Annex VI: Constructed Wetland for Grey Water Processing

This Annex sets out the applicants' proposed wetland system, but please note that this is does not form part of the current full planning application. For information purposes only, it provides specific descriptions of:

- The design, dimensions, and structure
- The technical basis (Constructed Wetlands Association)
- The planting and maintenance approach
- The environmental benefits it brings to the site and the wider catchment
- Materials specifications

1. Design, dimensions, and structure

The design has been sourced from the Constructed Wetlands Association Design Guidelines for "Constructed Wetlands to Treat Domestic Septic Tank Effluent", although the proposed use case is for grey water, rather than outflow from a septic tank. Nevertheless, the Constructed Wetland (CW) is sized to provide 15m^2 of surface treatment area, as would be required for a septic tank outflow.

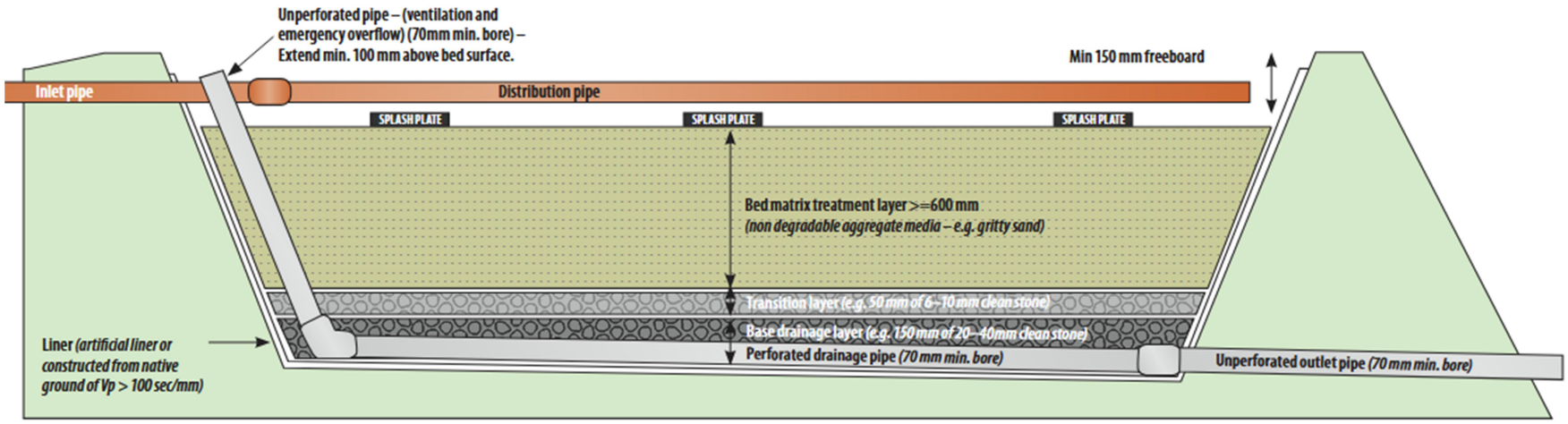


Figure 1

The design (figure 1) comprises an initial treatment bed, planted with a mix of common reeds (*Phragmites australis*) and great reedmace (*Typha Latifola*). Both are native species with good filtration and chemical removal properties. Reedmace is particularly effective for phosphate removal[1]. The reed bed is followed by an open water reservoir (OWR), with mixed aquatic plants with a strong emphasis on native species. This section will be of the same size and allow for recirculation through the treatment bed if water flows are low, as well as providing a source of water for irrigation. Recirculation is anticipated to be needed, as the flow of water into the treatment bed is likely to be lower than required for the ongoing support of the wetland. Overflow from the OWR will be to an area planted in willow, providing the final treatment step.

