Appendix:
YKY63_WINEP Enhancement Case Annexes

YKY63_WINEP Enhancement Case Annexes

YorkshireWater

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This Appendices document is separate to and supports the main business plan document.

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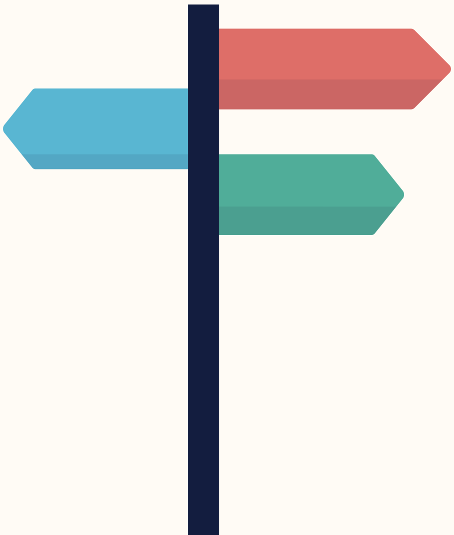
Business plan links
This icon can be clicked on to go to the main Yorkshire Water Business Plan document where more information can be found.

More detail on this subject can be found in **Chapter 8 Part 2: What our plan will deliver**



Contents

I. WINEP Annexes

This document contains the Annexes relating to the WINEP overall case and the various subcases.

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WINEP Enhancement Case

Table 1.1: List of Annexes

Annex		Case/Subcase(s)
A1	Economic Evaluation	WINEP Overall Case
B1	Enhance	Storm Overflow Reduction Plan Inland Bathing Waters
B2	Reduce and Enhance	Storm Overflow Reduction Plan Inland Bathing Waters
B3	PCD scheme costs and allocations	Storm Overflow Reduction Plan
C1	Enhance	Inland Bathing Waters
C2	Reduce and Enhance	Inland Bathing Waters
D1	Capex Scheme costs for nutrient removal PCD	River Water Quality Improvements
E1	National Landbank Assessment Report	Schemes to make the recycling of sludge to land more robust
E2	Water UK IED Supporting Document	Schemes to make the recycling of sludge to land more robust
E3	YWS PR24 Sludge to Land Strategy Final Report	Schemes to make the recycling of sludge to land more robust
E4	WINEP Sludge Driver Evidence Support	Schemes to make the recycling of sludge to land more robust

A. Annexes for Overall Case

A1. Economic Evaluation

Yorkshire Water approach to the economic evaluation of WINEP24 Options

Introduction

This report describes the approach Yorkshire Water (YW) has taken to calculate the monetised costs and benefits information presented in the WINEP Options Assessment Reports (OARs).

We have ensured alignment with the Options Development Guidance, and any alternative approaches we had to take is described and rationalised in detail. Note that any reference in this document to the WINEP Options Development Guidance (WINEP ODG) is specific to the July 2022 version. Additionally, references to the WINEP Wider Environmental Outcomes (WEO) are specific to what is included the WINEP Wider Environmental Outcomes metrics v2.0 spreadsheet.

This document is further divided into 5 sections:

1. The Yorkshire Water 6 Capitals approach and alignment with the Wider Environmental Outcomes Approach
2. Benefits assessment using the recommended metrics for the 4 wider environmental outcomes
3. Optional and parallel benefit assessment
4. Cost assessment
5. Net Present Value Cost-Benefit and the Benefit-Cost Ratio

There is also an Appendix which shows the mapping of the benefit metrics used in the assessment against the WINEP WEOs.

1. The Yorkshire Water 6 Capitals approach and alignment with the Wider Environmental Outcomes Approach

Yorkshire Water utilises the 6 Capitals approach in investment decision making and in sustainable accounting[1], and this is part of our Decision Making Framework[2]. The 6 Capitals as applied in YW are outlined in Figure 1 below.

Figure 1. The 6 Capitals in Yorkshire Water

By using the 6 Capitals approach, YW is able to examine, express and quantify (where possible) its impacts and dependencies on 6 Capitals assets. This helps Yorkshire Water to better understand risks and opportunities and how it creates or destroys value with what the business does or doesn't do. As an extension of this, the business is also able to put a monetary value of impacts, which express a cost or benefit, where practicable.

[1] See this link for more information: https://www.yorkshirewater.com/about-us/capitals/

[2] Here is a short YouTube clip on Yorkshire Water's Decision Making Framework: https://www.youtube.com/watch?v=iZ6CixsmPSA

We consider this 6 Capitals approach to be in line with the objectives of the WINEP WEO approach. It is stated in the WINEP wider environmental outcome metrics v2.0 spreadsheet that the metrics should be used to measure the potential impact on, and changes to, natural assets, ecosystem service/good and the benefits they provide. Additionally, these metrics have been recommended to support water companies to use a natural capital approach in the options development and proposal, and to ensure consistency, comparability, and proportionality.

The Service Measures and 6 Capitals Framework is part of our Decision Making Framework. Service Measures capture the different risks and impacts of investing (as well as not investing), and our Service Measures cover different areas of clean and wastewater services and other impacts (e.g. on land use, health and safety). These Service Measures are further divided into Impact Categories which measure the extent or type of service failure/improvement. See Table 1 below for examples, although note that this is not a complete list and some that are shown may not necessarily be relevant to WINEP options.

Service Measure	Impact Category	Metric Quantity
River Water Quality	WINEP Bad to Poor	Kilometres of river
	WINEP Poor to Moderate	Kilometres of river
	WINEP Moderate to Good	Kilometres of river
Leakage	Leakage	Ml/d
Pollution incidents	Category 1	Nr of incidents
	Category 2	Nr of incidents
	Category 3	Nr of incidents
	Category 4	Nr of incidents
Land Use	Area of existing inland wetland	Hectares
	Area of additional inland wetland	Hectares
	Area of existing coastal wetland	Hectares
	Area of additional coastal wetland	Hectares

Table 1. Sample list of Service Measures and Impact Categories in Yorkshire Water's Decision Making Framework

These Service Measures and Impact Categories are mapped to Capitals metrics, and this mapping represents an impact/dependency relationship between the Capitals metrics and Yorkshire Water's activities and service[3]. These capitals metrics represent different aspects of benefit under a particular Capital. For example, metrics under Natural Capital represent ecosystem service benefits as shown in Table 2 below.

[3] This is based on the Natural Capital Coalition's Natural Capital Protocol: https://capitalscoalition.org/capitals-approach/natural-capital-protocol/?fwp_filter_tabs=training_material

Capital	Metric	Definition
Natural	Crops & livestock	Provision of agricultural land, products and livestock.
	Fisheries	Provision of products from the marine and coastal environment.
	Energy	Provision of products that can be used to produce energy.
	Water supply	Provision of (fresh) water supplies/resources.
	Global climate	Regulation of global climate given GHG emissions.
	Air quality	Regulation of air quality given pollution levels.
	Flood regulation	Protection from natural hazards, specifically floods.
	Water quality	Regulation of environmental processes that affect water quality.
	Pollination	Provision of pollination services to produce pollinator dependent crops.
	Recreation	Individual/societal use of the environment for recreational purposes.
	Amenity	Effects of the state of the natural environment on amenity or aesthetics of an area.
	Non-use value	Value derived from the knowledge that the environment and/or ecosystems are maintained or improved regardless of (current) human use.

Table 2. Natural Capital metrics in YW's Service Measure and 6 Capitals Framework

Where an impact/dependency relationship exists, we consider that there is an equivalent monetised value. We view that this impact/dependency approach is aligned with the WINEP WEO approach and the Natural Capital Logic Chain. Figure 2 below illustrates the logic of our approach from an investment requirement to a 6 Capitals valuation of the impacts of a potential solution option, while Figure 3 shows the Natural Capital Logic Chain as shown in the WINEP WEO metrics v2.0 spreadsheet.

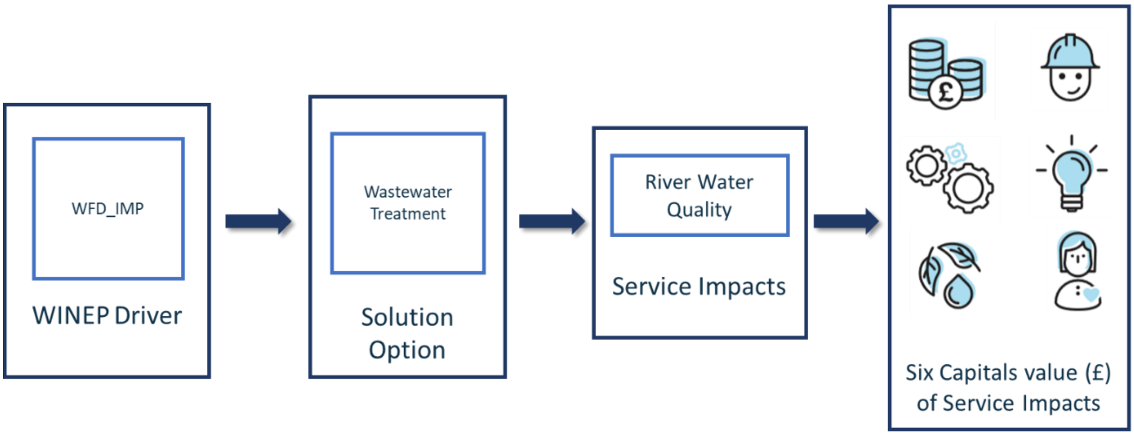

Figure 2. Capturing and valuing the impacts of a WINEP solution option

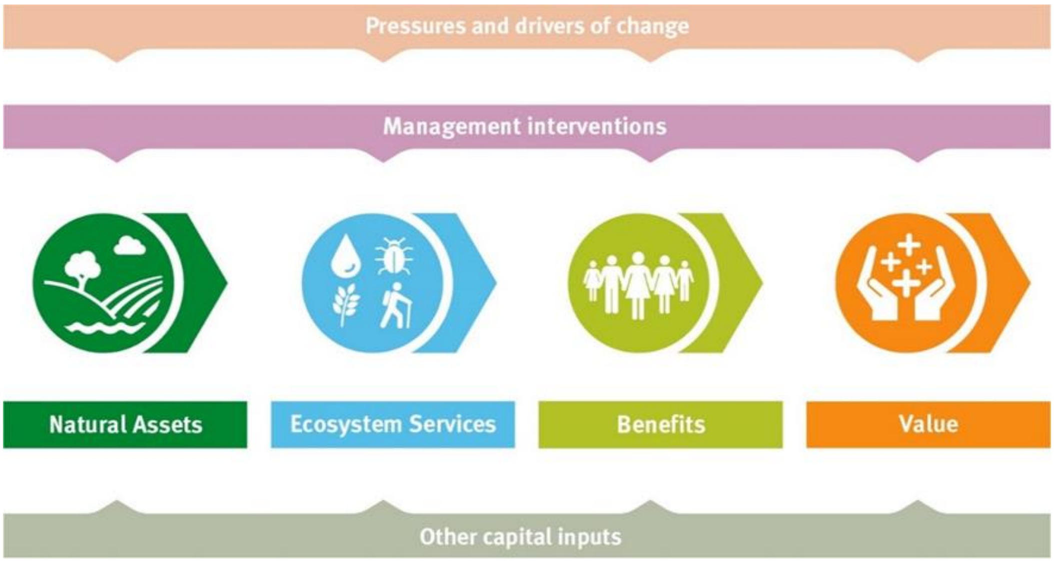

Figure 3. The Natural Capital logic chain

To further ensure alignment, we also reviewed and mapped the metrics that capture ecosystem goods and service benefits in the WINEP WEO with our Service Measure and 6 Capitals Framework. For example, we have an existing Land Use Impact Category of 'Semi-Natural Grassland' which directly maps to the WEO Natural Capital asset/habitat of semi-natural grassland in terms of the ecosystem service 'rate' and the £ valuation used. In this case, we did not make changes to our Service Measure and 6 Capitals Framework. In cases where there are gaps between the WINEP WEO and our Service Measure and 6 Capitals Framework in terms of natural capital assets and/or benefit valuation evidence, we added these in, referring to the metrics and benefit valuation evidence provided in the WINEP WEO metrics v2.0 spreadsheet. For other impacts that we consider important but are not captured by the WINEP WEO, the benefit valuation evidence for these come from Yorkshire Water's Customer Willingness to Pay studies, and benefit transfers for Ecosystem Service benefits valuation. This is further discussed in Section 3 on the Optional Parallel Benefit Assessment.

What is described in the paragraph above is summarised in Figure 4 below.

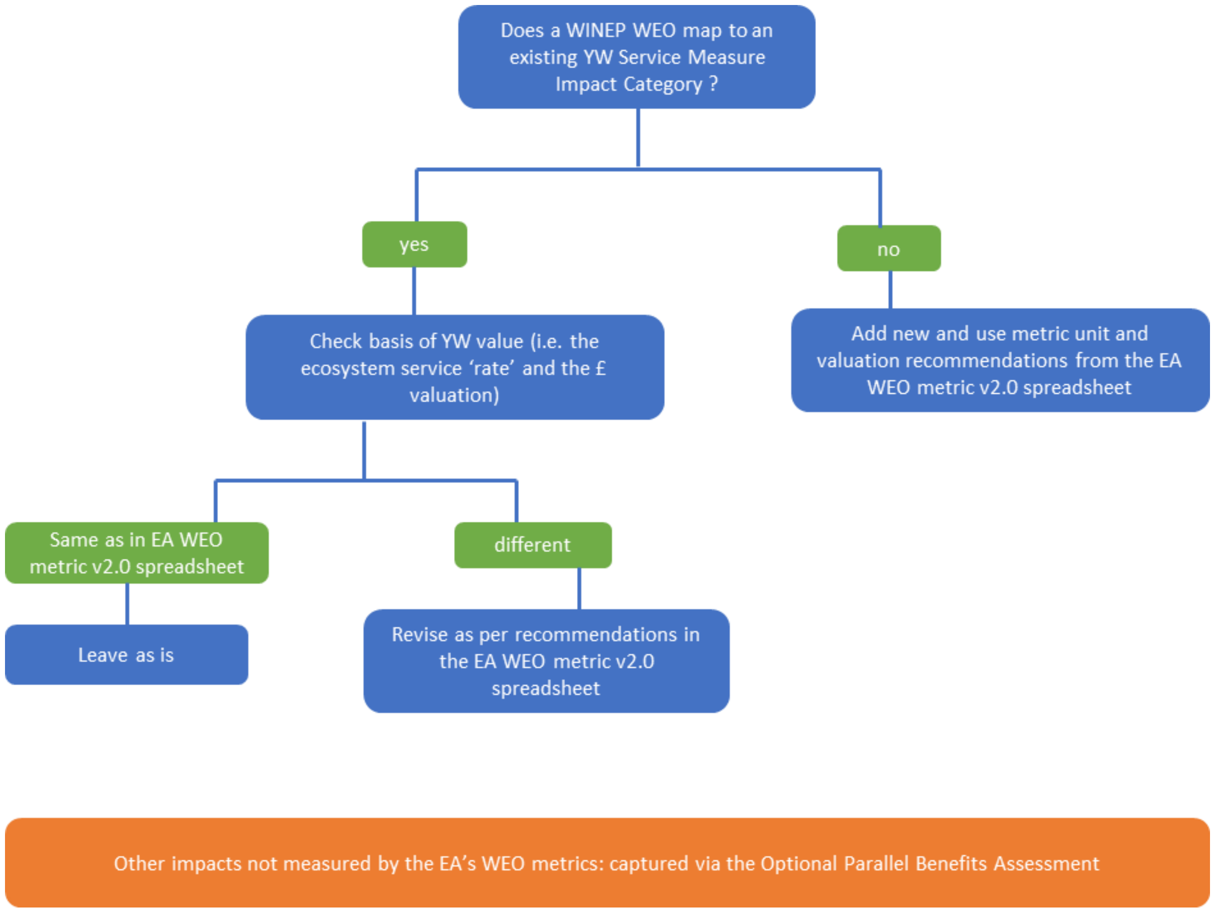

Figure 4 Ensuring alignment between the WINEP WEO approach and the YW Service Measure and 6 Capitals framework

2. Benefits assessment using the recommended metrics for the 4 wider environmental outcomes

The WINEP ODG nor the WINEP WEO metrics v2.0 spreadsheet does not provide explicit guidance on which WEO metrics are relevant for specific WINEP drivers. However, we have considered the following principles referred to in the WINEP ODG when undertaking the benefit (impact) assessment:

1. Delivery of environmental net gain and delivering quantifiable benefits to the environment and society; and
2. Taking a Natural Capital approach to inform options development

As a reminder the four WEO metrics and the Ecosystem Services mapped to them are:

Ecosystem Services (from Natural Capital Assets)	Natural Environment	Net Zero	Catchment Resilience	Access, Amenity and Engagement
Biodiversity	✓			
Climate Regulation		✓	✓	
Hazard Regulation - flood			✓	
Water Quality	✓		✓	
Water Purification	✓		✓	
Water Supply	✓		✓	
Recreation				✓
Angling				✓
Food- shellfish	✓			
Air Quality	✓			
Education				✓
Volunteering				✓

Figure 5. WINEP WEO metrics and ecosystem services mapping

From these, we considered the following questions for the monetisation of the benefits of WINEP options, in view of our Service Measures and 6 Capitals Framework that we have adapted to be in line with the WINEP WEO:

- Which Service Measures are affected by the delivery of this WINEP option?
- Can we quantify the impact[4], and if yes, how much is the assumed/projected impact?

The above follows the logic presented in Figure 2, and is applied to all WINEP solutions considered under the different WINEP drivers.

In this section, we provide further details on how we utilised the recommended metrics for the four WEO to quantify the benefits of WINEP options.

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[4] This is an important part of the assessment. If the impact of a solution cannot be quantified, then it is difficult to monetise the benefits or costs of the impact.

Biodiversity and ecosystem services from habitats/land use types

As per the WINEP WEO metrics spreadsheet, we have not put a monetary value on biodiversity.

In cases where the WINEP option also has an impact on a habitat or land use type (e.g. creation or loss of broadleaved woodland), the assumed benefits or dis-benefits of these are related to the ecosystem service benefits from that habitat type. The ecosystem services listed below, which are mapped to the WINEP WEO metrics, are the ones that are assumed to be affected through an impact on habitat or a land use type:

- Climate regulation
- Hazard regulation- flood
- Water purification
- Water supply
- Air quality

River Water Quality Benefits

In the case of River Water Quality benefits, we chose to disaggregate the WINEP WEO valuation evidence across a few Natural Capital benefit metrics. In our Service Measure and 6 Capitals framework, our original valuation on the benefits of river water quality improvement is from our PR19 Customer Valuation exercise and this assumed that river water quality benefits are from the Natural Capital metrics of recreation, amenity and non-use values. This is different from the water purification benefits delivered by specific habitats such as wetlands.

The rationale for this disaggregation is so that YW gains better understanding of the benefits that are impacted by investment in WINEP options. This disaggregation is supported by the range of final benefits from Water Quality that is stated in the WINEP WEO metrics v2.0 spreadsheet:

> *The benefits that are provided by good water quality include: recreational benefits for anglers, rowers, other users of riparian*

habitat (e.g. walkers, bird watchers), more general local amenity benefits, non-use values associated with improved riparian habitat for plants and birds, and lower costs of supplying potable water[5].

For this, we used the central monetised estimates of river water quality benefits in the Yorkshire and Humber area from the updated NWEBS values[6] for different water quality classification improvements. We then mapped the six ecosystem components for river water quality from NWEBS to the three Natural Capital metrics of recreation, amenity and non-use value. This gives us a proportion to apply to the central monetised estimate of river water quality benefits to get separate estimates for recreation, amenity and non-use value benefits. This is shown in Table 3 below.

NWEBS ecosystem component	EA Water appraisal guidance mapping	YW Natural Capital metric mapping	% to apply to NWEBs central estimate
fish	Non-use	Non-use	0.67 (or four-sixths)
other animals such as invertebrates	Non-use	Non-use	
plant communities	Non-use	Non-use	
condition of river channel and flow of water	Non-use	Non-use	
clarity of water	Aesthetic	Amenity	0.17 (or one-sixth)
Safety of water for recreational contact	Recreation	Recreation	0.17 (or one-sixth)

Table 3. NWEBS ecosystem components and mapping to aspects of River Water Quality benefits

[5] Defra (2021). Enabling a Natural Capital Approach. https://www.gov.uk/guidance/enabling-a-natural-capital-approach-enca

[6] Environment Agency (2013). Updating the National Water Environment Benefit Survey values: summary of the peer review.

The disaggregated values still sum up to the total benefit value, therefore the benefit value from river water quality improvement is not reduced or increased. For the sake of illustration, if the central monetised value of improving a km of river from bad to poor is £10, this means that £6.67 is associated with non-use value, £1.67 is associated with amenity, and another £1.67 is associated with recreation. Other recreational benefits from improved river water quality, especially on angling is not reflected here and is instead captured under the 'Recreation- Angling' Wider Environmental Outcome.

For WINEP options under the Storm Overflow driver(s), we referred to the Storm Overflow Evidence Project (SOEP)[7]. This is to ensure that we follow an industry and EA recognised approach and to ensure consistency in capturing monetised benefits between our WINEP24 and DWMP options appraisal approach.

The SOEP outlines 3 main benefit areas from storm overflows, and shown in Table 4.

Benefit	Impact	Metric of impact
River Water Quality	'bad' to 'poor'	kms per year
	'poor' to 'moderate'	kms per year
	'moderate' to 'good'	kms per year
Public health	'non-swimmable' to 'swimmable'	kms per year
Social impact	Reduction of one pollution incident	Incident per year
	Reduction of one VWSF (volume weighted spill frequency) count	Incident per year

Table 4. Benefit areas from reducing risks from Storm Overflows from the SOEP.

On 'River Water Quality', the SOEP document specifies river health benefit via the ecological status of the river. Specifically, that this is represented by the non-market benefits of the Water Framework Directive, given the water quality components of fish, invertebrates, and plants. On 'Public Health', the

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[7] Storm overflows evidence project (publishing.service.gov.uk)

impact is reflected by a recreational benefit in SOEP, specifically a length of river that was previously 'unswimmable' becoming 'swimmable' because of a reduction in overflow spills. For these two benefit areas, SOEP also recommends the use of the NWEBS values. Due to this, we view that using this SOEP approach to capturing benefits on river water quality and public health from Storm Overflow related options is in line with a WEO approach. This is because the benefit areas covered and the basis of the valuation are the same. We also used the same benefit apportionment approach from SOEP: 50% (or three-sixths) of the NWEBS benefit valuation is associated with non-use values; and 16.67% (or one-sixth) of the NWEBS benefit valuation is associated with recreation. Note that the monetised NWEBS benefit value we use are also ones relevant for the Yorkshire and Humber area.

The 'Social Impact' from reduced spills from Storm Overflows are noted in the SOEP document as the increased satisfaction of general users and non-users of water courses. This can be associated with the aesthetic impact given storm overflow impacts on rivers. We included this in the river water quality benefit assessment to ensure consistency in capturing monetised benefits between our WINEP24 and DWMP options appraisal approach.

Recreation

The WINEP WEO Metrics v2.0 spreadsheet recommends the use of the Outdoor Recreation Valuation (ORVal) tool to estimate existing number of visits to a site and how much this could change due to intervention. For several of our WINEP options, there are large uncertainties associated with quantification of impact that would allow us to use the ORVal tool properly. Due to this, we have elected not to use the ORVal tool to value the impact on recreational activities that are separate to the ones captured under the Water Quality and Angling Ecosystem Services. However, in line with our Service Measures and 6 Capitals framework approach, we have captured some recreational benefits associated with changes in bathing water quality. This is outlined in more detail in Section 3 for the Optional Benefits Assessment.

Food – shellfish

Yorkshire Water does not have any WINEP drivers associated with shellfish waters. Additionally, we have not been able to quantify impacts on shellfisheries (and fisheries) from solutions that target water quality. These mean we have not captured any impacts on shellfish landings.

Water supply, education, and volunteering

For these three ecosystem services, we used the measures and unit metrics as per what is set out in the WINEP WEO metrics v2.0 spreadsheet.

WEO dis-benefits

Section 4 describes the cost assessment process to evaluate the financial and whole life cost of WINEP options. Part of the Yorkshire Water process to estimate the capital and operational costs of a solution is the estimation of the associated carbon emissions and carbon costs.

The carbon impacts of a WINEP option are associated with capex and opex: a volume of capital or embedded carbon is associated with capex and a volume of operational carbon is associated with opex. Capital carbon volume is estimated via carbon models associated with Yorkshire Water's Unit Cost Models or via generic carbon models. On the other hand, operational carbon volume is estimated via multipliers which estimate a carbon volume per £1 of expenditure on different opex categories (e.g. chemicals, energy). This approach follows the methodology developed for the Yorkshire Water Whole Life Cost (WLC) Calculator[8], but adjusted to take into account current data, e.g. on emissions associated with electricity use.

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[8] Turner and Townsend, 2016. *Whole Life Cost Assessment Guidance Document: Supporting Asset Management and the wider Yorkshire Water business in the standardised assessment of Whole Life Cost and Carbon*. Version 2.3, 30 March 2016

We apply the central carbon values per tCO2e as per Annex 1 in the BEIS approach published in September 2021 on the valuation of greenhouse gas emissions[9] to calculate the carbon cost. The estimated (30 year present value) carbon cost for WINEP solutions are presented under the 'dis-benefits' lines in the WINEP OAR. This follows the advice provided by Ofwat via the EA WINEP and PR24 query process on where to report the carbon costs of WINEP solutions[10].

3. Optional and parallel benefit assessment

The WINEP ODG allows for the use of other benefit metrics to perform an optional parallel benefit assessment to highlight additional benefits that are not captured via the WINEP WEO. We have made use of this optional and parallel benefit assessment to demonstrate the following:

- benefits associated with reduced sewer flooding and surface water run-offs due to Storm Overflow solutions;
- benefits associated with bathing water quality improvements; and
- other benefits from habitat and land use types such as amenity, carbon sequestration (climate regulation), and air quality.

Similar to the WINEP WEO approach, we also ask the same questions to identify if these (optional and parallel) benefits are relevant to WINEP options:

- Which Service Measures are affected by the delivery of this WINEP option?
- Can we quantify the impact, and if yes, how much is the assumed/projected impact?

Benefits from reduction of sewer flooding risks and surface water run-off

[9] https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation
[10] Gough, C., email correspondence, 21 April 2022.

Some solutions related to the Storm Overflow drivers have been assessed in terms of impacts on reducing the risk of internal and/or external sewer flooding and surface water run-off. This is to align with the approach for evaluating the benefits of Yorkshire Water's DWMP solutions.

The benefits from reduced risk of internal and external sewer flooding are mostly associated with social impacts: incidents of sewer flooding, whether inside or outside properties, have negative impacts on households and communities that are affected. Flooding inside properties tend to have a larger impact on well-being than flooding outside of properties.

Within our Service Measures Framework, we measure internal and external sewer flooding impacts as follows:

Sewer Flooding Impact Category	Metric quantity
Internal sewer flooding of a cellar	Number of incidents
Internal sewer flooding of a habitable area	Number of incidents
Flooding of minor roads	Number of incidents
Flooding of major roads	Number of incidents
External flooding within the property boundary not inhibiting access	Number of incidents
External flooding within the property boundary inhibiting access	Number of incidents
External flooding causing societal disruption i.e. impact on Schools, Hospitals, Sensitive properties etc.	Number of incidents

Table 5. Yorkshire Water Impact Categories on Internal and External Sewer Flooding

The monetised valuation associated with these have been sourced from Yorkshire Water's PR19 Customer Willingness to Pay Study. For the assessment of relevant Storm Overflow solutions in this Optional Parallel Benefit assessment, we focused on the benefit values associated with Social Capital, i.e. the value of impacts to Yorkshire Water customers. Note that we have not categorised these benefits under any of the 'Wider Environmental Outcomes' metrics. It is possible to map this under the ecosystem service of 'Natural Hazard Regulation - Flood' and 'Catchment Resilience'. However, the benefits may be delivered by traditional (grey or concrete-based) solutions and therefore not delivered by natural capital assets.

Storm Overflow solutions are also associated with the reduction of surface water run-offs into the sewerage system. The benefits we are focusing on here is the reduction in operational carbon emissions due to a reduction in wastewater volume to be pumped and treated.

Bathing Water improvement benefits

There are several WINEP drivers related to Bathing Water Quality that are relevant for Yorkshire Water. Improvements to Bathing Water Quality can be associated with benefits such as reduced human health risk (when swimming), recreational benefits, non-use values, and additional local economic benefits.

We recognise that some of the WEO metrics can be used to capture benefits associated with bathing water quality (improvements), e.g. recreation (using the ORVal tool), angling, and possibly food (shellfish). However, for recreation impacts, we feel that there are large uncertainties associated with quantification of impact that would allow us to use the ORVal tool properly or to quantify impact on shellfisheries.

Within our Service Measures and 6 Capitals framework, there are 3 Impact Categories associated with Bathing Water Quality. The table below shows these alongside their metric quantity and a short description of the impacts.

Bathing Water Impact Category	Metric quantity	Description
Bathing Water Compliance Failure	Number of failures	The expected number of bathing water sample failures.
Bathing Water Deterioration in Classification	Number of bathing waters	The expected number of bathing waters deteriorating in classification from their current status. Improvements in bathing water classification can be reflected by entering negative numbers.
Bathing Water Loss of Blue Flag Status [due to water quality]	Number of bathing waters	The expected number of bathing waters losing blue flag status.

Table 6. Yorkshire Water Bathing Water Service Measure Impact Categories

The monetised valuation associated with these have been sourced from Yorkshire Water's PR19 Customer Willingness to Pay Study. For this Optional Parallel Benefit assessment, we focused on the benefit values allocated over recreation, non-use value and well-being (i.e. health impacts).

Other benefits from habitat and land use types

Within our Service Measures and 6 Capitals Framework, there are land use types benefits that are not included in the WINEP WEO. Table 7 below lists these but note that not all of these land use types may have been used for the WINEP benefit assessment as they may not be relevant for the WINEP solutions.

Land Use Type	Natural Capital benefit
Greenspace	Amenity, Global Climate, Air Quality
Bare ground	Amenity, Global Climate, Air Quality *These are expressed as costs (e.g. decrease in amenity for an additional hectare of bare ground).*
Coniferous woodland	Amenity
Broadleaved woodland	Amenity
Semi-natural grassland	Amenity
Farmland	Amenity
Mountains, moors and heaths	Amenity
Coastal margins	Amenity
Wetlands and floodplains	Amenity, Flood Regulation, Air Quality

Table 7. Other Natural Capital benefits from habitat and land use types

The monetised benefits associated with these are from a benefits transfer.

WEO dis-benefits

As with the WINEP WEO benefit assessment, we have also included estimates of carbon emissions from solutions in the optional and parallel benefit assessment. The approach for this follows what is described in Section 2, under the WEO dis-benefits heading.

4. Cost Assessment

The capital cost of a WINEP solution represent costs to 'build' a solution and is estimated through one or a combination the following:

- Using Yorkshire Water's Unit Cost Models which account for different 'component parts' of an asset (e.g. a tank, a pump);
- Estimating 'lump sum' costs in cases where using unit cost models are not appropriate (e.g. modelling costs); or
- Using a unit cost estimate (e.g. £ per unit of P removed).

For unit cost estimates, we used a simple unit cost model[11], where we sourced historical cost data and relevant explanatory variables in order to come up with a unit cost. For example, a unit cost for P removal is calculated by looking at historical costs of schemes associated with P removal and explanatory variables of PE (Population Equivalent) and the level of consent required.

Re-investment requirements for individual asset components are also taken into consideration where relevant, e.g. replacing a pump at end of life every 15 years. This is so that the whole life cost of the asset is captured properly in the present value calculation.

Operational costs on the other hand, are associated with energy and chemical use, labour, maintenance, business rates, and disposal and transport of sludge. Not all WINEP solutions will be associated with every type of operational cost.

The 'whole life cost' of a solution is taken as the present value sum of (annuitised) capex and opex incurred by Yorkshire Water. The next section provides additional information on the present value calculation. As mentioned in the previous sections, carbon costs are not included in the whole life cost calculation and these are part of the 'dis-benefits' lines instead.

We also included the value of partnership contribution to capex or opex, but only if applicable to the solution. Note that contribution capex, if applicable, is not treated in the present value calculation the same way as Yorkshire Water capex, i.e. contribution capex is not capitalised using the Spackman approach. Partner Contribution is not part of the whole life cost calculation.

These costs are reported under the 'Costs' heading of the OAR, specifically in the Monetised Information section.

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[11] This 'simple unit cost model' is different to the Yorkshire Water Unit Cost Models.

5.Net Present Value Cost-Benefit and the Benefit-Cost Ratio

Calculation tool

The 'system' part of our Decision Making Framework is the software, Enterprise Decision Analytics. One function of this software enables us to do complex and large scale calculations such as optimisations. We are using EDA to support the calculation of net present value (NPV) costs, benefits, net-benefit and the benefit-cost ratio of WINEP solutions.

Price base

Prior to any annuitisation, discounting and net-benefit calculations, we ensured that all monetised (cost and benefit) values for each WINEP solution have been deflated to the 20/21 CPIH price base.

Time to benefits

For all solutions, an assumption on 'time to benefits' (or TTB) was applied. This means that WEO and other impacts are incurred a year or more after a solution is built: we do not assume that benefits are incurred in the same year as the start year of 'building' a solution unless for cases where we know that this is true. Where the solution cost is estimated using Yorkshire Water Unit Cost Models, a TTB is automatically calculated. The TTB could also be manually entered and based on expert judgement, and may be applicable to solutions whose costs are estimated using lump sums or unit cost estimates.

Annuitisation of capex

As mentioned in the previous section, capex represents the cost to build the asset associated with the solution and includes 'end of life' replacement costs for individual asset components.

We have annuitised capex including replacement capex, as per the requirement in the WINEP ODG. This shows a 'smoothed' cost over time, reflecting costs added to the regulatory capital value (RCV) rather than a 'lumpy' profile associated with capex. The assumed cost of capital is the vanilla Wholesale Allowed Return on Capital for Yorkshire Water at the CMA Final Determination. The calculation of annuitised capex for a solution is also determined by the asset life of that solution and in our calculations, we have taken a weighted average asset life (considering the different asset components as necessary) per WINEP solution.

Discounting

All monetised values have been discounted over a 30 year period using the HM Treasury Green Book discount rate or social time preference rate of 3.5%. Since we have kept the assessment period to 30 years, we have not applied the declining discount rate, which goes to 3.0% from year 31 and 2.5% from year 76[12].

Net-Benefit and Benefit-Cost Ratio

For some WINEP drivers and investment needs, more than one solution has been identified (e.g. one 'traditional' grey solution, and another 'blue/green' solution). To allow us to compare the costs and benefits of these solution options consistently, we made the assumption that the start year of all WINEP24 solutions is in 2025. We emphasise that this does not override any agreements made or yet to be made between Yorkshire Water and the Environment Agency on early starts, compliance dates or other areas which determine the starting year of an (agreed) solution. We have done this purely to remove the effect of discounting on NPV if we allow for different start years between solutions: it is 'cheaper' in present value terms to defer action to a later year than to start it now therefore we have ensured that this is assumption is not included in the calculation.

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[12] Our time period of assessment starts with a Year 0, therefore a 30 year time period covers Years 0 to Year 29. Additionally, we referred to the Impact Assessment Calculator published by BEIS for the discount factor calculation.

We have set up calculations to produce results for the different rows in the 'Monetised Information' section of the OAR as shown in Table 8 below. Note that the rows related to the 'Business Plan' numbers have been removed. Additionally, we referred to Table 1 in the WINEP ODG to identify the cost and benefit variables and calculations relevant to the rows.

OAR 'Monetised Information' Section Rows
Costs
Cost estimate
Partner co-funding
Total % partner contribution
Net Cost Estimate (defined as gross costs minus partner contributions)
Benefit assessment: using recommended metrics for the 4 WINEP wider environmental outcomes
Benefit estimate
Benefit estimate- Natural Environment
Benefit estimate- Net zero
Benefit estimate- Catchment resilience
Benefit Estimate - access, amenity and engagement only
Dis-benefit estimate
Cost-benefit assessment: using recommended metrics for the 4 WINEP wider environmental outcomes
Net cost-benefit
Benefit-cost ratio
Optional Parallel Benefit Assessment: calculated using: ***- the recommended metrics for the 4 WINEP wider environmental outcomes, or a justified alternative metric to the recommended metric*** ***- supplementary metric(s)***
Benefit estimate
Benefit estimate- Natural Environment
Benefit estimate- Net zero
Benefit estimate- Catchment resilience
Benefit Estimate - Access, Amenity and Engagement only
Dis-benefit estimate
Cost-benefit assessment: using the recommended metrics for the 4 WINEP wider environmental outcomes or alternative metric, and/or supplementary metrics
Net cost-benefit
Benefit-cost ratio

Table 8. OAR 'Monetised Information' Section populated where relevant

For the different benefit estimates (i.e. the total benefit estimate and the 4 WEO benefit estimates), we do not recommend that the 4 WEO benefit estimates are summed to get to the total benefit estimate as there will be double counting. This is because different benefit metrics fall under more than one WEO.

Appendix: Mapping of YW Service Measures 6 Capitals Framework to the WINEP WEOs.

Note: those in black text are included in the WINEP WEOs benefit assessment, while those in blue text are included under the 'Optional Parallel Benefits Assessment'. Other benefits included in the Optional Benefit Assessment but do not fall strictly within the 'Wider Environmental Outcomes' are those associated with the reduction in internal and external sewer flooding risk. These are not shown in the Table below but are shown in Table 5 in Section 3 of the report.

Ecosystem Services (from Natural Capital Assets)	Natural Environment	Net Zero	Catchment Resilience	Access, Amenity and Engagement
Biodiversity	not monetised			
Climate Regulation		**Natural_Global_Climate** LandUse_Areaofexistingcoastalwetland LandUse_Areaofadditionalcoastalwetland LandUse_Areaoffarmland LandUse_Areaofgreenspace LandUse_Areaofmountainsmoorsandheaths LandUse_Areaofseminaturalgrassland LandUse_Areaofpeatlandinactivelyerodingcondition LandUse_Areaofpeatlandindrainedcondition LandUse_Areaofpeatlandinmodifiedcondition LandUse_Areaofpeatlandinnearnaturalcondition LandUse_Areaofbroadleavedwoodland LandUse_Areaofconiferouswoodland WaterUse_Surfacewaterinterceptedharvested WaterUse_Surfacewaterseparatedfromcombined	**Natural_Global_Climate** LandUse_Areaofexistingcoastalwetland LandUse_Areaofadditionalcoastalwetland LandUse_Areaoffarmland LandUse_Areaofgreenspace LandUse_Areaofmountainsmoorsandheaths LandUse_Areaofseminaturalgrassland LandUse_Areaofpeatlandinactivelyerodingcondition LandUse_Areaofpeatlandindrainedcondition LandUse_Areaofpeatlandinmodifiedcondition LandUse_Areaofpeatlandinnearnaturalcondition LandUse_Areaofbroadleavedwoodland LandUse_Areaofconiferouswoodland	
Hazard Regulation - flood			**Natural_Flood_Regulation** LandUse_Areaofexistinginlandwetland LandUse_Areaofadditionalinlandwetland LandUse_Areaofexistingcoastalwetland LandUse_Areaofadditionalcoastalwetland LandUse_Areaofcoastalmargins LandUse_Areaofwetlandsandfloodplains LandUse_Areaofmountainsmoorsandheaths LandUse_Areaofbroadleavedwoodland LandUse_Areaofconiferouswoodland	
Water Quality	**Natural_Amenity** RiverQuality_WINEPBadtoPoor RiverQuality_WINEPPoortoModerate RiverQuality_WINEPModeratetoGood **Natural_NonUse_Value** RiverQuality_WINEPBadtoPoor RiverQuality_WINEPPoortoModerate RiverQuality_WINEPModeratetoGood RiverQuality_DWMPBadtoPoor RiverQuality_DWMPPoortoModerate RiverQuality_DWMPModeratetoGood		**Natual_Amenity** RiverQuality_WINEPBadtoPoor RiverQuality_WINEPPoortoModerate RiverQuality_WINEPModeratetoGood **Natural_NonUse_Value** RiverQuality_WINEPBadtoPoor RiverQuality_WINEPPoortoModerate RiverQuality_WINEPModeratetoGood RiverQuality_DWMPBadtoPoor RiverQuality_DWMPPoortoModerate RiverQuality_DWMPModeratetoGood	

YorkshireWater

Ecosystem Services (from Natural Capital Assets)	Natural Environment	Net Zero	Catchment Resilience	Access, Amenity and Engagement
Water Purification	**Natural_Water_Quality** LandUse_Areaofexistinginlandwetland LandUse_Areaofadditionalinlandwetland LandUse_Areaofexistingcoastalwetland LandUse_Areaofadditionalcoastalwetland LandUse_Areaofcoastalmargins LandUse_Areaofmountainsmoorsandheaths		**Natural_Water_Quality** LandUse_Areaofexistinginlandwetland LandUse_Areaofadditionalinlandwetland LandUse_Areaofexistingcoastalwetland LandUse_Areaofadditionalcoastalwetland LandUse_Areaofcoastalmargins LandUse_Areaofmountainsmoorsandheaths	
Water Supply	**Natural_Water_Supply** WaterUse_Watersupplyfromabstraction		**Natural_Water_Supply** WaterUse_Watersupplyfromabstraction	
Recreation				**Natural_Recreation** RiverQuality_WINEPBadtoPoor RiverQuality_WINEPPoortoModerate RiverQuality_WINEPModeratetoGood RiverQuality_DWMPNonSwimmabletoSwimmable PollutionIncidents_DWMPReductionofoneminorpollutionincident PollutionIncidents_DWMPReductionofoneVWSFcount BathingWater_ComplianceFailure BathingWater_Deteriorationinclassification BathingWater_Lossofblueflagstatus **Social_Well-being** BathingWater_ComplianceFailure BathingWater_Deteriorationinclassification BathingWater_Lossofblueflagstatus **Natural_Amenity** RiverQuality_WINEPBadtoPoor RiverQuality_WINEPPoortoModerate RiverQuality_WINEPModeratetoGood LandUse_Areaofconiferouswoodland LandUse_Areaofbroadleavedwoodland LandUse_Areaofseminaturalgrassland LandUse_Areaoffarmland LandUse_Areaofmountainsmoorsandheaths LandUse_Areaofcoastalmargins LandUse_Areaofgreenspace LandUse_Areaofbareground LandUse_Areaofwetlandsandfloodplains

Ecosystem Services (from Natural Capital Assets)	Natural Environment	Net Zero	Catchment Resilience	Access, Amenity and Engagement
Angling				**Natural_Recreation** Recreation_Anglingfisherycoarsetogame Recreation_Anglingfisherycoarsetomixed Recreation_Anglingsmalltomediumfishsize Recreation_Anglingmediumtolargefishsize Recreation_Anglinglowtomediumfishquantity Recreation_Anglingmediumtohighfishquantity
Food- shellfish	x			
Air Quality	**Natural_Air_Quality** LandUse_Areaofcoastalmargins LandUse_Areaoffarmland LandUse_Areaofwaterbodies LandUse_Areaofwetlandsandfloodplains LandUse_Areaofgreenspace LandUse_Areaofbareground LandUse_Areaofmountainsmoorsandheaths LandUse_Areaofseminaturalgrassland LandUse_Areaofbroadleavedwoodland LandUse_Areaofconiferouswoodland			
Education				**Social_Wellbeing** AdditionalMetrics_Educationalvisitsbyschoolchildrentonaturereserves
Volunteering				**Social_Wellbeing** AdditionalMetrics_NatureBasedVolunteering

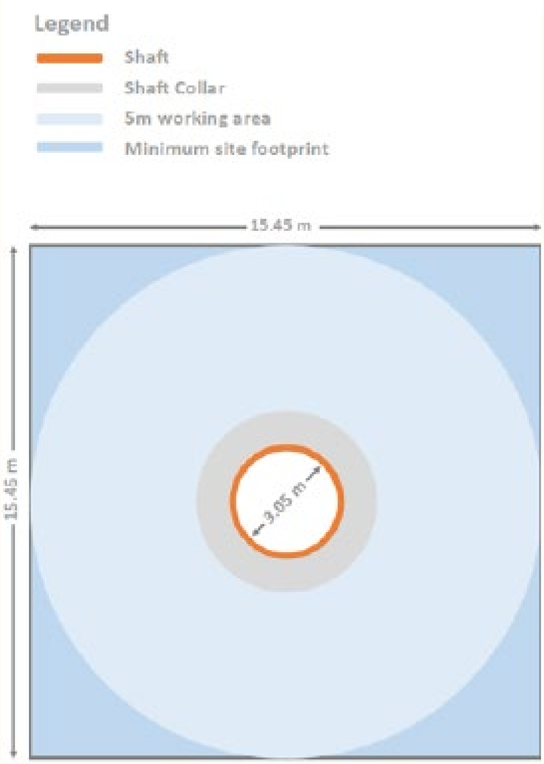
B. Annexes for Storm Overflow Reduction Plan

B1. Enhance

The storage tank volumes were approximated based on the spill volume of the target+1 spill when spills are ranked by volume.

Storage volumes were translated to one of four standardised tank diameters, ranging from 3.05m to a maximum of 25m diameter. An allowance for a site working area (proportional to shaft diameters) during construction was allowed for and is shown in Figure 1 below.

Figure 1: Example land parcel requirement for 3.05m dia. shaft



An automated GIS routine was run to compile a regional dataset of land parcels. These were discounted if there was intersection with any of the following sensitive site designations listed below:

- World heritage sites
- Ramsar sites
- Proposed/candidate Ramsar sites
- Special Protection Area (SPA)
- Possible/candidate Special Protection Area (cSPA)
- Special Area of Conservation (SAC)
- Possible/candidate Special Area of Conservation (cSAC)

Flags were placed on land parcels intersecting the following designations:

- Scheduled monument
- Listed building
- Registered battlefield
- Registered parks and gardens
- Archaeological important areas
- Locally listed heritage assets
- Conservation area (Built)
- Heritage coasts

- Sites of Special Scientific Interest (SSSI) and associated Impact Risk Zones
- Local and National Nature Reserves
- Ancient woodland
- Areas of Outstanding Natural Beauty (AONB)
- National Park
- Marine Conservation Zones
- Local Wildlife Sites (LWS)
- Site of Importance for Nature Conservation (SINC)
- Local Geological Site (LGS)
- Nature Improvement areas
- Priority Habitat Areas

Site designations were only included where information was available in nationally available datasets (as published in September 2022) and within a GIS format.

Suitable land parcels were identified for each storm overflow solution. Land parcels had to:

- Have an area greater than the required plan area (constraints on circularity were included)
- Be within 1.6km search radius of the storm overflow (from centre point of the land parcel)

Where more than one suitable land parcel was identified a 'preferred' land parcel was assigned based on proximity to the storm overflow. This was a high-level assessment and some identified land parcels may not be suitable once construction constraints are considered.
Each overflow was assessed independently and there is a risk that the same land parcel is selected for multiple storm overflow solutions.

A further automated GIS routine was used to approximate a preferred pipe route from the storm overflow location to the centre point of the preferred land parcel. Pipe routes were excluded from intersecting certain key site designations (as per tank parcel routine) and from passing through buildings, structures and property curtilage identified within MasterMap. The shortest permissible path was selected as the preferred option.

It has been assumed that the pipe from the storm overflow to the storage tank will be a gravity pipe and at the same diameter as the existing overflow spill pipe. Tank emptying is assumed to be a pumped rising main, with pump and rising main size related to the proposed tank diameter. A comparison of the storage volume to the tank emptying rate was conducted, where this was found to be prohibitive, the option was rejected as unfeasible. This reduces the viable options available to address the need and a reduce and enhance solution was proposed.

High-level outline designs were created for the tank solutions to support the cost build up. An allowance for standard items such as; manholes, pumps, hydro ejectors, odour control units, MCC, power supply, screen and screen chamber were made.

Screens have been sized based on the incoming pipe diameter only. This may mean screens, and associated screening chambers, are over or under sized when local hydraulic conditions are factored in.

Where pipe routes cross key constraints such as watercourses, railway lines and major roads, these have been flagged within the generated schematic design. No adjustment is made within the cost build up at this stage, further assessment will be undertaken in any subsequent design stage. An additional depth of excavation was provided for to make allowance for the plug, cover slab and depth loss due to head losses or depth loss due to the weir height.

Key metrics such as pipe size, length, pump return rate, tank size, screen size have been utilised to develop a high-level Bill of Quantities (BoQ) for each solution. The generated BoQ was supplied to our in-house costing team to allow company cost models to be applied. This provided total CAPEX, OPEX, embodied carbon and operational carbon values for each storm overflow scheme.

The following standard assumptions were made within the cost build up:

- Gravity mains to be constructed from concrete at a depth of 2-4m within a Type 3/4 road (as defined in the New Roads and Street Works Act 1991).

- Rising mains to be constructed from plastic material within a Type 3/4 road.
- Hydro ejectors assume to be all duty except 1 standby
- Run time of return pumps and hydro ejectors assumed to be 4%
- M&E maintenance calculated as annual fraction of the capital value of the asset.

B2. Reduce and Enhance

Where possible sub-catchments connected to each storm overflow were assessed defined by iteratively tracing upstream of each storm overflow within the available hydraulic models and identifying those sub-catchments connecting to the storm overflow (independent of any other overflow). Starting at the furthermost downstream point and working upstream, unique areas draining to each storm overflow were defined and removed from the next iteration. Iterations were completed until a unique area was defined or it was determined not possible to assign.

No hydraulic assessment of the network connectivity has been undertaken. Consequently, hydraulic break points may exist between storm overflows, and the effect of these has not been considered.

Once all the sub-catchments connected to a storm overflow had been identified the difference in connected impermeable area between the baseline model and the impermeable area reduction model for each sub-catchment can be summed. This provides the total impermeable area for removal per storm overflow.

The Impermeable Area reduction in the model, reduced area connected to both the foul/combined system and the storm system. Reduction in area connected to the storm network is not expected to significantly influence the operation of the storm overflow. However, it may bring wider benefits within the sub-catchments. Consequently, all modelled sub-catchments that were not assigned to a storm overflow were geospatially queried and where possible linked to storm overflow.
Whilst these areas may overlap geospatially, the impermeable area will have been assigned to either the foul/combined or the storm system within the hydraulic model and therefore the area is not double counted between system types.

Overflows at WwTWs were discounted from this approach. These were excluded, as the sub catchment area concept, i.e. the area between the last storm overflow(s) and the WwTW, was deemed unlikely to result in sufficient area reduction to significantly impact on the spill frequency from the WwTW overflows.

Standard designs were created for the SuDS intervention types listed below to provide a notional £/m2 or £/m3 of intervention:

- Detention basins
- Pocket basin
- Geocellular storage
- Bio-retention (road and verge)
- Permeable paving
- Commercial waterbutt

Indicative solutions were generated characterising varying housing densities and available green space. In each solution a blend of the SuDS features above was assumed with the proportional split of each SuDS feature varying in each solution.

A high-level BoQ was generated for each indicative solution. Required storage volumes were calculated based on the average M30-480minute winter rainfall depth for 2050 across the region. Conveyance features used indicative lengths based on the required area for removal. This provided an indicative £/ha to deliver a blended set of SuDS interventions which varies based on housing density and available green space.

Each sub-catchment was split into a 100m x 100m grid and each grid square queried to determine:

- The proportion of grid square covered by impermeable area
- The proportion of impermeable area assigned to the hydraulic model
- The housing density within the grid square
- The proportion of available green space within the grid square

Each grid square has been assigned to an indicative solution and the impermeable area removal within the model is used to factor the solution cost per hectare up or down. An area weighted average has then been used to determine a final £/ha.

No allowance of system type within the sub-catchments has been made. An estimate of operational costs has been made using nationally available unit costs. Estimates of embodied and operational carbon have been made using adapted in-house models.

B3. PCD scheme costs and allocations

I. Storm overflows (Primary Drivers IMP2 and IMP4/Inland)

Cost categories– INL

Category	INL_A	INL_B	INL_C	INL_D	INL_E	INL_F	INL_G	INL_H	INL_I
No. of storm overflows	52	40	38	19	18	8	7	3	1
Average unit cost (£m)	0.71	1.59	2.36	3.47	4.56	5.50	6.27	7.29	8.59

Named schemes –INL

Site	Cost (£m)
Stairfoot Grange CSO	20.174

Allocations – IMP/INV

Category	**List of associated schemes**
INL_A	S02000 DERBY ROAD 242_CSO, S00801 ST LAWRENCE ROAD_CSO, S01911 HONLEY NEWTOWN_NO 2 CSO, S00117 UPWELL STREET_CSO, S01910 BEAUMONT PARK_CSO, S02100 OLD MILL LANE_CSO, S01335 Old Whittington STW, S02042 MILFORD PLACE_CSO, S00259 ST MARYS WALK 112_CSO, S00255 SKIPTON ROAD 109_CSO, S01999 DERBY ROAD GARAGE_CSO, S00471 YORK LANDING LANE_CSO, _S00695 STOCKSBRIDGE_CSO, S01792 ST Augustines Avenue CSO, S01854 CLAREMONT 271_CSO, S01490 STOURTON_CSO, S00266 Cambridge Street CSO, S00106 Treeton CSO, S01363 Keighley Marley STW, S02013 BRIDGE INN KEIGHLEY_CSO, S01989 RAWCLIFFE BANKSIDE_STW, S02083 CANKLOW_CSO, _S00627 Brinsworth Street CSO, S00719 Westbury Place CSO, S01766 Honley Bridge CSO, S00610 DANBY_STW_, S01189 Storforth Lane CSO, S00591 CASTLETON_SPS, S01209 Foss Bank CSO, S01832 VESPER ROAD_CSO, S00589 GOATHLAND GRNWAY_CSO, S01571 Carlise Street RND CSO, S01870 Broadlea Hill CSO, S00756 Dalton Brook CSO, S00107 Whiston Vale CSO, S00465 BOOTHAM HOSPITAL_CSO, S01274 Ash Grove Castleton CSO, S00267 West Park CSO, S00420 HEWORTH GREEN, S01570 Atlas Works CSO, S01292 Brockholes Lane CSO, S00858 Kendray Doncaster RD CSO, S01998 Derby Road North CSO, S00745 Barnsley MFI CSO, S01913 Whitehead Lane No2 CSO, S00463 Marygate Lane CSO, S01846 South Drive No2 CSO, S02184 Airmyn Crossing CSO, S01855 ST Augustines Drive CSO, S00472 Queens Staith CSO, S00159 Fartown Bradford Road CSO, S01945 Rawcliffe Park CSO.
INL_B	S01652 Bar Lane CSO, S01872 Leymoor Road CSO, S00800 Sheffield Road Tinsley CSO, S02023 Cricket Inn Crescent CSO, S01831 Headingley Station CSO, S02170 Willow Lane Beck CSO, S00712 Fosters Garage CSO, S00258 ST Marys walk 29 CSO, S01864 Fraser Avenue No2 CSO, S00868 Edmunds Road CSO, S02076 Lockwood Scar CSO, S00855 Pastures Road No2 CSO, S00260 Hotel Majestic CSO, S01596 Manor Drive CSO, S01370 Bagley Beck Rodley CSO, S01892 Dearne Hall Road CSO, S01789 Main Road Farm CSO, S01527 Deveron Grove No2 CSO, S01645 Woodlands Donc Road CSO, S00860 Bacon Lane CSO, S01591 South Street Keighley CSO, S00067 Burn Road CSO, S00269 Strawberry Dale CSO, S01773 Dark Lane No2 CSO, S01629 Ballotini Works CSO, S02174 Queens Square CSO, S00532 Malton Holmsfield CSO, S01331 Hangingwater Road CSO, S00264 Montpellier RD27 CSO, S01410 Pontefract Road Barnsley CSO, S00467 Queen Street Bridge CSO, S00454 Huntington Road CSO, S01413 Fraser Drive CSO, S01563 King George CSO, S01802 Hird Street No2 CSO, S00732 Millshaw No2 CSO, S01900 Harrogate Road 298 CSO, S01474 Ferryboat Lane SPS,S00209 Tadcaster Brittania CSO, S01087 Valley Road South CSO.
INL_C	S02082 Clifton Lord Street CSO, S00207 Tadcaster West CSO, S00754 Thurnscoe CSO, S00678 Brompton Road CSO, S01928 Wyther Lane No2 CSO, S00622 Beck Bottom CSO, S00675 Jordan CSO, S01897 Bradford Road CSO, S01813 Canal Road CSO, S01461 Treeton Mill Lane CSO, S00093 Oakenshaw Catchment Crofton STW, S01672 Rawmarsh No2 CSO, S00829 Clifton Park CSO, S01610 Gilstead Lane 128 CSO, S02169 Longroyd Manch Road CSO, S00681 Park Mill CSO,

	S01695 Worry Goose Lane CSO, S00268 Albert Street CSO, S00032 Vicar Road Darfield CSO, S00834 Carr Green CSO, S00256 Jenny Plain Bridge CSO, S00658 Swillington Works CSO, S01569 Bobbinmill Lane CSO, S01841 Westland Road CSO, S01995 Ledgard Way CSO, S02200 Mill Green CSO, S01468 Crossflats No2 CSO, S01633 Steeton CSO, S01877 Swinton Road CSO, S00641 Bagley Lane 39 CSO, S00798 Town Street Sheffield CSO, S00743 Stockwell Hill CSO, S00450 Skeldergate CSO, S00457 Foss Islands Road CSO, S01159 Oakdale Avenue CSO, S00208 Tadcaster East CSO, S00188 Draughton Priors Lane CSO, S01074 Victoria Road Shipley CSO.
INL_D	S01839 Jack Lane CSO, S01073 Victoria Terrace CSO, S01941 Avenue Farm CSO, S01440 Old Goole CSO, S01714 Rooms Lane No2 CSO, S01836 Victoria Gardens CSO, S00814 Fulford Main Street CSO, S01556 Primrose Lane CSO, S00783 Ackworth STW,S01505 Works Road CSO, S01581 ST Pauls Street CSO, S01366 Lemonroyd STW, S02127 West ST Worsbrough CSO, S01514 Smithies LN Barnsley CSO, S01593 Vickers Road CSO, S01040 Harrogate North STW, S00804 Stannington Road No2 CSO, S01172 Rivellin Valley 3 CSO, S01988 Royal Oak Rawcliffe CSO.
INL_E	S01986 Saltaire Road No2 CSO, S00897 Skye Lane CSO, S01771 Honley Huddersfield Road 2 CSO, S01833 Spen Lane 184 CSO, S01069 Newlaithes Road No1 CSO, S00718 Burgoyne Road CSO, S01619 Station Lane W17 No2 CSO, S01089 Fitzwilliam Centre CSO, S00731 Thorpe Hesley CSO, S01843 Sussex Avenue CSO, S01528 Bondgate CSO, S01782 Langsett Raod CSO, S00755 Burntwood Close CSO, S00064 Wide Lane Woodlands 2 CSO, S01756 Wyke Old Lane CSO, S00442 Lendal Hill CSO, S00013 Glenoit Mill CSO, S01883 Darton Church ST No2 CSO.
INL_F	S00880 Scrooby Street CSO, S00713 Brinsworth CSO, S01815 Redbrook Road CSO, S01763 Water Street No2 CSO, S01493 Dockfields CSO, S00069 Ben Shaws CSO, S00788 Willow Lane CSO, S01924 Village Place No2 CSO.
INL_G	S01851 Thornville Road CSO, S01601 Morton CSO, S00802 Ferrars Road CSO, S01842 Middleton Grove CSO, S00710 Union Street CSO, S00865 Marygate Landing CSO, S02122 West Street CSO.
INL_H	S00081 Long Lane CSO, S01064 All Saints Square CSO, S00676 Watersmeet CSO.
INL_I	S00653 Thurgoland CSO.

II. Coastal overflows

Cost categories – Coast

Category	Coast_A	Coast_B	Coast_C	Coast_D	Coast_E	Coast_F
No. of storm overflows	2	6	2	1	1	2
Average unit cost (£m)	0.61	1.53	2.35	3.13	4.13	5.55

Named schemes – Coast

Site		Cost (£m)
S00510	Filey Transfer CSO	12.593
S00576	Endeavour Wharf CSO	15.772
S00931	Hilderthorpe Road CSO	15.859
S01374	Bessingby Road CSO	15,952
S01003	ST Annes Road CSO	33,705
S01482	Hornsea CSO	44,778
S01373	Springfield Avenue 2 CSO	85,383
S00510	Filey Transfer CSO	12,593

Allocations – Coast

Category	**List of associated schemes**
Coast_A	S00585 NEW ROAD BRIDGE, S00587 Upgang Lane No2 CSO.

Coast_B	S00595 East Crescent CSO, S02242 Royal Hotel CSO, S00603 Esplande Whitby CSO, S00582 Robin Hoods Bay LWR CSO, S01144 Limekiln Lane No2 CSO, S00578 Whitby Pier Road CSO.
Coast_C	S01002 Sands Lane Brid CSO, S00850 Aquarium Top CSO.
Coast_D	S00581 Whitby Road BDG CSO.
Coast_E	S00605 Runswick Beck CSO.
Coast_F	Runswick Beck CSO, Crescent Terrace CSO.

III. Non-designated bathing water overflows

Cost categories – NDBath

Category	NDBath_A	NDBath_B	NDBath_C	NDBath_D	NDBath_E
No. of storm overflows	2	3	2	0	4
Average unit cost (£m)	0.75	1.62	2.04		4.17

Named schemes – NDBath

Not applicable.

Allocations – NDBath

Category	**List of associated schemes**
NDBath_A	S00277 CRAGG TOP_CSO, S00279 Spital Croft CSO
NDBath_B	S00273 Waterside 47 CSO, S00276 Boroughbridge Road CSO, S00275 Waterside 49 CSO
NDBath_C	S00231 Abbey Road No2 CSO, S00274 Waterside 48 CSO
NDBath_D	
NDBath_E	S00204 Langwith Valley CSO, S01160 Collingham Leeds Road/CSO, S01175 Scott Lane/CSO, Wetherby Bypass/CSO.

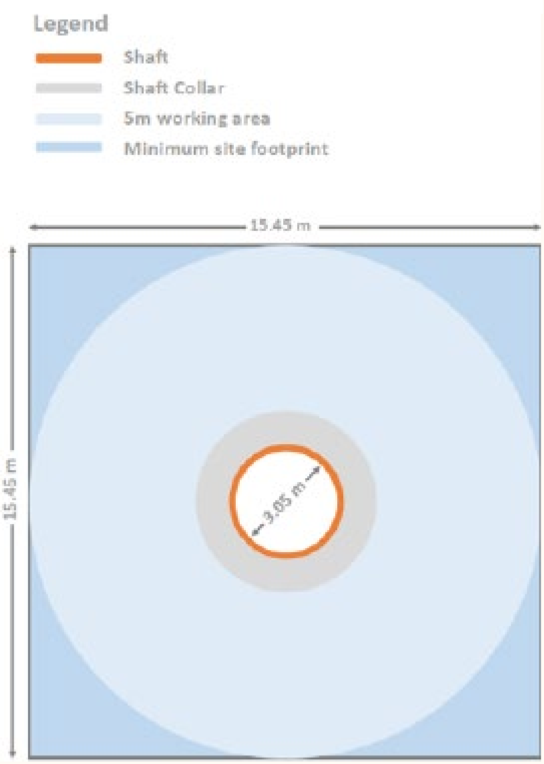
C. Annexes for Inland Bathing Waters

C1. Enhance

The storage tank volumes were approximated based on the spill volume of the target+1 spill when spills are ranked by volume.

Storage volumes were translated to one of four standardised tank diameters, ranging from 3.05m to a maximum of 25m diameter. An allowance for a site working area (proportional to shaft diameters) during construction was allowed for and is shown in Figure 1 below.

Figure 1: Example land parcel requirement for 3.05m dia. shaft



An automated GIS routine was run to compile a regional dataset of land parcels. These were discounted if there was intersection with any of the following sensitive site designations listed below:

- World heritage sites
- Ramsar sites
- Proposed/candidate Ramsar sites
- Special Protection Area (SPA)
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Flags were placed on land parcels intersecting the following designations:

- Scheduled monument
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- Registered parks and gardens
- Archaeological important areas
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- Sites of Special Scientific Interest (SSSI) and associated Impact Risk Zones
- Local and National Nature Reserves
- Ancient woodland
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Site designations were only included where information was available in nationally available datasets (as published in September 2022) and within a GIS format.

Suitable land parcels were identified for each storm overflow solution. Land parcels had to:

- Have an area greater than the required plan area (constraints on circularity were included)
- Be within 1.6km search radius of the storm overflow (from centre point of the land parcel)

Where more than one suitable land parcel was identified a 'preferred' land parcel was assigned based on proximity to the storm overflow. This was a high-level assessment and some identified land parcels may not be suitable once construction constraints are considered.
Each overflow was assessed independently and there is a risk that the same land parcel is selected for multiple storm overflow solutions.

A further automated GIS routine was used to approximate a preferred pipe route from the storm overflow location to the centre point of the preferred land parcel. Pipe routes were excluded from intersecting certain key site designations (as per tank parcel routine) and from passing through buildings, structures and property curtilage identified within MasterMap. The shortest permissible path was selected as the preferred option.

It has been assumed that the pipe from the storm overflow to the storage tank will be a gravity pipe and at the same diameter as the existing overflow spill pipe. Tank emptying is assumed to be a pumped rising main, with pump and rising main size related to the proposed tank diameter. A comparison of the storage volume to the tank emptying rate was conducted, where this was found to be prohibitive, the option was rejected as unfeasible. This reduces the viable options available to address the need and a reduce and enhance solution was proposed.

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Screens have been sized based on the incoming pipe diameter only. This may mean screens, and associated screening chambers, are over or under sized when local hydraulic conditions are factored in.

Where pipe routes cross key constraints such as watercourses, railway lines and major roads, these have been flagged within the generated schematic design. No adjustment is made within the cost build up at this stage, further assessment will be undertaken in any subsequent design stage. An additional depth of excavation was provided for to make allowance for the plug, cover slab and depth loss due to head losses or depth loss due to the weir height.

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- Hydro ejectors assume to be all duty except 1 standby
- Run time of return pumps and hydro ejectors assumed to be 4%
- M&E maintenance calculated as annual fraction of the capital value of the asset.

C2. Reduce and Enhance

Where possible sub-catchments connected to each storm overflow were assessed defined by iteratively tracing upstream of each storm overflow within the available hydraulic models and identifying those sub-catchments connecting to the storm overflow (independent of any other overflow). Starting at the furthermost downstream point and working upstream, unique areas draining to each storm overflow were defined and removed from the next iteration. Iterations were completed until a unique area was defined or it was determined not possible to assign.

No hydraulic assessment of the network connectivity has been undertaken. Consequently, hydraulic break points may exist between storm overflows, and the effect of these has not been considered.

Once all the sub-catchments connected to a storm overflow had been identified the difference in connected impermeable area between the baseline model and the impermeable area reduction model for each sub-catchment can be summed. This provides the total impermeable area for removal per storm overflow.

The Impermeable Area reduction in the model, reduced area connected to both the foul/combined system and the storm system. Reduction in area connected to the storm network is not expected to significantly influence the operation of the storm overflow. However, it may bring wider benefits within the sub-catchments. Consequently, all modelled sub-catchments that were not assigned to a storm overflow were geospatially queried and where possible linked to storm overflow.
Whilst these areas may overlap geospatially, the impermeable area will have been assigned to either the foul/combined or the storm system within the hydraulic model and therefore the area is not double counted between system types.

Overflows at WwTWs were discounted from this approach. These were excluded, as the sub catchment area concept, i.e. the area between the last storm overflow(s) and the WwTW, was deemed unlikely to result in sufficient area reduction to significantly impact on the spill frequency from the WwTW overflows.

Standard designs were created for the SuDS intervention types listed below to provide a notional £/m2 or £/m3 of intervention:

- Detention basins
- Pocket basin
- Geocellular storage
- Bio-retention (road and verge)
- Permeable paving
- Commercial waterbutt

Indicative solutions were generated characterising varying housing densities and available green space. In each solution a blend of the SuDS features above was assumed with the proportional split of each SuDS feature varying in each solution.

A high-level BoQ was generated for each indicative solution. Required storage volumes were calculated based on the average M30-480minute winter rainfall depth for 2050 across the region. Conveyance features used indicative lengths based on the required area for removal. This provided an indicative £/ha to deliver a blended set of SuDS interventions which varies based on housing density and available green space.

Each sub-catchment was split into a 100m x 100m grid and each grid square queried to determine:

- The proportion of grid square covered by impermeable area
- The proportion of impermeable area assigned to the hydraulic model
- The housing density within the grid square
- The proportion of available green space within the grid square

Each grid square has been assigned to an indicative solution and the impermeable area removal within the model is used to factor the solution cost per hectare up or down. An area weighted average has then been used to determine a final £/ha.

No allowance of system type within the sub-catchments has been made. An estimate of operational costs has been made using nationally available unit costs. Estimates of embodied and operational carbon have been made using adapted in-house models.

D. Annexes for River Water Quality Improvements

D1. Capex Scheme costs for nutrient removal PCD

The table below lists the capex associated with the phosphorus, BOD and ammonia drivers of the scheme for each site.

Costs have been uplifted from the April 2022 to the required price base by a multiplier of 1.0496 In some cases, a capex of £0 is cited and explained in the comments. Zero costs are cited where we do not believe we will need a capex scheme to deliver the driver, for example we expect that the Carthorpe WwTW BOD driver will be met by the AMP7 Phosphorus scheme. Zero capex is also cited where a driver limit is superseded by a tighter limit under a different driver.

There are 10 schemes where 2 costs are cited for Phosphorus removal; this is where we have two-phase schemes, Phase 1 will deliver the WFD_ND driver by 31st March 2026, Phase 2 will deliver the tighter WFD_IMP and EnvAct_IMP1 driver by 31st Mar 2030. At these schemes we expect Phase 2 to involve augmenting the Phase 1 works.

Table D1.1: Proposed Capex by Site and Driver

SITE/Scheme NAME	Driver Code	Ammonia-CAPEX	BOD -CAPEX	Phosphorus -CAPEX	Cost per site	COMMENT
ABERFORD/STW	WFD_IMP & EnvAct_IMP1			£2,449,271	£2,449,271	
ALDBOROUGH/STW	WFD_IMP & EnvAct_IMP1			£3,564,773	£3,564,773	
AMPLEFORTH VILLAGE/STW	WFD_IMP & EnvAct_IMP1			£4,659,289	£4,659,289	
APPLETON WISKE/STW	WFD_IMP		£733,033		£3,665,165	
	WFD_IMP & EnvAct_IMP1			£2,932,132		
ASKHAM BRYAN/STW	WFD_IMP & EnvAct_IMP1			£2,359,474	£2,359,474	
ATWICK/STW	WFD_IMP & EnvAct_IMP1			£1,796,421	£1,796,421	
BALDERSBY/STW	WFD_IMP & EnvAct_IMP1			£1,241,246	£1,241,246	
BARWICK IN ELMET/STW	WFD_IMP & EnvAct_IMP1			£3,990,487	£3,990,487	
BECKWITHSHAW/STW	WFD_IMP & EnvAct_IMP1			£4,196,103	£4,196,103	
BOLTON ON DEARNE/STW	WFD_IMP & EnvAct_IMP1			£9,024,831	£9,024,831	
BRANDESBURTON/STW	WFD_IMP		£1,163,082		£5,815,412	
	WFD_IMP & EnvAct_IMP1			£2,813,494		Phase 2 Mar 2030
	WFD_ND			£1,838,836		Phase 1 -Mar 2026

SITE/Scheme NAME	Driver Code	Ammonia-CAPEX	BOD -CAPEX	Phosphorus -CAPEX	Cost per site	COMMENT
BURLEY IN WHARFEDALE/STW	U_IMP2			£0	£4,902,069	U_IMP2 Superseded by WFD Limit
	WFD_ND			£4,902,069		
BURTON PIDSEA/STW	WFD_IMP	£1,416,763	£944,508		£2,361,271	
CARLTON HUSTHWAITE/STW	WFD_IMP & EnvAct_IMP1			£2,797,250	£2,797,250	
CARTHORPE/STW	WFD_IMP		£0		£0	No CAPEX required-Site will meet BOD
CAWTHORNE/STW	WFD_IMP & EnvAct_IMP1			£5,675,976	£5,675,976	
CHERRY BURTON/STW	WFD_IMP & EnvAct_IMP1			£3,014,922	£4,760,661	
	WFD_ND			£1,745,739		
CLAXTON/STW	WFD_IMP & EnvAct_IMP1			£2,973,380	£2,973,380	
COLBURN/STW	U_IMP2			£2,576,267	£2,576,267	
COLD HIENDLEY/STW	WFD_IMP & EnvAct_IMP1			£3,336,546	£5,469,747	Phase 2 Mar 2030
	WFD_ND			£2,133,201		Phase 1 -Mar 2026
CRANE MOOR/STW	WFD_IMP & EnvAct_IMP1			£5,129,851	£5,129,851	
CUDWORTH/NO 2 STW	EnvAct_IMP1			£7,117,056	£7,117,056	
	WFD_IMP			£0		Superseded by EnvAct_IMP1
DANBY WISKE/STW	WFD_IMP & EnvAct_IMP1			£3,319,811	£3,319,811	

SITE/Scheme NAME	Driver Code	Ammonia-CAPEX	BOD -CAPEX	Phosphorus -CAPEX	Cost per site	COMMENT
DANBY/STW	*25YEP_IMP & EnvAct_IMP1*			*((£4,796,315)*	*((£4,796,315))*	*Already included in Enhancement Case For 25 Year PLan*
DARFIELD/NO 2 STW	WFD_IMP & EnvAct_IMP1			£3,795,206	£3,795,206	
DARTON/STW	EnvAct_IMP1			£7,074,678	£7,074,678	
	WFD_IMP			£0		Superseded by EnvAct_IMP1
EASINGTON/STW	WFD_ND	£1,176,141		£1,176,141	£2,352,282	
EAST COWTON/STW	WFD_IMP	£1,002,081	£1,002,081		£5,010,404	
	WFD_IMP & EnvAct_IMP1			£3,006,242		
ELVINGTON/STW	HD_IMP & EnvAct_IMP1			£2,369,327	£2,369,327	
ESCRICK/STW	WFD_IMP & EnvAct_IMP1			£2,349,569	£2,349,569	
FARLINGTON/STW	WFD_IMP & EnvAct_IMP1			£2,299,006	£2,299,006	
FLAXTON/STW	WFD_IMP & EnvAct_IMP1			£5,097,107	£5,097,107	
GREAT SMEATON NO1/STW	WFD_IMP & EnvAct_IMP1			£3,332,481	£3,332,481	
HALIFAX COPLEY/STW	WFD_IMP	£0			£6,704,457	No CAPEX required-Superseded by WFD_ND
	WFD_ND	£6,704,457				
HAMBLETON/STW	EnvAct_IMP1			£7,038,035	£7,038,035	

SITE/Scheme NAME	Driver Code	Ammonia-CAPEX	BOD -CAPEX	Phosphorus -CAPEX	Cost per site	COMMENT
	WFD_IMP			£0		Superseded by EnvAct_IMP1
HARLEY/STW	WFD_IMP & EnvAct_IMP1			£2,509,487	£5,018,974	
	WFD_IMP	£2,509,487				
HARLINGTON/STW	EnvAct_IMP1			£9,308,004	£9,308,004	
	WFD_IMP			£0		Superseded by EnvAct_IMP1
HARROGATE NORTH/STW	U_IMP2			£0	£3,436,901	U_IMP2 Superseded By WFD Limit
	WFD_IMP & EnvAct_IMP1			£3,436,901		
HAXBY WALBUTTS/STW	WFD_IMP & EnvAct_IMP1			£8,112,177	£8,112,177	
HOLTBY/STW	WFD_IMP & EnvAct_IMP1			£3,214,787	£3,214,787	
HUNMANBY/STW	WFD_ND			£3,358,266	£3,358,266	
ILKLEY/STW	U_IMP2			£3,326,932	£3,326,932	
INGLEBY ARNCLIFFE/STW	WFD_IMP & EnvAct_IMP1			£3,447,183	£3,447,183	
KEYINGHAM/STW	WFD_IMP	£7,916,908	£3,392,961		£11,309,869	
KIRK HAMMERTON/STW	WFD_IMP & EnvAct_IMP1			£3,739,634	£3,739,634	
KIRKBY FLEETHAM/STW	WFD_ND	£474,727			£474,727	
KIRKBYMOORSIDE/STW	HD_IMP & EnvAct_IMP1			£3,350,290	£3,350,290	

SITE/Scheme NAME	Driver Code	Ammonia-CAPEX	BOD -CAPEX	Phosphorus -CAPEX	Cost per site	COMMENT
KIRKLINGTON/STW	WFD_ND			£1,265,002	£1,265,002	
KNARESBOROUGH/STW	U_IMP2			£0	£8,113,439	U_IMP2 Superseded by WFD Limit
	WFD_IMP & EnvAct_IMP1			£4,949,198		Phase 2 Mar 2030
	WFD_ND			£3,164,241		Phase 1 -Mar 2026
LECONFIELD/STW	WFD_IMP & EnvAct_IMP1			£3,603,396	£5,444,772	Phase 2 Mar 2030
	WFD_ND			£1,841,376		Phase 1 -Mar 2026
LEEMING BAR/STW	U_IMP2			£420,622	£420,622	
LEVEN/STW	WFD_IMP & EnvAct_IMP1			£2,670,103	£4,343,087	Phase 2 Mar 2030
	WFD_ND			£1,672,984		Phase 1 -Mar 2026
LEYBURN/STW	WFD_ND			£2,367,171	£2,367,171	
LONG MARSTON/STW	WFD_IMP & EnvAct_IMP1			£2,708,636	£2,708,636	
LONG RISTON NORTH/STW	WFD_IMP & EnvAct_IMP1			£2,604,030	£2,604,030	
LUNDWOOD/STW	WFD_IMP & EnvAct_IMP1			£7,467,387	£7,467,387	
MARKINGTON/STW	WFD_IMP		£1,195,618		£1,195,618	
MAUNBY/STW	WFD_IMP		£1,366,576		£4,555,254	Phase 2 Mar 2030

SITE/Scheme NAME	Driver Code	Ammonia-CAPEX	BOD -CAPEX	Phosphorus -CAPEX	Cost per site	COMMENT
	WFD_IMP & EnvAct_IMP1			£3,188,678		Phase 1 -Mar 2026
MICKLEFIELD/NO 2 STW	WFD_IMP & EnvAct_IMP1			£4,388,067	£4,388,067	
MIDDLETON TYAS/STW	WFD_ND	£0			£0	No CAPEX required
NAFFERTON/STW	WFD_ND			£2,480,576	£2,480,576	
NORTH COWTON/STW	WFD_IMP	£838,072	£838,072		£4,190,359	
	WFD_IMP & EnvAct_IMP1			£2,514,215		
NORTH DEIGHTON/STW	WFD_IMP & EnvAct_IMP1			£2,568,012	£2,568,012	
NORTHALLERTON/STW	WFD_IMP		£3,052,883		£10,176,276	
	WFD_IMP & EnvAct_IMP1			£7,123,393		
NOTTON VILLAGE/STW	WFD_IMP & EnvAct_IMP1			£3,824,920	£6,700,844	Phase 2 Mar 2030
	WFD_ND			£2,875,924		Phase 1 -Mar 2026
OTTRINGHAM/STW	WFD_IMP	£1,557,230	£1,557,230		£3,114,460	
PATELEY BRIDGE/STW	WFD_IMP & EnvAct_IMP1			£3,856,269	£3,856,269	
PATRINGTON/STW	WFD_IMP		£1,248,674		£2,497,348	
	WFD_ND	£1,248,674				
	U_IMP2			£0	£2,783,947	U_IMP2 Superseded by WFD Limit

SITE/Scheme NAME	Driver Code	Ammonia-CAPEX	BOD -CAPEX	Phosphorus -CAPEX	Cost per site	COMMENT
RAWCLIFFE YORK/STW	WFD_IMP & EnvAct_IMP1			£2,783,947		
ROOS/NO 2 STW	WFD_IMP	£677,380			£677,380	
RUFFORTH/STW	WFD_IMP & EnvAct_IMP1			£1,423,525	£2,333,647	Phase 2 Mar 2030
	WFD_ND			£910,122		Phase 1 -Mar 2026
SAND HUTTON/STW	WFD_IMP & EnvAct_IMP1			£1,211,551	£1,211,551	
SEAMER/STW	WFD_IMP	£5,218,579			£5,218,579	
SHERBURN IN ELMET/STW	WFD_ND		£2,812,559		£2,812,559	
SHIPTON/NO 2 STW	WFD_IMP & EnvAct_IMP1			£4,158,248	£4,158,248	
SILKSTONE/STW	WFD_IMP & EnvAct_IMP1			£5,058,054	£5,058,054	
SINDERBY/STW	WFD_IMP & EnvAct_IMP1			£1,899,219	£3,817,050	Phase 2 Mar 2030
	WFD_ND			£1,917,831		Phase 1 -Mar 2026
SKIPSEA/STW	WFD_IMP	£1,187,300	£1,187,300		£5,936,501	
	WFD_IMP & EnvAct_IMP1			£3,561,901		
STAPLETON PARK/STW	WFD_IMP & EnvAct_IMP1			£4,285,119	£4,285,119	

SITE/Scheme NAME	Driver Code	Ammonia-CAPEX	BOD -CAPEX	Phosphorus -CAPEX	Cost per site	COMMENT
SUTTON WHITESTONECLF/STW	WFD_IMP & EnvAct_IMP1			£3,190,343	£3,190,343	
TANKERSLEY/STW	WFD_IMP & EnvAct_IMP1			£4,276,565	£4,276,565	
TEMPLE NORMANTON/STW	WFD_IMP & EnvAct_IMP1			£3,574,255	£3,574,255	
THORP ARCH/STW	U_IMP2			£420,622	£420,622	
TOCKWITH/STW	WFD_IMP & EnvAct_IMP1			£3,247,142	£3,247,142	
TUPTON/STW	WFD_IMP	£2,991,400			£2,991,400	
WARTHILL/STW	WFD_IMP & EnvAct_IMP1			£2,414,821	£2,414,821	
WATH ON DEARNE/STW	EnvAct_IMP1			£6,883,431	£6,883,431	
	WFD_IMP			£0		Superseded by EnvAct_IMP1
WATTON/STW	WFD_ND			£2,704,211	£2,704,211	
WENTWORTH/STW	WFD_IMP	£2,613,965			£5,227,930	
	WFD_IMP & EnvAct_IMP1			£2,613,965		
WEST ROUNTON/STW	WFD_IMP		£986,838		£4,934,191	
	WFD_IMP & EnvAct_IMP1			£3,947,353		
WETHERBY/STW	U_IMP2			£420,622	£420,622	

SITE/Scheme NAME	Driver Code	Ammonia-CAPEX	BOD -CAPEX	Phosphorus -CAPEX	Cost per site	COMMENT
WHELDRAKE/STW	HD_IMP & EnvAct_IMP1			£2,245,097	£2,245,097	
WILLIAMTHORPE/STW	WFD_IMP & EnvAct_IMP1			£4,552,287	£4,552,287	
WITHERNWICK/STW	WFD_IMP & EnvAct_IMP1			£3,941,584	£3,941,584	
WOMBWELL/STW	WFD_IMP & EnvAct_IMP1			£5,043,189	£5,043,189	
WOODALL/STW	WFD_IMP & EnvAct_IMP1			£2,531,231	£2,531,231	
WOOLLEY VILLAGE/STW	WFD_IMP & EnvAct_IMP1			£2,694,711	£4,843,455	Phase 2 Mar 2030
	WFD_ND			£2,148,744		Phase 1 -Mar 2026
WORSBROUGH/STW	WFD_IMP & EnvAct_IMP1			£4,277,834	£4,277,834	
YEARSLEY/STW	WFD_IMP & EnvAct_IMP1			£3,171,152	£3,171,152	
YORK NABURN/STW	U_IMP2			£0	£12,363,908	U_IMP2 Superseded by WFD Limit
	WFD_IMP & EnvAct_IMP1			£12,363,908		
Grand Total					**£397,371,241**	

E. Annexes for Schemes to make the recycling of sludge to land more robust

E1. National Landbank Assessment Report

National Landbank Assessment

Project report by Grieve Strategic

in association with RSK ADAS

Executive Summary

1. The modelling for this study was undertaken in three parts:
   - The initial phase calculated the available land accounting for legislative and physical restrictions and competition from other organic manures;
   - The second phase calculated the available land and landbank required modelled on STC outputs and product information provided by the water industry; and
   - The third phase used data from the water companies based on the original WINEP submissions to understand the affect these planned changes would have on the available land and landbank required.
2. Five different scenarios (historic, baseline and 3 projected future pathways) based on the PR24 WINEP drivers were developed and modelled to understand the effect of increasingly stringent environmental restrictions on the agricultural landbank. These were modelled using an updated version of the ALOWANCE GIS modelling tool with current Sludge Treatment Centre (STC) configuration and treatment processes and possible future configurations.
3. For scenarios 1 – 3 there is sufficient available agricultural land to enable 100% of British biosolids to be recycled. For scenarios 4 and 5 there is insufficient available agricultural land to enable 100% of British biosolids to be recycled, with at least two thirds of biosolids under scenario 4 requiring another outlet.
4. The key factors which result in the increase in landbank required (between scenario 3 and scenarios 4 and 5) are a ban on applications in the late summer/autumn to winter cereals and increased restrictions on phosphate applications.
5. Data provided by the WaSCs on their original WINEP submissions show there would be a reduction in the haulage distance (and therefore landbank required). However, this reduction would not be sufficient as 60% of biosolids (based on submission for the end of AMP8) or 35% of biosolids (based on submissions for the end of AMP9) would require an alternative outlet.
6. This modelling highlights the effect the EA's interpretation of the Farming Rules for Water (particularly associated with recycling in the autumn and phosphate management) can have on recycling organic manures (including biosolids). Given the implications for the water industry as well as other producers of organic manures (e.g. livestock farmers, anaerobic digestion facilities) there is a need for coordinated planning at a national scale to manage reductions in and competition for available landbank and to enable the development of alternative outlets (if required). Without this there cannot be efficient and timely management of what is a national issue.

