Pond Notes

Notes on Building a Wildlife Pond
For Hare's Corner Projects

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FH Wetland Systems

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Some Considerations for Designing your Wildlife Pond

When designing your pond layout there are a number of factors that may be helpful to consider, summarised as follows:

Intended use	Location
Size and shape	Bank slope
Depth	Water source
Lining requirements	Planning permission and liaison with official bodies
Plants and planting	Ecological impact

A summary of the construction process is included at the end of this document, along with sketches of different pond layout options for different sites.

Intended use

The intended use of the pond will be an important factor in determining the size, depth and location. Potential uses may include wildlife benefit, habitat enhancement, nutrient and/or sediment removal, or amenity use, irrigation water storage or an attractive water feature within the landscape.

If you want a gravity-fed irrigation source for your farm or garden, then keeping the pond elevation as high as possible will be important. For a wildlife pond, any size, shape or layout will be beneficial, but generally shallow bank slopes, undulating margins and an island may be useful factors to consider. For wildlife ponds, the greater the area of any protected space, the greater the number of species that will thrive there. Also a diversity of habitats will support a greater number of species; such as deep areas, shallow margins, a wetland marsh fringe, an island, some wet grassland etc.

Location

The location of your pond will depend on a number of important factors. These will include the site topography, the water source, the liner type required (if any), personal preferences based on the layout of your garden or farm, and the required use of the pond. Consider these factors when assessing the most suitable pond location.

A tool used in Permaculture designs is to build an irrigation pond on the key-point of the land (see fig. 5). This is the point at which the elevation is still high in the farm, but where excavation of a pond will still give a generous volume of water for storage. For more on the use of farm ponds for irrigation see
https://permacultureapprentice.com/permaculture-water-management/

Size and Shape

The size will depend on the intended use, availability of space, budget, and the type of water source on site. Wildlife ponds large enough to have an island and a mosaic of habitat types around it will support more species than a tiny garden pond – but any size will provide valuable habitat nonetheless. If you have high groundwater or a supply of clean spring water from a farm drain and heavy clayey soils for lining, then you can make a large pond at lower cost and easier construction than if you are on gravelly free draining soils or karst limestone.

Vis a vis shape: for wildlife ponds, having an island is useful, and having scalloped edges is also helpful to maximise the shoreline length. For silt trap ponds, maximise the distance between the inlet point and the outlet point to enhance the capacity for settlement across

the pond base. For water storage ponds the shape may be less important than volume, but consider benefiting wildlife at the same time by maximising edge length and making the edge slope very shallow.

Bank slope
A very shallow undulating bank slope will generally provide greater wildlife benefit, broadening this important edge habitat and also making it easier for insects, birds and frogs to enter and exit. That said, the steeper the bank slope, the greater the area of open water and total storage volume of the pond per unit area of the total project.

If space is limited and you want to combine good storage volumes (specifically for irrigation ponds) and a shallow edge for wildlife, then consider deepening the pond only towards the centre. Thus have a shallow perimeter edge of between 1:5 and 1:20 for the first few metres around the edge, deepening more steeply (1:2 to 1:3) to the centre.

Note that if a plastic liner is needed, the edge should have a stead slope from base to pond edge, so that air bubbles or rising groundwater can migrate out along the side without raising pockets of trapped air beneath the plastic. If this is the case, add nutrient poor subsoil on top of the edge plastic (from base to edge and extending over any visible liner) to achieve the undulations and shallow edge slope. If a clay base is present, or if there is high groundwater, then the edge can be more undulating again, providing seasonally variable pools around the pond fringe.

Depth
While depths of up to 30cm are generally the most valuable for wildlife benefit, deep water is useful for irrigation water storage and for those species that prefer deeper water. It's also useful for maintaining some open water if levels fluctuate widely throughout the year. If your pond is designed as a silt trap, then a water depth of 1m will provide greater settlement than a shallow pond, and will require less frequent maintenance to remove accumulated silt. For more detail on pond depths see factsheet 4: https://freshwaterhabitats.org.uk/projects/million-ponds/

Water source
Water sources may include roof runoff, field runoff, farm drains or streams, groundwater or rainfall. The reliability of the water source will influence the liner type selected. If you are relying on rainfall, then an artificial liner will almost certainly be necessary. On heavy soils such as marl or peat, modest inputs from a roof or clean yard may well suffice (after a small filter marsh area to screen out fines and leaf litter etc.). Where groundwater is high, no liner may be needed, but levels may fluctuate seasonally and require consideration at the design stage.

Lining requirements
The best and most cost effective liner is impermeable underlying subsoil such as marly clay or peat. Where an artificial liner is needed in order to hold water, a number of options such as EPDM (butyl), polyethylene or geo-synthetic liners may be used. Depending on the desired use for the pond and the reliability of the water source, several layers of silage pit cover plastic may make a suitable pond liner at very little cost. If using a plastic liner, ensure that there is a gradual slope up from the base to the outer edge, so that air cannot become trapped beneath the liner and float it.

From a wildlife perspective, it's generally considered better to use existing subsoil as the liner, even if it means allowing the pond to dry out seasonally, rather than to import a

synthetic liner into the site. For more detail on pond liners see factsheet 7: https://freshwaterhabitats.org.uk/projects/million-ponds/

Liner costs vary widely with grade and durability. Several layers of silage pit cover plastic will cost under €1/m^2; polytunnel plastic *c*. €4/m^2; more durable EPDM liners *c*. €15/m^2. Bentonite clay liners or bagged bentonite can cost *c*. €18/m^2. The selection will depend on the degree to which you will tolerate small amounts of leakage; the potential for topping up water levels (such as direct from house or shed gutters); and the degree to which you want clear open water. This is more of an aesthetic consideration than anything, since wildlife will value seasonal ponds as well as permanent ones. Note that most liners will benefit from several sheets of old silage pit cover plastic or other suitable protective sheet above and below the main impermeable liner. I suggest against using old synthetic carpet or underlay due the potential for releasing microplastics into the subsoil over time.

Plants and planting

For an amenity pond such as a garden pond or swimming pond, you may wish to plant some tall species which will look well from the outset; such as yellow flag (*Iris pseudacorus*) or bulrush (*Typha latifolia*). Note that many marsh plants are very vigorous and will take over shallow ponds if left to grow unchecked. For silt trap ponds, early planting with tall wetland plants will be useful to help slow the flow of water and enhance settlement of silt and debris in the water.