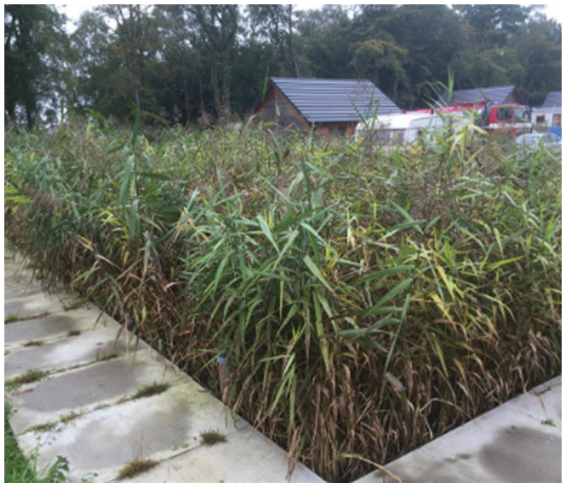
The size of the proposed reed bed for the CW is 5m long by 3m wide, with a 1m depth, plus freeboard. Sample images are provided, to give a sense of the aspect of the proposed CW:



This photograph shows a constructed wetland reed bed when the construction phase is complete, but the plants are not yet established.

[1] https://hal.science/hal-04184774v1

While the reeds in this photograph are somewhat overgrown, it does illustrate how the reed bed might look, once the plants have become established.



The size of the proposed OWR matches the reed bed, being 5m long by 3m wide, however its depth will be graded to maximise accessibility for the greatest number of native species.



This image provides an illustration of what the OWR might look like, once the plants are established.

The overall shape of the completed CW, with all its elements, will be broadly L-shaped. The reed bed will be planted east to west, some distance from the central hedgerow in the second field, approximately halfway down the sloped area. The OWR will be situated to the westerly end and run north to south, with its depth graded to work with the natural gradient of the land. A berm will be constructed to hold the deeper north end in place, while the southern end will be allowed to provide a natural shallowness for ingress/egress of amphibians.

From the southern end of the OWR, the willow planting will be arranged in such a way as to join up with the central hedgerow, to provide a wildlife corridor, so that amphibians *et al* can safely migrate between the OWR and other areas, including the river, Pond and Dewpond. The willows will be managed in a variety of different ways to ensure low growth is providing the required wildlife corridor cover. These methods will include pollarding and coppicing, thereby encouraging both long-term and shorter-term growth at the crowns and lower down the trunks.

2. Technical basis

Constructed wetlands (CW) are, exactly as the name suggests, wetlands that have been engineered and constructed. They are designed to take advantage of the same processes that occur in natural wetland vegetation, soils, and microbiomes to improve the quality of the water that passes through them. However, due to the more controlled flow and layout, they enable a more consistent and reliable effect. Originally conceived in the 1950s, they were initially used during the 1960s for municipal wastewater treatment. In recent years, the use of them has expanded to include processing of industrial wastewater, including mine drainage, processing of effluent and landfill leachate[2].

A wide range of designs is possible and many have been tested for various purposes[2]. The focus here will be on a vertical subsurface flow system (VSSF), as this is the chosen design, although the inclusion of an OWR and a willow coppice would technically make this a hybrid system. The OWR is referred to as such, rather than the more technically-correct 'free water surface wetland (FWS)', since although it will provide a further level of treatment, its primary function is as a source of water, and to provide appropriate habitat for both vertebrate and invertebrate fauna.

A VSSF wetland, more commonly referred to as a 'reed bed' is a hydrologically isolated area, with a fill of material that allows the free passage of water at a relatively slow rate, planted with macrophytes.

[2] Peter F. Stanbury, Allan Whitaker, Stephen J. Hall, Chapter 11 - Effluent treatment, Editor(s): Peter F. Stanbury, Allan Whitaker, Stephen J. Hall, Principles of Fermentation Technology (Third Edition), Butterworth-Heinemann, 2017, Pages 687-723, ISBN 9780080999531, https://doi.org/10.1016/B978-0-08-099953-1.00011-9.

