Earth Lined Lagoon Feasibility and Construction Guidelines

for

New Manor Farm, Polsham, Wells, Somerset BA5 1RP

looking west, over (left to right) test pits 4, 5 1, 3, 2

looking east, over test pit 6

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Contents

1 FARM DETAILS 3

1.1 Reasons for the visit 3

1.2 Farming Rules for Water implications 4

2 SLURRY AND FOULED WATER QUANTITIES TO BE DIRECTED TO THE PROPOSED LAGOON 4

3 EARTH-LINED LAGOON SIZING AND PROPOSED SITE 6

3.1 Proposed site 7

4 EARTH LINED LAGOON FEASIBILITY 8

4.1 Test pits and preliminary soil examination 8

4.2 Test pit profiles 11

4.3 Laboratory testing of permeability 12

5 EARTH LINED LAGOON CONSTRUCTION 12

5.1 General site and soil considerations 12

5.2 Base and bank design 13

5.3 Site preparation 15

5.4 Base and bank construction 16

5.5 A cautionary note about 'key trenches' 18

5.6 Site plans 19

6 OTHER LAGOON CONSTRUCTION AND MANAGEMENT CONSIDERATIONS 20

6.1 Filling the lagoon 20

6.2 Access and stirring 20

6.3 Fencing and bank vegetation 22

6.4 Odours and Ammonia emissions 22

7 NEXT STEPS 25

8 CONSENTS AND LEGISLATION 26

8.1 Environment Agency 26

8.2 Planning 26

8.3 Health And Safety 27

9 USEFUL INFORMATION 27

SUMMARY

- Limited fouled water storage capacity at New Manor farm is compromising winter management.
- The farm would like to add 6 months' slurry and fouled water storage capacity; for better nutrient management, to further reduce soil damage and pollution risks from winter spreading, and to comply with Farming Rules for Water management requirements.
- An earth-lined lagoon to contain 6 months' slurry, yard runoff and dairy and parlour washings could be constructed on a 0.85 hectare (2.1 acre) site situated on very gently sloping land 600 metres to the south-west of the farmyard.
- Test pits show the lagoon site to be feasible for earth-lined lagoon construction. Soil samples have been taken for subsequent laboratory testing of permeability.
- Construction guidelines have been given for lagoon construction. These are based on CIRIA C759b information.

1 FARM DETAILS

New Manor farm is run as a specialist dairy unit based on 440 owned, and 920 rented acres. Most of this land falls within a Nitrate Vulnerable Zone (NVZ).

Land use is mainly to grass, which is grazed or conserved as clamp and baled silage, and some is grown as forage maize.

At New Manor farmyard, 745 dairy cows (year-round calving, with average milk yield 10,000 litres per cow per year) are milked and cubicle-housed for 6 winter months on sand. Just under 100 dry cows, fresh calvers, and new-born calves are winter bedded on straw. Replacement stock are contract reared in other farm buildings.

Currently, slurry is stored in a large earth-bank lagoon at the farmyard, and dairy and parlour washings and some fouled yard runoff is pumped into an above-ground steel tank.

1.1 Reasons for the visit

The farm is planning to increase slurry and fouled water storage capacity for better nutrient management, and to further reduce soil damage and pollution risks from winter spreading.

There is land on the farm which is suitable for the construction of an impermeable earth-lined lagoon for slurry storage. This report summarises volumes to be stored and gives an example lagoon size for the containment of this material.

During the visit, test pits were dug on the proposed lagoon site and soils were assessed for permeability. Based on these findings, example lagoon base and bank construction details are given, in accordance with the recommendations given in CIRIA guides:

Livestock manure and silage storage infrastructure for agriculture, parts C759a and C759b

Full details are provided at the end of this report.

1.2 Farming Rules for Water implications

The **Farming Rules for Water (FRfW)** were introduced in 2018 (details, and where to find up to date guidance, can be found at the end of this report). Within these rules, slurry application to land must take into account crop need and soil condition, and application limits need to be complied with during winter months (see EA guidance notes for details).

Taking into account its cropping, soil types, and topography, the farm has taken the decision to provide **6 months slurry and fouled water storage** in the proposed lagoon, in addition to the existing storage capacity at the farmyard.

2 SLURRY AND FOULED WATER QUANTITIES TO BE DIRECTED TO THE PROPOSED LAGOON

Calculation of excreta and fouled water volumes in this report is based on NVZ Guidance data; also used in **AHDB's Slurry Wizard**, which can be downloaded from:
https://ahdb.org.uk/knowledge-library/slurry-wizard

Excreted slurry collected from the cubicle buildings and scraped from yards (in current NVZ Guidance format) will be:

Livestock type	Livestock number	Proportion of excreta collected as slurry	Volume per livestock unit per month m^3	Slurry volume produced each month m^3	Slurry volume produced in 6 months m^3
Dairy cow after first calf (over 9000 litres milk yield)	745	100%	1.92	1,430	**8,582**

Rainfall:

Year	Oct	Nov	Dec	Jan	Feb	Mar	6 month winter total	winter monthly average
899	89	86	96	89	64	71	**496**	83

These figures are based on the farm's postcode, as used in PLANET software for nutrient planning (see appendix for how to obtain a free copy).

Based on 496 mm of winter rainfall, and the farm's information on open yard areas, the **Fouled water** volumes arising will be:

Source of fouled water	Area (m^2) *	Volume, wettest month (Dec) (m^3)	Volume in six winter months (m^3)	NVZ Definition
Dairy and parlour washings 745 cows milking @ 20 litres per cow per day		462	2,712	dirty water (LFW)
seven silage clamps	4,320	414	2,141	dirty water (LFW)
dirty water totals	**4,320**	**876**	**4,853**	90% of total
dry cow feed/loafing yard	400	39	199	slurry
FYM storage and apron	680	66	337	slurry
'slurry' totals	**1,080**	**105**	**536**	10% of total
Fouled water totals: 'Slurry' and 'dirty water' combined	**5,400**	**981**	**5,389**	
		216,000	*1,186,000*	*gallons*

* yard areas have been rounded up to the nearest 10 m^2

Under current NVZ regulations, lightly fouled water is described as 'dirty water', which can be spread during the closed period. On the other hand, excreted slurry and fouled yard runoff described as NVZ 'slurry' (see table above) cannot be spread to land during the closed period.

However, to fully comply with the Farming Rules for Water, the decision has been taken to store all fouled water over the winter period, irrespective of its NVZ definition.

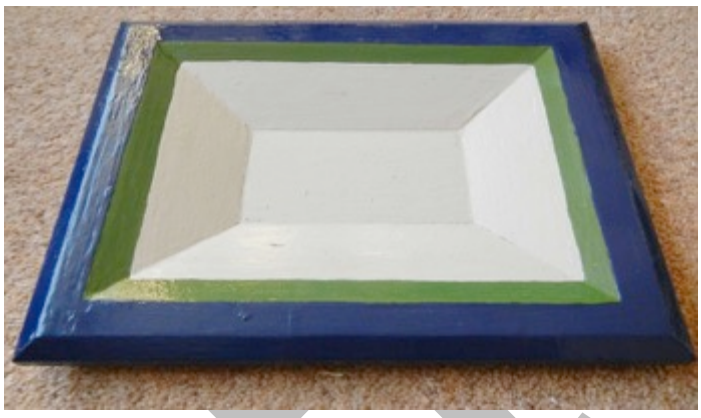
In total, therefore, **6 months' slurry and fouled water** will be

8,582 + 5,389 = **13,971 m^3**

3 EARTH-LINED LAGOON SIZING AND PROPOSED SITE

As an example of lagoon dimensions to contain all the slurry and fouled water from winter housing (13,971 m^3), if a rectangular 6 metre deep lagoon were to be built on flat ground, it would need to be 90 x 60 metres along the inside top banks, giving a total volume of 20,700 m^3 (*4.6 million gallons*). These dimensions allow for