7. It is vital conversations continue between the various affected parties and regulators/policy makers, particularly as there are not currently 'ready made' alternatives for how biosolids (or other organic manures) can be managed to prevent these issues (without incineration). Initiatives like the Long-term Bioresources Strategy are key in allowing all parties to be involved in the conversation and in delivering viable sustainable solutions.

Summary of landbank modelling by scenario

Data	S1	S2	S3	S4	S4 AMP8	S4 AMP9	S5
Amount to land (tds)	881,700	972,500	1,056,000	1,138,600	1,039,900	813,100	1,186,700
Landbank required (ha)	488,300	994,600	1,235,900	5,562,400	4,860,100	3,352,800	12,012,200
Landbank available (ha)	4,781,000	2,958,000	2,688,500	2,407,000	2,407,000	2,407,000	1,745,000
Average return period	1.3	2.2	2.3	8.2	8.4	8.7	14.5
Maximum distance to access suitable landbank (km)	57	71	82	425	425	261	>500

Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

1. Table of Contents

1. Introduction

1.1 Background

The eleven British water and sewage companies (WaSCs) commissioned Grieve Strategic (in conjunction with RSK ADAS) to undertake a landbank assessment to support long-term biosolids management and the identification of risks and issues as part of the current Price Review (PR24) planning process, including the Water Industry National Environment Programme (WINEP).

The most recently representative data available at the time this work began suggests approximately 3.6 million tonnes (c. 90%) of sewage sludge per annum is recycled to agricultural land. Therefore maintaining a sustainable agricultural landbank to be able to recycle biosolids is strategically important for all WaSCs. Any changes to the total amount of sludge produced, the type of treatment process used, or any of the external factors (e.g. regulations governing biosolids recycling, changes in livestock numbers, etc.) will likely affect how far or even if there is sufficient agricultural land to recycle biosolids.

Grieve Strategic in association with RSK ADAS undertake landbank assessments for a range of commercial clients (including all eleven WaSCs previously) who want to understand the landbank available and the landbank required by their operations based on various scenarios. The landbank assessment makes use of Geographic Information Systems (GIS) and the ALOWANCE software tool (originally developed for the Department of the Environment, Food and Rural Affairs – Defra). The software has been updated extensively over the years in terms of the data it uses e.g. the Agricultural Survey, updated legislations (e.g. NVZ areas and Water Resources Regulations) and livestock nitrogen (N) production standards, the inclusion of information on 'competing' non-farm organic material quantities (i.e. biosolids, compost, digestate, paper crumble) and the algorithms used to calculate landbank required and therefore maximum haulage distances.

This National Landbank Study for the eleven British WaSCs aims to support the identification of risks and issues as part of stage 2 of the PR24 WINEP process. It will also inform WaSCs WINEP resilience assessment and plans for PR24 and beyond including investigating and quantifying the effects of unprecedented uncertainty surrounding the regulations governing the recycling of organic manures to agricultural land. This approach fits with Ofwat's favoured approach of minimising expenditure until absolutely necessary while maintaining resilience. Moreover, although Ofwat's key parameters (climate change, technology, population and environmental ambition) appear not to apply to bioresources, these and other factors have been considered when evaluating the landbank assessments.

1.2 Landbank pressures

In terms of pressure on landbank, there are a wide range of factors that could and do affect the amount of agricultural landbank available for biosolids recycling. The regulatory environment has and continues to be subject to change, which can create uncertainty and pressure on the landbank. The regulations governing the recycling of biosolids to agricultural land are under review and there has and continues to be significant discussion concerning the Farming Rules for Water (FRfW) regulations. Although the introduction of Statutory Guidance in relation to the FRfW appears to have abated concerns, there is still uncertainty around certain requirements and what may happen in the future. Phosphate management is likely to continue to come under renewed focus probably leading to a tightening of rules beyond what is currently allowed under the Biosolids Nutrient Management Matrix and even in terms of nitrogen management (e.g. autumn applications). Moreover, the exact form of the EA Sludge Strategy is still being decided, but it is likely to have a significant impact on the process, logistics and operations associated with the recycling of biosolids to agricultural land as well as other potential threats (including poly- and perfluoroalkyl substances (PFAS), microplastics and antimicrobial resistance).

There are a range of other factors that can or could come to affect biosolids recycling that cannot fully be included in the landbank modelling. These factors (including climate change, farm subsidy changes, nutrient neutrality) are considered qualitatively in Section 5 of this report and need to be kept under review as they could have a significant affect on agricultural landbank availability.

2. Methodology

The quantitative landbank assessment was undertaken using the ALOWANCE software tool in conjunction with Graphical Information System (GIS) to produce a spatial and graphical estimates of current and future landbank availability under various scenarios (i.e. possible future biosolids quantities and properties, and increasingly stringent environmental restrictions). The landbank assessment is composed of two key parameters; the land available and the land required. The combination of these outputs from the quantitative modelling are in the form of maps and tables, which covers all of Britain.

2.1 Available agricultural land

The agricultural landbank is calculated using data from the Agricultural Survey, which is then reduced to account for ALOWANCE restrictions (e.g. legislative and physical restrictions including topography, watercourses, Groundwater Source Protection Zones, Environmentally Sensitive Areas, Sites of Special Scientific Interest, National Nature Reserves, Nitrate Vulnerable Zone (NVZ) restrictions, account is taken of the nutrients supplied by livestock manures (whether directly deposited or managed) and organic manures (e.g. anaerobic digestate, compost, paper crumble), organically managed farmland, soil pH, and soil heavy metal concentrations), the exclusion of ready to eat crops and peas/beans and a voluntary odour buffer zone of 50 metres (from urban areas). Finally, the rotational exclusions (e.g. those specified by the whisky distilling industry which stipulate that biosolids must not be applied within crop rotations including malting barley) further reduce the remaining landbank to give the amount of available land. The available agricultural land can be further reduced by a tightening of the restrictions, particularly the environmental and legislative controls, some of which are included in the later scenarios.

2.2 Landbank required

The landbank requirement was modelled and estimated using STC output and product information provided by the water industry. To assess the landbank requirement for each WaSC it was necessary to assess the probable acceptability of biosolids products on farm, the application rate and the minimum frequency of return to land (amongst other considerations particularly for later scenarios).

The rotational landbank requirement was calculated based on the Biosolids Nutrient Management Matrix return periods (Table 1) (including information on cross compliance soil types and soil P Index), along with estimates on biosolids acceptability (depending on product type) and application rate (225 kg N/ha giving a mean rate of c.5 tds/ha). For the avoidance of doubt, the rotational landbank will be larger than the area that would be required each year based on limitations on frequency of application. The required agricultural land can be further increased by a tightening of the restrictions, particularly an increase in the phosphate return period and a reduction in farmer acceptance (e.g. as per the later scenarios).

Table 1. Biosolids Nutrient Management Matrix

ADAS soil P Index	Maximum potential application of ***lime stabilised biosolids*** [a]	Maximum potential application of ***all other biosolids* types**
0/1/2	250kg/ha total N in any twelve month period	250kg/ha total N in any twelve month period
3	250 kg/ha total N in any twelve month period – application 1 year in 4 on sandy soils and 1 year in 2 on all other soils	250 kg/ha total N in any twelve month period – application 1 year in 2 on sandy soils [b]
4	250 kg/ha total N in any twelve month period – application 1 year in 5 on sandy soils and 1 year in 3 on all other soils	250 kg/ha total N in any twelve month period – application 1 year in 4 on sandy soils [c] and 1 year in 3 on all other soils
5 and above	No application	No application

[a] Lime addition rate >5% w/w on a dry solids basis

[b] Composted biosolids can be applied annually and

[c] Can be applied 1 year in 2

Notes:

- Soil extractable P analysis must be less than 5 years old (0-15cm soil sampling depth on arable land; 0-7.5cm on grass).
- Soil types based on Cross Compliance soil categories.
- No biosolids applications directly in front of legumes (e.g. peas, beans), except for composted biosolids which is very low in readily available N.
- Septic tank sludge is not included within the scope of the Matrix.

The landbank availability maps represent the theoretical maximum distance (to the nearest 1 km) to access both suitable and sufficient agricultural land for recycling biosolids from that site. In this study the model used straight line distances (i.e. as the crow flies) to calculate the maximum distance to reach the required landbank. Where STC 'radials' overlap a bespoke merging process allows the radials to fairly represent the landbank requirement for each STC, however, only STCs from an individual WaSC could merge (i.e. the three combined Anglian Water sites can merge to form one 'radial', but they cannot merge with the radial rings created by their neighbouring WaSCs).

2.3 Modelling methodology

2.3.1 Landbank available

The modelling was undertaken using an updated and enhanced version of the ALOWANCE tool, which was originally developed for Defra to calculate how much agricultural land was available to recycle additional organic manures. The ALOWANCE tool calculates the available agricultural land after account for a wide range of factors which can limit it including:

- Physical and topographic restrictions (e.g. steep slopes, distances from watercourses, springs etc.).
- Excluded land/restrictions on applications (e.g. Source Protection Zones, Sites of Special Scientific Interest, organically farmed land, etc.).
- Restrictions on soils with low pH, elevated PTEs or elevated phosphorus.
- Land utilised by deposited or managed livestock manures.
- Land utilised by non-farm organic manures (e.g. composts, digestates, paper crumble etc.).
- Land utilised by 'sensitive' crops (e.g. ready to eat or legumes) or outdoor pigs.

The ALOWANCE tool has been updated with new datasets and to cover additional areas as well considering rotational exclusion clauses (such as malting barley) as well as odour buffers surrounding sensitive receptors.

2.3.2 Landbank required

A theoretical STC producing 10,000 TDS of biosolids with a nitrogen content of 4.3%, applied at the maximum application rate (i.e. 250 kilograms total nitrogen per hectare – kgN/ha) would need 1,720 hectares. However, this is an annual figure (i.e. the annual landbank required) and does not account for other factors including:

- Phosphate – the return period depends on the phosphorus index and soil type and the biosolids type and it is not always annual.
- Farmer acceptance – not all farmers will want or can have biosolids due to a wide range of factors (e.g. concerns over contaminants, bad experience, objection in principle, negative affect of operations, crop rotation, access, small fields/farm size, unwilling to pay).

Including the above gives a rotational landbank requirement, for example, a theoretical STC producing 10,000 TDS of biosolids with a nitrogen content of 4.3% applied at 240 kgN/ha is 1,800 hectares. Accounting for farmer acceptance at 40% (a standard figure for conventionally treated anaerobically digested biosolids) increasing this to c.4,500 hectares. Accounting for phosphorus restrictions (assuming a typical soil and typical digested biosolids) using the Biosolids Nutrient Management Matrix increasing this further to c.5,700 hectares. If this is multiplied up for the approximately 850,000 TDS of biosolids produced in Britain gives an annual landbank requirement of 150,000 hectares or a rotational landbank of c.480,000 hectares.

2.4 Landbank scenarios

A range of increasingly stringent landbank scenarios were modelled based on the Price Review 2024 (PR24) Water Industry National Environment Programme (WINEP) drivers, as outlined below. The scenarios outlined below (and detailed in full in Appendix I) include increasingly stringent restrictions including an interpretation of the Farming Rules for Water (FRfW), agricultural demand for biosolids, physical restrictions, farmer acceptance and increased sludge production and changed biosolids properties. These scenarios were shared with the Environment Agency prior to the modelling to garner their feedback, which was included in the final scenarios used during the modelling.

Scenario 1: Historic 2020 pre-FRfW – business as usual: existing sludge production volumes and regulatory controls (i.e. current BAS restrictions and Sludge (Use in Agriculture) Regulations).

Scenario 2: Baseline (post FRfW) – minimal restrictions: increased sludge volumes and properties, restrictions in line with the initial 20 Measures (as per the water industry initiative in response to the FRfW, including increased restrictions on autumn applications (e.g. shallower/lighter soils), slight increase in restrictions in sensitive catchments and near sensitive sites and in SPZ2, and no application at P index 4 and above).

Scenario 3: AMP8 low change – modest restrictions: increased sludge volumes and properties, slightly increased restrictions on phosphate additions (e.g. no application at P index 4 and above, and matching offtakes at P index 3), reduced farmer acceptance (to model concerns over contaminants (e.g. PFAS and microplastics) or regulatory uncertainties) and restrictions in line with the 20 measure (as above).

Scenario 4: AMP8 medium change – significant restrictions: increased sludge volumes and properties, increased restrictions on phosphate additions (e.g. no applications at P index 4 and above, and matching offtakes at P index 2 and 3), further reduced farmer acceptance (to model concerns over contaminants (e.g. PFAS and microplastics) and regulatory uncertainty), restrictions in line with the 20 measures (as above) and no autumn applications (except ahead of OSR and grass), significant reduction in demand for biosolids on grassland (to model a ban on conventionally treated biosolids and longer no-graze/harvest periods for enhanced treated biosolids), and a moderate increase in restrictions in sensitive catchments and near sensitive sites and in SPZ2.

Scenario 5: AMP8 high change – plausible worst-case: increased sludge volumes and properties, increased restrictions on phosphate additions (e.g. no applications at P index 4 and above, and matching P to crop offtakes), limited farmer acceptance (to model concerns over contaminants (e.g. PFAS and microplastics) and regulatory uncertainty), restrictions in line with the 20 measures (as above) and no applications in sensitive catchments, no applications within 500m of sensitive sites or within SPZ2, reduced application rates (as a result of concerns over nitrate leaching) and restrictions on applications to grassland.

3. Phase I: Available land

Phase I involved determining the landbank available after accounting for the legislative and physical restrictions and competition from other organic manures as in Section 2.1. The legislative restrictions also include the restrictions that affect available land across each of the five scenarios as detailed in Section 2.3.

Figure 1 shows the historic available agricultural land totalling c.4.6 million hectares of land of which c.1.5 million hectares is arable and c.3.1 million hectares is grass.

Figure 2 shows the baseline available agricultural land totalling c.2.8 million hectares of land of which c.1.3 million hectares is arable and c.1.5 million hectares is grass.

Figure 3 shows the AMP8 low change available agricultural land totalling c.2.5 million hectares of land of which c.1.2 million hectares is arable and c.1.3 million hectares is grass.

Figure 4 shows the AMP8 medium change available agricultural land totalling c.2.3 million hectares of land of which c.1.1 million hectares is arable and c.1.2 million hectares is grass.

Figure 5 shows the AMP8 high change available agricultural land totalling c.1.7 million hectares of land of which c.0.8 million hectares is arable and c.0.9 million hectares is grass.

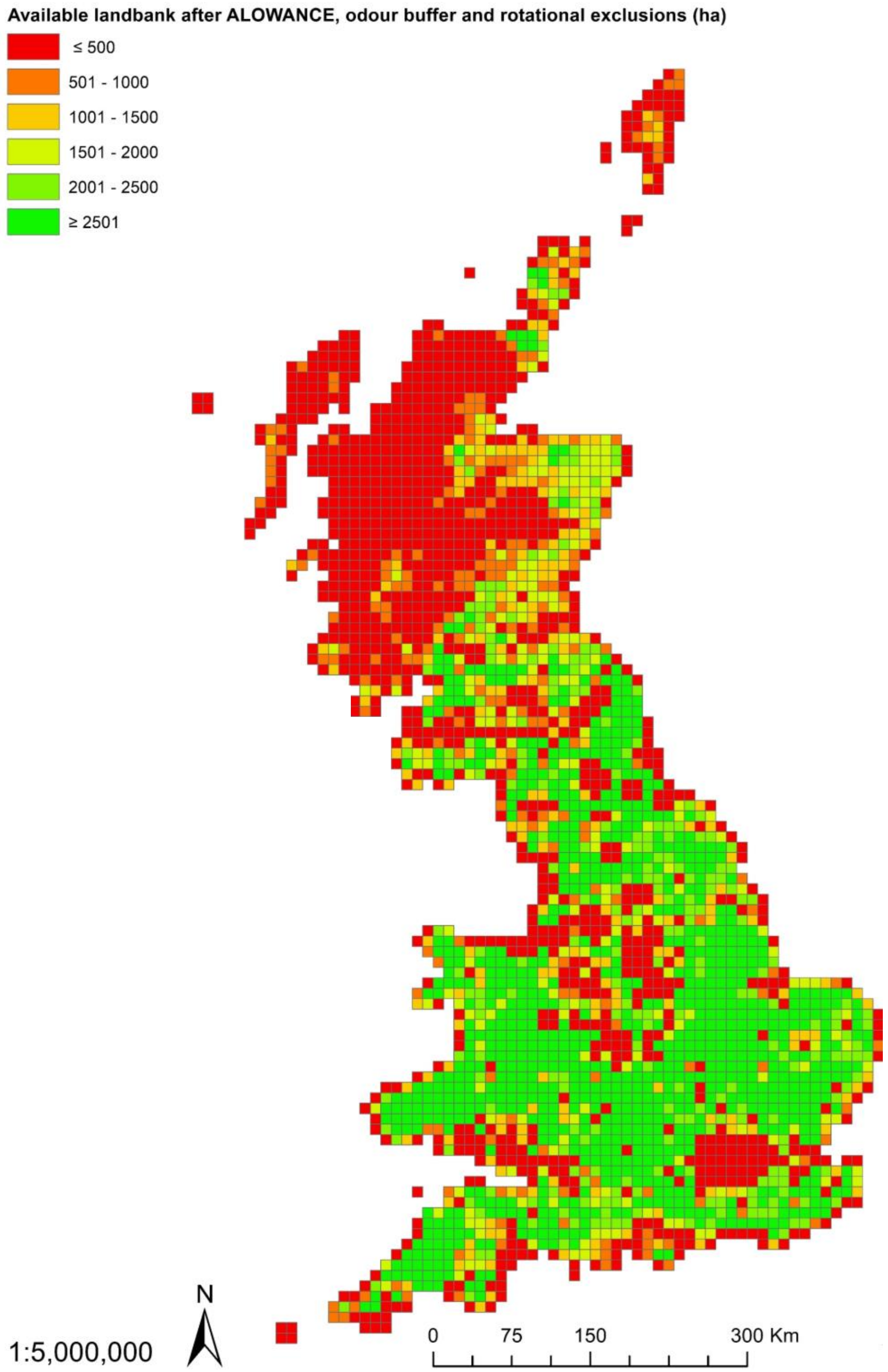

Figure 1. Scenario 1 baseline available land based on historical data

Note Landbank availability – each square = 10,000 hectares (red 2,500)

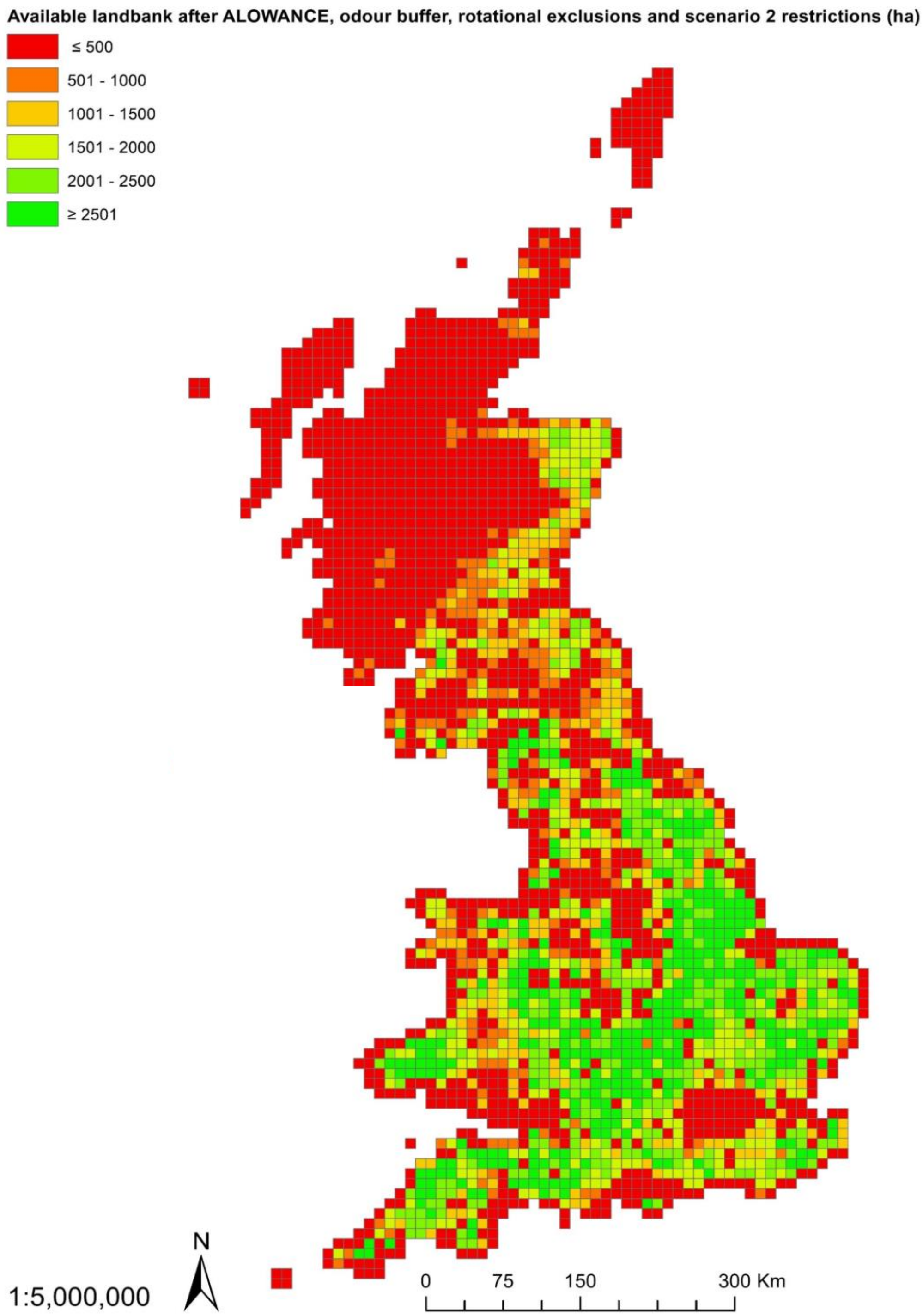

Figure 2. Scenario 2 current: available land

Note Landbank availability – each square = 10,000 hectares (red 2,500)

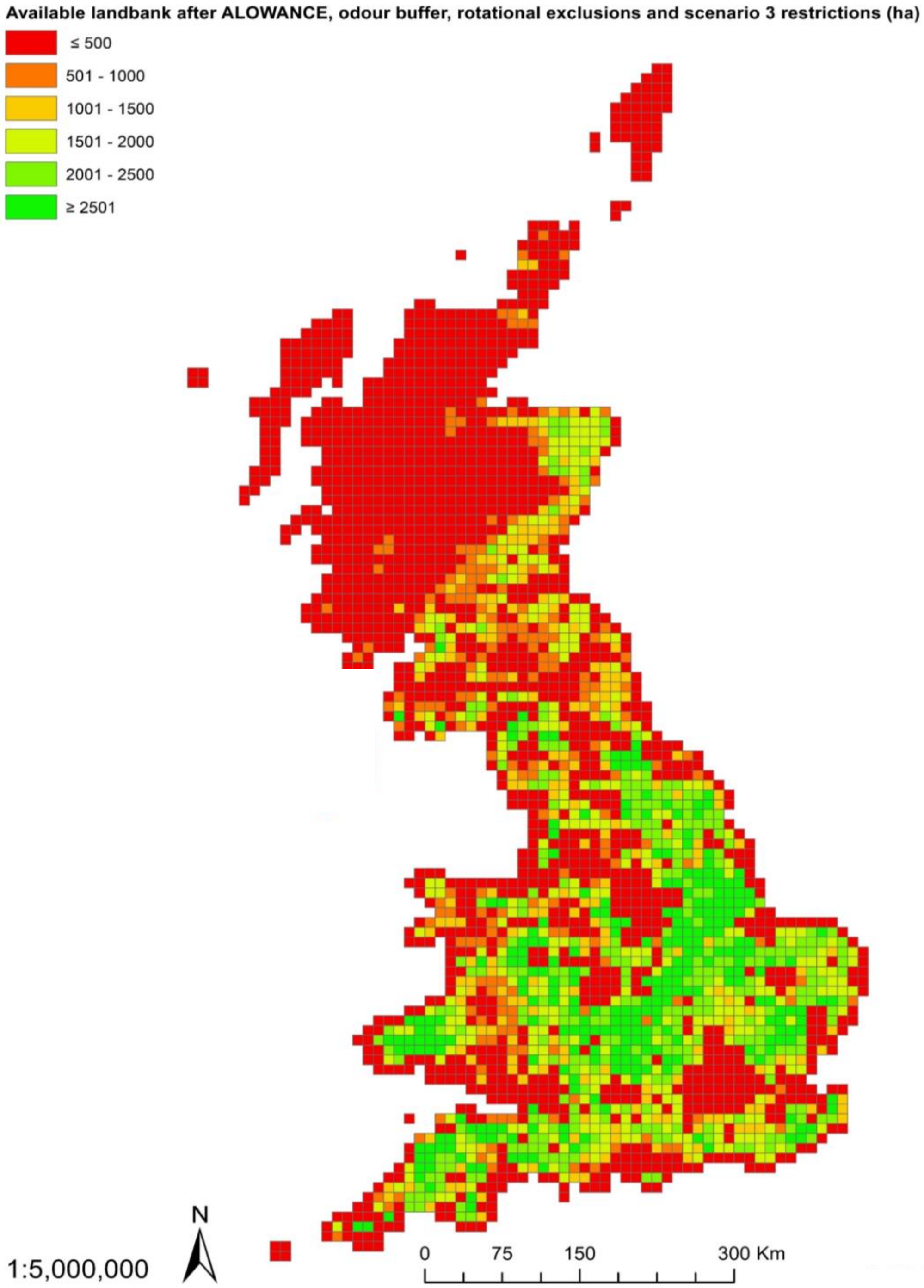

Figure 3. Scenario 3 minimal change: available land

Note Landbank availability – each square = 10,000 hectares (red 2,500)

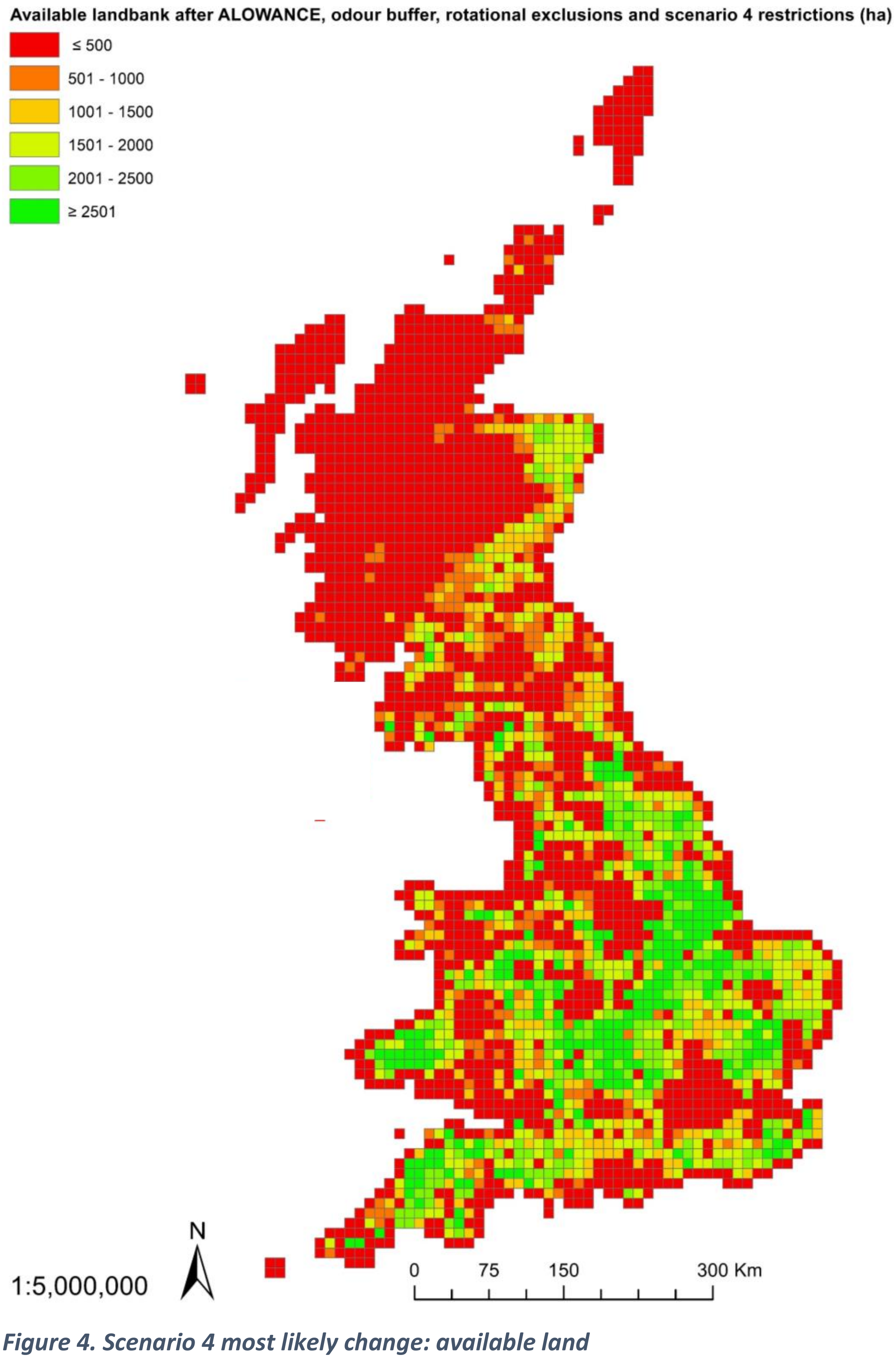

Figure 4. Scenario 4 most likely change: available land

Note Landbank availability – each square = 10,000 hectares (red 2,500)

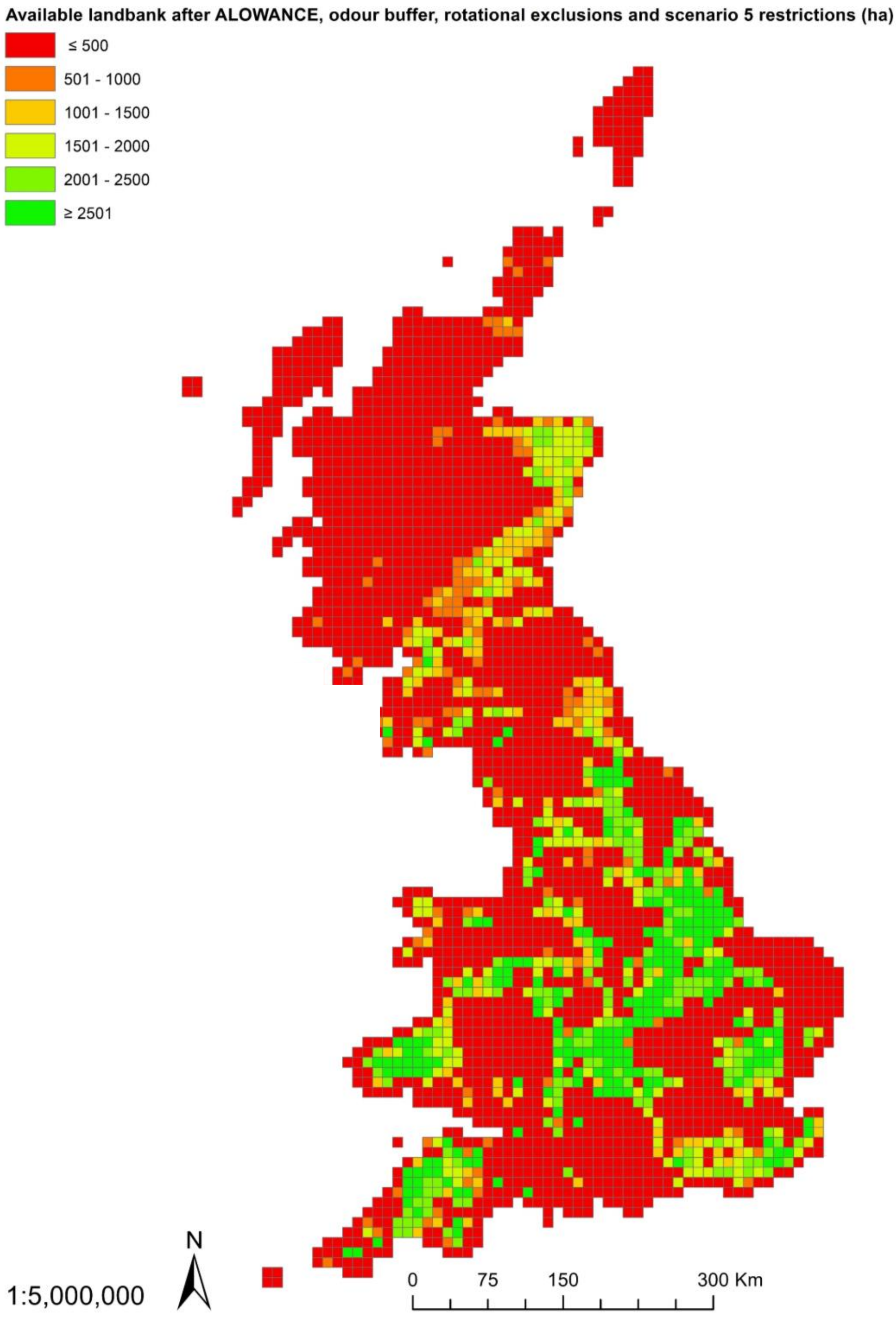

Figure 5. Scenario 5 maximum change: available land

Note Landbank availability – each square = 10,000 hectares (red 2,500)

The results for the five landbank scenarios are shown in Table 2 and Figure 6 below.

Table 2 Available land for each scenario in hectares

	Scenario 1 – historic	Scenario 2 – baseline (post FRfW)	Scenario 3 – AMP8 low change	Scenario 4 – AMP8 medium change	Scenario 5 – AMP8 high change
Total[1]	4,595,000	2,796,000	2,527,000	2,339,000	1,697,000
Arable[1]	1,453,000	1,300,000	1,165,000	1,098,000	783,000
Grass[1]	3,142,000	1,496,000	1,363,000	1,242,000	914,000

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

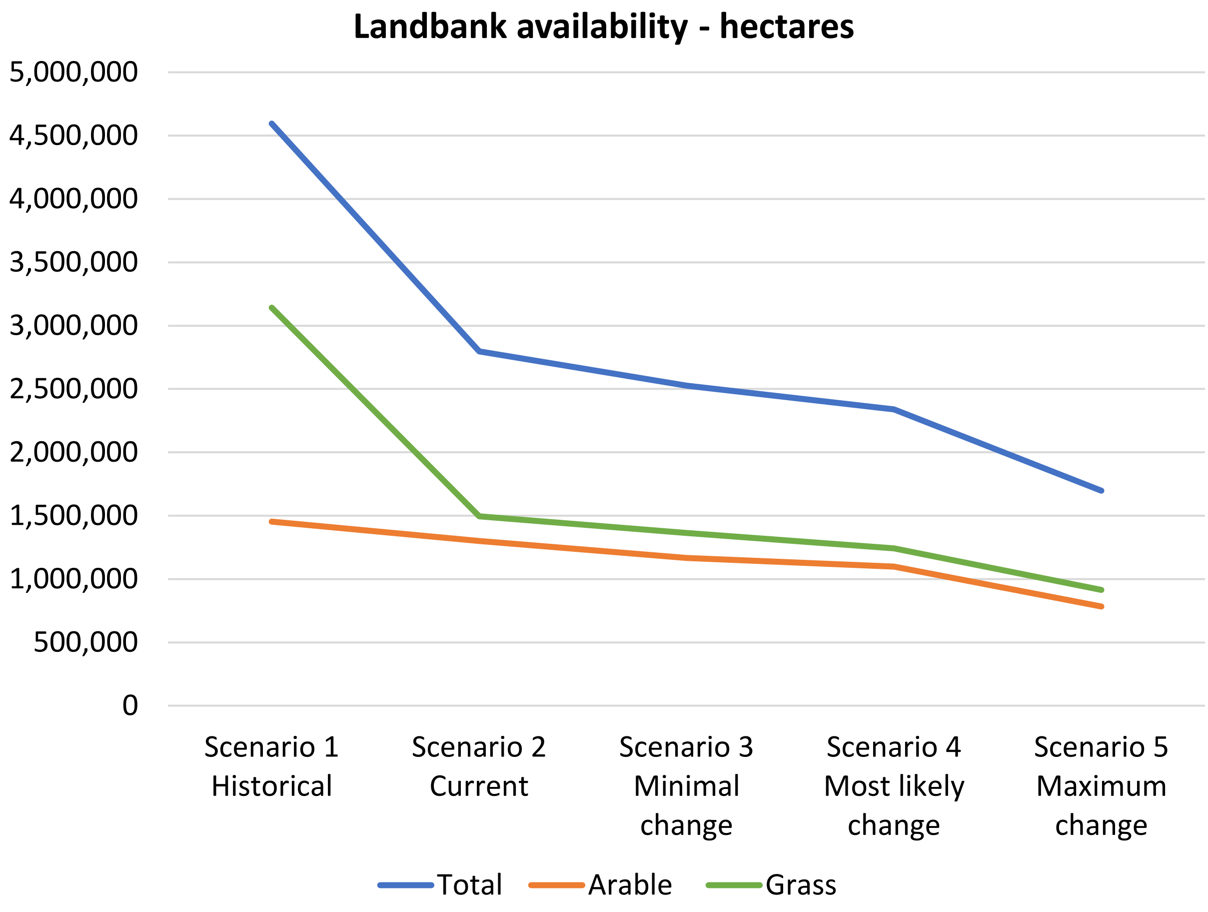

Figure 6. Landbank availability graph for Total land, arable and grassland

The effect of the FRfW 20 measures (as well as reduction in farmer acceptance and increase in sludge volume and properties) is shown by the difference between the historic (S1) and baseline (S2) scenarios i.e. a reduction in available land of c.40% (from c.4.6 million to c.2.8 million hectares). The changes in available land thereafter are not as significant (the change between scenario 2 and scenario 5 is a total of c.1 million hectares). However, this likely an under representation as many of the restrictions in the later scenarios affect the landbank required much more significantly than the available land.

4. Phase II

4.1 Landbank scenarios

Phase II builds on phase I, but in addition to considering the effect on the available landbank it includes consideration of the quantity of biosolids recycled and importantly the properties of those biosolids i.e. the landbank required (see Section 2.2).

Due to the time constraints associated with the PR24 WINEP process, it was not possible to model each STC within each company, so sites were combined into a maximum of three locations. The company level information is summarised in the tables below, specifically:

- Scenario 1 – Historic: Table 3
- Scenario 2 – Baseline (post FRfW): Table 4
- Scenario 3 – AMP8 low change: Table 5
- Scenario 4 – AMP8 medium change: Table 6
- Scenario 5 – AMP9 high change: Table 7

Table 3. STC outputs and product properties: scenario 1 – historic

Company	Total to land (TDS)[1]	Average nitrogen content (%)	Average phosphate content (%)
Anglian Water	90,400	4.9	6.1
Dwr Cymru	42,500	4.5	5.0
Northumbrian Water	27,200	4.5	5.0
Severn Trent	139,500	4.7	7.9
Scottish Water	68,500	4.8	6.9
Southern Water	59,700	4.9	6.4
South West Water	48,200	4.0	2.2
Thames Water	166,200	4.4	7.1
United Utilities	109,500	3.9	5.8
Wessex Water	42,600	5.0	4.1
Yorkshire Water	87,400	4.9	6.0
Total	**881,700**	**-**	**-**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

Table 4. STC outputs and product properties: scenario 2 – baseline

Company	Total to land (TDS)[1]	Average nitrogen content (%)	Average phosphate content (%)
Anglian Water	97,100	5.1	6.9
Dwr Cymru	46,800	4.5	5.5
Northumbrian Water	29,900	4.5	4.5
Severn Trent	153,500	4.7	8.7
Scottish Water	74,200	4.8	7.3
Southern Water	65,600	4.9	7.0
South West Water	53,000	4.0	2.4
Thames Water	182,800	4.4	7.8
United Utilities	126,600	3.9	6.5
Wessex Water	46,900	5.0	4.5
Yorkshire Water	96,100	4.9	6.6
Total	**972,500**	-	-

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

Table 5. STC outputs and product properties: scenario 3 – AMP8 low change

Company	Total to land (TDS)[1]	Average nitrogen content (%)	Average phosphate content (%)
Anglian Water	103,000	5.1	7.2
Dwr Cymru	51,000	4.5	6.0
Northumbrian Water	32,600	4.5	4.9
Severn Trent	167,400	4.7	9.5
Scottish Water	76,800	4.8	8.6
Southern Water	71,600	4.9	7.6
South West Water	57,900	4.0	2.6
Thames Water	199,400	4.4	8.5
United Utilities	140,300	3.9	7.6
Wessex Water	51,200	5.0	4.9
Yorkshire Water	104,800	4.9	7.2
Total	**1,056,000**	-	-

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

Table 6. STC outputs and product properties: scenario 4 – AMP8 medium change

Company	Total to land (TDS)[1]	Average nitrogen content (%)	Average phosphate content (%)
Anglian Water	110,000	5.1	7.5
Dwr Cymru	55,300	4.5	7.0
Northumbrian Water	35,300	4.5	5.7
Severn Trent	181,400	4.7	11.1
Scottish Water	75,400	4.8	10.2
Southern Water	77,600	4.9	8.9
South West Water	62,700	4.0	3.0
Thames Water	216,600	4.4	10.0
United Utilities	155,300	3.9	10.3
Wessex Water	55,400	5.0	5.7
Yorkshire Water	113,600	4.9	8.4
Total	**1,138,600**	-	-

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

Table 7. STC outputs and product properties: scenario 5 – AMP8 high change

Company	Total to land (TDS)[1]	Average nitrogen content (%)	Average phosphate content (%)
Anglian Water	113,100	5.1	7.5
Dwr Cymru	57,400	4.5	7.5
Northumbrian Water	36,700	4.5	6.2
Severn Trent	188,400	4.7	11.9
Scottish Water	84,500	4.8	11.5
Southern Water	80,500	4.9	9.6
South West Water	65,100	4.0	3.2
Thames Water	224,400	4.4	10.7
United Utilities	161,100	3.9	11.0
Wessex Water	57,600	5.0	6.1
Yorkshire Water	117,900	4.9	9.0
Total	**1,186,700**	-	-

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

4.2 Rotational landbank

The rotational landbank required in hectares for each combined STC was calculated using the methodology described in the earlier section. To ensure the model was as accurate as possible for each WaSC, the amount of biosolids that could be applied to the grass landbank was restricted based on data supplied by each company. The landbank maps represent the theoretical maximum distance (to the nearest 1 km) to access both suitable and sufficient agricultural land for recycling biosolids from that site.

The results for five landbank scenarios are shown below:

Table 8 and Figure 7: scenario 1.

Table 8. Rotational landbank required for each combined STC (scenario 1)

Company	**Total to land (TDS)[1]**	**Acceptance**	**Hectares[1]**
Anglian Water	90,400	30%	94,300
Dwr Cymru	42,500	60%	13,800
Northumbrian Water	27,200	60%	9,200
Severn Trent	139,500	40%	89,000
Scottish Water[2]	68,500	56%	34,500
Southern Water	59,700	45%	33,800
South West Water	48,200	37%	26,100
Thames Water	166,200	64%	66,100
United Utilities[2]	109,500	51%	44,700
Wessex Water	42,600	37%	29,500
Yorkshire Water	87,400	45%	47,300
Total	**881,700**	**-**	**488,300**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Acceptance figures have been averaged.

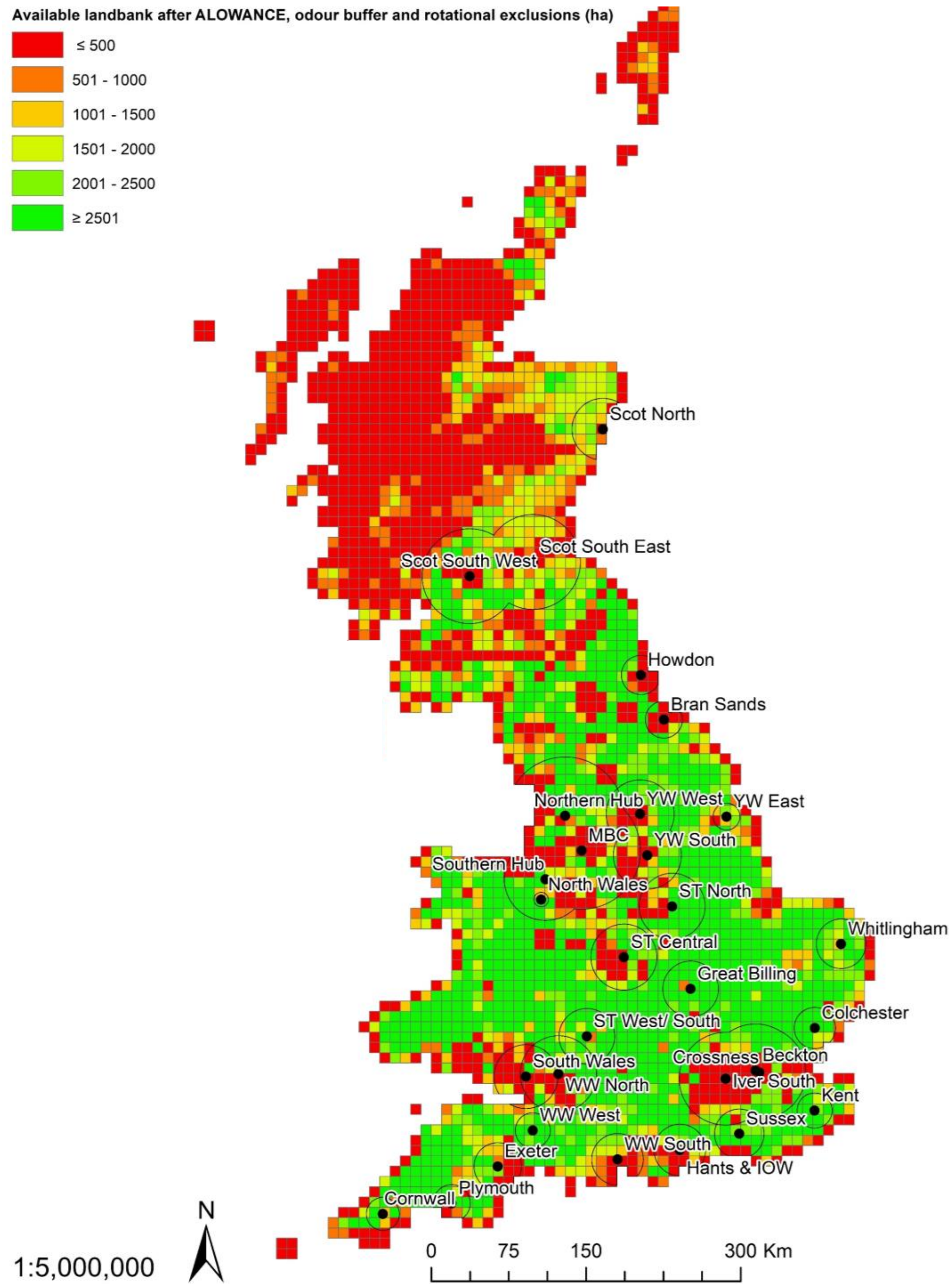

Figure 7. Scenario 1 baseline STC configuration.

Table 9 and Figure 8: scenario 2.

Table 9. Rotational landbank required for each combined STC (scenario 2)

Company	Total to land (TDS)[1]	Acceptance (%)	Hectares[1]
Anglian Water	97,100	29%	213,400
Dwr Cymru	46,800	57%	20,900
Northumbrian Water	29,900	57%	13,300
Severn Trent	153,500	38%	177,800
Scottish Water[2]	74,200	54%	66,600
Southern Water	65,600	43%	76,000
South West Water	53,000	35%	40,600
Thames Water[2]	182,800	60%	143,700
United Utilities[2]	126,600	49%	88,300
Wessex Water	46,900	35%	60,600
Yorkshire Water	96,100	43%	93,400
Total	**972,500**	**-**	**994,600**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Acceptance figures have been averaged.

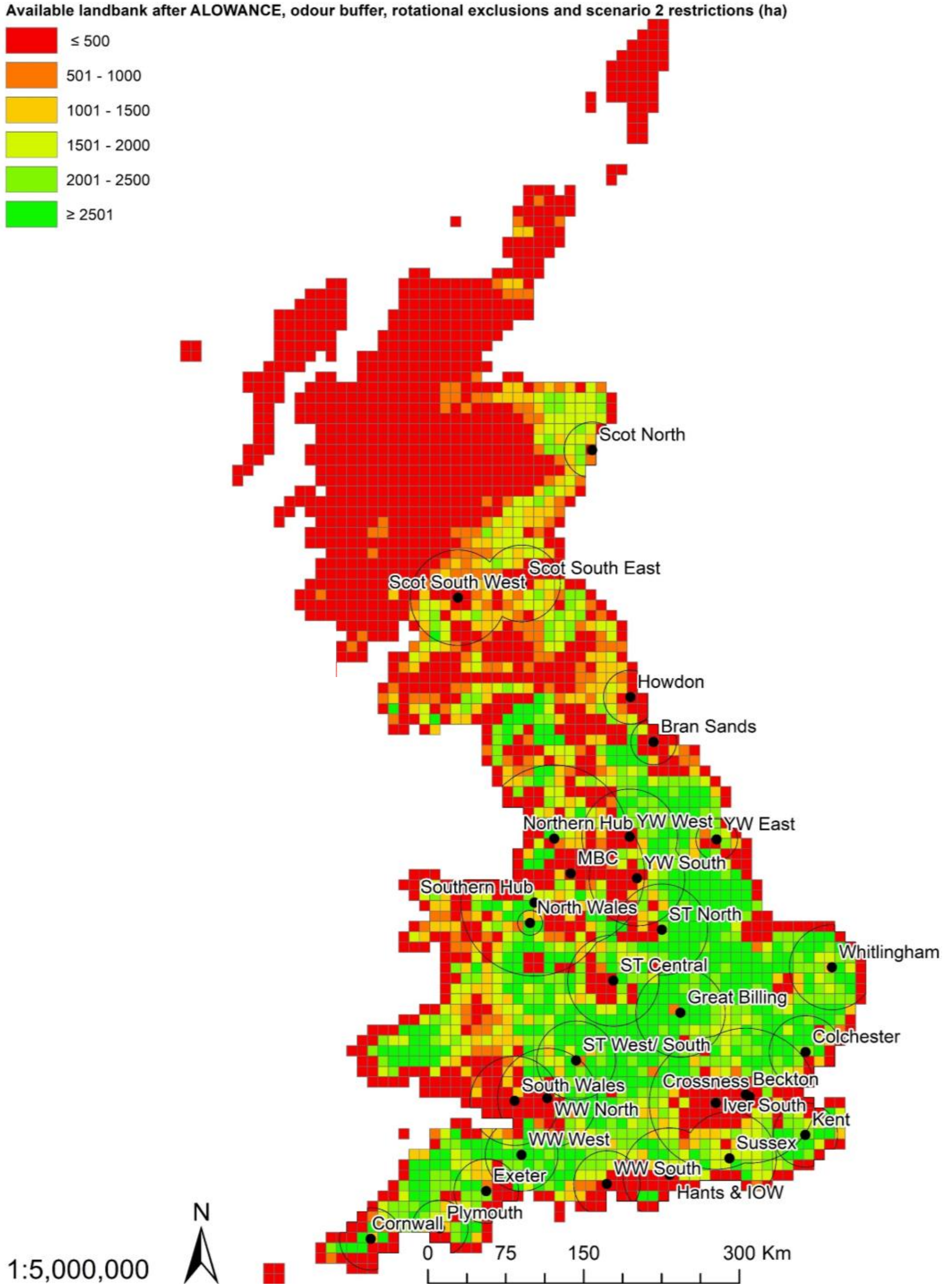

Figure 8. Scenario 2 baseline STC configuration.

Table 10 and Figure 9: scenario 3.

Table 10. Rotational landbank required for each combined STC (scenario 3)

Company	Total to land (TDS)[1]	Acceptance	Hectares[1]
Anglian Water	103,000	26%	266,600
Dwr Cymru	51,000	51%	25,800
Northumbrian Water	32,600	51%	16,300
Severn Trent	167,400	34%	211,900
Scottish Water[2]	76,800	48%*	72,300
Southern Water	71,600	38%	111,600
South West Water	57,900	32%	49,000
Thames Water[2]	199,400	53%*	186,000
United Utilities[2]	140,300	44%*	106,900
Wessex Water[2]	51,200	32%*	73,400
Yorkshire Water	104,800	38%	116,100
Total	**1,056,000**	**-**	**1,235,900**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Acceptance figures have been averaged.

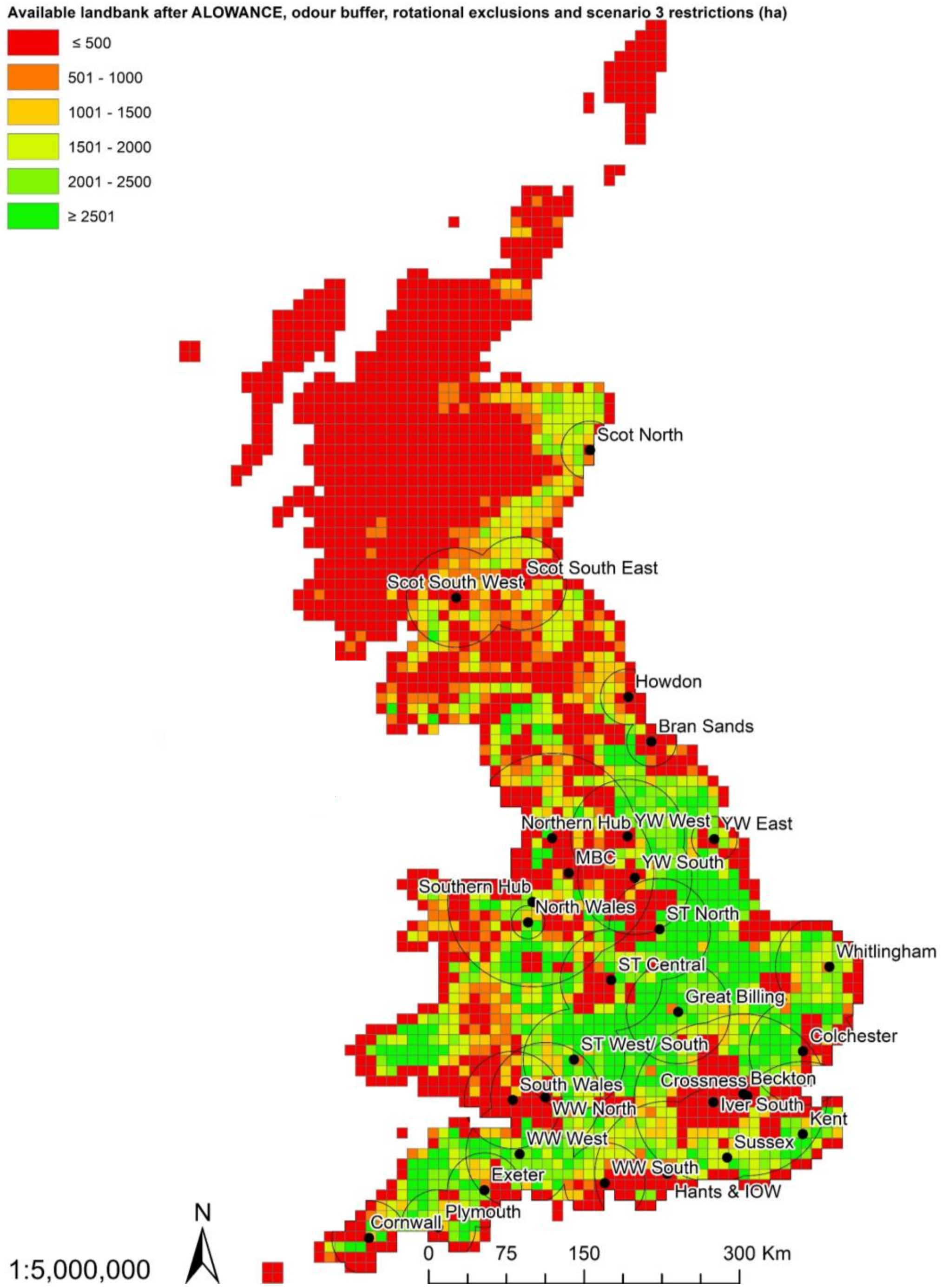

Figure 9. Scenario 3 baseline STC configuration.

Table 11 11 and Figure 10: scenario 4.

Table 11. Rotational landbank required for each combined STC (scenario 4)

Company	Total to land (TDS)[1]	Acceptance	Hectares[1]
Anglian Water	110,000	23%	1,068,300
Dwr Cymru	55,300	45%	128,600
Northumbrian Water	35,300	45%	102,800
Severn Trent	181,400	30%	1,014,400
Scottish Water[2]	75,400	43%*	222,000
Southern Water[2]	77,600	34%	373,300
South West Water	62,700	28%*	192,900
Thames Water	216,600	47%	959,300
United Utilities[2]	155,300	39%*	502,100
Wessex Water	55,400	37%	372,600
Yorkshire Water	113,600	45%	626,100
Total	**1,138,600**	**-**	**5,562,400**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Acceptance figures have been averaged.

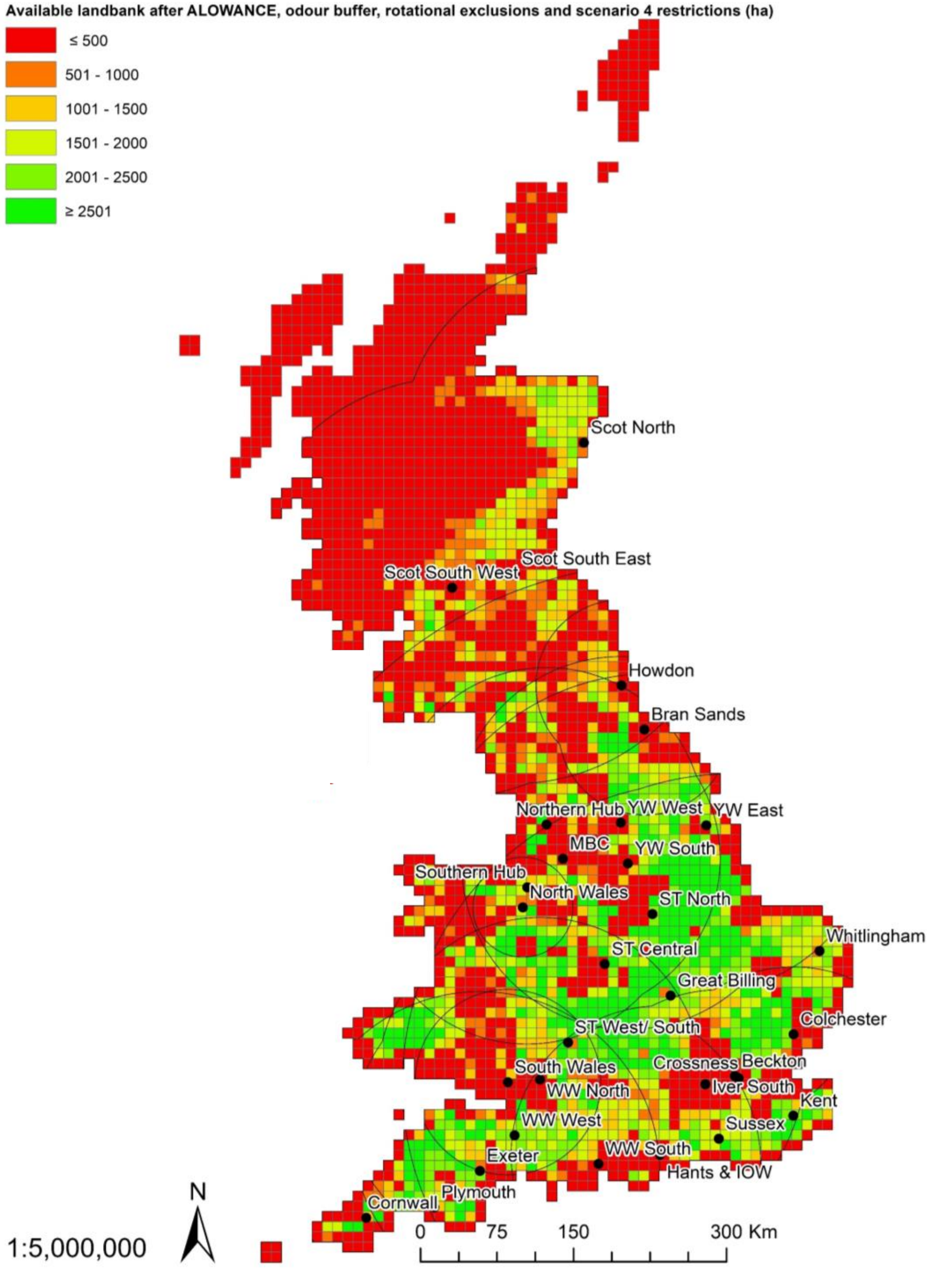

Figure 10. Scenario 4 baseline STC configuration.

Table 12 and Figure 11: scenario 5. Please note: there is insufficient landbank available for individual companies, hence there are not radial rings for all combined STCs shown on Figure 11.

Table 12. Rotational landbank required for each combined STC (scenario 5)

Company	Total to land (TDS)[1]	Acceptance	Hectares[1]
Anglian Water	113,100	18%	2,083,500
Dwr Cymru	57,400	36%	377,200
Northumbrian Water	36,700	36%	187,900
Severn Trent	188,400	24%	1,982,300
Scottish Water[1]	84,500	34%*	557,100
Southern Water	80,500	27%	1,251,700
South West Water	65,100	22%	589,700
Thames Water[1]	224,400	38%*	1,839,700
United Utilities[1]	161,100	31%*	1,087,400
Wessex Water[1]	57,600	22%*	871,900
Yorkshire Water	117,900	27%	1,183,800
Total	**1,186,700**	**-**	**12,012,200**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Acceptance figures have been averaged.

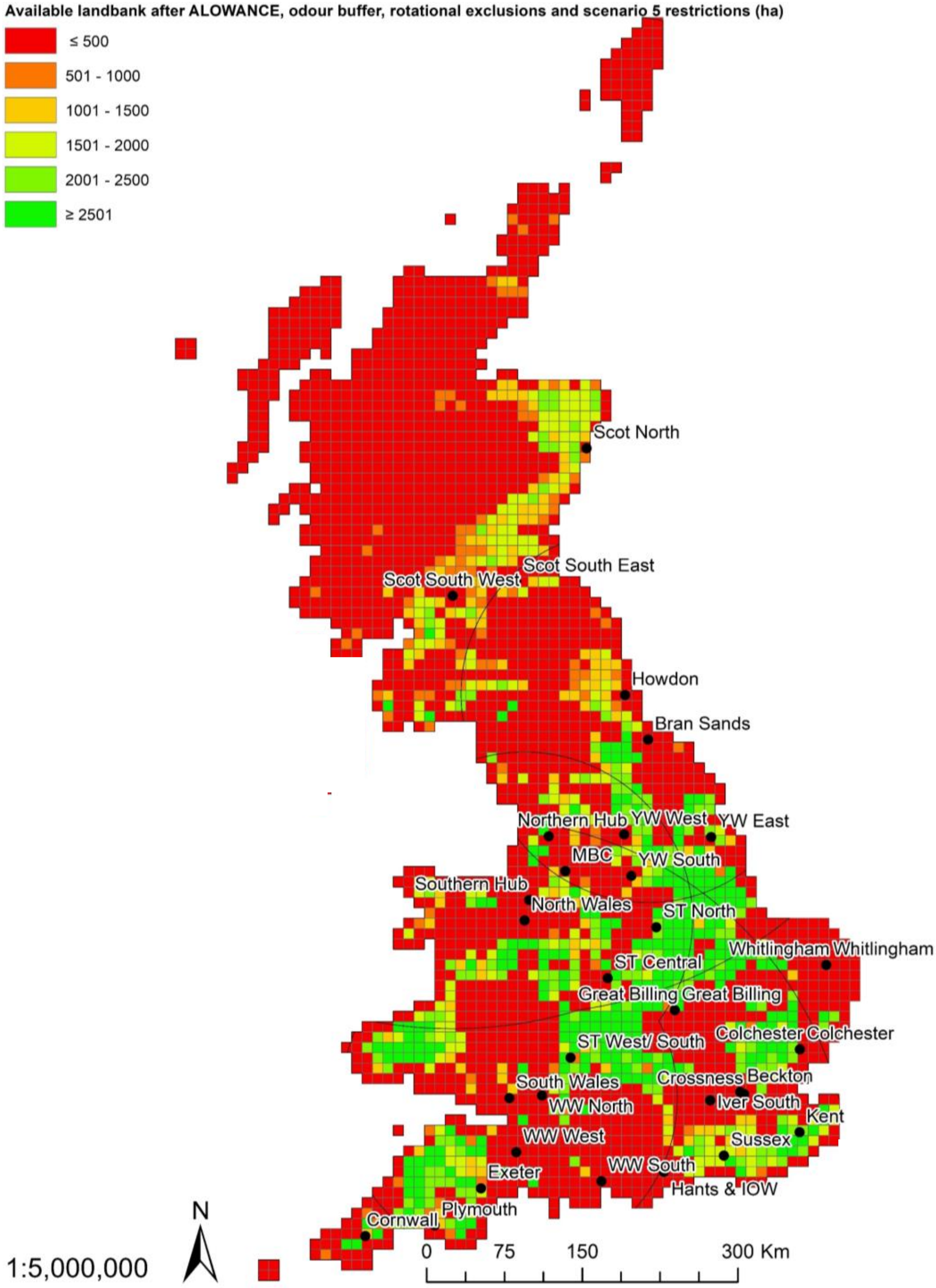

Figure 11. Scenario 5 baseline STC configuration.

The data for the five scenarios is summarised in **Error! Reference source not found.** 13 and Figure 12 (e.g. landbank required and landbank available) and estimated maximum distance to access suitable landbank are summarised Table 14.

Table 13. Summary of data for scenarios 1 – 5.

Data	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Figure	7	8	9	10	11
Amount to land (tds)	881,700	972,500	1,056,000	1,138,600	1,186,700
Landbank required (ha)	488,300	994,600	1,235,900	5,562,400	12,012,200
Landbank available (ha)	4,781,000	2,958,000	2,688,500	2,407,000	1,745,000
Average return period	1.3	2.2	2.3	8.2	14.5

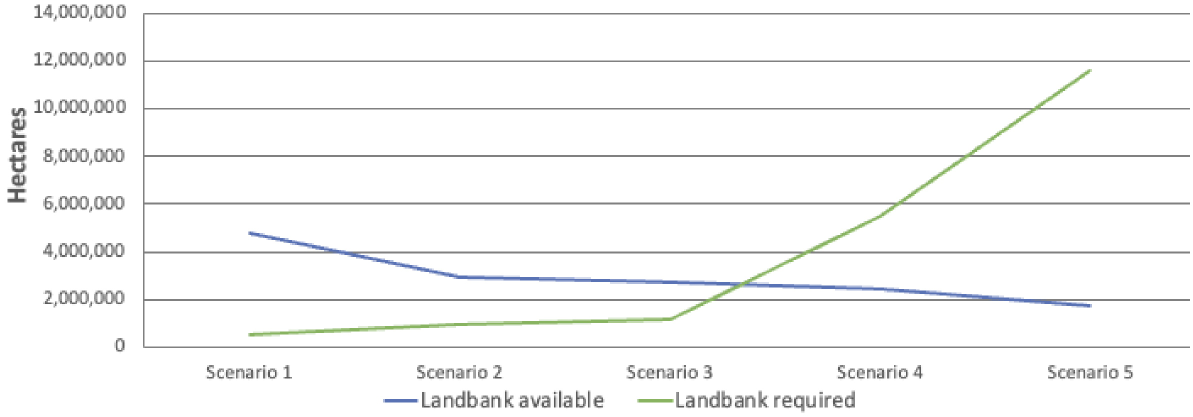

Figure 12. Summary of data for scenarios 1 - 5.

Table 14. Summary of estimated maximum distances (km) to access suitable landbank for scenarios 1 – 5 with baseline configuration.

Company	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Figure	*7*	*8*	*9*	*10*	*11*
Anglian Water	27	43	52	425	>500
Dwr Cymru	31	43	47	91	162
Northumbrian Water	19	26	27	84	158
Severn Trent	32	44	49	236	>500
Scottish Water	46	46	48	208	419
Southern Water	25	45	70	146	>500
South West Water	23	31	36	176	356
Thames Water	45	64	77	297	>500
United Utilities	57	71	82	154	>500
Wessex Water	37	48	53	159	>500
Yorkshire Water	33	46	55	163	>500

The landbank assessment is clear that for scenarios 1, 2 and 3 there is sufficient available agricultural land to recycle all British biosolids via the modelled STC configurations. There are however ‘hotspots’ of competition, particularly in the southeast (London), northwest (Greater Manchester) and southwest (South Wales/Bristol) meaning in these areas biosolids will have to be transported further than the distances quoted – this likely matches the current situation. Even using the biosolids quantity/quality data in scenario 5 there will be sufficient land for scenarios 1-3.

For scenarios 4 and 5 there is insufficient available agricultural land to recycle all British biosolids via the modelled STC configurations. The two key areas of sensitivity driving the change between scenarios 3 and 4 (i.e. why there was more landbank required than was available) are the restriction on applications before winter cereal crops in the late summer/autumn and increased restrictions on phosphate additions.

5. Phase II: WINEP submissions

5.1 Landbank scenarios

This work builds on Phase II by modelling the effect of companies original WINEP submissions as they were due to be at the end of AMP8 (i.e. 2030) and AMP9 (i.e. 2035). These two revised STC configurations were modelled against scenario 4 as this is the point where the landbank required exceeded the landbank available and the water industry wanted to understand if their WINEP submissions would be sufficient to ensure there was sufficient available land to recycle their biosolids. Please note: these are the original WINEP submissions as of January 2023, before the EA assessed the applications so they will differ significantly from what eventually will be included.

The modelling methodology is the same as undertaken in Phase II and the company level information is summarised in the tables below:

Table 15. STC outputs and product properties: scenario 4 (AMP8 medium change) – original WINEP submission to end AMP8

Company	**Total to land (TDS)[1]**	**Average nitrogen content (%)**	**Average phosphate content (%)**
Anglian Water	110,000	5.1	7.5
Dwr Cymru	55,300	4.5	7.0
Northumbrian Water	35,300	4.5	5.7
Severn Trent	181,400	4.8	11.1
Scottish Water	75,400	4.8	10.2
Southern Water	57,100	4.8	8.6
South West Water	-	-	-
Thames Water	216,100	4.4	10.0
United Utilities	140,300	3.9	10.3
Wessex Water	55,400	5.1	5.7
Yorkshire Water	113,600	4.8	8.6
Total	**1,039,900**	**-**	**-**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

Table 16. STC outputs and product properties: scenario 4 (AMP8 medium change) – original WINEP submission to end AMP9

Company	**Total to land (TDS)[1]**	**Average nitrogen content (%)**	**Average phosphate content (%)**
Anglian Water	30,000	5.1	7.0
Dwr Cymru	55,300	4.5	7.0
Northumbrian Water	19,600	4.5	6.0
Severn Trent	142,500	4.9	11.0
Scottish Water	75,400	4.8	10.2
Southern Water	19,700	4.7	7.9
South West Water	-	-	-
Thames Water	192,300	4.4	10.3
United Utilities	140,300	3.8	10.3
Wessex Water	27,700	5.0	5.7
Yorkshire Water	110,300	4.8	8.6
Total	**813,100**	**-**	**-**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

5.2 Rotational landbank

The rotational landbank required for each combined STC was calculated using the methodology described in the earlier section. To ensure the model was as accurate as possible for each WaSC, the amount of biosolids that could be applied to the grass landbank was restricted based on data supplied by each company. The landbank maps represent the theoretical maximum distance (to the nearest 1 km) to access both suitable and sufficient agricultural land for recycling biosolids from that site.

The results for the landbank scenarios are shown below:

Table 17 and Figure 13: scenario 4 with WINEP AMP8.

Table 17. Rotational landbank required for each combined STC (scenario 1) WINEP AMP8

Company	**Total to land (TDS)**[1]	**Acceptance**	**Hectares**[1]
Anglian Water	110,000	30%	1,068,900
Dwr Cymru	55,300	60%	128,600
Northumbrian Water	35,300	60%	102,800
Severn Trent	181,400	40%	920,200
Scottish Water[2]	75,400	56%	221,600
Southern Water	57,100	45%	249,100
South West Water	-	37%	-
Thames Water	216,100	64%	963,900
United Utilities[2]	140,300	51%	393,700
Wessex Water	55,400	37%	184,700
Yorkshire Water	113,600	45%	626,600
Total	**1,039,900**	**-**	**4,860,100**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Acceptance figures have been averaged.

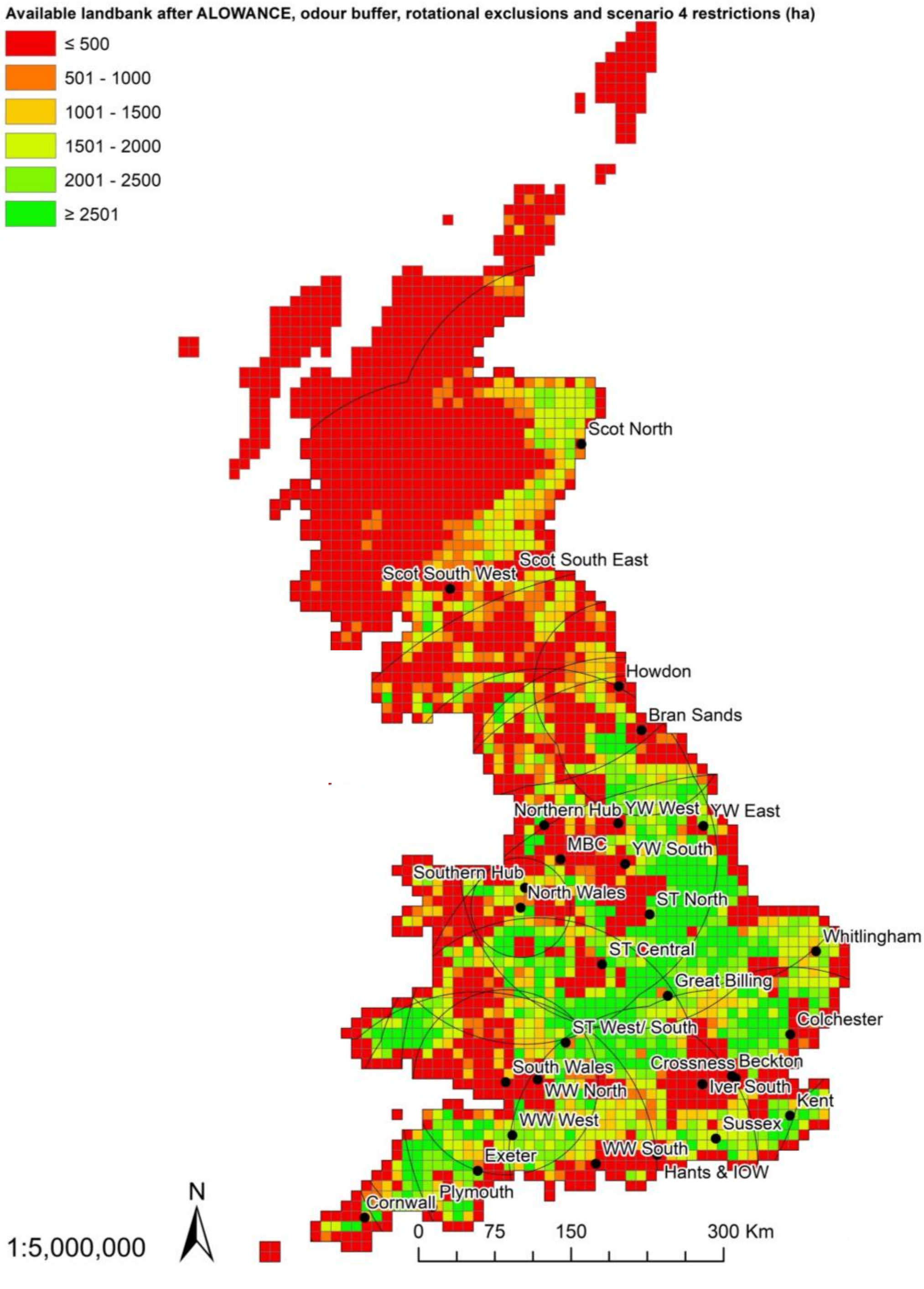

Figure 13. scenario 4 WINEP AMP8 STC configuration.