For wildlife benefit it may be quite appropriate to simply let your pond colonise naturally with plants. Another option is to bring in a handful of sediment from a nearby drain, pond or stream on the land to bring in seeds and insects. The One Million Ponds project (factsheet 8) specifically recommends against introducing plants. There is a very significant risk of bring in aquatic invasive species at the same time – or unwittingly buying invasive species! Instead you can simply allow your pond edge to colonise naturally over time, providing a bare soil habitat in the meantime, which is useful for early colonising species.

Planning permission and Liaison with official bodies

Planning permission is not needed for a pond as long as the change in ground level is less than 3 feet. Specifically, S.I. No. 236/1964 - Local Government (Planning and Development) Act, 1963 (Exempted Development) Regulations, 1964, states that "The construction of any path, drain or pond or the carrying out of any landscaping works within the curtilage of a dwellinghouse" is classed as exempted development, on condition that "The level of the ground shall not be altered by more than 3 feet above or below the level on the appointed day."

If you are working within an existing stream, then liaison with Inland Fisheries Ireland will be required. If working within an SAC (Special Area of Conservation), liaison with NPWS (National Parks and Wildlife Service) will be needed. In some areas other public bodies may also have a role to play in assessing the proposed works (OPW where weirs are being considered on a watercourse; ESB where power-lines or access to same may be impacted in any way, etc.).

Working within existing streams and protected areas is generally discouraged and permission to do so may not be granted, or granted subject to extensive conditions. Avoid working in existing streams and protected areas unless there is a good reason otherwise, and then only after obtaining approval from the appropriate body.

Ecological impact
Your pond should be net beneficial for local wildlife. As such it is important to ensure that you're not building it within a protected area or existing vulnerable or protected habitat. For more detail on protecting existing habitats see factsheet 6: https://freshwaterhabitats.org.uk/projects/million-ponds/

While it's tempting to build your pond at the very lowest part of your field or land holding, this area may already support species that like the seasonal moisture levels in the soil. Have a look at the plants growing on your selected pond site and it they are the same as the surrounding field (notable rushes or grass) then dig in and create your pond. However if the species in this low spot are different – wider leaved or lower growing or tall wetland vegetation for example; distinct from the grass or rushes in the rest of the field – then leave this area alone and build your pond close by instead of directly over these species. That way you will help to promote the existing aquatic plants rather than digging them up to build your pond.

Summary of the Construction Process

1. Select your location and design your pond layout, shape and depth.
2. Remove the topsoil and use elsewhere in the garden or farm.
3. Remove topsoil from the perimeter embankment on the lower side, if a lower retaining dam is to be used.
4. Excavate the subsoil to the required depth, building perimeter embankments on the lower side if a dam is needed, or throughout the pond margin as a way to dispose of excess subsoil into the project area (while avoiding blocking inflow of surface runoff water if that is needed as a water source).
5. If the subsoil is relatively impermeable, compact the base well with the excavator. Alternatively assess the need for a liner and use one if required; covering with 200-300mm of soil to protect it from damage.
6. In a clay lined pond, compact any retaining dams well in rises of 15cm to get a good solid earthen mound with a good seal.
7. Create shallow gradients or a stone splash-deck at the inlet and outlet points (if present) to prevent erosion.Replace loose subsoil or topsoil on the pond edge and perimeter for plant establishment.
8. Plant with locally sourced plant species if required, or allow to establish naturally.

The most common mistakes/pit-falls

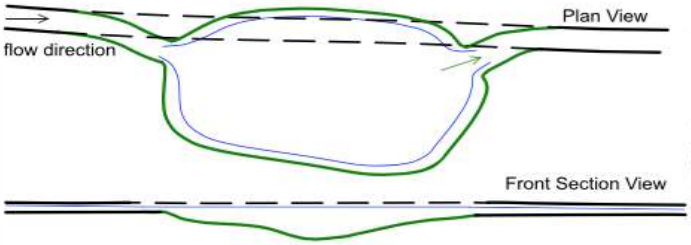
1. **Edge slope too steep** – be sure to keep the edge very very shallow if at all possible.
2. **Clay not holding water in summer** – ensure that lower clay embankment is well tracked with the digger; not just with the bucket. A plastic liner may be needed; or route in more water from a large roof; or be content with an ephemeral pond.
3. **Plastic liner leaking** – tricky to remedy, but to look for possible leaks, clear perimeter soil at the estimated level of the leak, search the liner for holes or folds which may allow water to overflow at a low point. Block with bitumen radon barrier tape.
4. **Plastic liner not set level** – seek low point and raise up liner by propping up with sod on each side. That can sometimes help to raise water levels to full liner potential.
5. **Invasive plants taking over** – don't buy from a garden centre due to the risk of buying alien invasive plants. Watch for bulrush or common reed in the early years to avoid these native plants taking over completely.

Some Pond Layout Options

Following are some layout options which may offer suggestions as to your own pond design based on your own landscape topography and water table levels etc.Fence from livestock or children where needed.

Pond creation in a widened drain (no plastic liner)

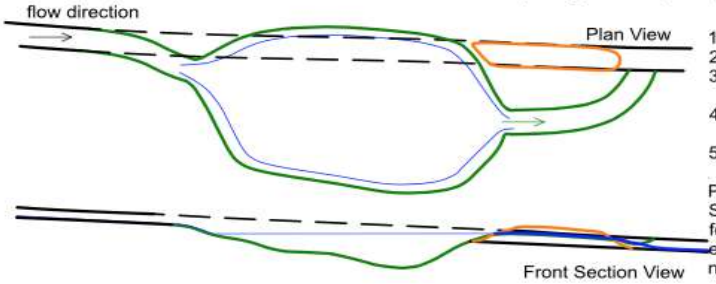
Pond in level drain, high water table



1 - clear topsoil and vegetation and remove to build up soil elsewhere in field
2 - remove subsoil to required depth
3 - reroute inlet and outlet streams to lengthen flowpath for enhanced silt settlement
4 - soften edges to create shallow slope for wildlife and safety (<1:3)

Pond will fill naturally with high water table.
Seasonal drying may occur. This is still ok for wildlife.
For more open water dig broader pond.