- 1 in 2½ slopes on the inner lagoon banks (see scale model image to the right, photo below, and diagram in CIRIA 759b)
- the rain falling into the lagoon over 6 winter months
- a 750 mm design and operating freeboard (green strip in the model)



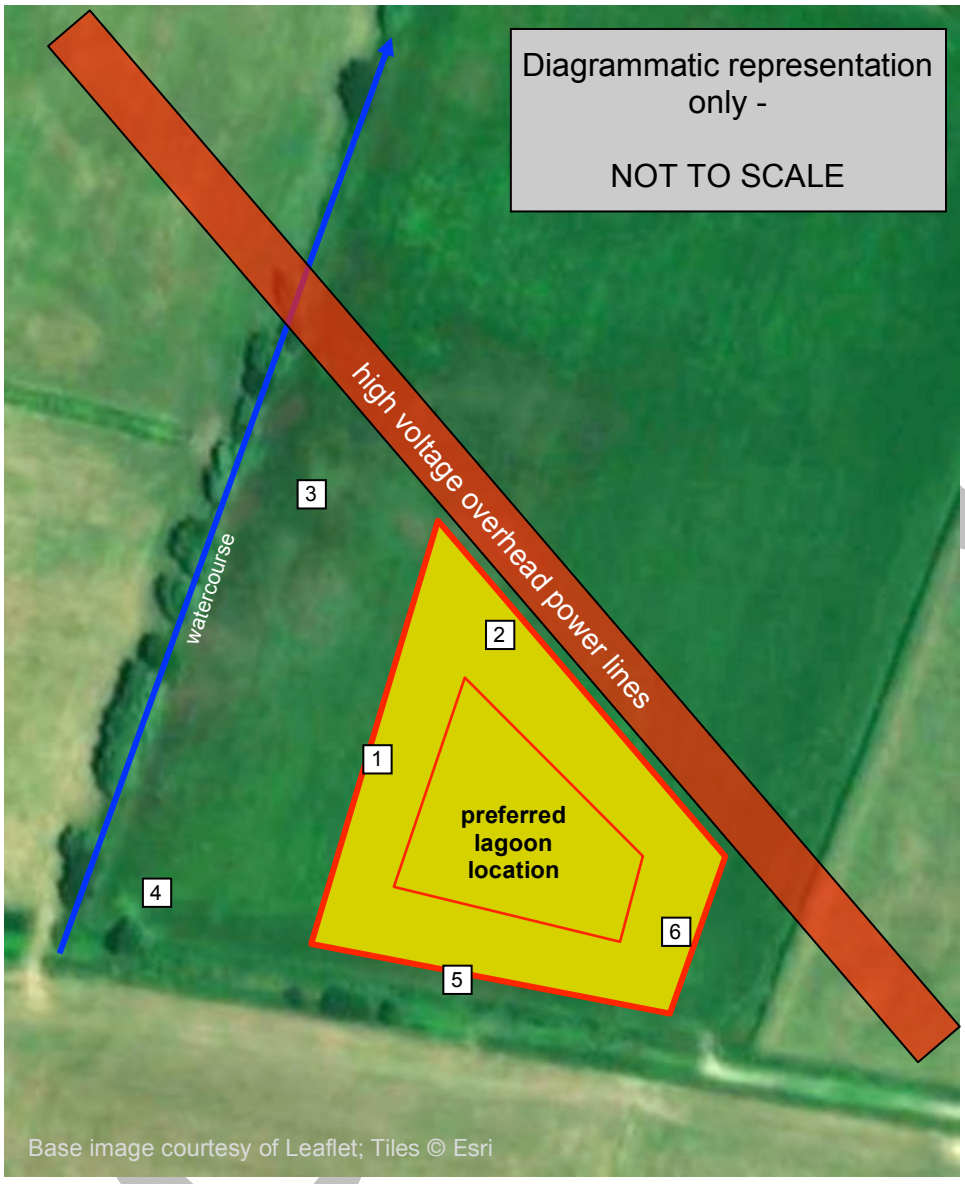
Overall land area required could be in the order of 0.85 hectares (2.1 acre) including the outer banks. The floor of the lagoon would be 60 metres long x 30 metres wide.

However, due to overhead power line constraints at the proposed lagoon site, its final shape may not be rectangular, but the above example gives some idea of the dimensions that you need to work to.

Also note that, if you are planning to add a ramp down the long side of the lagoon (more on this later), you would, for instance, need to make the lagoon 2 metres wider to allow for the storage volume lost from a 4 metre wide ramp.

3.1 Proposed site

The proposed lagoon site is situated 600 metres to the south-west of New Manor farmyard, at grid reference ST 509 420. It is shown over an air photo of part of the field in which it will be sited (north at the top):

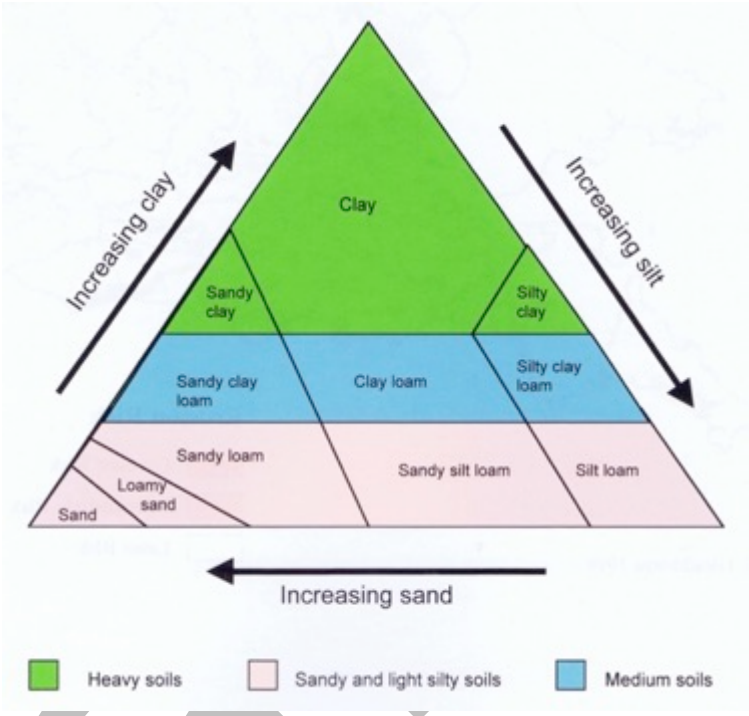


Notes

- The lagoon outline and inner bank tops are shown in red
- The land falls gently towards the north-west, about a metre over the length of the lagoon
- The test pit locations are numbered 1 to 6
- The nearest watercourse is 70 metres to the west of the proposed lagoon site

4 EARTH LINED LAGOON FEASIBILITY

The most suitable soils for impermeable lagoon base and embankment construction have a 20-30% clay content, shown as the blue 'clay loam' area in the middle of the soil texturing diagram to the right.



These soils have a suitably low permeability (10^{-9} metres per second or less), combined with high strength.

Clay contents above 30% (green areas) result in very low permeability, but care is needed during construction to ensure that embankments are stable, and that any cracking during dry weather does not compromise lagoon permeability.

In clay loam and clay soils, up to 30% stone content can be tolerated without compromising permeability.

4.1 Test pits and preliminary soil examination

The farm's preferred lagoon had been rectangular in shape, located on the west side of the field. However, as the test pits were excavated, they revealed water-saturated gravelly layers at depth, rather than the anticipated blue clay. In test pit 5, blue clay was found immediately below the topsoil and yellow clay layers, with no gravel or water ingress.

An additional test pit (6) confirmed that the east side of the field was drier at depth, so the decision was taken to fit the lagoon into this location, keeping clear of the overhead power lines.