Table 18 and Figure 13: scenario 4 with WINEP AMP9.

Table 18. Rotational landbank required for each combined STC (scenario 1) WINEP AMP9

Company	Total to land (TDS)[1]	Acceptance	Hectares[1]
Anglian Water	30,000	30%	354,200
Dwr Cymru	55,300	60%	128,600
Northumbrian Water	19,600	60%	54,600
Severn Trent	142,500	40%	631,300
Scottish Water[2]	75,400	56%	221,600
Southern Water	19,700	45%	61,700
South West Water	-	37%	-
Thames Water	192,300	64%	882,800
United Utilities[2]	140,300	51%	393,700
Wessex Water	27,700	37%	99,400
Yorkshire Water	110,300	45%	524,900
Total	**813,100**	**-**	**3,352,800**

[1] Note: Data has been rounded to the nearest 100 to obtain a value that is easier to report/communicate and to avoid misleading precision associated with reported values.

[2] Acceptance figures have been averaged.

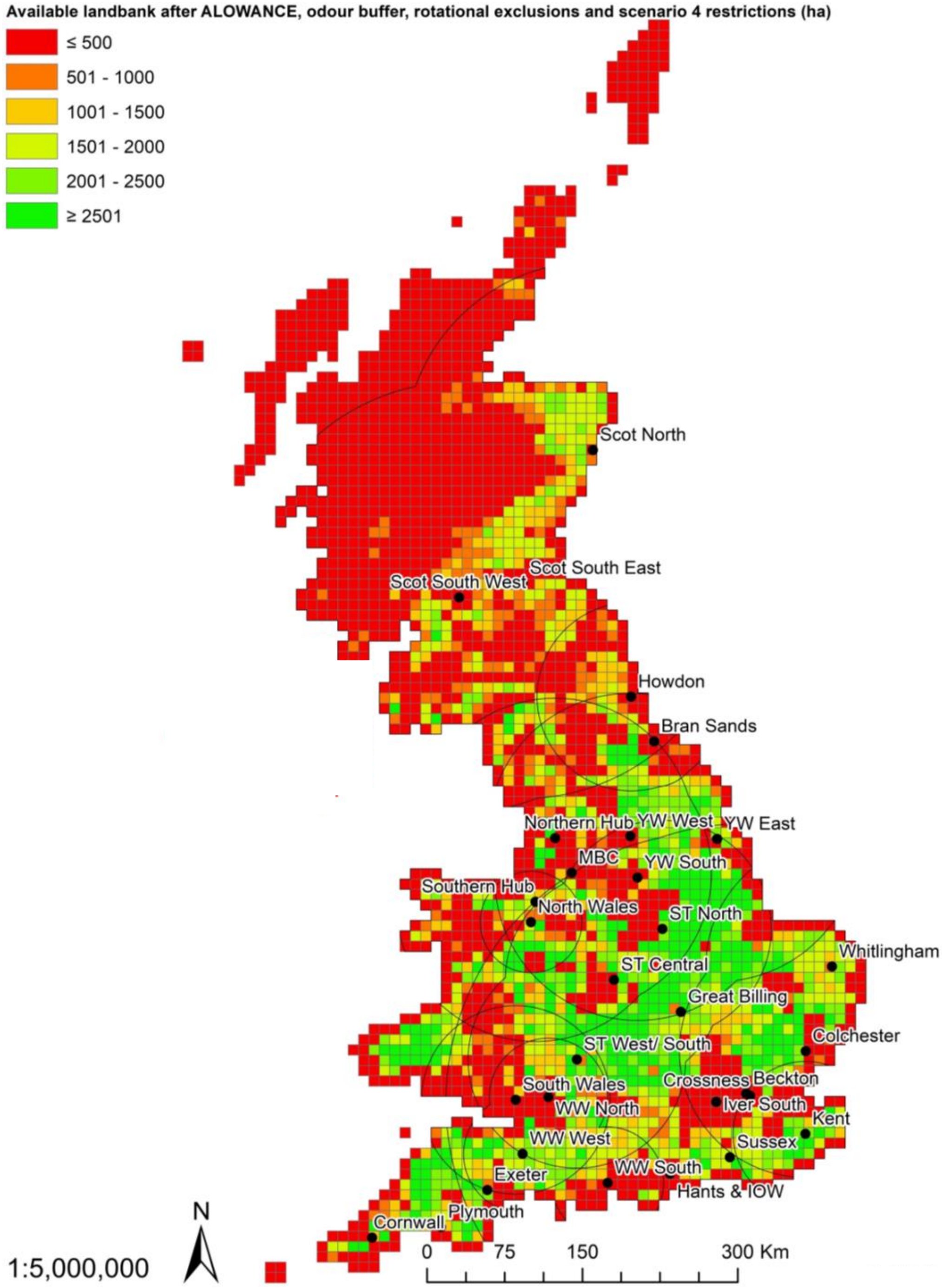

Figure 14. scenario 4 WINEP AMP9 STC configuration.

The data for the two WINEP scenarios (end AMP8 and AMP9) is summarised in Table 19 and Figure 15 (e.g. landbank required and landbank available) along with the baseline STC configuration (scenario 4). The estimated maximum distances to access suitable landbank are summarised Table 20.

Table 19. Summary of data for scenario 4, scenario 4 WINEP AMP8 and scenario 4 WINEP AMP9.

Data	Scenario 4	Scenario 4 WINEP AMP8	Scenario 4 WINEP AMP9
Figure	10	14	15
Amount to land (tds)	1,138,600	1,039,900	813,100
Landbank required (ha)	5,562,400	4,860,100	3,352,800
Landbank available (ha)	2,407,000	2,407,000	2,407,000
Average return period	8.2	8.4	8.7

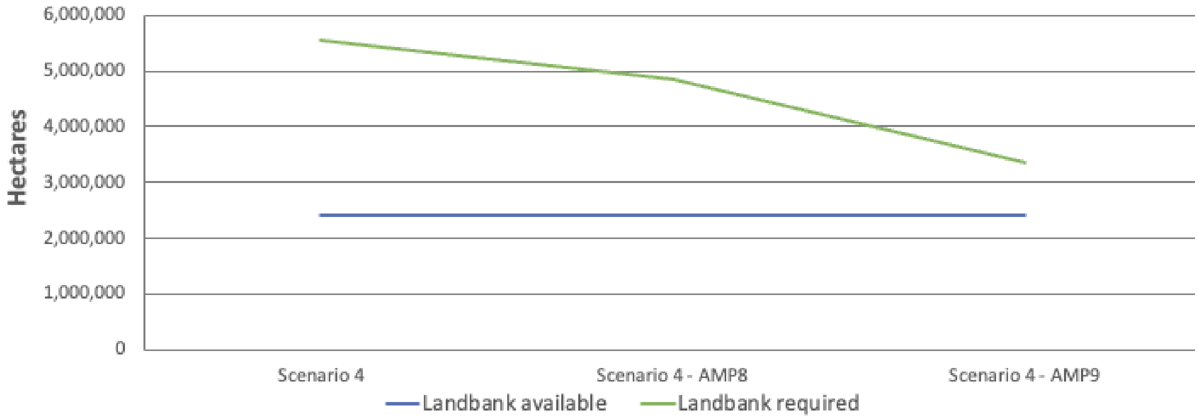

Figure 15. Summary of data for scenarios 4, scenario 4 WINEP AMP8 and scenario 4 WINEP AMP9

Table 20. Summary of estimated maximum distances (km) to access suitable landbank for scenario 4, scenario 4 WINEP AMP8 and scenario 4 AMP9.

Company	Scenario 4	Scenario 4 WINEP AMP8	Scenario 4 WINEP AMP9
Figure	*10*	*14*	*15*
Anglian Water	425	425	122
Dwr Cymru	91	91	91
Northumbrian Water	84	84	44
Severn Trent	236	172	105
Scottish Water	208	208	208
Southern Water	146	115	70
South West Water	176	-	-
Thames Water	297	300	261
United Utilities	154	135	135
Wessex Water	159	83	57
Yorkshire Water	163	163	138

Despite the changes in STC configurations across the water industry, there is still more landbank required even with the original WINEP submissions than is available under scenario 4.

6. Alternative treatment options for biosolids

6.1 Background

Just under 90% of the sewage sludge produced in the UK is recycled to agricultural land as biosolids. Biosolids applied to agricultural land supplies major and minor plant nutrients, especially phosphate, nitrogen and sulphur as well as supplying stable organic matter to improve soil health and sequester carbon. The use of biosolids (and other organic manures) reduces farmers reliance on manufactured fertilisers, which are expensive and require vast quantities of carbon to produce or are mined non-renewable resources.

The methods used to treat sewage sludge to produce biosolids and its resultant form have changed over time with raw sludges being replaced with, liquid digested sludge, thermally dried granules, dewatered digested cake, lime treated cake, co-compost and advanced anaerobically digested cake. A range of legislative, operational and financial drivers has resulted in these changes with companies continuing to investigate new treatment processes that may be relevant in the future, such as Advanced Thermal Conversion processes.

In addition to the constant evolution in treatment processes, discussions regarding interpretations of elements of the Farming Rules for Water regulations and the possible effect on applications before autumn sown cereals (amongst others) has resulted in increased interest in possible alternative treatment options. This is particularly pertinent for biosolids as industry data suggests that c.75% are applied annually in the late summer/autumn, with the majority in advance of cereal crops.

This short report considers existing alternative treatment technologies and what benefits they could provide as well as any potential unintended consequences.

6.2 Biosolids forms

6.2.1 Digested biosolids cake

The vast majority of biosolids recycled to agricultural land (over 70%) is produced via anaerobic digestion, with or without pre-treatment to increase digestion and produce more methane. The liquid digested biosolids is then dewatered to approximately 25% dry solids (depending on the treatment process and dewatering technology) before being stored and spread on agricultural land as stackable cake.

Organic manures particularly bulky solid manure like biosolids cake are spread with either, side or read discharge spreaders. Cereal crops are usually sown with tramlines, effectively roadways in fields where no crops are planted allowing sprays or fertiliser to be applied from. However, these are on average 24 metres apart (or even more), which makes spreading biosolids cake to growing crops more difficult. Modern spreading equipment does enable biosolids (and other solid organic manures) to be topdressed from tramlines in the spring, although the risk of crop damage is increased, particularly given the width of tyres required to minimise compaction, meaning many landowners may be unwilling to accept this practice. It would also result in increased ammonia volatilisation, odour nuisance and P loss (through run-off), as incorporation is not possible where a growing crop is present. There would be a need to engage with food chain stakeholders as topdressing to a growing crop creates a different perception of food safety risk to applications before drilling, who have previously raised concerns. Conversely, the autumn is ideally suited to spreading of biosolids as the ground is drier enabling heavy machinery to access the land without a risk of compaction; this is particularly important when spreading on medium or heavy soils made up of clay. It is also possible to incorporate the biosolids ahead of planting the subsequent crop. Where there are lighter soils (e.g. sandy), it is more likely that they will drain quickly and are less impacted by the weather making topdressing, a more practical option, however, the lack of incorporation will still give rise to increased odour and other emissions.

6.2.2 Co-compost

Composting is being discussed as an alternative solution as the resultant product generally contains less readily available nitrogen (and therefore crop available nitrogen) than other organic manures and therefore could be permitted to spread in the autumn to crops that do not have an autumn manufactured fertiliser requirement. This is particularly the case for green waste compost, which contains negligible or no readily (or crop) available nitrogen as a result of the low level in the input materials (e.g. grass clippings and woody material).

Sewage sludge has previously been co-composted with other input materials by the water industry so there is information on how that was undertaken and the properties of the resultant co-composted biosolids. Due to the physical nature of sewage sludge (or biosolids – as some companies co-composted sewage sludge and some biosolids) and its chemical composition (i.e. nitrogen to carbon ratio) it could only be composted with added fibrous and high carbon material, such as green waste or straw (or straw-based farmyard manure). Information provided by various water companies confirm they had to mix approximately 2 parts green waste (or similar) to 1 part sewage sludge (or biosolids) to create a material that would compost, specifically that the material would remain aerobic and allow the microbes to breakdown the carbon and produce a sanitised and stable co-compost. However, the addition of two thirds of green waste (or similar) will triple the amount of material being treated and significantly increase (more than double) the quantity of product to be recycled to land thus increasing the required landbank and associated costs by a similar proportion. There are also management challenges when composting, co-compost is typically produced in open windrows which pose odour risks to those near the treatment site. It requires large areas of impermeable surface and is a lengthy process, which adds more cost and requires managing. Moreover, in the past the permitting of sites and in particular the EWC code of the resultant compost posed difficulties for operators, however, this would hopefully be something that could be resolved.

Using data provided by several water companies, co-composted biosolids has a similar level of total nitrogen, meaning the application rate will not be significantly different, but that less is readily available. However, the co-compost still had approximately 5-10% of total nitrogen in a readily available form, which is below that of digested cake (typically around 15%), but is well above the level found in green waste compost. As a result, if there were a restriction on applying organic manures containing readily available nitrogen to crops without an autumn manufactured nitrogen requirement, this would apply just as much to co-composted biosolids as digested cake meaning it is a not a solution to this problem. Finally, the reduction in readily available nitrogen, while potentially useful from a water quality perspective, would result in an increased reliance on manufactured fertiliser nitrogen (as less would be supplied by biosolids), which would have a negative effect on climate change given the carbon footprint of manufactured fertiliser nitrogen.

6.2.3 Pelletisation

Pelletising biosolids is a consideration for the water industry currently, however, producing a dry granulated/pelletised biosolids product is not new. Many water companies have previously used thermal driers to produce a granulated biosolids and there are currently sites still operating in Scotland using this technology. The key reasons companies (outside of Scotland) moved away from this technology were due to the cost to operate these facilities and operational concerns (e.g. fire risk). Drying plants required large quantities of energy (e.g. natural gas) to drive off almost all the moisture and to produce a granule. Data provided by the water industry shows that a typical drum dryer using natural gas would cost approximately £400 per tonne dry solids (TDS) equivalent to the total cost per TDS of current activities (therefore doubling the cost of the bioresources activity). Please note the exact cost will vary by site, energy price, existing infrastructure, etc. In addition to the financial cost, using natural gas also has a significant carbon footprint, which is estimated at c.460g CO_2e per TDS. If the cost and carbon emissions are scaled up to (for example) the c.850,000 TDS of biosolids recycled to land, it would give a cost of approximately £340 million with c.400 million tonnes CO_2e produced per annum. There are more modern drying technologies that can operate at lower temperatures or make use of existing on-site heat sources (if available); the cost of these will vary considerably depending on a range of factors (e.g. availability of an existing heat source, size, existing infrastructure, upstream technology) but without operational facilities it is not possible to be certain of the cost (particularly CAPEX and ongoing maintenance requirement), or climate change impact. However, the energy costs are estimated to be around 10-15% lower than those of conventional driers.

Pelletising biosolids would provide various operational efficiencies as the lack of water means pellets are easier and less costly to transport, particularly longer distances. They are easier to store, typically in bags meaning any losses from storage would be reduced. Pellets are easier to apply accurately and evenly to agricultural land and granulated or pelletised biosolids products could in theory be topdressed onto a growing crop without damaging the crop in the spring, as pellets could be applied via conventional fertiliser application equipment (e.g. spinning disc spreaders) operating from tramlines, as is the case for manufactured fertiliser. However, there is an important difference between pelletised biosolids and manufactured fertiliser that will affect how they can be utilised in practice. The nutrient density of pelletised biosolids is much lower than that found in manufactured fertilisers, which results in higher application rates. Where Ammonium nitrate is typically applied at around 0.25 t/ha, pelletised biosolids are likely to be applied at 6 t/ha; this means a typical spreader could only hold enough pelletised biosolids to spread less than a hectare whereas it can spread up to 10 hectares with manufactured fertiliser. This will require repeatedly driving over the same tramlines, due to the limited capacity of the fertiliser spreaders, which would likely cause crop damage and/or increase the risk of soil compaction. Alternatively, more modern 'muck spreaders' utilise a similar spinning disc technology and these could be used to apply pelletised biosolids and their increased capacity would prevent the need to drive over tramlines multiple times. However, they are not mounted to a tractor like a fertiliser spreader, but follow like a trailer and have much wider tyres to prevent compaction, meaning they would likely cause some damage to the crops around the tramlines and the increased weight would give rise to compaction if used on damp soils like those in the spring (despite using wide low ground pressure tyres). These practicalities will reduce the attractiveness of pellets to farming customers as any compaction would have to be rectified and damaged crops would lose them money. There would also be a need to engage with food chain stakeholders as topdressing to a growing crop creates a different perception of food safety risk to applications before drilling.

For biosolids pellets to be directly comparable to manufactured fertilisers, the nutrient density would need to be significantly increased (e.g. from 4% total phosphate to nearer 46% phosphate). Whereas, pellets have a very similar nutrient content and profile to biosolids cake (on a dry solids basis), without an increased nutrient content, there will still be difficulties with applying in the spring and therefore applications will be limited to being applied before drilling in the autumn as per biosolids cake. However, as pellets contain readily available nitrogen and without the Statutory Guidance autumn applications in advance of most crops would not comply with the EA's interpretation of the Farming Rules for Water. It is worth noting that companies are investigating ways to extract nutrients from the wastewater and sludge treatment process (e.g. ammonia stripping, struvite precipitation, phosphorus extraction), but none of these technologies have been employed commercially yet (with the exception of struvite precipitation to reduce build-up on pipes).

6.2.4 Liquid digested biosolids

Liquid digested biosolids was previously recycled to agricultural land, but the introduction of the restrictions contained in the Nitrate Pollution Prevention regulations (such as closed spreading periods) and the operational (and financial) implications resulted in companies moving to producing a dewatered cake. However, if it became not possible to apply dewatered biosolids cake before autumn sown cereal crops, liquid digestated biosolids could be applied via precision application equipment (e.g. trailing hose, bandspreaders) in the spring as this machinery can operate off tramlines. However, applying liquids requires specialist equipment for spreading and there are strict rules on application and timing, and they also require costly transport movements using specialist tanker vehicles and permanent storage facilities. Tanker based applicators require wide low ground pressure tyres to limit compaction, which would cause crop damage around the tramline. Alternatively, umbilical systems are available which reduce the weight of the applicator significantly, however, they require a pipe to be pulled across the field which can give risk to crop damage. All liquid waste with the potential to cause pollution is required to be stored in a secure impermeable lagoon/container with secondary containment. The risks associated with managing high readily available nitrogen containing liquid manures, such as ammonia volatilisation and increased run-off, would likely offset any saving in over winter nitrate leaching. Additionally, this would negatively affecting climate change commitments as well as resulting in an enormous capital and operational cost. Moreover, the use of very heavy (>40 tonne) equipment on potentially wet/damp soils in the spring make soil compaction (and therefore runoff and other forms of pollution) a significant concern. In this situation, there would also be a need to engage with food chain stakeholders as topdressing to a growing crop creates a different perception of food safety risk to applications before drilling. It is worth noting the water industry moved away from recycling liquid digested biosolids to land due to the logistical, environmental and cost implications, particularly related to the storage requirements imposed by the Nitrate Vulnerable Zone regulations that requires organic manures to be stored over the winter period.

6.3 Conclusions

Investigating alternative treatment and processing options can only be a positive as the water industry looks for ways to manage its materials more efficiently and to reduce their future environmental and carbon footprints. However, composting or pelletising a significant proportion of biosolids is unlikely to be a viable alternative at an industry scale and could lead to significant unintended consequences from a climate change perspective and financially, at least with current technologies. Pelletisation could reduce transport, storage and some spreading difficulties, but due to the impracticalities of spring applications, it would not be a solution if there was a restriction on applying organic manures in the autumn before autumn sown cereals. The logistical, environmental and cost implications of applying liquid digested biosolids make it unviable. Technologies that extract nutrients from wastewaters and/or sewage sludge would prove beneficial, but they are not yet commercially viable. Finally, drying (or pelletisation) could be a necessary step for future treatment options that are still being investigated (e.g. Advanced Thermal Conversion).

In the short-term (and without substantial improvements in technology), dewatering biosolids cake more efficiently so as to reduce the water being transported/spread, reducing the readily available nitrogen content and recycling it to agricultural land is likely to make best use of these valuable materials without negatively effecting the environment, climate change targets or significantly increasing costs.

The following table summarises the pros and cons of them in comparison with the baseline, which is dewatered digested cake:

Criteria	**Liquid digested biosolids**	**Pelletised biosolids**	**Co-Compost**
Application to autumn cereals[1]	✗	✗	✗
Topdressed to growing crop in spring[2]	✓~	✓✓~	✓~
Practicality (i.e. transport, storage and spreading)	↓↓↓	↑	↓↓
Risk of compaction	↑[3]	↓	←→
Emissions to air	↑↑↑	←→	←→
Losses to water	↑↑↑	←→	←→
Contaminants (e.g. POPs, microplastics, etc.)	←→	←→	←→
Carbon impact from treatment, transport, storage and application	↑↑	↑↑↑	↑
CAPEX	↑↑↑	↑↑↑	↑↑
OPEX	↑↑	↑↑↑	↑↑

✗ = no; ✓~ = yes, with more ticks signifying greater potential, but with practical limitations; ↑= increase, with more arrows signifying a larger increase; ↓ = decrease, with more arrows signifying a larger decrease; ←→ = no significant change.

[1] Based on the assumption that organic manures containing readily available nitrogen cannot be applied in the autumn to crops without an autumn manufactured nitrogen requirement. The same applies to the baseline (digested cake).

[2] Based on using precision spreading equipment (e.g. a bandspreader for liquids and a spinning disc solid manure spreader). The same applies to the baseline (digested cake).

[3] Assumes the use of a tanker-based bandspreader for liquids. Use of an umbilical system would reduce the compaction risk but increase the risk of crop damage (where applying to a growing crop).

7. Discussion

It is clear from the statistics and the mapping that as the environmental scenarios increase, so does the landbank required and the available land decreases. This results in haulage distances increasing from those in the baseline scenario (average across all WaSCs) of c.30 kilometres to the point that there is insufficient available agricultural land in scenarios 4 and 5.

For scenarios 4 and 5, there is a sizeable reduction in the available land, almost 2-fold for scenario 4 and almost 3-fold for scenario 5 equating to a reduction of c. 2.3 million and 3 million hectares respectively (over scenario 1).

For scenarios 1 – 3 the landbank required is at a maximum just over 1.2 million hectares and the restriction on the available land means there is comfortably sufficient available agricultural land within c.80 kilometres of all WaSCs STC's. The landbank required for scenarios 4 and 5 increases significantly by c.4,500,000 ha and c.11,000,000 ha respectively (over scenario 2).

The key 'inflection point' is the change in landbank required (and to a lesser extent the reduction in landbank available) between scenarios 3 and 4. The scenarios contain a number of different factors that all add up to affecting either the landbank available or landbank required (or in some cases both). However, there are some factors that are key in there being insufficient land, specifically:

- The effect of the constraints on late summer/autumn applied biosolids equates to an extra c.2,500,000 ha for scenario 4 and an extra c.6,000,000 ha for scenario 5 (over scenario 2)
- Increased phosphate constraints of scenario 4 equates to an extra c.1,000,000 ha and an extra c.2,000,000 ha for scenario 5 (over scenario 2)
- Increased quantities and P content constraints of scenario 4 equates to an extra c.750,000 ha and an extra c.2,000,000 ha for scenario 5 (over scenario 2). However, using 'current' biosolids quantity/quality data there will still be insufficient land under scenarios 4 and 5

Due to the increasingly stringent environmental restrictions, the water industry provided their original WINEP submissions to the end of AMP8 and AMP9 to see if those changes were sufficient for their to be enough agricultural land. The changes proposed decreased the haulage distances (and therefore the landbank required), however these were not sufficient, at least based on scenario 4, to offset the effect of the environmental restrictions. Moreover, even with the investment outlined 60% of the biosolids (based on the WINEP AMP8 scenario) or 35% of biosolids (based on the WINEP AMP9 scenario) would require an alternative outlet.

As detailed above, the restrictions that have the greatest affect on increasing the landbank required is the potential ban on the use of biosolids (and other organic manures) in advance of winter cereals in the late summer/autumn and increased restrictions on phosphate management.

There has been much discussion surrounding the EA's interpretation of the Farming Rules for Water in late summer/autumn 2020. This resulted in widespread discussion within the agricultural community, an EFRA committee hearing and various research studies to understand the possible implications of such an interpretation. This resulted in the Secretary of State for the Environment introducing Statutory Guidance on how the Farming Rules for Water should be enforced. It is vital the use of biosolids (or any nutrient source) provides benefit and does not cause harm to the environment. However, given the disagreement over this interpretation and in particular the possible effects it could have on the environment and agriculture more broadly, further discussion with all relevant and impacted parties would seem a logical requirement.

This modelling exercise only applies the EA's interpretation of the Farming Rules for Water for biosolids; if it was applied to the approximately 90 million tonnes of livestock manures and c.10 million tonnes of other organic manures the situation would be even more extreme. As such it is clear that given the scale of the issues, not only affecting the water industry, but the agricultural industry too that there is a need for coordinated planning at a national scale to manage reductions in and competition for available landbank and to enable the development of alternative outlets (if required). Without this there cannot be efficient and timely management of what is a national issue.

It is vital conversations continue between the various affected parties and regulators/policy makers, particularly as there are not currently 'ready made' alternatives in how biosolids can be managed to prevent these issues (without incineration). Initiatives like the Long-term Bioresources Strategy are key in allowing all parties to be involved in the conversation and in delivering viable, sustainable solutions.

8. Conclusions

Five different scenarios (historic, baseline and 3 projected future scenarios) based on the PR24 WINEP drivers were developed and modelled to understand the effect of increasingly stringent environmental restrictions on biosolids recycling. These were modelled using an updated version of the ALOWANCE GIS modelling tool with data provided by the WaSCs on their current Sludge Treatment Centre (STC) configuration and treatment processes and possible future configurations associated with initial WINEP submissions.

For scenarios 1, 2 and 3 there is sufficient available agricultural land to recycle 100% of British biosolids via the modelled STC configurations. However, there are 'hotspots' of competition, particularly in the southeast, northwest and southwest meaning in these areas biosolids will have to be transported further in these locations.

For scenarios 4 and 5 there is insufficient available agricultural land to recycle 100% of British biosolids via the modelled STC configurations, with at least two thirds of biosolids under scenario 4 requiring another outlet. The two key areas of sensitivity driving the change between scenarios 3 and 4 are the restriction on applications before winter cereal crops in the late summer/autumn and increased restrictions on phosphate additions, associated with the EA interpretation of the FRfW.

Data provided by the WaSCs on their original WINEP submissions was modelled against the restrictions associated with scenario 4. The changes proposed decreased the haulage distances (and therefore the landbank required), however these were not sufficient to offset the effect of the environmental restrictions. Moreover, even with the investment outlined 60% of the biosolids (based on the WINEP AMP8 scenario) or 35% of biosolids (based on the WINEP AMP9 scenario) would require an alternative outlet due to insufficient land.

This modelling highlights the effect the EA's interpretation of the Farming Rules for Water (particularly associated with recycling in the late summer/autumn and phosphate management) can have on recycling organic manures (including biosolids). Given the implications for the water industry as well as other producers of organic manures (e.g. livestock farmers, anaerobic digestion facilities) there is a need for coordinated planning at a national scale to manage reductions in and competition for available landbank and to enable the development of alternative outlets (if required). Without this there cannot be efficient and timely management of what is a national issue.

It is vital conversations continue between the various affected parties and regulators/policy makers, particularly as there are not currently 'ready made' alternatives in how biosolids (or other organic manures) can be managed to prevent these issues (without incineration). Initiatives like the Long-term Bioresources Strategy are key in allowing all parties to be involved in the conversation and in delivering viable sustainable solutions.

9. Appendix I. Details of landbank scenarios

WINEP Spreadsheet Reference	Risk / Issue	Scenario 1 Historical	Scenario 2 Baseline	Scenario 3 Minimal Change	Scenario 4 Medium Change	Scenario 5 High Change
1	Sludge (use in Agriculture) Regulations (SUiAR) 1989	Baseline	Baseline	-	-	-
7 / 8	Environment Agency national sludge strategy / move to EPR	-	-	No change/changes do not reduce landbank	Slight reduction in farmer acceptance	Significant reduction in farmer acceptance
9	BAS Compliance	Baseline	Baseline	Baseline	Baseline	Baseline
12 / 21 / 23	Farmer Acceptance	Baseline %	Small reduction	Slight reduction	Moderate reduction	Significant reduction
13	Public Perception	Primarily addressed through farmer acceptance concerns, particularly regarding contaminants (see items 39, 42, 43). Any sector specific changes (e.g. a ban on a specific land uses) can not be modelled as they are unforeseen events that cannot be predicted.				
17 / 57 / 58	Market competition affecting supply / demand of biosolids to land	Baseline	Baseline	Baseline (biosolids quantities will increase in-line with item 26)	Baseline (biosolids quantities will increase in-line with item 26)	Baseline (biosolids quantities will increase in-line with item 26)
		Assumes no change in farm or other non-farm organic manures (except biosolids)				

WINEP Spreadsheet Reference	Risk / Issue	Scenario 1 Historical	Scenario 2 Baseline	Scenario 3 Minimal Change	Scenario 4 Medium Change	Scenario 5 High Change
18	Flooding - storage	Cannot be modelled quantitatively as storage changes won't directly effect the quantity of available land				
24	Climate Change Adaptation and Resilience	Cannot be modelled quantitatively as geographic distribution of any possible changes are unknown				
25 / 31 / 60 / 63	Changing Farming Practices Climate Change Disease (oil seed rape) Increase in low / no-till practices					
	Agricultural Demand for Biosolids - arable Restrictions on arable cropping (due to perceived nutrient concerns)	Baseline %	Reduction in line with 20 Measures	Slight increased restrictions (above 20 Measure)	Moderate restrictions (above 20 Measure)	Significant restrictions (above 20 Measure)
	Agricultural Demand for Biosolids - grassland	Baseline %	Baseline %	Slight reduction in allowances	Moderate reduction in allowances	Significant reduction in allowances

WINEP Spreadsheet Reference	Risk / Issue	Scenario 1 Historical	Scenario 2 Baseline	Scenario 3 Minimal Change	Scenario 4 Medium Change	Scenario 5 High Change
26	Supply demand balance biosolids produced	2020	2025	Low increase	Medium increase	High increase
27	Physical Restrictions	BAS Compliance only	BAS Compliance plus 20 Measures	BAS Compliance plus 20 Measures	BAS Compliance plus 20 Measures	BAS Compliance plus 20 Measures
28 / 32 / 35 / 61 / 62	Water Framework Directive Regulations, Nutrient Neutrality and Farming Rules for Water	BAS Compliance only	BAS 20 measures	BAS 20 measures	BAS 20 measures	BAS 20 measures
30	Sensitive Catchments	No specific restrictions	Increased restrictions in sensitive catchments (in line with 20 Measures)	Greater restrictions in sensitive catchments (beyond those within 20 Measures)	Tighter restrictions in sensitive catchments (well beyond those within 20 Measures)	Very tight restrictions on spreading in sensitive catchments
61 / 32 / 62 / 29	Phosphorus restrictions	Baseline BNMM restrictions	Increased restrictions based on soil P (in line with 20 Measures)	Greater restrictions based on soil P (above 20 Measures)	Strict restrictions based on soil P (above 20 Measures)	Significant restrictions based on soil P (above 20 Measures)

WINEP Spreadsheet Reference	Risk / Issue	Scenario 1 Historical	Scenario 2 Baseline	Scenario 3 Minimal Change	Scenario 4 Medium Change	Scenario 5 High Change
33	Designated sites / priority habitats	BAS Compliance only	Increased restriction near sensitive sites and in SPZ2 (in line with 20 Measures)	Greater restriction near sensitive sites and in SPZ2 (beyond those within 20 Measures)	Greater restrictions near sensitive sites and in SPZ2 (well beyond those within 20 Measures)	Very tight restriction on spreading near sensitive sites or within SPZ2
37	25 year environment plan / environment act targets	Baseline sludge composition N/P ratio	Small increase in P content Increased sludge quantity is covered in item 26	Slight increase in P content Increased sludge quantity is covered in item 26	Modest increase in P content Increased sludge quantity is covered in item 26	Sizable increase in P content Increased sludge quantity is covered in item 26
39 / 29	Chemicals Investigations Programme	Baseline %	Baseline %	Slight reduction in farmer acceptance (to model concerns over contaminants)	Modest reduction in farmer acceptance (to model concerns over contaminants)	Reduction in farmer acceptance (to model concerns over contaminants

WINEP Spreadsheet Reference	Risk / Issue	Scenario 1 Historical	Scenario 2 Baseline	Scenario 3 Minimal Change	Scenario 4 Medium Change	Scenario 5 High Change
42 / 29	Microplastics	Baseline %	Baseline %	Slight reduction in farmer acceptance (to model concerns over contaminants)	Modest reduction in farmer acceptance (to model concerns over contaminants)	Reduction in farmer acceptance (to model concerns over contaminants
43	PFAS	Baseline %	Baseline %	Slight reduction in farmer acceptance (to model concerns over contaminants)	Modest reduction in farmer acceptance (to model concerns over contaminants)	Significant reduction in farmer acceptance (to model concerns over contaminants)

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E2. Water UK IED Supporting Document

Industrial Emissions Directive Supporting Document

IED Supporting Document

Water UK

31 May 2023

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1. Executive Summary

Transformation in the regulation of sewage sludge treatment and the need to comply with the Industrial Emission Directive (IED) is leading to an investment requirement across the water industry of c. £2.0bn. The publication of the Environment Agency (EA) Appropriate Measures guidance in 2022, introducing additional requirements with associated costs, has further compounded this challenge for the Water and Sewerage Companies (WaSCs) to comply with the IED. The compliance approach taken by the EA appears more precautionary than the original intent of IED, and consequently the scale of change is resulting in a significant challenge to the industry in terms of feasibility, affordability and deliverability. Non-compliance with permit conditions is not an option, as this may result in enforcement action and possibly prosecution.

This report presents the outputs of an assessment of the compliance requirements being driven by Appropriate Measures standards.

The way Bioresources is regulated is undergoing a significant phase of transformation, with one key area of adaptation concerning Environmental Permitting. In 2019 the Environment Agency (EA) concluded that anaerobic digestion (AD) of sewage sludge at treatment works is subject to Environmental Permitting requirements under the Industrial Emissions Directive (IED). This conclusion was formed following a review of whether this was covered by Urban Wastewater Treatment Directive (UWWTD) exclusions. The application of IED provisions to sewage sludge treatment centres requires demonstration of ‘best available techniques’ (BAT). The EA, when informing the Sector that it needed to comply with IED indicated this was a low-cost impact as a fully costed risk-assessment of the implications had not been undertaken. Whilst the Water Industry are supportive of the need to reduce the risk of industrial emissions, there needs to be a pragmatic implementation, considering the environmental benefit, funding, affordability, carbon impacts and deliverability of the requirements.

At the time of IED implementation in 2019, the Water Industry were required to comply with BAT as set out in best available technique reference documents (BREF) [6], with full compliance by August 2022. The anticipated low-cost and quick turn-around was explained by the EA as they expected compliance to be predominantly a paperwork exercise [anecdotal unsubstantiated reference].

The European Commission approach through BREF is based around a risk-based assessment pertaining to a specific site and its impact on local receptors. The guidance is designed to allow flexibility to adapt as further improvements in BAT are developed. Whilst the industry was working to comply with BREF, the EA published Appropriate Measures for the Biological treatment of Waste in September 2022. This document sets out additional standards for operators to comply with at facilities in England, and whilst the EA’s Appropriate Measures framework is fundamentally achieving the same goals as BAT, there are several aspects where the EA appear to have been more cautious and prescriptive with tighter or more specific controls. The EA appear to have deemed the risk posed by permitted facilities that handle biowaste (the EA’s generic term for any organic waste, as Appropriate Measures applies to other organic wastes as well as sewage sludge) are higher than original BAT conclusions but have not articulated a clear reason why they have come to those conclusions.

Figure 1-1 below illustrates the impact of appropriate measures and BREF 2018 Standards compliance on a notional digestion facility.

This shift in environmental compliance expectations from Appropriate Measures has had significant implications for IED compliance across the Water Industry and thus the level of investment is greater than could have been foreseen in 2019. Furthermore, the timescales to deliver the significant levels of investment will likely take activities to deliver the requirements well into the AMP8 period. It should be noted that Appropriate Measures doesn’t define time periods for completion of any improvements, and this may indicate that the EA accept that the timescales for implementation must be flexible and depend on the specifics of each case (e.g., the nature and complexity of the works).

Current estimates indicate that c.£2.0bn of investment will be needed to address IED requirements, the majority to comply with secondary containment (£0.6bn) and covering of treated sewage sludge storage (£1.3bn). Appropriate Measures requirements drive covered storage investment, and for secondary containment this is driven by Appropriate Measures for existing PPC permits being revised, and BREF for new permits.

The expenditure required at each site is highly variable and is only able to be determined accurately once the site-specific assessments are made to determine the improvement conditions required. However, for both BAT and Appropriate Measures compliance the key factor in determining the scale of investment is the calculation and attitude to risk accepted by the regulator. The differing levels of risk within the assessments of improvement conditions seen across sites have had a consequent impact on the expenditure planned. This is leading to a large disparity between company investment requirements, with this disparity clearly seen across the devolved nations in their adoption of IED BREF for waste treatment. We recommend consistent interpretation of guidance is essential to avoid confusion and excessive investment or under-forecasting of the eventual outcome.

The EA has deemed that the risk posed by permitted facilities that handle biowaste is greater than other industries and it is within the EAs right to make that judgement. We consider than the EA has adopted a precautionary principle approach in setting their Appropriate Measures guidance. It would be helpful if the EA would set out its reasoning to further understand this risk assessment basis.

At PR19 the timing of the regulatory change, between draft and final determination, resulted in a disparity in funding defined for IED compliance between companies. Alignment between environmental and economic frameworks is essential and we recommend consideration should be given to how funding for IED and Appropriate Measures can be included in PR24, given investment will go beyond 2024. The materiality of this investment need, in context to an entire industry spend of c.£2.4bn (PR19 total), makes it evident that it is essential companies have adequate resources to deliver improvements in realistic timescales.

Beyond PR24, it is clear that the changing regulation of the Bioresources treatment has implications for how investment requirements are identified within the Bioresources price control. The regulation of sewage sludge, now sitting within the EPR framework, means that there can be frequent and numerous changes and updates made to the EPR framework which are within the EA's control rather than requiring primary legislative change, for example, changes to guidance or accompanying website text. This can lead to new or tighter standards being implemented quickly and these types of changes cannot be predicted or accounted for in WaSC 5-year investment planning cycles.

We would suggest the water sector discusses with the EA the extension of the 4-year hands-off period, (already in place for the wastewater discharge permits) for waste permits following change to a permit or guidance. Given that BAT will change over time, driven by changes in technology and tightening of permit requirements, current waste permits will periodically change. It is therefore recommended that 'sludge permit' investment planning is considered more akin to wastewater discharge permits, in that it is clearly defined in the WINEP with associated modelling and clearly mapped out deliverables. This will ensure that regulators and the Water Industry are able to work collaboratively to deliver the best environment outcomes, at the most efficient cost for customers in an agreed and realistically deployable timeframe.

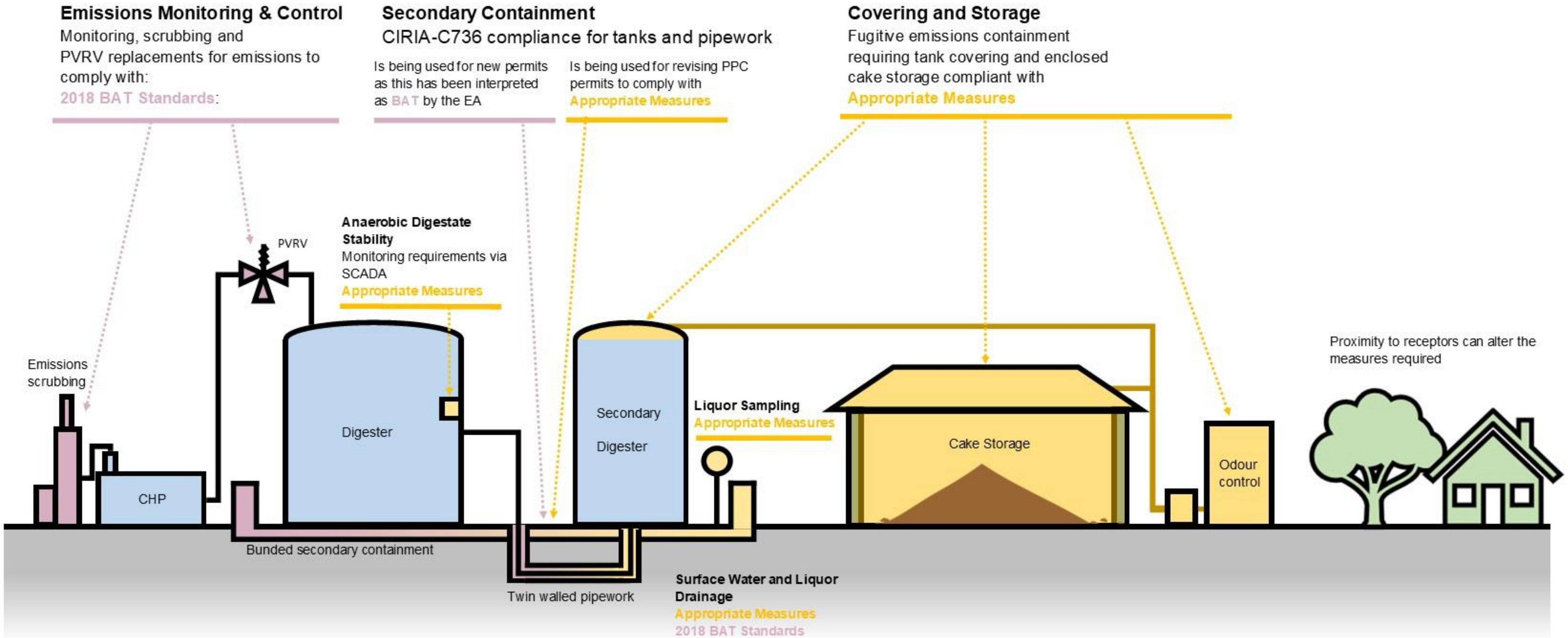

Figure 1-1: Illustrated Impacts of Appropriate Measures and BAT 2018 Standards

2. Introduction

The EU Industrial Emissions Directive (IED) [1], as transposed into UK law under the Environmental Permitting Regulations [2], is the main instrument to regulate pollutants to reduce emissions to air, land and water from industrial installations. The IED crucially expanded the requirements of the original Integrated Pollution Prevention and Control (IPPC) Directive to cover the biological treatment of sewage sludge for recovery (i.e., Anaerobic Digestion (AD)) where processes operate above threshold levels.

Whilst the sector has broadly accepted the applicability of IED to sewage sludge treatment activities, Atkins understands that the deliverability of IED compliance within AMP7 has been questioned by the industry. The key areas of concern are in terms of what is required and what should be prioritised, both from a supply chain, funding perspective and deliverability within prescribed timescales. Water UK is therefore seeking independent technical consultancy advice regarding the Environment Agency's implementation of IED, including any perceived scope creep or where there is lack of clarity.

Atkins has been asked to provide an impartial technical supporting document, which will identify a set of recommendations for escalating to the relevant parties in the Environmental Agency (EA). The intention is that this will support Director level discussions between Industry, the EA and Ofwat, to establish and agree a collaborative way forward which delivers IED compliance in a consistent manner, with funding appropriately apportioned across AMP7 and future AMPs.

3. Environmental Regulatory Framework

The way Bioresources is regulated is changing significantly. Historically, sewage sludge treatment for recovery within the curtilage of a Sewage Treatment Works (STW) and recovery to land benefited from an exclusion from the EU Waste Framework Directive (WFD) by virtue of:

- The treatment being covered by the Urban Wastewater Treatment Directive (UWWTD) [3]
- The recovery of biosolids to agricultural land being covered under the Sewage Sludge Directive (SSD) as implemented by the Sludge (Use in Agriculture) Regulations (SUiAR) [4]

However, it is important to note that the EA has a legal obligation to reduce emissions that could damage or be of risk to human health and the wider environment and it is their statutory obligation to do so. It is because of this that the EA is responsible for enacting the IED across all industries that are covered by the regulations.

3.1. Change Impacting the End-to-End Bioresources Activity

There have been two recent regulatory changes impacting end-to-end Bioresources activities:

1. The application of the IED regime to Sludge Treatment Centres (STCs) undertaking the biological treatment of waste exceeding 100 tonnes per day for recovery (i.e., Anaerobic Digestion) and the EA seeking Environmental Permits through the Environmental Permitting Regulations (EPR) [2]
2. As an associated initiative, the Environment Agency (EA) have published a Policy Paper 'Strategy for safe and sustainable sludge use' [5] which highlights their intention to move the use of biosolids in agriculture within the Environmental Permitting Regulations (EPR) with permits as a delivery mechanism. The EA continue to work with Defra, Water UK, the waste industry and others to develop the strategy with the aim to submit a request for legislative change in mid-2023 to revoke SUiAR (exact date and extent to these changes is still to be confirmed).

There have been ongoing discussions around how sewage sludge is classified in terms of its waste categorisation for a number of years. Although the IED was transposed in England and Wales by amendments to the EPR in February 2013, there was initial uncertainty surrounding the applicability of this directive to sewage sludge treatment and management, on the basis that:

- Previously the AD of sewage sludge was **not** covered by the former IPPC Directive (which was subsumed into IED), unless the resulting digestate was produced for disposal (e.g., landfill / incineration).
- Sewage sludge treatment and management activities were deemed already covered under the UWWTD and therefore excluded from the IED scope (known as the "UWWTD exclusion").

A review by the EA was undertaken [6] to determine the applicability of the IED to STWs undertaking the biological treatment of sewage sludge and the EA set out an interim position which deferred the need for water companies to apply for IED-EPR permits. On 9th July 2019, Water and Sewerage Companies (WaSCs) received an official letter from Sarah Chare (Director of Operations) at the EA formally confirming the requirement to apply for permits following a paper tabled at an EA / Water UK Strategic Steering Group meeting on 2nd April 2019. The original deadline for compliance was August 2022 and this has moved to a 'best endeavours' compliance approach by the EA to December 2024 to account for permitting delays.

This identified the following number of facilities as demonstrated by Table 3-1 below.

Table 3-1: IED Sites by Company

	Total IED Sites	Existing Waste Installations
Anglian	10	0
Dŵr Cymru	1	0
Northumbrian	1	1
Severn Trent	27	9
Southern	16	1
South West	5	0
Thames	25	0
United Utilities	31	24
Wessex	5	0
Yorkshire	14	1
Total	**136**	**37**

Source: Competition and Markets Authority [26]

3.2. Implications of Compliance with the IED

This change in implementation of IED has had significant implications for the whole water industry in AMP7. It introduced a requirement for sites now regulated under IED to meet the additional requirements to increase environmental protection to meet Best Available Techniques (BAT) conclusions for waste treatment under IED for the first time.

The European Commission defines a set of Best Available Techniques (BAT) to be applied for the specific installations covered within the IED scope, which means the best economically and technically viable techniques to prevent, minimise and reduce emissions to air, water, and land. AD Installations must comply with the EU Waste Treatment BAT and this is articulated in best available technique reference documents (BREF) issued in August 2018 [7] [8] [9] as guidance for implementation and act as the basis of the emissions limits placed within Environmental Permits. BREFs and the BAT conclusions they contain form the basis for permitting 'installations'. As these BAT conclusions were established in 2018, and at the time the Water Industry was advised about IED implementation (2019) these formed the standard to demonstrate IED compliance.

Existing EU BAT continues to have effect in the UK and WaSCs will have until 4 years after BAT conclusions are issued to comply with the requirements or seek a derogation from the requirements. This means providing evidence of why the proposed technology is as good or better than BAT.

Subsequent to all WASCs submitting IED permit applications, the Appropriate Measures for the Biological Treatment of Waste was published by the Environment Agency on 21st September 2022. There is a lot of overlap between BAT for waste installation facilities and necessary measures for waste operation facilities. In England and Wales, this is stipulated through the Environment Agency 'Biological waste treatment: appropriate measures for permitted facilities' guidance [10] (also known as 'Appropriate Measures'). This covers the technologies applied, in addition to processes governing the design, construction, operation & maintenance and decommissioning of the assets used to manage the waste. The EA uses the term 'appropriate measures' to cover both sets of requirements.

AD facilities require environmental permits under the IED, and the EA implements this through the EPR framework which uses a risk-based approach ranging from exemption through to 'lower risk' Standard Rules permits and bespoke permits. If an operator wants to propose an alternative measure which differs from Appropriate Measures, the guidance states this must achieve the same level of environmental protection and evidence must be provided as to why the alternative is equivalent to (or better than) the measures proposed in the guidance. In certain situations, the EA may deem that a higher standard of environmental protection may be needed, e.g., proximity to sensitive receptors etc. In all cases the EA makes the decision over whether an intervention meets the requirements.

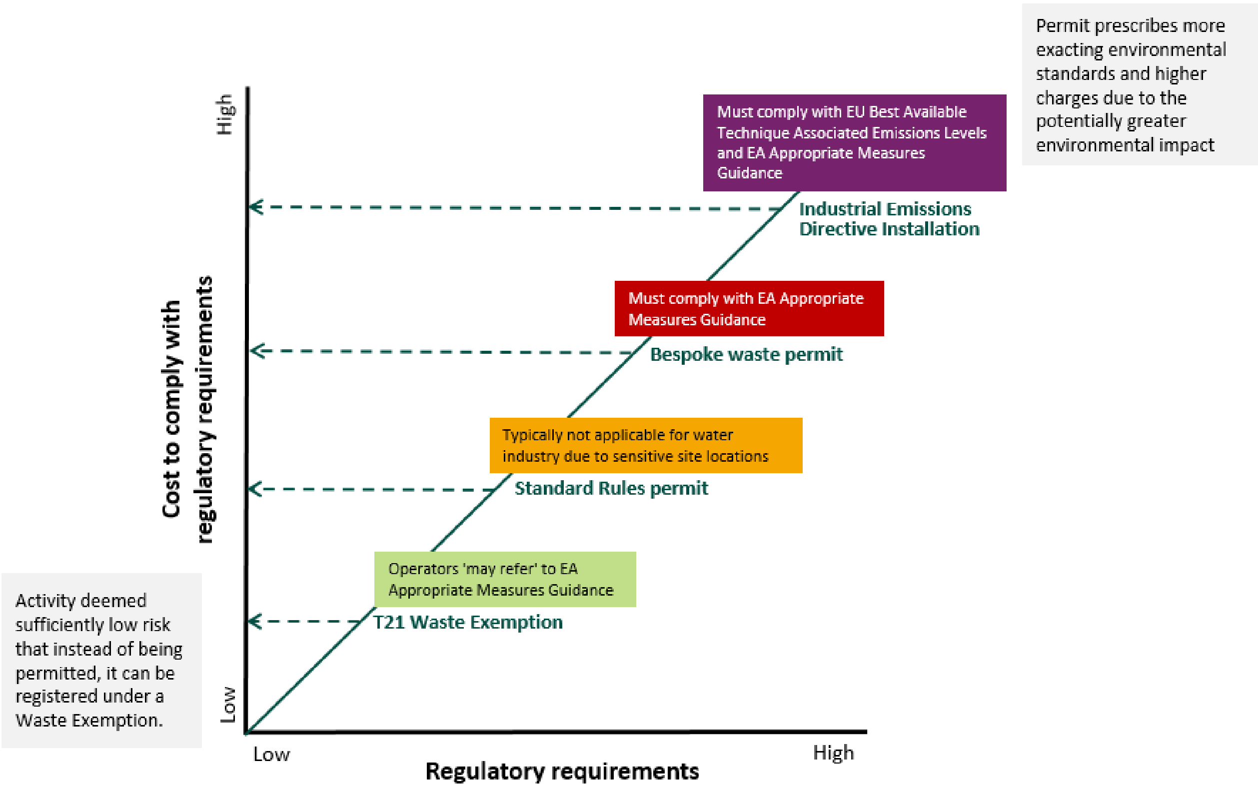

Figure 3-1: Regulatory Requirements and Costs to Comply

Source: United Utilities produced visual 2023 [11]

Timescales for compliance with the EA's Appropriate Measures guidance at existing facilities are not currently set out within the guidance. With regard to standard, 'good practice' requirements it states:

"Where improvements are relatively low cost, operators should prioritise them based on the risk posed by their facility. They should implement these improvements as soon as possible and no later than 12 months after the publication date of this guidance".

With regard to long-term and capital-intensive improvements it goes on to state:

"Operators should periodically review, modify and update management, process systems or equipment in line with existing permit conditions. This may include periodic capital investment".

It is of note that other published Appropriate Measures guidance, for other wastes, treatment types or industries, set out the common expectation on timescales for compliance with long-term and capital-intensive improvement:

“Operators should complete these improvements as soon as practicable and within 3 years”. [12, 13]

This statement is omitted from the guidance for biological waste treatment. No evidence or reasoning has been provided as to why this is excluded. The omission of time periods may indicate that the EA accept that the timescales for implementation must be flexible and depend on the specifics of each case (e.g., the nature and complexity of the works).

3.3. How the Waste Framework “works differently”

The UK will be implementing its own BREF/BAT Conclusions [14] going forward and permit variations will be required in the future to consider any changes associated with updates e.g., stricter Emission Limit Values (ELVs) etc. This mechanism is already ‘live’ and BAT Conclusions will be published as statutory instruments and used as the basis for permit conditions for industry, this will likely be an EA-initiated permit variation. The UK regime will retain the four-year timeframe for implementing BAT. While the BREF/BAT conclusions for some sectors are currently being reviewed, waste treatment is not included in this first batch of reviews to implement UK guidance.

There are frequent and numerous changes and updates made to the EPR framework which are within the EA’s control that do not require primary legislative change, for example, changes to guidance or accompanying website text. When the EA wants to up-date / change an existing set of Standard Rules, they do not normally consult on minor administrative changes, but there is a consultation period for substantive changes to existing standard rules which is normally a minimum of 28 days with a further 12 weeks to follow the revised rules [15]. If operators cannot meet the new requirements, or if the rule set is being removed, they must apply for a bespoke permit. This can lead to new or tighter standards being implemented with a quick turnaround and these types of changes cannot be predicted or accounted for in WaSC 5-year investment planning cycles. This can leave the operator with limited time to respond, especially if multiple facilities are impacted by the changes, and poses challenges in terms of the practicality and funding of delivery.

Therefore, for the Water Industry the key issues aligning with the above are:

1. There is no choice around not doing the activity and doing something different – sewage sludge management must continue to process the material received.
2. Funding is regulated for WaSCs as they have to operate within 5-year agreement periods, so funding will be specifically allocated rather than available if needed to manage change.

STCs that have the same assets may have differing permit requirements under EPR. These differences are driven by an assessment based on the potential risk to the local receptors, it includes; the age of the assets, treatment complexity, size and nature of the activities being carried out and the location of the site. The European Commission (EC) approach thorough BREF is based around a risk-based assessment pertaining to a specific site and its impact on local receptors. The guidance is intended to allow flexibility to change as improvements in BAT are developed. The EA framework is intended to allow the same, i.e., flexibility to make minor changes; however as stated in the previous paragraph this could lead to changes occurring outside WaSC funding cycles.

There is debate as to whether compliance with government advice and guidance has the force of law and there are complexities from the interaction between so called "soft law" (i.e., government advice and guidance) and "hard law" (i.e., legislation and regulations) [16]. To have the force of law in this context, the Court held that guidance or advice would need statutory authority. This was considered in the test case between The Financial Conduct Authority v Arch and Others [2020] EWHC 2448 (Comm). Whilst guidance itself is not law and does not operate to override legal duties or obligations, government advice and guidance, may in practice, have the “force of law” and the EA Appropriate Measures guidance makes it clear that the standards are enforceable, and these measures are likened to Environmental Permit conditions and associated compliance with those.

4. Impact of 'Appropriate Measures for Biological Treatment of Waste'

4.1. Review of Technical Disparities between BAT and EA Guidance

This section summarises the review and direct comparison of Appropriate Measures for the Biological Treatment of Waste (here after Appropriate Measures) against the applicable BAT reference (BREF) document from the European Commission (EC) over a number of key areas (see Table 4-1). BREF for Waste Treatment was published in 2018 to support the implementation of the IED and Appropriate Measures was published by the Environment Agency in September 2022. The following were also studied for this review given that they are also live and are applicable reference documents from the EC for IED implementation:

- BREF for Emissions from Storage (2006) [8] which addresses the storage and the transfer/handling of liquids, liquefied gases and solids, regardless of the sector or industry; and
- the Joint Research Council (JRC) Reference Report on Monitoring (ROM) of Emissions to Air and Water from IED Installations (2018) [9] which provides guidance for the application of the BAT conclusions on monitoring in order to help competent authorities to define monitoring requirements in the permits of IED installations.

When consulting on an earlier version of Appropriate Measures, the EA's September 2019 response document 'Biowaste permits: review to improve environmental outcomes' the EA has stated at that time '*Appropriate Measures are not too different from BAT. There is nothing new in the BREF operational measures that we have not already considered as Appropriate Measures*.' [17] Responses to the EA on Appropriate Measure from WaSCs generally provided feedback that it was too prescriptive with wide reaching requirements [18].

Table 4-1 below summarises the high-level findings of the review. It demonstrates where requirements, in our expert opinion, set out by BREF and Appropriate Measures are very similar (green), where Appropriate Measures requirements go above those set out by BREF (amber) or where Appropriate Measures requirements significantly exceed those of BREF (red).

Table 4-1: Summary of BREF for Waste Treatment / Appropriate Measures Comparison

Focus Area	Sub-Areas
Covering / Storage	Volume / residence time
	Storage areas
	Covering
	Storage tank design
	Lagoons
	Handling / transfer
Primary Containment / Failure Modelling	Monitoring
	Maintenance planning
	Operational areas
Secondary Containment	Minimising risks
Emissions Control / Monitoring	General
	Bioaerosols
	Point source emissions
	Biofilters
	Pre-treatment abatement scrubbers
	Fugitive emissions
Liquor Sampling	Sample analysis
Surface Water / Liquor Drainage	Infrastructure and inspection
Anaerobic Digestate Stability	Parameter monitoring / maintenance

Overall, it was found that Appropriate Measures tends to set out blanket requirements for all equipment / procedures using terminology such as 'you must', whereas BAT implements a more risk-based approach including terminology that is open to flexibility and practicability. BAT gives more leniency for existing facilities in implementing the full range of best practices, recognising the constraints posed by existing layout / infrastructure.

Appropriate Measures only recognises this in some instances, for example, new containment structures must be built in line with CIRIA C736 whereas existing containment should be assessed against CIRIA C736 or an approved industry standard to develop an improvement plan.

The EA has deemed that the risk posed by permitted facilities that handle biowaste is higher and it is within the EAs right to make that judgement. We consider that the EA has adopted a precautionary principle approach in setting their Appropriate Measures guidance. It would be helpful for the EA to set out its reasoning to further understand this risk assessment basis.

The sub-sections below summarise the requirements prescribed by Appropriate Measures / BAT across each of the areas of focus, and these summaries provide the evidence and narrative to support the red, amber and green ratings applied to each of the focus areas in Table 4-1 above.

4.1.1. Covering and Storage

4.1.1.1. Volume / Residence Time

Table 4-2: Requirements on Volume / Residence Time as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
Waste storage capacity of the site is clearly stated and not exceeded, with monitoring in place.	Wastes should be treated on or removed from site within one month preferably, or six months as a maximum. Maximum residence time of untreated wastes should be clearly stated and not exceeded.	Wastes must not be over accumulated and should be treated or removed from site as soon as possible. No specific timeframe given for maximum residence time.

Appropriate Measures and BREF are largely comparable for volume and residence time requirements hence the **green** rating for this sub-area in Table 4.1

4.1.1.2. Storage Areas

Table 4-3: Requirements on Storage Areas as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
Waste should be stored on an impermeable surface with enclosed drainage.	Storage on an impermeable surface with enclosed drainage is applicable to bulk storage vessels and highly putrescible wastes.	Storage on an impermeable surface with enclosed drainage is applicable to all waste storage areas.
	Where possible, highly putrescible wastes should be contained within an enclosed building with ventilation and emissions abatement, however, this can be substituted by being treated within a maximum period of 24 hours in some instances.	*'Highly putrescible wastes, including odorous and ammonia-rich wastes'* must be stored in a contained or enclosed building.
		Storage areas must adhere to CIRIA C736 recommendations. This prescribes a greater level of detail for storage area design, as outlined in Section 5.3 and Appendix A1, based on a risk-based approach.

Appropriate measures refers to 'Highly putrescible wastes, including odorous and ammonia-rich wastes' which must be stored in a contained or enclosed building; the latter section of this clause goes beyond the original BREF wording which implies products prior to treatment. Post digested sludge has been stabilised and therefore should no longer be highly putrescible, however it can still be odorous and ammonia-rich and therefore is open to interpretation as to whether storage buildings need to be fully enclosed. However, it should be noted that if there is concern about offense caused to local receptors this will also be picked up through local planning conditions.

CIRIA C736 was originally published in 1997 as "R164 Design of containment systems for the prevention of water pollution from industrial incidents". The guide was revised and updated, in 2014, to reflect changes in legislation, construction design and practice and lessons learned from a number of incidents (particularly Buncefield), near misses and inspections. Therefore, the concepts pre-date IED BREF and Appropriate Measures. Guidance is provided on the design, and construction of new secondary containment systems and also the inspection, maintenance, repair, extension and upgrading of existing installations. It advocates a risk-based approach to managing the storage of inventory.

The retrofitting of the most onerous elements of the CIRIA standard (i.e., application of design of new sites rather than risk-based approach around retrofitting) to existing facilities is the key driver of cost under this item. For example, not taking into consideration the material of construction of tanks (concrete) and the risk of failure (very low), may negate the need for physical secondary containment and be managed through control systems. This represents a significant change compared to BREF and hence the **'red'** rating in Table 4.1. Furthermore, the extent for retrospective application of CIRIA C736 requires clarification when considering the type of waste and the related cost of completing works to the required standard. Guidance on what may be considered appropriate retrospective solutions or to what extent the use of risk assessments would be accommodated by the EA is required.

4.1.1.3. Covering

Table 4-4: Requirements on Covering as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
	Risk-based approach towards the implementation of covering.	Blanket approach towards the implementation of covering.
	Waste should be stored and treated in covered areas, depending on the risk it poses to soil / water. Enclosed storage reflects best practice however it is recognised that open tanks may be required in some cases. In particular it caveats that 'typically, the waste and containers that are not sensitive to light, heat, extreme ambient temperatures or water ingress are excluded' from covering requirements and in this case 'adequate bunding of storage areas and containment / treatment of water run-off is usually enough to ensure effective environmental protection.'	For new facilities, '*all tanks, vessels or lagoon that store or treat hazardous or liquid wastes*' must be covered with fixed covers. For new and existing facilities all bulk storage tanks must be covered and, as far as possible, all waste containerised. Any transfer or management activities must be performed under cover and any activities that may produce emissions must be facilitated within an enclosed building with air extraction and abatement.

BREF specifies a risk-based approach to covering and that waste should be stored and treated in covered areas, depending on the risk it poses to soil / water, it also recognises that open tanks may be required in some cases. Appropriate Measures goes beyond this by requiring covering for all bulk storage tanks and for transfer / management areas where these 'may produce emissions'. Given the ambiguity of this, it may be challenging to decipher what may be appropriately excluded. This represents a step change compared to BREF which will drive additional compliance costs to cover and hence the **'red'** rating in Table 4.1

4.1.1.4. Storage Tank Design

Table 4-5: Requirements on Storage Tank Design as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
	Storage tank design should give consideration to the physio-chemical properties of the material being stored, operational processes required for management, maintenance requirements, risk mitigation, past experiences in storage of the material and considerations for firefighting operations. Depending on the risks posed to soil / water, tanks and vessels should be installed with overflow detectors and / or overflow pipes connected to a contained drainage system.	All storage tank design must adhere to CIRIA C736 (see Section 5.3). The design requirements are stipulated through reference to the relevant British Standards (e.g., BS EN 14015:2004 for welded steel tanks) and codes of practice for both above ground and below-ground tanks suitable for containment of the appropriate substance. CIRIA C736 also covers secondary containment requirements (where applicable) of the primary storage vessel, including drainage, leak detection, inspection and maintenance plans, proximity to structures / equipment within the containment and considerations for firefighting operations.

Again, the retrofitting of the CIRIA standard (for design of new sites) to existing facilities is the key driver of cost under this item. This represents a step change compared to BREF and hence the **'red'** rating in Table 4.1.

4.1.1.5. Lagoons

Table 4-6: Requirements on Lagoons as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
	Lagoon requirements are based on the risks posed by the waste. Sufficient freeboard must be maintained when a basin / lagoon is not covered. If emissions to air are significant, a plastic, floating or rigid cover should be used. Where there is a risk of soil contamination, an impermeable barrier e.g., clay layer / flexible membrane should be applied.	Blanket requirements for lagoons are given, based on whether these are new or existing. New lagoons must always maintain 750mm of freeboard and have 'an engineered, impermeable, rigid or flexible cover.' Existing lagoons must always maintain 750mm of freeboard and have 'an engineered, impermeable, rigid or flexible cover' or 'floating covers or a crust.' Existing lagoons must be risk-assessed by a qualified engineer with any issues that are identified resolved.

These requirements for Appropriate Measures are more prescriptive than BREF and reflects the **'amber'** rating in Table 4.1, and are aligned with the more onerous requirements detailed in CIRIA C736.

4.1.1.6. Handling / Transfer

Table 4-7: Requirements on Handling / Transfer as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
There must be a documented process for waste handling / transfer activities, and a dedicated area for their performance.	Storage areas should be located in a way that minimises unnecessary handling of wastes.	The design and operation of facilities must be set up to minimise waste handling.
	Waste is treated under cover *depending on* the risks it poses to soil / water.	Waste is managed in a covered area.
	Wastes that may generate diffuse emissions are stored, treated and handled in an enclosed building, depending on the expected type of emissions.	If an activity could produce emissions, it must be performed in an enclosed building with air extraction, abatement and drainage.

This requirements for Appropriate Measures are more prescriptive than BREF which takes a risk-based approach and reflects the **'amber'** rating in Table 4.1.

4.1.2. Containment and Failure Modelling

4.1.2.1. Monitoring and Maintenance Planning

Table 4-8: Requirements on Maintenance Planning as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
Implementation of manual or automatic monitoring of storage equipment is required in order to 'provide sufficient early warning of system failures which may lead to containment failing'.		
Implementation of manual or automatic monitoring of storage equipment in order to 'provide sufficient early warning of system failures which may lead to containment failing'.	There must be a preventative approach to maintenance, control and testing and a regular inspection and maintenance programme. JRC Reference Report on Monitoring of Emissions to Air and Water from IED Installations (guidance for BAT implementation), suggests that a proactive maintenance plan and risk-based inspection plan, e.g., the risk and reliability approach [9], should be determined and followed.	There must be a scheduled inspection, maintenance and monitoring programme for all equipment, in line with manufacturers' guidelines

The approach set out by Appropriate Measures is likely to be more onerous in this regard as manufacturers' guidelines often require more regular inspection / maintenance than would be required based on performance. However, maintenance and monitoring planning have been deemed comparable hence the rating **'green'** in Table 4.1.

4.1.2.2. Operational Areas

Table 4-9: Requirements on Operational Areas as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
	Operational areas are made impermeable to the concerned liquids and connected to a drainage system depending on the risks posed to soil / water and are maintained to ensure that any leaks / spillages are prevented or swiftly actioned. Where there is an overflow to the sewer, automatic monitoring systems are likely to be required.	Operational areas must all have an impermeable surface, spill containment kerbs, sealed construction joints and be connected to a contained drainage system.

This requirements for Appropriate Measures are more prescriptive than BREF which takes a risk-based approach and reflects the **'amber'** rating in Table 4.1. BREF would allow and assessment of the failure mode (e.g., likelihood of catastrophic failure verse leakage, consideration of the tank material), whereas Appropriate Measures dictates certain requirements.

4.1.3. Secondary Containment

4.1.3.1. Minimising Risks

Table 4-10: Requirements on Secondary Containment as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
	The use of below-ground equipment is minimised. Where these are used secondary containment may be needed depending on the risks posed to soil / water.	Below-ground tanks and components must all have secondary containment and an engineered leak detection system.
	Secondary containment is required for above-ground tanks where wastes pose a significant risk of pollution to soil or water.	Secondary containment is required for all above-ground tanks.
	In all instances, the installation of secondary containment may be limited in the case of existing plants.	Secondary containment is required where there is a significant risk based on the sensitivity of potential receptors.
	Emissions from Storage [8] (guidance for BAT implementation) specifies that secondary containment must be coated with an impermeable material and have the same height as the maximum liquid level, a total capacity 25% greater than the capacity of the associated tank or sufficient capacity to accommodate the loss of containment of the largest tank within the area covered as applicable.	For new facilities, secondary containment is in adherence with CIRIA C736 or an equivalent standard. For existing sites, a risk-based assessment should be performed against CIRIA C736 or an approved standard and an improvement programme / process monitoring implemented to control process releases. Secondary containment is required to have adequate capacity for spillages

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
		/ leakages or have tanker connection points within the bund. Further automatic and manual inspection requirements are prescribed.

The EA expects that relevant guidance (e.g., CIRIA C736 detailed further in Section 5.3) is adhered to for new and existing facilities and appropriate tools (e.g., the Anaerobic Digestion and Bioresources Association (ADBA) spreadsheet) are used in evidencing how IED compliance will be achieved.

Whilst both Appropriate Measures and BREF require secondary containment, having to use these methods outlined above in Appropriate Measures guidance for existing facilities and permit revisions is the main difference which is driving investment in retrofitting.

In addition, within BREF it is stated that secondary containment should be able to accommodate the total volume from the largest tank within the containment area. Moreover, the 25% of total capacity rule also specified by BREF is used as the recommended minimum for intermediate bulk storage vessels only in CIRIA C736. This specifies situations in which the 25% rule must be implemented, however EA has advised that adherence to the more conservative 25% rule is expected.

The differences between BREF and CIRIA C736 may result in costs for compliance beyond those if only BREF requirements were met. CIRIA C736 and ABDA guidance follows a more conservative, blanket approach to risk assessment, delivering a singular overall site classification designed with higher levels of containment than may be required for individual areas. For example, areas close to a sensitive receptor require higher classification than areas with no pathway to a sensitive receptor, rather than accounting for the risks posed by site operations and inventory. The risk rating of a source does not include qualitative factors such as the risks of spillage reaching a sensitive receptor, for which remedial measures could be implemented where necessary. Assuming a 'high' environmental hazard rating results in overall sites becoming classified under Class 2 and as such additional infrastructure and remediation may be required in cases where Class 1 would be sufficient.

This represents a step change in costs compared to BREF and hence the **'red'** rating in Table 4.1.

4.1.4. Emissions Control and Monitoring

4.1.4.1. General

Table 4-11: Requirements on General Emissions Control and Monitoring as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
Creation of an emissions inventory to characterise all emissions to air / water and an odour management plan, with adherence to EN13725, EN 16841 1/2 or an alternative ISO / international standard for the monitoring of odour.	Required '*monitoring of key process parameters at key locations*'.	Emission limits / monitoring requirements may be set in permits, based on the emissions inventory and environmental risk assessment. These may be in reference to specific processes / emissions.
	High integrity equipment should be used, e.g., valves, gaskets, pumps, although adds this may be restricted in the case of existing plants due to operability requirements.	High integrity components, e.g., seals or gaskets or leak test certificated Pressure Relief and Vacuum Relief Valves (PVRVs) must be used for emissions control.

Appropriate Measures and BREF are largely comparable for general emissions control and monitoring requirements hence the **'green'** rating for this sub-area in Table 4.1. However, it has been noted that there are significant changes with regards to liquor sampling from BREF in regard to the long list of determinants to analyse for and that emission limits may be applied to permits based on this monitoring (which does represent scope creep from BREF) - this is discussed further in 4.1.5.

4.1.4.2. Bioaerosols

Table 4-12: Requirements on the Emission and Monitoring of Bioaerosols as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
Identification of potential bioaerosol emission sources and implementation of measures to minimise their release.	No sampling methods / indicators for bioaerosols are specified, given a lack of international consensus on sampling methods / indicators, and on whether monitoring can be used effectively.	Monitoring of bioaerosols to ensure that control methods are performing effectively if the facility is located within 250m of a sensitive receptor.

It should be noted that other assets (outside the IED boundary) have the potential to generate bio-aerosols which then makes it difficult to be conclusive on whether an IED site would be meeting appropriate measure on occasions. The requirements for Appropriate Measures are more prescriptive than BREF which takes a risk-based approach and reflects the **'amber'** rating in Table 4.1.

4.1.4.3. Point Source Emissions

Table 4-13: Requirements on Point Source Emissions as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
The *'abatement of emissions using one / a combination of the following techniques:* • *bio filtration, bio trickling or bio scrubbing* • *scrubbing (for example wet or chemical)* • *adsorption, for example activated carbon* • *thermal oxidation* • *fabric filter – for mechanical biological treatment to remove dust'*	BREF does not specify monitoring requirements for the abatement system specifically, however for channelled emissions to the air, it cites three factors that should be monitored every 6 months – ammonia, hydrogen sulphide and odour. It does state that monitoring of ammonia and hydrogen sulphide can substitute for odour monitoring, and vice versa.	Monitoring and assessment to ensure that the abatement system is effective. An efficiency assessment of the abatement system must take place at least once a year with fourteen factors that may be included, such as pH, moisture content, back-pressure, gas flow, gas temperature, ammonia, hydrogen sulphide and odour. Odour control unit results are included in the installations annual reporting template. Procedures must be in place for responding to and managing any loss in abatement efficiency detected and for proactive maintenance of the abatement system.

Whilst BREF does state that monitoring of ammonia and hydrogen sulphide can substitute for odour monitoring, and vice versa, this has proven not to be the case – all three have to be monitored as per monitoring clauses in the two new IED permits received by two WaSCs. This will be more onerous in practice given the greater regularity of monitoring required and hence the **'amber'** rating in Table 4.1.

4.1.4.4. Biofilters

Table 4-14: Requirements on Biofilters as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
No significant difference in the effort required to implement either approach. Common requirements in terms of process and design of biofilters.	Specifies 5 monitoring parameters, including moisture content and medium pH, gas humidity and temperature and removal efficiency.	Specifies 15 monitoring parameters that should be observed, including inlet gas temperature and humidity, filter media moisture, pH and bacterial viability, thatching and compaction, vegetation and surface condition, and removal efficiency.

Both documents prescribe the same requirements in terms of process and design of biofilters. In terms of monitoring requirements. BREF gives fewer parameters for monitoring but in practice, it was considered that there would not be a significant difference in the effort required to implement either approach, hence the **'green'** rating in Table 4.1.

4.1.4.5. Pre-treatment Abatement Scrubbers

Table 4-15: Requirements on Pre-Treatment Abatement Scrubbers as Specified by Appropriate Measures and BREF

Common Point	BREF	Appropriate Measures
An acid, alkaline, or water scrubber may be required for gas pre-treatment prior to biofiltration.	No specific requirements for scrubbers beyond their implementation.	Additional prescriptions given around the selection of aqueous absorbing solutions, flow rates, and around monitoring processes and measures.

Both documents suggest that an acid, alkaline, or water scrubber may be required for gas pre-treatment prior to biofiltration. BREF does not make any specific requirements for scrubbers beyond their implementation, whereas Appropriate Measures makes additional prescriptions around the selection of aqueous absorbing solutions, flow rates, and around monitoring processes and measures, hence the **'amber'** rating in Table 4.1.

4.1.4.6. Fugitive Emissions

Table 4-16: Requirements on Fugitive Emissions as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
The segregation of water streams and recirculation of wash-waters / water collected from spillages / process water streams (e.g., liquors) as much as possible is required.	Employs a risk-based approach to storage tanks containment. It prescribes an impermeable surface for waste treatment areas depending on the risks posed to soil / water. According to the BREF on Emissions from Storage [8], BAT is to achieve a '*negligible risk level*' for soil pollution from the use of above ground tanks, although it suggests that an '*acceptable risk level*' may be sufficient in some situations.	All operational areas are required to have impermeable surfaces, spill containment kerbs, sealed construction joints and are connected to a contained drainage system
	For existing plants, the segregation of water streams can be	Documentation of all components and implementation of systems (to

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
	considered within the constraints associated with the existing layout of the collection system. This is particularly pertinent to sewage treatment works based on the layout of existing facilities where there is generally common drainage for wash-water returns to the head of the works and surface water. Furthermore, the degree of circulation may be '*limited by the water balance of the plant, the content of impurities (e.g., odorous compounds) and/or the characteristics of the water streams (e.g., nutrient content).*' The utilisation of subsurface components is minimised, however where these are used secondary containment may be required following a risk-based approach.	minimise and detect leaks) required for all subsurface components. This includes secondary containment and leakage detection for all pipework, sumps and storage vessels, and the implementation of an inspection and maintenance programme.

Appropriate Measures is more prescriptive in that all operational areas which have impermeable surfaces are connected to a contained drainage system, whereas BAT employs a risk-based approach to storage tanks containment. It prescribes an impermeable surface for waste treatment areas depending on the risks posed to soil / water. The JRC Reference Report on Monitoring of Emissions to Air and Water from IED Installations describes in more detail when secondary containment or an impervious barrier should be employed, based on the risk level and whether it is a new or existing tank [9].

Whilst both documents require the segregation of water streams and recirculation of wash-waters / water collected from spillages, BREF adds that for existing plants, the segregation of water streams can be considered within the constraints associated with the existing layout of the collection system. This is particularly pertinent to sewage treatment works based on the layout of existing facilities where there is generally common drainage for dewatering liquors, wash-water returns to the head of the works and surface water.

For subsurface structures, Appropriate Measures requires the documentation of all components and implementation of systems to minimise and detect leaks. BREF suggests that the utilisation of subsurface components is minimised, however where these are used secondary containment may be required following a risk-based approach (see Section 4.1.3).

The above represents a step change compared to BREF and hence the **'red'** rating in Table 4.1.

4.1.5. Liquor Sampling

4.1.5.1. Infrastructure and Inspection

Table 4-17: Requirements on Liquor Sampling as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
Customised sampling procedures required for bulk liquids, and both refer to the same standards for the sampling of wastes. Sampling points have an impermeable surface with self-contained drainage.	If a sampling plan following these methods cannot be achieved, sector-specific procedures for the waste in question may be followed instead.	

	Requires sample analysis to be facilitated by a laboratory capable of performing this in a timely manner at the required speed and that this may need to be on site depending on the equipment required.	Specifies that a UKAS approved laboratory must undertake the analysis of samples.

Both documents require customised sampling procedures for bulk liquids, and both refer to the same standards for the sampling of wastes. BREF caveats that if a sampling plan following these methods cannot be achieved, sector-specific procedures for the waste in question may be followed instead. Both documents further require that sampling points have an impermeable surface with self-contained drainage.

For the analysis of samples, BREF requires that this is facilitated by a laboratory capable of performing this in a timely manner at the required speed and that this may need to be on site depending on the equipment required. Appropriate Measures specifies that a UKAS approved laboratory must undertake the analysis of samples. There is a significant amount of liquor sampling, in terms of flows and chemicals prescribed by the EA, and this means that, given that these go to the head of an STW, there is a risk attached to this requirement. For example, if return liquors breach a limit, WaSCs would be asked to confirm an improvement plan to reduce this below ELVs, however there may be limited ways this could be reduced, if liquor treatment is deemed non-viable.

