.1 Managing riparian vegetation

In order to manage riparian vegetation successfully for biodiversity, the following principles should be followed:

- **Structural variation:** different heights of marginal vegetation provides variety in structure. This allows different plants and animals to colonise, increasing biodiversity. Where large areas of a wetland habitat type are present, vegetation should be evenly grouped into different areas, with each area being rotationally cut every 4-7 years (Sussex Wildlife Trust, 2013). Figure 33 illustrates how lineside riparian vegetation could be managed on rotation. This can be done by dividing the total area of coverage of a particular riparian habitat (e.g. reedbed) into several plots, ensuring each plot is cut at least once every four years. In relation to reedbeds, the water level should be reduced to ground level or below to enable safe access. Reed cutting should be undertaken between September and March, where possible (RSPB, 2015).
- **Selective control:** selective control management should be adopted when managing riparian vegetation (Environment Agency, 2015). Figure 34 illustrates examples of selectively controlling riparian vegetation (Environment Agency, 2014).
- **Timing the cuts:** the optimal time for cutting of all riparian vegetation types is from the end of August to the end of October as this avoids bird nesting and fish spawning seasons which are between March to July and November to June. Where fish are not present, management could feasibly be undertaken during the Autumn. Broad-leaved emergent species can be cut back up to December, whereas submerged plants die back in the winter.

  An assessment will need to be made whether to cut less material earlier in the year, removing less plant material and have to carry out a second cut or cut once in mid to late summer. Leaving to cut in mid to late summer or later is more time-consuming and challenging due to the greater volume of vegetation.

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- **Removal of all arisings:** following cuts, all arisings should be removed from the habitat to prevent decomposition leading to fertile soils, this can encourage growth of undesirable species and reduce biodiversity.