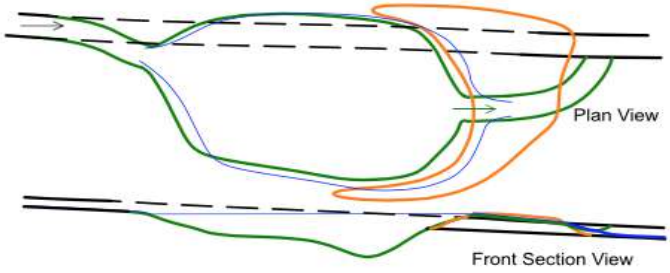
Pond in sloping drain, clay/peat subsoils



1 - clear topsoil and vegetation and remove to field or garden.
2 - remove subsoil to required depth across pond.
3 - build clay bund within the channel, compacted well onto a bare clay base (having removed vegetation to avoid leakage later)
4 - well compacted bund to be higher than surrounding ground to avoid erosion of fresh earth
5 - soften edges to create shallow slope for wildlife and safety (<1:3)

Pond will fill from inflow.
Seasonal drying may occur if drain runs dry in summer. This is still ok for wildlife. For more open water dig broader pond or build perimeter embankment. In all drain damming works be mindful to avoid flooding neighbouring lands.

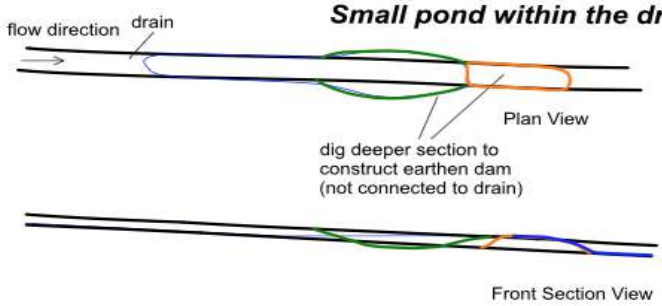
Pond in sloping drain, clay/peat subsoils, increasing depth by building a higher dam



1 - clear topsoil and vegetation from pond base and perimeter embankment base and remove to field or garden.
2 - remove subsoil to required depth across pond.
3 - build clay bund within the channel, compacted well onto a bare clay base (having removed vegetation to avoid leakage later)
4 - build clay bund around lower pond perimeter, compact well
5 - create slight depression (15cm) at selected location as spill-over location for new water exit point and route in a long shallow flow-path back into the main channel
6 - perimeter bund to be higher than surrounding ground to avoid erosion of fresh earth, except at spill-over location; to be covered with grassed sod for protection from erosion
7 - soften pond edges to create shallow slope for wildlife and safety (<1:3)

Pond will fill from inflow.
Seasonal drying may occur if drain runs dry in summer. This is still ok for wildlife. For more open water dig broader pond or raise perimeter embankment. In all drain damming works be mindful to avoid flooding neighbouring lands.

Small pond within the drainage channel



1 - clear topsoil and vegetation from areas being worked on (both bund and wider section) and remove to field or garden
2 - excavate subsoil from drain edge above bund
3 - build clay bund within the channel, compacted well onto a bare clay base (having removed vegetation to avoid leakage later)
4 - create slight depression (15cm) along the centre of the clay bund for raised water exit point and cover with grassed sod for protection from erosion
5 - soften pond edges to create shallow slope for wildlife and safety (<1:3)

Pond will fill from inflow.
Seasonal drying may occur if drain runs dry in summer. This is still ok for wildlife. For more open water dig broader pond.
In all drain damming works be mindful to avoid flooding neighbouring lands.For steep sided channels a much larger dam can be made for a larger pond.

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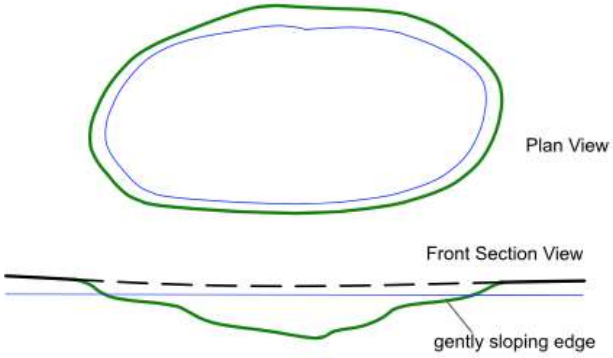
Pond creation on level site with high water table (no plastic liner, soil removed from pond area)

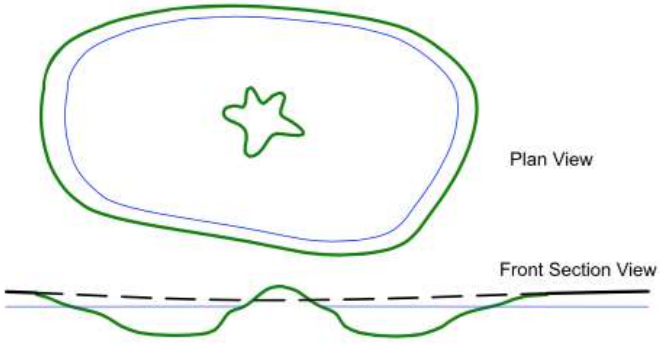
Pond on level ground with high water table



1 - clear topsoil and vegetation and remove to build up soil elsewhere in field or garden
2 - remove subsoil to required depth, being mindful of summer and winter groundwater levels when planning excavation depths
3 - soften edges to create shallow slope for wildlife and safety (<1:3)

Pond will fill naturally with high water table.
Seasonal drying may occur. This is still ok for wildlife.
For more open water dig broader and/or deeper pond.

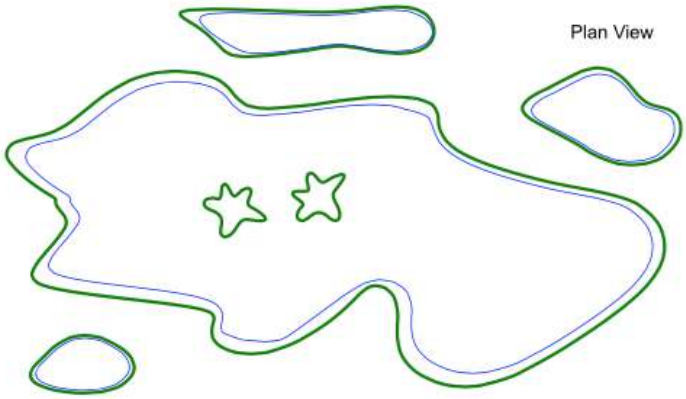
Pond on level ground with high water table, showing island in centre



1 - clear topsoil and vegetation and remove to build up soil elsewhere in field or garden
2 - remove subsoil to required depth, being mindful of summer and winter groundwater levels when planning excavation depths
3 - leave or mound up island for wildlife interest and to use some of the excavated soil
4 - soften edges to create shallow slope for wildlife and safety (<1:3)

Pond will fill naturally with high water table.
Seasonal drying may occur. This is still ok for wildlife.
For more open water dig broader and/or deeper pond.
Star shaped islands offer greater edge habitat and shelter for birdlife.