Whilst we have deemed the comparison of Appropriate Measures against BREF as **'amber'** rating in Table 4.1, it has become apparent that there are more detailed implications of guidance the EA is referring the sector to which is not directly mentioned in Appropriate Measures. The EA have pointed to 'Surface Water pollution risk assessment for your environmental permit' guidance (updated February 2022) [19] which includes discharging hazardous chemicals and elements to surface water. This is requiring >150 determinants for liquor sampling, many of which reportedly can't be tested for in UK labs. This could drive significant additional cost and risk.

4.1.6. Surface Water and Liquor Drainage

4.1.6.1. Parameter Monitoring / Maintenance

Table 4-18: Requirements on Surface Water and Liquor Drainage as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
Adequate drainage infrastructure needed capable of collecting surface drainage. Rainwater, wash waters and spillages must be collected and either recirculated or sent for further treatment. Drainage systems are isolated from flammable waste storage areas.	This is applicable to existing plants 'within the constraints associated with the layout of the water drainage system.' This is particularly pertinent to sewage treatment works based on the layout of existing facilities.	Requires a weekly inspection of all drainage channels.
Storage area infrastructure to contain contaminated run-off, prevent any mixing of incompatible wastes, and ensure that fire cannot spread. Bulk storage vessels must have self-contained drainage, and overflow pipes must be directed to a contained drainage system e.g., secondary containment or another vessel with suitable control measures in place.		

Both documents set out the need for adequate drainage infrastructure capable of collecting surface drainage. BREF caveats that this is applicable to existing plants 'within the constraints associated with the layout of the water drainage system.' This is particularly pertinent to sewage treatment works based on the layout of existing facilities. Both documents require that drainage systems are isolated from flammable waste storage areas. Appropriate Measures further requires a weekly inspection of all drainage channels. These requirements are broadly comparable hence the **'green'** rating in Table 4.1.

4.1.7. Anaerobic Digestate Stability

Table 4-19: Requirements on Anaerobic Digestate Stability as Specified by Appropriate Measures and BREF

Common Point	BREF Only Requirements	Appropriate Measures Only Requirements
Monitoring and control of the AD process and waste to ensure digestate stability required.	Suggests that the monitoring of parameters can be implemented '*depending on the feedstock, the anaerobic digestion system adopted and the use of digestate*.' Monitoring defined as including '*logging, checking and acting upon the data at frequent intervals, influenced by the rate of change in the process*.'	Monitoring and control of all factors, using SCADA equipment to record and display data for those that are continuously monitored. A daily visible inspection of digesters is stipulated, in addition to the installation of a hazardous gas warning system for feeding systems installed within buildings.
A common set of factors given for monitoring procedures, e.g., pH of the digester feed, temperature, liquid / foam levels.		Requires that digesters are kept within optimal operating temperatures to maintain stability, and that changes are made to feedstock and micro-nutrient dosing depending on recordings taken of process parameters. Installation of an alarm mechanism that automatically stops the feeding reactor in response to a gas pressure alarm is also required.

Both documents require the monitoring and control of the anaerobic digestion process and waste to ensure digestate stability, with a common set of factors given for monitoring procedures, e.g., pH of the digester feed, temperature, liquid / foam levels.

However, Appropriate Measures requires monitoring Residual Biogas Potential (RBP) and complying with limits in PAS110 (and the suggestion of lowering the limit from 0.45 to 0.25 by the EA for WaSCs). Secondly, we have been made aware of communication from the EA that if digestate is unstable, tanks must be covered and connected to biogas systems. If the digestate is stable, it can be covered in another way (odour abatement). Either way, tanks require covering so the monitoring is to inform what type of cover (there is no option for not covering tanks). This represents potential scope creep from the BREF guidance and that links back to the **'amber'** rating in Table 4.1

5. Suitability of 'Appropriate Measures' Technical Reference Documentation

The Appropriate Measures guidance references several other documents and some of these related guidance documents have been in use for a number of years prior to the publication of Appropriate Measures. We have reviewed these for completeness and to assess the suitability of those technical documents in establishing the standards to comply with Appropriate Measures requirements. This includes:

- The Practical Guide to AD (second edition) [20] was published by Anaerobic Digestion and Bioresources Association (ADBA) in 2017 which was recognised by the EA in promoting best practice.
- The 2014 Construction Industry Research and Information Association report *'Containment systems for the prevention of pollution'* (CIRIA C736) [21] provides guidance on the implementation of a hierarchal risk assessment and classification system for the prevention and mitigation of hazardous loss of containment from primary storage. CIRIA C736 is referenced in both Appropriate Measures and ADBA for recommendations related to the design and construction of secondary containment systems and upgrades of existing installations.
- Intensive Farming: How to comply with your environmental permit [22], was published by the EA in 2016 and applies to intensive farming but has some commonality with biowaste treatment.

The review of other documentation is not exhaustive and other examples of guidance may be available such as Surface water pollution risk assessment for your environmental permit [23] which covers liquor returns with additional requirements.

5.1.1. Headline summary

Appendix A summarises and directly compares the above-mentioned guidance documents in reference to the focus areas outlined in Section 4 (i.e., Appropriate Measures). The headline summary is as follows:

- ADBA guidance is not as comprehensive as the requirements of Appropriate Measures guidance. There is a possibility that Appropriate Measures may also drive investment in the wider AD sector. The guidance seems aimed at smaller, new build Anaerobic Digestion developments rather than existing WwTWs and may not be appropriate to apply when retrofitting to existing sites.
- Tank covering and storage alongside requirement for secondary containment to comply with CIRIA C736 drives the most significant requirements leading to a total capital investment of £2.0bn. In addition, where Appropriate Measures and ADBA require adherence to CIRIA C736, the guidance provided in the document can be considered more prescriptive than BREF for the determination of containment volume.
- Intensive Farming: How to Comply with your Environmental Permit guidance is not as comprehensive as the requirements of Appropriate Measures. There is a possibility that Appropriate Measures may also drive investment in the intensive farming sector.

Therefore, the implementation of Appropriate Measures guidance consistently across all applicable waste treatment activities and sectors will establish new levels of environmental protection above BREF 2018.

5.2. ADBA – The Practical Guide to AD, Second Edition

The ADBA guide sets out best practices across the design, operation, maintenance and decommissioning of AD facilities, based on scientific research, industry practices and legal documentation. In some areas the guide signals specific best practices to guide decision making and in others, e.g., environmental management / monitoring, it refers to the applicable legislative documents and their requirements. The guide is therefore not comprehensive in itself but does contain detailed recommendations across a number of areas. Some of these are drawn out in Appendix A to illustrate the scope of the guidance document in comparison to those reviewed in Section 4.

Information within the ADBA guide largely supports the planning and establishment of an AD facility, with some guidance around operating procedures. Where relevant, it signals to the appropriate regulations / standards to inform decision making. In particular it refers to following CIRIA C736, similarly to Appropriate Measures, for the design / construction of containment. Some areas covered in Section 4 were not covered by the guide, for example liquor sampling / surface water and liquor drainage.

Table 5-1: Summary of ADBA the Practical Guide to AD / Appropriate Measures Comparison

Focus Area Rating
Covering / Storage
Primary Containment / Failure Modelling
Secondary Containment
Emissions Control / Monitoring
Liquor Sampling
Surface Water / Liquor Drainage
Anaerobic Digestate Stability

Table 5-1 above demonstrates how the ADBA guidance compares with the requirements set out by Appropriate Measures. As above, it demonstrates where requirements, in our expert opinion, set out by ADBA and Appropriate Measures are very similar (green), where Appropriate Measures requirements go above those set out by ADBA (amber) or where Appropriate Measures requirements significantly exceed those of ADBA (red). The areas that ADBA guidance did not cover (Liquor Sampling; Surface Water / Liquor Drainage) were rated as grey on this basis.

5.3. CIRIA C736

CIRIA C736 was published in 2014 [21] to provide practical guidance on secondary containment systems around best practices on spill prevention, mitigation, and response. Adherence to CIRIA C736 is required across a number of areas in Appropriate Measures, including secondary containment, storage areas and storage tank design. Appendix A discusses the implications where observance of CIRIA C736 guidance is referenced in the implementation of Appropriate Measures, and how this compares to the requirements of BAT or other technical guidance documentation.

Table 5-2 summarises how guidance in CIRIA C736, as referenced for adherence by Appropriate Measures, compares with the requirements set out by BREF, specifically for contained storage systems and secondary containment. As above, it demonstrates where recommendations, in our expert opinion, set out by CIRIA C736 are very similar (green), where CIRIA C736 recommendations go above those set out by BREF (amber) or where CIRIA C736 recommendations significantly exceed those of BREF (red). Several focus areas were not applicable to CIRIA C736 given that it is a standard specific to containment systems, these were therefore not given a rating (grey).

It should be noted that CIRIA C736 was developed prior to BREF and Appropriate Measures were released and was based on UK containment experiences and as such does go further than the later recommendations of BREF; the EA have used CIRIA C736 in their interpretation of BREF requirements at a national level for all new permit applications and are now using Appropriate Measures for permit variations.

Table 5-2: Summary of CIRIA C736 / BREF Comparison

Focus Area Rating
Storage
Containment / Failure Modelling
Secondary Containment
Emissions Control / Monitoring - Not applicable in C736
Liquor Sampling - Not applicable in C736
Surface Water / Liquor Drainage
Anaerobic Digestate Stability - Not applicable in C736

In BREF it is stated that secondary containment should be able to accommodate the total volume from the largest tank within the containment area. Moreover, the 25% of total capacity rule also specified by BREF is used as the recommended minimum for intermediate bulk storage vessels only in CIRIA C736. Rather, the recommendations on estimating capacity for local systems (designated areas surrounding primary storage vessel to contain spills) follow a scenario-specific approach which accounts, where appropriate, for total loss of containment from primary storage, rainwater, firefighting agents, cooling water and dynamic effects.

It is noted that CIRIA describes secondary and tertiary containment, while the BREF only refers to secondary containment. CIRIA defines that secondary containment “minimises the consequences of failure of primary storage by preventing the uncontrolled spread of the inventory” and “is achieved by equipment that is external to and structurally independent of the primary storage”. CIRIA defines that Tertiary containment “minimises the consequences of a failure in the primary and secondary containment systems”.

CIRIA C736 has wide applicability, however Section 1.2 of the guidance describes issues that are not covered in the guide. This specifically states that “sewage and sewage effluents, farm waste and related materials” are excluded as “Stored inventory”.

The guidance also notes in Section 1.1.3 that the “costs of upgrading existing facilities might outweigh the environmental benefits, and therefore not be viable, or that other equally effective risk reduction measures to those suggested in this guidance may be implemented”.

5.4. Intensive Farming: How to Comply with your Environmental Permit

‘Intensive farming: How to comply with your environmental permit’ [22] was published by the EA in 2010 as a guidance note to the farming sector on the standards and measures it is expected to comply with in order to manage risks to air, land and water. This applies to farms regulated under the Environmental Permitting Regulations (EPR) [2], which require a bespoke permit to operate. Farms operating under this framework are expected to adhere to BAT and justify any departures from BAT to the EA on a site-specific basis. The requirements outlined in the document are considered the minimum conditions that should be met to achieve the objectives set out, as they apply to each facility. It notes that measures will be reviewed on the publication of future revisions to BREF notes.

The document specifies that all new facilities are expected to conform to the required standards, whereas existing plants will need to be upgraded to meet standards within a specified timescale. The types of potential upgrades (or improvement conditions) that may be required are categorised within the document, with timescales that are either 6 or 12 months for implementation relative to each category. It is noted that an alternative timescale can be used if agreed and specified by the EA.

Table 5-3: Summary of Intensive Farming Guidance / Appropriate Measures Comparison

Focus Area Rating
Covering / Storage
Containment / Failure Modelling
Secondary Containment
Emissions Control / Monitoring
Liquor Sampling
Surface Water / Liquor Drainage – Not comparable
Anaerobic Digestate Stability

Table 5-3 above demonstrates how the Intensive Farming guidance compares with the requirements set out by Appropriate Measures. As above, it demonstrates where requirements, in our expert opinion, set out by Intensive Farming guidance and Appropriate Measures are very similar (green), where Appropriate Measures requirements go above those set out by Intensive Farming guidance (amber) or where Appropriate Measures requirements significantly exceed those of Intensive Farming guidance (red). The areas that Intensive Farming guidance did not cover (Liquor Sampling; Anaerobic Digestate Stability) were rated as grey on this basis. Surface Water / Liquor Drainage was considered not directly comparable (grey) due to requirements being substantially different, based on the unique risks posed in the operating environments covered.

6. Collation of National Investment Programmes

To comply with BAT and Appropriate Measures, significant expenditure of capex and opex is predicted for both AMP7 and AMP8. In order to assess whether there was variability across sites, regions and companies Atkins conducted a review of all the planned and forecasted expenditure by WaSCs to enhance sites to meet these requirements. The expenditure projected for each WaSC for compliance with IED by site was collated by Atkins by asking WaSCs to complete the below information:

- Site (option to anonymise)
- Driver (BAT or Appropriate Measures)
- Intervention type
- Detailed description of intervention
- Capital cost
- Opex cost
- Implementation timescale

The overall aggregate investment by the industry based on available data to comply with Appropriate Measures and BAT is a total capex and one-off-opex expenditure of £2.0bn. This would be a growth in totex of over 80% compared to AMP7 Final Determinations. It should be noted that WaSCs are still exploring costs and many have not yet had permits and the associated improvement conditions determined. This results in there being potential increases or decreases in this value depending on the outcomes at these sites. This will also generate ongoing opex requirements: many companies were not able to provide ongoing opex estimates due to this uncertainty on requirements, however for the five companies that did this came to a total of £46m per year.

Based on the specific interventions detailed by the WaSCs in their submissions, overall spend has been divided for the purposes of comparison into several themes which (apart from permit application costs) align to the headings in Section 4.:

- Permit Application Costs
- Secondary Containment
- Covering and Storage
- Emissions Control and Monitoring
- Liquor Sampling
- Surface Water and Liquor Drainage
- Anaerobic Digestate Stability
- Other (minor capital works that enable multiple themes above)

The division of spend is shown in Figure 6-1 for all companies. Spend on covering storage to prevent fugitive emissions is the most significant of the spend items, with secondary containment the only other item with more than a 10% share of costs. It is important to note that due to the scale of investment included in this analysis even the costs with a small proportion are significant aggregate spends.

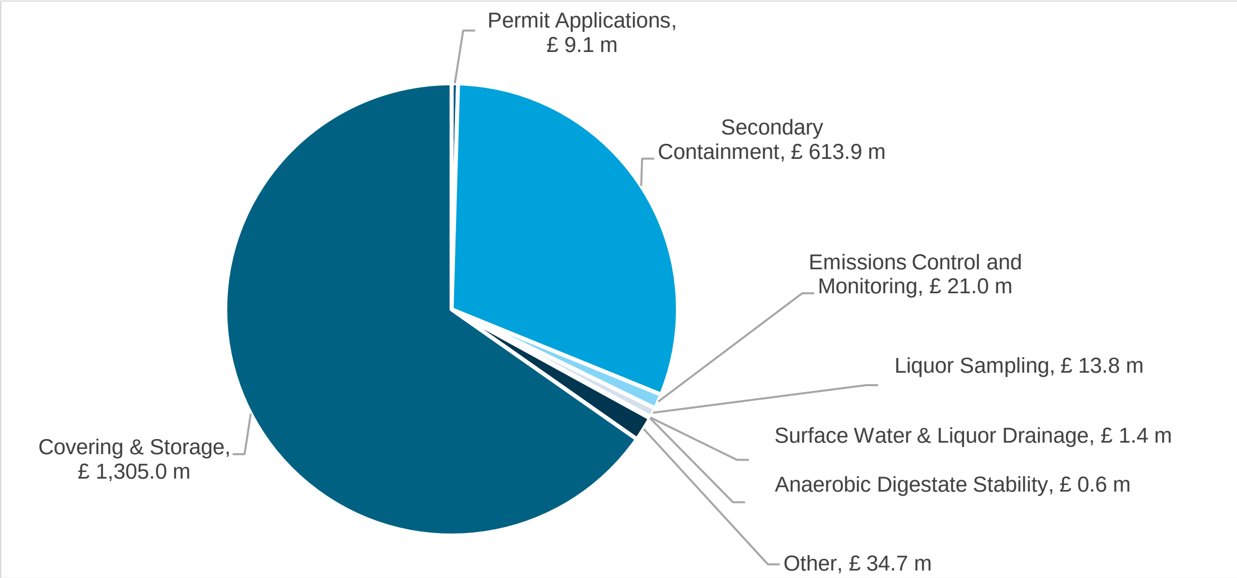

Figure 6-1: Overall Split of Capex and One-off Spend by Theme

This is also shown below in Figure 6-2 broken down by company, with significant variation in the ratio of spend across each of these themes.

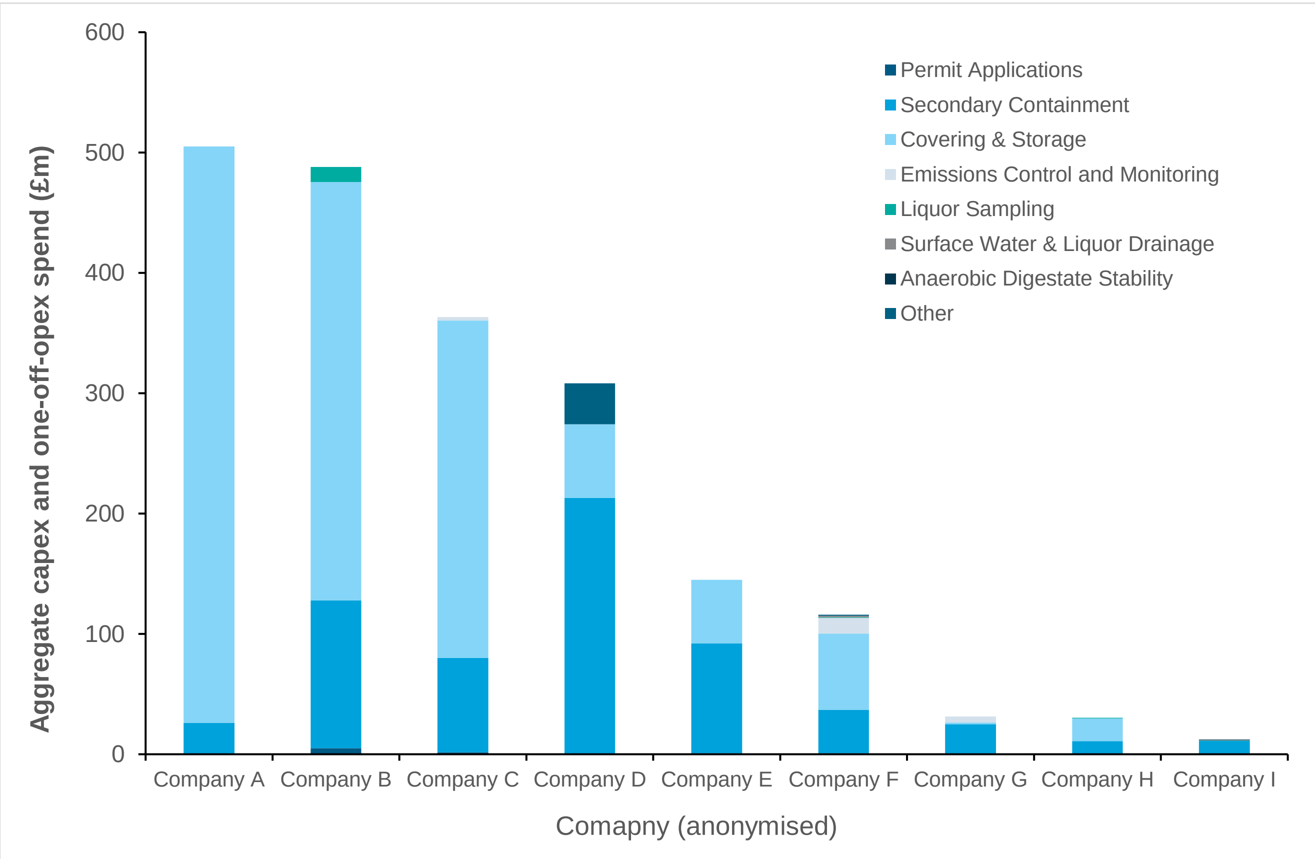

Figure 6-2: Aggregate One-off Spend by Company

Significant spend is driven by CIRIA-C736 and covering of storage. The division between appropriate measures-driven spend and BAT driven spend is also shown for each theme in Figure 6-3. The division of costs between Appropriate Measures and BAT is largely consistent across the spend themes, individual companies however differed on whether they cited their CIRIA-C736 related spend as being against BAT (7 of 9), Appropriate

Measures (1 of 9) or mixed (1 of 9). This is driven by the difference between the current permit status of each site: feedback from the WaSCs has indicated that the EA has interpreted CIRIA-C736 to be BAT for all new permit applications, whereas for the revision of existing PPC permits to comply with IED the compliance with Appropriate Measures causes CIRIA-C736 compliance to be required.

Storage covering was mostly aligned to Appropriate Measures, although some spend was allocated to BAT. This was driven by the significant differences seen in storage-covering technologies employed for biosolids cake. Cake storage ranged from completely enclosed and odour-controlled storage compliant with Appropriate Measures, though to Dutch-barn storage compliant with BAT. This was split by company, rather than being variable between companies and therefore appears to be differing interpretations of guidance rather than a difference in receptor presence. Sites were anonymised in many cases before submission to Atkins, so it could be that this is driven by the assets present on site.

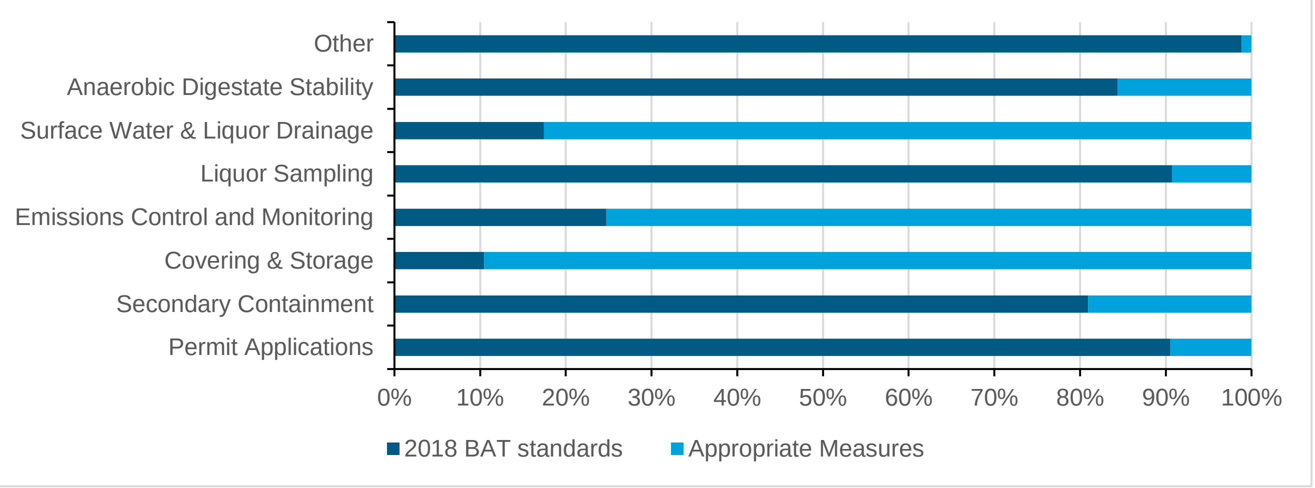

Figure 6-3: Spend Split between BAT 2018 and Appropriate Measures Focus Areas

There is significant site-by-site variation in the interventions required. This is driven by different starting points in terms of technologies employed, required standards at the time the site was constructed, local receptors and the guidance given by area teams at the EA to individual companies.

The spend by site, and the variability within companies is shown in Figure 6-4. Site variability within companies also varied significantly, validating that the starting point and site-specific geographies were a significant factor. The variability in the per-site numbers for each company is also striking. The number of sites where interventions were required as a proportion of a WaSC's total number of digestion sites was highly variable. There was also no consistency in treatment process, with interventions seen on sites with both advanced and conventional anaerobic digestion. This lack of consistency is to be expected due to the significantly different starting positions and receptors present on each site. The overall average per site is £17.8m, however company averages range from £50.5m to £6.1m per site.

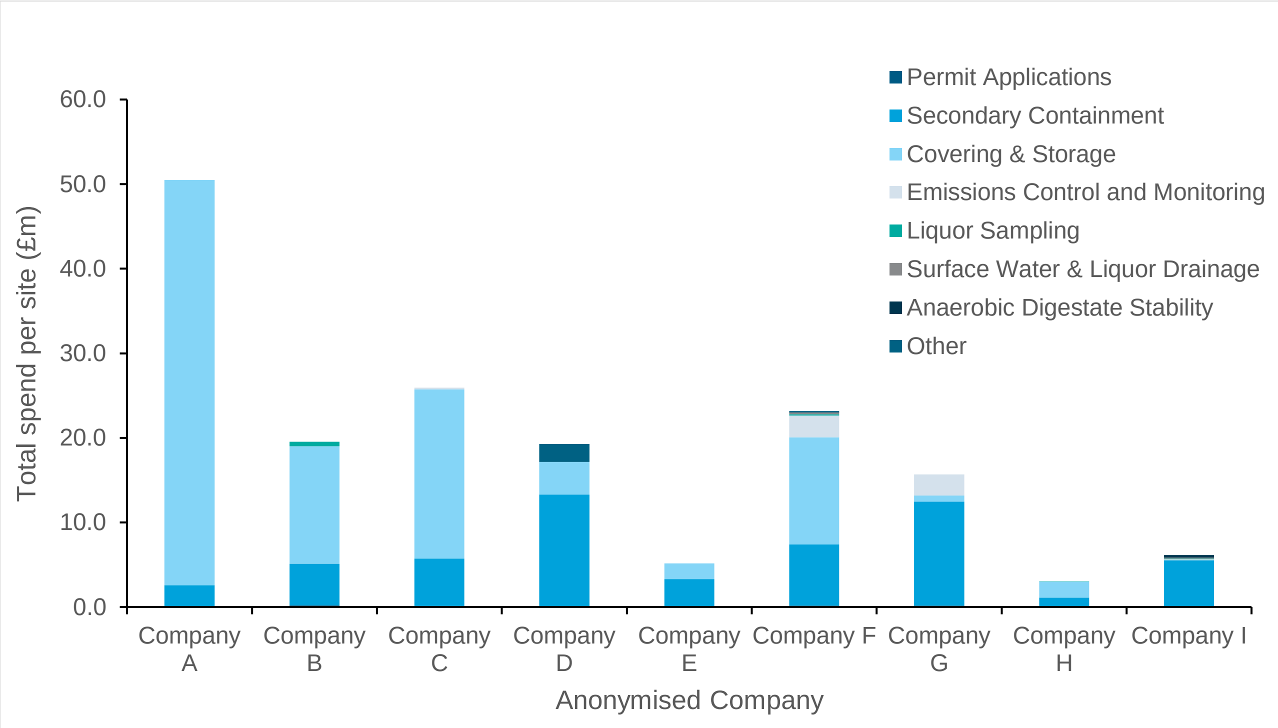

Figure 6-4: Total One-off Spend per Site by Company

Overall, there is not a standardisation of interventions by site, which makes comparison of costs across companies challenging when the assessment of risk is performed in isolation for each site. The risk assessment process which drives interventions being proposed (such as CIRIA C736 and fugitive emission prevention) is an area where a standardised approach across England could be achieved.

It should also be noted that the Competition & Markets Authority (CMA) made a judgement in 2020 (PR19) against IED BREF 2018 investment for two companies, this was prior to Appropriate Measures measure guidance in 2022 which has raised standards further – this is discussed in more detail in Section 7.

7. Baseline for AMP7 Delivery and AMP8 Requirements

The nature of planning for the site-level improvements that are required for compliance with BAT and Appropriate Measures is inherently site specific as is discussed in Section 6. This was borne out by the Competition & Markets Authority (CMA) decision in 2020 which stated:

In general, the CMA observes that IED compliance costs appear highly sensitive to the assessment of detailed requirements at specific sites. This accords with the Environment Agency's view that 'accurate estimates of the costs attributable to IED will only be available once all the site and company specific factors have been assessed and the review or issue of permits has been completed.' [24]

The notification to WaSCs that IED was to apply to their facilities was received at late stages of the PR19 process (July 2019, after draft determinations were submitted and only 5 months prior to Ofwat's Final Determination), giving limited time for any of these site-specific uncertainties to be resolved. At this time companies were required to comply with 2018 BREF alone, as Appropriate Measures was not yet published.

Companies were able to only plan for the paperwork exercise of applying for permits and determining the improvement conditions required as part of their PR19 submissions for AMP7, however the site-specific nature of the scope required means that there is no method of planning that can be undertaken before these permit application discussions with the EA have taken place.

In AMP7 as permitting has started (noting as of 24th May 2023 3 sites out of 100 have received permits), companies are better able to understand the precautionary regulatory position of the EA. As the implementation of BREF is subjective and based on risk assessment this has a material impact on compliance costs.

Also, in AMP7, and after all permit applications were made, as outlined previously, the EA published Appropriate Measures guidance in September 2022. This, as set out above has further raised the bar in environmental protection standards and the associated costs of compliance. Given the timing of the publication of the guidance it has likely led to significant re-work and re-design of IED solutions. A single compliance date, within AMP, to meet both the requirements of BREF and Appropriate Measures is not appropriate or feasible.

This is a large variability in spend per company (Figure 6-2), spend per site (Figure 6-4) and spend per theme (Figure 6-1). This aligns with the CMA findings that:

"There is a high level of uncertainty around the cost of IED compliance, arising from potential differences in needs, scope, and efficient costs for a large number of activities. This makes setting ex-ante allowances particularly problematic." [24]

The CMA decision was prior to Appropriate Measures guidance in 2022 which has raised standards further and therefore the cost to comply cannot be expected to be the same as the CMA indicated. Alignment between environmental and economic frameworks is essential and we recommend consideration is given to how funding for IED and Appropriate Measures can be included in PR24. At PR19 the timing of the regulatory change has resulted in a disparity in funding for IED compliance between companies, this potentially undermines Ofwat's aspirations to create a level playing field and stimulate the Bioresources Market. The materiality of the investment needs, in context to an entire industry spend Final Determination in AMP7 of £2.4bn, make it evident that it is essential companies have adequate resources to deliver improvements in realistic timescales.

Given the detail of site-specific improvement conditions has been formulated after the PR19 deadline, alternative funding mechanisms will need to be sought by water companies with corresponding improvement condition dates agreed by the Environment Agency. A minimum requirement to be fulfilled within AMP7 would be for WaSCs to successfully apply for permits (£ 8,806 k) and enact capital repairs rather than enhancements. The initiation of monitoring regimes (£17,628 k) could also be concluded on a case-by-case basis. The implementation of major civil assets (containment, tank covers) would however require the alignment detailed above on regulatory timescales for both funding and permit conditions.

The variability across sites (Figure 6-4) also means that a blanket date for compliance to be achieved is very difficult to propose without unfairly penalising individual companies with more significant investment programmes due to the site-specific nature of their assets physical positions.

There are also practical and economic reasons for using site-specific improvement condition deadlines. These include the fact that some sites will be undergoing significant construction work in AMP7 or AMP8 as part of the wastewater quality programme and their nature will either mean economies of scale make inclusion of IED investment desirable, or conversely that the scale of construction would hinder ability to maintain environmental compliance in the interim. CDM regulations require tight control of contractors activities, and one principal contractor to be in control of the works on site, with this adding a layer of complexity where sites are already undergoing capital works for discharge-related quality schemes. There are also supply-chain risks of the companies all requiring similar capital works on this scale within a similar set of deadlines, this is also likely to hamper deploy-ability of these interventions at an affordable cost.

8. Emerging Risks

During this assessment, we have identified a number of areas whereby there could be additional risks or permitting requirements or scope creep. These are as follows:

- A number of directly associated activities could also be captured by IED. Physical-chemical sites (i.e., dewatering and liming) that feed to a specific STC could be deemed a directly associated activity. There is a precedent set by a previous court ruling UU vs EA judgement for disposal under IPPC [25] that any intermediate treatment before the sewage sludge reached the incineration plant was also captured under IPPC regulation. Further Legal clarification may be required, and costs associated with these risks haven't been included to date. There are potentially significant cost implications across the industry should all upstream physical-chemical treatment sites also be captured under IED. The majority of these sites across the industry currently operate under a T21 waste exemption. These sites do not require waste permits and Appropriate measures guidance for exempt facilities states operators "can also use" the guidance, rather than being regulated to comply.
- It is highly unachievable that all permits will be issued in time for 2024 deadline and WaSCs may potentially be deemed non-compliant with associated risk of enforcement. It is unclear what level of enforcement will be applied or if any requirements will be made by the EA to potentially provide temporary solutions to resolve issues or whether WaSCs will need to escalate permanent delivery requirements at potentially greater cost. In addition, there may be a possible impact on the annual EA Environmental Performance Assessment (EPA) future EPA waste metric score/star rating associated with any non-compliance with permits.
- The EA can make changes to website and guidance without the need for public consultation e.g., clarifying types of activities you can and cannot carry out, and the types of waste you can treat. There is a possibility that investment decisions could be out of date before they come to fruition, this could leave WaSCs open to compliance issues, having to write-off assets early, abortive spend on developing scopes that then need to change or additional funding requirements going forward as permits are reviewed. Ofwat will need to be aware of these potential changes to allow costs to be included in econometric models and avoid penalising companies who may appear inefficient with abortive early works; IED was originally perceived as a 'one-off' investment but may be in the future more akin to sewage works discharge permits.
- There is some additional uncertainty which arises from further tightening of exempt activities (e.g., sewage sludge imports between STCs for treatment known as T21 exemptions). The EA might extend Appropriate Measures to exempt activities in the future. The original July 2020 consultation [26] on the draft guidance stated, '*The guidance is relevant for exempt sites*.' It also states, '*All exemptions as detailed in Schedule 3 of the Environmental Permitting Regulations (EPR) 2016, must comply with the relevant objectives as well as the limits and conditions set out in the individual exemptions*.' This wording is softened in the 2022 guidance which states '... *Facilities that operate under a relevant waste exemption can also use this guidance'.*
- Increased liquor return sampling may identify chemicals of concern which could have adverse impacts on receiving sewage works discharge permits, or require liquor treatment plants that have not yet been included in costings. Whilst these chemicals could be controlled through greater source controls (e.g., Trade Effluent consents), it may be difficult to understand the source due to the nature of sludge being transported for treatment. Alternatively, upon identification of a parameter that exceeds a limit, WaSCs may be required to undertake an improvement plan, which could be additional liquor treatment plant, if such a plant exists to treat the parameter of concern. Such monitoring is likely to be more onerous than that required for Ofwat market reform monitoring of liquors, but will give valuable information to inform this.
- Following a recent presentation on emissions control ('Biogas leaks methane: Confronting the challenge of process emissions') at the World Biogas Expo 2023, the EA may be minded to take a stricter approach to the control of any fugitive biogas emissions overall. This may influence the implementation of Appropriate Measures and the associated requirements in England. However, a recent communication with the EA via email in May 2023 indicated that the emission rates / residual biogas potential listed in PAS110 will likely be adopted for the time being.

9. Conclusions and Recommendations

Based on the analysis of Appropriate Measures requirements and associated, forecasted investment, the below sets out key conclusions around the impact of IED compliance based on the current approach and recommendations to support implementation and delivery (Table 9-1). The need to reduce the risk of industrial emissions is widely supported by the Water Industry, however a pragmatic approach to implementation is required so that this can be reasonably achieved whilst minimising the risk of unintended consequences, e.g., for customer affordability, carbon footprint impacts or wider environmental impact.

Investment Planning

The Water sector is supportive of the need to control emissions that could cause environmental harm. However, there is concern that the EA's implementation of Appropriate Measures goes beyond the original intent of BAT, resulting in significantly higher investment than could have been predicted when IED was instructed to the industry prior to PR19 final determinations and what the CMA considered appropriate. Furthermore, there have been delays in obtaining permits which has resulted in companies being unable to achieve permit compliance before the 2024 deadline, with investment unavoidably continuing into AMP8. Consideration needs to be given to how funding can be included in PR24 (and avoid a repeat of Post PR19 IED scenario with WaSCs making claims via the CMA) and mechanisms allowed to ensure adequate time and resources are permitted to deliver improvements in realistic timescales, which may be tied to other investment on site and needs to be considered under wider Planning regulations and Construction Design and Management (CDM) Regulations [27] requirements. The material investment required (c£2.0bn) cannot be absorbed by companies within the size of the existing Bioresources Price Control

Timeframe for Change Implementation

There are frequent and numerous changes and updates made to the EPR framework which are within the EA's control rather than requiring primary legislative change, for example, changes to guidance or accompanying website text. This can lead to new or tighter standards being implemented quickly and these types of changes cannot be predicted or accounted for in WaSC 5-year investment planning cycles. We would suggest the water sector discusses with the EA the extension of the 4-year hands-off period, (already in place for the wastewater discharge permits) for waste permits following change to a permit or guidance. Given that BAT will change over time, driven by changes in technology and tightening of permit requirements, current waste permits will periodically change; it is therefore recommended that 'sludge permit' investment planning is considered more akin to wastewater discharge permits in that it is clearly defined in the WINEP with associated modelling and clearly mapped out deliverables. IED is briefly mentioned in the WISER [28] and we would encourage the EA to build on that process with sludge permitting becoming a WINEP driver.

Regulatory Clarity

The EA has a legal obligation to reduce emissions that could damage or be of risk to human health and the wider environment and it is their statutory obligation to do so. BAT Conclusions states '*The techniques listed and described in BAT conclusions are neither prescriptive nor exhaustive. Other techniques may be used that ensure at least an equivalent level of environmental protection*'. It is within the EA's gift to take a more prescriptive approach where they deem risk is higher, but it would be beneficial to understand where and what is causing this concern so that the industry can effectively address this or provide the level of evidence needed to allow a lower level of intervention. The EA guidance is legally enforceable as it is based on legislation which is embedded in statute. BAT may suggest a risk-based leniency but the reality is the EA are taking a more cautious approach and applying prescriptive interventions.

It should be noted that CIRIA C736 was developed prior to BREF and Appropriate Measures were released and was based on UK containment experiences and as such does go further than the later recommendations of BREF; the EA have used CIRIA C736 in their interpretation of BREF requirements at a national level for all new permit applications and are now using in Appropriate Measures for permit variations.

Risk Alignment

The expenditure on each site is highly variable; this is to be expected as was validated by the CMA [24], and is only able to be determined accurately once the site-specific assessments are made to determine the improvement conditions required. However, for both BAT and Appropriate Measures compliance the key factor in determining the scale of investment is the calculation and attitude to risk of the regulator. The differing levels of risk within the assessments of improvement conditions seen across sites have had a consequential impact on the expenditure planned. This is driven by differences in interpretation between local and national Environment Agency teams on the level of acceptable risk. For example:

- The inclusion of odour control on cake storage covering, compared to simple barns has significant spend implications: requirement for fully enclosed digestate storage results in creating an environment where compliance with the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) causes significant additional initial and ongoing expenditure. This can be seen in the significant difference in covering costs per site in Figure 6-2.

A standard approach to risk across all companies and assets is required to ensure each site concludes their capital investment in a standardised position. As this cannot be completed by standardising the interventions it should be completed by: (a) standardising the guidance to local Environmental Agency officers and National Permitting Team, and (b) completing a review at a national level to ensure this is consistent between regulators. Whilst this may have an adverse impact on the spend of some or all companies, it would be a consistent and logical solution to the issue of maintaining equality across companies. Consideration should be given to wider environmental concerns as well as the IED requirements, such as the climate impact of pouring large volumes of concrete and the associated embedded carbon dis-benefits.

National Alignment

All parties need to be aware that STCs that have similar assets may have differing permit requirements under EPR. These differences are driven by an assessment based on the potential risk to the local receptors, the age of the assets, complexity, size and nature of the activities being carried out and the location of the site. The EC approach through BREF is based around a risk-based assessment pertaining to a specific site and its impact on local receptors. The guidance is designed to allow flexibility to change as improvements in BAT are developed. The EA framework is meant to allow the same, i.e., flexibility to make minor changes. Therefore, this will mean that there will be differences in permitting, however there needs to be consistency in the interpretation of guidance between national and local EA permitting officers, and national regulators, to ensure a common baseline.

The aggregate expenditure in other nations within the UK is significantly different to England, with corresponding expenditure that is not in the same order of magnitude. To ensure equity across the country as a whole as well as with other sectors of industry, this should be collaborated upon across regulatory bodies so that appetites for risk are not so divergent.

Table 9-1: Table of Recommendations

	Recommendation
1	Consider how funding can be included in PR24 with mechanisms to ensure adequate time and resources are permitted to deliver improvements in realistic timescales, accounting for other investment on site and wider Planning regulations and Construction Design and Management (CDM) Regulations [27] requirements.
2	Provide clarity around the causes of concern driving the EA's more cautious approach to BAT implementation to provide a shared understanding and enable the industry to effectively discuss / address these.
3	Discussion between the EA and water industry to consider the extension of the 4-year hands-off period (already in place for the wastewater discharge permits) for waste permits following change to a permit or guidance.
4	Clear definition of 'Sludge permit' investment planning in the WINEP with associated modelling and clearly mapped out deliverables, in line with the approach to wastewater discharge permits.
5	Ensure consistency in the interpretation of guidance between national and local EA permitting officers, and national regulators, to provide a common baseline.
6	Develop a standard approach to risk across all companies and assets to ensure each site concludes their capital investment in a standardised position. As this cannot be completed by standardising the interventions it should be completed by: (a) standardising of the guidance to local Environmental Agency officers and National Permitting Team (b) completing of a review at a national level to ensure this is consistent between regulators.
7	Assess the wider environmental concerns associated with meeting the IED requirements, such as the climate impact of pouring large volumes of concrete and the associated embedded carbon dis-benefits.

10. References

[1] European Commission, "Directive 2010/75/EU of the European Parliament and of the Council," 2010. [Online]. Available: https://www.legislation.gov.uk/eudr/2010/75/contents.

[2] UK Government, "The Environmental Permitting (England and Wales) Regulations 2016," 2016. [Online]. Available: https://www.legislation.gov.uk/uksi/2016/1154/contents/made.

[3] European Commission, "Council Directive of 21 May 1991 concerning urban waste water treatment (91/271/EEC)," 21 05 1991. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A01991L0271-20140101.

[4] UK Government, "The Sludge (Use in Agriculture) Regulations 1989," 1989. [Online]. Available: https://www.legislation.gov.uk/uksi/1989/1263/contents/made.

[5] Environment Agency, "Environment Agency strategy for safe and sustainable sludge use," 15 07 2020. [Online]. Available: https://www.gov.uk/government/publications/environment-agency-strategy-for-safe-and-sustainable-sludge-use/environment-agency-strategy-for-safe-and-sustainable-sludge-use.

[6] Environment Agency, *Briefing: Industrial Emissions Directive - Waste Sector,* July 2024.

[7] European Commission, "Best Available Techniques (BAT) Reference Document for Waste Treatment," 2018. [Online]. Available: https://op.europa.eu/en/publication-detail/-/publication/782f0042-d66f-11e8-9424-01aa75ed71a1/language-en.

[8] European Commission, "Emissions from Storage," 07 2006. [Online]. Available: https://eippcb.jrc.ec.europa.eu/sites/default/files/2022-03/efs_bref_0706_0.pdf.

[9] European Commission, "JRC Reference Report on Monitoring of Emissions to Air and Water from IED Installations," 2018. [Online]. Available: https://eippcb.jrc.ec.europa.eu/sites/default/files/2019-12/ROM_2018_08_20.pdf.

[10] Environment Agency, "Biological waste treatment: appropriate measures for permitted facilities," 21 09 2022. [Online]. Available: https://www.gov.uk/guidance/biological-waste-treatment-appropriate-measures-for-permitted-facilities.

[11] United Utilities, *United Utilities Produced Visual,* 2023.

[12] Environment Agency, "Non-hazardous and inert waste: appropriate measures for permitted facilities," 12 07 2021. [Online]. Available: https://www.gov.uk/guidance/non-hazardous-and-inert-waste-appropriate-measures-for-permitted-facilities/1-when-appropriate-measures-apply.

[13] Environment Agency, "Chemical waste: appropriate measures for permitted facilities," 18 11 2020. [Online]. Available: https://www.gov.uk/guidance/chemical-waste-appropriate-measures-for-permitted-facilities/1-when-appropriate-measures-apply.

[14] Defra, "Establishing the Best Available Techniques for the UK (UK BAT)," 20 12 2022. [Online]. Available: https://www.gov.uk/government/publications/establishing-the-best-available-techniques-for-the-uk-uk-bat/establishing-the-best-available-techniques-for-the-uk-uk-bat.

[15] Environment Agency, "Environmental permits: when and how we consult," 16 04 2019. [Online]. Available: https://www.gov.uk/government/publications/environmental-permits-when-and-how-we-consult/environmental-permits-when-and-how-we-consult#when-we-consult-on-standard-rules.

[16] Ashurst, "Does government advice and guidance have the force of law?," 23 09 2020. [Online]. Available: https://www.ashurst.com/en/news-and-insights/legal-updates/does-government-advice-and-guidance-have-the-force-of-law/.

[17] Environment Agency, "Biowaste permits: review to improve environmental outcomes - response document," 09 2019. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/906742/200919_CfE_response_for_publishing_TL_approved_accessible.pdf.

[18] Environment Agency, “Consultation outcome: Appropriate measures for the biological treatment of waste: consultation response document,” 27 07 2021. [Online]. Available: https://www.gov.uk/government/consultations/appropriate-measures-for-the-biological-treatment-of-waste/public-feedback/appropriate-measures-for-the-biological-treatment-of-waste-consultation-response-document#responses-to-consultation-questions-4-to-13.

[19] Environment Agency, DEFRA, “Surface water pollution risk assessment for your environmental permit,” 25 02 2022. [Online]. Available: https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit.

[20] ADBA, “The Practical Guide to AD: Second Edition,” 10 2017. [Online].

[21] I. Walton, “Containment systems for the prevention of pollution (C736),” CIRIA, 2014.

[22] Environment Agency, “Intensive farming: comply with your environmental permit,” 01 2010. [Online]. Available: https://www.gov.uk/government/publications/intensive-farming-introduction-and-chapters.

[23] Environment Agency, “Surface water pollution risk assessment for your environmental permit,” 01 02 2016. [Online]. Available: https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit.

[24] Competition and Markets Authority, “Anglian Water Services Limited, Bristol Water plc, Northumbrian Water Limited and Yorkshire Water Services Limited price determinations,” 09 2020. [Online].

[25] England and Wales Court of Appeal (Civil Division), “United Utilities Water Plc V Environment Agency for England and Wales,” 19 05 2016. [Online]. Available: https://www.casemine.com/judgement/uk/5a8ff71460d03e7f57ea7391.

[26] Environment Agency, “Appropriate measures for the biological treatment of waste,” 10 07 2020. [Online]. Available: https://consult.environment-agency.gov.uk/environment-and-business/appropriate-measures-for-the-biological-treatment/.

[27] UK Government, “The Construction (Design and Management) Regulations 2015,” 2015. [Online]. Available: https://www.legislation.gov.uk/uksi/2015/51/contents/made.

[28] Defra, “Water industry strategic environmental requirements (WISER),” 11 05 2022. [Online]. Available: https://www.gov.uk/government/publications/developing-the-environmental-resilience-and-flood-risk-actions-for-the-price-review-2024/water-industry-strategic-environmental-requirements-wiser.

[29] Environment Agency, “SR2012 No 11: anaerobic digestion facility including use of the resultant biogas,” 21 03 2013. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1078597/SR2012_No11_Anaerobic_digestion_facility_including_use_of_the_resultant_biogas_Part_A_installation_withdrawn.pdf.

[30] Environment Agency, “SR2012 No 12: anaerobic digestion facility including use of the resultant biogas (waste recovery operation),” 16 11 2012. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/790709/SR2012_No12_Anaerobic_digestion_facility.pdf.

[31] Environment Agency, “H4 Odour Management: How to comply with your environmental permit,” 03 2011. [Online]. Available: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/296737/geho0411btqm-e-e.pdf.

[32] EU, “Directive 2014/34/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres (ATEX),” 2014. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0034. [Accessed 09 05 2023].

[33] Wrap, “PAS110:2014 Specification for whole digestate, separated liquor and separated fibre derived from the anaerobic digestion of source-segregated biodegradable materials,” [Online]. Available: https://wrap.org.uk/sites/default/files/2021-03/PAS110_2014.pdf.

[34] Environment Agency, “Guidance: Waste quality protocols review,” 2021 12 1. [Online]. Available: https://www.gov.uk/government/publications/waste-quality-protocols-review/waste-quality-protocols-review#completed-reviews.

[35] EI, “High level framework for process safety management,” 2010. [Online]. Available: https://publishing.energyinst.org/topics.

[36] EI, “Environmental guidelines for petroleum distribution installations, Energy Institute, London.,” 2007 . [Online]. Available: https://publishing.energyinst.org/topics.

[37] UK GOV, “The Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991,” 1991. [Online]. Available: https://www.legislation.gov.uk/uksi/1991/324/contents/made. [Accessed 09 05 2023].

[38] N. S. EA, “Pollution Prevention Guidelines (PPG) 26 Storage and handling of drums and intermediate bund container,” 2004. [Online]. Available: https://www.gov.uk/government/publications/storing-and-handling-drums-and-intermediate-bulk-containers-ppg26. [Accessed 09 05 2023].

Appendix A. Suitability of 'Appropriate Measures' Technical Reference Documentation

The Appropriate Measures guidance references several other documents and some of these related guidance documents have been in use for a number of years prior to the publication of Appropriate Measures. We have reviewed these for completeness and to assess the suitability of those technical documents in establishing the standards to comply with Appropriate Measures requirements. This includes:

- The Practical Guide to AD (second edition) [20] was published by Anaerobic Digestion and Bioresources Association (ADBA) in 2017 which was recognised by the EA in promoting best practice.
- The 2014 Construction Industry Research and Information Association report *'Containment systems for the prevention of pollution'* (CIRIA C736) [21] provides guidance on the implementation of a hierarchal risk assessment and classification system for the prevention and mitigation of hazardous loss of containment from primary storage. CIRIA C736 is referenced in both Appropriate Measures and ADBA for recommendations related to the design and construction of secondary containment systems and upgrades of existing installations.
- Intensive Farming: How to comply with your environmental permit [22], was published by the EA in 2016 and applies to intensive farming but has some commonality with biowaste treatment.

A.1. ADBA – The Practical Guide to AD, Second Edition

The ADBA guide sets out best practices across the design, operation, maintenance and decommissioning of AD facilities, based on scientific research, industry practices and legal documentation. In some areas the guide signals specific best practices to guide decision making and in others, e.g., environmental management / monitoring, it refers to the applicable legislative documents and their requirements. The guide is therefore not comprehensive in itself but does contain detailed recommendations across a number of areas. Some of these are drawn out below to illustrate the scope of the guidance document in comparison to those reviewed in Section 4.

Information within the ADBA guide largely supports the planning and establishment of an AD facility, with some guidance around operating procedures. Where relevant, it signals to the appropriate regulations / standards to inform decision making. In particular it refers to following CIRIA C736, similarly to Appropriate Measures, for the design / construction of containment. Some areas covered in Section 4 were not covered by the guide, for example liquor sampling / surface water and liquor drainage.

Table A-1 below demonstrates how the ADBA guidance compares with the requirements set out by Appropriate Measures. As above, it demonstrates where requirements, in our expert opinion, set out by ADBA and Appropriate Measures are very similar (green), where Appropriate Measures requirements go above those set out by ADBA (amber) or where Appropriate Measures requirements significantly exceed those of ADBA (red). The areas that ADBA guidance did not cover (Liquor Sampling; Surface Water / Liquor Drainage) were rated as grey on this basis. It is clear that the guidance is aimed at smaller, new build Anaerobic Digestion developments rather than existing WwTWs and this may not be appropriate to apply when retrofitting to existing sites.

Table A-1: Summary of ADBA the Practical Guide to AD / Appropriate Measures Comparison

Focus Area Rating
Covering / Storage
Containment / Failure Modelling
Secondary Containment
Emissions Control / Monitoring
Liquor Sampling
Surface Water / Liquor Drainage
Anaerobic Digestate Stability

Table A-1 demonstrates how the ADBA guidance compares with the requirements set out by Appropriate Measures. As above, it demonstrates where requirements, in our expert opinion, set out by ADBA and

Appropriate Measures are very similar (green), where Appropriate Measures requirements go above those set out by ADBA (amber) or where Appropriate Measures requirements significantly exceed those of ADBA (red). The areas that ADBA guidance did not cover (Liquor Sampling; Surface Water / Liquor Drainage) were rated as grey on this basis.

A.1.1. Covering and Storage

The ADBA guide recommends careful planning of storage capacity for AD facilities, ensuring that closed periods for agricultural spreading / delivery failures can be accommodated without exceeding capacity. This will be based on local context considering crop requirements, rainfall etc. and the governing regulations. This focuses more on planning for the maximum storage capacity required on site, where Appropriate Measures only stipulates not exceeding capacity.

It signals that when constructing permanent stores this needs to be in line with the relevant Health, Safety and Environmental and planning regulations and may require bunding and / or leak detectors in place. It does not explicitly refer to the need for an impermeable surface / enclosed storage or drainage as covered in Appropriate Measures. However, it does suggest that for new facilities storage should be constructed in line with CIRIA C736.

In terms of covering, the document largely refers to regulatory requirements to determine the need. It suggests that covering may be required for digestate stores, based on the now superseded IPPC Directive. The recommendation is for gas-tight covers with biogas collection and with access for agitation equipment. It references the superseded Standard Rule 11 [29] and Standard Rule 12 [30] for ‘anaerobic digestion facility including use of the resultant biogas (waste recovery operation)’, which specify that all storage and process tanks should be located within impermeable bunds and that digestate must be stored within covered containers / lagoons. Although less prescriptive, this largely reflects the requirements of Appropriate Measures. A key difference is that it principally focuses on storage tanks / lagoons as opposed to areas used for transfer / management activities. It does advise that all potential sources of odour are covered where possible, which could include such areas.

A.1.2. Containment and Failure Modelling

ADBA states that storage design must be suitable for the expected volume of throughput and constructed in line with CIRIA C736 and other relevant guidance / standards, as per Appropriate Measures, for new facilities. It suggests that bunding may be required for liquid-storage, based on local planning authority requirements and states that this should all be discussed with the regulator during the planning process.

Maintenance

The ADBA guide advises that all rotating equipment should have regular, scheduled maintenance based on specific intervals in their operation, which is likely to be in line with manufacturers recommendations, however it does not explicitly suggest following them. In principle it is a similar approach to that described in Appropriate Measures.

When designing systems, it also suggests considering how they will be maintained and ensure that suitable access is factored into the design.

A.1.3. Secondary Containment

The ADBA guide generally takes more of a risk-based approach to secondary containment, as opposed to a blanket approach as in Appropriate Measures. It suggests that for new facilities; secondary containment should be considered at an early stage and factored into the design as appropriate. Risks of pollution should be considered whether from possible handling / overfilling / equipment failures or other foreseeable events, and secondary containment installed to mitigate these where identified. It further refers to CIRIA C736 standards to determine the level of containment required for the installation of new secondary containment, which is in adherence with Appropriate Measures.

A.1.4. Emissions Control and Monitoring

The ADBA guide refers back to BREF to cover the full requirements for managing and monitoring the environmental impact of an AD facility. It further details the below recommendations:

Covering / Containment

As per Section 4.1.1 above, the document recommends covering of storage / treatment areas using gas-tight covers with biogas collection, in addition to the installation of secondary containment / bunding of areas where there is a risk of pollution in order to minimise emissions to soil / air / water.

Biogas system

The guide contains a number of recommendations around maintaining the AD system to mitigate environmental risks. This includes:

- Maintaining the appropriate pressure for the AD system and designing equipment e.g., pipework / roofing that is built to withstand the maximum pressure.
- Fitting vacuum-relief valves to all pipes and vessels to protect from over-pressure.
- Choosing materials for equipment in line with the maximum pressure and the operating temperature.

These are in line with the Appropriate Measures guidance for high-integrity components. However, it does not go further to describe implementation of an abatement system, for example, for which a number of requirements are included in Appropriate Measures.

It also suggests a number of maintenance and monitoring procedures to reduce risks. This includes periodic monitoring and maintenance of the pressure systems once installed and foam monitoring to prevent any spillage from foaming. The guide suggests installing a foam monitor and including freeboard in the digester of 1-2m to manage containment in case of an incident and an emergency, foaming relief vent to mitigate additional pressure should foaming occur. This is more detailed than the guidance within Appropriate Measures, although that does also require monitoring foam levels. It may also be covered under the general requirement in Appropriate Measures to '*consider and reduce the risk of accidental emissions*' including through '*loss of containment – all polluting matter.*'

Leakage

As above, the guide advises that the risks of leakage / spillage from incidents should be assessed and planned for with secondary containment installed as required. It also states that run-off from stores will need to be managed appropriately to mitigate potential for pollution. It references that the regulator may additionally require the installation and monitoring of spillage and leak detectors. This is largely in line with the requirements of Appropriate Measures. However, Appropriate Measures has a blanket requirement for the provision of secondary containment for all tanks and an impermeable surface for all operational areas, which thus goes further than the ADBA guidance.

Odour

The guide states that an odour risk assessment should be undertaken and an odour-management plan (OMP) developed and implemented if required. This is a slight departure from BREF and Appropriate Measures, which stipulate the creation and implementation of an OMP in all cases. It suggests a number of potential odour management techniques, including the installation of covers, regular cleaning and scrubbing / biofilters. It references the superseded Standard Rule 11 [29] and Standard Rule 12 [30], which state that '*any buildings used for waste storage must be fitted with a biofilter or scrubbing system to control odour*'. Measures to manage odour are not referenced specifically in Appropriate Measures, although the EA has issued a separate guidance note to aid the development an OMP which contains a number of potential control methods [31].

Monitoring

Aside from odour, other parameters may need to be monitored to ensure protection of the environment. The guide indicates that should a facility be operating under a bespoke environmental permit it will need to be supported by a quantitative environmental risk assessment that considers all emissions to air / soil / water. This echoes BREF and Appropriate Measures. It references that environmental conditions will be assessed on the decommissioning of a plant and will need to demonstrate that no significant environmental damage has been caused. This will require monitoring throughout the plant's operation. It also references that bioaerosol monitoring may be required for plants that fall within EPR. It states that all monitoring equipment must to be designed in line with the equipment for potentially explosive atmospheres (ATEX) directive [32] for use in an explosive atmosphere. Overall, this is more general than Appropriate Measures, which contains a number of explicit monitoring parameters and states that additional monitoring requirements may be set in permits, however at a high level it is in alignment.

A.1.5. Anaerobic Digestate Stability

The ADBA guide gives a significant amount of direction regarding maintaining digester and digestate stability. Similar to Appropriate Measures it gives a number of parameters to monitor and control to maintain optimal conditions although in several areas the recommendations are more specific than those stipulated by Appropriate Measures. Both advise monitoring and maintaining digester temperature, although the ADBA guide specifically suggests ensuring that it does not change by more than 1°C per day. It also gives specific recommendations around mixing practices, not included in Appropriate Measures, to ensure that at least 85% of the digester volume is active. Appropriate Measures requires that changes are made to feedstock to enable an optimal process, depending on process parameter recordings. Likewise, the ADBA guide gives some general guidance to optimise pre-treatment processes and preparation of feedstock.

In addition to the parameters above, and those set out in Appropriate Measures, the ADBA guide suggests additional monitoring requirements including observing carbon dioxide, methane and ammonia concentrations in the biogas to indicate AD process health. It suggests either using a portable biogas monitor or installing a fixed, continuous monitoring system. Appropriate Measures specifically requires the installation of SCADA equipment for all continuously monitored factors and an automatic alarm system for gas pressure.

The ADBA guide references Publicly Available Specification (PAS) 110 'Producing Quality Anaerobic Digestate' as a suitable standard to assess digestate quality although sewage sludge is excluded from its remit as it's not classed as 'source segregated' [33]. It's important to note that the anaerobic digestate quality protocol (QP) was reviewed by the EA in February 2020, the outcome of which was that the QP needed revision; a task and finish group has been set up and the revision process has commenced [34].

A.2. CIRIA C736

CIRIA C736 was published in 2014 [21] to provide practical guidance on secondary containment systems around best practices on spill prevention, mitigation, and response. Adherence to CIRIA C736 is required across a number of areas in Appropriate Measures, including secondary containment, storage areas and storage tank design. The section below discusses the implications where observance of CIRIA C736 guidance is referenced in the implementation of Appropriate Measures, and how this compares to the requirements of BAT or other technical guidance documentation.

Table A summarises how guidance in CIRIA C736, as referenced for adherence by Appropriate Measures, compares with the requirements set out by BREF, specifically for contained storage systems and secondary containment. As above, it demonstrates where recommendations, in our expert opinion, set out by CIRIA C736 are very similar (green), where CIRIA C736 recommendations go above those set out by BREF (amber) or where CIRIA C736 recommendations significantly exceed those of BREF (red). Several focus areas were not applicable to CIRIA C736 given that it is a standard specific to containment systems, these were therefore not given a rating (grey).

Table A-2: Summary of CIRIA C736 / BREF Comparison

Focus Area Rating
Storage
Containment / Failure Modelling
Secondary Containment
Emissions Control / Monitoring - Not applicable in C736
Liquor Sampling - Not applicable in C736
Surface Water / Liquor Drainage
Anaerobic Digestate Stability - Not applicable in C736

In BREF it is stated that secondary containment should be able to accommodate the total volume from the largest tank within the containment area. Moreover, the 25% of total capacity rule also specified by BREF is used as the recommended minimum for intermediate bulk storage vessels only in CIRIA C736. Rather, the recommendations on estimating capacity for local systems (designated areas surrounding primary storage vessel to contain spills) follow a scenario-specific approach which accounts, where appropriate, for total loss of containment from primary storage, rainwater, firefighting agents, cooling water and dynamic effects.

It is noted that CIRIA describes secondary and tertiary containment, while the BREF only refers to secondary containment. CIRIA defines that secondary containment "minimises the consequences of failure of primary storage by preventing the uncontrolled spread of the inventory" and "is achieved by equipment that is external to and structurally independent of the primary storage". Tertiary containment is defined that it "minimises the consequences of a failure in the primary and secondary containment systems".

CIRIA C736 has wide applicability; however, Section 1.2 of the guidance describes issues that are not covered in the guide; this specifically states that "sewage and sewage effluents, farm waste and related materials" are excluded as "Stored inventory".

The guidance also notes in Section 1.1.3 that the "costs of upgrading existing facilities might outweigh the environmental benefits, and therefore not be viable, or that other equally effective risk reduction measures to those suggested in this guidance may be implemented".

A.2.1. Containment and Failure Modelling

Appropriate Measures establishes operational and construction requirements for storage in above and below ground tanks and lagoons. Where adherence to CIRIA C736 guidance is referenced, it pertains to its general guidance on pollution prevention, as well as design, performance and construction standards such as freeboard height, leakage detection and transfer system equipment for lagoons, above / below containment tanks and bunds of various forms. The guidance also matches the different requirements of low, medium and high overall site risks to the type of containment structure.

In BREF requirements associated with secondary containment and leak detection are not explicitly covered for all appropriate containment structure types and may be considered less stringent than Appropriate Measures / CIRIA C736. However, it is specified that leak detection should be applied on above ground tanks that contain liquids that can potentially cause significant pollution of soil or watercourses. BAT guidelines also require leak detection on underground tanks either constructed with two walls or with a single wall and secondary containment. Recommendations on leak detection systems and leak testing in CIRIA C736 cover a wider range of installation types and scenarios. For example, it is recommended that leak detection is required on all primary storage vessels where it is not possible to visually inspect for leakage (i.e., insufficient clearance) and additionally for all higher risk (Class 3) containment facilities. The guide further references recognised standards and codes of good practice for guidance on leak detection systems and leak testing specific (e.g., BS 799-5:2010 for tanks).

A.2.2. Secondary Containment Systems

Appropriate Measures and ADBA refer to CIRIA C736 as a recognised standard to ensure that the design, performance and construction of new-build and existing secondary containment facilities meet the minimum legislative or regulatory requirements. This is unlike the requirements of BREF, which does not reference any recognised standards for determining the performance or level of containment required.

For existing primary containment facilities, BREF acknowledges that the installation of secondary containment may be restricted and necessitates that a risk-based approach should be undertaken to assess both the level of secondary containment required, including the level of impermeability, based on the level of risk posed by the loss of containment to soil and/or water. Nonetheless by referencing CIRIA C736, Appropriate Measures and ADBA offer a more comprehensive coverage of secondary containment requirements for existing facilities according to a low, medium or high overall risk rating (or class 1, 2 or 3, respectively). As discussed in Appendix A1, the guidance provides an extensive risk-based methodology for determining appropriate containment measures for a wide range of structure types, as well as consolidated recommendations for any necessary modifications, extensions, or refurbishments. These risk-specific recommendations aim to ensure that consistent standards are implemented for both newly constructed containment systems and existing secondary containment facilities based on the specific risk assessment and classification of the site. However, CIRIA C736 doesn't offer a 'do nothing' option for secondary containment, such as operational monitoring to control low risk spills from say concrete tanks.

The guidance also gives a general overview of design and performance recommendations for new-build facilities, categorised according to the determined site risk ratings or class of containment. Generally, the requirements increase progressively from class 1 to class 3 in terms of design, construction integrity, and operation and maintenance of the containment system. For example, leakage detection systems would only be required for class 3 lagoons / bunds for periodic monitoring / testing. These standards for new-build and installed secondary containment facilities are summarised according to containment structure type in Appendix A1 (see Table 0A-2). Guidance specific to the class of secondary containment is also provided on drainage and transfer systems for intercepting and conveying the polluting substances to the containment area/s.

Where Appropriate Measures and ADBA require adherence to CIRIA C736, the guidance provided in the document can be considered more prescriptive than BREF for the determination of containment volume. In BREF it is stated that secondary containment should be able to accommodate the total volume from the largest tank within the containment area. Moreover, the 25% of total capacity rule also specified by BREF is used as the recommended minimum for intermediate bulk storage vessels only in CIRIA C736. Rather, the recommendations on estimating capacity for local systems (designated areas surrounding primary storage vessel to contain spills) follow a scenario-specific approach which accounts, where appropriate, for total loss of containment from primary storage, rainwater, firefighting agents, cooling water and dynamic effects.

A.2.3. Storage, Surface Water and Liquor Drainage

In the context of liquid storage from waste, the requirements outlined in BREF specify that storage areas should have impermeable surfaces depending on the potential risks associated with soil and/or water contamination. Guidelines for BAT also require bulk storage vessels to rest on an impervious surface with contained drainage. Similarly, Appropriate Measures requires that the storage of wastes and bulk storage vessels should be situated on impermeable surfaces with contained drainage, but references adherence to recommendations contained within CIRIA C736.

However, where recommendations on storage and containment areas are provided in CIRIA C736, requirements on surface impermeability differs according to the type of containment structure and transfer system. This is due to the impracticality of specifying a precise '*watertight'* level of impermeability. Rather, the guidance prescribes that an adequate level of impermeability can be achieved by adhering to the recommended design and construction methods appropriate to the containment class, as well as meeting the performance specification given in relevant recognised standards and codes of practices. However, for earth-based surfaces (e.g., in bunds and lagoons), the equivalent of a maximum permeability coefficient of 1×10^{-9} m/s and soil depth of 1 m is specified. Suitable impermeable lining systems or coatings are recommended in circumstances where it is not practical for this criterion to be met.

Appropriate Measures also references CIRIA C736 as a means to ensure conformity of storage systems. CIRIA C736 provides detailed design and construction recommendations for local secondary containment systems, specifically bunds. These recommendations consider several performance criteria that accounts for all credible '*modes of escape of pollutant from the primary storage vessel, modes of failure of the bund, incident scenarios, loadings, and chemical and physical exposure (particularly fire).*' Although provided in less detail, BREF also refers to similar performance criteria for the design of storage tanks and includes similar considerations on regular inspection and maintenance regimes of storage assets.

In terms of operation and maintenance, Appropriate Measures prescribes regular inspection / maintenance programmes which are in line with manufacturer's recommendations for all equipment, including secondary containment. Where CIRIA C736 is referenced, this guidance further advises duty holders to prepare and conduct regular inspection and maintenance programmes specific to the containment facility to ensure the integrity of primary, secondary, and/or tertiary containment is not compromised by leaks or defects. Although no specific recommendations on inspection and maintenance programmes are provided, appropriate guidelines (e.g., by the Energy Institute [35] [36] which have since been revised) are suggested and referenced. Additionally, it is stipulated that inspection regimes should undergo consultation with the appropriate regulator and be completed by competent personnel with expertise in the particular containment structure.

A.3. Intensive Farming: How to Comply with your Environmental Permit

'Intensive farming: How to comply with your environmental permit' [22] was published by the EA in 2010 as a guidance note to the farming sector on the standards and measures it is expected to comply with in order to manage risks to air, land and water. This applies to farms regulated under the Environmental Permitting Regulations (EPR) [2], which require a bespoke permit to operate. Farms operating under this framework are expected to adhere to BAT and justify any departures from BAT to the EA on a site-specific basis. The requirements outlined in the document are considered the minimum conditions that should be met to achieve the objectives set out, as they apply to each facility. It notes that measures will be reviewed on the publication of future revisions to BREF notes.

The document specifies that all new facilities are expected to conform to the required standards, whereas existing plants will need to be upgraded to meet standards within a specified timescale. The types of potential upgrades (or improvement conditions) that may be required are categorised within the document, with timescales that are either 6 or 12 months for implementation relative to each category. It is noted that an alternative timescale can be used if agreed and specified by the EA.

Table A-3 below demonstrates how the Intensive Farming guidance compares with the requirements set out by Appropriate Measures. As above, it demonstrates where requirements, in our expert opinion, set out by Intensive Farming guidance and Appropriate Measures are very similar (green), where Appropriate Measures requirements go above those set out by Intensive Farming guidance (amber) or where Appropriate Measures requirements significantly exceed those of Intensive Farming guidance (red). The areas that Intensive Farming guidance did not cover (Liquor Sampling; Anaerobic Digestate Stability) were rated as red on this basis. Surface Water / Liquor Drainage was considered not directly comparable (grey) due to requirements being substantially different, based on the unique risks posed in the operating environments covered.

Table A-3: Summary of Intensive Farming Guidance / Appropriate Measures Comparison

Focus Area Rating
Covering / Storage
Containment / Failure Modelling
Secondary Containment
Emissions Control / Monitoring
Liquor Sampling
Surface Water / Liquor Drainage – Not comparable
Anaerobic Digestate Stability

A.3.1. Covering and Storage

Appropriate Measures requires that all tanks, vessels or lagoons used for storing or treating liquid wastes at new facilities should have fixed covers. Intensive Farming guidance likewise requires that all new, substantially reconstructed or substantially enlarged slurry storage systems are covered and specifies that these should be rigid covers, or another effective technique. However, it caveats that slurry tanks may be exempt from covering if their content is considered dilute (<1% dry matter content). It further requires that an 'effective covering method' is demonstrated for any new earth banked lagoons.

For existing slurry stores, Intensive Farming guidance requires that slurry stores are covered, but this can be with a rigid or floating cover. Straw or peat will be accepted as suitable cover for pig slurry with a dry matter content >5%, although this will be considered on a site-by-site basis. Where non-rigid covers are used, the guidance specifies that stirring of slurry is minimised and is introduced below the surface to manage potential emissions. Covering is further required for water tanks, in order to minimise emissions to water.

Appropriate Measures requires covering for all *bulk* storage tanks in existing facilities as opposed to a blanket statement for all tanks. It specifies that covered areas must be equipped with good ventilation. It does not include a requirement for covering of water tanks, however, it does additionally require that all transfer / management activities are performed under cover. Furthermore, activities that may produce emissions will need to be facilitated in an enclosed building with air extraction and abatement.

Overall, both guidance notes require covering of tanks, however Appropriate Measures appears more onerous as it prescribes fixed covers in all instances irrespective of the tank contents and dry matter.

A.3.2. Containment and Failure Modelling

A.3.2.1. Maintenance planning

Similar to Appropriate Measures, Intensive Farming guidance stipulates that inspection and maintenance should comply with the manufacturers' recommendations. However, Appropriate Measures can be considered more onerous as Intensive Farming guidance permits the use of alternative inspection and maintenance schedules provided the justification is documented. Conversely, the guidance places a more stringent requirement on carrying out preventative maintenance rather than a scheduled programme stated in Appropriate Measures.

The guidance also requires that an accident management plant is maintained and implemented by the facility operator. It states this can be achieved by following the '*risk assessment for accidents in Part 1 of H1 Environmental Risk Assessment'* including detailing a specific risk management plan. A more containment-specific accident management plan is required by Appropriate Measures which considers emissions, leakages and spills from containers.

A.3.2.2. Operational areas

The Intensive Farming guidance states the non-prescriptive requirement that the design and construction of new containment systems should be able to manage the specific volumes of substances that are to be contained. However, specifically for new or existing slurry storage systems it prescribes compliance to measures detailed in

Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991 (amended 1997) [37]. Although Appropriate Measures applies a relatively blanketed approach for the design and construction of containment or storage systems it references CIRIA C736 for recommendations related to new containment structures and for the assessment and classification of existing structures against its risk-based methodology. Similar technical requirements are stated within both CIRIA C736 (which refers to the relevant recognised standards or codes of practice of different containment systems) and Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991 in terms of design standards for agriculture (BS 5502-50:1993+A2:2010), material selection, impermeability, freeboard height, design life, and maintenance (see Table 0). However, the requirements outlined in the Intensive Farming guidance are more comprehensive when referring to the specific design of slurry storage facilities.

A.3.3. Secondary Containment

The intensive farming document takes a risk-based yet more broad approach as compared to Appropriate Measures for the requirement of secondary containment. It states where there is a risk, rather than significant risk, for loss of containment of polluting liquids to potential receptors (land or water) that '*appropriate'* secondary containment is required following a risk assessment for an accident management plan. However, where Appropriate Measures requires adherence to CIRIA C736 or an equivalent standard for determining the necessary level of new-build or existing secondary containment, intensive farming considers that other appropriate measures may also be used to prevent and mitigate the loss of containment from primary containment. No recognised standards or codes of practice are specified.

The document further covers a scenario where no secondary containment is required (e.g., for primary storage in lagoons) and stipulates that a regular inspection and maintenance regime should be carried out to a degree that would provide equivalent protection. Appropriate Measures includes requirements for scheduled manual and automatic inspections for secondary containment, as well as a maintenance programme (which covers all equipment).

A.3.4. Emissions Control and Monitoring

Similar to Appropriate Measures, Intensive Farming Guidance specifies that facilities should develop a management system that identifies any risks of pollution that may arise from activities / assets on site in order to implement measures for their mitigation / management.

Point source emissions

Appropriate Measures recommends abatement techniques for point source emissions and states that emissions limits may be set in permits, based upon the emissions inventory and risk assessment. On the other hand, Intensive Farming Guidance prescribes limits for all point source emissions to air, water or land, which must not be exceeded. It states that any point source emissions from sources / emissions points that are not listed will not be permitted. In particular it highlights that there should be '*no untreated point source emissions directly into surface water'* and a suitable treatment method e.g., constructed wetland or sediment trap, should be implemented as appropriate. Further measures given to prevent point source emissions to water include the regular decontamination of yards to reduce the quantity of contaminated water for disposal. It stipulates that there should not be direct or indirect releases to groundwater and where there are, compliance with the Groundwater Regulations will be required.

Fugitive emissions

Intensive Farming highlights that any fugitive emissions of substances must not cause pollution, and this will be considered a breach of permit conditions. However, this can be retracted if it is shown that appropriate measures have been taken to prevent or minimise those emissions. This is similar to the discourse of Appropriate Measures which states that '*You must use appropriate measures to control potential fugitive emissions to land and water and make sure they do not cause pollution.*' For Intensive Farming, preparation and submission of a fugitive emissions management plan for EA approval may be required if emissions are expected. On the other hand, Appropriate Measures requires the implementation of an accident management plan, spillage response plan and a leak detection and repair plan in all cases.

Other measures given to reduce the risk of fugitive emissions are largely similar to those prescribed by Appropriate Measures, including secondary containment (see Section 4.1.3), maintenance of buildings, impervious surfaces and containment kerbs to minimise the risk of leaks, regular inspection of the pipework systems, separation of contaminated water / discharge streams from non-contaminated streams unless they have been treated, and recirculation of collected water streams where practicable.

Odour

The Intensive Farming guidance document specifies that activities should not give rise to odour at levels likely to cause pollution outside the site unless appropriate measures have been implemented to prevent or minimise the odour. Preparation and submission of an odour management plan for EA approval may be required, as per Appropriate Measures. However, for Intensive Farming this is only the case where an installation is within 400m of sensitive receptors or where odour complaints have been received in respect to an installation. Measures that can be taken to reduce odour are given in H4 Odour guidance [31] and should be selected based on the balance of costs and environmental benefits.

Monitoring

Appropriate Measures sets out a number of parameters to monitor for in terms of emissions sources and abatement system efficiency (see Section 4.1.4) as a blanket approach, although further site-specific monitoring requirements may be set in permits. Intensive Farming guidance on the other hand does not give specific parameters for emissions monitoring, and states that (where applicable) these will be specified in permits in respect to point source emissions, surface water or groundwater, noise, ambient air, process and land. It notes that few installations will be required to meet these conditions although ammonia monitoring is likely to be required if the facility is in close proximity to a sensitive conservation site. Monitoring requirements will be enforced on a site-by-site basis.

A.3.5. Surface Water and Liquor Drainage

The approaches of both documents to surface water / liquor drainage are largely based upon the key risks faced in their relative settings, particularly with regards to soil / water pollution. Appropriate Measures focuses on preventing contaminated run-off and any mixing of incompatible wastes and reducing the risk of fire spreading. The measures given to achieve these include adequate drainage infrastructure for collecting surface drainage and spillages, self-contained drainage for bulk storage vessels and drainage systems that are isolated from flammable waste storage areas.

Intensive Farming guidance is targeted towards preventing any surface water contamination from wash-waters / wastes / materials handled on site. It stipulates that all drainage systems should be identified in an accident management plan and that any contamination of clean water drains should be prevented. Slurry, such as seepage from manure, entering surface water drains is highlighted as a particular risk that should be prevented. It is required that drainage channels are kept clear, and procedures are established to divert drainage to slurry / dirty water tanks if there is potential for contamination of surface water systems. It suggests that temporary bunds around drains / diverter valves may be implemented to achieve this.

Appendix B. CIRIA C736 Recommendations

B.1. Risk Assessment and Containment Classification

Within CIRIA C736, a risk assessment and classification framework is provided that guides the identification and management of potential hazards and environmental risks. The framework, based on industry best practices, facilities the determination of the capacity and integrity requirements of containment facilities, ensuring that they are adequate for their intended use. The guidance also covers recommended practices on surface impermeability, leakage detection, drainage and inspection and maintenance regimes specific to secondary and tertiary containment. These recommendations are tailored to the type of containment system, whether local, remote, or combination of both, the structure type, including bunds, lagoons, or tanks, and the classification, which may be class 1, 2, or 3. However, it should be noted that CIRIA C736 does not include good practice recommendations specific to certain types of installations, stored inventory, and activities such as the maintenance of primary containment systems, underground and buried storage tanks, storage of cryogenic substances and sewage effluents, and incident clean-up.

The CIRIA C736 three-tier method for containment classification considers the risks associated with the hazardous loss of containment from primary storage and site classification, which is based on the combined hazard ratings of the source material/s, pathways between source and receptor and potential receptors e.g., WwTW treated effluent. Based on the results of the risk-based assessment, the guide then provides specific recommendations for managing the assessed level of risk appropriate to the class of containment. Recommendations cover design, construction and performance considerations with increasing requirements corresponding to the three classes in terms of design and construction integrity. Class 2 and class 3 containment systems, located on sites classified as relatively medium and high overall risk, respectively, include more detailed recommendations compared to class 1 containment systems which are located on sites classified as low overall risk. The guide further provides increased requirements for classes 2 and 3 in terms of testing, inspection, and maintenance of the containment system to ensure ongoing integrity.

The guide recommends that the risk assessment and capacity requirements of secondary containment should be routinely reviewed in accordance with the specific methodology set out in the report, but as minimum this should be undertaken every five years or where *'there are any modifications made to the primary or secondary containment; the volume of material in the primary containment is increased; the nature of the material in the primary containment is change/reclassified; or the potential pathways and/or receptors have changed.'* Once the class secondary containment system has been validated, it is recommended that a gap analysis exercise be conducted to identify any deficiencies in the system's design or operation against criteria that are specific to its containment class. This exercise also includes determining the necessary improvements to ensure that the identified risks have been managed sufficiently to comply with the law. Where the class of a secondary containment facility has not been determined (e.g., for pre-1994 and small sites) the guidance stipulates that a baseline asset survey should be completed by competent personnel to identify and evaluate the effectiveness of existing control measures, irrespective of class, to then allow classification by the CIRIA C736 risk-based methodology.