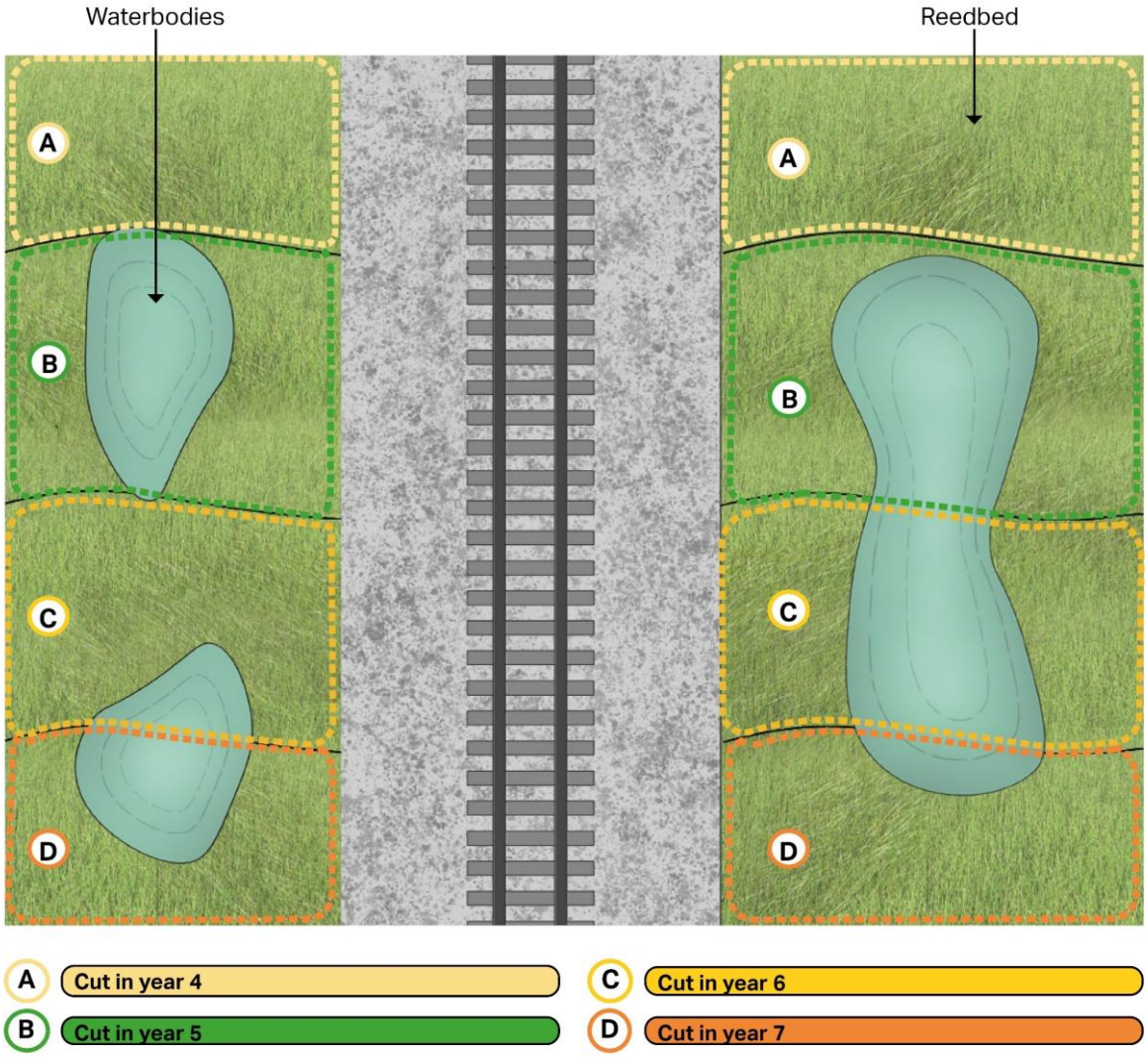

Figure 33 – Indicative rotational cutting plan for a lineside riparian site

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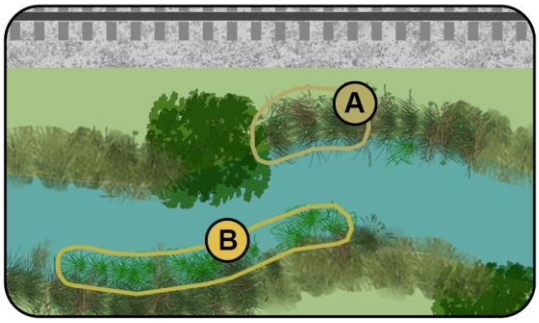
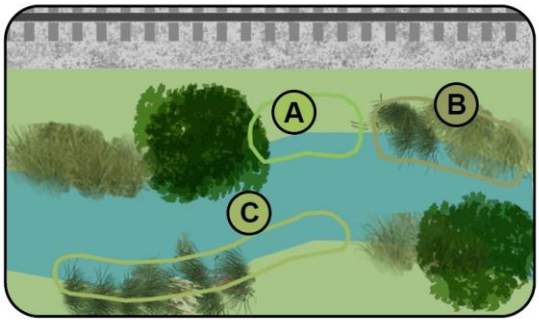


River before riparian vegetation management

A — Excessive growth of riparian vegetation, potentially caused by nutrients or sewage polluting the water.

B — Excessive growth of INNS, potentially caused by nutrient run-off, from agricultural land, or sewage polluting the water.

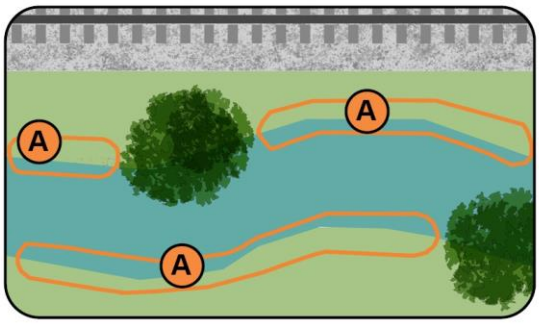


River selectively managed

A — Defined areas of vegetation removal creates open sections of the waterbody.

B — Defined areas of vegetation retention provides habitat for biodiversity whilst reducing the overdominance of vegetation.

C — Removal of INNS enables other plant species to grow without being outcompeted.



River not selectively managed

A — Removal of all riparian vegetation and invasive species provides little habitat for wetland species. Large scale vegetation removal can encourage vigorous growth, requiring increased vegetation management in the future.

Figure 34 – Selective control management approaches to riparian vegetation

Figure 35 describes in more detail variations of typical techniques for managing riparian vegetation.

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Hand management

Manual removal or cutting vegetation with hand tools such as scythes, knives, sickles rakes machetes is generally only feasible on small areas as it is very labour intensive. Tools can be used on banks or in boats.

NOTE: *For more information in relation to hand management techniques, refer to Section 7.3.1 the Environment Agency's Aquatic and Riparian Plant Management Technical Guide.*
https://assets.publishing.service.gov.uk/media/6034e181d3bf7f26576beefa/SC120008-R2_Technical_guide.pdf

Hot foam

This technique kills weeds without being labour intensive or using toxic chemicals. Hot foam comprises of hot water, steam, and a naturally derived foaming agent e.g. oil seed rape creating a thermal layer which kills the plants. Hot foam can only be applied to riparian vegetation adjacent to the watercourse not submerged or emergent species. It is currently expensive as it is a new technique and therefore not commonly used.

NOTE: *For more information in relation to the use of specialist machinery, refer to Section 7.3.2 of the Environment Agency's Aquatic and Riparian Plant Management Technical Guide.*
https://assets.publishing.service.gov.uk/media/6034e181d3bf7f26576beefa/SC120008-R2_Technical_guide.pdf

Specialist machinery

Large waterbodies or channels (deeper than 0.4m) with significant vegetation to manage may require use of specialist machinery such as mechanical harvesters, weed boats or amphibious vehicles fitted with specialist attachments. Once cut, plant material must be collected from the water and disposed appropriately. Managing INNS with these machines should be avoided as many of the attachments can result in fragmentation of plant material leading to dispersal and re-establishment downstream.

NOTE: *For more information in relation to the hot foam technique, refer to Section 7.7.1 the Environment Agency's Aquatic and Riparian Plant Management Technical Guide.*
https://assets.publishing.service.gov.uk/media/6034e181d3bf7f26576beefa/SC120008-R2_Technical_guide.pdf

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Figure 35 – Riparian vegetation management techniques

Where drainage is the primary function, tall growing vegetation should be cut back and removed up to several metres from the banks of the waterbody (e.g. ditch or pond). Low growing marginal vegetation should be planted to help prevent encroachment of trees and shrubs, and bank erosion from occurring. Section 6.4.4 outlines design examples for drainage features.

6.6.1.2 Managing ponds and ditches

If ponds or ditches become filled up with sediment it can reduce the water quality, capacity for drainage and value to biodiversity. However, dredging to maintain areas of deep water can cause significant damage to wildlife which is often much richer in shallower areas of ponds and ditches (Freshwater Habitats Trust, 2013). Therefore, removal of silt should only be undertaken as a last resort (Asselin, Demgen, & Johnson, 2005).