Level ground, high water table: Pond/wetland mosaic to maximise habitat value



1 - clear topsoil and vegetation and remove to build up soil elsewhere in field or garden or build up as mounds or islands
2 - remove subsoil to required depth, being mindful of summer and winter groundwater levels when planning excavation depths
3 - leave or mound up island for wildlife interest and to use some of the excavated soil
4 - soften edges to create shallow slope for wildlife and safety (<1:3)

Pond will fill naturally with high water table.
Seasonal drying may occur. This is still ok for wildlife.
For more open water dig broader and/or deeper ponds.
Mosaic of ponds provide a broader range of habitat types for wildlife. Star shaped islands offer greater edge habitat and shelter for birdlife.

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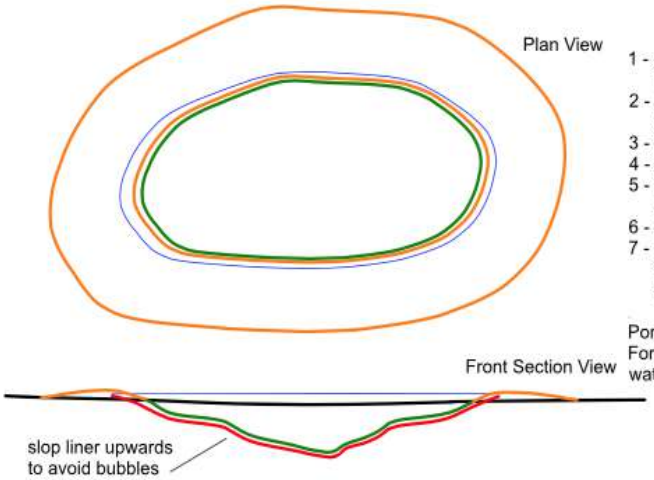
Pond creation using liners

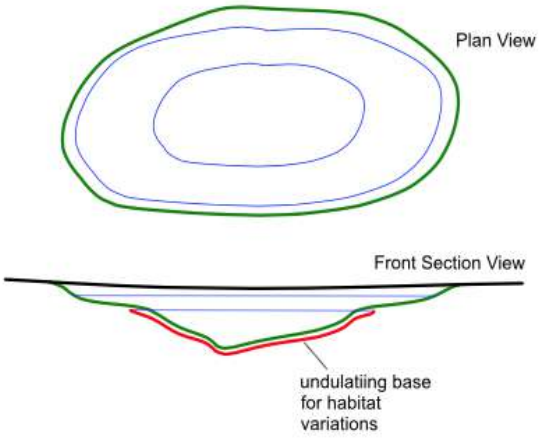
Slightly raised pond using perimeter edge to hide excavated soil



1 - clear topsoil and vegetation from pond and perimter bund area and remove to build up soil elsewhere in field or garden
2 - remove subsoil to required depth, moving subsoil to the pond perimeter to build up a raised edge
3 - set some soil to one side for use on top of liner
4 - ensure that edges are gently sloping for wildlife and safety (<1:3)
5 - lay liner across pond base, keeping a lot of slack to avoid puncuture when soil is replaced
6 - ensure that the upper liner perimeter is level all around
7 - replace soil to a depth of 15cm across full liner or across liner edge if pond is too braod to do the work to do the work without tracking onto the lined area

Pond will fill from rainfall only and possibly from upslope runoff.
For water sources other than direct rainfall consider shed or house roof water or piped inputs from upgradient stream or drain.

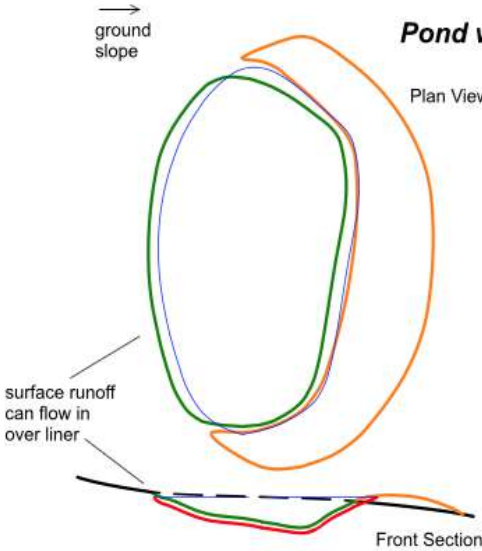
Pond in medium draining soils with reduced plastic sheet for permanent pond in the lower section and seasonal flooding in winter



1 - clear topsoil and vegetation from pond and perimter bund area and remove to build up soil elsewhere in field or garden
2 - remove subsoil to required depth for use elsewhere also
3 - set some soil to one side for use on top of liner
4 - ensure that edges are gently sloping for wildlife and safety (<1:3)
5 - lay liner across pond base (either high around the edge for a larger permanent pool or for a seasonal variation in water on heavy soils lay a liner just in the lower section for permanent water cover, but allowing water to fall and rise in the upper section as a marsh/bog garden
6 - keep a lot of slack to avoid puncuture when soil is replaced. Ensure that the upper liner perimeter is level all around
7 - replace soil to a depth of 15cm across full liner or across liner edge if pond is too braod to do the work to do the work without tracking onto the lined area

Pond will fill from rainfall only and possibly from upslope runoff.
For water sources other than direct rainfall consider shed or house roof water or piped inputs from upgradient stream or drain.

Pond with liner on sloping ground



1 - clear topsoil and vegetation from pond base and perimeter embankment base and remove to field or garden.
2 - excavate subsoil to required depth across pond.
3 - build clay bund with excavated subsoil around lower perimeter, compacted well onto a bare clay base
4 - set some soil to one side for use on top of liner
5 - soften pond edges to create shallow slope for wildlife and safety (<1:3)
6 - lay liner across pond base, keeping a lot of slack to avoid puncuture when soil is replaced
7 - ensure that the upper liner perimeter is level all around
8 - replace soil to a depth of 15cm across full liner or across liner edge if pond is too braod to do the work to do the work without tracking onto the lined area

Pond will fill from rainfall only and possibly from upslope runoff.
For water sources other than direct rainfall consider shed or house roof water or piped inputs from upgradient stream or drain.