For new-build and existing secondary containment facilities, the guidance provides a risk-based process to assess and determine containment capacity that applies to all sizes and types of containment systems. The method draws on current approaches based on '110%' and '25%' rules used by Pollution Prevention Guidance 26 [38] to estimate the volume required to contain the maximum credible spill – not only the volume of the primary storage vessel. The method also accounts for specific risks covered by credible worst-case scenarios which are associated with site specific conditions and to be agreed with regulators and potentially the Fire and Rescue Service.

The recommendations on estimating capacity for local systems (designated areas surrounding primary storage vessel to contain spills) can be summarised as follows:

- Allowance based on risk assessment of a credible spill scenario while accounting for tertiary containment (measures for additional level of spill protection such as diversion tanks and lagoons). Otherwise, minimum capacity of 100% of the primary containment volume for single-tank installations to be used.
- Allowance for total volume of accumulated rainfall with annual exceedance probability (AEP) of 10% (if uncovered) with a minimum retention period of eight days.
- Minimum freeboard (increased height to account for uncertainty factors) of 100 mm for firefighting agents (e.g., foams).

- Freeboard allowance for dynamic effects which varies depending on the type of containment structure e.g., 250 mm for secondary containment tanks.

Additional allowances, such as the provision of sufficient capacity to manage firefighting and cooling water, are also included in containment capacity estimates for remote systems (designated areas located away from spilling or leaking equipment) and combined systems, which contain elements of both local and remote systems along with the means of collecting and transferring spills.

B.2. Secondary Containment Requirements

Table 0B-1: Summary of Key Design, Construction and Performance Recommendations for Secondary Containment Systems

Design/performance requirement	Description
Bunds	
Capacity and retention	See capacity requirements detailed in Section 4.1.3. Footprint to be determined using assessed capacity and height limitations. Minimum retention period of watertight containment for eight days including all content arising from primary containment, rainwater and firefighting agents.
Height of wall (freeboard)	High enough to retain volume of material from primary containment, including allowances for firefighting agents (100 mm minimum) and surge (250 mm for blockwork bunds) Maximum height of 1.5 m (for non-collar bunds)
Proximity to bund wall and accessibility	No structure to be located closer to the bund wall than its own height for Class 3 only. Sufficient access to walls (750 mm minimum clearance) and floors beneath primary containment (600 mm minimum clearance) to permit inspection and for maintenance for Classes 2 and 3
Jetting	Account for the possibility of jetting failure to ensure any discharge is contained within the bund for Classes 2 and 3
Leakage detection	Provision of leak detection system through the base of primary containment where it is not practical to visually inspect or access parts of the floor for Class 3 (i.e., where primary vessel is resting on bund floor) Leak testing of all joints and wall penetrations completed for Classes 2 and 3 after construction phase completed
Drainage from bunds	Provision to empty collected liquids from bunds using mobile/fixed pumps No provision of gravity discharge unless bund is part of a combined system for Classes 2 and 3.
Pipework and associated equipment	Penetrations of bund walls should not be permitted where possible for Classes 2 and 3. No provision to draw-off collected liquids via outlet in bund wall. Pipework, pumps, valves and other equipment associated with the operation of the primary container to be located within containment.
Impermeability	Recommended design and construction method to be executed according to the performance specification of the bund and containment class to ensure adequate level of permeability is reached. Bunds and all other forms of construction to be watertight (liquid retaining) as defined by compliance with recognised standards (e.g., British Standards) or codes of practice
Structural integrity	Bunds to be capable of withstanding the static and dynamic loads associated with liquid spills from primary containment, firefighting operations, and wind loading (collar bunding to follow EN 1991-1-4:2005+A1:2020). Bund floor to be capable of withstanding loads from activities within bunded area and ground stress effects such as differential settlement. Bund walls to be structurally independent from the primary containment, as well as being supported independently from other ancillary structures. For a design life of 50 years, bunds and its components to be capable of withstanding effects of weather, aggressive ground conditions, disturbances and abrasion, fire and corrosive materials e.g., via provision of protective surface.
Lagoons, earth bunds and earth floors	
Design considerations	Design, modifications, construction and ground investigation activities should be completed by competent personnel. Earth embankments, bunds and floors to be designed to comply with BS EN 1997-1:2004 requirements and ground investigations completed according to BS EN 1997-2:2007.

Design/performance requirement	Description
	Lagoons and earth bunds to be designed for a 20-year life subject to regular maintenance and if acting as local secondary or tertiary containment should not be used for functions that reduce their effective capacity. In determining the capacity for earth embankment bund walls 750 mm should be provided as the minimum freeboard height.
Construction	A desk study should be carried out during early-stage planning by competent personnel. Specific guidance should be followed for works related to the site preparation and construction of lagoons and earth bund embankments. For lagoons/bunds of Classes 2 and 3, construction works for liner installation should adhere to a construction quality assurance (CQA) plan.
Impermeability and lining systems.	Earth surfaces should be limited to the equivalent of soil with a permeability coefficient of no greater 1 $x10^{-9}$ m/s and minimum depth of 1 m. Embankment construction limited to soil permeability coefficient of 1 $x10^{-9}$ m/s Soil permeability to be established via methods in BS 5930:1999 for *in situ* testing, BS 1377-5:1990 for laboratory testing or BS EN 1997-2:2007. Impermeable membrane lining systems securely anchored should be required for containment Classes 2 and 3. Materials should be fire resistant or provide adequate protection to ensure lining integrity where flammable substances are contained.
Proximity to receptors	Following regulatory approval of a site, the requirements of the Water Resources (Control of Pollution) (Silage, Slurry and Agricultural Fuel Oil) (England) Regulations 2010 should be adhered to in the absence of specific governance controls. Lagoons should not be located within 50 m radius of a boreholes that abstract water.
Leakage	Suitable leakage detection system required for Class 3 lagoons/bunds for periodic monitoring/testing.
Pipework and associated equipment	Embankments should not be penetrated below the design liquid surface level A sleeve should be installed if a pipe penetration is required in an embankment.
Maintenance	Routine inspections to be carried out. Guidance on the repair and inspection of lining systems should be followed as provided by the manufacturer/supplier and Energy Institute.
Containment tanks	
Design considerations	As buffer capacity 250 mm of minimum freeboard should be provided with no overflows within the freeboard depth. The full tank depth to be taken as the maximum design depth when assessing hydrostatic loading.
Leakage	Leak detection system required for Class 3 tanks (where they rest on the ground).
Integrity	Containment tanks should be subject to routine inspection and testing, and should be informed by the risk assessment and manufacturer's specification.
Above ground containment tanks	
Design and construction considerations	The relevant British Standards, including codes of good practice, should be adhered to for the following tanks suitable for above ground containment: • Proprietary cylindrical tanks (BS 5502-50 to BS 5502-22:2003+A1:2013) as Class 1 standards for agricultural buildings/structure with tank base constructed to EN 1992-3:2006 • Welded steel tanks (BS EN 14015:2004) • Carbon steel tanks (BS 799-5:2010) for oil storage • Pressed steel sectional rectangular tanks (BS 1564:1975 Type 1) for liquid storage. • Glass reinforced plastic tanks (BS EN 13121-3:2008+A1:201) • Reinforced concrete/masonry tanks (BS EN 1992-3:2006). Above ground reinforced masonry tank only for Class 1.
Below-ground containment tanks	
Design and construction considerations	Design of below ground structures should be in accordance with: • BS EN 1997-1:2004 for geotechnical aspects. • BS EN 1997-2:2007 which covers guidelines for testing and using geotechnical laboratory data to assist design. As required by BS EN 1997-1:2004 design and ground investigations should be conducted by competent personnel.
Other tank systems	Above ground tanks such as *in situ* reinforced concrete and glass reinforced plastic tanks may be adapted and installed below ground, provided that the manufacturers' specifications demonstrate their suitability for such use. In applications where *in situ* reinforced concrete is used as structural support for tanks the concrete does not need to be specified to BS EN 1992-3:2006.

Design/performance requirement	Description
***In situ* reinforced concrete and masonry bunds**	
Design considerations	Design, modifications and construction activities should be completed by competent personnel. *In situ* reinforced concrete to comply with BS EN 1992-:2006 class 1 tightness for all three classes. Reinforced masonry bunds to be designed following BS EN 1996-1-1:2005+A1:2012 for non-flammable material and Class 1 containment. Prefabricated bunds to comply with risk-based capacity requirements and designed in accordance with structural codes to withstand static and dynamic forces from primary containment spills.
Leakage and penetrations	Cracking to be controlled and joints should be minimised. Where penetrations through bund walls cannot be avoided, they should not provide a potential leakage path during a credible incident. Leak testing to be in accordance with appropriate British Standard or code of practice. Penetrations through the floor of the bund should be avoided. Waterstops should be installed within both expansion and contraction joints, be resistant to spills, and fire resistant if relevant. For bunds of Class 2 and 3, waterstops should be included in kicker joints.
Lining	Provision of slip membrane e.g., 1000-gauge polyethylene beneath bund floor.
Concrete	Concrete should be specified to BS EN 206-1:2000 and BS 8500-1:2006+A1:2012 and cement composition to BS EN 1992-3:2006. Guidance in Concrete Society to be followed.

Appendix C. Data Collation Tables

The data tables matching the figures are shown below. Only Figure 6-4 does not have an accompanying table, this is due to the ease of identification of the individual WaSCs when listing the total number of permitted sites.

Table C-1: Table Accompanying Figure 6-2

Theme	Capex and one-off-opex (£m)								
	Company A	Company B	Company C	Company D	Company E	Company F	Company G	Company H	Company I
Permit Applications	0.4	5.0	1.6	0.0	0.7	0.9	0.3	0.2	0.1
Secondary Containment	25.6	122.9	78.5	213.0	91.4	36.2	24.6	10.8	11.0
Covering & Storage	479.1	347.6	280.3	61.3	52.9	63.4	1.5	18.9	0.0
Emissions Control and Monitoring	0.0	0.0	3.0	0.0	0.0	12.9	5.0	0.0	0.2
Liquor Sampling	0.0	12.5	0.0	0.0	0.0	0.7	0.0	0.4	0.2
Surface Water & Liquor Drainage	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.2
Anaerobic Digestate Stability	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.5
Other	0.0	0.0	0.0	34.0	0.0	0.7	0.0	0.0	0.0

Table C-2: Table Accompanying Figure 6-1

Theme	Capex and one-off-opex (£m)		
	2018 BAT standards	Appropriate Measures	Total
Permit Applications	8.21	0.86	
Secondary Containment	496.80	117.09	
Covering & Storage	136.72	1,168.23	
Emissions Control and Monitoring	5.20	15.84	
Liquor Sampling	12.50	1.28	
Surface Water & Liquor Drainage	0.24	1.15	
Anaerobic Digestate Stability	0.54	0.10	
Other	61.32	0.71	
Total			

Table C-3: Table Accompanying Figure 6-3

Theme	Capex and one-off-opex (£m	
	2018 BAT standards	Appropriate Measures
Permit Applications	8.21	0.86
Secondary Containment	496.80	117.09
Covering & Storage	136.72	1,168.23
Emissions Control and Monitoring	5.20	15.84
Liquor Sampling	12.50	1.28
Surface Water & Liquor Drainage	0.24	1.15
Anaerobic Digestate Stability	0.54	0.10
Other	61.32	0.71

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E3. YWS PR24 Sludge to Land Strategy Final Report

MOTT MACDONALD

PR24 Sludge to Land Strategy

Final Report (Draft)

1 July 2022

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PR24 Sludge to Land Strategy

Final Report (Draft)

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Contents

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Figures

Glossary

Term/Acronym	Description
AAD	Advanced Anaerobic Digestion (generally including sludge pre-treatment, e.g. thermal hydrolysis)
ACT	Advanced Conversion Technologies
AD	Anaerobic Digestion
APC	Air Pollution Control (for incinerator flue gas treatment)
BAS	Biosolids Assurance Scheme
BtG	Biomethane (injection) to grid
CHP	Combined Heat and Power
D&B	Design and build
DBFOM	Design, build, finance, operate and maintain
DBO	Design, build and operate
Defra	Department for Environment, Food & Rural Affairs
DS	Dry solids
EA	Environment Agency
EfW	Energy from Waste
EPR	Environmental Permitting Regulations
ESP	Electrostatic Precipitator
FBI	Fluidised Bed Incineration
FOG	Fats, Oils and Grease
FRfW	Farming Rules for Water
GHG	Greenhouse Gases
HGV	Heavy Goods Vehicle
HHV	Higher Heating Value
IED	Industrial Emissions Directive
LHV	Lower Heating Value
MSW	Municipal Solid Waste
NOx	Nitrogen oxides
P	Phosphorus
PE	Population Equivalent
Q&G	Quality and Growth model
SSI	Sewage Sludge Incinerator (mono incinerator for sludge only)
STC	Sludge Treatment Centre (usually providing anaerobic digestion of sludge)
STF	Sludge Treatment Facility (sludge thickening or dewatering plant)
SUAR	Sludge (Use in Agriculture) Regulations
t	Wet tonnes
tDS	Tonnes Dry Solids
THP	Thermal Hydrolysis Process (e.g. Cambi THP, Veolia Biothelys and others)
VS	Volatile Solids
WaSC	Water and Sewerage Company
WINEP	Water Industry National Environment Programme
WTS	Water Treatment Sludge
WWTW	Wastewater Treatment Works
YWS	Yorkshire Water Services

Executive summary

Background

YWS requires a 'PR24 sludge to land strategy' to identify an efficient, costed alternative strategy for YWS to adopt in the event that curtailment or even cessation of the sludge to land recycling route occurs in the near future (up to 2030) as a result of changes to the regulations governing the recycling of biosolids to agricultural land.

The project has evaluated the impacts of three scenarios:

1. Recycling to land continues as now and risks to the landbank are not realised
2. Recycling to land becomes restricted to limited land use areas and time periods by 2030
3. Recycling to land is no longer the best commercial option and / or is fully restricted by regulation by 2030.

The analysis has built upon the findings of the Water UK national biosolids strategy (which has evaluated several scenarios for the future of sludge management in the UK), by applying the generic report findings to YWS's asset base and specific disposal routes.

The project has also identified a use for the approx. 30% of YWS's water treatment sludge (WTS) that is not currently discharged to the sewer but is mostly sent to the Burnby Lane facility.

Water UK biosolids report

A report entitled "*An assessment and evaluation of the loss of the biosolids-to-agricultural-land recycling outlet*" was commissioned by Water UK and was published in draft on the 17 December 2021. At the time of writing this Sludge to Land strategy a final version of the Water UK report was not yet available.

The Water UK report assesses various technologies that could be adopted in the face of tighter restrictions on the use of biosolids in agriculture. With respect to thermal treatment options the Water UK report concludes that only sludge incineration is commercially available and proven at the scales required by the UK water sector and that other technologies such as pyrolysis and gasification require further development.

We concur with this general finding and have used incineration technology as the basis for options used under Scenario 3 (no recycling of biosolids to land).

Sludge forecasts

Wastewater sludge production forecasts to 2025 and 2030, pre- and post- anaerobic digestion, have been prepared to inform the landbank assessment and identification of alternative recycling routes. Forecasts for clean water treatment sludge production over the same timescales have also been prepared.

Wastewater sludge quantities produced by YWS' WWTWs are expected to increase sharply by 2025 and 2030 (18% increase by 2025 and a further 6% increase between 2025 and 2030 – compared to an expected population increase in the YWS region of only 2.32% from 2020 to 2030). The increase is mostly due to the impact of tighter phosphorus consents under the WINEP, resulting in increases in both chemical sludge and overall sludge production per PE.

This will cause a similar increase in total treated sludge (biosolids) for recycling to agriculture, as well as a significant increase in the P content of biosolids sludge from most STCs.

Clean water treatment sludge production is expected to grow more slowly over the same timescales, in line with population growth (i.e. an approximate 2.32% increase from 2020 to 2030).

Landbank assessment

A landbank assessment was undertaken for Scenarios 1 and 2.

Based on this assessment the following conclusions have been drawn:

- **Scenario 1 -** There is sufficient land within the YWS region to recycle the biosolids it produces and this is likely to be the case even with the forecast growth in sludge quantity (and P content) by 2030.
- **Scenario 2 –** based on current discussions between the EA and water industry more land will be required due to the forecast increase in volumes of biosolids produced, predicted increases in phosphorus content and increased focus on phosphorus additions, however, despite this, YWS is still predicted to be able to recycle the biosolids it produces in 2030 within its region. However, there is likely to be an increase in haulage distances (from a weighted average of 30km in 2020 to a maximum weighted average of around 40km in 2030) – and hence cost increases for haulage as well as biosolids management.

The other pressures on biosolids recycling (e.g. concerns over contaminants and changes in regulatory regime) could affect operational management (and therefore management costs), but are unlikely to have a significant impact on the quantity of available land and therefore the distance biosolids has to be transported in the medium term.

Biosolids strategy options

Potential biosolids strategy options have been assessed for scenarios 2 and 3.

Scenario 2 options

Strategic options proposed for Scenario 2 have the primary aim of increasing resilience of YWS's sludge recycling operations against future tightening of regulations by increasing the proportion of biosolids achieving enhanced product quality. These options provide additional advanced AD capacity (AAD, using thermal hydrolysis processes) or low/medium temperature drying using waste heat.

A 'do nothing' option has also been included - maintaining and improving existing treatment assets and performance but not making significant changes in the types of treatment processes.

The options analysis concluded that Option 2.1 – implementation of additional AAD capacity - results in the lowest opex and operational carbon emissions (compared to Option 2.2 and the 'do nothing' option). The option would also increase landbank availability, reduce biosolids quantities and create more biogas energy than the 'do nothing' option.

However, Option 2.1 requires significant additional capex (and embodied carbon emissions), with a financial payback period in excess of 20 years (the horizon for the analysis).

Hence, in financial terms the best value option (and the least capex) could be considered to be the 'do nothing' option.

Scenario 3 options

In line with the findings of the Water UK report, two sludge incineration options were identified under this scenario: using a dedicated sludge incinerator (Option 3.1) and diversion of sludge to municipal waste incinerators (Option 3.2). In each case the existing sludge treatment processes (AD or AAD, with biogas energy recovery) were assumed to be retained.

The analysis identified significant technical constraints with the municipal waste option and hence this was not carried forward for detailed cost and carbon analysis.

Hence, Option 3.1 is considered to be the only option under Scenario 3 at this time (with a total capex value of £261m), until other, potentially more attractive options such as pyrolysis or gasification are commercially available and proven at the required scale. Option 3.1 has assumed two SSIs on separate sites which is considered a robust solution for planning purposes, however, constructing two lines on a single site may provide lower overall costs.

Adaptive pathways analysis

An adaptive pathways analysis is presented in this report which indicates a number of different pathways (approaches to sludge treatment) and decision points which might result in a changes to alternative pathways.

A key point highlighted by such an analysis is that the technologies that could eventually be required under Scenario 3 (such as incineration or more novel alternatives such as pyrolysis) can be used in combination with different sludge products (raw, conventionally or advanced digested or dried sludge). Hence, Scenario 3 options could be implemented following and build upon Scenario 2 options (and the Scenario 1 baseline treatment assets) with minimal risk of creating obsolete assets.

Water treatment sludge options

There are a range of possible methods to manage the 30% of YWS's WTS that is not discharged to sewer. The most sustainable option in the short-term is considered to be recycling to agricultural land, following a similar approach to that which applies to biosolids.

There is an operational and permitting cost to this option, but it is likely to be less than the cost of other options, especially in the short-term. A high level assessment (including an assumed 50km haulage distance) indicates an annual cost for this option in the order of £270,000.

To ensure this option is possible for all sources, more information is required to understand where the WTS is produced and ensure the material is suitable for use on agricultural land. There are potentially more cost-efficient solutions, but they are much less certain and the initial costs to develop these outlets would be much greater, although some could be investigated alongside more 'bankable' options like agricultural recycling.

Potential delivery routes

The scope for this strategy asks that the strategy should also provide a potential alternative 'no capex' delivery route (e.g. DBFOM) for the best value option(s).

The potential for a DBFOM type delivery route for new SSI capacity (Option 3.1) has been described and high level indicative costs have been assessed.

Discussions with a major provider of SSI plants have confirmed an interest in delivering SSI in the UK water sector if opportunities arise – through either D&B, DBO or DBFOM routes.

Recommendations and next steps

Based on the findings of the land bank assessment and subsequent options analysis we recommend the following approaches and options:

- If Scenario 3 occurs (loss of the sludge to land route) in the short/medium term then construction of SSI plants (Option 3) would be the only option which is both commercially available and proven at the required scale. A more detailed feasibility study would then be required to confirm the optimum numbers and capacities SSIs to construct.
- If alternative thermal treatment scenarios become commercially available and proven at the required scale before Scenario 3 occurs then these should be assessed in comparison with the SSI option in order to select the most cost effective and sustainable solution. In the meantime, YWS should continue to monitor the development of these alternative technologies.
- If no further restrictions are placed on biosolids use in agriculture, beyond those currently envisaged under Scenario 2 (2b variant) then the ‘do nothing‘ option may be sufficient in the short and medium term.

1 Introduction

1.1 Background

This report describes the proposed ‘PR24 sludge to land strategy’ for Yorkshire Water Services (YWS).

YWS requires the ‘PR24 sludge to land strategy’ to identify an efficient, costed alternative strategy for YWS to adopt in the event that curtailment or even cessation of the sludge to land recycling route occurs in the near future (up to 2030) as a result of changes to the regulations governing the recycling of biosolids to agricultural land.

The project is required to evaluate the impacts of three scenarios:

4. Recycling to land continues as now and risks to the landbank are not realised
5. Recycling to land becomes restricted to limited land use areas and time periods by 2030
6. Recycling to land is no longer the best commercial option and / or is fully restricted by regulation by 2030.

As part of this work, the analysis is required to build upon the findings of the Water UK national biosolids strategy[1] (which has evaluated several scenarios for the future of sludge management in the UK), by applying the generic report findings to YWS’s asset base and specific disposal routes.

The project is also required to identify the most expedient use or disposal route for the approx. 30% of YWS’s water treatment sludge (WTS) that is not currently discharged to the sewer but is mostly sent to the Burnby Lane facility.

The required project activities and outputs are as follows:

- Sludge production forecasts to 2025 and 2030, pre and post digestion, to inform the landbank assessment as well as to be factored into the final treatment option assessment.
- Landbank re-assessment taking into account proposed regulatory changes in 2023 and the national biosolids strategy (Water UK, 2021).
- Development of a cost-efficient investment strategy for Yorkshire Water to transport, treat and dispose of wastewater sludge’s against scenarios 2 and 3 above. The strategy should consider the planned configuration of Yorkshire Water’s current 14 treatment assets, the forecast volumes of sludge production by 2030, the benefits that can be gained from sludge treatment and sludge treatment by-products, such as biogas production and renewable energy generation, and the operational and carbon effects of the proposed interventions.
- Calculated transport and logistics costs for the scenarios baselined against the current plan.
- The strategy should consider what is best practice treatment and recycling/disposal internationally and how new and emerging technologies could be implemented within Yorkshire Water’s business.
- The strategy should also provide a potential alternative delivery route (no capex e.g. DBFOM) for the best value option(s) and provide details of the market engagement carried out in order to support the proposed commercial arrangements.

[1] *An assessment and evaluation of the loss of the biosolids-to-agricultural-land recycling outlet*, Draft Report, 17 December 2021 (produced by ADAS and Cranfield University on behalf of Water UK)

- The costs (capex and opex) should be robust and able to stand up to scrutiny for internal assurance and regulatory challenge and demonstrate cost efficiency against regulatory benchmark models.
- The project should develop a strategy for clean water treatment sludges with the same objectives as waste water taking into account the available recycling/disposal routes and potential benefits that can be gained compared to the current route.
- The costed strategy will inform YWS's PR24 submission under the Water Industry National Environment Programme.

1.2 Study team

This report has been produced by a combined team of Mott MacDonald and Grieve Strategic. Grieve Strategic has been responsible for the landbank assessment aspects and has been assisted in this by ADAS RSK using its ALOWANCE model.

1.3 Structure of this report

This report includes the following information and analyses:

1. **Introduction** – describes the background to this Sludge to Land Strategy, the 3 scenarios assessed and this final report (this section)
2. **Summary of the Water UK biosolids report** – with additional commentary from Mott MacDonald elaborating on specific aspects
3. **Sludge forecasts** – describes the basis and key assumptions for the forecasts used to inform the land bank assessment and subsequent strategy analyses
4. **Landbank assessment** – describes the assumptions and findings of the landbank assessment for scenarios 1 and 2
5. **Biosolids strategy options by scenario** – identifies and assesses the potential strategy options for scenarios 2 and 3 – including technical, capital and operational cost and carbon analyses and a strategic overview (adaptive pathway approach). Based on this analysis, a 'best value' approach is identified for Scenarios 2 and 3.
6. **Water treatment sludge solutions -** identifies and assesses the potential strategy options for water treatment sludge
7. **Potential delivery routes –** discusses potential delivery routes, advantages and disadvantages and likely market appetite.
8. **Conclusions and recommendations**

Further details are provided in appendices.

2 Summary of the Water UK Biosolids Report – with additional commentary

A report entitled "*An assessment and evaluation of the loss of the biosolids-to-agricultural-land recycling outlet*" has been prepared by ADAS and Cranfield University on behalf of Water UK and was published in draft on the 17 December 2021 (this report is referred to as the 'Water UK report' in this Sludge to Land Strategy report).

YWS's scope for this PR24 Sludge to Land Strategy requires the strategy analysis to build upon the findings of the Water UK report (which has evaluated several scenarios for the future of sludge management in the UK), by applying the generic report findings to YWS's asset base and specific disposal routes.

This section therefore presents a summary of the findings of the Water UK report that are relevant to the YWS Sludge to Land Strategy. At the time of writing this Sludge to Land Strategy report for YWS the final version of the Water UK report has not been published. However, we understand that no major changes from the draft report are expected and hence we have based this section on the draft report.

We had added additional analysis to a number of sections below, providing additional information or conclusions based on our own experience where we feel this is useful to provide further background on some subjects or to provide updated information. These sections are clearly identified in order to avoid confusion with the content of the Water UK report content.

2.1 Background to the Water UK project

The Water UK project assessed the impact on the water industry and the wider society of losing the biosolids to land recycling outlet. In doing so it addressed four specific requirements, as follows:

- Assess the alternatives available to farmers and estimate their associated costs, benefits and trade-offs
- Quantify the cost to Water Companies of the loss of the agricultural route and assess the environmental impacts of potential alternative outlets
- Assess the capacity of the industry to respond to loss of the agricultural route in the short term and assess how well the alternative outlets align with the waste hierarchy and Government expectations
- Identify additional work and actions required to support companies' operations in case of a loss of the agricultural route

The Water UK report also included an evidence review of societal concerns over the acceptability of biosolids use in agriculture.

The Water UK report scope did not include water treatment sludge treatment or use.

2.2 Benefits of biosolids use in agriculture

The report states that around 87% of the 4 million wet tonnes of biosolids produced each year in the UK are applied to agricultural land[2]. The report also notes that the applied biosolids are an important source of plant nutrients supplying around 5,640 tonnes of crop available nitrogen, 37,500 tonnes of phosphate (P_2O_5), 2,400 tonnes of potash (K_2O) and 5,700 tonnes of sulphur (SO_3). This represents an estimated £47 million in manufactured fertiliser replacement value. Nutrients from biosolids also save approximately 33,000 tonnes of CO_2 by offsetting emissions from manufactured N and P fertiliser production. Stable organic matter from biosolids also enhances a range of soil properties including workability, water holding capacity, structural stability, biological activity and nutrient cycling.

The report concluded that biosolids use in agriculture was consistent with Defra's policy objectives and 25 year environmental plan, contributing to a circular economy and GHG emissions reduction.

2.3 Findings on societal concerns

The Water UK project's evidence review showed that there are societal concerns over the acceptability of biosolids recycling to agricultural land including issues of soil and public health, from microplastics, anti-microbial resistance, persistent organic chemicals and microbial pathogens. However, the review also showed that biosolids recycling to agricultural land is recognised as being beneficial in terms of recycling nutrients to land. The most commonly reported concern relating to biosolids was odour and the impact that odour had on the health and well-being of those affected.

2.4 Experience in other countries

2.4.1 Water UK report findings

The Water UK report discussed current and proposed approaches in other north European countries including Austria, Germany, Sweden and Switzerland.

The report described how Germany is moving from biosolids use in agriculture to incineration with restrictions limiting sewage sludge applications to land from plants with greater than 50,000 population equivalent (pe) to be enforced by 2032. Germany has approximately 20 sludge mono-incinerators with a combined capacity of 580,000 tDS/year and a further 7 private sector sludge incinerators with a combined capacity of 830,000 tDS/year for untreated sludge. The country has a large programme of sewage sludge incinerator construction.

Switzerland and Austria have implemented mandatory phosphorous (P) recovery legislation which effectively bans biosolids application to land, and the Swedish Government has appointed an inquiry to propose a ban on spreading biosolids on land.

2.4.2 Additional commentary on experience in other countries

The following supplementary analysis has been prepared by Mott MacDonald for this report.

Although the EU supports the recycling of sewage sludge to land as a sustainable approach, there are varying approaches taken to sewage sludge management across all European countries with some still relying on sludge use on agricultural land and some relying on

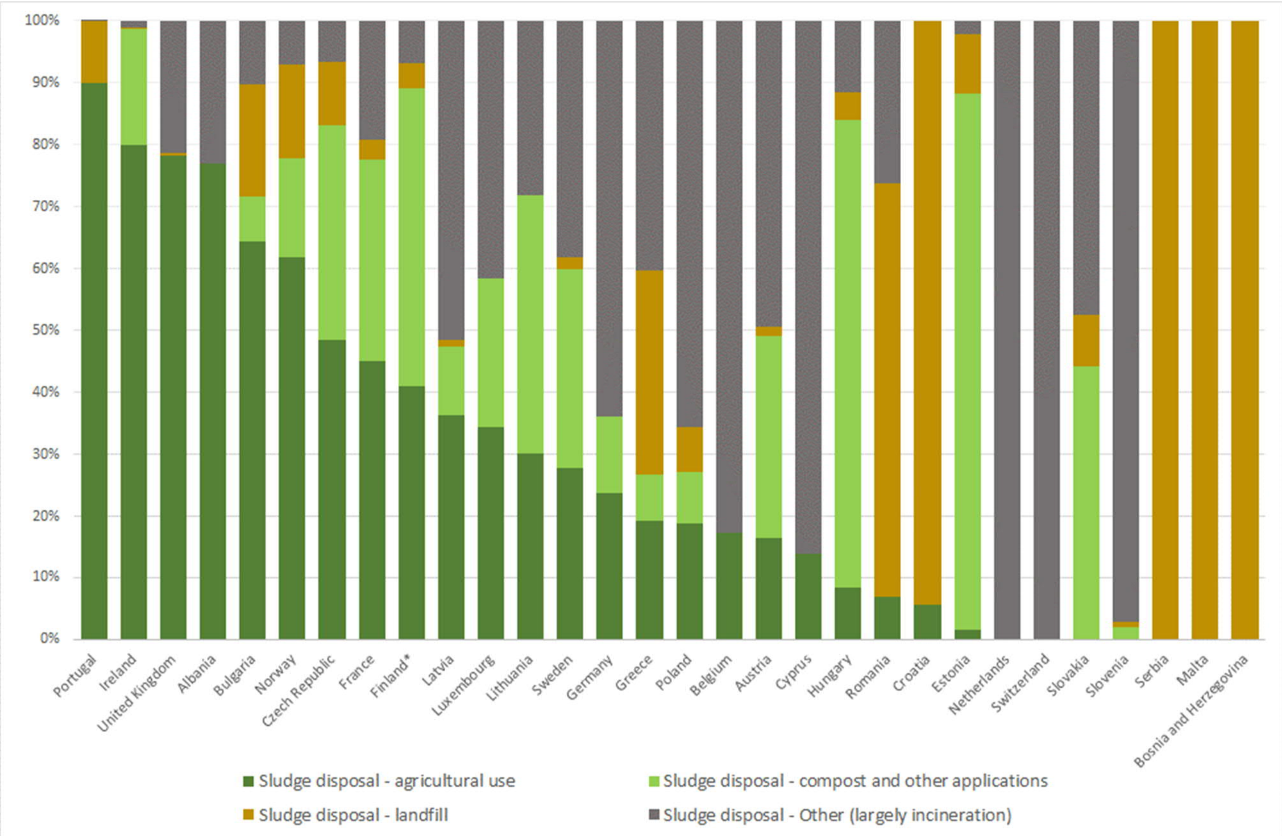
[2] An estimated 4 million tonnes of biosolids are produced annually in the UK (BAS 2021). Approximately 87% of biosolids (3.5 million tonnes) is applied to agricultural land with 6% used for land reclamation or restoration, 4% incinerated (Northern Ireland and London) and 3% used in industrial processes (including cement manufacture).

incineration. In 2017, 51% of sludge in Europe was reported to be recycled to land (35% directly as treated sludge and 16% as a part of compost) and 44% incinerated).

Figure 2.1 shows the variation in sewage sludge disposal routes across Europe.

The UK and France, the next largest sewage sludge producers after Germany are the largest recyclers of biosolids to agriculture (by volume). Other countries relying on agriculture include Portugal, Ireland, Bulgaria and Norway. Whereas countries such as the Netherlands rely entirely on incineration and, as noted in the Water UK report, Germany is moving in the same direction.

Figure 2.1: Sewage sludge use and disposal routes by European country



Source: Eurostat sewage sludge production and disposal data, 2017, updated using latest data available for specific countries

Countries predominantly using incineration

A number of countries have taken more cautious approach to quality limit setting and have affectively prohibited the recycling of treated sludge to land by setting more stringent heavy metal limits than those in the Sewage Sludge Directive. Examples of such countries include the Netherlands, Belgium, Finland, Sweden, Germany and Austria.

The approaches taken in the Netherlands and Germany are described here.

The Netherlands has set extremely tight limits on heavy metal and organic compounds levels in sewage sludge and sets its soil limits based on naturally occurring background levels rather than levels thought to impact human or plant health. Furthermore, there is competition from manure due to intensive livestock production and hence increasing risks of nitrate pollution – resulting in tighter standards for sludge use.

Due to the prohibitive cost of treating sludge to these limits recycling to land is not feasible. As a result, almost all sewage sludge is incinerated in the Netherlands (>99%). However, there is a drive to recover as much value from the sewage sludge as possible prior to incineration – focussing on both nutrients and energy recovery. Hence, nearly all sludge is anaerobically digested prior to incineration – using both conventional and advanced AD processes. Furthermore, there is significant research and development in 'bio-refinery' technologies for the recovery of various innovative materials, such as biopolymers, and nutrients as well as for phosphorous recovery from incinerated sludge ash.

In Germany, sludge recycling to land, for agriculture or landscaping, has been declining with a corresponding increase in the quantity of sludge incinerated from 25% of total sludge disposal in 2001 to 60% in 2014. This was largely in response to the EU Nitrates Directive, which has had a larger impact on agriculture in Germany than in, for example, the UK, due to greater competition from pig slurry manures. As noted in the Water UK report the 2018 Sewage Sludge Ordinance will further restrict the direct application of sludge to land and require compulsory phosphorous recovery at all WWTPs >100,000 PE by 2029 and WWTP > 50,000 by 2032, either through wastewater, sewage sludge or sewage sludge incinerator ash.

Although there are a few examples of sewage sludge pyrolysis and gasification plants in these countries these are all at small scale and it is noticeable that currently ongoing or proposed thermal treatment projects are predominantly large scale sewage sludge incinerators.

Best practice in the UK

Amongst countries using biosolids in agriculture the UK can be considered one of the leaders in terms of biosolids quality, assurance and monitoring. In the UK, current best practice in treatment and disposal seeks to maximise biogas energy production, helping to reduce both opex and net carbon emissions, and ensure a good quality compliant biosolid product. Over the last four AMP periods a number of companies have implemented a high proportion of advanced AD processes which can produce more biogas per unit of sludge treated and are able to produce an enhanced quality product with lower odour risk and potentially increased landbank options (including grassland). Table 2.1 illustrates the distribution of treatment capacity by treatment type across the WaSCs in England and Wales.

Table 2.1: Sludge treatment capacity (tDS/year) by treatment type – England and Wales

Treatment type	MAD	AAD (all types)	Liming	Incineration or 'other'	Total
Anglian Water	3,500	154,600	-	-	**158,100**
Southern	142,200	-	-	-	**142,200**
Severn Trent	132,700	183,600	-	-	**316,300**
South-West	15,800	-	29,900	3,800	**49,500**
Thames	159,500	364,200	3,900	39,200	**566,800**
United Utilities	68,000	131,600	3,800	-	**203,400**
Welsh	8,700	64,700	-	-	**73,400**
Wessex	31,400	48,400	10,200	-	**90,000**
Yorkshire	102,300	25,300	-	-	**127,600**
Northumbrian	-	80,000	-	-	**80,000**
Total	**664,100**	**1,052,400**	**47,800**	**43,000**	**1,807,300**
% distribution by type	37%	58%	3%	2%	**100%**

Source: STC data extracted from Bioresources_Dashboard_Data-2020-21.xlsx, accessed May 2022 from Ofwat website: https://www.ofwat.gov.uk/regulated-companies/markets/bioresources-market/bioresources-market-information/

YWS has a relatively low proportion of sludge treated using an advanced AD process compared to most other WaSCs.

2.5 Impacts of potential regulatory changes including Farming Rules for Water

The Water UK report noted that the Farming Rules for Water (FRfW) and potential future requirements for compliance with other environmental regulations relating to Urban Wastewater Treatment Directive, Industrial Emissions Directive and the Waste Directive would be likely to lead to restrictions on the use of biosolids in agriculture.

Landbank assessments carried out as part of the Water UK project indicated that that under the Environment Agency's (then) interpretation of the FRfW there would be insufficient land area available to accommodate biosolids currently applied before the establishment of winter cereals in the autumn, suggesting that approx. 60% of biosolids currently applied to land in England would require an alternative use. **However, it should be noted that the Water UK report was produced prior to more recent discussions with the Environment Agency (EA) which have indicated a less onerous position, which should allow biosolids recycling to continue at similar levels to current, albeit with an enhanced level of monitoring. This aspect is discussed further in Section 4 of this report.**

2.6 Review of alternative outlets for biosolids

2.6.1 Water UK report findings

The Water UK report also assessed a number of alternative outlets for biosolids, other than application to agricultural land, including the following:

- Forms of thermal treatment (incineration, gasification and pyrolysis)
- Other land based uses including land restoration, forestry, non-food crops (for bioenergy)
- Landfill

The report also briefly mentioned the options of combusting biosolids with coal in power stations, with MSW, wood chips and in cement kilns.

The report also reviewed other new technologies which might be beneficial, though would only provide a partial solution. These included:

- Novel nutrient recovery including new products (e.g. the CCm technology)[3]
- Treatment and volume reduction by insects (currently being developed with food wastes)
- Mineral extraction
- Various technologies for producing platform chemicals for industrial applications

The main conclusion of the Water UK report was that the only existing technologies (other than use in agriculture) available for treatment, final use or disposal of sludge are different forms of thermal treatment, i.e. sludge incineration, pyrolysis and gasification.

However, the report also noted that there are no examples of pyrolysis and gasification technologies in use at the required scale for biosolids in the UK or Europe – hence there is

[3] CCm technologies (https://ccmtechnologies.co.uk/), a method of producing fertiliser products by adding carbon dioxide, ammonia and phosphorus to organic materials. The technology is still being developed for use with biosolids, using ammonia and phosphorus from the wastewater treatment process with the objective of creating an 'enhanced fertiliser product' for use in agriculture.

insufficient operational experience and reliable cost data for these technologies. Furthermore, uses for the resulting 'biochar' solid product are also currently uncertain (but the subject of on-going research). In contrast, incineration technologies were noted as being well-established.

The report noted that other land based uses could not provide a consistent and reliable solution and landfill disposal would be technically difficult (lack of capacity), expensive and environmentally unsustainable (loss of nutrients and carbon, methane emissions and leachate generation). The report also noted that with respect to the more novel technologies identified, 'a number of critical issues limit technology application and scale-up at the current state of development'.

For incineration the Water UK report focussed on co-combustion of sludge in municipal solid waste (MSW) incinerators, where such plants have some remaining capacity. The report stated that in the UK there are 54 operational plants with 15 more under construction and a combined capacity of 20 million tonnes per year, of which 90% of capacity was already allocated to MSW. These plants mostly use moving grate furnace technology which is appropriate for MSW but less suitable for sludge cake. Hence, sludge cake would need be added in relatively small quantities and blended into the MSW feed.

The Water UK report found that if all the biosolids currently applied to agricultural land was diverted to MSW incinerators then this would use up the estimated spare capacity of the existing and planned MSW incinerators in the UK[4] and require an additional approx. 2 million tonnes of MSW incinerator capacity for the remaining sludge (in addition to an increase in sludge dewatering capacity and safe short-term storage). The report concludes that the alternative would be to construct dedicated sewage sludge incinerator (SSI) plants across the UK, which use a fluidised bed furnace technology appropriate for sludge cake, instead of the moving grate technology. The report proposes that approx. 31 SSIs would be required assuming an average capacity of 29,000 tDS/year).

The report noted that the main downsides of a move from agricultural use to incineration were as follows:

- Nutrient loss (no longer going to soils – though technologies for extracting P from ash are in development)
- Carbon loss (lost to atmosphere, with no organic carbon going to soil)
- Cost increase (capex and opex)

The Water UK report provided a high level assessment of capital and operating costs for sludge incineration (noting that it is difficult to prepare such cost estimates given the number of variables at a national level). **Based on comparison with our own database of recent sludge incinerator project costs we consider that capital and operating costs would be significantly higher than those stated in the Water UK report.**

2.6.2 Additional commentary on alternative outlets

We have undertaken similar technology reviews for other clients in the last year and in general would agree with the findings of the Water UK report.

In particular, we generally concur with the Water UK report regarding alternative sludge treatment and disposal routes, but with additional observations, as follows:

[4] The analysis does not mention the extent to which some of this headroom would be needed for maintenance down-times and hence would not be available all of the time.

- Modern sewage sludge incinerators are a proven technology and plants at the required scales are currently being implemented at multiple sites across mainland Europe.
- Thermal treatment technologies such as pyrolysis and gasification show promise as an alternative treatment and disposal route but there are currently relatively few operating demonstration plants and no plants at similar scales to those that would be required for regional STCs such as Knostrop and Esholt.
- Co-combustion of sludge in MSW incinerators is a technically feasible alternative. However, there are a number of constraints and drawbacks with such an approach, not fully addressed in the Water UK report, which are discussed further in Section 5.4?.
- A range of other novel biosolids treatment technologies and uses are being explored with a number of pilot plants being operated in the UK (e.g. for the CCm technology described in the Water UK report). However, such innovations are still at early stages of development and there is insufficient cost and performance data in the public domain to enable their impacts to be assessed with confidence for this YWS strategy. Furthermore, their environmental impacts (including carbon footprint) and ability to deal with emerging contaminants are also not yet fully understood. Hence, trials and further development of such technologies should continue in the hope that they provide beneficial solutions in the medium and longer term.

Both mono-sludge incinerator and MSW incinerator technology options are discussed in Section 5.4 of this Sludge to Land Strategy report.

2.7 Conclusions of the Water UK report

A summary of the Water UK report conclusions is as follows:

- The application of biosolids to land remains a viable and beneficial practice. This process supports government objectives in maximising the value and recovery of resources, i.e. returning nutrients to land, maximising the use of stable organic matter for soils, limiting greenhouse gas emissions to atmosphere by reducing the need for manufactured nitrogen and phosphorous fertiliser in crop production systems. This practice currently maximises the value of resource recovery.
- The report identified odour complaint as the major cause for concern over current practices in applying biosolids to land.

If a change of practice is required, then a feasible transition pathway needs to be defined that achieves the following:

- Diverts materials from direct application to land to technologies that continues to promote resource recovery whilst minimising GHG emissions
- Is achievable within technology development and investment timescales whilst not entailing excessive cost in the short or longer term
- Can be implemented rapidly at a rate that prevents the accumulation of biosolids in storage (which has the potential to cause unmanageable or hazardous conditions).

3 Sludge Forecasts

This section presents a summary of the sludge production forecasts used in the preparation of the Sludge to Land Strategy. Further details of the approach and data sources used are provided in Appendix A of this report.

3.1 Approach

Wastewater sludge production forecasts to 2025 and 2030, pre and post anaerobic digestion, have been prepared to inform the landbank assessment and assessment of alternative recycling routes. Forecasts for clean water treatment sludge production over the same timescales have also been prepared.

The wastewater sludge forecasts have been developed using the following steps:

- Confirmation of the 2020 sludge production baseline
- Review of changes in sludge treatment locations over the 2020 to 2030 period
- Analysis of potential changes in sludge phosphorus content due to changes in wastewater treatment (largely due to the WINEP programme) over the period to 2030
- Preparation of sludge forecasts from 2020 to 2030 taking into account the above changes

A similar approach was used for the water treatment sludge forecasts.

3.2 Wastewater sludge forecasts

3.2.1 Key assumptions and findings

In preparing the wastewater sludge forecast to 2030 we have taken account of the following expected changes in sludge treatment centre (STC) operations, as conveyed by YWS:

- Bridlington and Naburn STCs will both close by 2025;
- Huddersfield STC is operational again;
- Hull STC has recently been refurbished, providing additional sludge treatment capacity, but constraints on the site's ability to use additional biogas may constrain sludge throughput until 2025.

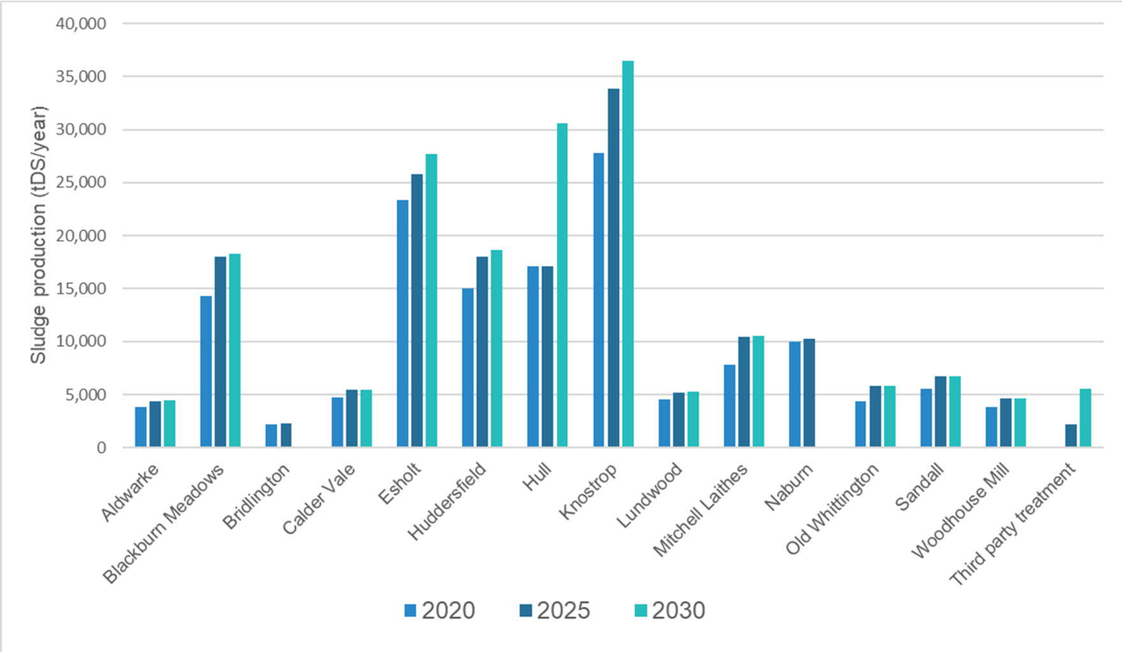
To replace the capacity lost by closure of sludge treatment centres it is expected that export of a proportion of sludge for treatment by 3rd parties may be introduced from 2025 onwards. For the purposes of this study (including the landbank assessment) it has been assumed that this sludge would not be recycled to agriculture within the YWS region and hence has been excluded from the 2030 estimates.

The 2030 treated sludge outputs for each STC have been calculated using assumed VSS contents and destruction rates (see Appendix A). The projected sludge quantities (pre and post-treatment) for each STC for 2020-2025 and 2025-2030 are presented in Figure 3.1 and Table 3.1.

Table 3.1 indicates that wastewater sludge quantities produced by YWS's WWTWs are expected to increase sharply by 2025 and 2030 (18% increase by 2025 and a further 6% increase between 2025 and 2030 – compared to an expected population increase in the YWS region of only 2.32% from 2020 to 2030). The increase is mostly due to the impact of tighter phosphorus consents under the WINEP, resulting in increases in both chemical sludge and overall sludge production per PE. This will cause a similar increase in total treated sludge (biosolids) for recycling to agriculture.

The impact of these changes on the biosolids phosphorus content is discussed in Section 3.2.2.

Figure 3.1: Sludge production (pre-treatment) by destination (tDS/year)



Source: Data from Table 3.1

Table 3.1: Sludge forecasts to 2030 (tDS/year)

STC	Sludge (pre-treatment) (tDS/year)			Projected increase (%)		Sludge (post-treatment) (tDS/year)		
	2020	2025	2030	2020-2025	2025-2030	2020	2025	2030
Aldwarke	3,861	4,397	4,419	14%	0%	2,500	2,900	2,900
Blackburn Meadows	14,351	17,997	18,330	25%	2%	9,500	11,900	12,100
Bridlington	2,231	2,262	0	1%	0%	1,500	1,500	0
Calder Vale	4,769	5,413	5,494	13%	2%	3,100	3,600	3,600
Esholt	23,399	25,822	27,673	10%	7%	14,000	15,400	16,500
Huddersfield	14,999	18,025	18,621	20%	3%	9,900	11,900	12,300
Hull	17,103	17,154	30,580	0%	78%	11,300	11,400	20,300
Knostrop	27,833	33,831	36,517	22%	8%	18,400	22,400	24,200
Lundwood	4,561	5,158	5,246	13%	2%	3,000	3,400	3,500
Mitchell Laithes	7,809	10,429	10,509	34%	1%	5,200	6,900	7,000
Naburn	9,971	10,289	0	3%	0%	6,600	6,800	0
Old Whittington	4,330	5,789	5,818	34%	1%	2,900	3,800	3,900
Sandall	5,517	6,683	6,687	21%	0%	3,600	4,400	4,400
Woodhouse Mill	3,795	4,607	4,670	21%	1%	2,500	3,100	3,100
Sub-total	**144,531**	**167,856**	**174,565**	**16%**	**4%**	**94,000**	**109,400**	**113,800**
Third party treatment	0	2,167	5,501	Started	154%		0	0
Total	**144,531**	**170,023**	**180,066**	**18%**	**6%**			

Note: Sludge pre-treatment values taken from Quality and Growth Model v12. Sludge post-treatment values derived using solids destruction assumptions in Appendix A.1.1 of this report and rounded to nearest 100.

Table 3.2: Treated sludge (biosolids) forecast to 2030 – wet tonnes/year

STC	Sludge (post-treatment) (tDS/year)			Cake % dry solids	Sludge (post-treatment) (wet tonnes/year)		
	2020	2025	2030		2020	2025	2030
Aldwarke	2,500	2,900	2,900	20.8%	12,300	14,000	14,100
Blackburn Meadows	9,500	11,900	12,100	24.3%	39,000	49,100	50,000
Bridlington	1,500	1,500	0	20.9%	7,000	7,200	0
Calder Vale	3,100	3,600	3,600	21.2%	14,800	16,900	17,200
Esholt	14,000	15,400	16,500	28.8%	48,700	53,500	57,400
Huddersfield	9,900	11,900	12,300	27.1%	36,600	44,100	45,600
Hull	11,300	11,400	20,300	25.1%	45,000	45,300	80,700
Knostrop	18,400	22,400	24,200	25.0%	73,500	89,700	96,800
Lundwood	3,000	3,400	3,500	21.1%	14,300	16,200	16,500
Mitchell Laithes	5,200	6,900	7,000	24.0%	21,500	28,800	29,000
Naburn	6,600	6,800	0	23.8%	27,700	28,600	0
Old Whittington	2,900	3,800	3,900	24.0%	11,900	16,000	16,100
Sandall	3,600	4,400	4,400	19.3%	18,900	22,900	23,000
Woodhouse Mill	2,500	3,100	3,100	23.0%	10,900	13,300	13,500
Total	**94,000**	**109,400**	**113,800**		**382,100**	**445,600**	**459,900**

Note: Cake % dry solids value for 2020 provided by YWS. Assumed to stay same until 2030. Sludge post-treatment quantities rounded to nearest 100.

3.2.2 Phosphorus content

An increase in the average mass of sludge produced at YWS WWTWs and then treated at STCs from 2020 to 2030 is expected due to tightening in phosphorus consents and hence increased P removal under the WINEP.

The 2030 nitrogen and phosphorus (as P_2O_5) contents in biosolids have been assessed and the results are presented in Table 3.3. The assumptions and methodology used to derive these values are described in Appendix A.

Table 3.3: Biosolids N and P content forecasts

STC name	Ave Biosolids N content (%)		Ave Biosolids P_2O_5 content (%)		Ave Biosolids P content (g/kg) (NOT P_2O_5)	
	2020	2030	2020	2030	2020	2030
Aldwarke	5.2	5.2	5.3	7.5	23.1	32.7
Blackburn Meadows	5.2	5.2	6.3	7.5	27.5	32.7
Bridlington (1)	6.6	n/a	7	n/a	30.5	n/a
Calder Vale	5.1	5.1	5.6	7.5	24.4	32.7
Esholt	4.3	4.3	6.2	7.5	27.1	32.7
Huddersfield	4.2	4.2	6.3	7.5	27.5	32.7
Hull	4.9	4.9	6.9	6.9	30.1	30.1
Knostrop	4.5	4.5	6.3	7.5	27.5	32.7
Lundwood	5.4	5.4	4.5	7.5	19.6	32.7
Mitchell Laithes	4.9	4.9	3.5	7.5	15.3	32.7
Naburn (1)	5.3	n/a	6.5	n/a	28.4	n/a
Old Whittington	4.5	4.5	4.8	7.5	20.9	32.7
Sandall	5.7	5.7	5.5	7.5	24	32.7
Woodhouse Mill	5.5	5.5	5	7.5	21.8	32.7

Note (1): Bridlington STC and Naburn STC assumed to be shut down before 2030

3.3 Water treatment sludge forecasts

A forecast has been prepared for the approximately 30% of YWS's water treatment sludge (WTS) that is currently sent to the Burnby Lane disposal facility.

The data sources used in preparing WTS forecasts to 2030 are described in Appendix A.2. The key assumptions used in the forecasts are as follows:

- The measured 2020 sludge production has been assumed to increase to 2030 in proportion to the wastewater PE forecasts data presented in the 'Quality and Growth Model v12' (Stantec, 2021). Hence, a percentage growth of 1.26% has been used between 2020-2025 and 1.05% between 2025-2030, giving a total increase from 2020 to 2030 of 2.32%.
- The total measured and predicted site sludge production has been used for assessing future disposal options. Hence, the forecasts assume that sludge lagoons are not used for storage/disposal in the future.

The measured 2020 sludge quantities and forecasts to 2030 for each WTW are presented in Table 3.4.

Table 3.4: WTW sludge production projections to 2030

WTW	Coagulant type	Product type	Ave % dry matter	Current use/disposal route	Year	Sludge output, (tDS/year)	Sludge output (Wet tonnes/year)
Acomb Landing WTW	Aluminium Sulphate	Cake	16	Cake to Burnby Lane landfill	2020	503	3,143
					2030	515	3,216
Elvington WTW	Aluminium Sulphate	Cake	16	Cake to Burnby Lane landfill	2020	1,876	11,723
					2030	1,920	11,995
Huby WTW	Aluminium Sulphate	Cake	16	Cake to Burnby Lane landfill	2020	71	445
					2030	73	455
Loftsome Bridge WTW	Aluminium Sulphate	Cake	16	Cake to Burnby Lane landfill	2020	441	2,755
					2030	451	2,819
Thornton Steward WTW	Aluminium Sulphate	Cake	16	Reclamation - North East	2020	130	815
					2030	133	834
Tophill Low WTW	Aluminium Sulphate	Cake	16	Agricultural land - Farm near Driffield	2020	296	1,852
					2030	303	1,895
Langsett WTW	Ferric Sulphate	Cake	20	Reclamation – Sheffield area	2020	282	1,444
					2030	289	1,478
Loxley WTW	Ferric Sulphate	Cake	20	Reclamation – Sheffield area	2020	236	1,180
					2030	241	1,207
Total					2020	**3,835**	**23,356**
					2030	**3,924**	**23,899**

4 Landbank Assessment

This section summarises the key assumptions, approach, findings and conclusions of the landbank assessment undertaken for this Sludge to Land Strategy by Grieve Strategic. The more detailed report of the landbank assessment is provided as Appendix B of this report.

4.1 Scenarios assessed and approach

As described in Section 1.1, YWS has identified three strategy scenarios for assessment under this strategy. Two of these scenarios required landbank modelling and this work has been carried by Grieve Strategic, in conjunction with RSK-ADAS, using its ALOWANCE model. The third scenario assumes that recycling biosolids to agricultural land is no longer viable and hence this scenario was not modelled.

The two scenarios requiring landbank modelling are as follows:

1. Recycling to land continues as now and risks to the landbank are not realised
2. Recycling to land becomes restricted to limited land use areas and time periods by 2030

The approach used for the landbank assessment includes the following steps:

- Assessment of available landbank – the theoretical ‘available’ landbank, accounting for restrictions as well as competition from other organic materials. For Scenario 1 this is based on current restrictions, whilst Scenario 2 takes into account additional potential restrictions by 2030
- Assessment of landbank required for the biosolids under each scenario – sets out the key assumptions and findings for each scenario
- Assessment of the maximum haulage distance to the available landbank

4.2 Key findings of the landbank assessment

The key findings of the landbank assessment for each scenario are described below.

4.2.1 Scenario 1 - Recycling to land continues as now

For this scenario the current area of agricultural land in the YWS region (approx. 991,000 ha) was reduced by 69% to account for ALOWANCE model restrictions, a 50 metre odour buffer and rotational exclusion clauses, to leave a **theoretically available landbank** of approx. 307,000 ha (approx. 31% of the original agricultural land area).

The assessment used the 2020 biosolids production (approx. 81,600 tDS/year[5]). After accounting for the rate of application, acceptability on farm and the allowed maximum application frequency (once every year - i.e. the shortest return period following the requirements of the Biosolids Nutrient Management Matrix), it was assessed that a minimum of approx. 50,400 ha of rotational landbank was required for recycling the biosolids produced by YWS. This would require biosolids to be transported up to 31 kilometres[6] from STCs.

[5] Value based on YWS Bioresources team data for 2020, which is lower than the value predicted using YWS’s ‘Quality and Growth model data for 2020 and presented in Section 3 (see Appendix A, Section A.1.2 for further discussion).

[6] The estimated maximum haulage distances for each STC to the available landbank (and rotational landbank requirements) were calculated for each scenario. The modelled maximum haulage distances for Scenario 1 (2020) matched those reported by YWS, which demonstrates the ALOWANCE model was working correctly.

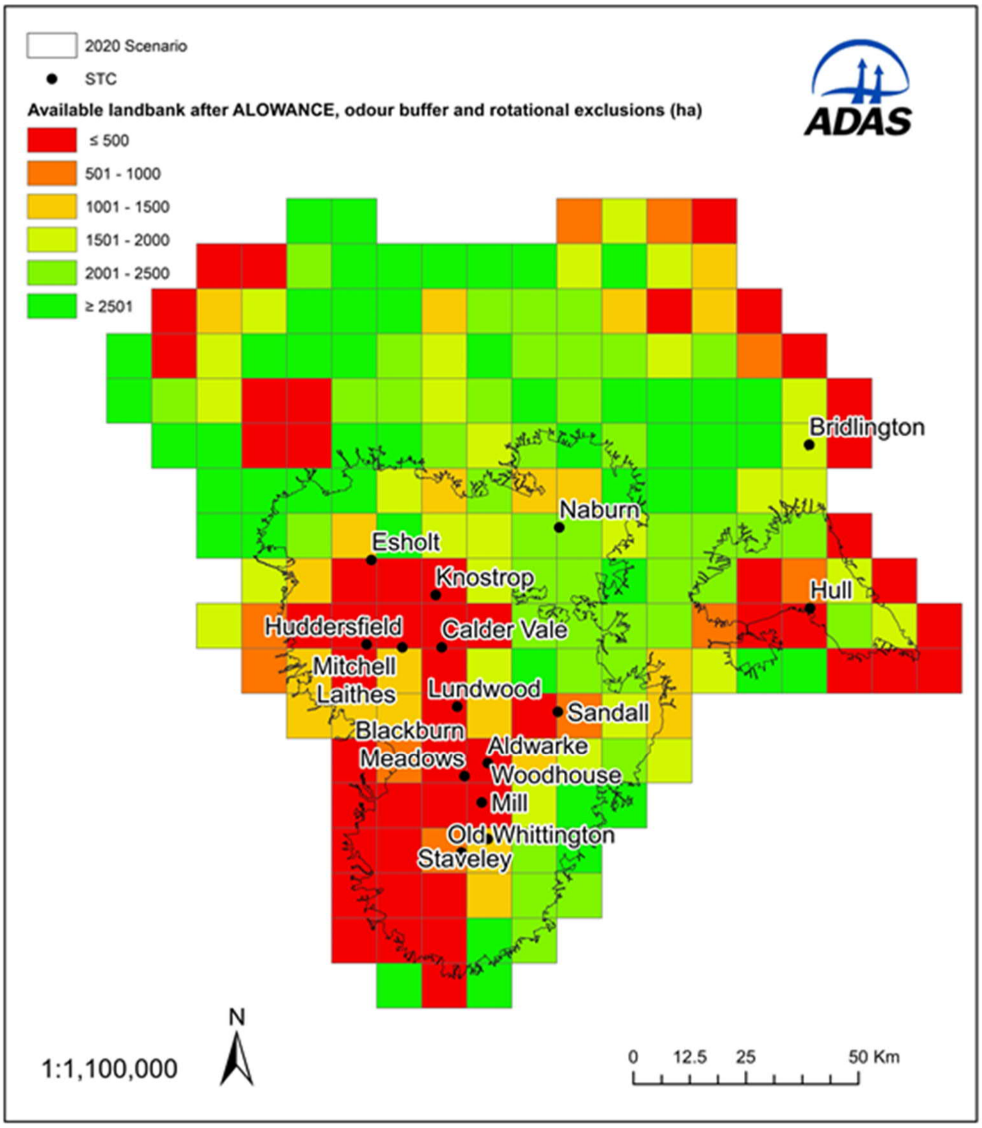
The results for Scenario 1 are presented in Table 4.1 and graphically in Figure 4.1. The results are summarised and compared with those for Scenario 2 in Table 4.3.

At this application frequency soil P indices would be increased in the long-term (as more phosphate would be applied by biosolids applications (and possibly other sources) than would be removed by crops), reducing and potentially even preventing biosolids applications. However, this would be dependent on the availability of the phosphate in biosolids. The Fertiliser Manual (RB209) states that 50% of the phosphate is crop available, but experimental data suggests it may be significantly less than this (approx. 10% based on digested biosolids).

Table 4.1: Scenario 1 - Rotational landbank requirement for each STC

STC name	Location	Product (tDS/year)	Treatment/ product	Standard	Landbank (ha)
Aldwarke	Rotherham	1,900	AD cake	Conventional	1,100
Blackburn Meadows	Sheffield	9,100	AD cake	Conventional	5,000
Bridlington	Bridlington	800	AD cake	Conventional	600
Calder Vale	Wakefield	2,300	AD cake	Conventional	1,100
Esholt	Shipley	14,500	AAD cake	Conventional	7,400
Huddersfield	Huddersfield	-	AD + lime cake	Conventional	-
Hull	Hull	10,800	AD + lime cake	Conventional	8,400
Knostrop	Leeds	23,100	AD + lime cake	Conventional	16,100
Lundwood	Barnsley	1,000	AD cake	Conventional	500
Mitchell Laithes	Dewsbury	6,800	AD cake	Conventional	3,500
Naburn	York	4,800	AD cake	Conventional	2,900
Old Whittington	Chesterfield	2,500	AD cake	Conventional	1,300
Sandall	Doncaster	2,000	AD cake	Conventional	1,200
Woodhouse Mill	Sheffield	2,000	AD cake	Conventional	1,300
Total		**81,600**			**50,400**

Figure 4.1: Scenario 1 - STC maximum distance to access suitable land 2020



Source: Grieve Strategic / ADAS
Note: Each square is 10,000 ha

4.2.2 Scenario 2 - Recycling to land becomes restricted by 2030

Scenario 2 was modelling with the following changes in inputs:

- Predicted growth in biosolids production figures for 2030 combined with increased biosolids phosphorus content
- Reduced farmer acceptance (to 35%, compared to 45% for scenario 1)
- Tighter phosphorus restrictions
- No applications on sandy/shallow soils
- No applications in the autumn on or in advance of crops without a manufactured fertiliser nitrogen requirement (to reflect the Environment Agency's position on FRfW at the time the scenario was devised), and

- No applications within 200 metre of a sensitive site or within a Source Protection Zone 2
- Maximum amount of biosolids that can be applied to grass landbank increased to 10%

Further details of modelling assumptions are provided in Appendix B.

The assessment used the 2030 biosolids production (approx. 113,800 tDS/year, see Section 3). These changes reduced the **theoretically available landbank** in the YWS region to 90,800 ha (and increased the landbank required to 465,200 ha, almost 10 times that required in 2020 for Scenario 1. To reach such a landbank would theoretically result in biosolids having to be transported as far as south-west England and into Scotland, up to a maximum of 410 kilometres, which would make recycling biosolids to agricultural land no longer viable.

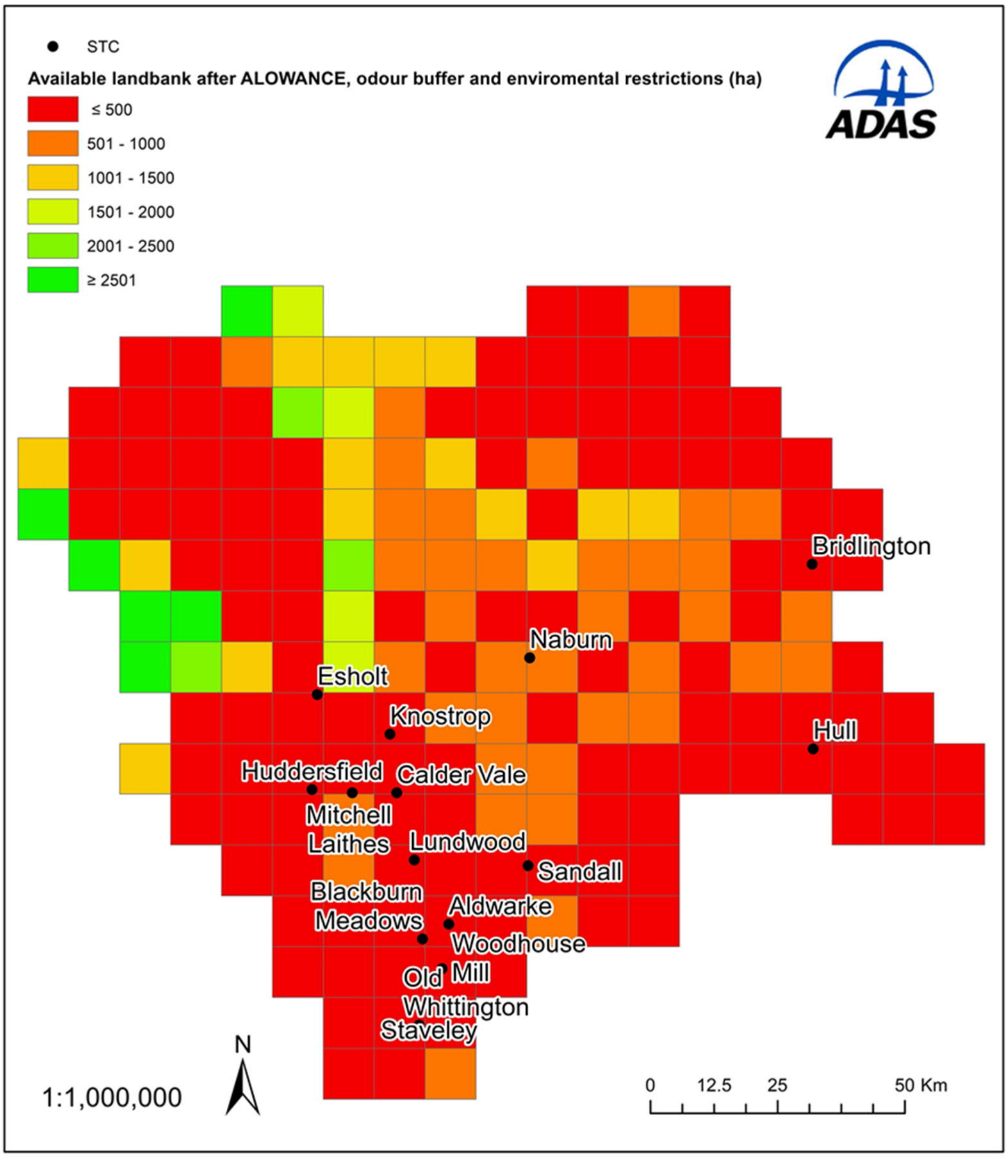
The results for Scenario 2 are presented in Table 4.2 and graphically in Figure 4.2. No haulage radial rings (for maximum haulage distance) are shown on Figure 4.2 because they are outside the YWS region. The results are summarised and compared with those for Scenario 2 in Table 4.3.

Table 4.2: Scenario 2 - Rotational landbank requirement for each STC

STC name	Location	Product (tDS/year)	Treatment/ product	Standard	Landbank (ha)
Aldwarke	Rotherham	2,900	AD cake	Conventional	11,900
Blackburn Meadows	Sheffield	12,100	AD cake	Conventional	49,300
Bridlington	Bridlington	-	AD cake	Conventional	-
Calder Vale	Wakefield	3,600	AD cake	Conventional	14,800
Esholt	Shipley	16,500	AAD cake	Conventional (1)	76,400
Huddersfield	Huddersfield	12,300	AD + lime cake	Conventional	50,100
Hull	Hull	20,300	AD + lime cake	Conventional	75,700
Knostrop	Leeds	24,200	AD + lime cake	Conventional	98,300
Lundwood	Barnsley	3,500	AD cake	Conventional	14,100
Mitchell Laithes	Dewsbury	7,000	AD cake	Conventional	28,300
Naburn	York	-	AD cake	Conventional	-
Old Whittington	Chesterfield	3,900	AD cake	Conventional	15,700
Sandall	Doncaster	4,400	AD cake	Conventional	18,000
Woodhouse Mill	Sheffield	3,100	AD cake	Conventional	12,600
Total		**113,800**			**465,200**

Note (1): Although Esholt STC has a THP plant it is not considered to currently produce an enhanced treated product as the final dewatering process uses final effluent (without disinfection) for polyelectrolyte dilution.

Figure 4.2: Scenario 2 - STC maximum distance to access suitable land 2030



Source: Grieve Strategic / ADAS
Notes: (1) Each square is 10,000 ha. (2) No haulage radial rings are shown on the map because they are outside the YWS region.

4.3 Discussion

The modelling of the maximum haulage distances for 2020 match those reported by YWS, which demonstrates the ALOWANCE model is working correctly and is a suitable tool for the landbank assessment.

Scenario 2 – 'worst case' and 'best estimate'

Scenario 2 was designed as a plausible worst-case situation in 2030 and was based on the regulatory constraints being proposed by the EA in late 2021. Scenario 2 confirms the findings of the Water UK report and demonstrates that there would be insufficient landbank, not only within the YWS region but in the whole of England (after applying the same restrictions to all land and biosolids) hence, confirming that recycling biosolids to agricultural land would not be viable in those circumstances.

However, since that scenario was agreed and modelled (at the end of 2021), there has been positive progress in the negotiations with the EA over the FRfW with the water industry agreeing proactive measures to further tighten the controls governing biosolids recycling, therefore reducing the risk of significant agricultural diffuse pollution. The Department for the Environment, Food and Rural Affairs (Defra) guidance to the EA has been published recently, although more clarification is required particularly related to phosphorus management. At the time of writing the water industry is in discussion with the EA over the detail of the proactive measures. Although these measures will impact on biosolids recycling, they are not expected to result in significant increases in haulage distances. There will most likely be increased controls resulting in increased costs, but there is expected to be limited impact on a regional or national basis on the available agricultural land and therefore haulage distances compared to the 2020 scenario.

In summary, under this less onerous ‘best estimate’ scenario, it is thought that a combination of the increased biosolids quantity in 2030, increased phosphorus content of the biosolids, the proactive measures and the restrictions within the Defra guidance would only increase the average maximum haulage distance to 35-40 kilometres, compared to the weighted average maximum distance of 30 km for Scenario 1. However, it is proposed that once the requirements have been confirmed with the EA, YWS could model the scenario so it can fully understand the impacts on its recycling operations.

Table 4.3 compares the modelled results for scenarios 1 and 2 with the current ‘best estimate’ of haulage distances if a less onerous version of Scenario 2 is agreed with the EA.

Table 4.3: Comparison of key outputs for each scenario

Data	Units	Scenario 1	Scenario 2 *Plausible worst case*	Scenario 2 *Current ‘best estimate’ (1)*
Modelled year		2020	2030	2030
Quantity of biosolids taken to agricultural land	tDS/year	81,600	113,800	113,800
Landbank required	ha	50,400	465,200	n/a
Landbank available in the YWS region	ha	307,000	90,800	n/a
Average maximum distance to access landbank	km	28	410	n/a
Weighted average maximum distance to access landbank	km	30	410	35-40

Note: (1) ‘Best estimate’ scenario has not been modelled using ALOWANCE (as revised requirements have only emerged in discussions after Scenario 2 was already modelled), hence the lower haulage distances are based on expert judgement.

Phosphorus management

One factor that will continue to come under greater scrutiny will be management of phosphorus. It is possible that restrictions will be increased via the guidance on the FRfW, but any impact is likely to be restricted to soils with higher phosphorus contents, affecting only land at P index 3 and 4[7]. However, the current focus on improving water quality is only going to continue, particularly with more focus on nutrient neutrality, and phosphorus will be a particular issue as more water courses are at risk from phosphorus pollution than from nitrogen. Compounding the issue from a biosolids perspective is that due to the increased focus on phosphorus, all water

[7] ADAS Soil P index - a measure of the phosphorus content of soil

companies (including YWS) have schemes to remove even more phosphorus from their final effluent, which will result in even greater concentrations in biosolids (as is included within the Scenario 2). A key, but not the only reason the quantity of land required in 2030 (for scenario 2) increased almost 10-fold from 2020 (scenario 1) were the phosphorus restrictions. Although most of the land within the YWS region is at P index 0, 1 and 2, restrictions on applications at P index 3 and 4 will influence YWS recycling and would likely result in biosolids having to be transported further. Further work would be required to ensure restrictions on phosphorus inputs do not have a dramatic effect on biosolids recycling, including understanding the availability of phosphorus in biosolids as well as investigating ways to extract phosphorus from biosolids.

Contaminant concerns

The issue of contaminants in biosolids will also continue to be a focus. This has always been the case with concerns over microbiological parameters and potentially toxic elements being replaced with concerns over persistent organic pollutants (POPs) such as Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) and Polycyclic aromatic hydrocarbons (PAHs) and microplastics. At present there is no evidence of harm from the use of biosolids in relation to these contaminants. However, there are huge unknowns and more work is required to understand any possible impacts and also to identify if treatment or source controls can reduce any impact from these potential pollutants.

In the medium term these concerns could affect operational management (and therefore management costs) but are unlikely to have a significant impact on the quantity of available land and therefore the distance biosolids has to be transported.

EA's Sludge Strategy

Finally, the EA's Sludge Strategy is to move biosolids recycling from the Sludge (Use in Agriculture) Regulations (SUAR) to the Environmental Permitting Regulations (EPR). The water industry appears to have accepted this direction of travel and is working to make EPR as 'light touch' as possible via the use of the Biosolids Assurance Scheme (BAS) with Earned Recognition; something that is mentioned within the EA's Sludge Strategy. The level of impact on YWS operations will depend on how successful the industry is in gaining 'light touch' regulations, but the impacts for YWS (as well as the industry as a whole) could be:

- Requirements to make the BAS both a stakeholder and regulatory tool, i.e. a regulatory checklist with reporting to the EA
- Increased requirements, also in the BAS e.g.:
  - Acceptable wastes 'white list' for inputs to sludge treatment
  - A new requirement to monitor for selected determinands (e.g. Persistent Organic Pollutants – POPs) in biosolids
  - Require each Member to have an odour management plan demonstrating how odour will be managed during the storage of biosolids in permanent stores and temporary field heaps, and during spreading
- The need to apply for a permit
- Increased workload to complete notification/deployment applications ahead of activities e.g. >25 days for field storage and between 2 and 7 days for spreading
- The potential for EA queries and interventions
- Fees payable to the EA for permits and notifications – these could be as high as current deployment fees, i.e. approx. £1,700 per storage activity (could be whole farm) notification
- Increased management and oversight to oversee and control the increased complexity associated with recycling biosolids under the EPR

The change from SUAR to EPR should not disrupt biosolids recycling to agricultural land in terms of the land available or required, however, there may be cost and timing issues to consider for YWS including:

- Increased management costs (to complete the additional paperwork)
- Increased storage requirements to manage delays to approval
- Disruption to farmer acceptance
- Increased fees due to the EPR cost structure

4.4 Conclusions on the landbank assessment findings

The 2020 landbank scenario (Scenario 1) confirms there is sufficient land within the YWS region to recycle the biosolids it produces and this is likely to be the case even with the forecast growth in sludge quantity (and P content) by 2030. However, if the restrictions and regulatory controls increased to match those considered in the 2030 'plausible worst-case' scenario (Scenario 2) then recycling biosolids to agricultural land would no longer be viable. However, the plausible worst-case scenario does not reflect the current best estimate of the land recycling controls in 2030 based on current discussions between the EA and water industry and the Defra guidance on FRfW. More land will undoubtedly be required due to the increased volumes of biosolids predicted to be produced, predicted increases in phosphorus content and increased focus on phosphorus additions, but these changes are nowhere near as restrictive as those modelled in Scenario 2 meaning that YWS is predicted to be able to recycle the biosolids it produces in 2030 within/around its region.

The other pressures on biosolids recycling (e.g. concerns over contaminants and changes in regulatory regime) could affect operational management (and therefore management costs), but are unlikely to have a significant impact on the quantity of available land and therefore the distance biosolids has to be transported.

5 Biosolids Strategy Options by Scenario

This section identifies and assesses the biosolids strategy options for each scenario and the development of a cost-efficient investment strategy for YWS to transport, treat and dispose of wastewater sludge.

5.1 Scenario requirements

YWS requires this report to identify an efficient, costed alternative strategy for YWS to adopt in the event that curtailment or even cessation of the sludge to land recycling route occurs in the near future (up to 2030).

The project is required to evaluate the impacts of three scenarios:

1. Recycling to land continues as now and risks to the landbank are not realised
2. Recycling to land becomes restricted to limited land use areas and time periods by 2030
3. Recycling to land is no longer the best commercial option and / or is fully restricted by regulation by 2030.

This analysis is required to build upon the findings of the Water UK national biosolids strategy, which has evaluated several scenarios for the future of sludge management in the UK (key aspects are summarised in Section 2), by applying the generic report findings to YWS's asset base and specific disposal routes.

The following sections (5.2 to 5.4) describe the scenario assumptions, potential strategy options for each scenario and the short listed options which have been carried forward for detailed analysis.

The capital and operational costs for the proposed strategy options, together with operational carbon impacts, are presented in Section 5.5. The approach and key assumptions for the cost analyses are presented in Appendix C of this report.

Section 5.6 presents a potential 'adaptive pathway' approach to implanting the different options whilst Section 5.7 identifies the 'best value' option.

5.2 Scenario 1- Recycling to land continues as now ('BAU')

Under Scenario 1 it is assumed that YWS's treatment processes, predominantly conventional mesophilic AD with one site providing enhanced treatment, and recycling to agricultural land, would continue unchanged to 2030, in line with the YWS Bioresource team's existing strategy. These treatment processes enable YWS to produce significant quantities of biogas and generate renewable energy from its fleet of CHP engines (YWS also proposes a number of these sites will move to converting biogas to biomethane for grid injection and/or vehicle use).