Factors to consider for management of ponds and ditches:

- Before desilting an ecological survey of the pond or ditch should be carried out.
- If there is space to create another pond nearby, leave the existing pond to succession rather than desilting. This option is better for wildlife (Pond Action, 2000).

Dredging should be carried out when the pond mud is black and full of decomposed leaves. No more than half of the silt should be removed in any one year due to the silt containing eggs, larvae and plant seed. By retaining half of the silt, the pond or ditch can restock with wildlife (Norfolk Wildlife Trust, 2021).

The best time to dredge is when the water levels are at their lowest, usually late summer to early autumn. However, ecological surveys should identify species present and timings may need to be adapted accordingly.

The most appropriate method of removing silt for the majority of the Network Rail lineside is use of hand techniques or silt pumping opposed to engineering solutions or use of heavy machinery.

NOTE: *Refer to page 15 of the Environment Agency's Channel Management Handbook for appropriate times to undertake dredging or de-silting in relation to ecological considerations.*

NOTE: *Dredging must be agreed with a suitably qualified ecologist before it is undertaken. In addition, where silt build up is a continuous problem, the guide outlines prevention solutions from page 199: https://assets.publishing.service.gov.uk/media/603500cad3bf7f265b74bbb2/Channel_management_handbook.pdf.*

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6.6.2 Restocking and replanting

Wetland vegetation should be managed to maintain as many species and as much structural diversity as possible. If one species becomes dominant, consider selective removal on rotation, refer to Section 6.6.1.1. Consider replanting if key plant species die out or are outcompeted by undesirable species, refer to Section 6.5.1.1 for details on planting.

6.6.3 Monitoring and inspections

Wetland should be inspected and monitored at least once a year as outlined below, by a suitably qualified professional, such as an ecologist

NOTE: *The routine maintenance schedule for wetland including when to undertake inspections is set out in the schedule folder.*

NOTE: *Refer to NR/L2/ENV/122 Module 02 for information on the requirements for Habitat Management Plans.*

6.6.3.1 Ecological monitoring and assessing biodiversity

Habitat and botanical surveys should be undertaken, preferably at least once annually, between April and September, prior to the wetland being cut. Monitoring should assess change in botanical, insect and fish communities as an indicator for biodiversity against baseline data. Baseline data collection and monitoring should be designed specifically to the habitats present and could include the following:

- **National Vegetation Community (NVC):** detailed botanical survey undertaken annually to consistently assess changes in floral species abundance and diversity.
- **Macrophyte survey:** surveying the presence and coverage of submerged and floating macrophytes within ponds and ditches is important in order to assess the development of such habitats. Surveys should be undertaken between June and September.
    - **Waterbodies >2ha:** WFD UKTAG Lake Assessment Method: Macrophytes and phytobenthos (2014);
    - **Ponds:** Pond PSYM (Predictive System of Multimetrics) Survey.
- **Macroinvertebrate survey:** surveying the composition of macroinvertebrates within wetland waterbodies can indicate the health and success of enhancement of a habitat. Surveys should be undertaken twice a year, once in spring (March – May) and once in autumn (September-November) and should be undertaken using the following guidance:
    - **Waterbodies >2ha:** WFD UKTAG Lake Assessment Methods Benthic Invertebrate Fauna (2008);
    - **Ponds:** Pond PSYM (Predictive System of Multimetrics) Survey.
- **Fish surveys:** Fish surveys should be informed by habitats present and connectivity to other waterbodies and watercourses such as rivers. The type of

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survey undertaken depends on a number of factors including access, depth of silt, plant cover and depth of water. Surveys should avoid the coarse fish spawning season (March 15th – June 15th).

    - A range of techniques can be used to survey fish populations, including eDNA, electric fishing, seine netting or fyke netting.

- **Biodiversity Net Gain (BNG):** data collected from NVC surveys can be used to undertake BNG assessments. BNG assessments should assess whether the progression of the habitat's condition and distinctiveness is on target to achieve the prediction in line with the time to target condition.

NOTE: *Surveys, annual ecological monitoring and BNG assessments should be devised and undertaken by an experienced ecologist.*

Following inspections and monitoring, changes to the management regime may be recommended to enhance or restore the wetland. The first few years of establishment are likely to require multiple inspections. Inspections are important to:

- Ensure the habitat management plan objectives are being met;
- Report on wetland vitality and failures, and inform and instruct remedial work;
- Assess the health of wetland and identify actions to address biosecurity issues; and
- Report on the condition and effectiveness of plant protection and any remedial action required.

NOTE: *Suitably qualified professionals for undertaking inspections of wetland establishment include Chartered Members of the Landscape Institute or ecologists. Landscape architects can provide assistance with practical issues relating to establishment whereas ecologists can provide detailed technical information.*

NOTE: *Refer to NR/L2/ENV/122 Module 02 for information on the requirements for Habitat Management Plans.*

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6.6.3.2 Inspecting signs of damage and disease

The best time to assess wetland health is spring. Inspections can be undertaken in summer; however, this may not be suitable for periodically dry wetland. Some examples of visible signs of damage and disease are provided in Figure 36.