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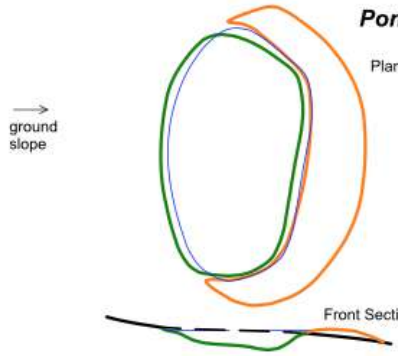
Pond creation on sloping site with heavy clay or peat soils

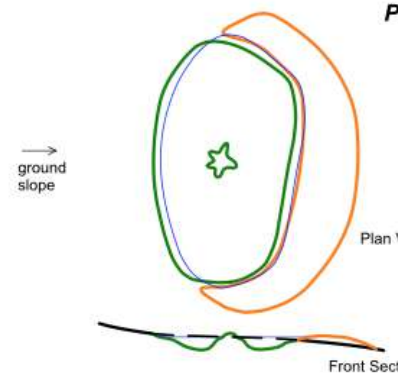
Pond on sloping site



1 - clear topsoil and vegetation from pond base and perimeter embankment base and remove to field or garden.
2 - excavate subsoil to required depth across pond.
3 - build clay bund with excavated subsoil around lower perimeter, compacted well onto a bare clay base (having removed vegetation to avoid leakage later)
4 - soften pond edges to create shallow slope for wildlife and safety (<1:3)

Pond will fill from rainfall only and possibly from upslope runoff.
Seasonal drying will occur if soil is not sufficiently impermeable
This is still ok for wildlife.
For more open water dig broader pond or raise perimeter embankment or use plastic liner if needed to hold more water.
For water sources other than direct rainfall consider shed or house roof water or piped inputs from upgradient stream or drain.

Pond on sloping site with island

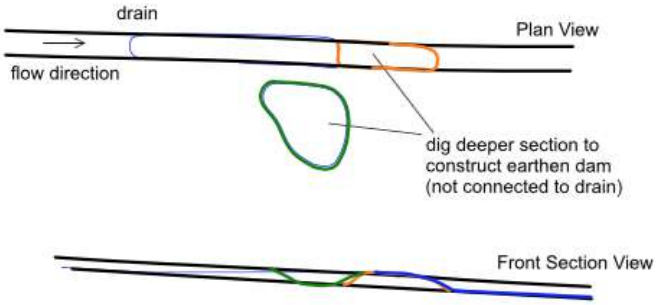


1 - clear topsoil and vegetation from pond base and perimeter embankment base and remove to field or garden.
2 - excavate subsoil to required depth across pond.
3 - build clay bund with excavated subsoil around lower perimeter, compacted well onto a bare clay base (having removed vegetation to avoid leakage later)
4 - soften pond edges to create shallow slope for wildlife and safety (<1:3)

Pond will fill from rainfall only and possibly from upslope runoff.
Seasonal drying will occur if soil is not sufficiently impermeable
This is still ok for wildlife.
For more open water dig broader pond or raise perimeter embankment or use plastic liner if needed to hold more water.
For water sources other than direct rainfall consider shed or house roof water or piped inputs from upgradient stream or drain.
Star shaped islands offer greater edge habitat and shelter for birdlife.

Pond creation in peat bog setting

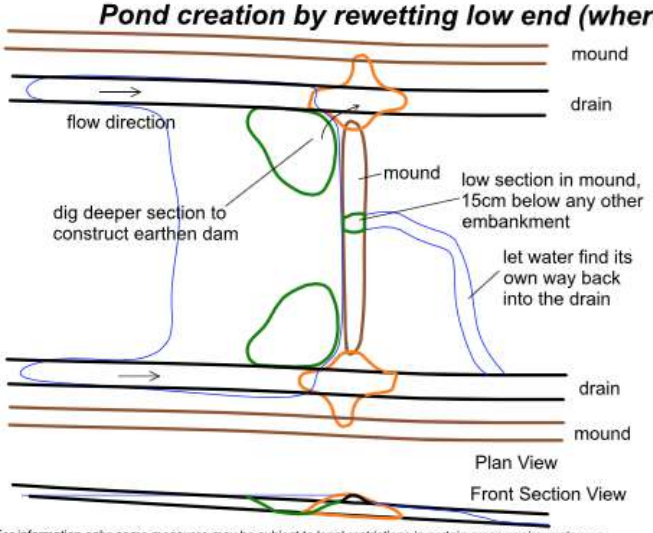
Habitat restoration by rewetting low end of drained bog channel



1 - clear vegetation from areas being worked on (both bund and pond area) and set to one side for use to cover drain bund later
2 - excavate subsoil from pond area to generate bund material
3 - build peat bund within the channel, compacted well onto a bare peat drain base (having removed vegetation to avoid leakage later)
4 - mound bund over the level of the surrounding bog
5 - cover all bare peat with vegetation and tamp well into place with digger
6 - repeat along drain to raise water level for as great an area as is available

Channels will fill from inflow and revegetate over time.
Seasonal drying may occur if bog water level drops in summer.
This is still ok for wildlife.
Explore opportunities for greater rewetting around this area to create a wider preserved bog habitat.
In all drain damming works be mindful to avoid flooding neighbouring lands.

Pond creation by rewetting low end (where all of bog is in the one ownership)



1 - clear vegetation from areas being worked on (both bund and pond area) and set to one side for use to cover drain bund later
2 - excavate subsoil from pond area to generate bund material
3 - build peat bund within the channel, compacted well onto a bare peat drain base (having removed vegetation to avoid leakage later)
4 - similarly plug any other obvious outfalls, wtih peat compacted onto peat (without vegetation to act as a conduit for water)
5 - create slight depression (15cm deep) in a selected location for new raised water exit point
6 - cover all bare peat with vegetation and tamp well into place with digger
7 - soften pond edges to create shallow slope for wildlife and safety (<1:3)

Pond will fill from inflow.
Seasonal drying may occur if bog water level drops in summer.
This is still ok for wildlife.
For more open water dig larger pond or enhance the retaining dam.
In all drain damming works be mindful to avoid flooding neighbouring lands.

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Pond Lining Options

Ideally wildlife ponds would be built in areas where there is no need for an artificial liner. Areas of high groundwater or heavy clay soils are both ideal for pond creation. This allows a pond to be built at very little cost, and with very little machine time and embodied resources in the form of digger diesel or liner plastic.

Where the soil does not hold water quite so effectively, effective steps may sometimes be taken to reduce water losses from the pond; notably by puddling existing clay subsoils to enhance water holding capacity and/or by increasing the water inputs from shed roof surfaces or from clean yard or driveway runoff. Note that any runoff to your pond should be filtered through a wetland buffer zone or planted swale en route to the pond to keep your wildlife pond clear.