For Scenario 1, the landbank assessment modelling demonstrates that the available landbank in the YWS region should continue to be sufficient for the type and quantity of biosolids product expected by 2030. Under this scenario it has been estimated that the weighted average maximum biosolids haulage distance of 30 km in 2020 (from the ALOWANCE model)[8] may

[8] In this report we use the ALOWANCE model distances. Using the actual 2020 distances for each STC gives a similar average haulage distance but a higher weighted average haulage distance (i.e. when taking into account product quantities) of 35km as the two largest STCs, Knostrop and Esholt, also have longer actual haulage distances in 2020 than the average predicted by the ALOWANCE model.

increase to 30-35 kilometres due to growth in biosolids production and increased sludge P content following implementation of the anticipated AMP7 and AMP8 WINEP programmes. This would result in increased haulage costs but no significant sludge treatment investment needs other than maintaining resilience of existing assets.

No further assessment of this scenario is undertaken in this study – though existing costs are used in Section 5.5 as comparators for predicted costs for the strategy options under Scenarios 2 and 3.

5.3 Scenario 2 - Recycling to land becomes more restricted by 2030

For Scenario 2, as described in Section 4.2, the landbank assessment modelling considered a plausible worst case scenario, based on the regulatory constraints being proposed by the EA in late 2021. The modelling results showed that the resulting haulage distances would be so large as to make recycling biosolids to agricultural land no longer viable. Hence, this 'worst case' scenario would effectively have the same impact as Scenario 3 (and hence solutions for Scenario 3 would also be applicable to this 'worst case' scenario).

However, as described in Section 4.3, since that scenario was agreed and modelled, there has been positive progress in the negotiations with the EA over the proposed changes in regulatory measures (a 'best estimate' compared to the previous 'worst case'). Although these revised measures will impact on biosolids recycling, they are not expected to result in significant increases in haulage distances compared to Scenario 1. An increase to an average maximum haulage distance of 35-40 kilometres has been estimated (if no mitigation options are implemented), compared to the weighted average maximum distances for Scenario 1 of 30 km and 30 - 35km in 2020 and 2030, respectively.

To differentiate between these two alternative versions of Scenario 2 we refer to the 'plausible worst case' version of this scenario as 'Scenario 2a' and the current 'best estimate' version as 'Scenario 2b'. As Scenario 2a has the same impact as Scenario 3, the solutions for Scenario 3 assessed in Section 5.4 would also serve for Scenario 2a – hence, Scenario 2a is not assessed further in this report.

At the time of completing this report (June 2022) the revised requirements underlying Scenario 2b have still to be finally confirmed by the EA. However, given that the industry is reasonably confident that the revised requirements will be agreed we have used Scenario 2b as the basis for subsequent analysis of strategy options for Scenario 2.

5.3.1 Potential options for Scenario 2b

As noted above, under Scenario 2b, it is assumed that YWS would still be able to rely on recycling biosolids to agricultural land, although with a small increase in average biosolids haulage distances and increased management requirements. YWS has estimated that the increase in costs compared to Scenario 1 (using 2030 throughputs) would be approximately £0.5m/year, including increases in both haulage costs and biosolids management overheads[9]. Using the anticipated increase in haulage distance for Scenario 2b and YWS's typical unit haulage costs indicates that approx. £0.12m/year of this increase would be due to the increased haulage distance.

Assuming that the additional biosolids management costs are due to regulatory requirements and hence unavoidable, then options under Scenario 2b could focus only on means to reduce the additional haulage costs. The least cost options for achieving this would probably be

[9] Information provided by Andrew Calvert (YWS) in email on 24 March 2022.

improvements in dewatering performance, aiming to produce a higher dry solids concentration at STCs which currently produce relatively wetter cakes (<21%DS).

However, there is the residual risk that regulations would continue to tighten over the next decade, further reducing the available landbank and increasing haulage distances. In this case, producing alternative biosolids products, such as enhanced treated biosolids cake or pellets, would be more likely to mitigate the impact of such changes even if only provided for a proportion of YWS's biosolids output. These enhanced treated products would also reduce haulage costs to farm land.

Hence, strategic options for Scenario 2b have been proposed with the primary aim of increasing resilience of YWS's sludge recycling operations against future tightening of regulations by increasing the proportion of biosolids achieving enhanced product quality.

The selected options are as follows:

Option 2.1: Increase the proportion of enhanced quality product to increase/safeguard the available landbank. Increasing the proportion of enhanced quality product would increase the available landbank (e.g. by enabling more grassland to be used) and hence reduce biosolids haulage distance and costs. Other benefits would be reduced volume of biosolids product (through increased solids destruction and, in some cases, improved dewaterability) and increased biogas energy generation (providing additional revenue and further contribution to achieving net zero commitments).

Option 2.2: Produce a proportion of dried biosolids product to increase/safeguard the available landbank. Producing a proportion of enhanced quality dried biosolids product (e.g. pellets/granules) would increase the available landbank and potentially enable spreading in the spring using conventional fertiliser spreading techniques (i.e. top dressing to a growing crop). Other benefits would be a reduced volume of a dried biosolids product which would also require less storage capacity and similarly much reduced haulage costs (due to not transporting water).

The acceptability of using dried sludge in this way would need to be discussed with farmers and their customers (e.g. food chain stakeholders) as, unlike for conventional spreading of biosolids cake, the biosolids pellets would not be incorporated into the ground so would be in closer contact with crops and could give rise to odour, however, these problems are not thought to be insurmountable. Furthermore, producing a dried product might open up other use options, such as in cement plants.

These options achieve differing levels of benefit, are not mutually exclusive and could be implemented in parallel. Hence, the following analysis provides an indication of possible costs and benefits of different options, that could be implemented together or in sequence as part of an adaptive pathway (this aspect is discussed further in Section 5.6).

Reduction in biosolids Phosphorus (P) content

A significant reduction in the residual P content in the biosolids (e.g. by 75%) could also potentially increase the available landbank (and hence reduce haulage distances) by enabling the frequency of application to be increased for P sensitive soils. However, most P reduction approaches focus on removing P from treated effluent and liquors and usually result in increased P concentrations in the sludge.

Ostara's 'Pearl' system would reduce the P content of the sludge as the P is recovered in the form of struvite granules which are harvested, dried and then sold by Ostara a fertiliser. However, there are insufficient data on the extent of P reduction that can be achieved in the biosolids cake, however, indications are that any P reduction would not be sufficient to significantly improve the frequency with which the cake can be applied to P sensitive soils. As a result, reduction of P content in the biosolids was not considered as an option for this strategy.

5.3.2 Option technical details

Option 2.1 – Increase proportion of enhanced quality biosolids product

Under Option 2.1 there are a number of competing advanced AD (AAD) technologies with the more successful ones using a thermal hydrolysis process (THP) pre-treatment (e.g. Cambi THP) or a biological hydrolysis process (e.g. the 'Helea' process, formerly called 'HpH'). Both provide increased solids destruction and biogas production as well as a log 6 pathogen kill to achieve an enhanced treated product. However, only THP results in a step improvement in sludge dewatering characteristics.

THP is widely used for upgrading existing conventional AD plants as the resulting improved sludge rheology enables higher dry solids concentrations in the digester feed, hence enabling increased dry solids throughput for existing digesters.

YWS already has an AAD plant at Esholt which uses a Veolia version of THP (Biothelys). However, the plant's output is not considered to be an enhanced treated product as polyelectrolyte preparation for the final dewatering stage uses final effluent which has not been disinfected.

To illustrate the potential costs and benefits of Option 2.1 we have assumed that two additional THP plants are built at Blackburn Meadows and Knostrop (see Figure 5.1). The additional capacity created at Blackburn Meadows and Knostrop would enable some of YWS's smaller and less cost efficient STCs to be closed (e.g. Aldwarke, Woodhouse Mill, Calder Vale and Mitchell Laithes, providing further cost efficiencies) with their indigenous sludge and existing imports dewatered and exported to the new AAD plants. Figure 5.1 also shows the closure of Naburn and Bridlington STCs – as is already proposed by YWS. In addition, Esholt would be upgraded to enable use of potable water for polyelectrolyte preparation and hence produce an enhanced treated product.

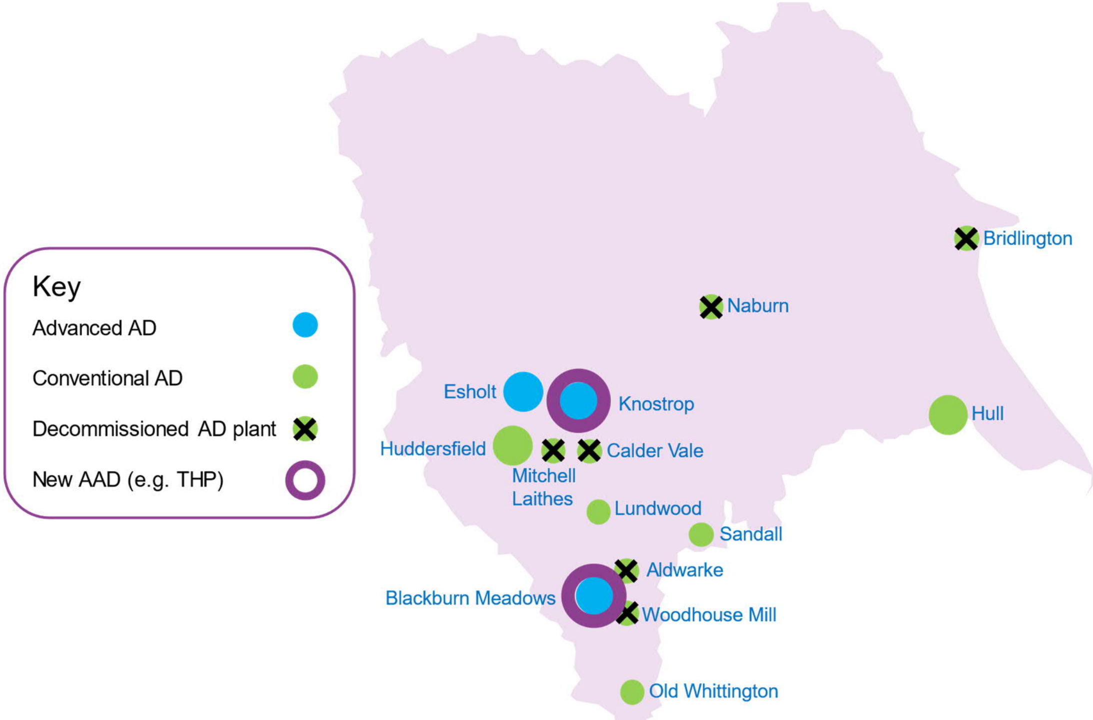
Implementation of the AAD plants would result in additional volatile solids destruction and improved dewatering performance, hence reducing the quantity of cake (wet tonnes/year) to be used in agriculture by 13%. Following implementation of this option approximately 59% of YWS's biosolids product would achieve 'enhanced treated' status.

The new AAD plants at Blackburn Meadows and Knostrop would include the following additional process plant:

- Sludge screening – for indigenous sludge at AAD plants and for thickened sludge at decommissioned STCs exporting sludge cake to the new AAD plants
- Pre-dewatering plant (to enable approximately 16.5%DS feed to the THP plant)
- THP Feed silo
- THP plant, sludge cooling and recirculation system
- Steam boilers (combination type, fired section assumed to be biogas fuelled)
- Additional biogas holder capacity (assume membrane type biogas storage)
- Additional CHP engine capacity for additional biogas production
- Additional dewatering plant capacity
- Additional side stream liquor treatment

The existing digesters would continue to be used and no additional digester capacity would be provided, however, the feed concentration would be increased to 10%DS (potentially higher values could be selected following more detailed process modelling). Each AAD site is understood to have an existing imported cake reception facility.

Figure 5.1: Option 2.1 – Additional Advanced AD treatment capacity



YWS has previously commissioned network capacity studies from the local gas distribution network operators in the areas around both Knostrop and Blackburn Meadows (commissioned in 2018 by Air Liquide on behalf of YWS). These studies determined that there would be capacity in the local grid for biomethane production from each plant based on current throughputs and biogas production. However, based on these previous assessments, there would not be capacity for the entire biomethane output if these STCs became regional AAD plants. Hence, for the purposes of preparing option costs for this report we have assumed that the additional biogas produced at each AAD site would be used in additional CHP engine capacity. If these projects are taken forward then a more detailed assessment may find that a combination of new biomethane plant capacity for a proportion of biogas production, along with existing CHP engines for the remainder, may produce a more cost effective and lower carbon solution.

Table 5.1 summarises the key parameters and impacts of this option. The haulage distance impacts of this option are discussed in Section 5.3.3, The costs of the option are presented in Section 5.5.

Table 5.1: Selection of Option 2.1 (AAD - THP) design parameters and quantities

Scenario		Scenario 2b, Option 2.1		Comments
Option ref		**2.1**	**2.1**	
Location		**Knostrop**	**Blackburn Meadows**	
Sludge treatment		AAD-THP	AAD-THP	
Sludge use/disposal		Agriculture	Agriculture	
Throughput – current forecast in 2030	tDS/y	36,520	18,330	
Throughput – proposed	tDS/y	52,520	27,420	See note 1
Product quantity	tDS/y	30,410	15,890	
Capacity - proposed	tDS/y	59,390	29,700	
Sludge digestion – key assumptions / results				
Primary digester feed concentration	%DS	10.0	10.0	Normal range 8 to 12%
Primary digester retention time	Days	17	16	
Primary digesters - total effective volume	m^3	22,780	11,390	85% effective volume
Organic loading rate	$kgVS/m^3/d$	4.3	4.6	
VS destruction	%VSD	62	61	
Total solids destruction	%	42	42	
Biogas yield	Nm^3/tDS	420	420	
CHP capacity: existing / future total	MWe	4.0 / 7.2	2.0 / 3.6	
Dewatering				
Digester output DS concentration	%DS	6%	6%	
Cake dry solids concentration	%DS	28.5	28.5	Normal range 27 to 31%
Cake production	tonne/d	292	153	

Notes:
1) Proposed throughputs include imports from other STCs (which could then become dewatering centres). Knostrop throughput includes current throughput for Calder Vale and Mitchell Laithes STCs, Blackburn Meadows throughput includes current throughput for Aldwarke and Woodhouse Mill STCs.

Option 2.2 - Produce a proportion of dried biosolids product

Producing a proportion of dried biosolids product as pellets would potentially enable spreading in the spring using conventional fertiliser spreading techniques as well as reducing the volume of required biosolids storage capacity.

The use of sludge drying to produce pellets or granules has decreased significantly in Europe due to high operating costs (energy and maintenance) and the availability of sufficient landbank for biosolids cake products. However, the development of ‘low temperature’ dryers, able to use relatively lower grade heat sources such as waste heat from other processes (e.g. from CHP engines) improves the cost effectiveness of this option, particularly if combined with cheap sources of low grade waste heat.

To illustrate the potential costs and benefits of Option 2.2 we have assumed that a low temperature dryer would be built at Knostrop (see Figure 5.2). Knostrop has been proposed for this option as (1) the STC is located adjacent to a MSW incinerator which could potentially provide sufficient low grade heat for the drying process (2) it is the largest conventional AD site and hence a single dryer at this location would have maximum impact and (3) Knostrop STC already produces a 25% dry solids cake and hence would require a lower additional drying energy than sites with less efficient dewatering.

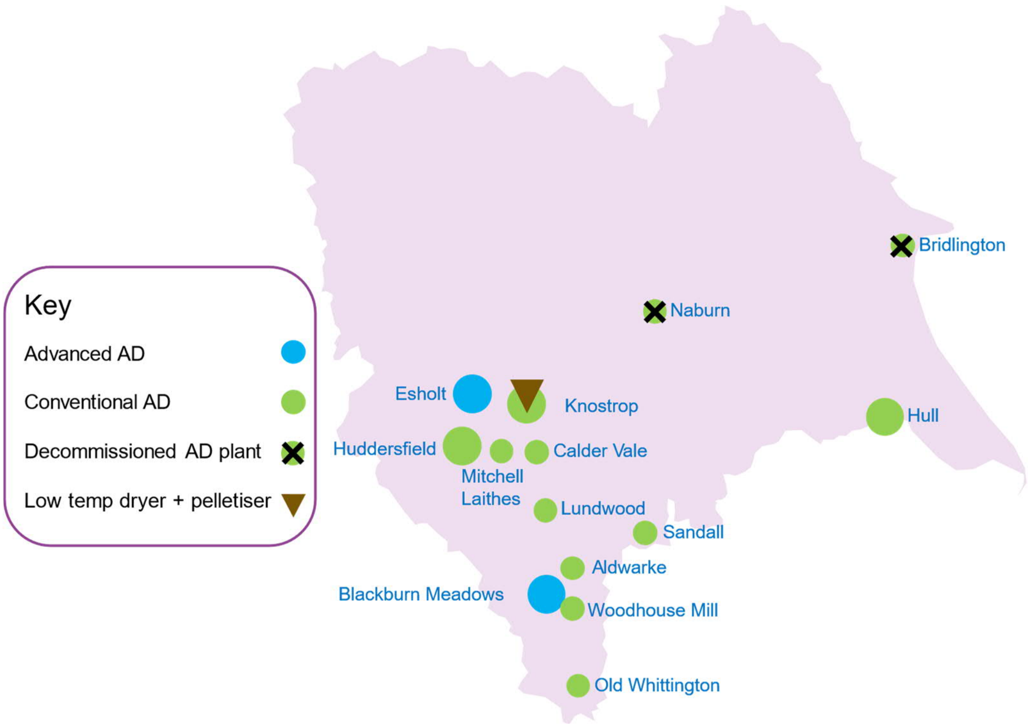
Unlike option 2.1, this option would not create new sludge digestion capacity.

It is assumed that the heat required for drying the digested sludge would be provided by the adjacent MSW incinerator (energy from waste) plant. YWS is understood to have had discussions with the owner regarding the potential to supply heat to the Knostrop site. The dryer heat demand would be equivalent to twice the total potential heat output of the Knostrop CHP engines (which is also used for heating the AD process).

Implementation of a dryer at Knostrop would reduce the quantity of product (wet tonnes/year) from Knostrop by 72% (from a forecast 265t/d to 74t/d in 2030) which would be a 15% reduction in product for the YWS region as a whole. Following implementation of this option approx. 21% of YWS's overall biosolids product would achieve 'enhanced treated' status.

Table 5.2 summarises the key parameters and impacts of this option. The haulage distance impacts of this option are discussed in Section 5.3.3. The costs of the option are presented in Section 5.4.

Figure 5.2: Option 2.2 – Low temperature dryer location



Note: Size of circle is proportional to relative sludge throughput

Table 5.2: Selection of Option 2.2 (drying plant) design parameters and quantities

Scenario		Scenario 2	Comments
Option ref		**2.2**	
Location		**Knostrop**	
Sludge treatment		Drying	
Sludge use/disposal		Agriculture	
Throughput	tDS/y	24,190	Forecast 2030 digested biosolids output
Product quantity	tDS/y	24,190	

Scenario		Scenario 2	Comments
Capacity - proposed	tDS/y	28,000	
Sludge drying			
Dryer type	%DS	Belt dryer, medium temperature type	
Operation	Days/year	8,000	
Heat source (water) temperature	°C	90	Assumed to be provided by EfW plant
Input dry solids concentration	%DS	25	
Product dry solids concentration	%DS	90	
Dried biosolids production	tonnes/day	74	As pellets at 90%DS
Water evaporation capacity	tonnes/h	8.7	
Thermal energy consumption (1)	MWh_{th}/y	59,400	Assumed to be provided by EfW plant
Electrical energy consumption (1)	MWh_{e}/y	5,200	Supplied from Knostrop STW

Notes:
1) Thermal and electrical energy consumption based on 'kWh/kg water evaporated' assumptions provided by Huber Technology, May 2022).

5.3.3 Impact on product haulage distances to agricultural use

As noted in Section 5.3.1, options under Scenario 2b focus on means to reduce the additional haulage costs caused by both growth and tighter regulations.

The estimated impacts of options 2.1 and 2.2 on haulage distances and costs are summarised in Table 5.3. Weighted average distances based on distance and wet tonnes of product from each STC.

The following data sources have been used:

- The 2020 baseline distances are based on information provided by the YWS bioresources team. The 2030 baseline distances take into account the findings of the landbank assessment, including estimates of additional distances due to changes in regulations and hence landbank availability. 2030 distances for options 2.1 and 2.2 reflect expected changes in biosolids quantities and products (see scenarios below).
- Total 2020 base recycling costs have been provided by YWS and the haulage costs element has been estimated based on biosolids quantities, distances and unit transport costs (the latter extracted from the Quality & Growth model v12). 2030 haulage costs for base case and options have then been estimated based on predicted changes in haulage distances and biosolids quantities.

The impact of options 2.1 and 2.2 are illustrated for two cases (A and B):

- A – No reduction in expected distances to landbank for enhanced treated sludge and hence the reduction in haulage costs is solely due to the reduction in biosolids quantity
- B – Expected distances for enhanced treated sludge are reduced as well – hence further reducing haulage costs

Under case B, the average haulage distances for enhanced product in Option 2.1 have been reduced by 10km for Knostrop and Blackburn Meadows and by 15km for Esholt (a higher allowance has been used for Esholt due to its proximity to grassland pasture which hasn't been used previously). Similarly, for Option 2.2, average haulage distances from Knostrop have been reduced by 15km for dried enhanced product. These changes in distance for future options have been based on judgement and not on further landbank modelling (which is outside the scope of this study). We would recommend that additional landbank modelling using the

ALOWANCE model is undertaken in order to confirm the future baseline and option impacts with more accuracy.

The following points are noted from the findings presented in Table 5.3:

For Option 2.1, the overall weighted haulage distance increases under case A, despite the reduction in YWS's total biosolids product with this option, though the haulage costs still fall (by nearly £0.5m. This arises because, overall, more biosolids product would be produced at STCs which (currently) have the longest haulage distances to farms, whilst smaller STCs that are decommissioned have relatively shorter current haulage distances. However, if enhanced treated cake enables haulage distance to be reduced (i.e. case B) then both the weighted average haulage distances and costs would be reduced significantly.

Option 2.2 would result in significant reductions in both weighted average haulage distances and haulage costs.

Table 5.3: Impacts on transport distances and costs for Options 2.1 and 2.2

Scenario		Scenario 1		Scenario 2		
Baseline type and Option ref		**Base-2020**	**Base-2030**	**Base-2030**	**Option 2.1**	**Option 2.2**
Sludge treatment		Existing	Existing	Existing	With new AAD	With drying
Sludge use/disposal		Agriculture	Agriculture	Agriculture	Agriculture	Agriculture
Product – average	tDS/y	93,987	113,839	113,839	105,830	113,839
	tonne/y	381,938	459,578	459,578	395,208	389,689
Proportion of product (dry solids) that is enhanced treated	%	0%	0%	0%	58%	21%
Case A - without reducing expected distances for enhanced treated biosolids						
Average distance	km	29 (1)	29	34	37	34
Weighted average distance (2)	km	35	36 (3)	41 (3)	43	38
Transport costs – total, all STCs	**£'000/y**	**3,130**	**3,240**	**3,360**	**2,950**	**2,750**
Case B - with reduced haulage distances for enhanced treated biosolids						
Average distance	km				33 (4)	33 (5)
Weighted average distance	km				37 (4)	37 (5)
Transport cost – total, all STCs	**£'000/y**				**2,810**	**2,740**

Notes:
1) Current average haulage distances to farmland provided by YWS (note that landbank assessment indicates a weighted average maximum distance of 30km in 2020)
2) Weighted average distances based on distance and wet tonnes of product from each STC
3) Additional weighted average distances for Base-2030 in Scenario 1 estimated in landbank assessment (see Section 5.3), taking into account additional sludge and higher P content. Additional weighted average distances for Base-2030 in Scenario 2 estimated in landbank assessment, taking into account additional EA restrictions (FRfW and other).
4) In Option 2.1, average haulage distances for enhanced product reduced by 10km for Knostrop, Blackburn Meadows and Esholt
5) In Option 2.2, average haulage distances from Knostrop reduced by 15km for dried enhanced product
6) Costs are for transport of product and exclude YWS bioresources management costs (which are assumed to be an additional £0.5m by 2030)

5.4 Scenario 3 - Recycling to land is no longer an option by 2030

Scenario 3 assumes that recycling biosolids to agricultural land is no longer viable and hence this scenario was not modelled during the landbank assessment. Potential drivers for such a scenario are discussed in Section 2 and 4.

Scenario 3 would require alternative solutions for sludge treatment and use/disposal and these are discussed below.

5.4.1 Potential options for Scenario 3

As noted in the Water UK report, under this scenario the only other existing technologies available for treatment and final disposal of sludge are different forms of thermal treatment. The Water UK report focusses on incineration, pyrolysis and gasification as thermal treatment options. Other potential options could include cement plants and more novel processes such a hydrothermal carbonisation (for which there are demonstration plants operating in the waste sector).

However, as also noted by the Water UK report, there are no examples of pyrolysis and gasification technologies in use at the required scale for biosolids in the UK or Europe – and uses for the resulting 'biochar' solid product are also currently uncertain. A similar conclusion can be drawn on hydrothermal carbonisation which has existing demonstration plants but at smaller scales and different feedstocks. Cement manufacturers have a long track record of using alternative fuels derived from waste, including sewage sludge, however, there are a number of potential technical, regulatory and commercial risks and constraints for such an option.

In contrast, incineration technologies were noted in the Water UK report as being well-established. We concur with this view as there are multiple examples of large sludge mono-incinerators in operation, under construction or planned, particularly in northern Europe.

Due to the activity in the incineration market there are good data for capital and operating costs that can be used for assessing options for the YWS region. In contrast, cost estimates for pyrolysis and gasification options would have greater uncertainty as they would be reliant on extrapolation of costs for much smaller plants, usually developed at pilot/demonstration scales.

Hence, for this section we focus on two incineration options and their applicability to the YWS region.

- Option 3.1 - Sewage sludge incinerators (SSI) – using fluidised bed technology
- Option 3.2 - MSW incinerators

5.4.2 Option technical details

Option 3.1 - Sewage sludge incinerators

There are a large number of sewage sludge incinerators (SSIs) around the world with more being built. Modern incinerators will usually include power generation using a steam turbine and sometimes export surplus heat for other uses such as district heating systems or industrial users.

A high proportion of SSIs in northern Europe have been designed to treat both conventional and enhanced digested sludge. Although digested sludge will have lost a proportion of its volatile calorific content this can be mitigated in the design using pre-dryers (within the SSI plant) to raise the %DS of the feedstock to autothermic levels. The benefits of retaining sludge anaerobic digestion prior to SSI are that it still provides valuable biogas energy and also reduces the quantity of remaining solids to be sent to the SSI plants[10].

[10] It is also noted that YWS's scope for this study also assumes that the ability to generate biogas through AD would be retained under Scenario 3.

Further details of recent and on-going SSI projects are provided in Section 7.

To illustrate the potential costs and benefits of Option 3.1 we have assumed that two new SSIs would be constructed to serve the entire region, ensuring each plant would have a cost effective scale. For the purposes of the analysis it has been assumed that the SSIs would be co-located with the STCs at Knostrop and Blackburn Meadows (see Figure 5.3) and these two plants would be sized for the total sludge production across the YWS region (including sludge currently proposed to be treated by 3rd parties).

For this option it has been assumed that all existing AD plants would be retained and hence the SSIs would be designed for digested sludge quantities and characteristics. To simplify this analysis, the small amount of YWS sludge currently proposed to be treated by 3rd parties has also been assumed to be anaerobically digested (by 3rd parties) and then sent to the new SSIs.

Figure 5.3: Option 3.1 – Assumed SSI locations

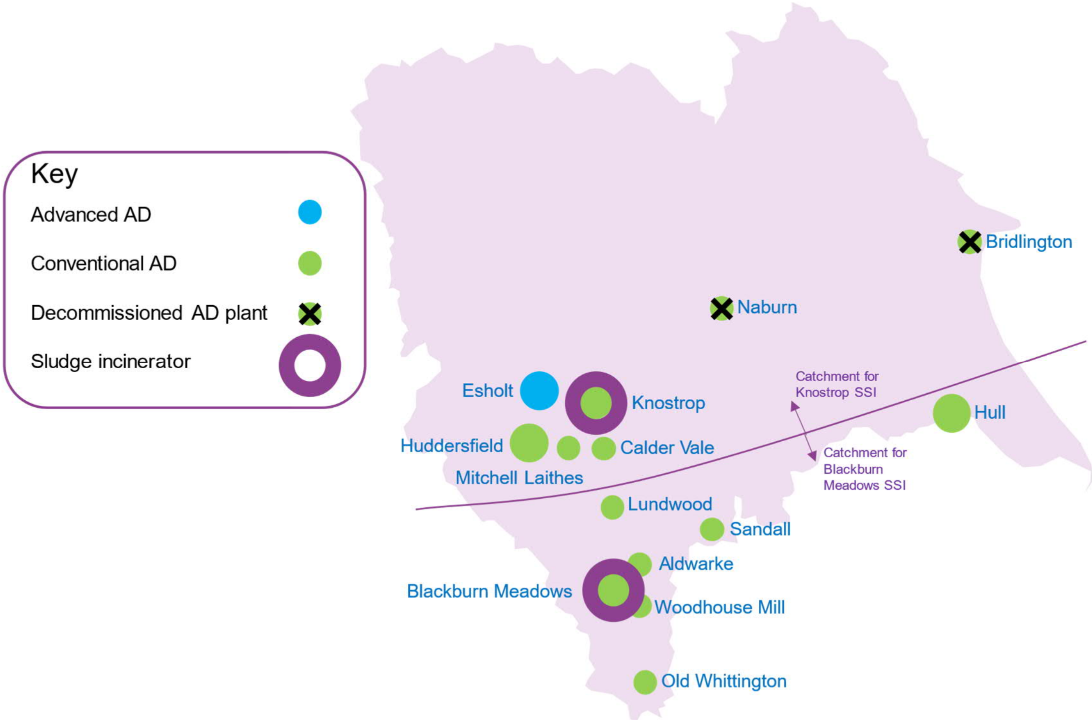


Table 5.4: Weighted average characteristics in feed to each SSI in 2030 – based on existing sludge digestion processes

Parameter	Units	SSI location		Comments
		Knostrop	Blackburn Meadows	
Dry solids load	tDS/y	63,650	50,190	Load received by incinerator in 2030, after any treatment (AD or AAD)
%VS content	%VS	48.0%	49.5%	
Volatile solids load	tDS/y	30,580	24,850	
Inert	tDS/y	33,070	25,340	
Moisture content	%	74.1%	76.5%	Assuming similar sludge dewatering performance at AD/AAD plants in the future
Wet tonnes	t/y	245,870	213,710	
Volatile content	%	12.4%	11.6%	% of wet cake
Inert (ash) content	%	13.5%	11.9%	
Calorific content LHV	MJ/kg	22.3	22.3	LHV, on dry and ash free basis

A typical modern SSI design has been assumed for this study with the sequence of process stages shown in Figure 5.4, including pre-drying stage, fluidised bed furnace, energy generation and flue gas treatment. Each SSI would include sludge cake reception and storage, blending hoppers, pre-dryers (steam heated), fluidised bed furnaces, steam turbines for power generation and flue gas treatment to latest IED Directive requirements.

The pre-drying stage would use steam to increase the dry solids concentration of the dewatered cake feedstock to between 35%DS and 45%DS in order to achieve an autothermic calorific content in the sludge. The amount of steam produced and used in the turbine and pre-drying varies with the volatile solids and moisture content of the sludge feed. It has been assumed that condensate and other waste streams at the SSI would be pre-treated to required standard for subsequent return to the wastewater treatment works.

Predicted plant operating performance has been used to estimate energy consumed and generated for each SSI and the findings are summarised in Table 5.5.

Incinerators require periods of down time for maintenance each year (typically 2 to 4 weeks) and hence the design capacity must be increased to accommodate this. We have assumed 8,000 hours operation per year (equivalent to 91% availability) in preparing the option cost estimates. The SSI would consume fossil fuels during start up and shut down cycles but would otherwise be designed to be autothermic during normal operation.

A wet flue gas treatment process would be used with ash and other residues collected in two stages:

- Fly ash collected in the electrostatic precipitation stage, prior to the addition of air pollution control (APC) reagents, and
- Other residues (APC residues, including gypsum and some ash) produced and collected in the remaining flue gas treatment stages

Fly ash from sewage sludge incinerators is generally classified as non-hazardous waste, however, the residues from the cleaning of flue gases (APC residues) are classified as hazardous waste.

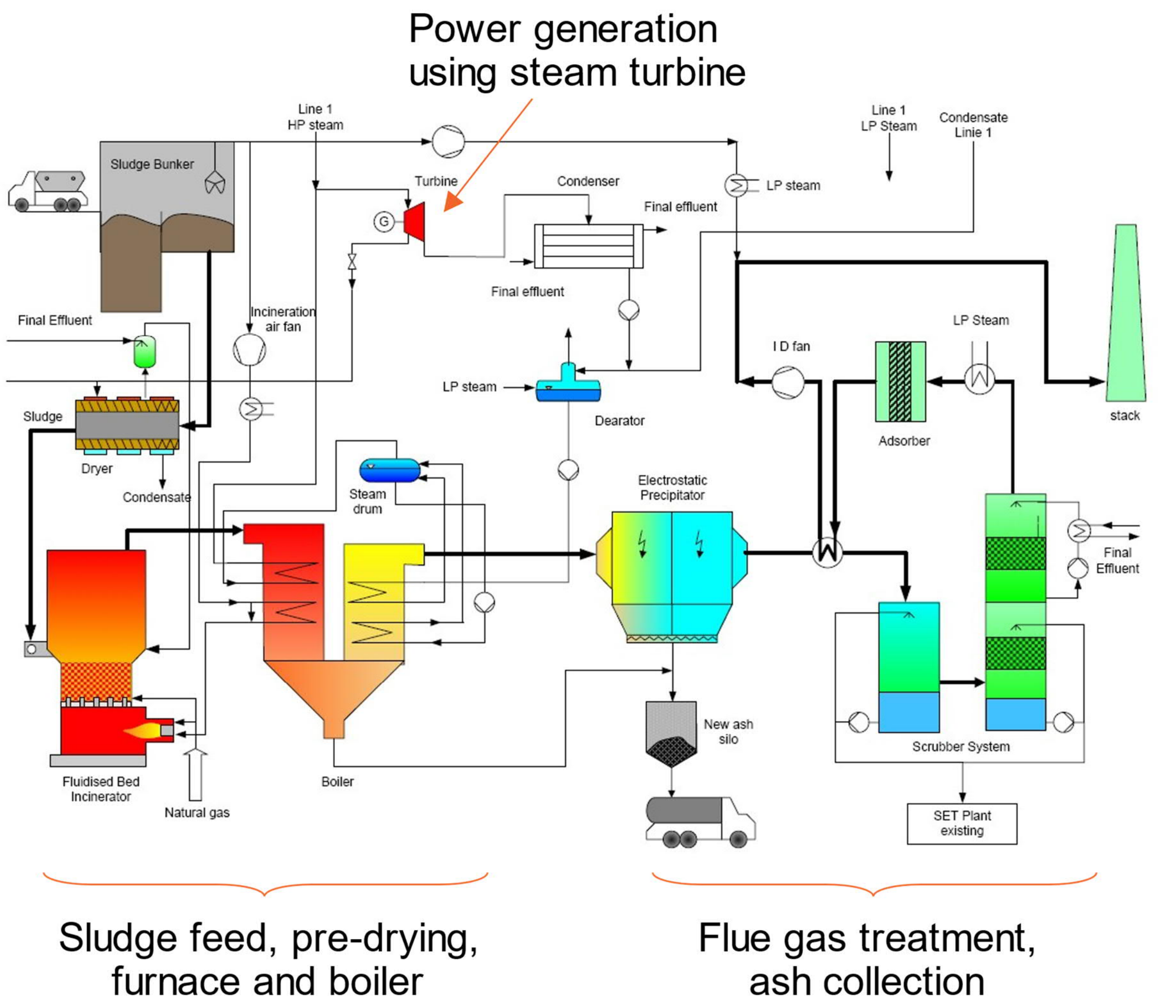
SSI operating performance has been modelled based on the above feedstock characteristics and the findings benchmarked against recent tender designs and published data for operating SSIs.

These findings have been used to derive capital and operating cost estimates which are presented in Section 5.5 and have also been benchmarked against recent projects.

Table 5.5: Key energy assumptions and quantities

Component	Units	Knostrop	Blackburn Meadows
Sludge throughput	tDS/y	63,650	50,190
Power generated by SSI steam turbines	MW	3.80	3.20
	kWh/tDS	480	510
Power used by SSI	MW	1.71	1.44
Net power generated (for use by WWTW or export)	MW	2.09	1.76
Natural gas used for SSI start-up/shut down (assume twice per year)	MWh/y	1,380	1,090

Figure 5.4: Schematic showing typical SSI process components (example includes pre-dryer)



Source: Outotec (SSI business of Outotec now owned by Küttner Martin GmbH)

Option 3.2 – MSW incinerators

There are multiple locations in the EU and worldwide where a proportion of dewatered or dried sludge is co-incinerated with municipal waste, usually through commercial contracts where the sludge supplier pays a gate fee to the waste incinerator operator.

Most MSW incinerators use moving grate incineration technology which has been used for MSW for more than a century and has more than 1,500 installations world-wide. In common with sludge incinerators, MSW incinerators usually include waste feedstock bunker, boilers, energy generation using steam turbines and extensive flue gas treatment trains.

Dewatered, partly dried and fully dried sewage sludge can be sent to a MSW incinerator . The incinerator may prefer cake particularly if the additional moisture is useful in the operation of the furnace.

The maximum amount of sludge which is technically possible to incinerate with MSW is dependent on the throughput of the MSW incinerators. Industry experience is that up to (approx.) 7% by weight of dewatered sludge cake can be incinerated with MSW without any observable impact in terms of higher unburnt matter in the bottom ash or higher ash build up at the super heaters, which are the two main concerns when co-combusting sludge with MSW. For short durations (1-2 weeks), industry experience suggests that up to 10% by weight of sludge can be incinerated with MSW if required.

Based on the treated sludge production for the YWS region in 2030, forecast to be 459,900 wet tonnes/year (see Table 3.2) and a 7% by weight limit for sludge inputs to MSW incinerators (and assuming no other technical, regulatory or commercial constraints), the required MSW capacity would need to be just over 6,500 ktpa (thousand tonnes per annum). The most recent energy from waste (EfW) plant statistics[11] indicate a total permit capacity in the YWS region of just 2,600 ktpa, equivalent to 40% of the total theoretical EfW capacity required. Furthermore, the same data source indicates that the plants in the YWS region are already operating at 90-91% of permit capacity, indicating that there is currently little headroom for additional feedstock and without additional capacity being constructed in the region this ‘headroom’ would be expected to reduce further by 2030.

Based on this assessment it is clear that incineration with MSW would not provide a technically feasibly solution for a significant proportion of sewage sludge produced in the YWS region (currently or in the future) – even before consideration of other technical, regulatory or commercial constraints. Commercially, experience elsewhere in Europe indicates that gate fees charged by merchant EfW for taking sludge are likely to be similar to or higher than those charged by SSI operators under DBFMO arrangements.

However, the option of co-incinerating sludge and MSW may serve as a partial solution and cater for maintenance shutdown periods if other thermal treatment options such as SSI are adopted.

Given the technical constraints on this option including uncertainties around available capacities and commercial arrangements this option has not been carried forward to detailed cost and carbon assessment in Section 5.5.

[11] UK Energy from Waste Statistics - 2021 (Tolvik Consulting, May 2022)

5.5 Cost and carbon assessment of scenario solutions

5.5.1 Costing approach

Cost estimates have been prepared for each of the options in Q1 2022 prices. The cost assessment findings are summarised in this section whilst a description of the approach and key assumptions is presented in Appendix C.

The following costs have been assessed:

- **Capex** – for sludge treatment (AAD and drying options) and SSI plants, split into MEICA, civil works and project delivery on-costs.
- **Net Opex** for sludge management related assets (i.e. the change in Opex occurring due to implementation of the options):
  - **Operational (regular) maintenance** – of treatment assets has been based on a percentage of capital cost and the results benchmarked against recent project data
  - **Personnel** – changes in operating staff costs for new plant (e.g. AD, AAD and SSI)
  - **Business rates** – changes in rates charged on the value of civil works assets
  - **Consumables (non-energy)** - mostly chemicals used for sludge thickening, dewatering, odour control, dewatering liquors treatment and incinerator flue gas treatment
  - **Energy consumption** (power, fossil fuels and purchased heat for the dryer option)
  - **Power generation** - using biogas CHP and incinerator steam turbines
  - **Transport** – for Scenario 2 options, additional sludge transport to new AAD plants and biosolids transport to agriculture, whilst for Scenario 3 options, taking treated biosolids from STCs to the two SSIs and ash/residues from SSIs to final use or disposal
  - **Landfill costs** – Gate fees and landfill tax payments for SSI ash and other residues disposal
  - **Management costs for agricultural use** – including both normal and additional 'FRfW' related costs based on an indicative assessment provided by the YWS Bioresources team
- **Income** – for any surplus power generated by YWS assets (CHP engines and incinerator steam turbines) and sold to the power grid
- **Net present value (NPV)** of all costs over a 20 year operational period using a 3.5% discount rate, including capex, capital maintenance (periodic replacement or renewal of assets), opex and income.
- **Payback** – a 'simple payback' calculation, estimated as the number of years taken before cumulative reductions in annual opex exceed the additional capital investment.

Opex estimates use typical unit performance rates (e.g. power and chemical usage and power generation, etc.) for different processes as well as unit cost rates. Quantities used in opex estimates are based on the performance of the different technologies for the forecasted sludge flows in 2030.

5.5.2 Baseline costs

YWS has provided two opex forecasts; one within the Quality and Growth Model, v12 (at five year intervals up to 2040) and one provided by the YWS Bioresources team for 2025. Both estimates are based on similar total (i.e. region wide) sludge throughputs and have similar total values, however, there are differences between individual STC throughputs and opex estimates.

We have used the bioresources team forecast for 2025 as the baseline estimate (as it provides a more granular breakdown for comparison purposes) and this is presented in Table 5.6 below.

5.5.3 Option costs

The results of the cost analysis for each option are presented in Tables 5.7 to 5.9 and are discussed in the following sections.

5.5.3.1 Capex

Capex estimates for all options are presented in Table 5.7.

Option 2.1 estimates

Capex estimates for Blackburn Meadows and Knostrop AAD options (Option 2.1) have been built up from previous THP projects. They have been compared to those estimated by YWS for these sites at PR19 and found to be similar (once adjusted for inflation to Q1'2022).

An approximate cost has been included for enabling Esholt to produce an enhanced treated standard. The cost has been based on providing a potable supply including small buffer tank for final dewatering polyelectrolyte make-up and dilution.

Some minor capex interventions related to the Aldwarke AD plant are proposed in AMP7 and AMP8 (and potentially at the other three AD plants proposed for decommissioning under Option 2.1). The capex estimates for Option 2.1 do not include potential savings from not implementing these AD plant improvements at the four AD plants.

Option 2.2 estimate

The dryer cost for Option 2.2 has been based on a budget supplier estimate (supply and install, provided by Huber)) combined with civil works and other MEICA costs (including LVA, substations and heat supply pipework) based on approximate capacities and recent unit cost estimates.

Option 3.1 estimates

The SSI option costs have been based on a blend of historic and recent tender costs for SSI projects in mainland Europe. These have used either D&B or DBFOM delivery approaches however, the EPC plant costs within these projects are comparable regardless of delivery route. A comparison of a number of recent SSI project prices is provided in Appendix C.

5.5.3.2 Opex

Table 5.8 presents a summary of the net change in YWS's opex estimate resulting from each option. The basis for the net opex for each option is described below.

Option 2.1

Option 2.1 net opex values include the change in opex resulting from upgrading Knostrop and Blackburn Meadows to AAD and includes the forecast changes in opex at smaller STCs which would be decommissioned under this option. Decommissioned STCs would become dewatering centres, with their raw sludge loads dewatered and diverted to the new AAD plants for treatment. Hence, the net opex for Knostrop is the total of the changes at Knostrop, Calder Vale and Mitchell Laithes, and similarly, the net opex for Blackburn Meadows also includes the changes as Aldwarke and Woodhouse Mill.

For both Blackburn Meadows and Knostrop, there is a reduction in net opex as the combination of benefits (increase in biogas energy generation, reduction in sludge volumes to be recycled and shorter haulage distances, as well as the reduction in operation and maintenance costs at decommissioned STCs) outweigh the additional opex costs (loss of CHP output at decommissioned STCs and the additional costs of transporting their raw sludge to the new AAD plants).

Haulage distances for enhanced treated biosolids are assumed to be reduced (compared to current distances for conventionally treated biosolids) – as discussed in Section 5.3.3.

Option 2.2

Option 2.2 net opex values for Knostrop reflect the changes resulting solely from providing an additional drying stage to treat the digested sludge output of Knostrop's existing AD process. There are no other changes to the existing AD plant at Knostrop (or other STCs). Option 2.2 would result in a net increase in opex as the benefits (large reduction in sludge volumes to be recycled and shorter haulage distances) are outweighed by the increased operating costs of the dryer, including purchase of low grade heat from the adjacent MSW incinerator as well as large additional operating staff, plant maintenance and power costs.

Option 3.1

Option 3.1 net opex values for the potential SSI plants at Knostrop and Blackburn Meadows include the increased opex associated with operating the SSI plant and disposing of the final product (ash and residues) as well as the additional costs of transporting digested sludge cake from all the STCs to the new incinerators.

Where these options are delivered under a DBFOM route then these opex estimates would be reflected in gate fees (along with capacity charges).

If non-hazardous ash can be used in the construction industry then this would help reduce opex for SSI options by minimising landfill charges, however, opex would still be higher than for other options.

Net present value (NPV)

NPV values have been prepared for each option and take into account all expected costs and revenues over a 20 year operational period, including capex, capital maintenance (periodic replacement or renewal of assets), opex and income. Lower NPV values represent lower overall cost to YWS.

A 'simple payback' calculation has also been provided, estimated as the number of years taken before cumulative reductions in annual opex exceed the additional capital investment. For Option 2.1 it can be seen that the payback would be more than the 20 year period used for the analysis. For options 2.2 and 3.1 the opex would be increase with the investment and hence there would not be a payback.

Options 2.1 and 2.2 are intended as a response to Scenario 2b (further partial restrictions on landbank) whilst Option 3.1 addresses Scenario 3 (recycling to biosolids is no longer possible or viable). Hence, it is not possible to use NPV estimates (or simple payback values) to select between scenario 2 and 3 options.

However, the following conclusions can be drawn:

- **Option 2.1** (implementing additional AAD capacity) and **Option 2.2** (dryer at Knostrop) result in similar reductions in weighted average haulage costs – which is a key objective of options under Scenario 2b. However, the combined NPV estimate for Option 2.1 (i.e. combining the NPVs for Blackburn Meadows, Knostrop and Esholt) is significantly lower than the NPV for Option 2.2. Option 2.2 has a higher NPV as the savings in transport of dried product are outweighed by the additional opex costs associated with heat purchase, maintenance and staffing.

- **Option 3.1** has a much higher combined NPV than Option 2.1 (and Option 2.2) – as a result of the significantly higher capex and opex associated with even modern SSI plant designs. Hence, Option 3.1 would only be implemented if Scenario 3 occurred.
- Published research indicates that ACT solutions, once commercially available and proven at the required scales, are likely to be lower in both capex and opex (and hence NPV) than SSI options and hence these technologies should continue to be developed by the water sector and considered as an option by YWS if Scenario 3 occurs.

5.5.4 Carbon assessment

A high level assessment of the operational carbon (greenhouse gas) impacts of the identified options has been carried out and the results are presented in Table 5.10. The assessment includes emissions due to energy consumption (power, fossil fuels), chemicals and process emissions. Emissions reduction due to renewable energy generation are also quantified.

The analysis has been based on the throughputs and process quantities derived for the operational cost assessment and emission factors used in the recent Water Sector Carbon Accounting Workbook published by UKWIR.

Process emissions assumptions for AD/AAD and SSI options have been checked against the findings of the recent UKWIR report '*Quantifying and Reducing Direct Greenhouse Gas Emissions from Waste and Water Treatment Processes - Phase 1*' (UKWIR, 2020) which confirmed that no changes from the Carbon Accounting Workbook assumptions was required at this stage.

The waste heat used for the drying option has been assumed to have zero carbon emissions.

The following conclusions can be drawn from the results in Table 5.10:

- **Option 2.1** (implementing additional AAD capacity) results in lower net GHG emissions than the baseline largely due to increased renewable energy generation and reductions in both fossil fuel consumption (at AD sites) and process emissions (due to moving from AD to AAD).
- **Option 2.2** (drying) despite much lower transport emissions, Option 2.2 has higher net emissions than Option 2.1, largely because the option does not result in additional renewable energy generation.
- **Option 3.1** has much higher combined GHG emissions than Option 2.1 and Option 2.2 – due to the high stack GHG emissions outweighing the benefits of renewable energy generation and reduced product transport.
- Published research indicates that ACT solutions, once commercially available and proven at the required scales, are likely to have lower GHG emissions than SSI options.

Table 5.6: Baseline Opex forecast for 2025 (in £'000/year in 2020 prices)

	Totals	Aldwarke	Blackburn Meadows	Calder Vale	Esholt	Huddersfield	Hull	Knostrop	Lundwood	Mitchell Laithes	Old Whittington	Sandall	Woodhouse Mill	Third party treatment
Throughput (tDS/year) (1)	**169.87**	**4.39**	**17.33**	**3.89**	**31.50**	**16.57**	**29.02**	**37.70**	**2.67**	**11.42**	**5.19**	**3.91**	**4.12**	**2.17**
Maintenance	**3,593**	186.0	307.1	156.5	938.1	275.7	365.1	492.2	159.9	223.6	169.7	158.5	160.3	0.0
Staff	**1,336**	60.0	140.0	60.0	200.0	180.0	176.0	180.0	60.0	100.0	60.0	60.0	60.0	0.0
Power consumption	**1,569**	163.1	118.2	71.0	305.8	158.3	0.0	137.9	88.8	145.1	121.8	160.7	98.1	0.0
Chemicals	**4,664**	109.4	744.3	149.4	1037.2	633.9	0.0	1178.5	67.6	411.5	117.2	106.1	108.9	0.0
Fuel costs	**498**	34.7	10.9	43.7	3.8	52.9	47.2	5.5	46.5	202.9	16.7	25.6	7.3	0.0
Business rates	**1,954**	74.6	347.4	70.9	248.6	211.6	228.1	416.9	107.3	109.9	51.9	40.0	46.8	0.0
Liquor treatment (2)	**3,539**	231.7	782.8	82.6	551.6	546.1	102.1	409.4	116.2	209.4	250.0	83.3	173.5	0.0
Other	**1,141**	26.3	104.0	23.3	189.0	139.2	174.1	301.6	35.3	68.5	31.2	23.4	24.7	0.0
Revenue (3)	**-14,106**	-291.2	-1681.7	-460.7	-3210.3	-1199.3	-1958.9	-2740.4	-224.5	-1096.0	-413.7	-356.9	-472.1	0.0
Sludge imports (4)	**10,050**	373.3	30.1	28.2	2469.2	657.4	2290.0	2933.8	135.9	308.1	433.2	321.6	69.1	0.0
Recycling (5)	**4,625**	121.7	363.4	78.4	717.7	523.1	856.8	1188.9	62.1	321.1	170.3	130.8	91.0	0.0
Recycling – add. for FRfW (5)	**500**	13.1	51.7	11.6	93.9	49.4	86.5	112.4	8.0	34.1	15.5	11.6	12.3	0.0
3rd party management	**595**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	595.3
Total OPEX	**19,957**	**1,103**	**1,318**	**315**	**3,545**	**2,228**	**2,367**	**4,617**	**663**	**1,038**	**1,024**	**765**	**380**	**595**
Unit cost (£'000 per tDS)	**114.5**	**251.2**	**76.1**	**81.0**	**112.5**	**134.5**	**81.6**	**122.5**	**248.0**	**90.9**	**197.1**	**195.9**	**92.3**	**274.5**
Haulage distance used for recycling costs (km)		**25**	**33**	**21**	**48**	**30**	**29**	**53**	**26**	**28**	**13**	**26**	**29**	**n/a**

Source: YWS Bioresources Team. Units in £'000/year unless otherwise indicated.

Notes: (1) tDS/year figures are as raw sludge, i.e. before solids destruction, and are based on the Q&G model v11. (2) Liquor treatment costs include separate liquor treatment plants as well as where the treatment is within the STW. (3) 'Revenue' includes the value of power generation (whether used on site or exported), ROC income, and income from biomethane to grid. (4) Sludge imports relate to the transport costs of importing sludge to the STC. (5) Recycling row costs are likely around £500k low due to changes associated with Farming Rules for Water. These costs are largely overhead and impact on all sites in proportion to the sludge treated. A separate row has been added to show these additional costs (at £500k) distributed by STC.

Table 5.7: Capital costs by option

Scenario		Scenario 2				Scenario 3	
Option ref		2.1	2.1	2.1	2.2	3.1	3.1
Location		Knostrop	Blackburn Meadows	Esholt	Knostrop	Knostrop	Blackburn Meadows
Additional sludge treatment		AAD-THP	AAD-THP	AAD-THP	Drying	Incineration	Incineration
Sludge use/disposal		Agriculture	Agriculture	Agriculture	Agriculture	Ash – construction and/or landfill	
Throughput – average	tDS/y	52,520	27,420	27,673	24,192	63,653	50,185
Capacity [(1)]	tDS/y	59,400	29,700	27,564	28,000	69,800	55,000
Civil Works	£m	11.0	10.2	0.2	3.5	24.5	20.7
MEICA	£m	29.8	19.7	0.2	28.0	66.2	55.9
Sub-total - base costs	**£m**	**40.8**	**29.9**	**0.4**	**31.5**	**90.7**	**76.5**
Contractors on-costs	£m	14.3	10.5	0.1	11.0	22.7	19.1
Total construction costs [(2)]	**£m**	**55.1**	**40.3**	**0.6**	**42.5**	**113.4**	**95.7**
YWS/Project Company on-costs [(3)]	£m	13.8	10.1	0.1	10.6	28.4	23.9
Total project costs (incl. owner's costs)	£m	**68.9**	**50.4**	**0.7**	**53.2**	**141.8**	**119.6**

Notes

1) Option 2.1 capacities for Knostrop and Blackburn Meadows based on digester capacity assuming a THP solution. Esholt capacity based on data reported to Ofwat. Option 2.2 dryer capacity based on supplier information. Option 3.1 based on average throughput and 8,000 hours/year operating time

2) Total construction costs include base costs and contractors on-costs (which vary with treatment type) and are considered appropriate for both traditional D&B approaches and for an EPC contract within a DBFOM procurement route.

3) 'YWS/Project Company on-costs' are assumed to be 25% of construction costs which is considered sufficient for either a DBFOM or traditional D&B route. For a DBFOM procurement route it is considered sufficient for both YWS's project overheads and the costs of the Project Company (which would be included within the DBFOM bid prices). For a D&B route the procurement on-costs would be incurred solely by YWS.

4) Costs are in Q1'2022 prices

Table 5.8: Net Opex breakdown by option

Scenario		Scenario 2				Scenario 3		Comments
Option ref		2.1	2.1	2.1	2.2	3.1	3.1	
Location		Knostrop	Blackburn Meadows	Esholt	Knostrop	Knostrop	Blackburn Meadows	
Sludge treatment		AAD-THP	AAD-THP	AAD-THP	Drying	*Existing*	*Existing*	
Sludge use/disposal		Agriculture	Agriculture	Agriculture	Agriculture	Incineration	Incineration	
Throughput – average	tDS/y	52,520	27,420	27,673	24,192	63,653	50,185	
Capacity	tDS/y	59,400	29,700	27,564	28,000	69,800	55,000	
Fixed operational and maintenance costs	**£'000**	**296**	**158**	**7**	**975**	**4,452**	**3,990**	
Fixed maintenance costs (regular)	**£'000**	**195**	**66**	**0**	**669**	**2,297**	**1,937**	See note 1
Fixed operational costs	**£'000**	**101**	**92**	**7**	**306**	**2,155**	**2,053**	
Staff costs	£'000	-50	19	0	216	1,505	1,505	See note 2
Business rates	£'000	151	73	7	90	650	548	See note 3
Variable operational costs	**£'000**	**-2,334**	**-1,382**	**-28**	**1,284**	**1,494**	**1,702**	
Consumables (chemicals, water supply)	£'000	201	149	0	109	845	667	See note 4
Fossil fuels	£'000	-130	-223	0	0	28	22	See note 5
Power consumption	£'000	-61	-188	0	601	1,976	1,664	See note 6
Power generation - used on site or exported	£'000	-2,466	-1,107	0	0	-3,952	-3,328	See note 7
Sludge transport to AAD/SSI sites	£'000	0	0	0	0	1,047	1,500	See note 8
Heat purchased (for dryer option)	£'000	0	0	0	1,188	n/a	n/a	See note 9
Liquor treatment	£'000	449	253	0	0			See note 10
Treated biosolids transport to agricultural use	£'000	0	0	-28	-614	n/a	n/a	See note 11
Biosolids recycling management costs	£'000	-27	-77	0	0	n/a	n/a	See note 12
SSI by-products transport to disposal	£'000	-300	-187	0	0	260	196	See note 13
Landfill fees + taxes: non-hazardous waste	£'000	0	0	0	0	882	661	

Scenario		Scenario 2				Scenario 3		Comments
Option ref		2.1	2.1	2.1	2.2	3.1	3.1	
Location		Knostrop	Blackburn Meadows	Esholt	Knostrop	Knostrop	Blackburn Meadows	
Landfill fees + taxes: hazardous waste	£'000	0	0	0	0	407	321	
Total annual O&M costs (including lifecycle)	**£'000**	**-2,038**	**-1,224**	**-21**	**2,259**	**5,946**	**5,692**	

Notes:

1) Fixed maintenance costs – based on percentage of capex for each option (0.3% for civil works and 1.5% to 2.0% for MEICA). The existing fixed maintenance costs have been reduced for AD sites being converted to 'dewatering only' under option 2.1.

2) Staff costs – costs for new plants based on typical manning levels elsewhere. Staff costs reduced for sites being converted to 'dewatering only'.

3) Business rates - increases based on percentages of new civil works costs. Rates reduced for site being converted to 'dewatering only' assuming that rates not paid on mothballed plant.

4) Consumables – for Option 2.1, costs based largely on assumed changes in thickening and dewatering at each AD/AAD site and include polyelectrolyte consumption for pre-dewatering at the new AAD (THP) sites. For Option 2.2 costs cover chemicals used for dryer exhaust air treatment. For Option 3.1 SSI sites chemical costs include flue gas treatment stream and are based on typical levels from recent projects.

5) Fossil fuels - reduction in overall costs largely due to closure of existing AD sites with current budgeted consumption for process heating

6) Power consumption - – costs for new plants based on typical power consumption levels (per tDS throughput) from previous projects. Power use reduced for sites being converted to 'dewatering only'.

7) Power generation – Option 2.1 assumes additional biogas produced by new AAD plants at Blackburn Meadows and Knostrop is used in CHP engines. ROCs income for nearly all CHP engines ends by 2030 and any new CHP capacity would not receive ROCs. If site moves to biomethane production then this assumption would need to be reassessed though the net change in opex/revenues are not expected to have a material impact on the cost / benefit of moving to AAD or not. The reduction in generation for AD sites converted to 'dewatering only' is included in the assessment. For Option 3.1, SSI power generation capacity is based on recent project designs. For both options 2.1 and 3.1 it is estimated that surplus power generated by the new AAD and SSI plants would be used by the adjacent wastewater treatment works.

8) Sludge transport – for Option 2.1, liquid imports to the four STCs that would be decommissioned are assumed to continue, with all indigenous and imported liquid sludge dewatered for export to the new AAD plants. Existing dewatered sludge imports to the four STCs are assumed to be diverted directly to Blackburn Meadows and Knostrop AAD plants. For Option 3.1, costs are based on transporting digested sludge from existing AD/AAD plants to the new SSIs (Option 3.1 costs also reflect ending of existing costs of biosolids transport to agriculture).

9) Heat purchase – for dryer option at Knostrop. Low/medium grade heat assumed to be purchased from existing MSW incinerator at 2p/kWh (based on heat cost data provided by YWS).

10) Liquor treatment – based on existing YWS unit cost assumptions (£/tDS) for liquor treatment and predicted changes in liquor quantities due to options, including condensate from drying processes.

11) Treated biosolids transport to agricultural use – costs for options 2.1 and 2.2 reflects changes in location, quantity and quality of final biosolids production. Haulage distances for enhanced treated products assumed to be lower (see Section 5.3.3 for further details).

12) Biosolids recycling management costs - Total agricultural recycling management costs in 2030 are assumed to remain unchanged for baseline and options 2.1 and 2.2. The cost for administering the SSIs in Option 3.1 (including activities such as disposal of SSI products or management of a DBFOM contract) are assumed to be similar in scale (i.e. approx. £1.5m to £2.0m/year) – hence no net reduction in opex for this element has been included for SSI options.

13) SSI by-products transport to disposal and **Landfill fees + taxes** – By products include ash and APC residues from flue gas treatment. Transport costs assume 75km one-way distance to suitable landfills. Landfill gate fees and taxes assume all ash and APC residues sent to landfill but only APC residues are treated as hazardous waste. If ash can be recycled (e.g. as a construction material) then this would enable disposal costs to be reduced.

Table 5.9: Breakdown of Net Present Value (NPV) by option

Option ref		Scenario 2				Scenario 3	
Option ref		**2.1**	**2.1**	**2.1**	**2.2**	**3.1**	**3.1**
Location		**Knostrop**	**Blackburn Meadows**	**Esholt**	**Knostrop**	**Knostrop**	**Blackburn Meadows**
Sludge treatment		AAD-THP	AAD-THP	AAD-THP	Drying	*Existing*	*Existing*
Sludge use/disposal		Agriculture	Agriculture	Agriculture	Agriculture	Incineration	Incineration
Capex PV	£m	82	59	0.8	66	163	138
Net Opex PV	£m	-43	-26	-0.4	47	125	119
Income PV	£m	0	0	0	0	0	0
Total NPV	£m	**39**	**33**	**0.4**	**113**	**288**	**257**
Simple payback	Years	>20	>20	>20	No payback	No payback	No payback

Note:
NPVs calculated over 20 years operation using a discount rate of 3.5%.

'Simple payback' estimated as the number of years taken before cumulative reductions in annual opex exceed the additional capital investment. For Option 2.1 it can be seen that the payback would be more than the 20 year period used for the analysis. For options 2.2 and 3.1 the opex would be increase with the investment and hence there would not be a payback.

Table 5.10: Net operational GHG emissions breakdown by option

Scenario			Scenario 2			Scenario 3	
Option ref		2.1	2.1	2.1	2.2	3.1	3.1
Location		Knostrop	Blackburn Meadows	Esholt	Knostrop	Knostrop	Blackburn Meadows
Sludge treatment		AAD-THP	AAD-THP	AAD-THP	Drying	*Existing*	*Existing*
Sludge use/disposal		Agriculture	Agriculture	Agriculture	Agriculture	Incineration	Incineration
Throughput – average	tDS/y	52,520	27,420	27,673	24,192	63,653	50,185
Energy related GHG emissions							
Power used	tCO2e/y	-32	-100	0	362	1,049	883
Power generated	tCO2e/y	-1,309	-588	0	0	-2,098	-1,766
Fossil fuel	tCO2e/y	-3,566	-748	0	0	254	200
Transport emissions	tCO2e/y	-14	-35	-34	-284	-1,541	-376
Sub-total - energy related GHG emissions	**tCO2e/y**	**-4,921**	**-1,471**	**-34**	**77**	**-2,336**	**-1,059**
Other GHG emissions							
Chemicals	tCO2e/y	-16	61	0	-42	531	466
Process Emissions	tCO2e/y	-7,405	-3,866	0	0	18,779	14,806
Sub-total - other GHG emissions	**tCO2e/y**	**-7,421**	**-3,806**	**0**	**-42**	**19,311**	**15,271**
Total operational GHG emissions	**tCO2e/y**	**-12,342**	**-5,277**	**-34**	**35**	**16,974**	**14,212**

Notes:

1) Assumed quantities (chemicals, power generation, transport distances, etc) taken from the Opex analysis (further details of quantities provided in notes for Table 5.8).

2) Emissions factors taken from recent Water Sector Carbon Accounting Workbook updated by UKWIR. Power grid emissions factors based on the latest BEIS forecast for 2030.

3) Process emissions assumptions for AD/AAD and SSI options have been checked against the findings of the recent UKWIR report 'Quantifying and Reducing Direct Greenhouse Gas Emissions from Waste and Water Treatment Processes - Phase 1' (UKWIR, 2020) which confirmed that no changes from the Carbon Accounting Workbook assumptions was required at this stage.

5.6 Adaptive pathways analysis for a sludge to land strategy

Ofwat requires that PR24 business plans are set out in the context of a 25-year long-term delivery strategy[12], outlining the long-term outcomes a company aims to deliver, and how they will deliver them in a range of plausible futures. To achieve this Ofwat requires companies to use adaptive pathways planning techniques, using future scenarios to test and develop the adaptive pathways, and confirm that the strategy represents the best way to meet long-term objectives.

Although such an approach was not part of the scope of works for this study this section provides an outline of a potential adaptive pathway to 2030 (the study horizon) and beyond and tests it against future scenarios.

The Ofwat guidance identifies a number of 'reference scenarios' for WaSCs to use as a starting point with others added by the companies as required. Ofwat's reference scenarios set out two parameters ('adverse' and 'benign') for four material **drivers** of uncertainty around future enhancement spending: **climate change, technology, demand** and **abstraction reductions**.

Companies are expected to set out 'core' and 'alternative' pathways in a long-term delivery strategy to be able to deliver the company's ambition under the reference and other selected scenarios.

Of the four drivers cited by Ofwat we consider that three can be applied, with some interpretation, to biosolids use on land. These are as follows:

- **Climate change** – Climate change impacts (warmer and wetter winters, hotter and drier summers, more extreme events) could significantly affect both farming practices and access to farmland (and hence also the demand for biosolids)
- **Technology** – the pace of development of alternative technologies for sludge treatment (e.g. sludge pyrolysis and gasification)
- **Demand** – which, for this study, we have taken as demand for biosolids on land from farmers and their food chain stakeholders which can be affected by future regulatory changes and stakeholder preferences (Ofwat's original description focusses on changes in demand for water and wastewater services due to growth, however, we consider demand from farmers to be more relevant for this strategy). Within this driver we would include risks to demand associated with contaminants (PFAS, microplastics, antimicrobial resistance, etc)

Ofwat's fourth driver, abstraction reductions, is not considered to be directly relevant to biosolids uses and is not considered further in this section. Companies are able to propose additional drivers in their adaptive pathways analysis, however, we consider that the three above, with the proposed 'biosolids' interpretations, are sufficient for the purposes of this strategy.

Figure 5.5 summarises the selected drivers and presents possible 'adverse' and 'benign' scenarios. Table 5.11 provides an assessment of how these drivers might drive different adaptive pathways and key outcomes/products, whilst Figure 5.6 presents an example of core and alternative adaptive pathways using the information in Table 5.11.

[12] PR24 and beyond: Final guidance on long-term delivery strategies, Ofwat, April 2022

Figure 5.5: Drivers and scenarios for adaptive planning

	Climate change	Technology	Demand
'Adverse' scenarios	**High:** Impacts affect both farming practices and access to farmland	**Slower:** slower development than expected	**Low:** Agricultural demand for biosolids reduces or is not viable – due to regulatory changes and stakeholder preferences
'Benign' scenarios	**Low:** Farming practices and access to farmland not significantly affected	Faster: faster development than expected, such that alternatives such as ACT available in next 5 years	**High:** Demand for biosolids continues including for expected growth

Note: Diagram adapted from Figure 1.4 in Final guidance on long-term delivery strategies, Ofwat, April 2022

Ofwat's guidance states that the core pathway should be consistent with best practice adaptation techniques and should include all activities that need to be undertaken to be ready for all plausible future scenarios.

In this analysis, the **core pathway** is based on YWS's current practices but taking into account the additional EA requirements and their potential impacts on biosolids management and use – i.e. landbank 'Scenario 2b' (see Section 5.3). Although further tightening of regulatory requirements in the future is plausible the potential extent and impact of such changes is more difficult to predict and could range from minor impacts to complete loss of the sludge to land route.

Table 5.11 and Figure 5.6 illustrate how changes in the drivers from 'benign' to 'adverse' scenarios would then require decisions to be made on alternative pathways ('decision points' in Figure 5.6). These decisions would need to be made early enough to enable commissioning of any new treatment plant by a required trigger point, at which time an alternative pathway would be followed.

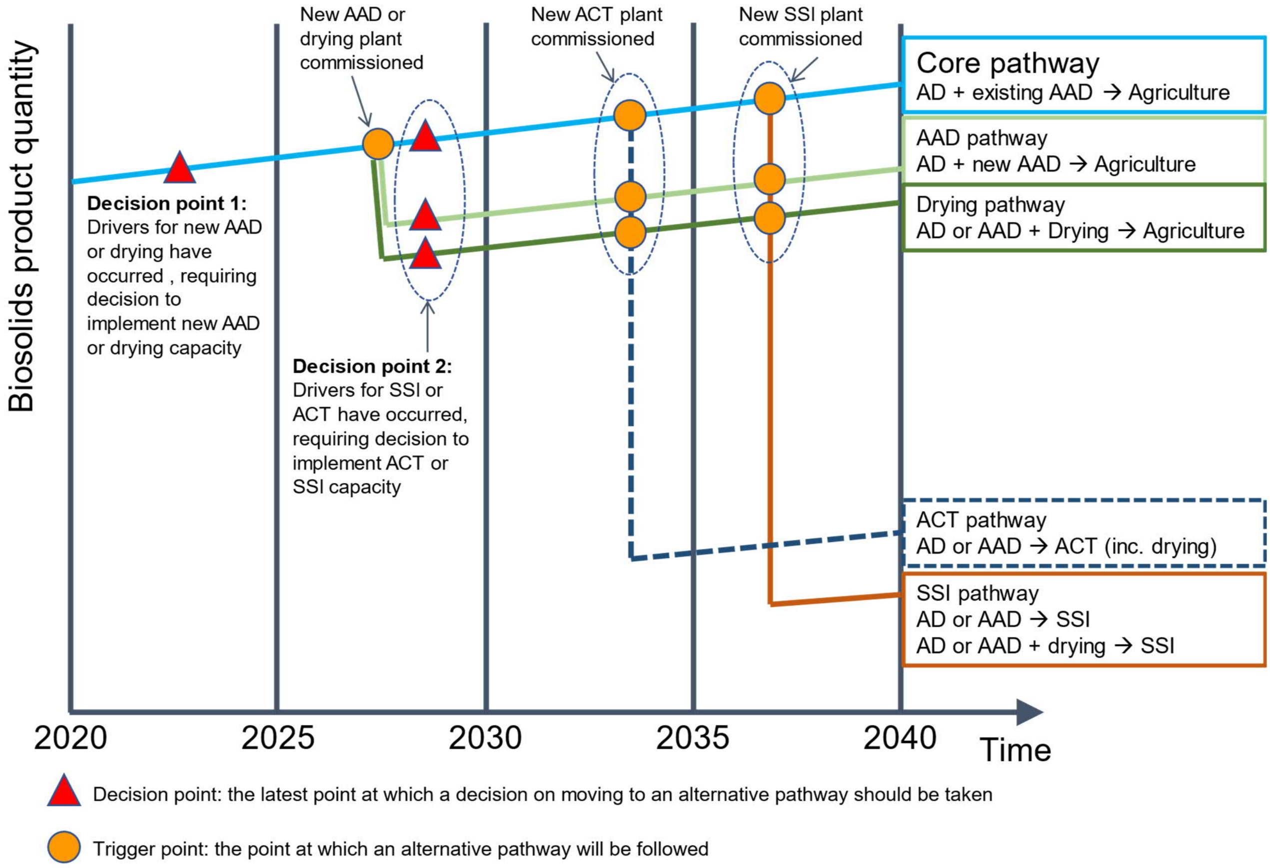
Figure 5.6 shows a number of alternative pathways and not all would be used – the decision on which pathway would be based on the circumstances / drivers occurring at each decision point. For example, in Figure 5.6 the decision points and pathway choices could be as follows:

- **Decision point 1 -** If the drivers for changing the quantity and quality of biosolids being produced for use in agriculture have occurred (e.g. increased demand for enhanced treated product) then YWS could choose to choose the AAD or drying pathway with commissioning occurring during the next AMP. It is unlikely that both pathways would be followed (except perhaps at Knostrop due to the potential availability of surplus heat).
- **Decision point 2 -** If the drivers for a combustion technology (ACT or SSI) have occurred then either of these technology pathways could be selected for implementation. If the ACT technology is commercially ready and confirmed to be more cost effective and sustainable at scale then this pathway could be followed rather than the SSI pathway.

Table 5.11: Potential drivers, adaptive pathways and key outcomes

Pathway	Drivers used in adaptive pathway assessment			Key outcome / treatment processes / biosolids uses
	Climate change	**Technology**	**Demand**	
Core pathway	Expected climate change impacts not sufficient (benign nor adverse) to change farming practices in region or access to farmland.	Continued and gradual improvements in design and operation of conventional and advanced AD, including in other related areas (e.g. improved dewatering practice, P recovery technologies, fugitive emissions control, biogas upgrading and CO2 capture, etc).	Demand is as per Scenario 2b described in this report (and increases in step with growth in biosolids production) and no further tightening of regulations / practices occurs in the short/medium term (after 2022).	Continue to rely primarily on conventional AD and existing AAD. Implement further AAD where there is clear cost / benefit. AD + existing AAD → Agriculture
AAD pathway	As above	As above. Existing AD plants would be upgraded using proven thermal treatment process prior to digestion. The resulting additional biogas could be used for biomethane and potentially hydrogen generation.	Driver to reduce total biosolids quantities and/or improve biosolids quality in order to mitigate impacts of increased constraints under Scenario 2b or future tightening of regulations. Increased demand for biogas energy (for biomethane and potentially hydrogen)	Continue to rely on AD but implement further AAD (e.g. THP) for a proportion of the biosolids production. Existing AD/AAD + new AAD → Agriculture
Drying pathway	Increased prevalence of wet weather significantly affects ability to store and spread cake on landbank.	Drying techniques using lower grade heat are already commercially available and proven at required scale. Potential to incorporate into future ACT solutions.	Driver to reduce total biosolids quantities and/or improve biosolids quality in order to mitigate impacts of increased constraints under Scenario 2b or future tightening of regulations. Demand for pellets/granules to increase the available landbank and potentially enable spreading in the spring.	Continue to rely on AD and existing AAD but implement low temperature drying using waste heat on sites where cost effective AD + existing AAD + drying → Agriculture AD or AAD + drying → Cement
SSI pathway	As above	SSI technologies to combust dried and/or dewatered sludge already commercially available and proven at required scale.	No demand for biosolids in agriculture due to regulatory or stakeholder restrictions or because it is no longer the best commercial option for farmers (i.e. Scenario 3). Can still be demand for by-products – such as ash and P extracted from ash	All sludge is digested and then incinerated in new SSI plants AD or AAD → SSI → Use/disposal AD or AAD + drying → SSI → Use/disposal
ACT pathway	As above	ACT technologies to combust sludge become commercially available and proven at required scale (would also incorporate drying stage). ACT technologies demonstrated to be more sustainable (in social, environmental and financial terms) than SSI.	As above, but products would be biochar and potentially hydrogen from syngas.	All sludge is digested and then combusted in new ACT plants AD or AAD → ACT (incl. drying) → Disposal or use

Figure 5.6: Potential alternative adaptive pathways for sludge to land strategy



Other points to note from Figure 5.6 are as follows:

- ACT and SSI technologies can be used in combination with different sludge products (raw, conventionally or advanced digested or dried). Hence, decision point 2 and the ACT or SSI pathways can start from the core, AAD or Dryer pathways.
- It is assumed that once an ACT technology is established it could be implemented more quickly (potentially by several years) than an SSI pathway due the longer planning and regulatory approval process expected for an SSI option (which would normally attract greater public scrutiny and opposition due to large flue gas emissions).
- Figure 5.6 focusses on the more significant potential drivers and technology options which would impact on biosolids quantity, quality and hence end use. However, there would be ‘sub-pathways’ for other ‘bolt-on’ technologies that could be added to treatment plants, for example, alternative biogas uses, nutrient recovery options or other higher value products as well as those related to providing increased resilience.
- The final use of disposal routes for biochar from ACT processes is the subject of on-going research.

Table 5.12 illustrates a range of adaptive pathways and treatment steps that could be used together with indicative costs (in Q1 2022 prices). For example, the SSI pathway with the treatment steps “Existing AD/AAD + new AAD → SSI” would have started as the AAD pathway and then become an SSI pathway at a later date.

Table 5.12 illustrates that if Scenario 3 is anticipated to occur in the medium term then transitioning from a core pathway to the SSI pathway (ie "Existing AD/AAD → SSI") would be the lowest capex route.

Table 5.12: Potential adaptive pathways and indicative costs

Pathway	Treatment steps	Use/Disposal	Capex	Opex	Comment
Core pathway	Existing AD/AAD	Agriculture	0	19	See note 1
AAD pathway	Existing AD/AAD + new AAD	Agriculture	120	16	See note 2
Drying pathway	Existing AD/AAD + Drying	Agriculture	53	21	See note 3
SSI pathways	Existing AD/AAD → SSI	Landfill, other uses	261	27	See note 4
	Existing AD/AAD + new AAD → SSI	Landfill, other uses	367	24	
	Existing AD/AAD + drying → SSI	Landfill, other uses	315	30	
ACT pathway	AD or AAD → ACT (incl. drying)	Landfill, other uses	n/a	n/a	See note 5

Notes:

1) Capex for core pathway excludes normal on-going expenditure including capital maintenance and other investments to maintain or enhance current treatment capacity. Opex is the base estimate provided by YWS Bioresources team.

2) AAD pathway capex involves implementation of all Option 2.1 components (ie new AAD at Blackburn Meadows and Knostrop and minor works at Esholt). Opex is Core pathway opex added to predicted reductions for Option 2.1.

3) Drying pathway capex involves implementation of Option 2.2 components (ie new dryer at Knostrop). Opex is Core pathway opex added to predicted increase for Option 2.2.

4) Three SSI pathways are shown, each starting from a different pathway (core pathway, AAD pathway or Drying pathway). Capex and opex are derived by adding capex and opex for the SSI options to the costs for the starting pathways. For the AAD pathway + SSI option the SSI capex and opex have been reduced by a small amount to account for the additional dry solids destruction in the AAD plants, which reduces the required capacity of the SSI plant.

5) The ACT pathway has not been costed at this stage as ACT plant options are not commercially available or technically proven at this scale and hence any costs would not be considered reliable.

5.7 Selection of the Best Value option

The scope for this strategy asks that the strategy should also provide a potential alternative 'no capex' delivery route (e.g. DBFOM) for the 'best value' option(s).

This section discusses the best value option for each scenario, based on the technical and cost analysis provided in Section 5.

5.7.1 Best value option for Scenario 2 (2b)

Scenario 2 (using the 2b variant – see Section 5.3.1) assumes that further tightening of restrictions between 2022 and 2030 are moderate and are likely to only result in moderate increases in haulage distances and management costs.

The least capex option for this scenario would be the 'do nothing' approach – maintaining and improving existing treatment assets and performance but not making significant changes in the types of treatment processes.

Option 2.1 – implementation of additional AAD capacity - results in the lowest opex and operational carbon emissions (compared to Option 2.2 and the 'do nothing' option). The option would also increase landbank availability, reduce biosolids quantities and create more biogas energy than the 'do nothing' option.

However, Option 2.1 requires significant additional capex (and embodied carbon emissions), with a financial payback period in excess of 20 years (the horizon for the analysis).

Hence, in financial terms the best value option could be considered to be the ‘do nothing’ option.

5.7.2 Best value option for Scenario 3

Scenario 3 assumes that recycling biosolids to agricultural land is no longer viable. In the absence of other technologies that are commercially available and proven at the required scale, only one option - sludge incineration - has been assessed (Option 3.1).

Hence, by default this would be considered the ‘best value’ solution at this time, until other, potentially more attractive options such as pyrolysis or gasification are commercially available and proven at the required scale.

6 Water Treatment Sludge Solutions

6.1 Use and disposal options

Water Treatment Sludge (WTS) is produced as a by-product of supplying drinking water. Much of the WTS produced by YWS's water treatment plants (approximately 70%) is discharged to sewers and is therefore managed at WWTW. The remaining 30%, equivalent to just over 20,000 wet tonnes/year (or approximately 5,000 tDS/year) of WTS must be managed. Currently nearly all of this is taken to Burnby Lane, which has approx. 5 years of capacity left. Hence, YWS will need a sustainable outlet for this material going forwards.