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Siltation

Silt build-up increases vegetation growth and acceleration to the next successional phase. Check water depth and ensure there is not excess silt which creates potential for the wetland drying out. Where this does occur excavation may be appropriate (see Section 6.6.1.2).

Lack of water throughout year

If a waterbody has become permanently dry, the habitat may not function as a wetland. This might be due to an unseasonably dry year or fluctuating ground water levels however, excessive siltation or vegetation growth may also be the cause. Consult with an ecologist and hydrologist to understand whether desilting of vegetation removal is appropriate.

Algal dominance

Algae, including blue-green algae (which is toxic to humans and animals) can smother the surface of waterbodies. This typically occurs due to poor water quality or excessive nutrients entering the water (see section 6.6.3.3). Barley straw can be used to limit algal dominance (see Figure 29).

Turbid water

Opaque brown to grey colouration of water indicates high turbidity. This can be caused by certain fish species or from excessive sediment suspended in the water e.g. from bank erosion, refer to bank stabilisation solutions in Section 6.4.11.

Biological control agents

Where invasive plant species colonise and dominate a habitat, biological control agents, such as using North American weevils to limit floating water fern (Azolla filiculoides), can be considered. Refer to CABI (2021) for information on the suitability of using biocontrol to eradicate problematic species.

Figure 36 – Examples of signs of damage and disease in wetland

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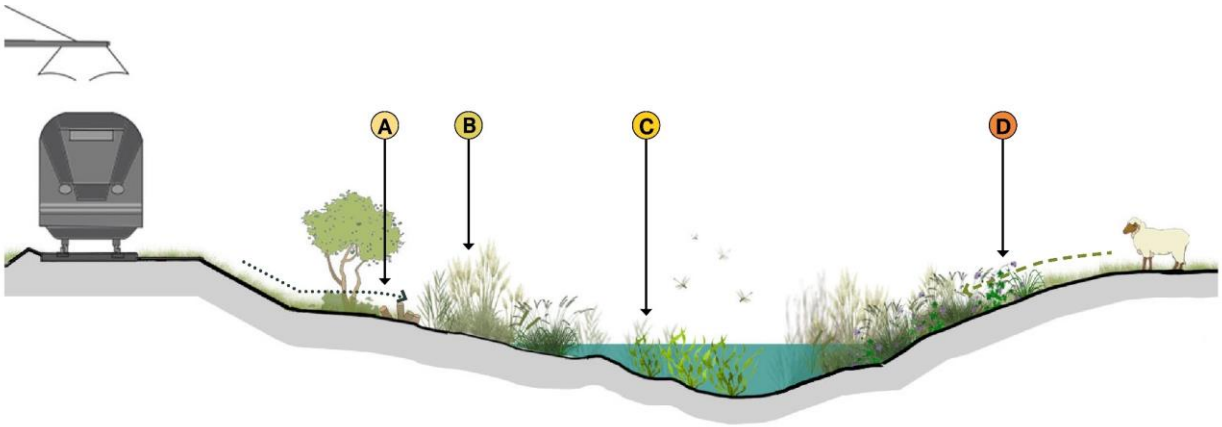
6.6.3.3 Poor water quality

Water quality plays an important factor in the ecological health of all waterbodies and wetland. Poor water quality can result in a reduction in biodiversity and ecological function.

Where poor water quality is an issue, and cannot be prevented from source, consider designing a wetland in which water flows through a larger variety of vegetation to help remove pollution from the water.

Figure 37 provides some examples of causes of poor water quality and potential management solutions.



A Leaf litter and sediment

Decaying vegetation and leaf litter decomposes to increase siltation and nutrient levels within the wetland. Consider removing areas of vegetation to reduce the amount of debris and leaf litter entering the wetland.

B Chemical pollutants

Pollutants such as oils which enter waterbodies can have detrimental impacts on biodiversity.
Planting vegetative barriers between waterbodies and wetlands can help prevent chemical pollutants from spreading.

C Low dissolved oxygen

Deoxygenation of water leads to an increase in anaerobic bacteria and can lead to the death of plant and animal life. Typically caused by algal dominance.
If caused by algal dominance, barley straw is an organic method of reducing and preventing algae growth.

D High concentrations of nutrients

Nutrients, for example, phosphates and nitrates that typically derive from sewage, agricultural and industrial pollution. These typically lead to eutrophication, encouraging algal blooms.
Where nutrient input cannot be stopped at source, design the wetland so that water flows through a large variety of vegetation to help remove the nutrients.

Figure 37: Causes of poor water quality and potential management solutions

NOTE: *To understand how to manage issues relating to nutrient enrichment of wetland and waterbodies, refer to Section 7.5.6 of the Environment Agency's Aquatic and Riparian Plant Management Technical Guide:*
https://assets.publishing.service.gov.uk/media/6034e181d3bf7f26576beefa/SC120008-R2_Technical_guide.pdf

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6.7 Wetland Restoration

This section provides guidance on how to successfully restore wetland in the lineside once it has reached or is starting to transition to the next successional phase of the development cycle.