Another option for keeping water in your pond is where there is a reliable inflow to the pond from a farm drain, for example, which can counterbalance seepage into suboptimal soil conditions. This can be a reliable way to keep your pond topped up, but note that if you are working within a waterway in any way then both Inland Fisheries Ireland and National Parks and Wildlife Service will need to be consulted beforehand to ensure that you are not in danger of causing damage to wildlife habitat. This can be a time-consuming process, so it may be easier to avoid any instream works of any sort if other options are readily achievable.

If more moisture holding is required then a liner may be required. The option you select will be based primarily on pond size, soil type, water source and budget. A summary of options available is set out below; not necessarily in order of preference.

1. High water table or existing heavy clay subsoils.
2. Importing clay or moving clay within the site.
3. Bentonite clay in bagged form
4. Geosynthetic clay liners (GCL)
5. Heavy duty plastic liners; including polyethylene (HDPE or LDPE), synthetic rubber (EPDM), polyvinyl chloride (PVC – not recommended due to toxicity in manufacture, recycling and incineration).
6. Lighter plastic lining options
7. Other materials for small ponds

1 - High water table or existing heavy clay subsoils.
This is the best option from many perspectives. Simply remove topsoil from the pond area and any embankments down-gradient of the pond; mould subsoil (building up the lower embankment with clean excavated clay laid onto on bare clay subsoil) and compact with the digger by driving on all banks. Ideally compact the clay embankments in a horseshoe around the pond in 6” rises by tracking over the embankment several times with each rise to enhance compaction. You may wish to maximise the inflow of water from up-gradient ground (if this area is clean). Wait for the pond to fill with rain.

For lining with clay, great care must be taken to ensure a good seal prior to replacement of top-soil. Care must also be taken to ensure that the soil does not dry

out and crack the clay liner, forming flow pathways that may not reseal upon rehydration. The Department of the Environment's *Constructed Wetland Guidance Document* outlines an effective method for clay lining of farm scale constructed wetland systems. The relevant section is copied into the appendix notes at the end of this document.

2 - Importing clay or moving clay within the site
This may be a viable option where good sticky grey clay is readily available, but will require a lot of digging and moving unless the source of clay is very close to the desired pond location. This option is best for seasonally variable pond water levels or where there is another source of water additional to rainfall such as a farm shed roof or clean farm road that does not have regular cattle on it.

3 - Bentonite clay in bagged form
This option allows for a pond to be lined without using plastic, which is important for some people. In general terms this method can be used to augment existing relatively heavy clays to enhance moisture holding capacity. Dig the bagged bentonite clay powder into the upper surface of the exposed soil after excavating the pond. Then roll the pond base and embankments to consolidate it prior to hydration. As above, there may be a seasonal drop in water levels during dry weather unless there is an additional water source such as shed roof etc. Reports on effectiveness of this method vary; and it is a relatively expensive process; at €17-35/m^2 when applied at 1 bag/m^2 (depending on the quantity purchased); plus the additional machine time in mixing the top layers of soil and clay together and rolling them.

4 - Geosynthetic clay liners (GCL)
These combine a pre-hydrated bentonite layer of *c*.1cm of clay sandwiched between two layers of woven polypropylene geotextile sheeting. This liner type is more suitable where soil types do not include existing heavy impermeable clays. Liners may be fitted in one large sheet by the supplier (due to the weight of the rolls) or alternatively by the land owner in small liner sections which are then jointed together by overlapping clay on clay and pressing together and applying bagged bentonite powder along the seams in line with the suppliers recommendations.

Indicative GCL liner costs are *c*.€8.50/m^2 + €120 for delivery + €35 for a bag of powdered bentonite clay for use at the seams (+ VAT at 23%). Thus for a small 5m x 5m pond of 750mm depth; allow a pond liner size of *c*.6.5m x 6.5m: *c*.€650 incl. VAT and delivery. Note that this liner type can be fiddly to install given the weight of the liner panels and as such it may add to the cost of the machine time on the project.

The installation day rate by the suppliers (e.g. Geoline – see next section) is *c*.€2200 + VAT and materials for laying long single runs of GCL liner. For larger ponds this method can be a lot easier than working with individual GCL panels (taking 10m x 20m of open water; or 12m x 22m of pond liner area) costs work out at *c*.€5200 including liner, materials and VAT.

5 - Heavy duty plastic liners
Standard plastic pond liner options typically include EPDM (ethylene propylene diene monomer rubber) or PVC in a synthetic 'butyl rubber' type material. EPDM is arguably the most straightforward pond liner type, given that it moulds easily to the

excavated pond shape and is relatively rust and durable. Over time it may be susceptible to puncturing by some plant roots such as common reed (*Phragmites australis*) which has a particularly strong sharp pointed rhizome. Given the very invasive nature of *Phragmites*, it is worth simply identifying this, our tallest native grass, and pulling it out if it begins to establish. The cost of EPDM is *c*.€12/m^2 plus protective geotextile top and bottom (at €2/m^2 for each side of the main liner). Thus for a modest pond size of 5m x 5m (with a liner size of between 6.5m x 6.5m for a 750mm deep pond or 7m x 7m for a 1m deep pond) the costs will vary from €870 to €1060 incl. VAT and delivery (depending on which size of liner you go for) for the EPDM plus geotextile.

Note that it is specifically recommended to avoid PVC for lining wildlife ponds due to the toxicity of PVC in manufacture, recycling and incineration. Despite PVC being cheaper to buy, there is little merit in creating a beautiful wetland wildlife oasis at the direct ecological and health costs to wherever your liner is produced or will ultimately be disposed of. So be sure to double check if you are buying an EPDM liner that it is not a PVC butyl-type liner.

Other heavy duty liners include LDPE and HDPE. 1mm LDPE (Low Density Polyethylene) is readily available in 7m widths and costs *c*.€9/m^2. Add €2/m^2 x 2 (for top and bottom) for the geotextile protective membrane. This is a more durable liner than EPDM, but is more difficult to fold and mould to the pond base contours. HDPE (High Density Polyethylene) is more rigid again, and is more suited to more industrial type applications such as landfill sites and the like.

If you are looking for a plastic liner it can sometimes be useful to have a sense of which thickness to select. *Treatment Wetlands* by Kadlec and Wallace (2009) lists minimum synthetic liner thicknesses for constructed wetlands as 0.76mm PVC or 1.00mm LDPE or HDPE. Some Irish suppliers offer a lifetime guarantee for PVC and HDPE for 0.5mm and 0.75mm thicknesses respectively. Danish guidelines for reed beds recommended minimum thickness for HDPE or LDPE of 0.5mm (Miljoministeriet, Okologisk Byfornyelse og Spildevandsrensning Nr.52, 2004), with geotextile or sand underlay and geotextile overlay for protection from sharps and roots.