For each test pit, soil was placed adjacent to each pit in discreet piles for hand texturing for clay content, and to establish stone content. A representative sample from soil zones judged to be suitably impermeable was bagged and left on the farm, to be sent off for soil permeability testing.

The photos overleaf show the main soil/ stone combinations excavated from the pits.

Topsoil - 400 mm deep. Well structured heavy clay loam.

This material would be **suitable** to form an impermeable lagoon layer, though you may prefer to use it for finishing the lagoon crest and outer banks, or for other uses on the farm

Clay layer - between 0.7 to 2.1 metres thick
Stoneless or near-stoneless yellow clay.
This material would be **very suitable** to form an impermeable lagoon layer

Below 1.4 to 2.5 metres depth in pits 1 to 4, wet gravel was found, with rounded stones to 120 mm.

This material would **not be suitable** to form an impermeable lagoon layer, though it might be useful for constructing farm track bases or hard-standing areas if laid onto a suitable geotextile membrane

Below the yellow clay layer in pits 5 and 6, **Blue clay** was found.

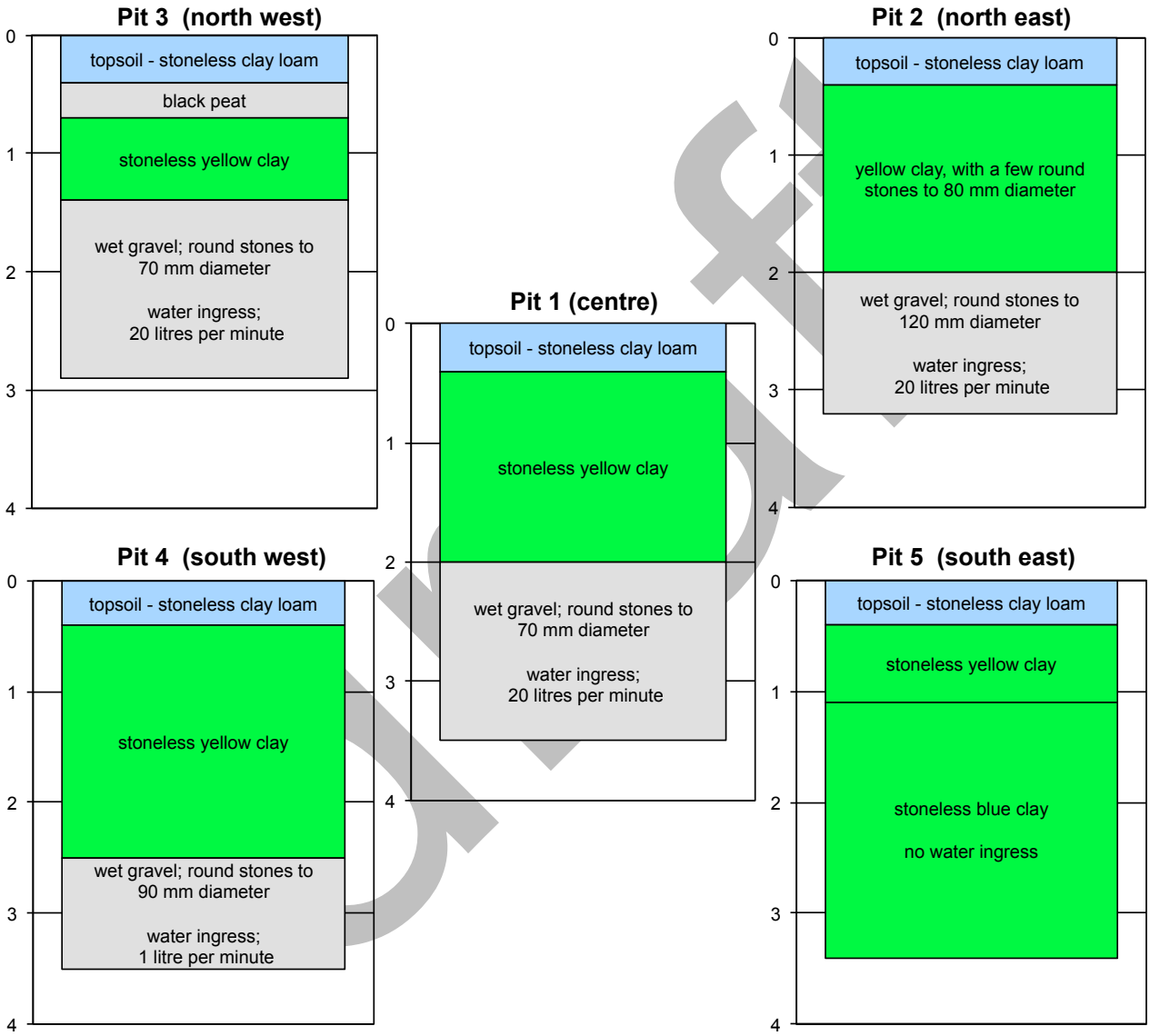
This was stoneless in pit 5, down to 3.4 metres depth (the maximum that the excavator could reach down to), and there was no water ingress. In pit 6, there was an angular stone layer at 3.2 metres depth (photo, top right), with slight water ingress

The stoneless material would be **very suitable** to form an impermeable lagoon layer, and the farm might find some use for any hard angular stone recovered during lagoon construction.

4.2 Test pit profiles

Soil textures and stone content from pits 1 to 5 are shown graphically below, with pit depth in metres shown on the y-axis.

- Soils judged to be suitable for construction of impermeable lagoon bases or banks are coloured blue (clay loams) or green (clays). Soils judged as unsuitable (more than 30% stone) are coloured grey
- Water ingress was noted in pits 1, 2, 3, and 4. Where this has occurred, it has been indicated as part of the layer description



The **conclusion** drawn from pit excavation, soil examination, and hand texturing is that sufficient quantities of suitable material are available for the construction of an impermeable earth-lined lagoon with impermeable layers at least a metre thick (see later for layup options).

However, the stonier, more permeable material (grey zones in diagram above), should not be used for the impermeable zones of the lagoon banks or base.

4.3 Laboratory testing of permeability

During the pit excavations, I sub-sampled the low-stone content clay layers in pits 1 to 5, and left the soil material with you to send off for lab testing.

The required test is Determination of the Permeability of Clayey Soils in a Triaxial Cell Using the **Accelerated Permeability Test** (Test Method - BS1377: Part 6: 1990: 6) In addition, a **Particle Size Distribution** will give clay, silt, and sand percentages of the sample.

Keep the soil test results, since these will confirm their suitability for lagoon construction.

5 EARTH LINED LAGOON CONSTRUCTION

5.1 General site and soil considerations

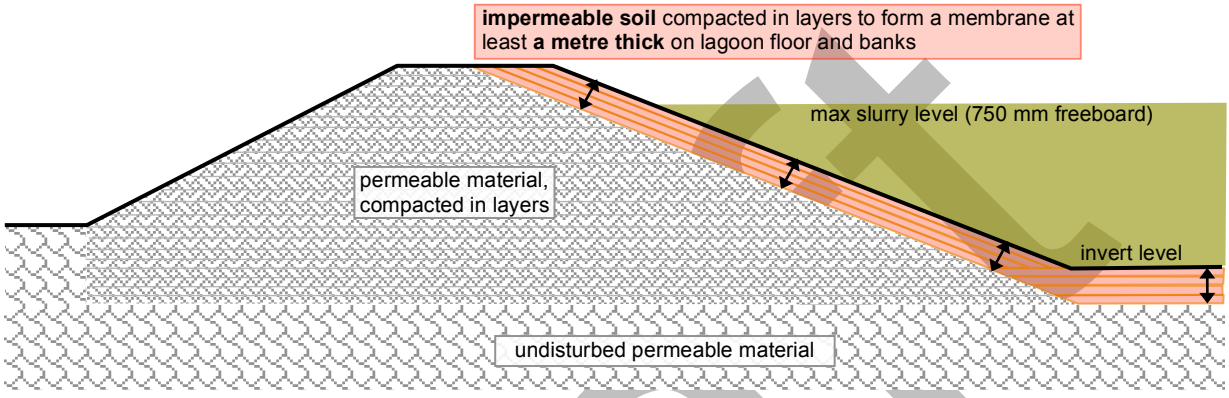
General considerations (from page 57 of **CIRIA guide 759b** section **7.4.1 Site Preparation**) are:

- The outsides of the embankments must be at least 10 metres from open drains and watercourses. (the nearest is 70 metres to the west of the site, so this is not an issue)
- Relocate any drains (none were found while digging the test pits)
- Remove all trees, scrub, roots, and other unsuitable material (none found on the site)
- Remove topsoil from the site, including the area of the embankments
- Remove and temporarily store the impermeable clay layer on or near to the site
- Excavate to final lagoon floor level (invert level) over the entire area of the proposed lagoon base, inner banks, and crests, and excavate additional width/depth to accommodate the impermeable soil liner if necessary (more on this later)
- Provide a proper key for embankment construction
- Using suitable impermeable soil-fill, place and compact in uniform layers using mechanical plant
- Provide a permanent safety fence, at least 1.3 metres high and of un-climbable construction

5.2 Base and bank design

We have shown that there is sufficient impermeable soil to be used as a liner. A number of options are open for construction, and are described on pages 60 and 61 of the **CIRIA guide** (section **7.4.4 Construction process – zoned construction**). In all the examples given, the banks and base of the finished lagoon have been lined with a metre-thick layer of suitably impermeable soil, **running continuously between the banks and base**.

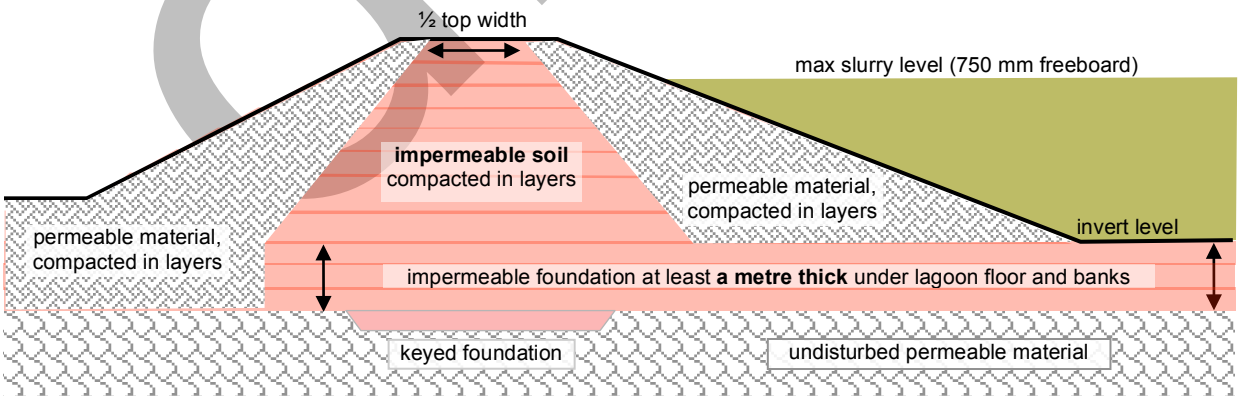
The simplest bank construction method for the New Manor lagoon would be to remove and stockpile the liner soil, construct the base and banks, and compact the liner soil back over it:



The required bank slopes are

- 1 in 2 (26 degrees) on the outside, and
- 1 in 2.5 (22 degrees) on the inside

Alternatively, the example profile below (1 in 2 slope on the outside; 1 in 2.5 on the inside) provides protection for the impermeable zone, which is located in the centre of the raised embankment, and faced with stonier material. This will help to contain the clay liner and reduce the chances of it cracking during dry weather, if the lagoon is empty at that time.



This does require more planning to place the impermeable layers in the correct locations and depths, though.

Embankment settlement

However thoroughly an embankment is constructed, settlement will occur, and this should be taken into account when designing the lagoon. A 10 per cent allowance should be added to the embankment height when initially constructed to allow for settlement, unless more precise estimates are available from detailed geotechnical investigations.

Embankment tops

Where the tops of the embankments are not to be driven on, suggested minimum widths are shown in the **Table 7.3**, from page 53 of the **CIRIA guide:**

Bank height (m)	Minimum top width (m)
2	2.5
3	2.75
4	3.0
5	3.25

The top of the embankment should be domed so that rainwater is directed away quickly. If the top of the embankment is used for vehicular access, the embankment must be wide enough to accommodate the vehicle without risk of damaging the top or internal/ external walls.

Outer embankment slopes

Typically, lagoons are built on the 'balanced excavation' principle (no material leaves, or is brought to the site). Generally, for a lagoon that will be 6 metres deep on completion, its base (known in the construction industry as 'invert level', or lowest level of water or slurry) will be on average 3 metres below the original field surface and the constructed banks 3 metres above it.

Although the CIRIA guide recommends slopes of 1 in 2 (26 degrees) as the maximum for the outer lagoon banks, it is also acceptable to make these up at a much lower angle of just a few degrees, as in these two photos of a recently completed lagoon on level land:

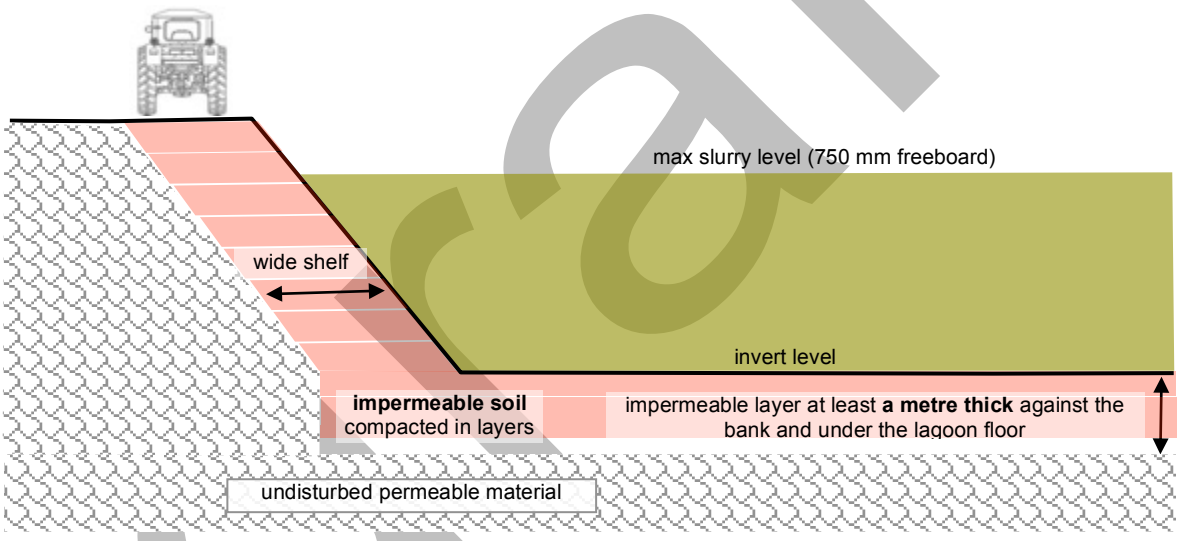
In this case, the height difference between the bank tops and invert level remains at 6 metres, but the contractor has excavated more soil so that invert level is slightly deeper below the original field surface (i.e. the lagoon has been dug 'deeper into the ground'). This has provided the additional soil needed to widen the outer banks.

Gentler outer lagoon slopes allow the reseeded pasture to be grazed or cut for silage, and land area lost to the lagoon crest and outer bank is considerably reduced. The impermeable material still needs to be compacted in shallow layers, and care must be taken that water drains back to the field and not into the lagoon.