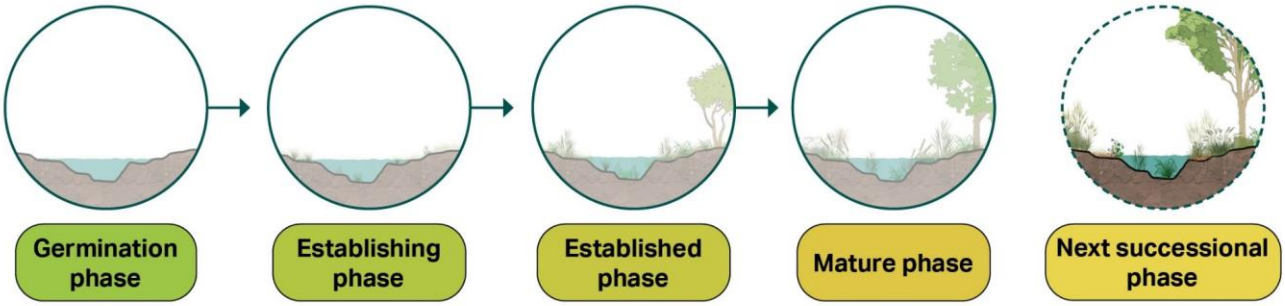

Figure 38 – Phases of wetland development cycle: applicable to next successional phase of wetland habitat

Best practice suggests the following general principles should be applied:

- Remove of scrub and trees where appropriate to restore wetland;
- Desilt wetland where silt build up has become problematic and prevents wetland from functioning as a drainage feature;
- Consider seeding or plug planting to accelerate restoration and increase biodiversity, if appropriate;
- Remove all cut vegetation once wetland is managed to prevent the soil becoming more fertile; and,
- Implementing an updated habitat management plan which ensures the wetland will be maintained and enhanced as a wetland.

Restoration is likely to be required once a habitat stops performing as a wetland after entering the next successional phase. During this phase, scrub and trees will dominate, which tends to lead to heightened siltation and modification of the habitat's physical structure. Figure 39 indicates different development phases linked to wetland and when restoration is typically required.

Wetland restoration is a last resort option. In some circumstances, the habitat which has developed where the wetland once was, may be a biodiverse habitat. Where this is the case, it may be more appropriate to conserve or enhance the newly developed habitat and create a drainage feature or wetland adjacent. For example, this may be the case where a woodland has formed on a former wetland site. If this occurs, consider the Preferred Habitat Objective and with an ecologist.

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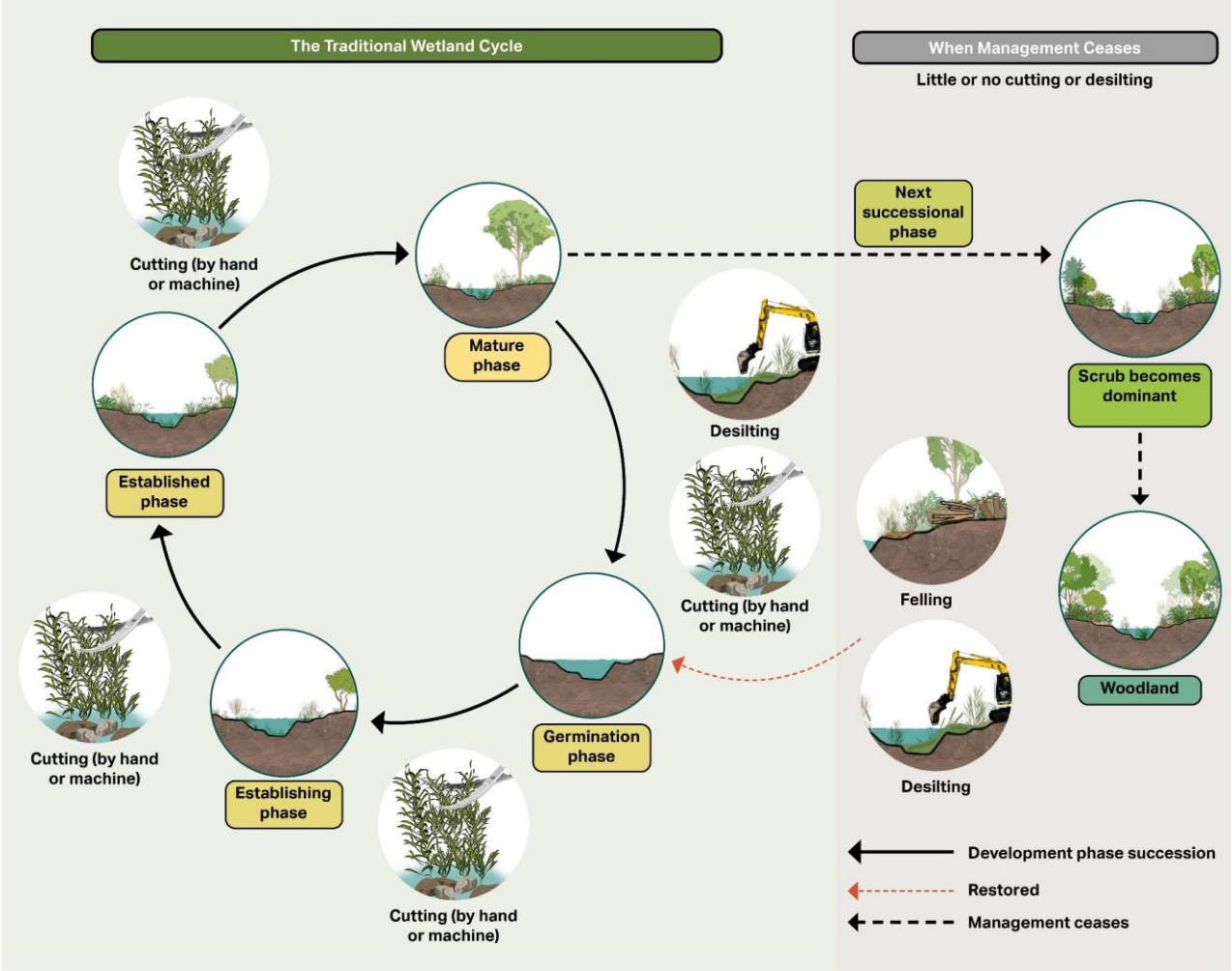