Prices for the above liner types are based on discussions with Geoline in Waterford, who supply GCL, EPDM, LDPE and other liner types. The cost estimates outlined here include a group discount for projects following advice on these pages, so mention Féidhlim Harty or FH Wetland Systems when seeking prices on your liner order.

Contacts include Ann Tracey at Geoline at anntracey@geoline.ie or 086-6090355 for EPDM or LDPE liners; or Karl at Rockworld Water Features at info@rockworld.ie or 045-870970 for EPMD liners. Note that there is no onus to run with any particular supplier. The information here is meant to be guidance rather than prescriptive.

6 - Lighter plastic lining options

While the heavier plastic liner options are very reliable for large pond projects, for small garden ponds or for ponds being built on relatively heavy soils, a lighter option

may also be effective. Options may include standard builders plastic, polytunnel plastic or silage pit cover plastic. These are not necessarily suitable for holding water on a year-round basis for sites with free draining soils, but may work to augment the existing water holding capacity of the soil or where seasonal variations in water levels are acceptable aesthetically. Bear in mind that seasonal or ephemeral ponds are valuable in their own right, so light, low cost liners may be an option for your project in certain circumstances. Another application for light plastic lining is where the pond is sufficiently small that it can easily be emptied and relaid if it does not hold water to your expectations.

For any of these options, the plastic may be protected by an additional layer above and below the main liner sheet. Old carpet is a common method of protecting the plastic, but this is only recommended for pure wool carpet with hemp or jute webbing, so that as the carpet decays you don't have a synthetic fibre carpet shedding microplastics into the soil. As a very general rule of thumb you may wish to use 2 layers of builders plastic; or 1 layer of polytunnel plastic (which is much more tear resistant than the former); or 4-8 layers of silage pit cover plastic (as an example you may wish to use 2-4 sheets of old pit cover plastic top and bottom to sandwich 2 new sheets of pit cover plastic in between). Note that for all plastic liner types it will be important to have a clean pond base on which to lay your plastic; and to lay the plastic very loose, without stretching it at all, but this is particularly important for the lighter plastic lining options. Water holding is by no means guaranteed, but if you are on a lower budget and have time to experiment then it may be an effective option.

7 – Other materials for small ponds

Ponds do not need to be large to have value for wildlife. Many garden ponds can be created by repurposing old containers as diverse as old baths, sinks, buckets, basins or bits of surplus liner or plastic sheeting. There are also rigid pre-moulded pond liners available from garden centres. In general terms if it is possible to make use of old materials rather than buying new ones, then this is better for the wider environment and thus the health of all of the biodiversity of life within it. They also have the advantage of being free.

The main thing to be conscious of for rigid containers of any sort is that they will almost inevitably have steep sides. Thus the edge slope will not be easy for insects or amphibians to enter and exit from. Also if mice or hedgehogs happen to fall in it is essential that they are given a reliable way to climb out again. Thus any rigid container should have an easy ramp of stone or logs to give a good solid entry and exit point for wildlife.

Sink the container into the ground. Add some clean sand or some subsoil to the base of the container for diversity of habitat (more interesting than the plastic base) and then add stones to create steps or platforms for wildlife to climb in and out. Given that these are such small ponds and that they are artificially lined, you may wish to bring in suitable pond plants and some pond water from a nearby pond to introduce a mix of seeds and macroinvertebrate species. Ensure that the plants are locally sourced form an area without aquatic invasives and not from a commercial garden centre – which carries a significant risk of introducing alien invasives by accident.

Transport and handling liners
With all liners it is important to transport, store, lay and work around with care. If a puncture occurs during construction work, this should be fixed immediately. In the long term, if the pond leaks it may be necessary to remove the plants, soil and liner and start with a new liner, so care at the construction phase is crucial. Sand blinding may be used for some site conditions or for some liner types. However where a synthetic liner is used on a heavy clay sub-soil, sand should be avoided. This will allow the potential for self-sealing in the event of a localised puncture. Before ordering a liner, talk with the suppliers about the particular application and let site conditions guide the decision.

Edge slope
Build a very shallow edge slope around your pond. This serves a number of functions. It is much safer; much more beneficial for wildlife; and also helps to hold the liner in place without needing additional liner length and width to create an anchor in the bank. A slope of between 1:5 and 1:20 is recommended by the 1-million ponds project in the UK.

Soil replacement
To maximise the ecological value of your pond and to protect the liner, it's recommended to replace 4'6” of nutrient poor subsoil over your liner after laying. Lay very gently with the digger bucket, over the top layer of protective geotextile membrane (for any plastic option), or directly over your GCL (geotextile clay liner). Do not compact this replaced soil since this would potentially damage the liner and also reduce the habitat value of the soil for wildlife. Also, avoid driving on your pond with the digger as soon as your liner goes in.

To maximise the wildlife value of your pond, replace subsoil in an undulating fashion around the outer perimeter. This will maximise the diversity of habitat spaces within the pond edge, encouraging greater wildlife diversity than a clean, contoured finish.

Plants and liners
Some wetland plants can be quite invasive in their growth habits, and some species such as Phragmites australis and Typha latifolia have the ability to puncture some types of plastic liners. If you have a good source of water entering your pond such as from a large shed roof or clean yard or farm road, then such punctures may be resealed sufficiently by the plant roots themselves. For any yard or road inputs, put in a wetland filter area or planted swale to clean the water prior to the pond.

The general guidance on new ponds is to leave them unplanted. This will allow certain pioneer species of plants and invertebrates (insects and other small organisms) to colonise early on and get a foothold where they may otherwise be simply displaced.

Groundwater issues or air pockets
On some sites, variability in groundwater levels or even water ponding on a site, can lift the liner from below and lead to bubbling of the liner membrane. The potential for this may be reduced by laying the liner over a good quality non-woven geotextile membrane (which can act as a conduit for air or water pockets) and by contouring the liner very gently and consistently from base to edge. Achieve your wildlife edge undulations with replaced subsoil around the pond perimeter rather than with your

initial excavation. In this way you can allow water and air bubbles to migrate out without catching on liner folds or unevenness.

If you have a seasonally high water table then perhaps the best approach is to create an ephemeral pond rather than one that will hold water all year round.