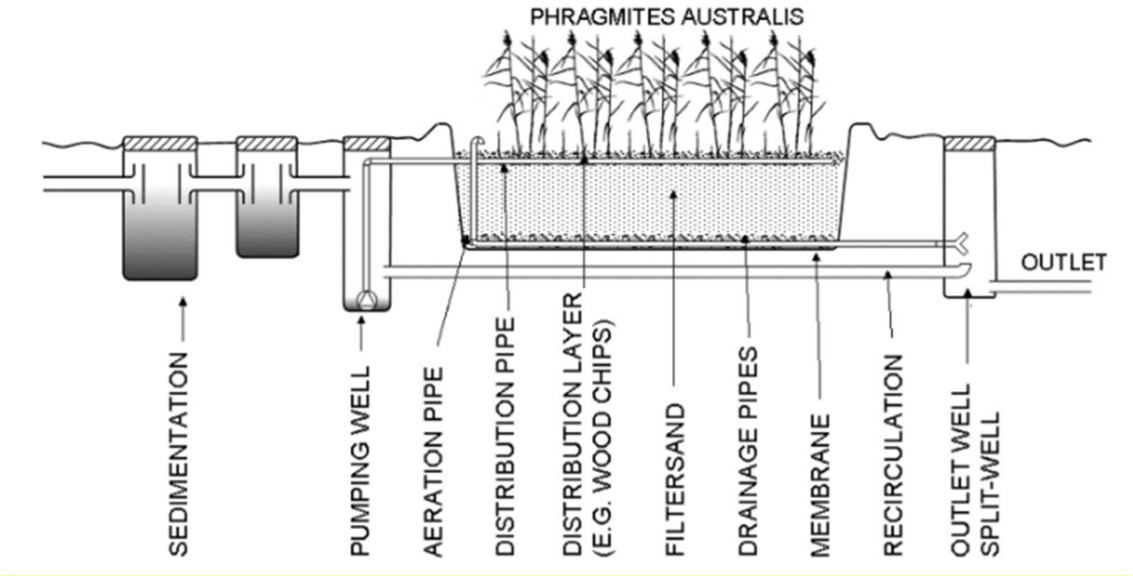


Figure 2: *An idealised cross-sectional diagram of a VSSF system for domestic sewage treatment, based on Danish guidelines*[3]*.*

The typical selection is *Phragmites australis*, although several other reed species have been used, including a variety of bulrushes. Of particular note is *Typha Latifola*, which has demonstrated enhanced phosphate removal over *Phragmites australis*[4]. For this reason, the applicant's design utilises both plants. The load is applied intermittently, either via a solar-powered pump system, or a sinking pipe valve. This permits the treatment bed to largely drain between cycles. This, in turn, allows the soil pores to rapidly diffuse oxygen from the atmosphere, maintaining a largely aerobic condition, although this will inevitably be lessened at the base of the system. This is supplanted by the release of oxygen from the root tips of wetland-adapted macrophytes, an adaptation to reduce and oxidise potentially harmful reducing substances in the rhizosphere[5].

For a variety of fairly technical reasons relating to redox chemistry and the ways in which biological systems process material in low oxygen conditions, which it would seem excessive to cover here (although Tom Pruen, BSc AppChemSci., PGDip Tox. would be happy to discuss this further if it would be helpful),

[3] Brix, H. (2005) *The use of vertical flow constructed wetlands for onsite treatment of domestic wastewater: New Danish guidelines*. Ecological Engineering 25, 491-500.

[4] Jiaqi Liu, Kejia Zhang, Esther Karunakaran, David Walker, Jacqueline Diaz-Nieto, et al.. Constructed Wetlands to Treat Urban Pollution in the UK. *Novatech 2023*, Jul 2023, Lyon, France. hal-04184774

[5] Peter F. Stanbury, Allan Whitaker, Stephen J. Hall, Chapter 11 - Effluent treatment, Editor(s): Peter F. Stanbury, Allan Whitaker, Stephen J. Hall, Principles of Fermentation Technology (Third Edition), Butterworth-Heinemann, 2017, Pages 687-723, ISBN 9780080999531, https://doi.org/10.1016/B978-0-08-099953-1.00011-9.

anaerobic digestion is best avoided in the surface layers as it tends to result in molecularly larger, partiall-digested outputs, which often smell. If the conditions are sufficiently reducing, the formation of methane and hydrogen sulphide will occur.

Aerobic conditions favour better breakdowns of complex molecules and a greater variety within the microbiome[6]. However, the predominantly aerobic nature of VSSF systems limits the removal of some chemical species. Notably, while excellent at ammonia removal, they are comparatively poor at nitrate removal. However, the formation of an anaerobic layer in the base of the OWR will facilitate the removal of nitrates, as the reduction of nitrates in anaerobic conditions is energetically favourable.