Figure 39 – Phases of the wetland development cycle and restoration process

6.7.1 Restoration approaches

The need for restoration should be assessed by an ecologist with reference to the results of monitoring and the Habitat Management Plan. Following this, the extent of vegetation clearance, desilting, ground works and replanting needed should be outlined, as well as identifying key features of value to biodiversity which should be retained.

Restoration can be achieved by clearing vegetation, removing silt and replanting as illustrated in Figure 40.

The approaches to vegetation clearance and desilting should follow the methods outlined in Section 6.6.1. If silt build-up has resulted in depressions or scrapes no longer being present, these will need to be re-dug, using appropriate machinery (see Section 6.6.1.2).

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It is important to understand whether the wetland was previously periodically or permanently wet. Where periodically wet, ensure that any desilting or ground works do not result in depressions becoming deeper to expose the water table, as this will alter the original nature of the wetland.

NOTE: *Effects on protected species should be considered before undertaking wetland restoration. A suitably qualified Ecologist should be consulted on the ongoing management works to ensure they are carried out sensitively.*

NOTE: *Before undertaking habitat restoration to drainage features, consult a suitably qualified engineer to ensure the primary drainage function and capacity is not compromised.*

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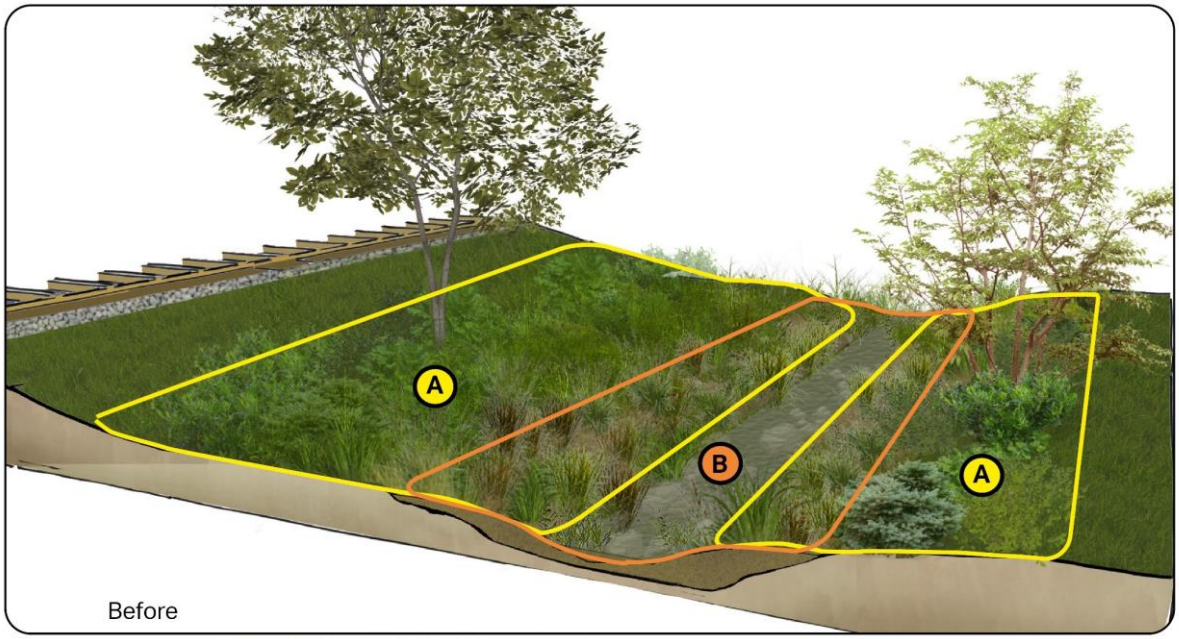