Ephemeral ponds

From a wildlife perspective, it's not necessary that your pond hold water all year round. While a pond should hold water for 4 months of the year or more, ponds that are seasonally dry provide distinctive habitats for certain species. This can provide a good excuse to experiment with your pond and your pond liner; carrying out the initial excavation in year 1 and then waiting to see how the pond behaves over the coming 12-24 months and recording the water levels. This can be a good approach where the soil may be suitable, but you're not sure. On the other hand, if you know that your soil is free draining, then putting in a liner at the outset is the most economical way to proceed.

The 1 Million Ponds project in the UK provides a wonderful resource on pond construction, including liners.(www.freshwaterhabitats.org.uk/projects/million-ponds) Their take on pond lining is set out here:

> "Pond liners are often not needed to create ponds. The rationale behind the Million Ponds Project is to put clean waterbodies back in the landscape, and the most sustainable and cost effective way of doing this is to make use of natural, clean water sources without the need for pond liners. Reliance on natural hydrology will mean that ponds will have natural fluctuations in water levels. Some may dry up in drier months but this is not a problem for wildlife. Temporary (seasonal) ponds, or ponds with large water level fluctuations, are important for a wide range of wildlife, and a much neglected habitat type.
>
> Practically, though, pond liners do allow ponds to be created on sites where the natural hydrology or geology is unsuitable, or where there is good reason to keep the pond separate from the groundwater, e.g. where groundwater may be polluted such as on reclaimed landfill sites. There are, however, significant drawbacks to using liners: the ponds are more expensive to create, more prone to damage and sudden water loss and have little flexibility if you want to modify the pond at a later date.
>
> Highly permeable and freely-draining soils are not ideal for pond creation, and can require lots of effort or resources to ensure water is retained, even with a liner. For example, the catchment of a lined pond in very permeable substrates like gravels or sands may be restricted to the area that is lined – other water drains straight into the ground. This could result in a pond that holds water only in periods of high rainfall, which can be an excellent wildlife habitat, but will disappoint anyone hoping to create a permanent water body. The catchment could be increased by extending the liner well beyond the pond margin, but it may be more appropriate to look for an alternative site to create a pond."

Appendix Notes on Clay Lining:

Additional information on clay lining is available in the Department of the Environment, Heritage and Local Government Integrated Constructed Wetlands Guidance Document for Farmyard Soiled Water and Domestic Wastewater Applications, 2010, Chapter 6, Construction, as follows:

Construction of the wetland base

There are two basic water-retaining elements in any ICW, the wetland base and the embankments. To achieve the necessary water retention, several methods may be deployed, depending on site topography, soil type, and quantity, and machinery available.

The construction of the wetland base is required to achieve sufficient integrity to prevent both leaks and excessive seepage and maintain hydric conditions for the formation of the wetland soil. A permeability of 1x10-8 m/s is necessary to both establish the wetland soil and protect ground water (see Section 2.7 above). Methods of achieving this level of permeability depend upon a site's subsoil analysis results. This may be achieved, following removal of topsoil, by various means including:
1. Levelling of ICW base area on sites where subsoils already have the required impedance.
2. Compaction of the subsoil, in layers of approximately of 150-200 mm, using vibrating rollers on the more permeable soils to achieve 500mm depth of subsoil liner.
3. Machine tracking with water on intermediate subsoils and again with the redistributed topsoil. This puddling technique is the method found to be the most effective. It has additional advantages in that it will demonstrate the water retention capacity of the wetland cell and provides optimal conditions for the establishment of vegetation.
4. Where subsoils are unsuitable, as indicated in the 'Trial Hole Analysis', imported material consisting of boulder clay or other high-clay content soil material may be substituted. This in turn should be compacted in layers of approximately 150-200 mm or puddle as in 3. above. An alternative is to use a geo-membrane or bentonite liner which may be as cost effective as importing suitable material.

The accumulation of organic matter from the influent will further decrease the rate of exfiltration as a result of the organic nature of the detritus. The essential component in achieving the necessary impedance to infiltration is that the structure remains adequately hydrated and the supporting soil free from conduits. If allowed to dry out and to be colonised by terrestrial vegetation, hydraulic conductivity may increase.

The construction machinery necessary to carry out the work will depend on site conditions and the scale of the undertaking, and may range from wheeled multi-tasked excavators to large tracked backhoe excavators and bulldozers.

Topsoil, because of its organic content, gathered at the site during the preliminary stage of construction is ideally suited to achieving impedance to infiltration and should be conserved for redistribution in preparation for final sealing and planting/seeding. The use of puddling where topsoil and/or subsoil is mixed with water to make self-levelling slurry is a proven method for achieving the required level of impedance where there may be some doubt with regard to infiltration. In some instances the extra topsoil may need to be used to enhance sealing. The use of water in the preparation of the wetland surface and for planting should be ideally available at this phase as it may facilitate a range of construction needs, such as the final levelling and the provision of optimal conditions for planting/seeding of the emergent plant species. A lysimeter placed 200- 400mm under a wetland cell will allow for qualitative and quantitative assessment of infiltrating water. Lysimeters must be fixed in place so that any collected water is accessible and reflects the adjacent soil conditions.

4. Construction of Embankments
Embankment construction needs to be to standards that will support vehicular traffic such as tractors, have slopes that minimise soil creep and be resistant to weather erosion. A layered and tracked building method in layers of

approximately 200 mm is recommended and has proven both effective and efficient.

The slope of the embankment should never be less than 1:1 - for biodiversity enhancement 2:1 or even wider ratios have special merit. The top profile of the embankment should be adequately compacted, level and wide enough to allow a tractor and mower to travel on safely. Corner and junction areas are required to be sufficiently wide to allow for easy turning of vehicles. This is supported by the curvilinear layout generally indicated in the ICW design.

Embankment construction should also be made up from the on-site materials and ideally exclude topsoil that can be used for puddling. The aim is to have low permeability in the embankments to allow for any future increasing water level in any of the wetland segments. The same construction principles apply as with the construction of the wetland base.

5. Water Retention Test

Notwithstanding that water absorption by soil, evaporation and rainfall may make the task of confirming that an ICW will retain water difficult, testing for this is probably the best indicator of compliance for client, designer, contractor and regulator. Puddled soils, subsoils and topsoil, in association with a free water surface will allow any conduits to be identified including missed drains and excessively porous patches. In addition the flatness of the soil's top surface can be checked.

This may be undertaken by filling the individual ICW segments/cells with water until a satisfactory degree of water-loss is confirmed. Where an appropriate water source is not available it may be necessary to conduct this test in wet weather.