Excavated slope profile

During construction, the excavated slopes will most likely expose pockets or layers of permeable material. A stable liner layer will need to be built up over the permeable areas.

If the impermeable material cannot easily be compacted by running up and down the bank, it may be easier to come up the bank with a 2-3 metre wide shelf, so that a vibrating roller can be safely towed along it:



The shelf could later be planed back to a metre thick, should the impermeable soil be needed elsewhere in the build. However, leaving the wider shelf in place would be preferable since it provides additional material - should light scouring or erosion of the bank surface occur during the life of the lagoon.

5.3 Site preparation

If the lagoon base and inner banks are to be **surface-lined** (first option in section 5.2), the site will need to be stripped to a depth of a metre below the final lagoon floor (invert) level in places where permeable material is found below invert. You will also need to excavate an additional metre or more into the hillside, depending on how you plan to line the cut slope.

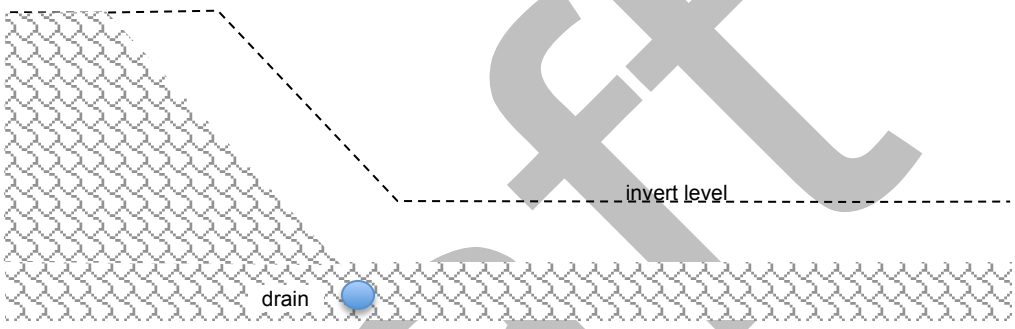
If planning to place an **impermeable core** within the lagoon banks (second option in section 5.2), the site will need to be stripped to a depth of a metre below invert level. The area that may need to be stripped must include that to be occupied by

the lagoon base, and that **under the inner banks and the lagoon crest**. You will also need to excavate an additional metre or more sideways into the field, depending on how you plan to line the cut slope.

Material should be stockpiled separately as topsoil, impermeable soil, and permeable material (too stony for the impermeable layers of the finished lagoon).

If found to be an issue during construction, groundwater can be intercepted by a shallow drain to suitable perforated drainage pipes located under or outside of the lagoon impermeable layers.

The easiest and safest way to achieve this would be to dig a shallow trench and lay the drain once the stable slope has been excavated (as described in section 5.2 above):



Otherwise, to excavate a deep vertical trench and lay a drain in the field above the lagoon would require substantial shuttering (in accordance with HSE recommendations) to ensure safe working.

5.4 Base and bank construction

It is important to ensure that soil is adequately compacted, as described in section **7.4.2 Construction process – soil compaction** in the CIRIA guide.

The photos below show this operation in progress.

A shallow (100-150mm) layer of soil with 20-30% clay content is being laid up and rolled 4-6 times by a heavy vibrating roller to ensure adequate compaction

Here, a shallow (250 mm) layer of soil with 30-40% clay content is being rolled 4 times by a 2 metre wide 8 tonne vibrating roller to ensure adequate compaction

The data in the table below, reproduced from **CIRIA guide C759b, page 59** is the kind of information that a reputable contractor needs in order to ensure that compaction is properly achieved:

Type of compaction plant	**Mass per metre width** or **Mass per wheel (Pneumatic-tyred roller)**	**Max. depth** of **compacted layer (mm)**	**Minimum number of passes**	**Soil types**
Smooth wheeled roller (or vibratory roller operating without vibration)	Over 2100 kg up to 2700 kg Over 2700 kg up to 5400 kg Over 5400 kg	125 125 150	8 6 4	Cohesive or granular
Grid roller	Over 2700 kg up to 5400 kg Over 5400 kg up to 8000 kg Over 8000 kg	150 150 150	10 8 4	Stiffer cohesive or granular
Sheepsfoot (tamping) **roller**	Over 4000 kg	225	4	Stiffer cohesive or granular
Pneumatic - tyred roller	Over 1000 kg up to 1500 kg Over 1500 kg up to 2000 kg Over 2000 kg up to 2500 kg Over 2500 kg	125 150 175 200	6 5 4 4	Softer cohesive or granular
Vibratory roller	Less than 700 kg Over 700 kg up to 1300 kg Over 1300 kg up to 1800 kg Over 1800 kg up to 2300 kg Over 2300 kg up to 2900kg Over 2900 kg up to 3600 kg Over 3600 kg up to 4300 kg Over 4300 kg up to 5000 kg Over 5000 kg	100 125 150 175 200 225 250 275	Unsuitable 12 8 4 4 4 4 4 4	granular

Note that, although **bulldozers** have been used to compact soils during slurry lagoon construction (pushing out a thin layer and using the machine weight over the track area to press the soil down), the CIRIA 759b recommendations do not include this method.

I would suggest that if a contractor is proposing to compact soil solely by bulldozer, they should provide specialist advice and/or have samples laboratory tested to show that adequate compaction will be achieved.

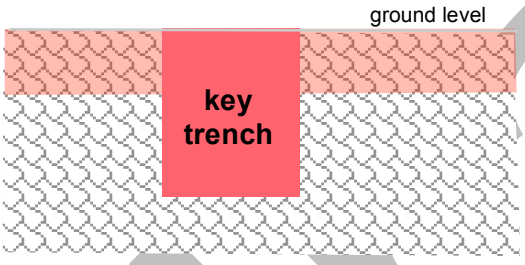
5.5 A cautionary note about 'key trenches'

As described on page 60 of the **CIRIA guide** (sections **7.4.3** and **7.4.4 Construction process**), any lagoon bank needs to be keyed into the underlying soil to secure the bank.

As shown in the CIRIA diagrams 7.9 and 7.10, if the ground onto which the banks will be built up has at least a metre thickness of impermeable soil below invert level, excavating down to the impermeable soil and building an impermeable bank or core up from it will ensure overall lagoon impermeability. However, this is **not** the case at New Manor, where there will be permeable layers at depth.

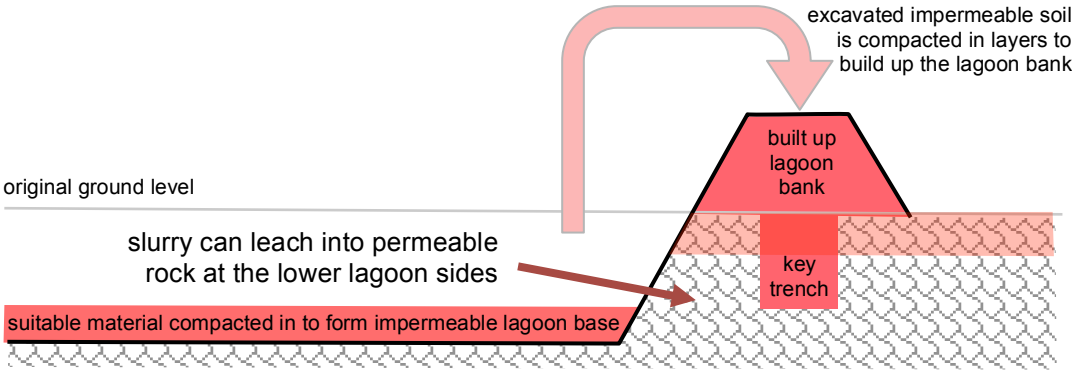
When constructing farm lagoons on sites over permeable material, a few contractors still believe that starting their build with a 'deep key trench' and finishing it with layup of clay soil onto just the lagoon base will be sufficient to make the finished lagoon impermeable.