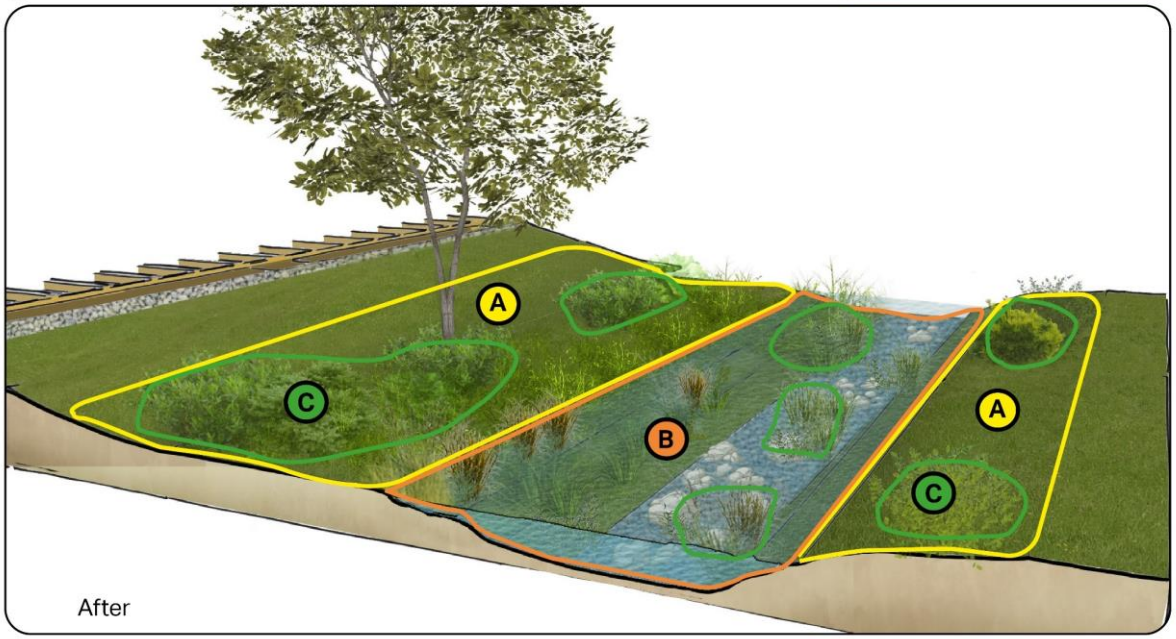

A **Scrub clearance**

Where scrub is dominant, limiting light and collecting sediment, areas should be cleared, ideally on a rotational basis allowing a small percentage of vegetation to be retained to create structural variation. This approach is outlined in section 6.6.1.1

B **Desilting and re profiling**

Excess sediment limiting waterflow and potentially reducing water quality should be dredged as outlined in section 6.6.1.2. Where drainage capacity allows, the introduction of new ground profiles such as shelves and ledges provide a habitat for a variety of planting types as outlined in section 6.4.5

C **Replanting**

To avoid a monoculture and maximise biodiversity, a range of planting types comprising of emergent, submergent and marginal plant species should be included in different areas of the ditch. See 6.4.6 for planting specification and section 6.4.7.1 for planting techniques.

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Figure 40 – Example of a drainage feature before and after habitat restoration

7 Sources of further information

7.1 References

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7.2 Figure References

Figure 6: Example of typical lineside Other Swamps habitat

High grass, garden, leaf, nature summer, plant, field, environment © Pixnio, 2018 https://pixnio.com/nature-landscapes/grass/high-grass-garden-leaf-nature-summer-plant-field-environment

Common Reed (*Phragmites australis*) © Peter O'Connor, 2014 https://www.flickr.com/photos/anemoneprojectors/16405233824

TALL Reed Canary Grass © born1945, 2006 https://www.flickr.com/photos/12567713@N00/179246154

Figure 7: Example of typical lineside aquatic marginal vegetation habitat

GT Hemlock Water Dropwort © Ian Alexander, 2019 (CC-BY-SA-4.0) https://commons.wikimedia.org/wiki/File:GT_Hemlock_Water_Dropwort.jpg

Lythrum salicaria, purple loosestrife 5 © Liz West, 2006 (CC-BY-2.0) https://commons.wikimedia.org/wiki/File:Lythrum_salicaria,_purple_loosestrife_5.jpg

Common Valerian (*Valeriana officinalis*) Lairich Rig, 2007 (CC-BY-SA-2.0) https://commons.wikimedia.org/wiki/File:Common_Valerian_(Valeriana_officinalis)_-_geograph.org.uk_-_1143992.jpg

Figure 8: Example of typical lineside pond habitat

Banded Demoiselle – Hampshire Dragonflies © Paul Richie, 2019 Banded Demoiselle – Hampshire Dragonflies

Emperor Dragonfly, Anax imperator (20510469152) © AJC1, 2015 (CC-BY-SA-2.0) File:Emperor Dragonfly, Anax imperator (20510469152).jpg - Wikimedia Commons

Brown hawker dragonfly (*Aeshna grandis*) dragonfly nymph late instar, Strumpshaw Fen, Norfolk © Charles J Sharp, 2014 (CC-BY-SA-4.0) File:Brown hawker dragonfly (Aeshna grandis) dragonfly nymph late instar.JPG - Wikimedia Commons

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Figure 10: Example of plant INNS associated with wetland sites

Himalayan Balsam © Oatsy40, 2014 (CC BY 2.0)
Himalayan Balsam | himalayan Balsam | oatsy40 | Flickr

Hydrocotyle ranunculoides © Dick Culbert, 2014 (CC BY 2.0)
Hydrocotyle ranunculoides | The Floating Marsh Pennywort is … | Flickr

Lagarosiphon major. Howardian, 1992 (30491279833) © Dr Mary Gillham Archive Project, 1992
File:Lagarosiphon major. Howardian, 1992 (30491279833).jpg - Wikimedia Commons

Crassula helmsii 2 © Benjamin Blondel, 2015 (CC-BY-SA-4.0)
File:Crassula helmsii 2.JPG - Wikimedia Commons

Azolla sp. Water fern © David Midgley, 2006 (CC BY-NC-ND 2.0)
Azolla sp. Water fern | Also a noxious weed in many parts th… | Flickr

TM4299: Parrot's Feather (Myriophyllum aquaticum) © Evelyn Simak, 2017 (CC BY-SA 2.0)
Parrot's Feather (Myriophyllum... © Evelyn Simak :: Geograph Britain and Ireland

Figure 11: Example of animal INNS associated with wetland sites

American mink © Ryzhkov Sergey, 2013 (CC-BY-SA-4.0)
File:American mink.jpg - Wikimedia Commons