3. Planting and maintenance approach

The reeds will be periodically harvested to ensure frequent new growth, as this provides optimal uptake of waterborne nutrients. The harvested material can be used for compost, or craft projects, according to on-site demand. The open water reservoir will be planted with mixed native aquatic and marginal plants to maintain/improve water quality, and provided habitat enrichment for wildlife. The mixed plants will include:

- Pink flowering rush (*Butomus umbellatus*);
- Water forget-me-not (*Myosotis scorpioides*);
- Water Avens (*Geum Rivale*);
- Marsh marigold (*Caltha Palustris*);
- Purple loosestrife (*Lythrum salicaria*);
- Bog bean (*Menyanthes trifoliate*);
- Hornwort (*Ceratophyllum dermersum*);
- Hair grass (*Elecharis acicularis*); and
- Brandy bottle (*Nuphar luteum*).

Overflow from the reservoir will be to an area planted in willow. This will provide a final treatment step, as well as an ongoing source of willow for craft projects and other on-site requirements, such as propagation for hedging/drainage improvement along the northern boundary of the site. The regular coppicing/harvesting of the willow will improve the health of the trees and prolong their life.

[6] Vymazal, J., Greenway, M., Tonderski, K., Brix, H., Mander, Ü. (2006). Constructed Wetlands for Wastewater Treatment. In: Verhoeven, J.T.A., Beltman, B., Bobbink, R., Whigham, D.F. (eds) Wetlands and Natural Resource Management. Ecological Studies, vol 190. Springer, Berlin, Heidelberg . https://doi.org/10.1007/978-3-540-33187-2_5.

The applicants intend to extend the northern boundary hedge using a combination of willow and hazel, with the willow specifically chosen for its hydrophyllic nature. The northern swathe of both fields tends to somewhat swampy conditions, and it is anticipated that the addition of willow, in particular, to this area will assist with reducing excessive water build up during and after extreme rain events.

4. Monitoring

The applicants intend to introduce brown trout (*Salmo trutta*) to the OWR, partly to provide a further potential revenue stream for the business, but also to act by way of a 'canary in the coal mine': if the oxygenation, pollutant, or other unfavourable element levels are not sufficiently balanced, the health of the trout will provide an early indication and interventions can be made.

5. Environmental benefits

All three sections of the CW will provide localised habitat improvement for a number of species:

- Reed beds are favoured by birds such as:
    - the bittern (*Botaurinae*);
    - marsh harrier (*Circus aeruginosus*);
    - Cetti's warbler (*Cettia cetti*);
    - bearded tit (*Panurus biarmicus*); and
    - reed bunting (*Emberiza schoeniclus*).
- Other wildlife also rely on reedbeds for shelter and food, and these may include:
    - water voles (*Arvicola terrestris*);
    - water shrews (*Neomys fodiens*);
    - harvest mice (*Micromys minutus*);
    - and various insects and fish.
- The planted open water reservoir will provide suitable habitat for a variety of native birds, amphibians and invertebrate species, such as:
    - Dippers (*Cinclus cinclus*);
    - Grey wagtails (*Motacilla cinerea*);

- Moorhens (*Gallinula chloropus*);
- Coots (*Fulica atra*);
- Mallards (*Anas platyrhynchos*);
- Teal (*Anas crecca*);
- Great crested newts (*Triturus cristatus*);
- Smooth newts (*Lissotriton vulgaris*);
- Common frog (*Rana temporaria*);
- Common toad (*Bufo bufo*);
- Dragonflies and Damselflies (*Odonata*); and
- Mayflies and Caddisflies (*Ephemeroptera*).

- The willow area will connect to and expand the central hedgerow, running north to south between the two fields of the landholding, providing additional cover for migrating mammals.

6. Materials specifications

- 0.35mm HDPE liners, with an expected lifespan in excess of 40 years;
- 100mm perforated polyethylene pipe ('land drain'), plus fittings;
- 100mm unperforated PVC pipe, plus fittings;
- Header tank (200l):



The applicants have been fortunate enough to be able to salvage several of these former AdBlue barrels. These have been thoroughly cleaned and allowed to air, such that they can be safely repurposed for water storage.

- Concrete paving slabs (as strike plates, to prevent the erosion of the treatment bed by water cycling).