The 'deep key trench' follows the mid-point of the proposed lagoon banks (once the topsoil has been stripped away), at a safe working depth - usually around two metres:



Low-permeability soil is compacted back into the trench in shallow layers.

Lagoon construction then proceeds by excavating impermeable material from inside the lagoon area and compacting this material over the key trenches. Laying up the metre-thick lagoon floor liner is often the last major job.



This approach saves on machinery and labour time, and may be effective for shallower lagoon construction. However, at the proposed lagoon site, with a 7 metre height difference between the lagoon banks and excavated base (allowing for excavation and re-compaction of the metre-thick liner), the following shortfalls may arise:

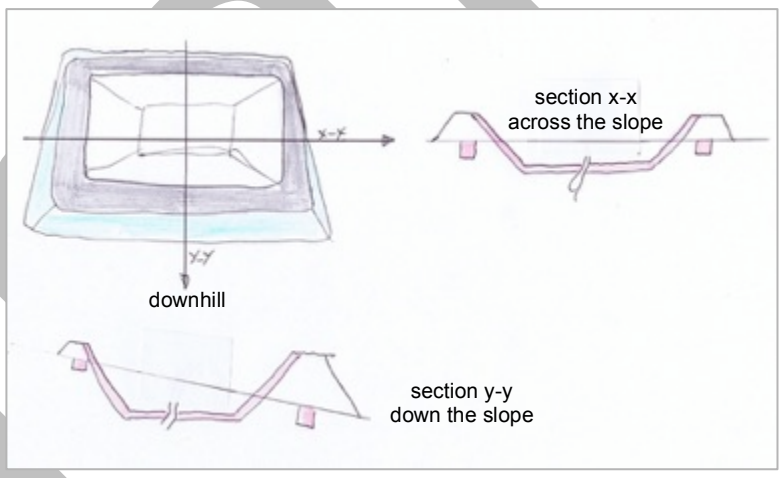
- the key trench may not have reached sufficient depth to meet the lagoon base liner
- the re-compacted lagoon base liner will not meet the re-compacted soil in the key trench

This can allow leakage from the finished lagoon through the unprotected permeable area.

5.6 Site plans

When discussing lagoon construction with a contractor, ensure that they describe in detail how they will ensure that the impermeable lagoon base liner will meet the impermeable bank liner - **on all sides and base of the lagoon**. Ask them to illustrate their proposed construction method with cross-sections (a rough sketch will be sufficient).

This example contractors' sketch shows a lagoon on a hillside that will be built with its long axis (x-x) across the slope, with the short axis (y-y) down the slope. The key trenches and metre-thick impermeable liner layers have been shown in red:



The important outcome of having a sketch is that there is no confusion over where the impermeable liner will be laid up, and it can be kept for future reference.

Misunderstandings have sometimes arisen where contractors have only given a verbal description of how they will build the lagoon when quoting for construction, and subsequently the farm has no records of exactly how it was built.

6 OTHER LAGOON CONSTRUCTION AND MANAGEMENT CONSIDERATIONS

6.1 Filling the lagoon

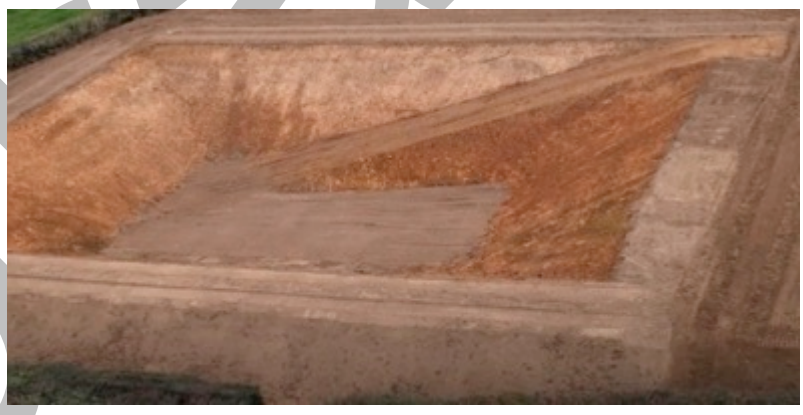
We discussed options for filling the lagoon. The important consideration is to avoid scouring away the lagoon lining soil by directing liquid flows down the lagoon's unprotected inner slopes.

Slurry or separated liquids will most likely be tankered to and/or be pumped to the lagoon. The discharge should be at the slurry level to avoid scouring the lagoon liner.

A simple way of achieving this is to use a cut pipe arrangement to direct it to the base of the lagoon without scouring the liner. This is shown in the photo to the right.

The halves of the pipe are secured at the top and at the join, and a small concrete apron at the bottom reduces the risk of scouring.

6.2 Access and stirring



I would advise providing drive-in access to the lagoon so that operations such as stirring and slurry removal can be undertaken from within it.

The lagoon can then be fenced along the inside top sides, and the crests and outer banks can be grazed, saving on fencing and annual maintenance costs.

Ramps can be constructed down the side of the lagoon (a maximum 1 in 8 slope is recommended), but remember to add half the width of the ramp to the overall lagoon design width, as the soil required to build it will reduce lagoon capacity.

Don't forget to mark the sides of the ramp (preferably with substantial posts) so that its edge can be seen when the lagoon is full.

Building ramps down the lagoon internal corners saves space, but the penalty is steeper slopes - 1 in 3.6, (or 16 degrees) on a lagoon with 1 in 2.5 internal bank slopes, as in the photo.

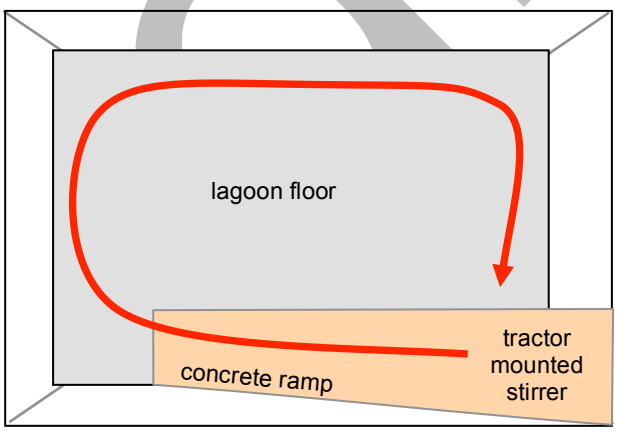
One way to make corner ramps safer would be to construct substantial H-section RSJ posts and a 'swing gate' halfway down the ramp, and leave it closed as the lagoon fills during the winter months.

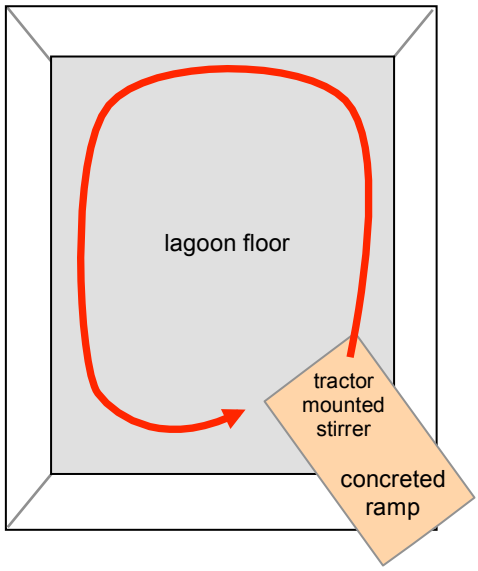
In spring, when a tractor and tanker (or a contractor's umbilical equipment) is backed down the slope, the closed gate will provide a backstop, in case of brake failure or operator error.

If the posts are inclined downslope, the 'gate' can be swung uphill once it is exposed, and latched to a third post further up the ramp.