There is a range of possible outlets for WTS, the main options include:

- Discharge to sewer and inclusion in biosolids
- Recycling to agricultural land
- Use in land restoration
- Use in soil manufacture
- Use in production of construction materials
- Use in novel processes to reduce diffuse pollution

Due to the ad-hoc nature of WTS management across the water industry there is very little information on annual production and uses, however, it is understood that the vast majority of WTS is either discharged to sewer or recycled to agricultural land.

Discharge to sewer and inclusion in biosolids

YWS already discharges approximately 70% of its WTS to sewer, however, the remote location of the remaining WTW makes this less viable for the remaining 30% of WTS, particularly due to the cost of transporting the material in its liquid form. Moreover, taking this 30% to a WWTW would increase treatment costs and take up treatment capacity in the wastewater and sludge treatment processes, without the benefit of biogas generation.

Recycling to agricultural land

The main alternative to sewer discharge is recycling to agricultural land. WTS is a waste meaning it has to be recycled under the EPR and specifically a '*Standard Rules 2010 Number 4 – Mobile Plant for Land Spreading*' permit. Most WTS can be recycled to agricultural land, but there are sites where the Potentially Toxic Elements (PTEs) will be sufficiently elevated as to make them unsuitable.

However, without accurate sludge composition data for each source it is not possible to estimate what proportion would not be suitable, although it is expected to be a minority. There is a cost to obtain the permit and then a cost per Deployment, and based on the typical nitrogen content of WTS (the limiting factor affecting application rates) YWS would need approximately 25 Deployments at a cost of approx. £40,000/annum.

Moreover, there would be a cost to manage, find land and transport the WTS to the farms. It is unlikely farmers would be willing to pay for the WTS, due to the limited nutrient and organic matter benefit it provides (although site-specific information would be needed to confirm this), but YWS should be able to find sufficient farmers to take the material. The biosolids landbank assessment highlights that apart from the 'plausible worst-case' scenario, there would be sufficient land to recycle not only the biosolids but also WTS within the YWS region. This could be confirmed by re-running the landbank assessment including site-specific WTS composition data and this would also provide predicted maximum haulage distances based on the location of the WTS production sites.

A high level assessment of an approximate annual budget for recycling WTS to agriculture is presented in Table 6.1. This is based on predicted WTS quantities and similar unit transport and management costs to those used by YWS in current biosolids budgets. The analysis is based on an assumed average haulage distance to farmland of 50km. This is greater than the distance estimated for Scenario 2b in the biosolids landbank assessment and hence is considered a reasonably conservative assumption.

Table 6.1: Estimated annual budget for recycling WTS to agriculture

Location	Various WTW		Comments
Sludge use/disposal	Agriculture		
Throughput – current forecast in 2030	tDS/y	3,924	Total for all WTW which do not currently discharge sludge to sewer, see Section 3.3 for breakdown.
	tonne/y	23,862	
Transport of sludge cake to farms	£'000/y	195	See note 1
Agricultural recycling management costs	£'000/y	35	See note 2
Permit costs	£'000/y	40	See note 3
Total	**£'000/y**	**270**	
Operational carbon emissions for transport	tCO_2/y	104	

Notes
1) Estimated using the unit transport costs used for biosolids in Q&Gv12 model and an assumed 50km one way haulage distance.
2) Estimate based on unit management cost derived from biosolids budget (approx. £9/m3 of cake)
3) Estimate based on an assumed 25 deployments

Use in land restoration

Use of WTS in land restoration is also common. WTS features on the '*Standard Rules 2010 Number 5 – Mobile Plant for Reclamation, Restoration or Land Improvement*' permit, meaning it can be used alongside other organic manures and mineral materials which are used in restoration projects. The primary issue is that land restoration sites are finite and once they have been restored any applications would be at much reduced rates. Moreover, WTS would be competing with a range of other materials some of which are able to justify elevated gate fees as they have no other options.

The price of land restoration is hugely variable and depends on the location of the site and the materials it is able to accept, but typically this will be in the range of £15 - £50 per tonne. As a result of the finite nature of land restoration sites and the price/competition, this is not likely to be a long-term option for the WTS. It could be an option where WTS sources contain elevated PTE concentrations that make them unsuitable for agricultural use as land restoration is typically able to accept such materials, depending on the nature of the site and its permit restrictions.

Use in soil manufacture

YWS as well as other companies has previously investigated and produced manufactured topsoil using WTS combined with other materials. Again there are legislative challenges that would need to be overcome but bespoke topsoils can command high prices especially when used in niche situations like green roofs. There is also a need for bulk quantities of topsoil and the move away from peat means companies are actively looking for alternative, sustainable materials like WTS.

The market is likely to be slow to develop, but in time could require significant quantities of WTS to mix with other organic manures and mineral materials to create bespoke topsoil mixtures.

Moreover, the margins in producing a saleable product would probably be much greater than in more traditional outlets.

Use in production of construction materials

Similar to topsoil production, the construction industry is interested in sustainable sources of aggregate type materials. The 'granular' nature of WTS would be of interest in fired or non-fired applications, however, the chemical composition of the WTS could affect firing temperatures and even the colour of the resultant building materials. This option has the potential to utilise significant quantities of the WTS produced by YWS and at viable rates, however, it will come down to the specific chemical and physical composition of the material and the affect they have on the physical and aesthetic properties of the resultant building materials – as well as demand and haulage costs.

Use in novel processes to reduce diffuse pollution

There have been and are ongoing studies investigating using the nutrient (particularly phosphorus) absorption properties of WTS to reduce diffuse pollution. Studies including using WTS in the production of manufactured reedbeds to clean-up effluent or using WTS in conjunction with livestock slurries (which contain nutrients in a highly available form). None of these options are commercially realistic and there are legal hurdles to overcome, but they could become high-value niche outlets for some of the material YWS produces.

6.2 Conclusions

There are a range of possible methods to manage the 30% of YWS's WTS that is not discharged to sewer. The most sustainable option in the short-term is considered to be recycling to agricultural land, following a similar approach to that which applies to biosolids.

There is an operational and permitting cost to this option, but it is likely to be less than the cost of other options, especially in the short-term. A high level assessment (including an assumed 50km haulage distance) indicates an annual cost for this option in the order of £270,000.

To ensure this option is possible for all sources, more information is required to understand where it is produced and ensure the material is suitable for use on agricultural land. There are potentially more cost-efficient solutions, but they are much less certain and the initial costs to develop these outlets would be much greater, although some could be investigated alongside more 'bankable' options like agricultural recycling.

7 Potential Delivery Routes

The scope for this strategy asks that the strategy should also provide a potential alternative 'no capex' delivery route (e.g. DBFOM) for the best value option(s).

Section 5.7 concluded that the best value options available at the current time were as follows:

- For Scenario 2 – the 'do nothing' option
- For Scenario 3 – Option 3.1 (SSI)

Hence, this section focusses on delivery routes for Option 3.1 (SSI plants).

7.1 Delivery routes currently used for SSI plants

Multiple sewage sludge incinerators have been commissioned globally in the last 10 years, are under construction or our planned for delivery in the next 10 years. Many of these are located in Europe. Most of these have or are being delivered by wastewater utilities using D&B routes though DBFOM and DBO routes have also been used.

Figure 7.1 provides examples of recent and on-going wastewater sludge incineration projects together with delivery routes where known.

Table 7.1: Examples of SSI projects – last 10 years and in progress

Location	Country	tDS/day (annual average)	Commissioning year	Delivery route
T Park	Hong Kong	500	2015	DBO
Zurich	Switzerland	82	2016	D&B
Glina, Bucharest	Romania	173	2020	D&B
Mainz	Germany	110	2021	
Bitterfeld	Germany	170	2022	
Tubli	Bahrain	118	2022	DBFOM
Dordrecht	Netherlands	231	2022	D&B
Hannover-Lahe	Germany	82	2023	
Sesto (Milan)	Italy	55	2023	
Straubing Bavaria	Germany	82	2024	D&B
Stavenhagen	Germany	99	2024	
Delfzjil	Netherlands	142	2024	
Berlin-Waßmannsdorf	Germany	186	2025	D&B
Tuas (IWMF)	Singapore	225	2025	D&B
Sindlingen, Frankfurt am Main	Germany	110	2025	D&B
Knapsacker Hugel	Germany	247	2025	
Waldheim, Baden-Württemberg	Germany	123	2025	D&B
Ghent	Belgium	178	2026	DBFOM
Gut Großlappen, Munich	Germany	110	2027	D&B
Wuppertal Buchenhofen	Germany	130	2028	D&B

Source: Mott MacDonald projects database.

The Ghent project, an example of a SSI plant being delivered using a DBFOM approach, is described further below.

7.2 Case study – DBFOM for a sludge incinerator

A recent example of a DBFOM sludge incinerator project is the Aquafin incineration project in Ghent, Belgium. Aquafin is a public utility that is responsible for the financing, expansion and operation of the wastewater and sludge treatment in Flanders.

In June 2022, Aquafin awarded a contract for the design, build, financing, operation and maintenance (DBFOM) of a 65,000 tDS/year sewage sludge incinerator to a consortium of Besix and Indaver. The contract includes 2 years for design, 2 years for construction (with commissioning in 2026) and 20 a year-period for maintenance and operations post commissioning. The technical solution is a single fluidised bed incineration line with flue gas treatment.

This project will enable Aquafin to treat this sludge in a single modern plant rather the current mixture of cement plants and an older existing SSI in Bruge.

Instead of power, the plant will generate high pressure steam which will be sold to an adjacent steel plant. The feedstock received by the incinerator comprises both cake and dried sludge and a high proportion of the feedstock has already been anaerobically digested. Aquafin intends to extract phosphorus from the fly ash in the future and will procure that part of the process separately.

The consortium will receive both fixed and variable payments from Aquafin, as follows:

- Fixed fees (per quarter) – covering the consortium's financing costs as well as fixed operating costs – effectively a 'capacity charge'
- Variable fees – based on a price per wet tonne of sludge received by the SSI (different unit prices for dewatered cake and dried sludge)

7.3 Potential SSI technology providers

There are a number of SSI technology providers operating in Europe. The most prominent are listed below. All these companies are active in the incinerator D&B market and also provide EPC contractor services within DBFOM consortia. Larger companies such as Veolia will often lead DBFOM consortia and may also take on the role of operating company within consortia.

SSI technology providers in Europe include the following companies:

- Indaver – Technology provider in the waste sector, delivering and operating both waste and sludge. As noted above, along with contractor Besix, Indaver was recently awarded a 65,000 tDS/year sludge incinerator in Belgium. More information: www.indaver.com
- Küttner Martin GmbH: Major technology provider that has bought a number of other leading technology providers over the last decade (e.g. Lurgi, BAMAG and Outotec). The company reference projects include the Zurich SSI (30,000 tDS/y completed in 2016 and the ongoing Tubli sludge incinerator in Bahrain (40,000 tDS/y) as well as a number of ongoing projects in Europe (https://www.kuettner-martin.de/en/home.html).
- Sludge2energy GmbH, a subsidiary company of WTE Wassertechnik GmbH and HUBER SE, was formed in 2018. The company reports to be currently building a number of incinerators in Europe (Sewage sludge | sludge2energy).
- Veolia – Global technology provider, delivering own technology (Pyrofluid) or sub-contracting to other technology providers as needed (has recently acquired much of Suez's European energy from waste operations)

7.4 Potential costs for a DBFOM route

As noted for the case study above, a DBFOM consortium will receive both fixed and variable payments from the asset owner, as follows:

- Fixed fees (per quarter) – effectively a 'capacity charge' covering the consortium's financing costs as well as fixed operating costs
- Variable fees – based on a price per wet tonne or per tonne of dry solids received by the SSI

Typically, for such contracts the fixed fees make up the bulk (>75%) of the total payment to a DBFOM company.

Based on recent project experience, for a project of the scale of the Knostrop SSI in Option 3.1 (£142m capex, 63,650 tDS/year throughput) an equivalent overall unit cost, including both fixed and variable fees, would be expected to be between £275/tDS and £375/tDS. A Blackburn Meadows SSI (£119.6m capex, 51,800 tDS/year throughput) could be expected to have slightly higher unit costs due to its smaller scale – with the upper end of the range potentially increasing to £400/tDS.

These unit costs are only indicative and based on prevailing market conditions in 2021. Changes in underlying factors such as costs of financing (interest rates), energy, consumables and labour costs, as well as construction market conditions, would be expected to have a significant impact on these unit costs.

7.5 Potential market appetite for SSI DBFOM projects in the UK

Most of the SSI technology providers listed above are already active in the UK municipal waste incineration market.

Veolia is also active in the UK water sector in general and is also part of the consortium for Project Omega, the DBFOM project operating a sewage sludge incinerator and five wastewater treatment plants in Northern Ireland. Project Omega was awarded in 2007 and is due to end in 2032. Veolia is part of the Project Company and is also the operating contractor for both wastewater treatment and the sludge incinerator.

Discussions with Veolia energy from waste staff have confirmed an interest in delivering SSI in the UK water sector if opportunities arise – through either D&B, DBO or DBFOM routes.

8 Conclusions and Recommendations

8.1 Background

This report has assessed potential options for YWS's 'PR24 sludge to land strategy'.

YWS requires the 'PR24 sludge to land strategy' to identify an efficient, costed alternative strategy for YWS to adopt in the event that curtailment or even cessation of the sludge to land recycling route occurs in the near future (up to 2030) as a result of changes to the regulations governing the recycling of biosolids to agricultural land.

The project has evaluated the impacts of three scenarios:

4. Recycling to land continues as now and risks to the landbank are not realised
5. Recycling to land becomes restricted to limited land use areas and time periods by 2030
6. Recycling to land is no longer the best commercial option and / or is fully restricted by regulation by 2030.

The analysis has built upon the findings of the Water UK national biosolids strategy (which has evaluated several scenarios for the future of sludge management in the UK), by applying the generic report findings to YWS's asset base and specific disposal routes.

The project has also identified a use for the approx. 30% of YWS's water treatment sludge (WTS) that is not currently discharged to the sewer but is mostly sent to the Burnby Lane facility.

8.2 Water UK biosolids report

A report entitled "*An assessment and evaluation of the loss of the biosolids-to-agricultural-land recycling outlet*" was commissioned by Water UK and was published in draft on the 17 December 2021. At the time of writing this Sludge to Land strategy a final version of the Water UK report was not yet available.

The Water UK report assesses various technologies that could be adopted in the face of tighter restrictions on the use of biosolids in agriculture. With respect to thermal treatment options the Water UK report concludes that only sludge incineration is commercially available and proven at the scales required by the UK water sector and that other technologies such as pyrolysis and gasification require further development.

We concur with this general finding and have used incineration technology as the basis for options used under Scenario 3 (no recycling of biosolids to land).

8.3 Sludge forecasts

Wastewater sludge production forecasts to 2025 and 2030, pre- and post- anaerobic digestion, have been prepared to inform the landbank assessment and identification of alternative recycling routes. Forecasts for clean water treatment sludge production over the same timescales have also been prepared.

Wastewater sludge quantities produced by YWS' WWTWs are expected to increase sharply by 2025 and 2030 (18% increase by 2025 and a further 6% increase between 2025 and 2030 – compared to an expected population increase in the YWS region of only 2.32% from 2020 to 2030). The increase is mostly due to the impact of tighter phosphorus consents under the WINEP, resulting in increases in both chemical sludge and overall sludge production per PE.

This will cause a similar increase in total treated sludge (biosolids) for recycling to agriculture, as well as a significant increase in the P content of biosolids sludge from most STCs.

Clean water treatment sludge production is expected to grow more slowly over the same timescales, in line with population growth (i.e. an approximate 2.32% increase from 2020 to 2030).

8.4 Landbank assessment

A landbank assessment was undertaken for Scenarios 1 and 2.

Based on this assessment the following conclusions have been drawn:

- **Scenario 1 -** There is sufficient land within the YWS region to recycle the biosolids it produces and this is likely to be the case even with the forecast growth in sludge quantity (and P content) by 2030.
- **Scenario 2 –** based on current discussions between the EA and water industry more land will be required due to the forecast increase in volumes of biosolids produced, predicted increases in phosphorus content and increased focus on phosphorus additions, however, despite this, YWS is still predicted to be able to recycle the biosolids it produces in 2030 within its region. However, there is likely to be an increase in haulage distances (from a weighted average of 30km in 2020 to a maximum weighted average of around 40km in 2030) – and hence cost increases for haulage as well as biosolids management.

The other pressures on biosolids recycling (e.g. concerns over contaminants and changes in regulatory regime) could affect operational management (and therefore management costs), but are unlikely to have a significant impact on the quantity of available land and therefore the distance biosolids has to be transported in the medium term.

8.5 Biosolids strategy options

Potential biosolids strategy options have been assessed for scenarios 2 and 3.

8.5.1 Scenario 2 options

Strategic options proposed for Scenario 2 have the primary aim of increasing resilience of YWS's sludge recycling operations against future tightening of regulations by increasing the proportion of biosolids achieving enhanced product quality. These options provide additional advanced AD capacity (AAD, using thermal hydrolysis processes) or low/medium temperature drying using waste heat.

A 'do nothing' option has also been included - maintaining and improving existing treatment assets and performance but not making significant changes in the types of treatment processes.

The options analysis concluded that Option 2.1 – implementation of additional AAD capacity - results in the lowest opex and operational carbon emissions (compared to Option 2.2 and the 'do nothing' option). The option would also increase landbank availability, reduce biosolids quantities and create more biogas energy than the 'do nothing' option.

However, Option 2.1 requires significant additional capex (and embodied carbon emissions), with a financial payback period in excess of 20 years (the horizon for the analysis).

Hence, in financial terms the best value option (and the least capex) could be considered to be the 'do nothing' option.

8.5.2 Scenario 3 options

In line with the findings of the Water UK report, two sludge incineration options were identified under this scenario: using a dedicated sludge incinerator (Option 3.1) and diversion of sludge to municipal waste incinerators (Option 3.2). In each case the existing sludge treatment processes (AD or AAD, with biogas energy recovery) were assumed to be retained.

The analysis identified significant technical constraints with the municipal waste option and hence this was not carried forward for detailed cost and carbon analysis.

Hence, Option 3.1 is considered to be the only option under Scenario 3 at this time (with a total capex value of £261m), until other, potentially more attractive options such as pyrolysis or gasification are commercially available and proven at the required scale. Option 3.1 has assumed two SSIs on separate sites which is considered a robust solution for planning purposes, however, constructing two lines on a single site may provide lower overall costs.

8.5.3 Adaptive pathways analysis

An adaptive pathways analysis is presented in this report which indicates a number of different pathways (approaches to sludge treatment) and decision points which might result in a changes to alternative pathways.

A key point highlighted by such an analysis is that the technologies that could eventually be required under Scenario 3 (such as incineration or more novel alternatives such as pyrolysis) can be used in combination with different sludge products (raw, conventionally or advanced digested or dried sludge). Hence, Scenario 3 options could be implemented following and build upon Scenario 2 options (and the Scenario 1 baseline treatment assets) with minimal risk of creating obsolete assets.

8.6 Water treatment sludge options

There are a range of possible methods to manage the 30% of YWS's WTS that is not discharged to sewer. The most sustainable option in the short-term is considered to be recycling to agricultural land, following a similar approach to that which applies to biosolids.

There is an operational and permitting cost to this option, but it is likely to be less than the cost of other options, especially in the short-term. A high level assessment (including an assumed 50km haulage distance) indicates an annual cost for this option in the order of £270,000.

To ensure this option is possible for all sources, more information is required to understand where the WTS is produced and ensure the material is suitable for use on agricultural land. There are potentially more cost-efficient solutions, but they are much less certain and the initial costs to develop these outlets would be much greater, although some could be investigated alongside more 'bankable' options like agricultural recycling.

8.7 Potential delivery routes

The scope for this strategy asks that the strategy should also provide a potential alternative 'no capex' delivery route (e.g. DBFOM) for the best value option(s).

The potential for a DBFOM type delivery route for new SSI capacity (Option 3.1) has been described and high level indicative costs have been assessed.

Discussions with a major provider of SSI plants have confirmed an interest in delivering SSI in the UK water sector if opportunities arise – through either D&B, DBO or DBFOM routes.

8.8 Recommendations and next steps

Based on the findings of the land bank assessment and subsequent options analysis we recommend the following approaches and options:

- If Scenario 3 occurs (loss of the sludge to land route) in the short/medium term then construction of SSI plants (Option 3) would be the only option which is both commercially available and proven at the required scale. A more detailed feasibility study would then be required to confirm the optimum numbers and capacities SSIs to construct.
- If alternative thermal treatment scenarios become commercially available and proven at the required scale before Scenario 3 occurs then these should be assessed in comparison with the SSI option in order to select the most cost effective and sustainable solution. In the meantime, YWS should continue to monitor the development of these alternative technologies.
- If no further restrictions are placed on biosolids use in agriculture, beyond those currently envisaged under Scenario 2 (2b variant) then the ‘do nothing‘ option may be sufficient in the short and medium term.

A. Sludge forecasts

This appendix provides further detail of the sludge production forecasts used in the development of the 'PR24 sludge to land strategy' for YWS. A summary of the key findings from this appendix are presented in Section 3 of this report.

This appendix was previously issued as '*Technical Note 1 – Sludge Forecasts*'.

A.1 Wastewater sludge forecasts

A.1.1 Key assumptions and data sources

The following wastewater sludge data were provided by YWS:

Table A.1: Biosolids sludge projection data sources

Data category	Description	Source
STC and treated sludge (biosolids) use information	STC information including: • Locations and treatment processes • Biosolids product type and standard • Sludge input and biosolids product quantities for 2020 (tonnes of dry solids, cake dry solids concentrations and wet tonnes) • Biosolids quality data (N, P_2O_5 % concentrations) • Biosolids application data (kg N/ha, receiving land types, farmer acceptance rates, average haulage distances, etc)	'YWS STC information.xslx' – populated by YWS bioresources team
Sludge inputs to each STC	Sludge input data for each STC including: • 2020 sludge production (pre-treatment) • Forecast sludge production to 2030 by STC • Changes to phosphorus consents at each WWTW, from 2020 to 2030 • Sludge treatment costs at each STC	'Quality and Growth Model v12' (updated by Stantec in 2021)

Using this data, the approach and assumptions used in preparing the wastewater sludge production forecasts were as follows:

- Data from the YWS 'Quality and Growth Model v12' ('Solids Production by Site' tab), updated by Stantec in 2021, has been used for the 2020 and 2030 sludge inputs to each STC (indigenous and imports).
- Previous sludge production data supplied by the YWS Bioresources team were reviewed and compared with the 'Quality and Growth Model v12' input sludge data for 2020 and discrepancies discussed with YWS.
- Future sludge solids destruction during treatment at STCs was estimated assuming 75% VSS (Volatile Suspended Solids) content in sludge inputs and a 45%VSS destruction in conventional anaerobic digestion. For Esholt STC (advanced anaerobic digestion) total solids destruction was taken as 40.3%, based on estimated solids destruction data provided by the Bioresources team. These future treated sludge quantities were then compared with 2020 biosolids recycling quantities data supplied by the YWS Biosolids Strategy team and discrepancies resolved with YWS.
- The dry solids concentrations (%DS) measured by YWS for the digested and dewatered biosolids taken to land from each STC in 2020 have been assumed to be the same in 2030.
- The future phosphorus content (as P_2O_5) in biosolids, used in the landbank assessment, has been assessed using the information on changes to phosphorus consents at each WWTW

between 2020-2030 contained in the 'Quality and Growth Model v12' (Stantec 2021). See Section A.1.4 for further details.

A.1.2 Sludge quantities in 2020

As noted above, two sources of sludge quantities data for 2020 were provided by YWS, as follows:

- ‘YWS STC information.xslx’ – prepared by the Bioresources team, which included 2020 sludge estimates pre- and post-treatment
- ‘Quality and Growth Model v12’, updated by Stantec for YWS, which provided 2020 pre-treatment estimates.

Table A.2 compares the sludge quantities data (tDS/year, pre- and post-treatment) for 2020 for each STC for the two data sources. The key differences between the two data sources is as follows:

- **Bioresources team** - The ‘pre-treated’ data includes indigenous sludge production and sludge that would normally have been imported into the STC – hence it is the theoretical throughput. The post-treatment sludge data are reported to be based on the measured biosolids quantity that was exported from the STC to agriculture.
- **Quality and Growth Model** – the model provides the 2020 pre-treatment estimates. The post treatment values were then derived by Mott MacDonald using the solids destruction assumptions in Section 2.1.

Table A.2: Sludge throughputs in 2020 (pre- and post-treatment - tDS/year)

STC name	Treatment process	Bioresources team		Quality and Growth Model	
		Pre-treatment - estimated	Post treatment - measured	Pre-treatment – from model	Post treatment – estimated (3)
Aldwarke	MAD	3,850	1,872	3,861	2,548
Blackburn Meadows	MAD	16,027	9,092	14,351	9,472
Bridlington	MAD	1,719	810	2,231	1,472
Calder Vale	MAD	3,558	2,251	4,769	3,148
Esholt	AAD (THP)	24,280	14,497	23,399	14,040
Huddersfield (1)	MAD	0	0	14,999	9,899
Hull	MAD + lime	15,683	10,836	17,103	11,288
Knostrop	MAD + lime	40,024	23,067	27,833	18,370
Lundwood	MAD	2,671	961	4,561	3,011
Mitchell Laithes	MAD	9,697	6,788	7,809	5,154
Naburn	MAD	9,444	4,817	9,971	6,581
Old Whittington	MAD	5,589	2,476	4,330	2,858
Sandall	MAD	4,525	1,973	5,517	3,641
Staveley (2)	MAD	0		0	0
Woodhouse Mill	MAD	4,398	1,973	3,795	2,505
Total		**141,465**	**81,413**	**144,531**	**93,987**

Notes: (1) Huddersfield STC was offline during 2020 and sludge normally treated at this site was diverted to other centres. (2) Staveley STC was closed in 2020. (3) Calculated using the solids destruction assumptions stated in Section 2.1.

The Bioresources team data show that Huddersfield STC was closed during 2020 for site upgrades and the sludge was temporarily diverted to other STCs for treatment (particularly

Knostrop STC but some to other sites). The Quality and Growth Model data show the theoretical sludge throughputs for Huddersfield during this period.

Staveley STC has been decommissioned and hence had no reported sludge throughput in 2020. It is assumed that much of the sludge previously treated at Staveley has been redirected to Old Whittington STC for treatment.

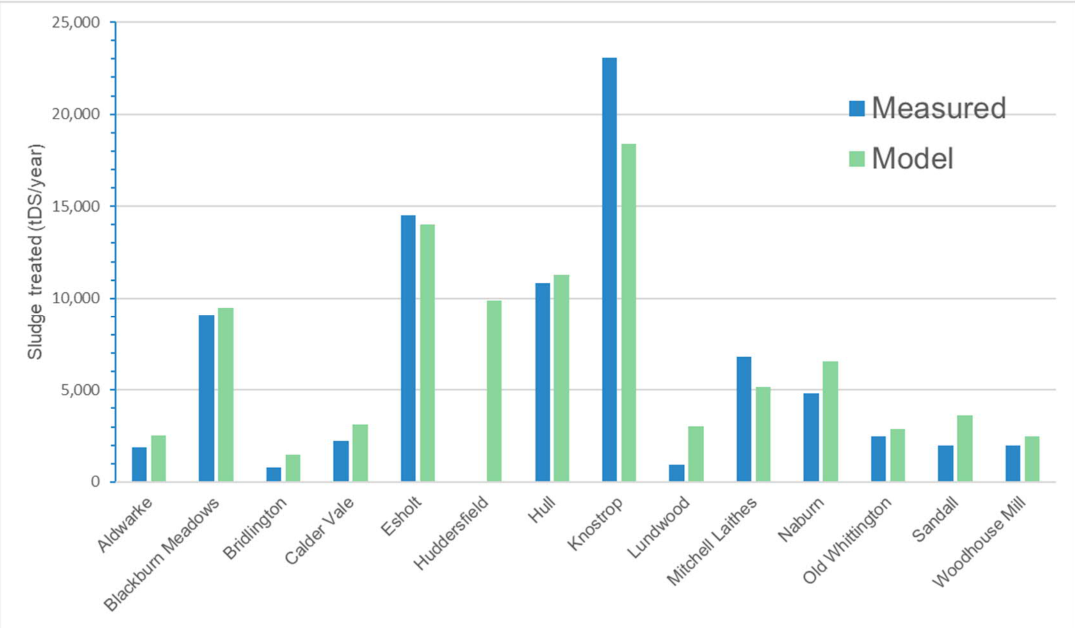
As seen in Table A.2, the majority of these sludge treatment centres treat sludge using mesophilic anaerobic digestion (MAD). Huddersfield, Hull and Knostrop STCs use MAD with the addition of lime and Esholt STC uses an advanced anaerobic digestion process (thermal hydrolysis process, THP, followed by anaerobic digestion).

YWS reports that all treated sludge produced in 2020 was used in agriculture. The Bioresource team data indicate this amounted to 81,413 tDS (341,100 wet tonnes). This is 15% less than the predicted (post-treatment) biosolids output derived using the Quality and Growth Model data – shown in Table A.2.

Whilst the 'measured' 2020 values (81,413 tDS/year) have been used in the landbank assessment for Scenario 1 (2020 baseline), YWS has stated that the Quality and Growth Model data should be used as the basis for future forecasts and hence the land bank assessment for Scenario 2 (2030 with landbank restrictions).

Figure A.1 presents in graphical form the 'post-treatment' sludge quantities data for 2020 presented in Table A.2.

Figure A.1: Sludge throughputs (post-treatment) in 2020 (tDS/year)



Source: 'Measured' data from YWS Bioresource team, 'Model' data derived from Quality and Growth Model v12 (Stantec, 2021) using solids destruction assumptions in Section A.1.1.

A.1.3 Sludge quantities forecast to 2030

In preparing the forecast to 2030 we have taken account of the following expected changes in sludge treatment centre operations, as conveyed by YWS:

- Bridlington and Naburn STCs will both close by 2025;
- Huddersfield STC is now operational again;
- Hull STC has recently been refurbished, providing additional sludge treatment capacity, but constraints on the site's ability to use additional biogas may constrain sludge throughput until 2025.

To replace the capacity lost by closure of sludge treatment centres it is expected that export of a proportion of sludge for treatment by 3rd parties may be introduced from 2025 onwards. For the purposes of this study (including the landbank assessment) it has been assumed that this sludge would not be recycled to agriculture within the YWS region and hence has been excluded from the 2030 estimates.

The 2030 treated sludge outputs for each STC have been calculated using the VSS contents and VSS destruction rates stated in Section A.1.1. The projected sludge quantities (pre and post-treatment) for each STC for 2020-2025 and 2025-2030 are presented in Table A.3 (tDS/year) and Figure A.2.

Table A.3 indicates that wastewater sludge quantities produced by YWS's WWTWs are expected to increase sharply by 2025 and 2030 (18% increase by 2025 and a further 6% increase between 2025 and 2030 – compared to an expected population increase in the YWS region of only 2.32% from 2020 to 2030). The increase is mostly due to the impact of tighter phosphorus consents under the WINEP, resulting in increases in both chemical sludge and overall sludge production per PE. This will cause a similar increase in total treated sludge (biosolids) for recycling to agriculture.

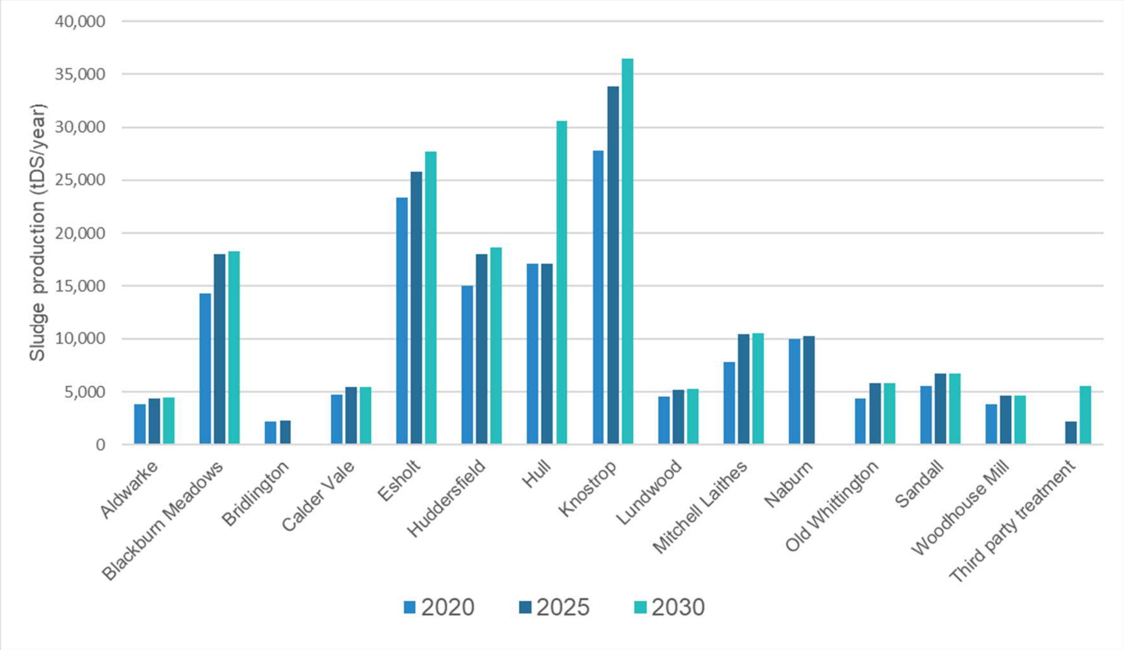
The impact of these changes on the biosolids phosphorus content is discussed in Section A.1.4.

Table A.3: Sludge forecasts to 2030 (tDS/year)

STC	Sludge (pre-treatment) (tDS/year)			Projected increase (%)		Sludge (post-treatment) (tDS/year)		
	2020	2025	2030	2020-2025	2025-2030	2020	2025	2030
Aldwarke	3,861	4,397	4,419	14%	0%	2,500	2,900	2,900
Blackburn Meadows	14,351	17,997	18,330	25%	2%	9,500	11,900	12,100
Bridlington	2,231	2,262	0	1%	0%	1,500	1,500	0
Calder Vale	4,769	5,413	5,494	13%	2%	3,100	3,600	3,600
Esholt	23,399	25,822	27,673	10%	7%	14,000	15,400	16,500
Huddersfield	14,999	18,025	18,621	20%	3%	9,900	11,900	12,300
Hull	17,103	17,154	30,580	0%	78%	11,300	11,400	20,300
Knostrop	27,833	33,831	36,517	22%	8%	18,400	22,400	24,200
Lundwood	4,561	5,158	5,246	13%	2%	3,000	3,400	3,500
Mitchell Laithes	7,809	10,429	10,509	34%	1%	5,200	6,900	7,000
Naburn	9,971	10,289	0	3%	0%	6,600	6,800	0
Old Whittington	4,330	5,789	5,818	34%	1%	2,900	3,800	3,900
Sandall	5,517	6,683	6,687	21%	0%	3,600	4,400	4,400
Woodhouse Mill	3,795	4,607	4,670	21%	1%	2,500	3,100	3,100
Sub-total	**144,531**	**167,856**	**174,565**	**16%**	**4%**	**94,000**	**109,400**	**113,800**
Third party treatment	0	2,167	5,501	Started	154%		0	0
Total	**144,531**	**170,023**	**180,066**	**18%**	**6%**			

Note: Sludge pre-treatment values taken from Quality and Growth Model v12. Sludge post-treatment values derived using solids destruction assumptions in Section A.1.1 of this appendix and rounded to nearest 100.

Figure A.2: Sludge production (pre-treatment) by destination (tDS/year)



Source: Data from Table A.3

A.1.4 Digested sludge characteristics

A.1.4.1 Phosphorous content

An increase in the average mass of sludge produced at YWS WWTWs and then treated at STCs from 2020 to 2030 is expected due to tightening in phosphorus consents and hence increased P removal under the WINEP.

The future phosphorus content in biosolids (as P_2O_5) has been assessed using the following data:

- 2020 phosphorus content (as P_2O_5) at each STC provided by the YWS Bioresources team;
- Information on changes to phosphorus consents at each WWTW between 2020-2030 contained in the 'Quality and Growth Model v12' (Stantec 2021).

From technical data and asset standards from other WaSCs, the phosphorus content in sludge from treatment works that do not carry a phosphorus consent is typically around 4-5%. However, where a tight phosphorous consent is imposed and treatment includes a biological nutrient removal (BNR) stage, that content increases up to 6.5%.

From the ‘Quality and Growth Model v12’ (Stantec 2021), we found the following:

- At the larger treatment works there will be a BNR stage and also chemical dosing to trim final effluent phosphorus
- All smaller sites with a phosphorus consent will produce chemical sludge

The ‘Quality and Growth Model v12’ (Stantec 2021) model was used to determine the percentage of total sludge received at an STC that will be from WWTWs with phosphorus removal schemes in 2025 and 2030 (see Table A.5). Where the percentage of total sludge to an STC from sites with phosphorus removal schemes is higher than 50%, a 2030 value of 7.5% for average biosolids P_2O_5 concentration has been used. Where that percentage is less than 50%, the existing measured 2020 P_2O_5 concentration has been retained.

The 7.5% phosphorus content (as P_2O_5) is within the range observed for other WaSC's biosolids with WINEP programmes.

This increase does not take into account any changes caused by different sludge treatment processes at each STC (MAD, MAD+Lime and AAD) but we believe that these will be relatively small and hence not material to the analysis.

Table A.4: Sludge from sites with P removal schemes

STC name	% of overall sludge from WWTW with P removal schemes in 2020	% of overall sludge from WWTW with P removal schemes in 2030
Aldwarke	98%	99%
Blackburn Meadows	98%	98%
Bridlington	18%	-
Calder Vale	97%	97%
Esholt	76%	78%
Huddersfield	96%	97%
Hull	1%	1%
Knostrop	96%	97%
Lundwood	91%	91%
Mitchell Laithes	100%	100%
Naburn	29%	-
Old Whittington	95%	96%
Sandall	98%	99%
Woodhouse Mill	100%	100%

Table A.6 presents the resulting biosolids N and P content forecasts to 2030 for each STC.

Table A.5: Biosolids N and P content forecasts

STC name	Ave Biosolids N content (%)		Ave Biosolids P_2O_5 content (%)		Ave Biosolids P content (g/kg) (NOT P_2O_5)	
	2020	2030	2020	2030	2020	2030
Aldwarke	5.2	5.2	5.3	7.5	23.1	32.7
Blackburn Meadows	5.2	5.2	6.3	7.5	27.5	32.7
Bridlington (1)	6.6	n/a	7	n/a	30.5	n/a
Calder Vale	5.1	5.1	5.6	7.5	24.4	32.7
Esholt	4.3	4.3	6.2	7.5	27.1	32.7
Huddersfield	4.2	4.2	6.3	7.5	27.5	32.7
Hull	4.9	4.9	6.9	6.9	30.1	30.1
Knostrop	4.5	4.5	6.3	7.5	27.5	32.7
Lundwood	5.4	5.4	4.5	7.5	19.6	32.7
Mitchell Laithes	4.9	4.9	3.5	7.5	15.3	32.7
Naburn (1)	5.3	n/a	6.5	n/a	28.4	n/a
Old Whittington	4.5	4.5	4.8	7.5	20.9	32.7
Sandall	5.7	5.7	5.5	7.5	24	32.7

STC name	Ave Biosolids N content (%)		Ave Biosolids P_2O_5 content (%)		Ave Biosolids P content (g/kg) (NOT P_2O_5)	
Woodhouse Mill	5.5	5.5	5	7.5	21.8	32.7

Note (1): Bridlington STC and Naburn STC assumed to be shut down before 2030

A.2 Water Treatment Sludge Forecasts

A.2.1 Key assumptions and data sources

The following data for 2020 sludge production was provided by YWS and used to prepare the water treatment sludge production forecasts:

- Sludge production data for each WTW that does not discharge to sewer (8 nr WTWs) including disposal points, cake dry solids content and tDS/year estimates ('sludge info WTW.xlsx' – populated by YWS Asset Management team[13])
- Sludge production data for all WTW ('Estimate of sludge solids based on TR189 for Motts.xlsx' – populated by YWS Innovation team[14])

The data covered water treatment sludge that is not currently discharged to sewer.

Sludge quality information was only available for Langset and Loxley WTW, the only two sites that dose ferric coagulant. Quality data was not available for the WTWs which dose Alum.

In preparing forecasts to 2030 we have made the following assumptions:

- The measured 2020 sludge production has been assumed to increase to 2030 in proportion to the wastewater PE forecasts data presented in the 'Quality and Growth Model v12' (Stantec, 2021). Hence, a percentage growth of 1.26% has been used between 2020-2025 and 1.05% between 2025-2030, giving a total increase from 2020 to 2030 of 2.32%.
- The total measured and predicted site sludge production has been used for assessing future disposal options. Hence, the forecasts assume that sludge lagoons are not used for storage/disposal in the future.

A.2.2 Clean water sludge forecasts

The measured 2020 sludge quantities and forecasts to 2030 for each WTW are presented in Section 3.3 of the report, Table 3.4.

[13] Provided by email (dated September 2021) by David Taylor (YWS Clean Water Asset Planning team)

[14] Provided by email (dated 28 September 2021) by Jenny Bank (Innovation team)

B. Landbank assessment

This appendix provides a detailed description of the landbank assessment carried out to inform the development of the 'PR24 sludge to land strategy' for YWS. A summary of the key findings from this appendix are presented in Section 4 of this report.

This appendix was previously issued as '*Technical Note 2 – Landbank assessment*'.

PR24 Sludge to Land Strategy

Technical Note 2 – Biosolids Landbank Assessment

in association with RSK ADAS

Executive Summary

Yorkshire Water Services (YWS) has commissioned Mott MacDonald, in partnership with Grieve Strategic, to prepare a 'Sludge to Land' Strategy to inform YWS' PR24 submission. Grieve Strategic, in conjunction with RSK ADAS, is responsible for landbank assessment components of the strategy development using the ALOWANCE model.

This project is required to identify an efficient, costed alternative strategy for YWS to adopt in the event that curtailment or even cessation of the sludge to land recycling route occurs in the near future (up to 2030).

YWS has identified two strategy scenarios to be covered by the landbank assessment:

- Scenario 1. Recycling to land continues as is and risks to the landbank are not realised
- Scenario 2. Recycling to land becomes restricted to limited land use areas and time periods by 2030

This report describes the approach and assumptions used for the assessment of landbank impacts under these two scenarios. This report will form an appendix of the Sludge to Land Strategy.

The findings of the landbank assessment are as follows:

1. The agricultural landbank within the Yorkshire Water region (c.991,000 hectares – ha) was reduced by 69% to account for ALOWANCE restrictions, a 50 metre odour buffer and rotational exclusion clauses to c.307,000 ha.

2. Data from Yorkshire Water indicated c.81,600 tonnes dry solids (tDS) of biosolids was recycled to agricultural land in 2020. After accounting for the rate of application, acceptability on farm and the 'legal' maximum application frequency (once every year) (i.e. the shortest return period), following the requirements of the Biosolids Nutrient Management Matrix, it was assessed that a minimum of c.50,400 ha of rotational landbank were required for biosolids recycling, which would require biosolids to be transported up to 31 kilometres from sludge treatment centres (STCs). However, at this application frequency soil P indices would be increased in the long-term reducing and potentially even preventing biosolids applications.

3. Predicted biosolids production figures for 2030 combined with increased biosolids phosphorus content, reduced farmer acceptance, tighter phosphorus restrictions, no applications on sandy/shallow soils, no applications in the autumn on or in advance of crops without a manufactured fertiliser nitrogen requirement and no applications within 200 metre of a sensitive site or within a Source Protection Zone 2, decreased the available landbank and increased the landbank required to 465,200 ha. To reach such a landbank would theoretically result in biosolids having to be transported as far as south-west

England and into Scotland, up to a maximum of 410 kilometres, which would make recycling biosolids to agricultural land no longer viable.

4. The 2030 scenario was not a best estimate of the situation in 2030, more a 'plausible worst-case'. Since the scenario was agreed and modelled, there has been progress with Defra and the EA on Farming Rules for Water that make the most 'stringent' of the restrictions highly unlikely. However, restrictions on phosphorus management will only increase and although on a national/regional basis they should have a limited effect on transport distances, they will cause operational issues (increasing costs) and will affect recycling in specific parts of Yorkshire Water's region. It is suggested that once the requirements have been confirmed with the EA, Yorkshire Water could model the scenario so it can fully understand the impacts on its recycling operations.

5. The other future pressures on biosolids recycling (e.g. concerns over contaminants and changes in regulatory regime) could affect operational management (and therefore management costs) but are unlikely to have a significant impact on the quantity of available land and therefore the distance biosolids has to be transported.

6. There are a range of possible methods to manage the water treatment sludge (WTS) that YWS produces that is not discharged to sewer. The most sustainable option in the short-term is recycling to agricultural land, following a similar approach to that which applies to biosolids. There is an operational and permitting cost to this option, but it is likely to be less than the cost of other options, especially in the short-term. To ensure this is possible for all sources, more information is required to understand where it is produced and ensure the material is suitable for use on agricultural land. There are potentially more cost-efficient solutions, but they are much less certain and the initial costs to develop these outlets would be much greater, although some could be investigated alongside more 'bankable' options like agricultural recycling.

Table of Contents

1. Background and Approach

Yorkshire Water Services (YWS) has commissioned Mott MacDonald, in partnership with Grieve Strategic, to prepare a 'Sludge to Land' Strategy to inform YWS' PR24 submission. Grieve Strategic, in conjunction with RSK ADAS, is responsible for landbank assessment components of the strategy development using the ALOWANCE model.

This project is required to identify an efficient, costed alternative strategy for YWS to adopt in the event that curtailment or even cessation of the sludge to land recycling route occurs in the near future (up to 2030).

YWS has identified three strategies scenarios to be assessed, two of which require landbank assessment using the ALOWANCE model (the third assumes recycling of sludge to agricultural land is no longer possible). The two scenarios requiring landbank assessment are as follows:

- Scenario 1. Recycling to land continues as is and risks to the landbank are not realised
- Scenario 2. Recycling to land becomes restricted to limited land use areas and time periods by 2030

This report describes the approach and assumptions used for the assessment of landbank impacts under these two scenarios. This report will form an appendix of the Sludge to Land Strategy.

The approach is described in the following sections:

- Assessment of available landbank – the theoretical 'available' landbank, accounting for current restrictions as well as competition from other organic materials
- STC outputs to agricultural land – treated sludge quantities and product quality assumed for the landbank assessment for 2020 and 2030
- Assessment of landbank required under each scenario – sets out the key assumptions and findings for each scenario
- Modelled distance to the available landbank
- Discussion
- Water treatment sludge
- Conclusions

Grieve Strategic, in conjunction with RSK ADAS previously undertook a landbank assessment for YWS in 2013. Since then there have been a number of substantial changes and updates to the ALOWANCE software tool, which may have a significant impact on the assessment of a) landbank requirement and b) landbank availability. These include updated data from the Agricultural Survey (where possible), updated NVZ areas and livestock nitrogen (N) production standards, the inclusion of information on 'competing' non-farm organic material quantities (i.e. biosolids, compost, digestate, paper crumble) and taking account of soil pH and heavy metal concentrations on landbank availability. The software has also been revised and improved to calculate haulage distances using the road network.

2. Assessment of available landbank

2.1. Theoretical agricultural landbank

The area of agricultural land (i.e. the theoretical landbank capacity) in the YWS region for the application of organic manures was c.991,000 hectares (ha) in 2020. Figure 1 shows the area of agricultural land (the theoretical landbank) across the YWS region divided into 10,000 ha squares. The locations of YWS sludge treatment centres (STC) are also shown.

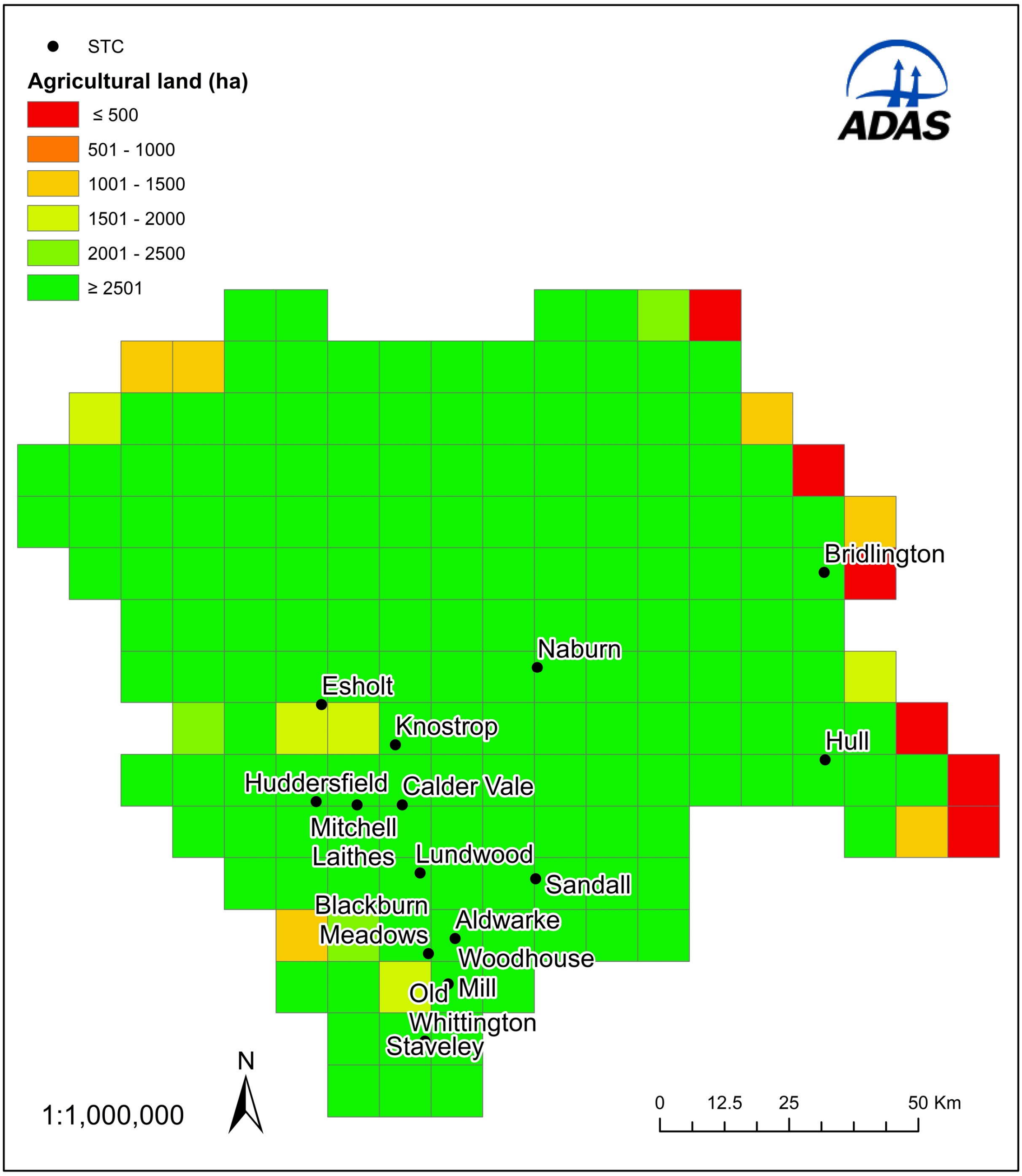


Figure 1. Area of agricultural land (the theoretical landbank) including YWS STCs (each grid square = 10,000 ha)

For comparison, the area of agricultural land (total cropped land plus permanent pasture) in Great Britain is c.11 million ha (see Figure 2).

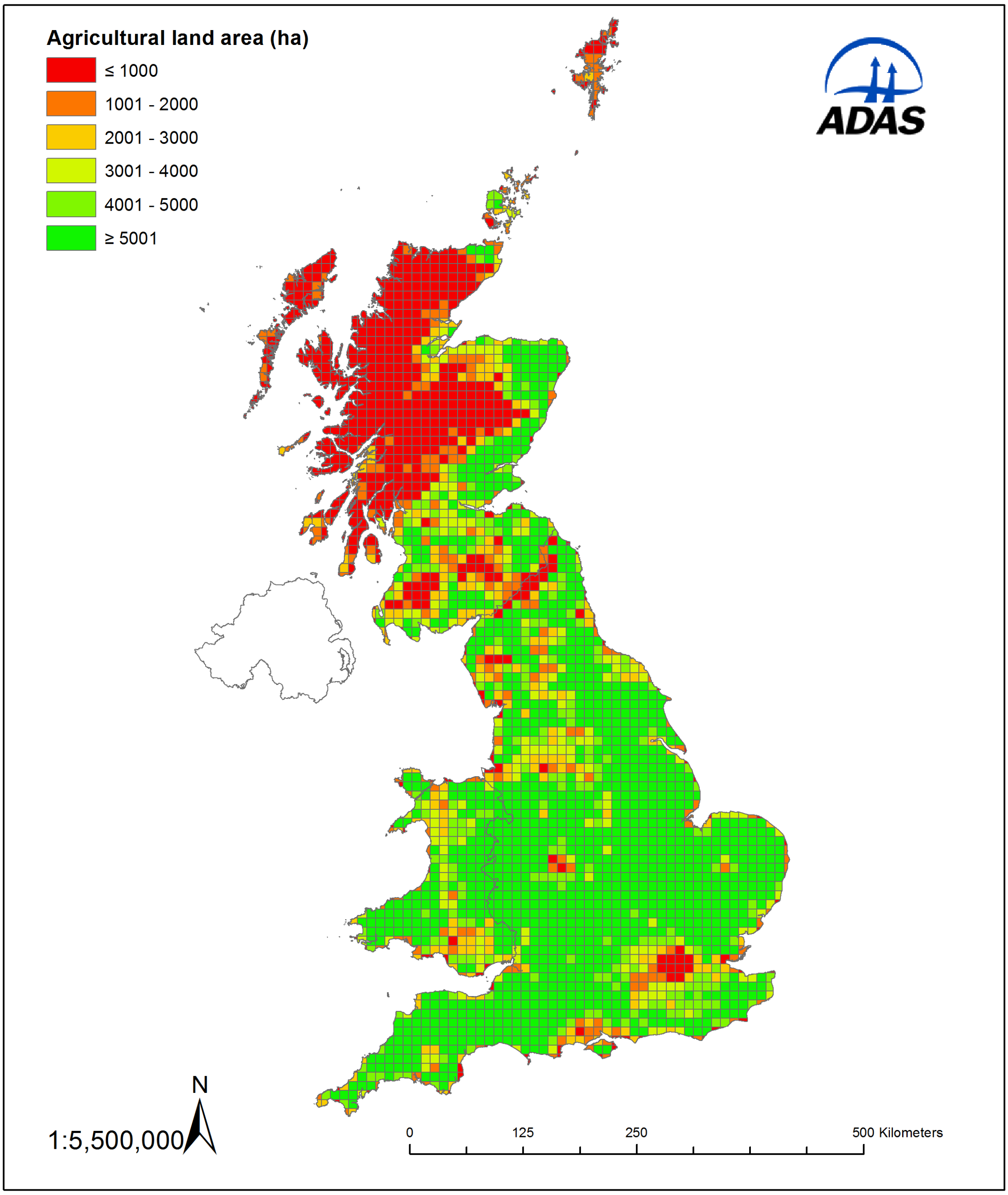


Figure 2. Area of agricultural land (the theoretical landbank) in Great Britain (each grid square = 10,000 ha)

2.2. Estimated landbank for biosolids applications

This describes the basis for the estimated landbank used for Scenario 1. Scenario 2 follows the same process, but with additional constraints.

The agricultural landbank in the YWS region (c.991,000 ha) was reduced by c.54% to account for ALOWANCE restrictions (i.e. accounting for physical and legislative restrictions, livestock manures and other non-farm organic materials such as biosolids (from other WaSCs), compost, other digestates and paper crumble) and a 50 metre odour buffer to c.460,000 ha. Finally, the rotational exclusions (e.g. those specified by the whisky distilling industry which stipulate that biosolids must not be applied with crop rotations including malting barley) further reduced the remaining landbank to c.307,000 ha, or c. 31% of the original agricultural area (see Figure 3).

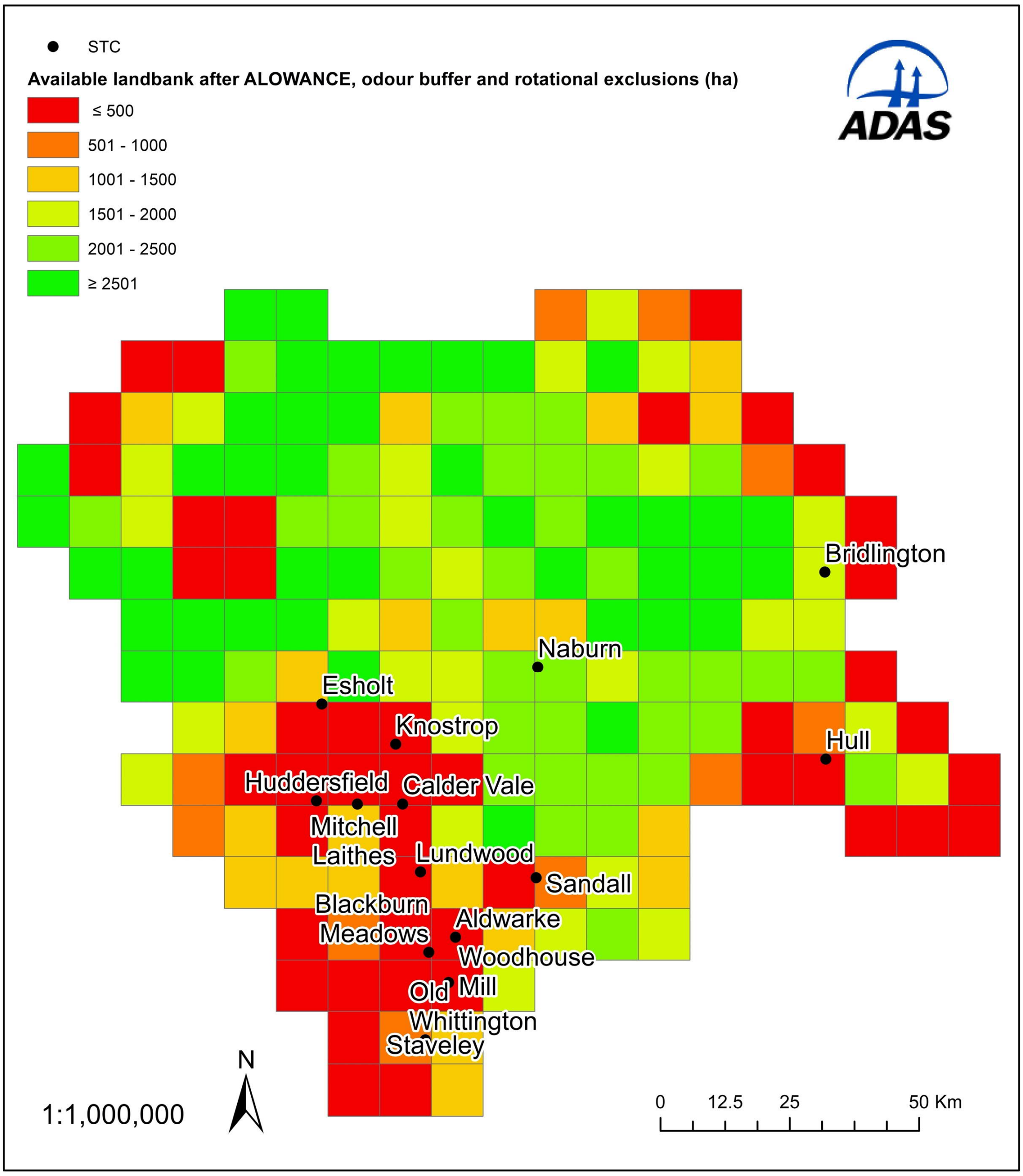


Figure 3. ALOWANCE estimated agricultural landbank (each grid square = 10,000 ha)

3. STC outputs

3.1. STC outputs to agricultural land, treatments and product standards

The 2020 and forecast 2030 treated sludge outputs for each STC are presented in Table 1 together with treatment/product types and quantities. For the landbank assessment the product types and treatment standards are assumed not to change between 2020 and 2030.

Table 1. STC output, treatment, product and standards in 2020 and 2030

STC name	Location	Sludge quantity (tDS/y)[1]		Treatment/product	Standard
		2020	2030		
Aldwarke	Rotherham	1,900	2,900	AD cake	Conventional
Blackburn Meadows	Sheffield	9,100	12,100	AD cake	Conventional
Bridlington	Bridlington	800	-	AD cake	Conventional
Calder Vale	Wakefield	2,300	3,600	AD cake	Conventional
Esholt	Shipley	14,500	16,500	AAD cake	Conventional
Huddersfield	Huddersfield	-	12,300	AD + lime cake	Conventional
Hull	Hull	10,800	20,300	AD + lime cake	Conventional
Knostrop	Leeds	23,100	24,200	AD + lime cake	Conventional
Lundwood	Barnsley	1,000	3,500	AD cake	Conventional
Mitchell Laithes	Dewsbury	6,800	7,000	AD cake	Conventional
Naburn	York	4,800	-	AD cake	Conventional
Old Whittington	Chesterfield	2,500	3,900	AD cake	Conventional
Sandall	Doncaster	2,000	4,400	AD cake	Conventional
Staveley	Staveley	-	-	-	-
Woodhouse Mill	Sheffield	2,000	3,100	AD cake	Conventional
Total		81,600	113,800		

[1] Note: Treated sludge outputs have been rounded to the nearest 100 tonnes.

4. Assessment of landbank required for each scenario

4.1. Key assumptions

To assess the landbank requirement for each outlet within the YWS region, it was necessary to assess the probable acceptability of biosolids products on farm, the application rate and the maximum application frequency (once every year) (i.e. the shortest return period allowed).

The Biosolids Nutrient Management Matrix became the verifiable standard under Cross Compliance (SMR 3) for biosolids applications when it was introduced in 2014. Although this standard has since been removed the Matrix is consistent with good practice advice (e.g. the Nutrient Management Guide (RB209), AHDB, 2018) and the Sludge (Use in Agriculture) Regulations (SI, 1989). Compliance with the Matrix is a requirement of the Biosolids Assurance Scheme (BAS), meaning all organisations are committed to abiding by it when applying biosolids to agricultural land. The Matrix was updated in 2019 and again in 2021, and is shown below (Table 2).

Table 2. Biosolids Nutrient Management Matrix

ADAS soil P index	Maximum potential application of *lime treated biosolids*[a]	Maximum potential application of *all other biosolids* types
0/1/2	250 kg/ha total N in any 12-month period	250 kg/ha total N in any 12 month period
3	250 kg/ha total N in any 12-month period – application 1 year in 4 on sandy soils and 1 year in 2 on all other soils	250 kg/ha total N in any 12 month period – application 1 year in 2 on sandy soils[b]
4	250 kg/ha total N in any 12-month period – application 1 year in 5 on sandy soils and 1 year in 3 on all other soils	250 kg/ha total N in any 12 month period – application 1 year in 4 on sandy soils[c] and 1 year in 3 on all other soils
5 and above	No application	No application

[a] Lime addition rate >5% w/w on a dry solids basis

[b] Composted biosolids can be applied annually, and

[c] Can be applied 1 year in 2.

In the case of the YWS region, the theoretical frequency of return based on the Matrix is an application once every year. This is because the majority of soils are P index 0, 1 or 2 with very few sandy soils and no lime treated biosolids.

It should be noted that strictly following the Matrix may result in the soil phosphorus concentration increasing over time as more phosphate will be applied by biosolids applications (and possibly other sources) than will be removed by the crop. In the long-term this would result in the soil phosphorus index increasing and if applications continue in line with the minimum frequency of return to land allowed by the Matrix, it may get to the point when no more applications would be allowed (see Section 6 for more discussion on phosphorus). However, this is dependent on the availability of the phosphate in biosolids. The Fertiliser Manual (RB209) states that 50% of the phosphate is crop available, but experimental data suggests it may be significantly less than this (c.10% based on digested biosolids).

The rotational landbank required for each STC or outlet was calculated using the methodology described above. To ensure the model was as accurate as possible for each STC, the amount of biosolids that could be applied to the grass landbank was restricted based on data supplied by YWS on current practice at each STC. In 2020, no grassland was used except a very small amount for sludge from Esholt (i.e. a maximum of 0.3 percent). In 2030, the modelling assumes all STCs could send a maximum of 10 percent to grassland, as although the restrictions on recycling conventionally treated biosolids to grassland are tight, applications are allowed in specific circumstances. These include applications ahead of a grass reseed, where the biosolids can be ploughed in and applications in the late summer/autumn where the grass will not be grazed until the following season (i.e. the following spring). Moreover, the modelling assumes no applications were allowed in the autumn on sandy or shallow soils (to reflect the greater nitrate leaching potential of these soils), no applications were allowed in the autumn unless the crop had an immediate recommendation for manufactured fertiliser nitrogen (to reflect the Environment Agency's (EA) position on Farming Rules for Water at the time the scenario was devised) and no applications were allowed within Source Protection Zone 2 or 200 metres of SSSIs and other sensitive sites (e.g. ESAs, NNRs, SPAs, SACs).

Table 3 provides a summary of the parameters used for modelling scenarios 1 and 2.

Table 3. Summary parameters for Scenarios 1 and 2

Parameter	Scenario 1	Scenario 2
Assessment data	2020	2030
Biosolids quantity to be recycled to land (tDS/year)	81,600	113,800
P content	Current	Increased (due to WINEP etc)
Physical restrictions	Current	Current
Legislative restrictions	Existing legal, good practice and rotational exclusion requirements	As for scenario 1 plus the following: No application to sandy or shallow soils in the autumn No application within 200m of sensitive sites No applications in SPZ 2 areas No applications in the autumn unless crops have an autumn nitrogen recommendation
Max. amount of biosolids that can be applied to grass landbank	0.3% (for Esholt)	10% for each STCs
Competition from other organic materials	Biosolids (other WaSCs), livestock manures, compost, waste AD digestate, paper crumble	Biosolids (other WaSCs), livestock manures, compost, waste AD digestate, paper crumble
Odour buffer	50m	50m
Farmer acceptance	45%	35%
Application rate	250 kg/ha total N in any 12-month period	250 kg/ha total N in any 12-month period
Return frequency (max) P Index 0-1 P Index 2 P Index 4+	Current Biosolids Nutrient Management Matrix return periods	 1 per 1 year 1 per 3 years 1 per 5 years

4.2. Rotational landbank required for STCs

4.2.1. Scenario 1

The rotational landbank requirement for the 2020 biosolids output from YWS was calculated based on the Biosolids Nutrient Management Matrix return periods (and information on cross compliance soil types and soil P index), along with estimates of farmer acceptance (45%) and application rate (250 kg total N/ha). This gave a rotational landbank requirement of 50,400 ha in 2020 (see Table 4).

It should be noted that although following the Matrix reflects the 'legal' minimum, there may be operational reasons why a water company or farmer/land manager may operate at a longer return period (e.g. crop rotation, charging policy, weather, fertiliser policy, biosolids type, operational difficulties).

Table 4. Rotational landbank requirement for each STC (2020) based on farmer acceptance and the minimum Biosolids Nutrient Management Matrix return periods

STC name	Location	tDS/year[1]	Treatment/ product	Standard	Hectares
Aldwarke	Rotherham	1,900	AD cake	Conventional	1,100
Blackburn Meadows	Sheffield	9,100	AD cake	Conventional	5,000
Bridlington	Bridlington	800	AD cake	Conventional	600
Calder Vale	Wakefield	2,300	AD cake	Conventional	1,100
Esholt	Shipley	14,500	AAD cake	Conventional	7,400
Huddersfield	Huddersfield	-	AD + lime cake	Conventional	-
Hull	Hull	10,800	AD + lime cake	Conventional	8,400
Knostrop	Leeds	23,100	AD + lime cake	Conventional	16,100
Lundwood	Barnsley	1,000	AD cake	Conventional	500
Mitchell Laithes	Dewsbury	6,800	AD cake	Conventional	3,500
Naburn	York	4,800	AD cake	Conventional	2,900
Old Whittington	Chesterfield	2,500	AD cake	Conventional	1,300
Sandall	Doncaster	2,000	AD cake	Conventional	1,200
Staveley	Staveley	-	-	-	-
Woodhouse Mill	Sheffield	2,000	AD cake	Conventional	1,300
Total		81,600			50,400

[1] Note: Values have been rounded to the nearest 100.

4.2.2. Scenario 2

The rotational landbank requirement for the predicted 2030 biosolids output from YWS was calculated based on the increased quantities of biosolids predicted to be produced (113,800 vs. 81,600 tDS in 2020), predicted increased phosphorus content of biosolids, and tighter phosphorus frequency of application restrictions than are currently the case under the Biosolids Nutrient Management Matrix return periods:

- annual applications at P index 0 and 1
- matching total phosphorus inputs to crop offtake over the rotation at P index 2 – c.1 year in 3, and
- supplying less phosphorus than is removed at P index 3 and 4 – c.1 year in 5).

Farmer acceptance was reduced to 35% to account for the impact of the expected move to the Environmental Permitting Regulations and due to potential increased customer/food chain stakeholder concerns over contaminants (e.g. microplastics and PFAS). This gave a rotational landbank requirement of 465,200 ha in 2030, almost 10 times that required in 2020,

Table 5.

Table 5. Rotational landbank requirement for each STC (2030) based on increased biosolids production and phosphorus content, reduced farmer acceptance and a restricted frequency of return

STC name	Location	tDS/year[1]	Treatment/ product	Standard	Hectares
Aldwarke	Rotherham	2,900	AD cake	Conventional	11,900
Blackburn Meadows	Sheffield	12,100	AD cake	Conventional	49,300
Bridlington	Bridlington	-	AD cake	Conventional	-
Calder Vale	Wakefield	3,600	AD cake	Conventional	14,800
Esholt	Shipley	16,500	AAD cake	Conventional	76,400
Huddersfield	Huddersfield	12,300	AD + lime cake	Conventional	50,100
Hull	Hull	20,300	AD + lime cake	Conventional	75,700
Knostrop	Leeds	24,200	AD + lime cake	Conventional	98,300
Lundwood	Barnsley	3,500	AD cake	Conventional	14,100
Mitchell Laithes	Dewsbury	7,000	AD cake	Conventional	28,300
Naburn	York	-	AD cake	Conventional	-
Old Whittington	Chesterfield	3,900	AD cake	Conventional	15,700
Sandall	Doncaster	4,400	AD cake	Conventional	18,000
Staveley	Staveley	-	-	-	-
Woodhouse Mill	Sheffield	3,100	AD cake	Conventional	12,600
Total		113,800			465,200

[1] Note: Values have been rounded to the nearest 100.

5. Modelled distance to available landbank from each STC

The travel distances were calculated using the UK road network, specifically initially using major roads (motorways, A and B classification roads) and assuming any available land within 100 metres of the road is accessible, until land is surrounded by those major roads, then the model assumes all that land is accessible. The travel distances represent the boundary of the area within which sufficient landbank for each STC is located. As such the distance to the outer edge of the radial can be considered to represent the theoretical maximum travel distance to available landbank. Where the radial rings of neighbouring STCs overlapped, the rings were merged under a single ring to give a better indication of the effect of a number of STCs 'competing' for the same agricultural landbank.

Average maximum haulage distances have been calculated to allow comparison between the two scenarios, both standard averages and weighted averages (i.e. an average which is adjusted depending on the tonnage from each site) have been calculated.

The estimated maximum haulage distances for each STC to the available landbank (and rotational landbank requirements) were calculated for each scenario. The modelled maximum haulage distances for 2020 matched those reported by YWS, which demonstrates the model is working correctly.

For 2020 the rotational landbank required is shown in Table 4 and the outputs from the modelling are shown in Figure 4. For 2030 the rotational landbank required is shown in

Table 5 and the outputs from the modelling are shown in Figure 5 and Figure 6.

In 2030, the available landbank was reduced to less than a third of that available in 2020 (90,800 vs. 307,000 ha) and the required landbank increased almost 10-fold compared to what was required in 2020 (465,200 vs.50,400 ha).

The summary data for the two scenarios are shown in Table 6 and the estimated maximum distances to access suitable landbank are summarised in Table 7 along with the average maximum distances.

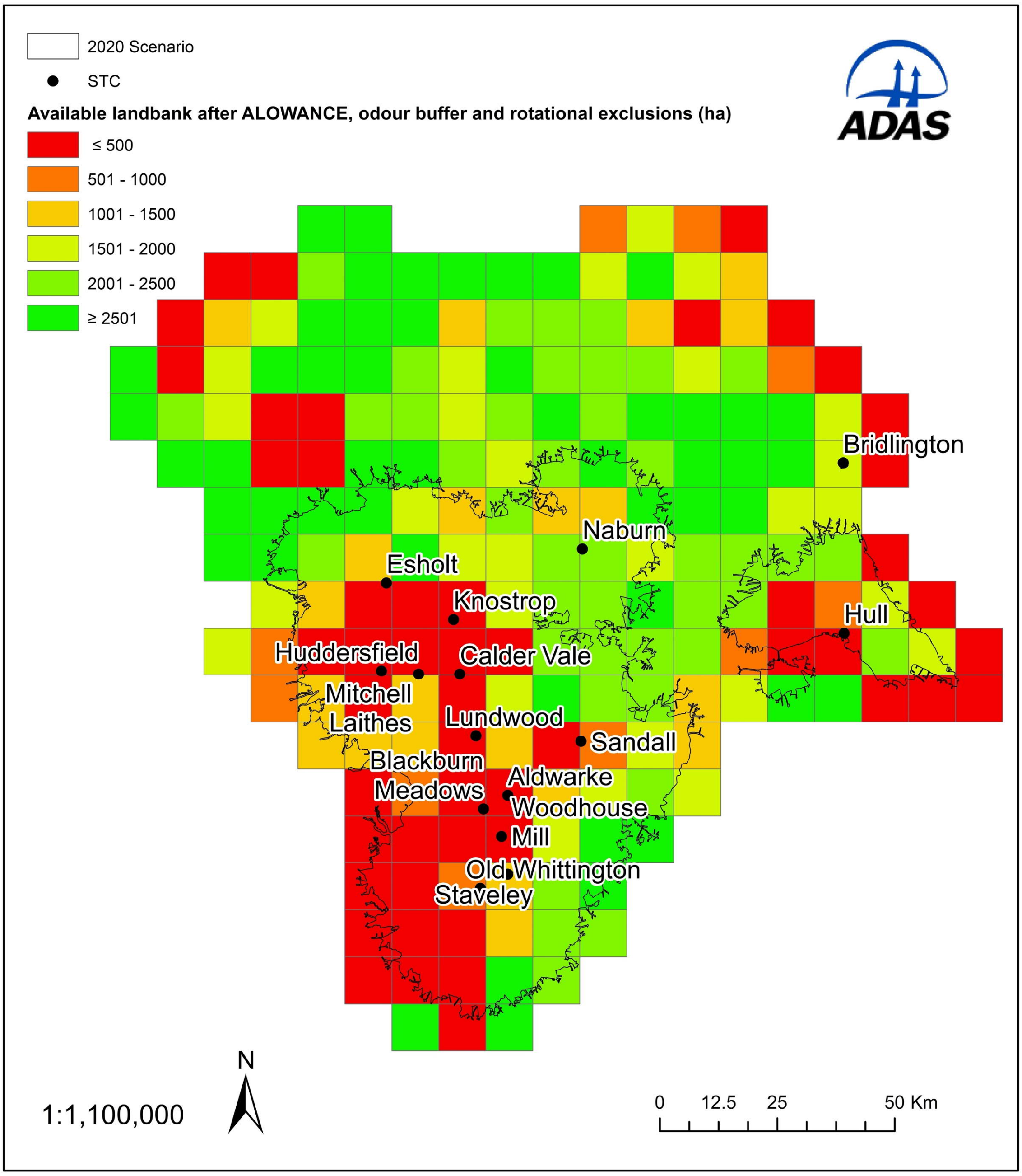


Figure 4. STC maximum distance to access suitable land 2020 (each grid square = 10,000 ha)

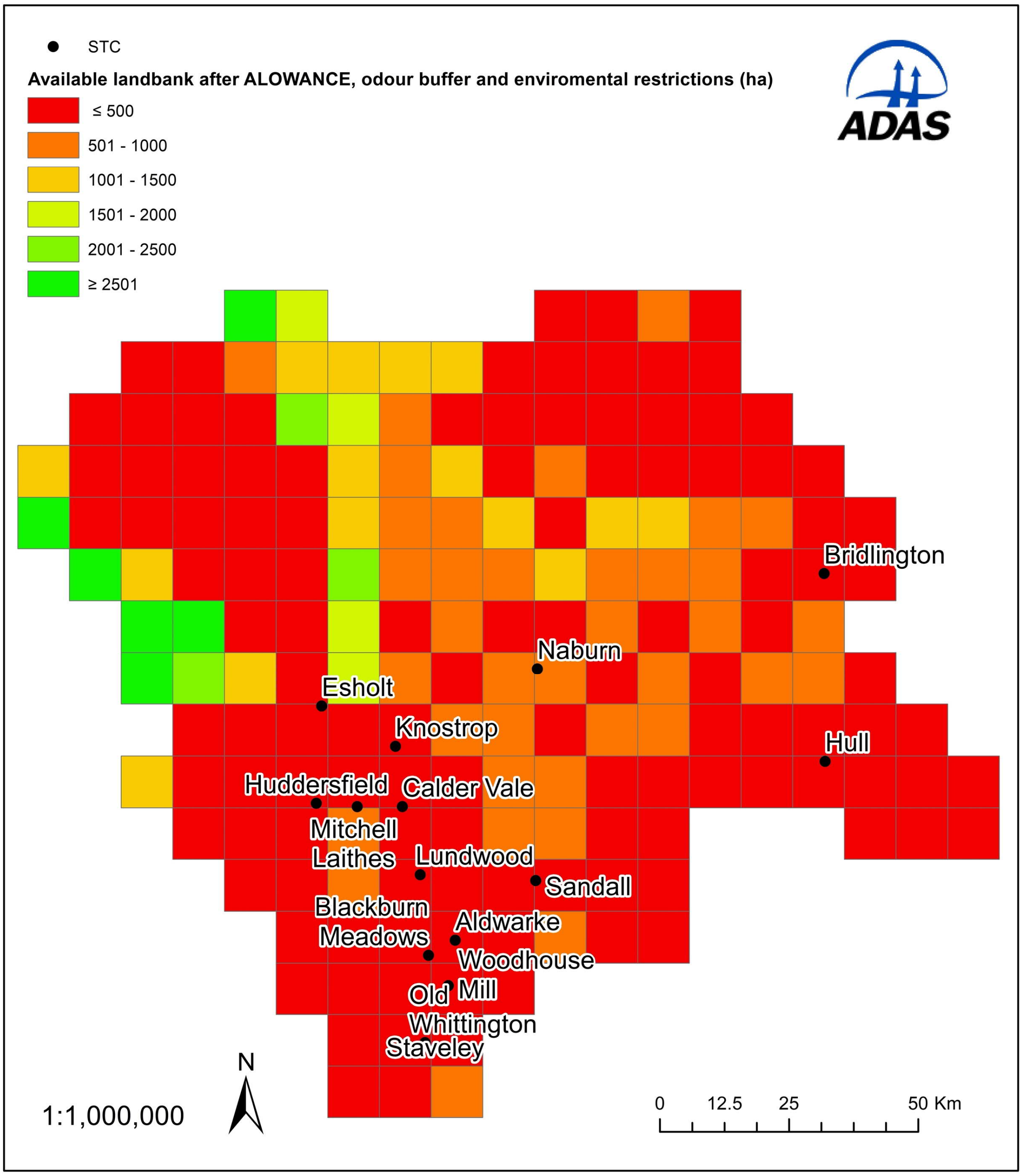


Figure 5. STC maximum distance to access suitable land 2030 (YWS region) (each grid square = 10,000 ha)

Note no haulage radial rings are shown on the map because they are outside the YWS region, see Figure 6.