Signal crayfish female Pacifastacus leniusculus © Astacoides, 2013
File:Signal crayfish female Pacifastacus leniusculus.JPG - Wikimedia Commons

Figure 12: Example of pests and diseases associated with wetland habitats

ElodeaNuttallii2 © Christian Fischer, 2011 (CC-BY-SA-3.0)
File:ElodeaNuttallii2.jpg - Wikimedia Commons

Going with the flow © M J Richardson, 2011 (CC BY-SA 2.0)
Going with the flow... © M J Richardson :: Geograph Britain and Ireland

Entengrütze / Kroos © Paul Keller, 2018 (CC BY 2.0)
Entengrütze / Kroos | Common duckweed (Lemna minor) on the s… | Flickr

Figure 13: Example of Eurasian beaver, gnawed wood and dam

Beaver Castor fiber © Ralf82, 2021 (Pixabay – free for commercial use)
https://pixabay.com/photos/beaver-castor-fiber-eurasian-beaver-5912466/

Castor fiber marks on Quercus robur © HermannFalkner/sokol (CC BY-NA 2.0)https://www.flickr.com/photos/hermannherbarium/5169989026/in/photostream/

Castor fiber dam © Joel Berglund (CC-BY-SA)
https://commons.wikimedia.org/wiki/File:Castor_fiber_dam.jpg

Figure 21: Examples of wetland plant species according to habitat type

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Butterbur. Petasites hybridus 0 Flickr – gailhampshire © gailhampshire, 2011 (CC-BY- 2.0) File:Butterbur. Petasites hybridus - Flickr - gailhampshire.jpg - Wikimedia Commons

Juncus-acutus_1 © Amadej Trnkoczy, 2010 (CC BY-NC-SA 2.0)
Juncus-acutus_1 | Juncus acutus L. Sharp Rush, DE: Stechende… | Flickr

Phalaris arundinacea © Matt Lavin, 2007 (CC BY-SA 2.0)
Phalaris arundinacea | The inflorescence is narrow and contr… | Flickr

Brown Fox Sedge (Carex vulpinoidea) in wet meadow at the Morton Arboretum – Flickr – Jay Sturner (2) © Jay Sturner, 2010 (CC-BY-2.0)
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NT5029: Amphibious Bistort (Persicaria amphibia) © Walter Baxter, 2020 (CC BY-SA 2.0) Amphibious Bistort (Persicaria amphibia) © Walter Baxter :: Geograph Britain and Ireland

ButomusUmbellatus4 © Christian Fischer, 2011 (CC-BY-SA 3.0)
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Healthy watercress plants © Scot Nelson, 2002 (CC0 1.0)
Healthy watercress plants | photograph: Wayne Borth | Flickr

Baldellia ranunculoides ssp. ranunculoides (Lesser Waterplantain / Stijve moeraweegbree) 0429 © Bas Kers, 2006 (CC BY-NC-SA 2.0)
Baldellia ranunculoides ssp. ranunculoides (Lesser Waterpl… | Flickr

Ranunculus flammula 1a © Aiwok, 2008 (CC-BY-SA-3.0, 2.5, 2.0, 1.0)
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Aquatic plants | Two characteristic plants of species-rich g… | Flickr

Sagittaria sagittifolia © Jeremy Halls, 2011 (CC BY-NC-SA 2.0)
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Fringed water lily. Forest Farm with large pond, 5.7.2000 © Dr Mary Gillham Archive Project's photostream, 2017 (CC BY 2)
Fringed water lily. Forest Farm with large pond, 5.7.2000 | Flickr

Chalk-stream Water-crowfoot, Ranunculus penicillatus subsp.pseudofluitans © Briantspuddle Wildlife & History's photostream, 2014 (CC BY-NC-SA 2.0)
Chalk-stream Water-crowfoot, Ranunculus penicillatus subsp… | Flickr

Water Violet (Hottonia palustris) – geograph.org.uk – 1264275 © Keith Edkins, 2009 (CC-BY-SA-2.0)
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Potamogeton Crispus © Christian Fischer, 1999 (CC-BY-SA-3.0)
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Figure 22: Examples of brackish water plant species

Ceratophyllum submersum winterform © Kristian Peters, 2006 (CC-BY-SA-3.0)
https://commons.wikimedia.org/wiki/File:Ceratophyllum_submersum_winterform.jpeg

Brackish Water Crowfoot Ranunculus baudotii © Len Worthington, 2008 (CC BY-SA 2.0)
https://creativecommons.org/licenses/by-sa/2.0/

Poplar Island in Talbot County, Md. © Alicia Pimental/Chesapeake Bay Program, 2008
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Figure 35: Riparian vegetation management techniques

Weed cutting on the Wilts & Berks canal © Vieve Forward, 2015 (CC BY-SA 2.0)
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Figure 1 Hot foam machine © Luisa Martelloni, Christian Frasconi, Mino Sportelli, Marco Fontanelli, Michele Raffaelli, and Andrea Peruzzi, 2019 (CC BY 4.0)
https://www.mdpi.com/2073-4395/9/9/490

Weed cutter at work on the Chesterfield Canal © Mike Nield, 2012 (CC BY- SA 2.0)
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Figure 36: Examples of signs of damage and disease in wetland

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Red Pond (Spirodela and Azolla) © bgv23, 2009 (CC-BY-2.0)
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