If you decide to construct the New Manor lagoon with the impermeable liner on the inside banks, lay up and compact a thicker liner layer under where the H-section posts will be placed, to ensure that any liquids that may run down their sides will not get any further.

As we discussed, stirring lagoon contents from the access ramp gives good results, provided that the lagoon contents are made to circulate, as in the examples below:





6.3 Fencing and bank vegetation

The Health and Safety Executive recommends that lagoon fencing should have an overall minimum height of at least 1.3 metres, including at least two strands of barbed wire spaced 100 to 150 mm apart at the top.

The example to the right shows a lagoon fenced inside the top banks

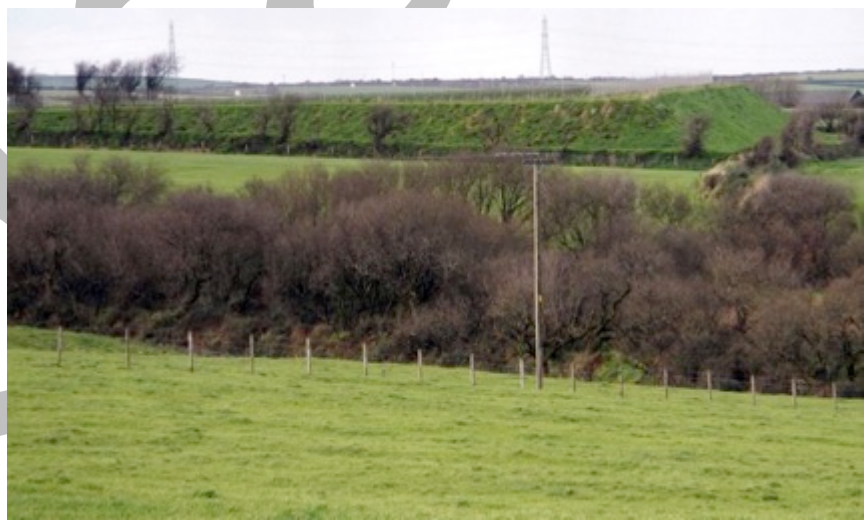
This requires less fencing material, and allows full access to the grassed banks for grazing and/or forage harvesting, depending final slope of the outer bank

Ensure that no trees are able to establish themselves on the lagoon banks. Root penetration can destroy bank impermeability.

In terms of impact in the landscape, grassed banks soon blend into the general field and hedge landscape.

The 2.5 acre lagoon in this photo lies in the North Cornwall coastal landscape, and the lower bank is 12 metres high

The banks are grazed by sheep, and within a year it has become difficult to distinguish the lagoon from the field and hedgerows around it



6.4 Odours and Ammonia emissions

In a slurry store or lagoon, undigested fibres in the cow's excreta rise to the surface and form a crust. This can be very effective in reducing odours and ammonia leaving the store. In a comprehensive 2007 research and review paper (full reference at the end of this report), it was shown that a reduction in ammonia emission of about 60% was typical from crusted stores.

With the proposed lagoon in place, its crust will remain undisturbed for the winter storage period, and slurry transfer from the existing lagoon to the new lagoon can be made with less surface disturbance, resulting in lower emissions overall.

The photo shows an example of a large lagoon with a crusted surface.

In the unlikely event that crusting does not take place quickly, straw can be blown onto the lagoon surface to accelerate the process.

For maximum benefit of slurry nutrients to crop growth (and reduction of nitrate losses by leaching), application of lagoon contents to land will normally be during the early spring months.

Where there may be sensitive receptors (e.g. dwellings) in the vicinity of the proposed lagoon or fields on which slurry is to be spread, the lagoon will have sufficient capacity to allow a delay in spreading, should there be a risk of odours reaching any nearby properties.

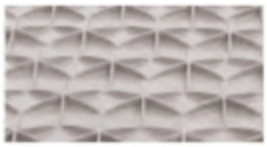
Clean air strategy, and Manufactured covers for slurry stores

As part of Defra's Clean Air Strategy 2019, proposed regulations to reduce ammonia emissions from farming will include 'a requirement for all slurry and digestate stores and manure heaps to be covered by 2027'. In the Strategy document, Defra states that it will 'support farmers to make investments in the farm infrastructure and equipment that will reduce emissions'

At this stage of policy development, it is not clear whether slurry crusting will be regarded as a legitimate slurry store cover, or whether an artificial (i.e. manufactured) cover will be required.

A guidance leaflet published by BPEX in 2003 (excerpt below) shows three possible types of manufactured covers for slurry lagoons with large surface areas (where a single span roof is not an option):

Permable covers

Type	Description	Advantage	Disadvantage
Lightweight Expanded Clay Aggregate (LECA) or foam glass 	• Applied in a layer 100 – 150 mm deep. • Moderate capital cost.	• Easy to install on existing • stores and lagoons regardless of shape and is effective. • No problems reported with pumps etc.	• Approximately 10% of the cover needs to be replaced annually. • These covers do not prevent rainfall from diluting the slurry.
Floating plastic plates 	• Free floating plastic plates, generally hexagonal in shape • Moderate cost, can be recovered and reused.	• Easy to install on existing stores and lagoons regardless of shape and is effective. • Up to 95% reduction in gas emissions can be achieved.	• These covers do not prevent rainfall from diluting the slurry

Impermeable covers

Type	Description	Advantage	Disadvantage
Lagoons – fixed floating plastic membrane 	• A large plastic sheet with integral floats and gas vents. • The edges of the cover are buried into the lagoon banks to retain it. • Moderate to high cost	• Rainwater can be pumped off the top. • Stirring is possible if design allows.	• Requires lagoon to be initially empty and embankments to be suitable for fixing. • Access for de-sludging is difficult.

These have varying levels of effectiveness in reducing ammonia emissions, and investment costs are currently high - up to half the lagoon construction cost.
More information on covering stores can be found in the 30 page publication **COGAP, Ammonia emissions** (details at the end of this report)

Handling considerations and durability for lagoon covers are still being addressed; and practical solutions for covering large lagoons continue to be developed.

In the coming years, more durable and cost-effective manufactured covers should become available, and it is likely that grant aid for covering slurry stores could be provided on a National scale.

Given the information above, my advice would be to regard the provision of 6 additional months storage and natural slurry crusting as a significant improvement on current ammonia emissions from slurry storage and handling at New Manor farm. As the regulations and grant options associated with Defra's Clean Air Strategy evolve, further investment decisions can be made on covering the lagoon.

7 NEXT STEPS

Soil testing

You have already sent the soil samples for laboratory testing. Results usually come back within 2-4 weeks.

Planning

You plan to submit a Prior Notification to the local planning authority. The detail in this report should satisfy most of the requested information

Contractors and quotes

You now have an example lagoon capacity and dimensions, based on a rectangular lagoon on a level site. Using copies of this report for information, you will be able to obtain quotes for construction from competent local contractors - I have already mentioned some of them, and can add more if you contact me.

When quoting a price, each contractor will be considering how many cubic metres of soil they will need to move on your site (e.g. to an off-site stockpile, then back to be re-compacted as a lagoon impermeable layer). They may either make a judgment based on experience, or may make a detailed site levels survey and, using the test pit data in this report, calculate soil movement costs. Either way, quotes can vary widely between contractors, especially on sloping sites.

If you obtain widely varying quotes or are unsure of exactly what each contractor is offering, then if needed I can help with comparing their quotes, or I can meet with yourselves and contractors on-site.

Site visits

If you feel that you would like site visits during the build, then I can make these, taking photos, discussing aspects of the build with the contractor, and providing a written summary of discussions and recommendations made.

The best times to make these site visits could be:

- once the site is stripped of topsoil and an area of around 20 x 20 metres of good liner soil has been excavated
- during construction, should groundwater become apparent (this can be drained away and construction can continue above the drained area)
- at, or near-to completion of the lagoon

Construction records

Whether or not you find that the above input is required, I would still urge you to photograph every stage of the build (20-30 photos per day, at least).