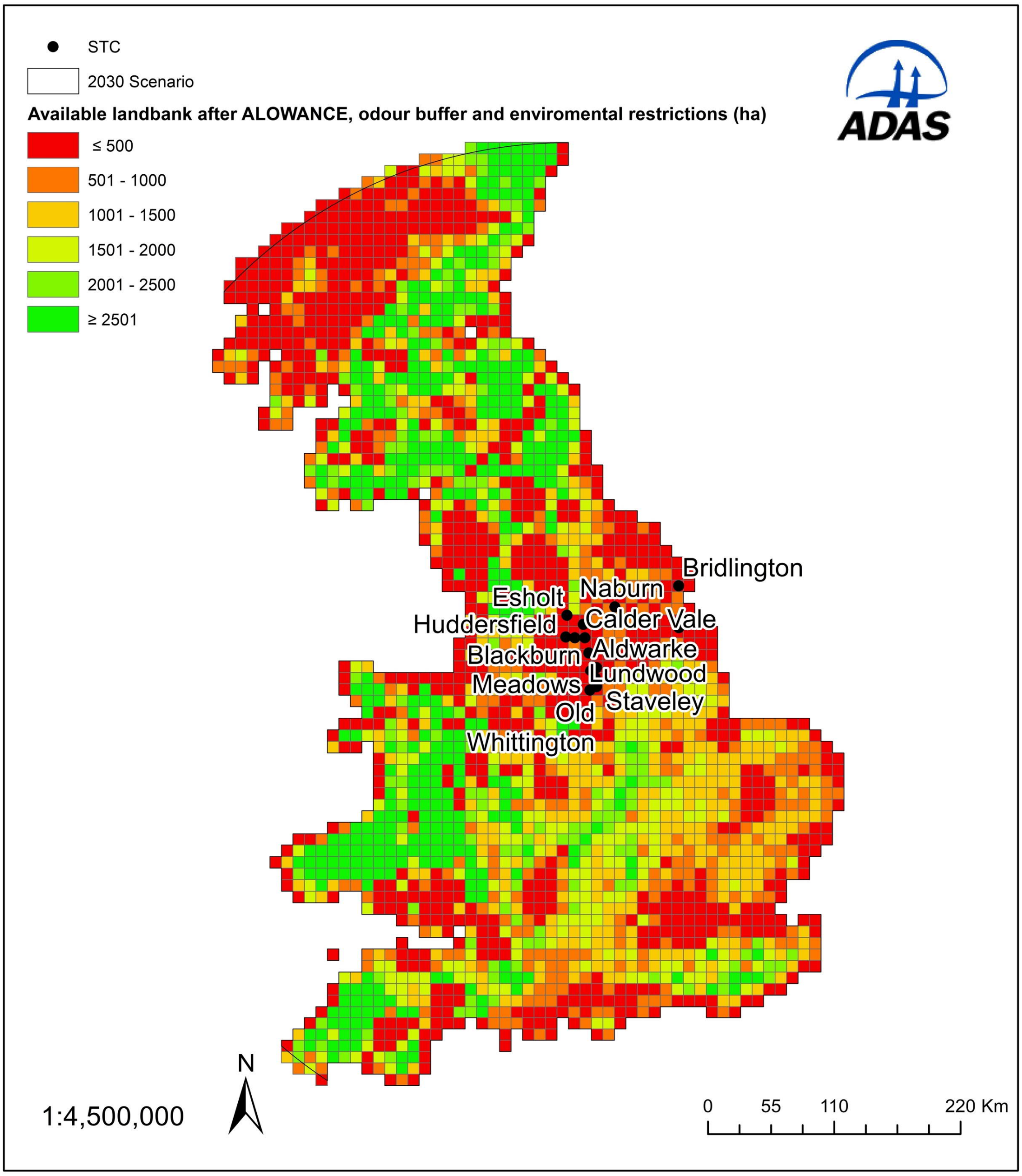


Figure 6. STC maximum distance to access suitable land 2030 (GB) (each grid square = 10,000 ha)

Table 6. Summary of data relating to the scenarios

Data	2020	2030
Figure	4	5 & 6
Quantity to land (tDS/year)	81,600	113,800
Landbank required (ha)	50,400	465,200
Landbank available (ha) in the YWS region	307,000	90,800

Note: Quantities have been rounded to the nearest 100.

Table 7. Summary of the maximum distances (km) to access suitable landbank

STC name	2020	2030[1]
Aldwarke	31	410
Blackburn Meadows	31	410
Bridlington	1	-
Calder Vale	31	410
Esholt	31	410
Huddersfield	-	410
Hull	30	410
Knostrop	31	410
Lundwood	31	410
Mitchell Laithes	31	410
Naburn	25	-
Old Whittington	31	410
Sandall	31	410
Staveley	-	-
Woodhouse Mill	31	410
Average maximum	28	410
Weighted average maximum	30	410

[1] Due to the distance it was not possible to use the road network method, distances are 'as the crow flies' i.e. straight line from the STCs.

6. Discussion

The modelling of the maximum haulage distances for 2020 match those reported by YWS, which demonstrates the model is working correctly. The 2030 scenario was designed as a plausible worst-case situation and the fact that there is insufficient land not only within the YWS region but in the whole of England (after applying the same restrictions to all land and biosolids) highlights that recycling biosolids to agricultural land would not be viable in those circumstances. It is important to note that the 2030 scenario is not a 'best estimate' of what the situation will be in 2030. Importantly, since that scenario was agreed and modelled (in 2021), there has been positive progress in the negotiations with the EA over the Farming Rules for Water with the water industry agreeing proactive measures to further tighten the controls governing biosolids recycling, therefore reducing the risk of significant agricultural diffuse pollution. The Department for the Environment, Food and Rural Affairs (Defra) guidance to the EA has been published recently and fits with pre-publication drafts, although more clarification is required particularly related to phosphorus management. At the time of writing the water industry is in discussion with the EA over the detail of the proactive measures, but although these measures will impact on biosolids recycling, they are not expected to result in significant increases in haulage distances. There will most likely be increased controls resulting in increased costs, but there is expected to be limited impact on a regional or national basis on the available agricultural land and therefore haulage distances compared to the 2020 scenarios. However, possible changes to phosphorus management as a result of the Defra guidance could affect biosolids recycling, particularly where soils are at a phosphorus index of 3 or 4.

The 'best estimate' of the regulatory requirements in 2030 has not been modelled, partly as the situation has been evolving over the course of the project, so the scenario could not have been defined. It is thought that a combination of the increased biosolids, increased phosphorus content of the biosolids, the proactive measures and the restrictions within the Defra guidance will increase the average maximum haulage distance to 35-40 kilometres, which compares with approximately 30 km for 2020. However, it might be useful to model the actual requirements once they are agreed to ensure the impacts on landbank are understood and any local impacts are accounted for.

If the regulatory requirements do not change in line with the 'best estimate' and the only change by 2030 is the quantity of biosolids produced and the phosphorus content of the biosolids, there would likely only be a small impact on biosolids haulage distances from the average maximum figure of c.30 km in 2020 to 30-35km in 2030, although this is only an estimate as this has not been modelled.

One factor that will continue to come under greater scrutiny will be management of phosphorus. It is possible that restrictions will be increased via the guidance on the Farming Rules for Water, but any impact is likely to be restricted to soils with higher phosphorus contents, affecting only land at P index 3 and 4. However, the current focus on improving water quality is only going to continue, particularly with more focus on nutrient neutrality, and phosphorus will be a particular issue as more water courses are at risk from phosphorus pollution than from nitrogen. Compounding the issue from a biosolids perspective is that due to the increased focus on phosphorus, all water companies (including YWS) have schemes to remove even more phosphorus from their final effluent, which will result in even greater concentrations in biosolids (as is included within the 2030 scenario). A key, but not the only reason the quantity of land required in 2030 (for scenario 2) increased almost 10-fold from 2020 (scenario 1) was due to the phosphorus restrictions. Although most of the land within the YWS region is at P index 0, 1 and 2, restrictions on applications at P index 3 and 4 will influence YWS recycling and would likely result in biosolids having to be transported further. Further work would be required to ensure restrictions on phosphorus inputs do not have a dramatic effect on biosolids recycling, including understanding the availability of phosphorus in biosolids as well as investigating ways to extract phosphorus from biosolids.

The issue of contaminants in biosolids will also continue to be a focus. This has always been the case with concerns over microbiological parameters and potentially toxic elements being replaced with concerns over persistent organic pollutants (POPs) such as Perfluoroalkyl and Polyfluoroalkyl Substances (PFAS) and Polycyclic aromatic hydrocarbons (PAHs) and microplastics. At present there is no evidence of harm from the use of biosolids in relation to these contaminants; in fact there is significant evidence quantifying the benefits of biosolids. However, there are huge unknowns and more work is required to understand any possible impacts and also to identify if treatment or source controls can reduce any impact from these potential pollutants.

Finally, the EA's Sludge Strategy is to move biosolids recycling from the Sludge (Use in Agriculture) Regulations (SUAR) to the Environmental Permitting Regulations (EPR). The water industry appears to have accepted this direction of travel and is working to make EPR as 'light touch' as possible via the use of BAS with Earned Recognition; something that is mentioned within the EA's Sludge Strategy. The level of impact on YWS operations will depend on how successful the industry is in gaining 'light touch' regulations, but the impacts for YWS (as well as the industry as a whole) could be:

- Requirements to make the BAS both a stakeholder and regulatory tool, i.e. a regulatory checklist with reporting to the EA.
- Increased requirements, also in the BAS e.g.:
    - Acceptable wastes 'white list' for inputs to sludge treatment;
    - A new requirement to monitor for selected determinands (e.g. Persistent Organic Pollutants – POPs) in biosolids; and
    - Require each Member to have an odour management plan demonstrating how odour will be managed during the storage of biosolids in permanent stores and temporary field heaps, and during spreading.

- The need to apply for a permit.
- Increased workload to complete notification/deployment applications ahead of activities e.g. >25 days for field storage and between 2 and 7 days for spreading.
- The potential for EA queries and intervention.
- Fees payable to the EA for permits and notifications – these could be as high as current deployment fees, i.e. c. £1,700/storage activity (could be whole farm) notification.
- Increased management and oversight to oversee and control the increased complexity associated with recycling biosolids under EPR.

The change from SUAR to EPR should not disrupt biosolids recycling to agricultural land in terms of the land available or required, however, there may be cost and timing issues to consider for YWS including:

- Increased management costs (to complete the additional paperwork)
- Increased storage requirements to manage delays to approval
- Disruption to farmer acceptance
- Increased fees due to the EPR cost structure

7. Water treatment sludge

In addition to biosolids, YWS produces Water Treatment Sludge (WTS) as a by-product of supplying drinking water. Much of the material that is produced (c.70%) is discharged into the sewer and is therefore managed at wastewater treatment plants, but just over 20,000 wet tonnes/year (or approximately 5,000 tDS/year) of WTS must be managed. Currently nearly all of this is taken to Burnby Lane, which has c.5 years of capacity left, but YWS needs a sustainable outlet for this material going forwards.

There is a range of possible outlets for WTS, the main options include:

- Discharge to sewer and inclusion in biosolids
- Recycling to agricultural land
- Use in land restoration
- Use in soil manufacture
- Use in production of construction materials
- Use in novel processes to reduce diffuse pollution

Due to the ad-hoc nature of WTS management across the water industry there is very little information on annual production and uses, however, it is understood that the vast majority of WTS is either discharged to sewer or recycled to agricultural land.

As previously, YWS already discharge approximately 70% of the WTS they produce to sewer, however, the remote location of the remaining water treatment works makes this less viable, particularly due to the cost of transporting the material in its liquid form. Moreover, there is then the cost (and capacity use) for the material to move through the wastewater and sludge treatment processes, with no prospect of biogas generation.

The main alternative to sewer discharge is recycling to agricultural land. WTS is a waste meaning it has to be recycled under the EPR and specifically a [Standard Rules 2010 Number 4 – Mobile Plant for Land Spreading] permit. Most WTS can be recycled to agricultural land, but there are sites where the Potentially Toxic Elements (PTEs) will be sufficiently elevated as to make them unsuitable. However, without accurate data on each source it is not possible to estimate what proportion would not be suitable, although it is expected to be a minority. There is a cost to obtain the permit and then a cost per Deployment, and based on the typical nitrogen content of WTS (the limiting factor affecting application rates) YWS would need approximately 25 Deployments at a cost of c.£40,000/annum. Moreover, there would be a cost to manage, find land and transport the WTS to the locations where it was to be recycled. It is unlikely farmers would be willing to pay for the WTS, due to the limited nutrient and organic matter benefit it provides (although site-specific information would be needed to confirm this), but YWS should be able to find sufficient farmers to take the material. The biosolids landbank assessment highlights that apart from the ‘plausible worst-case’ scenario, there would be sufficient land to recycle not only the biosolids but also WTS within the YWS region. However, re-running the landbank assessment including site-specific data on the WTS would be the only way to confirm this, including predicted maximum haulage distances based on the location of the WTS production sites.

Use of WTS in land restoration is also common. WTS features on the Standard Rules 2010 Number 5 – Mobile Plant for Reclamation, Restoration or Land Improvement permit, meaning it can be used alongside other organic manures and mineral materials which are used in restoration projects. The primary issue is that land restoration sites are finite and once they have been restored any applications would be at much reduced rates. Moreover, WTS would be competing with a range of other materials some of which are able to justify elevated gate fees as they have no other options. The price of land restoration is hugely variable and depends on the location of the site and the materials it is able to accept, but typically this will be in the range of £15 - £50 per tonne. As a result of the finite nature of land restoration sites and the price/competition, this is not likely to be a long-term option for the WTS. It could be an option where WTS sources contain elevated PTE concentrations that make them unsuitable for agricultural use as land restoration is typically able to accept such materials, depending on the nature of the site and its permit restrictions.

YWS as well as other companies has previously investigated and produced manufactured topsoil using WTS combined with other materials. Again there are legislative challenges that would need to be overcome but bespoke topsoils can command high prices especially when used in niche situations like green roofs. There is also a need for bulk quantities of topsoil and the move away from peat means companies are actively looking for alternative, sustainable materials like WTS. The market is likely to be slow to develop, but in time could require significant quantities of WTS to mix with other organic manures and mineral materials to create bespoke topsoil mixtures. Moreover, the margins in producing a saleable product would probably be much greater than in more traditional outlets.

Similar to topsoil production, the construction industry is interested in sustainable sources of aggregate type materials. The ‘granular’ nature of WTS would be of interest in fired or non-fired applications, however, the chemical composition of the WTS could affect firing temperatures and even the colour of the resultant building materials. This option has the potential to utilise significant quantities of the WTS produced by YWS and at viable rates, however, it will come down to the specific chemical and physical composition of the material and the affect they have on the physical and aesthetic properties of the resultant building materials.

There have been and are ongoing studies investigating using the nutrient (particularly phosphorus) absorption properties of WTS to reduce diffuse pollution. Studies including using WTS in the production of manufactured reedbeds to clean-up effluent or using WTS in conjunction with livestock slurries (which contain nutrients in a highly available form). None of these options are commercially realistic and there are legal hurdles to overcome, but they could become high-value niche outlets for some of the material YWS produces.

8. Conclusions

The 2020 landbank scenario (Scenario 1) confirms there is sufficient land within the YWS region to recycle the biosolids it produces and this is likely to be the case even with the forecast growth in sludge quantity (and P content) by 2030. However, if the restrictions and regulatory controls increased to match those considered in the 2030 'plausible worst-case' scenario (Scenario 2) then recycling biosolids to agricultural land would no longer be viable. Yet, the plausible worst-case scenario does not reflect the current best estimate of the land recycling controls in 2030 based on current discussions between the EA and water industry and the Defra guidance on Farming Rules for Water. More land will undoubtedly be required due to the increased volumes of biosolids predicted to be produced, predicted increases in phosphorus content and increased focus on phosphorus additions, but these changes are nowhere near as restrictive as those modelled in Scenario 2 meaning that YWS is predicted to be able to recycle the biosolids it produces in 2030 within/around its region.

The other pressures on biosolids recycling (e.g. concerns over contaminants and changes in regulatory regime) could affect operational management (and therefore management costs), but are unlikely to have a significant impact on the quantity of available land and therefore the distance biosolids has to be transported.

There are a range of possible methods to manage the WTS that YWS produces that is not discharged to sewer. The most sustainable option in the short-term is recycling to agricultural land, following a similar approach to that which applies to biosolids. There is an operational and permitting cost to this option, but it is likely to be less than other routes, especially in the short-term. To ensure this is possible for all sources, more information is required to understand where it is produced and ensure the material is suitable for use on agricultural land. Any material which is not suitable for use on agricultural land would most likely be utilised in land restoration. There are potentially more cost-efficient solutions, but they are much less certain and the initial costs would be much greater, although topsoil manufacture or novel uses to reduce diffuse pollution could be investigated alongside more 'bankable' options like agricultural recycling.

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C. Cost estimates

Section 5.5 of the report outlines the approach used for preparing capital and operating costs for this study. This appendix provides further details of the data and assumptions used to prepare these cost estimates.

C.1 Capital expenditure

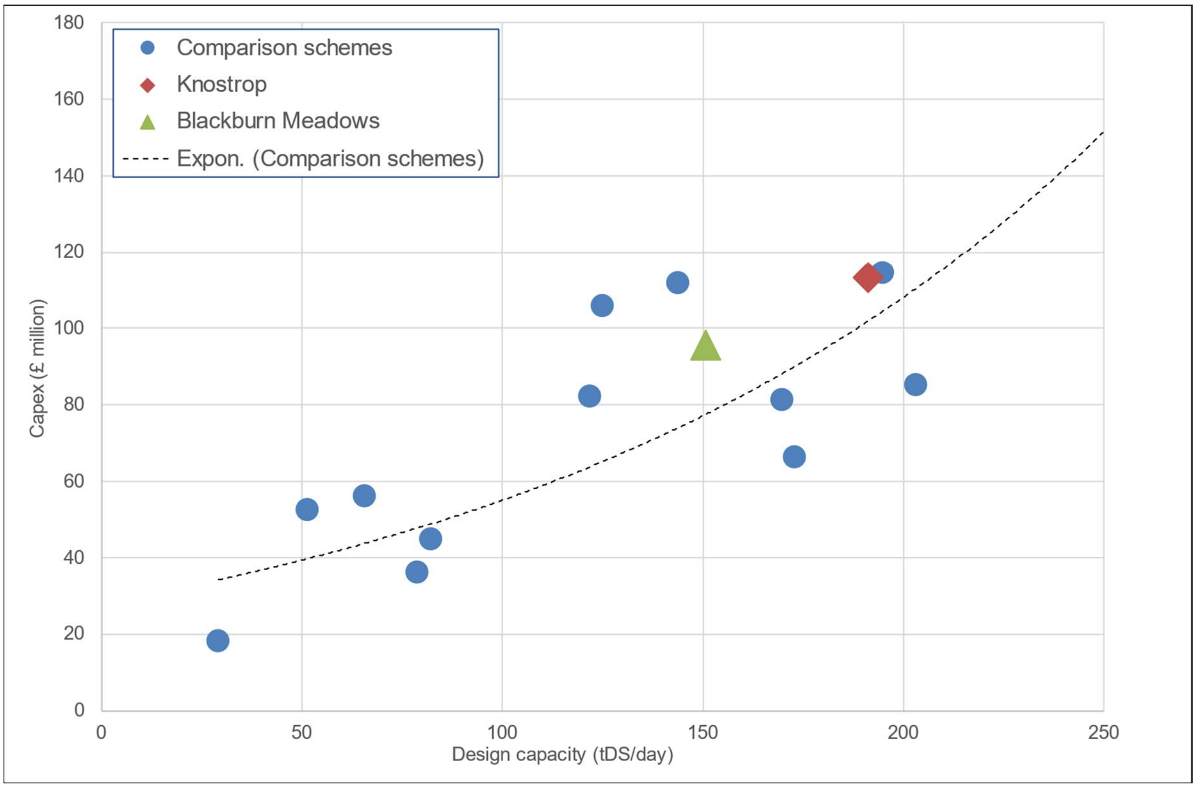
The scope of the capital costs presented in this report is described in Section 5.5 and the results summarised in Table 5.7. Construction (design and build) costs for sludge treatment have been based on a mixture of outturn cost data for projects constructed in the last 10 years as well as budget estimates provided by suppliers.

SSI construction costs have been based on a cost curve produced from tender data for other sludge incinerator projects in Europe. Figure C.3 presents the predicted costs for Option 3.1 and the data points used in the cost curve.

An estimate for YWS's project development on-costs (assumed to be equivalent to 25% of the construction cost) has been added to produce total project costs.

All costs are in Q1'2022 prices.

Figure C.3: Comparison of construction costs for SSI projects



Note: Costs are EPC construction costs and do not include on-costs for asset owners or project companies (for DBFOM procurement routes). Costs are in Q1'2022 prices. Comparison schemes are all located in Europe and mainly comprise projects built over the last 10 years.

Capital maintenance costs (periodic replacement or renewal of assets) are used in the estimation of whole life costs. They are based on the initial capex estimates for the different assets and typical asset replacement intervals from previous projects (including maintenance schedules provided for DBFOM projects).

C.2 Operational expenditure and income

Detailed net operating expenditure estimates have been produced for sludge treatment and SSIs (ie the opex estimates shown are the difference between the 'with' and 'without' project cases). The scope of the operating costs presented in this report is described in Section 5.5. and the results summarised in Table 5.8.

Predicted plant operating performance has been used to estimate energy consumed and generated for each option, with the following variations:

- SSIs performance has been based on mass and energy balance modelling, calibrated against published data for operating SSIs.
- AAD plants have been based on process modelling calibrated against operating performance and costs for similar AAD plants built in the last 15 years.
- Sludge dryer performance has been based on supplier budget estimates obtained for this report.

The basis for the various opex components are described in the following sections.

C.2.1 Staffing

Operational staff unit cost rates and hours are based on typical values for the UK and calibrated against YWS's existing opex data for each site. Additional staff hours have then been added for more complex treatment plants such as those using AAD and SSI, based similar SSIs and AAD plants in the UK and elsewhere.

The staffing for the SSIs has been based on 5 shift teams, each with 4 operating staff (365 day operation). For AAD plants and dryers, a 6 day week and smaller shifts have been assumed.

C.2.2 Annual operational maintenance

Annual operational maintenance of new assets proposed under each option have been estimated based on a percentage of the capex costs for the new assets (1.5% to 2% capex for MEICA equipment, depending on plant complexity, and 0.3% of capex for civil works including buildings).

Where existing AD assets are assumed to be decommissioned in the future (four AD plants under Option 2.1) then the estimated operational maintenance of existing assets has been reduced not been included in the option opex estimates.

C.2.3 Chemical consumption

Chemical and other material consumption for AD and AAD plants is predominantly associated with sludge thickening and dewatering. The baseline estimates for each site are based on unit consumption rates (e.g. kg/tDS for polyelectrolyte), consumption quantities and unit costs, with the results calibrated against YWS's existing opex estimates. Future estimates have then been derived for future throughputs. Chemicals are mainly used in SSI plants for boilers and flue gas treatment. Chemical consumption rates and costs have been based on both recent tenders and supplier budget estimates for plants with similar throughputs and treatment processes.

C.2.4 Power consumption and generation

Power consumption for the proposed sludge AD/AAD, drying and SSI plant has been estimated based on the predicted energy performance of each plant and a unit power cost of 13p/kWh.

Power generation by the AD plants (biogas CHP) and SSI (steam turbine) has been estimated based on the predicted energy performance of each plant in terms of biogas and steam production. Power generated and used on site (for both wastewater and sludge treatment) is treated as 'negative opex' and the value estimated using the same unit rate as for power consumption (13p/kWh). This is based on the assumption that all power would be consumed by the thermal treatment plant and adjacent YWS WWTWs and there would be no need to sell surplus power to the grid (at a potentially lower unit rate).

In general, there is sufficient on-site demand to use most of the generated power, however, when generation exceeds demand then there may be small amounts of surplus power that can be sold to the grid. This income has been based on a unit price of 6p/kWh, i.e. under 50% of the cost of power supplied.

C.2.5 Fossil fuel consumption

Assuming the SSI is operating correctly and the sludge feed is autothermic, then a modern well designed SSI should not require supplementary fossil fuel during normal operation. However, the SSIs will consume fossil fuel (assumed to be natural gas) during start up and shut down operations. Consumption has been based on the predicted fuel demand (based on previous projects) and a unit natural gas cost of 1.3p/kWh (based on 2021 values).

Fuel consumption estimates for existing AD plants have been provided by the YWS Bioresource team.

C.2.6 Transport costs

Transport costs have been based on unit transport rates (in £/m3) provided in the Quality and Growth Model v12, which vary according to distance bands. Transport costs have been estimated for the following:

- Treated sludge product transported from STCs for use in agriculture – with the quantity of material transported and the transport distance varying according to the site and treatment process (AD, AAD and drying). The baseline transport distances were provided by the YWS Bioresources team.
- For Option 2.1, transport of undigested sludge cake from the four AD sites proposed to be decommissioned to the new AAD plants at Blackburn Meadows and Knostrop – using measured haulage distances. Existing cake imports into those sites are assumed to be diverted directly to the new AAD plants.
- For Option 3.1, transport of digested sludge cake from existing AD and Esholt AAD plants to the new incinerators – using measured haulage distances.
- For Option 3.1, transport of ash and other residues to landfill. A one-way distance of 75km has been assumed.
- For water treatment sludge, transport of sludge cake from the WTWs for use in agriculture. A one-way distance of 50km has been assumed.

The existing costs for taking thickened and dewatered sludge from WWTWs to STCs have been provided by YWS's Bioresource Team and are predicted to be approximately £10m/y. For simplicity of analysis, this value has been assumed to be the same for all options.

C.2.7 Disposal costs

The following disposal costs have been assumed for fly ash and other residues from the SSI plant options:

- Gate fees for delivery of fly ash (deemed to be a non-hazardous waste) from SSIs to landfill. This has been based on a landfill gate fee of £25/tonne and a landfill levy of £3.15/tonne (applicable to inert material) - giving a total of £28/tonne.
- Gate fees for delivery of APC residues (deemed to be a hazardous waste) from SSIs to landfill. This has been based on a landfill gate fee of £50/tonne and a landfill levy of £99/tonne (applicable to hazardous material) - giving a total of £149/tonne.

For this study a conservative assumption has been made that non-hazardous fly ash will be taken to a landfill. However, if appropriate uses are found for this ash, for example as a construction material, then landfill gate fees and taxes would be avoided (though YWS may still incur additional transport costs). It is considered unlikely that the ash would achieve a significant income as a construction material.

C.2.8 Biosolids recycling to agriculture – management costs

The YWS Bioresource team has provided a total recycling opex forecast (£4.6m in 2025) which has been assumed to include both YWS's management activities and biosolids transport to farms. We have deducted the estimated transport costs (see Section C.2.6) and assumed the remainder is YWS's baseline biosolids management fee (approximately £1.5m/year). For Scenario 2 we have then added approximately £0.5m (based on YWS estimate) to allow for additional management costs arising out implementation of the Farming Rules for Water.

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E4. WINEP Sludge Driver Evidence Support

WINEP Sludge Driver Evidence Support

Biosolids Storage

12 August 2022

WINEP1

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Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
1.0	Report for Water UK	EP	<initials>	<initials>	<initials>	<date>
1.1	Updated report	EP	GS	SJW	RL	August 2022

Client signoff

Client	
Project	WINEP Sludge Driver Evidence Support
Job number	5213909 - 030
Client signature/date	

Contents

Figures

1. Introduction

The Environment Agency (EA) have included new sewage sludge regulatory drivers in the Water Industry National Environment Programme (WINEP) including drivers to improve resilience (SUiAR_IMP) and drivers associated with actions to prevent deterioration in soil quality or water quality (SUiAR_ND). There are also related drivers for investment associated with the Chemicals Investigation Programme (WFD_INV_CHEM) and for investigations/trials to reduce microplastics (WFD_INV_MP).

All Water and Sewerage Companies (WaSCs) in England have been involved in collaborative pre-work to understand the driver guidance and have developed an evidence log spreadsheet listing the common issues that need addressing to ensure a consistent approach is taken to address WINEP requirements.

Atkins were asked to provide specific expert subject matter support and evidence to help deliver specific aspects identified in the WINEP gap analysis. This request focused on biosolids storage with the aim of providing clearly defined evidence / options to support the delivery of WINEP, taking into account:

- Day-to-day operational storage requirements
- Contingency storage for exceptional events
- Comparison of storage recommendations with landbank analysis

As part of wider discussions with Water UK and the Environment Agency, this document summarises the review of best practices across guidance documentation and data analysis undertaken to assess Biosolids storage practices and contribute to WINEP sludge driver evidence support.

2. Methodology

The analysis was approached from three angles,

- A **review of best practices**, to build a picture of current requirements, guidance, and examples of best practice for biosolids and adjacent industries e.g., agriculture, food waste management etc.
- **Data analysis**, including a request for and analysis of WaSC qualitative and quantitative data surrounding current storage practices, assets and drivers and future strategies, and analysis of data pertaining to the influencing factors on storage strategies drawn from publicly available datasets.
- **Landbank assessment**, to consider the potential storage capacity required aligned to scenarios associated with the implementation of the Environment Agency's 'Strategy for Safe and Sustainable Sludge Use' which is an alignment with a move to Environmental Permitting Regulations (EPR) regime against the baseline.

Together, these were expected to generate an indication of acceptable levels of storage to mitigate operational risks and provide resilience, thereby mitigating the risk of potential environmental impacts of extended storage on farms. The analysis was also aimed at building a picture of the achievable practices that WaSCs could implement in order to build resilience into their storage strategies and capability.

The specific questions crucial to this were:

- What is a reasonable requirement for storage volume - This would need to cover operational and contingency storage, bearing in mind new restrictions around spreading (for example the Farming Rules for Water (FRfW)) that will likely lead to a change in spreading strategies, i.e., the quantities of biosolids spread over specific seasonal periods in line with crop cycles and nutrient demands.
- What other storage best practices should be considered - This is based on both the likely future obligations from other regulatory sources, and on wider risk reduction / environmental protection, bearing in mind the resource required for implementation.

2.1. Review of Best Practices

The review was split into several overarching themes, and the relevant requirements / suggested practices from the documents were reviewed and highlighted as they related to each. These themes covered the key aspects of storage that may require management and/or control and comprised the following:

- Volume
- Location
- Covering
- Containment
- Emissions
- Leachate management
- Odour control
- Noise and vibration
- Operational

These were agreed with the Steering Group during the first progress meeting. The documents reviewed are shown below in Table 2-1. This was a high-level review of the documents that were identified as the most pertinent to sewage sludge/biosolids management specifically and digestate more broadly, which detailed recommended practices for appropriate storage on-site (as opposed to on agricultural land). The majority of these were guidance documents, which sit alongside legislation to advise on best practice. Temporary storage requirements were reviewed only within the current industry standard, BAS Standard Issue 5 (Assured Biosolids Limited, 2020), which was used to benchmark present requirements against best practices detailed elsewhere.

Findings were presented back to the Steering Group and are covered in more detail below in Section 3.

2.2. Data Analysis

A first set of questions was circulated to participating WaSCs, which sought to understand current operational and contingency storage volumes and associated water company drivers. 10 companies were contacted out of which 8 responded to the requests. The aim of this was to identify a typical model for storage volume, and how Farm Rules for Water (FRfW) may exacerbate drivers for storage and therefore increase volume required.

Due to the variance demonstrated in response to the first set of questions, a second set was posed that focused on current haulage and spreading practices (volumes hauled and spread over the months of the year) and expectations around how these would change in response to FRfW. Again, qualitative questions were included to support an understanding of the drivers / reasoning behind specific haulage / spreading strategies. A full set of questions can be found in Appendix A.

Findings from the second set of questions were overlaid with UK climate data (average monthly temperature and rainfall) and typical crop cycles to highlight any periods for which storage would likely be required for an increased length, due to crossover between haulage / spreading cycles and increased risk of adverse weather conditions. The aim of this was to estimate the number of months' storage that would cover the worst probable scenario moving forward.

2.3. Landbank Assessment

The landbank assessment, completed by consultants Grieve Strategic and ADAS, modelled potential future changes to sludge management regulations / restrictions, external factors, emerging concerns and ongoing research, and the associated impacts as per the below.

Regulations / restrictions

- Sludge (use in Agriculture) Regulations (SUiAR) 1989
- Environment Agency national sludge strategy / move to EPR
- BAS Compliance
- Restrictions on arable cropping (due to perceived nutrient concerns)
- Water Framework Directive Regulations, Nutrient Neutrality and Farming Rules for Water
- Phosphorus restrictions
- 25-year environment plan / environment act targets
- Physical Restrictions
- Sensitive Catchments
- Designated sites / priority habitats

External factors

- Flooding - storage
- Climate Change Adaptation and Resilience
- Changing Farming Practices
- Climate Change
- Disease (oil seed rape)

Emerging concerns

- Microplastics
- Poly Fluorinated Alkyl Substances (PFAS)

Ongoing research

- Chemicals Investigations Programme

Impacts

- Farmer Acceptance
- Public Perception
- Market competition affecting supply / demand of biosolids to land
- Agricultural Demand for Biosolids – arable
- Agricultural Demand for Biosolids - grassland
- Supply demand balance biosolids produced

- Increase in low / no-till practices

A set of five scenarios were generated, which modelled the historical position (up to 2020), the end of AMP7 baseline, and minimum impact, maximum impact and most likely scenario positions following a 10-year period.

Based on these scenarios, and the resulting impacts considered likely based on the factors above, a prospective storage volume was calculated for each, which was aligned to the outcomes identified from the qualitative data analysis referred to in Section 2.2.

3. Key Findings

3.1. Review of Best Practices

From the review of best practices, it can be seen that overall, there is considerable variance among requirements from regulatory and guidance documentation. Although some common features are demonstrated, there isn't a single guidance document that WaSCs could point at to justify storage volumes and types. The findings against each category are detailed further below. As the current industry standard, **BAS Standard Issue 5** (Assured Biosolids Limited, 2020) is included as a point of reference and comparison for the other documents reviewed.

3.1.1. Volume

In **BAS Standard Issue 5** (Assured Biosolids Limited, 2020) it is specified that, within Scotland, the volume of biosolids in permanent storage '***must not exceed ninety per cent of the available capacity of the storage facility***.' Aside from this, volume is only referenced in terms of temporary storage where it details that field storage heaps should occupy '***as small a surface area as is practically required to support the mass of the heap***' and the total volume must be '***no greater than 1,250 tonnes fresh weight***.'

Elsewhere, requirements around volume were found to cover:

- Maximum site throughput, based on type of facility / characteristics of waste.
- Asset capacity, e.g., required volume for secondary containment.
- Overall storage volume requirement for operational contingency.

Maximum site throughput is detailed in the Standard Rules environmental permits, a set of fixed rules for common activities, based on the site type. The current Standard Rules specify that:

- For on-farm anaerobic digestion using farm wastes: '*The total quantity of waste or a combination of waste and non-waste including solids and liquids accepted at the site* ***shall not exceed 100,000 tonnes a year***.' (Environment Agency, 2021) (Environment Agency, 2021)
- For anaerobic digestion facilities as part of a waste recovery operation: '*Input* ***shall not exceed 35,000 tonnes a year***.' (Environment Agency, 2021)

Superseded Standard Rules specify that:

- **R13 permitted activities** for storage of wastes to be used in land treatment, as per the superseded **Standard Rule 17** (Environment Agency, 2016): '*the maximum quantity of waste accepted shall not exceed 75,000 tonnes per year. The maximum storage capacity of the site shall not exceed 75,000 cubic metres.*' (Environment Agency, 2016)
- Standard Rules (2010) 4 and 6 for mobile plants for land spreading of wastes / sewage sludge: '*For each deployment no more than 3000 tonnes in total of waste shall be stored at any one time. Of this no more than 1250 tonnes shall be non-stackable waste. No more than 3000 tonnes of waste shall be stored in a location at any one time. Of this no more than 1250 tonnes shall be non-stackable waste. Waste shall be stored for no longer than 12 months*.' (Environment Agency, 2016) (Environment Agency, 2016)

In terms of **asset capacity**, some general rules are widely repeated across the spectrum of documents:

- Maintenance **of at least 750mm freeboard** for all storage lagoons and tanks. (Environment Agency, 2020) (Environment Agency, 2021) (Environment Agency, 2013) (UK Gov, 1991) (Environment Agency, 2021) (Environment Agency, 2021) (Environment Agency, 2012) (Environment Agency, 2021) (Environment Agency, 2013) (Environment Agency, 2013) (Environment Agency, 2012)
- For bunded areas / secondary containment - **a capacity at least 110% of the largest vessel or 25% of the total tankage volume, whichever is the greater** (Environment Agency, 2021) (Environment Agency, 2021) (Environment Agency, 2021) (Environment Agency, 2013) (Environment Agency, 2012) (Environment Agency, 2011) (CIRIA, 2014); **CIRIA 736** (CIRIA, 2014) alternatively suggests **an allowance for the total volume of accumulated rainfall in response to a 10 per cent annual exceedance probability event for the duration of an event, 24 hours prior and 8 days following**.
- Most Standard Rule sets stipulate for underground tanks '*100% secondary containment capacity [with] 95% of that capacity maintained at all times.*' (Environment Agency, 2021) (Environment Agency, 2021) (Environment Agency, 2011) (Environment Agency, 2021) (Environment Agency, 2013) (Environment Agency, 2012)

- The **maximum capacity for all storage assets / sites must be defined and never exceeded**.

Finally, in terms of **overall storage volumes to account for contingency requirements**, few of the documents studied give explicit recommendations with a few exceptions as per below:

- **Guidance notes for farmers on Control of Pollution** (UK Gov, 1991) specifies that '*Where slurry will be spread on land on the premises will require capacity to* ***store the maximum quantity of slurry likely to be produced in a continuous 4-month period***' accounting for rainfall, other storage on site and making provision for at least 750 mm of freeboard for earth tanks and 300 mm of freeboard in all other cases. This is mirrored by **WRAP Quality Protocol for Anaerobic Digestate** (WRAP, Environment Agency, 2014), which advises that storage standards should meet requirements established within **Guidance notes for farmers on Control of Pollution** (UK Gov, 1991)**,** and is also echoed in **ADBA The Practical Guide to AD 2nd edition** (ADBA, 2017)**.**
- **Appropriate measures for the biological treatment of waste - Consultation** (Environment Agency, 2020) requires that lagoons (storing composting liquors / digestates) must **have at least 6 months storage capacity to account for closed land-spreading periods**.

3.1.2. Location

BAS Standard Issue 5 (Assured Biosolids Limited, 2020) does not mention location in reference to permanent storage, aside from requiring that '***members of the public are unable to gain access to it.***' In terms of temporary storage, it is specified that temporary field stores must be stored:

- *'Further than 10 metres from any watercourse*
- *Further than 50 metres from any spring or well, or from any borehole not used to supply water for domestic food or production purposes*
- *Further than 250 metres from any borehole used to supply water for domestic food or production purposes*
- *At suitable distances from domestic, public, recreational and industrial properties so as not to cause odour nuisance'*

They must not be stored:

- *'Within 10 metres of surface water, or an effective field drain, or within 30 metres of surface water where the land has a slope of >12 degrees (within Nitrate Vulnerable Zones)*
- *For longer than 12 months (in England) / 6 months (in Scotland) from the commencement of storage, except where the relevant government agency has provided approval*
- *In an Environment Agency Groundwater Source Protection Zone 1'*

The requirements across other documents vary in their scope and level of detail. The most common across all documents include the following - activities should be avoided in areas within:

- 10m of any watercourse;
- A groundwater source protection zone 1, or if a source protection zone has not been defined then within 50 metres of any well, spring or borehole used for the supply of water for human consumption. This must include private water supplies;
- A specified Air Quality Management Area;
- 200 metres of the nearest sensitive receptor.

The duration of time that waste should be stored on site is also referenced in several documents, particularly in relation to odour and pest control. Advice ranges from generic to more specific and varies depending on the type of waste / use, and whether it is treated or untreated. Examples of generic guidance include:

- **Appropriate measures for the biological treatment of waste Consultation draft** (Environment Agency, 2020) and **Reference Document on Best Available Techniques for the Waste Treatment Industries (superseded)** (European Commission, 2006) refer to the '*first-in first-out principle'*
- **EC Best Available Techniques (BAT) Reference Document for Waste Treatment** (Joint Research Centre (European Commission), 2018) suggests the establishment and monitoring of a maximum residence time

More specific requirements around residence time varies quite significantly in the suggested limits:

- **EC Best Available Techniques (BAT) Reference Document for Waste Treatment** (Joint Research Centre (European Commission), 2018) suggests that '*wastes are treated on, or **removed from, the site as soon as possible, preferably within 1 month of receipt, and at a maximum within 6 months***.'
- **The Biosolids Management Handbook: EPA Region VIII** (Bastian, 1993) specifies that, according to the Part 503 Regulation (EPA, 1994), '***sewage sludge [may] be stored for up to two years without any restrictions or control***.'
- **R13 permitted activities** for storage of wastes pending use in land treatment, as per the superseded **Standard Rule 17** (Environment Agency, 2016)**,** specify that waste is stored on site for no longer than 3 years.
- In regards to catering waste, **ADBA The Practical Guide to AD 2nd edition** (ADBA, 2017) suggests '*minimum post-AD storage of 18 days if wastes include meat'*.

For untreated wastes the guidance or Standard Rule sets largely suggest a reduced storage time, for example:

- **Standard Rule 2021 No 8** (Environment Agency, 2021), which is targeted specifically for on-farm anaerobic digestion facilities for farm wastes only, requires waste to be stored for '*the minimum time practicable before treatment'*.
- **Appropriate measures for the biological treatment of waste - Consultation draft** (Environment Agency, 2020) suggests that waste is stored for the minimum time possible prior to treatment / batch formation, and no longer than 5 days.

3.1.3. Covering

The requirements for permanent storage in Scotland, as per **BAS Standard Issue 5** (Assured Biosolids Limited, 2020), detail that within Nitrate Vulnerable Zones long term storage areas must either '***have a facility to collect, store and recover run-off or the biosolids must be covered with waterproof covering***'. Aside from this, covering is only mentioned in reference to transportation of biosolids to storage – where cover must be applied in order **to avoid spillage and minimise odour nuisance**.

From the existing guidance and other documents studied, the requirements for covering were limited to liquid organic wastes with requirements for covering solid wastes not included or not applicable'. Across those studied there is a broad consensus as regards covering. **The Clean Air Strategy 2019** (DEFRA, 2019) sets out a requirement for '*all slurry and digestate stores to be covered by 2027*' at the latest. Covering is seen as the key mechanism for reducing emissions from biosolids in storage and important in contributing to wider environmental and air quality targets, in line, for example, with the Industrial Emissions Directive (IED) (European Commission, 2010).

This is mirrored in most of the documents studied, with the majority of Standard Rules requiring '*all digestate to be stored within covered containers or covered lagoons*.' **A consultation on digestate management for the Green Gas Support Scheme** (Department for Business, Energy & Industrial Strategy, 2020) suggests that scheme participants provide fixed covers on new storage units and fixed or floating covers for existing sites.

ADBA (Anaerobic Digestion and Bioresources Association), provides guidance on best practice for the management of digestate for AD facilities across sectors, specifically recommends '*gas-tight covers with biogas collection*.' (ADBA, 2017)

3.1.4. Containment

For permanent biosolids storage, **BAS Standard Issue 5** (Assured Biosolids Limited, 2020) includes requirements for '***an impermeable base that allows run-off liquid to be collected***.' It furthermore specifies that '*permanent biosolids stores must be designed and constructed to ensure that, **as far as practicable, biosolids are contained and that members of the public are unable to gain access to it***.'

R13 permitted activities specify a requirement for 'secure storage', secure storage is defined as 'storage where waste cannot escape and members of the public do not have access to it and "secure containers" shall be interpreted accordingly.' (Environment Agency, 2016)

Elsewhere this is largely reiterated, and documents show a reasonable amount of consistency, though some are more detailed. The basic requirements that are cited in the majority of documents studied are:

- Storage of wastes on an impermeable surface with a sealed drainage system.
- Secondary containment for liquids whose spillage could cause harm to the environment.
- Maintenance of containers to ensure that they are fit for purpose.

Beyond this, several documents further specify that storage should be constructed and maintained to a recognised standard, and the standard most commonly referred to is **CIRIA 736** (CIRIA, 2014).

Superseded **Standard Rules 2012 No. 11, 2012 No. 12 and 2010 No. 15** (Environment Agency, 2013) (Environment Agency, 2012) (Environment Agency, 2011) further specify that:

'*Wastes [should be] stored within enclosed containers, reactor vessels or enclosed well ventilated buildings fitted with a biofilter (specifically designed to minimise the release of odour, bioaerosols and microorganisms) and/or scrubbing system*'

However, this is not reflected in the current Standard Rule sets.

3.1.5. Emissions

Emissions are not explicitly considered in **BAS Standard Issue 5** (Assured Biosolids Limited, 2020) for permanent storage, nor temporary storage. For Scotland, covering is a potential requirement in relation to containment (see above section 3.1.4), which is reflected as a mechanism for reducing emissions in other documents.

The requirements elsewhere for the reduction / management of emissions in relation to stored wastes typically specify:

- The implementation & maintenance of an emissions management plan.
- Covering of all digestate containers / lagoons. **Reference Document on Best Available Techniques for the Waste Treatment Industries (superseded)** specifies that '*The covers must be designed to prevent odour, emissions such as ammonia and rainwater ingress*.' (European Commission, 2006)

As mentioned above, the **Clean Air Strategy 2019** (DEFRA, 2019) considers the covering of storage to be the most significant action towards the reduction of emissions. More stringent requirements are found, as above (in Section 3.1.4), in the superseded **Standard Rules 2012 No. 11, 2012 No. 12 and 2010 No. 15** (Environment Agency, 2013) (Environment Agency, 2012) (Environment Agency, 2011): '*Wastes [should be] stored within enclosed containers, reactor vessels or enclosed well ventilated buildings fitted with a biofilter (specifically designed to minimise the release of odour, bioaerosols and microorganisms) and/or scrubbing system*'

3.1.6. Leachate Management

The common requirements for leachate management largely mirror those for containment as in Section3.1.4, given that appropriate containment will largely mitigate against leakage.

In **BAS Standard Issue 5** (Assured Biosolids Limited, 2020) this relates to an impermeable base that allows run-off to be collected and suitably constructed containers. In addition, for temporary storage, it is required that cake '***must not be likely to give rise to free drainage from within the stacked material, to minimise the risk of temporary diffuse pollution***.'

Additional measures that relate to leachate management are more varied across documents, including:

- **Standard Rule 2021 No. 7** (Environment Agency, 2021) – '*tanks fitted with level sensors*' **Environment Agency Non-hazardous and inert waste: appropriate measures for permitted facilities** (Environment Agency, 2021) - '*Regular inspection of storage areas, containers and infrastructure to ensure no loss of containment, with written records. Any spillages of waste logged and immediately cleaned up*.
- '**EC Best Available Techniques (BAT) Reference Document for Waste Treatment** (Joint Research Centre (European Commission), 2018) - '*Bunded areas where liquids are transferred; bunded areas designed and built to prevent seepage*. and '*Drainage infrastructure is capable of collecting and discharging all runoff water in case of heavy rains; rainwater collected and treated*.' Superseded **Standard Rules 2012 No. 11, 2012 No. 12 and 2010 No. 15** (Environment Agency, 2013) (Environment Agency, 2012) (Environment Agency, 2011) include a requirement for '*sealed construction joints'*.

3.1.7. Odour Control

Odour control in **BAS Standard Issue 5** (Assured Biosolids Limited, 2020) is mentioned in relation to location (see section 3.1.2), advising that storage is located to minimise odour nuisance to the public.

Across other documents, odour control requirements are largely connected to operational requirements, and the most common of these centre around:

- Minimising storage time of waste (particularly prior to treatment). Some specify a specific number of days e.g., no more than 5, or suggest following the '*first-in first-out'* principle (Environment Agency, 2020) (European Commission, 2006) whilst others leave an open statement.
- Regular cleaning & disinfection of tanks / storage areas.

Further common requirements included:

- Implementation & maintenance of an Odour Management Plan
- Covering of digestate (see Section 3.1.3). As above, **Reference Document on Best Available Techniques for the Waste Treatment Industries (superseded)** specifies that 'The covers must be designed to prevent odour, emissions such as ammonia and rainwater ingress.'

The requirement in the superseded **Standard Rules 2012 No. 11, 2012 No. 12 and 2010 No. 15** (Environment Agency, 2013) (Environment Agency, 2012) (Environment Agency, 2011), as referenced above in Sections 3.1.4 and 3.1.5, is an example of a more stringent requirement across multiple documents that applies to odour:

'*Wastes [should be] stored within enclosed containers, reactor vessels or enclosed well ventilated buildings fitted with a biofilter (specifically designed to minimise the release of odour, bioaerosols and microorganisms) and/or scrubbing system*'

3.1.8. Noise & Vibration

No requirements around noise and vibration were identified in **BAS Standard Issue 5** (Assured Biosolids Limited, 2020).

Noise and vibration management are referenced in **Best Available Technique** reference documents for waste treatment (Joint Research Centre (European Commission), 2018) (European Commission, 2006) and all **Standard Rules** documents, but not specified in the others studied. **Standard Rules** documents include a requirement to implement and maintain a noise & vibration management plan, specifically on request of the Environment Agency. Likewise, **Reference Document on Best Available Techniques for the Waste Treatment Industries (superseded)** and **EC Best Available Techniques (BAT) Reference Document for Waste Treatment** refer to utilisation of a noise and vibration management plan for waste treatment facilities in general and specify that these should include:

- *'a protocol containing appropriate actions and timelines;*
- *a protocol for conducting noise and vibration monitoring;*
- *a protocol for response to identified noise and vibration events, e.g., complaints;*
- *a noise and vibration reduction programme designed to identify the source(s), to measure/estimate noise and vibration exposure, to characterise the contributions of the sources and to implement prevention and/or reduction measures.'* (Joint Research Centre (European Commission), 2018)

Further techniques are suggested for managing noise and vibration emissions including consideration of the location of equipment and buildings, operational measures (e.g., closing of windows and doors) and noise and vibration control equipment.

3.1.9. Operational

No operational requirements are specified in relation to permanent storage in **BAS Standard Issue 5** (Assured Biosolids Limited, 2020). For temporary field storage it is specified that they '***must be subject to a routine inspection procedure as determined by the responsible organisation*.**'

In other documentation, operational requirements vary in detail and stringency, the most common among the documents studied being:

- Regular cleaning & disinfection of tanks / storage areas
- Routine inspection & maintenance e.g., inspection and works programme to ensure that all primary and secondary containment is fit for purpose

Other requirements found across multiple documents include:

- **Standard Rules 2021 No. 7** (Environment Agency, 2021) **/ EC Best Available Techniques (BAT) Reference Document for Waste Treatment** (Joint Research Centre (European Commission), 2018) - Implementation of appropriate leak detection / tanks fitted with level sensors
- **Standard Rules 2021 No. 7 / 2012 No. 16** (Environment Agency, 2012) (Environment Agency, 2021) - Establishment and monitoring of maximum capacity / residence time.

Additional requirements that specifically refer to solid fractions include:

- **PAS 110:2014** (WRAP, 2014) - the separation of whole digestate, separated liquor and fibre fractions from other materials, processes and stores on site.
- **PAS 100:2011** (WRAP, AfOR, 2011) – ensuring that input materials, composting batches and compost batches can be identified and traced from arrival on site to dispatch.

The requirement for separate storage of individual wastes is mirrored in the superseded **Standard Rule 17** (Environment Agency, 2016) as per **R13 permitted activities.**

3.2. Data Analysis

3.2.1. Current storage

Responses to the first data request, covering current storage capacities and drivers, delivered the following key findings:

- There is a wide range of site and system level capacities, depending on site / location specifics and spreading strategies of individual WaSCs.
- Operational storage varies due to specific operational requirements e.g., 4-day storage to provide long weekend capacity – longer term capacity (up to several months) to take account of operational outage and logistics management.
- Storage is currently and most commonly, on open concrete pads with only a limited number having any form of covering, although storage methods again vary by site depending on local constraints (such as planning requirements and distance to sensitive receptors).

Since the results generated did not indicate a clear 'norm' for operational / contingency storage capacities, further questions were devised in order to garner an understanding of additional capacity that may be required in response to FRfW.

The key drivers behind current storage capacity / strategy were further interrogated in the second data request, and the following were highlighted:

- Covered storage to reduce re-wetting
- Increased %DS experienced in covered barns
- Storage to address short term access to farms due to weather/soil compaction risks
- Optimisation of haulage regimes
- Legacy assets that are now expensive to modify
- Planning and odour impacts

3.2.2. Spreading / haulage strategies

Responses to the second data request, covering present and future haulage and spreading strategies, delivered the following key findings:

As demonstrated by Figure 3-1 there is the assumption that there will be little change in haulage to field profile – therefore WaSCs are currently assuming that they can continue with field storage.

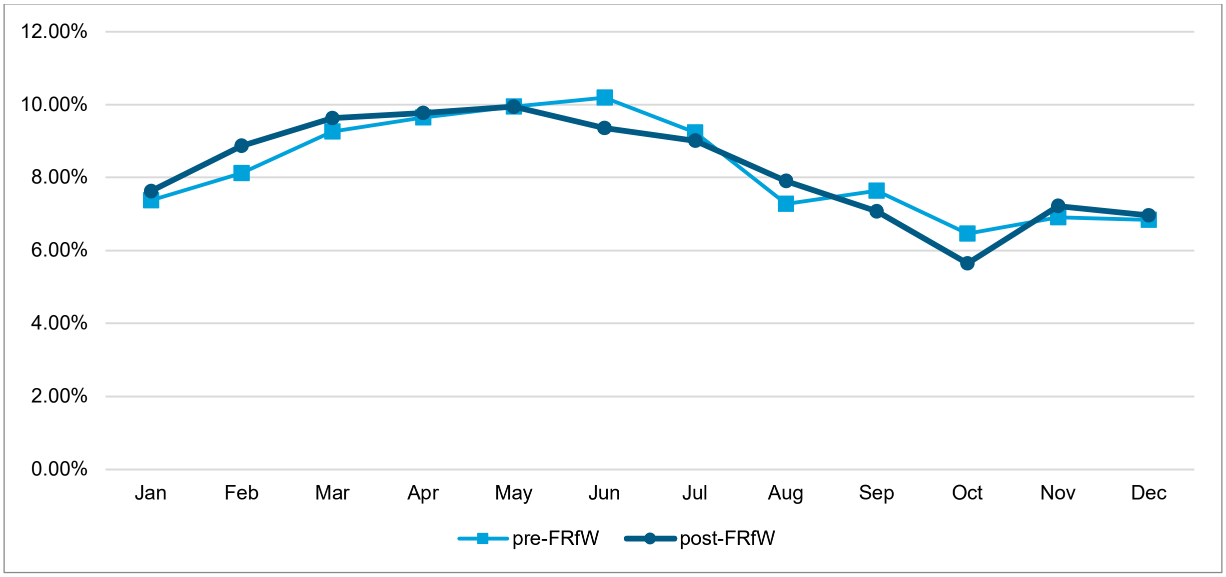

Figure 3-1 - Haulage Cycles

The data, as shown in Figure 3-2, also indicated that there is a projected shift from autumn to spring spread. This in turn would require greater reliance on access to fields in winter/spring periods to open up spring cropping. The report has assumed that the type of biosolids requiring haulage and storage will not change i.e., it will continue to be a stackable biosolids cake of minimum 20%DS in line with the latest BAS proposals. Consideration of other biosolids materials (e.g., liquid digestate, dried pelletised products) were not considered as it is not currently standard practice by any of the water companies.

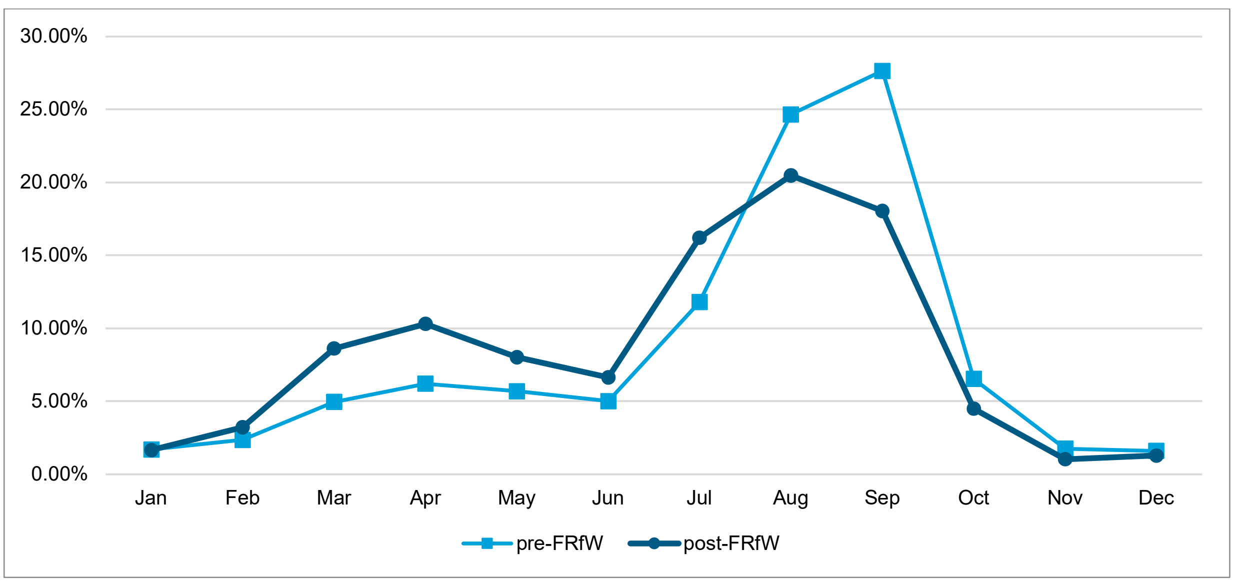

Figure 3-2 - Spreading Cycles

The reasons behind the changes cited above were covered in qualitative questions, which highlighted the following:

- Changing landbank and crop types driven by FRfW (e.g. sugar beet, grass, rape seed etc.)
- Changing supply and demand balance (i.e., volumes)

When WaSCs considered drivers and the impacts of new regulation, the following adjacent benefits of increased storage capacity could be realized, in addition to the environmental benefits that increased capacity affords:

- Resilience for challenges due to weather, asset issues, farmer plan changes, ground conditions (land unsuitable for storage).
- Ability to be more flexible and reduce OPEX cost.
- Improvement of customer service.

3.2.3. External Data

Key data trends around climate and farming practices were studied in conjunction with crop cycles to better understand how weather / landbank availability may impact future spreading / haulage strategies, and therefore storage requirements. This included UK government data sets around average temperature and rainfall and MET Office predictions around climate change, in addition to the UK crop calendar sourced from the U.S. Department of Agriculture (USDA).

3.2.3.1. Climate factors

- By the end of the 21st century, all areas of the UK are projected to be warmer, more so in summer than in winter.
- Rainfall patterns across the UK are not uniform and vary on seasonal and regional scales and will continue to vary in the future.
- Increases in the intensity of heavy summer rainfall events leading to increased flooding along with increased wetter winters. The consequences of these events can be seen due to the impacts of the "Beast from the East" which impacted farm access for greater than 10 days in 2018; and the unprecedented wet winter of 2015/16 which saw 11 named storms produce record level of rainfall from November 2015 - March 2016 in both monthly and seasonal accumulation records.
- A decrease in soil moisture during summers in the future, consistent with the reduction in summer rainfall.
- By 2070 precipitation expected to change by -47% in summer, and +35% in winter.

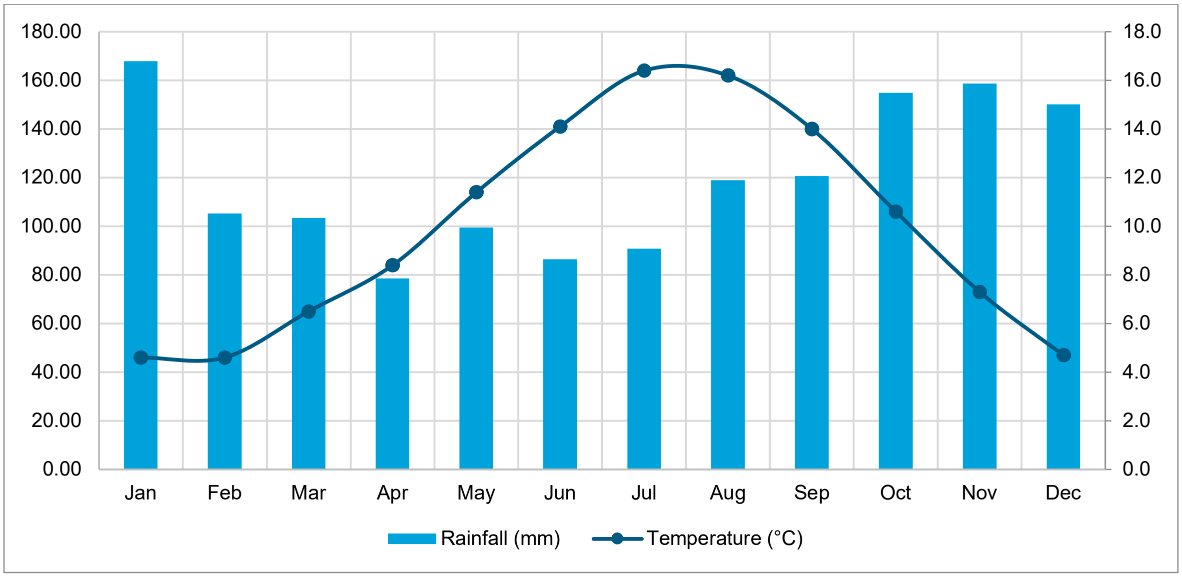

Figure 3-3 - 10-year mean weather data based on 'Annual mean temp with trends actual' (MetOffice, 2021)

3.2.3.2. Outlook for UK farming

Based on information released by The Department for Environment, Food and Rural Affairs (DEFRA, 2020)

- 31% said they have already invested in non-farming parts of the business, like tourism or letting buildings. 26% said they plan to widen the variety of enterprises in the next 3 years.
- Approximately 87% of farms said that they are not planning to move away from growing crops or keeping livestock in the next 3 years.
- Regulation required of farmers has dramatically increased and is likely to continue to do so.

- There is a greater drive to produce more food in UK reducing reliance on imports.

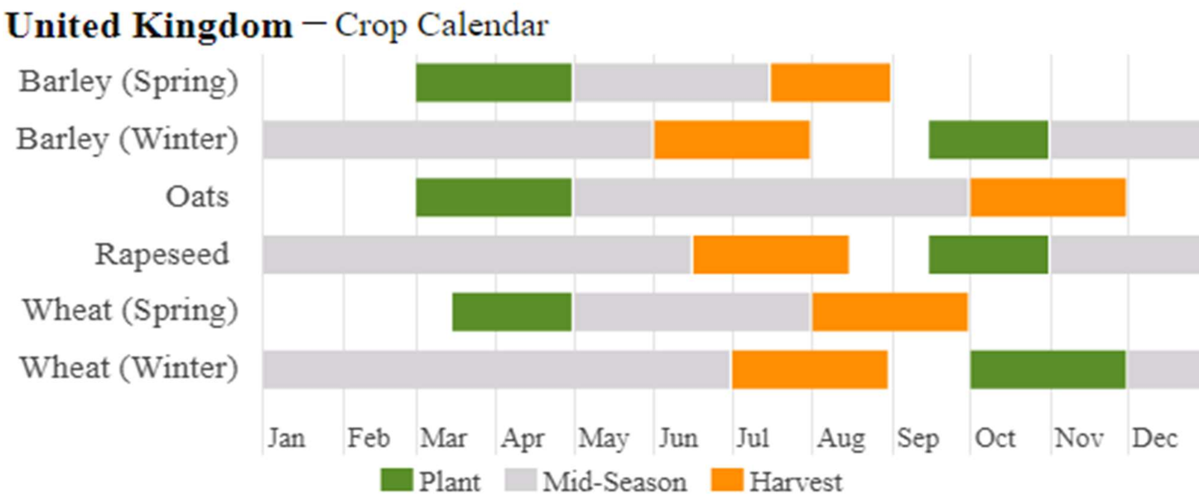

Figure 3-4 – UK Typical Farming Practice from 'Crop Calendars for Europe' (USDA, n.d.)

The farming industry as a whole is susceptible to major restrictions during epidemics. A direct consequence to biosolids recycling was seen in the Foot and Mouth outbreak in 2011, which inhibited access to many farms across the UK lasted for 11 months. Similar restrictions were observed in certain regions during the 10-years that BSE restrictions were imposed; during the H5N1 and H7N7 avian flu outbreaks in 2015 and again in 2021; 2002 SARs outbreak and the 2009 H1N1 - swine flu epidemics. These events cannot be foreseen but need to be considered in any mitigation measures as they can have serious adverse impacts on access to farms for recycling.

3.2.3.3. Deployment Times

With the proposed change from SUiAR to EPR there will be a need to apply for deployments for biosolids recycling to land activities (unless a low risk enforcement position or light touch approach can be agreed in due course). As this will be a new activity for the Water Industry in terms of applying for deployments there is no historic data that can be used to understand the timescales required. However, water companies have used deployments for Water Treatment Works sludge recycling and thus this can be used as a proxy to understand the current timescales.

The results are shown below:

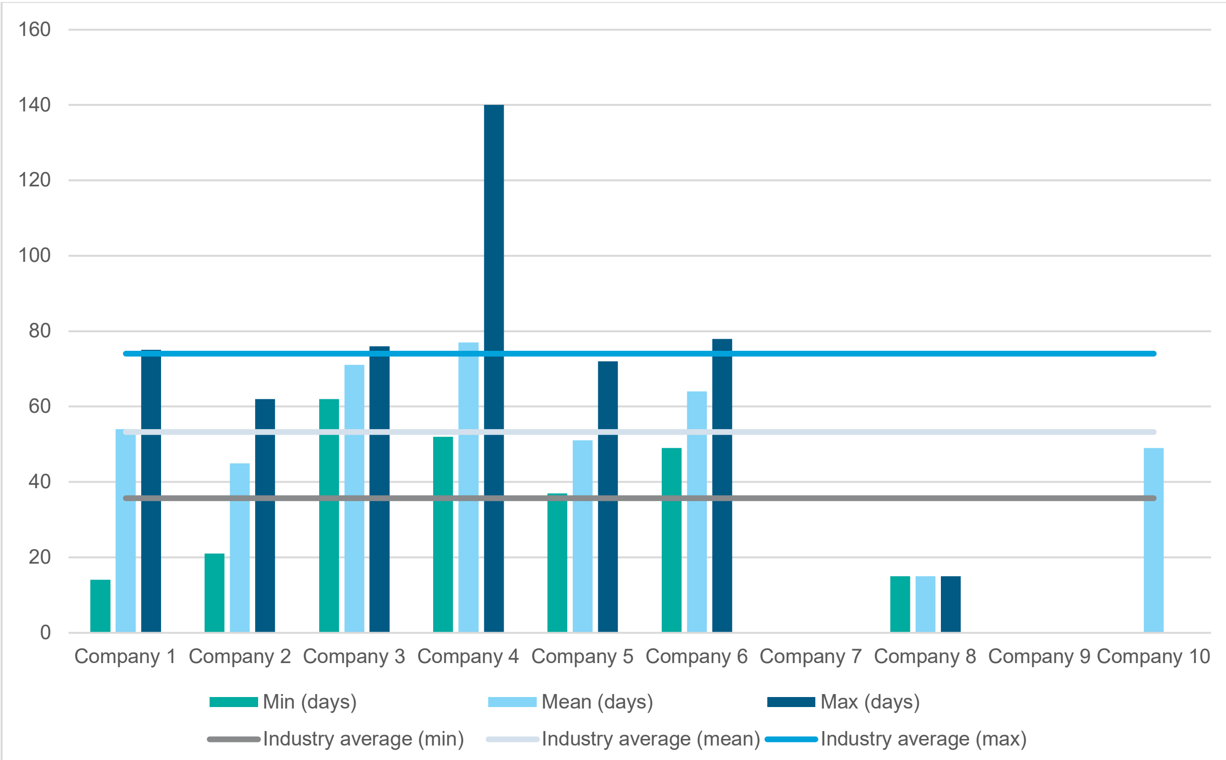

Figure 3-5 - Water Treatment Works Sludge Deployment Times

Figure 3-5 shows that the average time to receive a deployment permit is 53 days, however evidence does show that it can take up to 20 days for the application to be acknowledged before it is looked at. Therefore, during this time, sludges must be stored on the producer's site.

3.3. Landbank Assessment

The modelling exercise generated five scenarios, as per Figure 3-3 below, based on current and future regulatory requirements.

Scenario 1 Historical: 2020	**Scenario 2 Baseline: End AMP7**	**Scenario 3 10 year Minimal Change**	**Scenario 4 10 year Most Likely Change**	**Scenario 5 10 year Plausible Maximum Change**

Figure 3-6 - Landbank Assessment Scenarios

There are challenges in assigning a required storage capacity based on the assigned scenarios considering that:

1. Storage on STW is generally to allow logistic planning and buffer when access to farms limited.
2. The information doesn't quantify the amount of material that is being sent to land and thus how much on-field storage will be available.

However, considering the findings in conjunction with those from the Review of Best Practice (see Section 3.1) and Data Analysis (see Section 3.2), the following suggestions are made:

- **Scenario 1: Baseline (current position)** - minimum 1 month storage to allow logistics flexibility

- **Scenario 2: New BAS Compliance position (20 measures)** - minimum 3 months storage to allow logistics flexibility and over-winter storage when farm access limited
- **Scenario 3: Slight decrease in available land (due to continued restrictions and move to EPR)** - minimum 3 months storage to allow logistics flexibility (longer haulage runs) and over-winter storage (when farm access limited)
- **Scenario 4: Moderate decrease in available land** - minimum 6 months storage to allow logistics flexibility (longer haulage runs) and over-winter storage (when farm access limited) and inter-spreading season closed periods
- **Scenario 5: Significant decrease in available land** - (a) assuming that all biosolids can still go to agriculture: minimum 6 month storage to allow logistics flexibility (longer haulage runs) and over-winter storage (when farm access limited) and inter-spreading season closed periods; (b) assuming that some biosolids will be diverted to thermal outlets, reducing volumes to land: minimum 3 month storage to allow logistics flexibility (longer haulage runs) and over-winter storage (when farm access limited)

4. Conclusions & Recommendations

Considering the trajectory of haulage / spreading strategies, external pressures, best practices, and regulatory guidance highlighted through our research, the following recommendations are suggested.

- Monitoring of future haulage data annually to ensure that storage capacity is sufficient to keep up with new spreading regimes and predicted weather conditions.
- Climate change will result in increased periods where access cannot be guaranteed, additional storage will be required to mitigate this, but as this is likely to occur over an undefined period of time, this capacity can be delivered incrementally.
- Additionally, continency storage needs to be found to address the risk of agricultural epidemics that may limit access to field storage. Historically water companies found alternative storage sites, such as disused airfields and industrial sites, however most of these locations have been developed and are no longer widely available.
- Some additional storage is required now to manage current levels of risk around the changing recycling regime with further storage provided to address ongoing resilience needs. The suggestion would be nominally:
    - *1-month additional storage (short term, for immediate implementation) to allow changes in current practice, (best case) deployment application*
    - *3 months (mid-term, to address in AMP8) to allow for extended over-winter storage, move to EPR and mean deployment periods.*
    - *up to 6 months (long term, AMP8 and beyond) to address risks around loss of spring spreading due to climate change, resilience around epidemics and unforeseeable restrictions.*
- Increased on-site storage will promote greater control measures than increased storage on fields, generating overall environmental benefits for environmental pollution control and supporting the driver under the IED to reduce emissions. It will alleviate risks for WaSCs over winter access to land, thus contributing to resilience as per WINEP drivers.
- The data collection did not highlight any additional reliance on field storage by WaSCs. It was assumed that current S3 field storage guidance would continue as intended (i.e., to support short term storage as part of the supply of biosolids to farmers). Should WaSC be given greater flexibility for on-farm storage, for example to provide increased storage duration this could reduce the amount of on-site storage required at sludge treatment centres, however this carries a higher environmental risk that controlled storage on hardstanding, but with lower incurred costs.
- Support for greater investments in covering, to prevent re-wetting of material in storage during adverse weather. Covered storage is essential to mitigate the risk of rewetting and has evidenced %dry solids (DS) benefits.
    - *Covered storage should consist of a dutch barn (i.e. roof cover with open sides (thrust/push walls and containment drainage) as this assists ventilation and drying of the sludge.*
    - *Fully enclosed storage should only be employed if required by drivers such as planning requirements (odour) due to increased H&S concerns of vehicles operating inside a building*.
- It is recommended that Environmental Regulators issue guidance (preferably by including in any revised regulations) for storage capacity. This should be considered further as part of the wider Bioresources Strategy discussions.

5. References

ADBA. (2017). *The Practical Guide to AD: Second Edition.* London.

Agriculture, U. D. (n.d.). *Foreign Agricultural Services Data.* Retrieved from https://ipad.fas.usda.gov/rssiws/al/crop_calendar/europe.aspx

Agriculture, U. D. (n.d.). *Foreign Agricultural Services date.* Retrieved from https://ipad.fas.usda.gov/rssiws/al/crop_calendar/europe.aspx

Assured Biosolids Limited. (2020, 07). *Assured Biosolids - The UK Biosolids Assurance Scheme (BAS) Standard Issue 5 (July 2020).* Retrieved from https://assuredbiosolids.co.uk/wp-content/uploads/2020/07/BAS-Standard-Issue-5-10th-July-2020.pdf

Bastian, R. K. (1993). Part 1 X Biosolids Regulations. In *Biosolids Management Handbook: EPA Region V111.* Denver: US EPA.

CIRIA. (2014, 06). *Containment systems for the prevention of pollution (C736F).* Retrieved from https://www.ciria.org/CIRIA/CIRIA/Item_Detail.aspx?iProductCode=C736F&Category=FREEPUBS

DEFRA. (2019). *Clean Air Strategy 2019.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/770715/clean-air-strategy-2019.pdf

DEFRA. (2020, 3 5). *Farm Practices Survey October 2019 – General.* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/870305/fps-general-statsnotice-05mar20.pdf

Department for Business, Energy & Industrial Strategy. (2020, 12 21). *Consultation outcome: Green Gas Support Scheme (GGSS) digestate management.* Retrieved from https://www.gov.uk/government/consultations/green-gas-support-scheme-ggss-digestate-management

Environment Agency. (2011, 10 14). *SR2010 No 15: anaerobic digestion facility including use of the resultant biogas (superseded).* Retrieved from https://www.gov.uk/government/publications/sr2010-no15-anaerobic-digestion-facility-including-use-of-the-resultant-biogas

Environment Agency. (2012, 07 16). *SR2010 No 16: on-farm anaerobic digestion facility (superseded).* Retrieved from https://www.gov.uk/government/publications/sr2010-no16-on-farm-anaerobic-digestion-facility

Environment Agency. (2012, 11 16). *SR2012 No 12: anaerobic digestion facility including use of the resultant biogas (waste recovery operation) (superseded).* Retrieved from https://www.gov.uk/government/publications/sr2012-no12-anaerobic-digestion-facility-including-use-of-the-resultant-biogas-waste-recovery-operation

Environment Agency. (2013, 07 08). *[Withdrawn] How to comply with your environmental permit.* Retrieved from https://www.gov.uk/government/publications/how-to-comply-with-your-environmental-permit

Environment Agency. (2013, 03 21). *SR2012 No 10: on-farm anaerobic digestion facility using farm wastes only, including use of the resultant biogas (superseded).* Retrieved from https://www.gov.uk/government/publications/sr2012-no10-on-farm-anaerobic-digestion-facility-using-farm-wastes-only-including-use-of-the-resultant-biogas

Environment Agency. (2013, 03 21). *SR2012 No 11: anaerobic digestion facility including use of the resultant biogas (superseded).* Retrieved from https://www.gov.uk/government/publications/sr2012-number-11-anaerobic-digestion-facility-including-use-of-the-resultant-biogas

Environment Agency. (2016). *SR2010 No 17: Storage of wastes to be used in land treatment (storage of waste prior to use).* Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/790356/SR2010_No17_Storage_of_wastes_to_be_used_in_land_treatment.pdf#:~:text=R13%3A%20Storage%20of%20wastes%20pending%20recovery%20by%20land,stored%20on%20sit

Environment Agency. (2016). *SR2010No4: .* Retrieved from UK Gov: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/790263/SR2010_No_4_mobile_plant_for_landspreading.pdf#:~:text=Standard%20rules%20Chapter%204%2C%20The%20Environmental%20Permitting%20%28England,resulting%20in%

Environment Agency. (2016). *SR2010No6: Mobile plant for land spreading of sewage sludge.* Retrieved from UK Gov: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791455/SR2010_No_6_mobile_plant_for_landspreading.pdf

Environment Agency. (2020, 07). *Appropriate measures for the biological treatment of waste: Consultation draft July 2020.* Retrieved from https://consult.environment-agency.gov.uk/environment-and-business/appropriate-measures-for-the-biological-treatment/user_uploads/appropriate-measures-for-the-biological-treatment-of-waste---consultation-draft.pdf

Environment Agency. (2021, 07 12). *Non-hazardous and inert waste: appropriate measures for permitted facilities.* Retrieved from https://www.gov.uk/guidance/non-hazardous-and-inert-waste-appropriate-measures-for-permitted-facilities

Environment Agency. (2021, 12 20). *SR2021 No 6: anaerobic digestion facility, including use of the resultant biogas – installations.* Retrieved from https://www.gov.uk/government/publications/sr2021-no-6-anaerobic-digestion-facility-including-use-of-the-resultant-biogas-installations

Environment Agency. (2021, 12 20). *SR2021 No 7: anaerobic digestion facility, including use of the resultant biogas – waste recovery operation.* Retrieved from https://www.gov.uk/government/publications/sr2021-no-7-anaerobic-digestion-facility-including-use-of-the-resultant-biogas-waste-recovery-operation

Environment Agency. (2021, 12 20). *SR2021 No 8: on-farm anaerobic digestion facility using farm wastes only, including use of the resultant biogas – installations.* Retrieved from https://www.gov.uk/government/publications/sr2021-no-8-on-farm-anaerobic-digestion-facility-using-farm-wastes-only-including-use-of-the-resultant-biogas-installations

Environment Agency. (2021, 12 20). *SR2021 No 9: on-farm anaerobic digestion facility, including use of the resultant biogas – waste recovery operation.* Retrieved from https://www.gov.uk/government/publications/sr2021-no-9-on-farm-anaerobic-digestion-facility-including-use-of-the-resultant-biogas-waste-recovery-operation

EPA. (1994, 09). *A Plain English Guide to the EPA Part 503 Biosolids Rule.* Retrieved from https://www.epa.gov/sites/default/files/2018-12/documents/plain-english-guide-part503-biosolids-rule.pdf

European Commission. (2006, 08). *Reference Document on Best Available Techniques for the Waste Treatment Industries (superseded).* Retrieved from file:///C:/Users/PIEC1303/Downloads/superseded_wt_bref_0806.pdf

European Commission. (2010, 11 24). *DIRECTIVE 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 November 2010 on industrial emissions (integrated pollution prevention and control)* . Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0075&from=EN

Joint Research Centre (European Commission). (2018, 10 22). *Best available techniques (BAT) reference document for waste treatment.* Retrieved from https://op.europa.eu/en/publication-detail/-/publication/782f0042-d66f-11e8-9424-01aa75ed71a1/language-en

MetOffice. (2021, 07 09). *Annual mean temp with trends actual*. Retrieved from http://gss-data.org.uk/data/gss_data/climate-change/met-office-annual-mean-temp-with-trends-actual-catalog-entry

UK Gov. (1991). *The Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991.* Retrieved from https://www.legislation.gov.uk/uksi/1991/324/contents/made

USDA. (n.d.). *Crop Calendars for Europe*. Retrieved from USDA Foreign Agricultural Service: https://ipad.fas.usda.gov/rssiws/al/crop_calendar/europe.aspx

WRAP. (2014). *PAS 110:2014 Specification for whole digestate, separated liquor and separated fibre derived from the anaerobic digestion of source-segregated biodegradable materials.* The British Standards Institution.

WRAP, AfOR. (2011). *PAS 110:2011 Specification for composted materials.* The British Standards Institution.

WRAP, Environment Agency. (2014, 01). *Quality Protocol: Anaerobic Digestate*. Retrieved from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/292473/426765_EA_QP_Anaerobic_Digestate_web.pdf#:~:text=quality%20digestate%20from%20anaerobic%20digestion%20of%20source-segregated%20biodegradable,recovered%2

Appendices

Appendix A. Requested Data

A.1. First Data Request

- Current operational storage asset standard (i.e., amount of storage you would incorporate within a new asset – post treatment) and what is it based on (i.e., assumptions of stockpiling on site where it is to be spread)?
- Outline of what that storage looks like – i.e., dutch barn, odour-controlled building, isolated sites (away from domestic properties).
- Description of drivers for exceptional storage
- Current contingency storage asset standard - do you currently allow for contingency storage post treatment and if so, what number of days? Is it for the entirety of sludge production volume? Have you got strategic contingency sites e.g., outside of curtilage of works?

A.2. Second Data Request

- What has driven current storage capacities / different storage types (covered/enclosed/open/silo)?
- What was the previous (pre-FRfW) haulage and spreading cycle throughout the year (i.e what is planned to be hauled/spread each month (with/out FRfW)?
    - haulage (% of sludge production)
    - spreading (% of sludge production)
- What is the proposed (post-FRfW) spreading cycle (i.e what is planned to be hauled/spread each month (with FRfW)?
    - haulage (% of sludge production)
    - spreading (% of sludge production)
- What is the reason for the haulage/spreading regime changes going forward - what are the implications in terms of storage?
- What benefits do you see from having increased storage?
- Do you have contingency storage for untreated product?