Print and keep some of them with this report and any planning and/or contractor drawings as a permanent record of construction, should this be questioned by the

Environment Agency in the distant future. Photos stored on mobile phones and computer drives may no longer still be accessible in a few decades' time.

Environment Agency notifications

You must notify the Environment Agency in writing about any new, substantially enlarged or substantially reconstructed system at least 14 days before any construction begins. If, by this stage, you have not previously discussed your plans with the EA, or planning permission has been granted by Prior Notification, the EA are likely to request details of the proposed design and construction. The detail in this report should satisfy this, if requested.

Finally, remember that you also need to notify the EA that you intend to use the new structure, 14 days prior to its' first use.

8 CONSENTS AND LEGISLATION

If pollution control works have to be installed or enlarged, then legislation has to be complied with, and consents must be sought. If you intend to proceed with any building work, it is in your best interest to ensure that all necessary consents have been obtained before starting work and incurring expenditure. The following authorities should be contacted for guidance:

8.1 Environment Agency

Any proposals for the installation of new, or improvement or enlargement of existing slurry storage facilities need the consent of the Environment Agency.

You must notify the EA at least 14 days before construction commences, and again 14 days before you use any new, substantially enlarged or reconstructed pollution control facilities. Forms are available for this procedure from local EA offices.

8.2 Planning

Any new building, structure, tank or excavation for the storage of manure, slurry and fouled water which is to be built within 400 metres of the curtilage of a 'protected' building requires planning permission.

A 'protected' building is one that is occupied by people on a regular basis, such as a private dwelling or school. The definition excludes a dwelling or other buildings that are used for or in connection with agriculture.

The 400 metre rule is in addition to other restrictions on permitted development for agriculture, such as that of 'within 25 metres of the metalled portion of a road'.

Since January 1992, even if full planning permission is not required, the local planning authority requires to be informed of the siting, construction and size of

any planned agricultural buildings and any engineering operations on any size of agricultural unit.

Therefore, it is recommended that you contact your local Planning Authority to establish whether you need to submit a Notice of Intention or a full application for Planning Permission.

8.3 Health And Safety

The handling and storage of waste material, including organic wastes, carries the possible risk of exposing employees and members of the public to substances and/or factors affecting their health and safety.

All existing and proposed structures must comply with relevant Health & Safety legislation. Guidance on health and safety matters is available from your local Health & Safety Executive office.

9 USEFUL INFORMATION

Protecting our water, soil and air

A Code of Good Agricultural Practice for farmers, growers and land managers was published in 2009. This has comprehensive information on pollution laws, causes of pollution from farms, and ways to reduce pollution risks - including how to draw up a Farm Waste Management Plan.

The Code is published by The Stationery Office (TSO) and available from their office via PO Box 29, Norwich, NR3 1GN, telephone 0870 600 5522. Quote reference number ISBN 978 0 11 243284 5 if ordering a copy. It can also be downloaded from Defra's website at:
http://www.defra.gov.uk/foodfarm/landmanage/cogap/documents/cogap090202.pdf

Farming Rules for Water

Since 2 April 2018 new rules for all farmers in England have been introduced to help protect water quality. They apply to field storage of organic manures, application of organic and manufactured manures to land, livestock management near to watercourses, and soil nutrient testing for cultivated land.

More details and the policy document can be found at
https://www.gov.uk/government/news/new-farming-rules-for-water

The most recent update to the **Environment Agency** enforcement approach to these rules was released as **Statutory Guidance**, updated 16 June 2022, and can be found at
https://www.gov.uk/government/publications/applying-the-farming-rules-for-water/applying-the-farming-rules-for-water

NVZ requirements

Details of how to comply with the NVZ minimum storage requirements can be found in the Defra NVZ Guidance. Additional clarification is provided by the EA through their technical Q&A. All this material can be accessed through the GOV.UK website: https://www.gov.uk/nitrate-vulnerable-zones

PLANET Software

Planning **L**and **A**pplications of **N**utrients for **E**fficiency and the environmen**T** is a nutrient management decision support tool for use by farmers and advisers in England/Wales and Scotland for field level nutrient planning and for assessing and demonstrating compliance with the Nitrate Vulnerable Zone (NVZ) rules. It can be downloaded and used free of charge when you register at http://www.planet4farmers.co.uk

CIRIA guides C759; Livestock manure and silage storage infrastructure for agriculture

This report provides up-to-date information on the selection, sizing, costs and risks associated with farm waste storage as well as on the issues that may arise during the design, construction and operation phases.

The guide is divided into two parts:

Part 1 Selection guide C759a (60 pages, or 11 MB as a download) describes the legislative context and presents the characteristics of farm wastes and principles of waste treatment and disposal. Also, it summarises the main features of the most widely used storage systems, thus helping select the most appropriate store or narrow down the choice to the suitable options. This part is intended for those people who are seeking an overview of the topic and/or advice on the selection of the store (e.g. the farmers).

Part 2 Design and Construction guide C759b (150 pages, or 33 MB as a download) covers the general design, construction and installation aspects and provides specific details on the storage facilities, including, but not limited to, earth-banked lagoons, concrete stores, weeping walls, slurry bags and anaerobic digestion systems. This part also provides guidance on the maintenance and repair of structures, and health and safety considerations. It is aimed at a more technical audience, such as designers, consultants, material suppliers and contractors.

The CIRIA guidance is free to download, but you will need to register on their website to access it. The current direct link to the guides is
https://www.ciria.org/ItemDetail?iProductCode=C759F&Category=FREEPUBS
If this does not open the correct page, type CIRIA 759 F into a search engine. The CIRIA link should be the first listed.

On the current version of their website, CIRIA request you to 'buy' the publication CIRIA 759 F at zero cost, and you have to set up an account to do this. It is only after finishing your 'order' at the checkout that you are able to download the relevant guides.

Soil Suitability and Testing for Earth Lined Slurry Lagoons

This two page leaflet was posted on the Environment Agency website in April 2011 and outlines the necessary soil characteristics and tests for constructing an unlined earth lined slurry lagoon.

Defra's Slurry Improvement Grant

This grant is being made available to help replace, build additional, or expand existing slurry stores to provide 6 months' storage.

The first (pilot) round was announced in December 2022, and it is most likely that a second launch will be announced later in 2023. The first round supported the cost of slurry stores including tanks, lagoons and concrete stores fitted with impermeable covers and large permanent bags. It also funded items necessary for the basic functioning of new or expanded slurry stores, such as reception pits, slurry pumps and agitators.

To qualify for this grant, a new store must be fitted with an impermeable cover, unless a slurry bag is being installed, or slurry is being treated by acidification.

For more information and how to register interest and apply, visit:
https://www.gov.uk/government/publications/slurry-infrastructure-grant

Code of Good Agricultural Practice (COGAP) for Reducing Ammonia Emissions

This 30 page booklet was published in 2018. It gives a background on ammonia, sources of emissions, and how it causes environmental damage. It gives advice on storage, covering stores, and how effective each cover type is. It also covers field application of organic manures.

It can be downloaded from:
https://www.gov.uk/government/publications/code-of-good-agricultural-practice-for-reducing-ammonia-emissions

Research/review paper on Slurry Store Crusting

Natural crusting of slurry storage as an abatement measure
for ammonia emissions on dairy farms
by K. Smith (ADAS), T. Cumby, (Silsoe Research Institute) J. Lapworth (ADAS), T. Misselbrook (IGER), A. Williams (Silsoe Research Institute)
published in Biosystems Engineering 97 (2007) 464–471

Manufactured covers for slurry stores.

Covering Slurry Stores - Benefits, Practicalities and Available Options
This 2-page leaflet was produced by BPEX (Best Available Techniques for intensive rearing of poultry and pigs) in 2007