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East London Additional Sludge Treatment Capacity

6QWG Strategic Alternatives Review (SAR)

SAR Report

March 2009

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List of abbreviations

AIC	Average Incremental Cost
AMP	Asset Management Period (AMP 5: 2010 to 2015, AMP 6: 2015 to 2020, etc)
BRC	British Retail Consortium
CAPEX	Capital Expenditure
CBA	Cost Benefit Ratio
CHP	Combined heat and power
CSO	Combined Sewer Overflow
CTRL	Channel Tunnel Rail Link
DS	Dry Solids content (weight dry solids per unit weight of sludge, expressed as %)
EA	Environment Agency
ED	Enhanced Digestion
EDd	Enhanced Digestion followed by drying of the digested cake
EDdI	Enhanced Digestion followed by drying and subsequent incineration of the dried product.
EDI	Enhanced Digestion followed by mass-burn Incineration
EfW	Energy from Waste
EIA	Environmental Impact Assessment
ES	Environmental Statement
FFT	Flow to Full Treatment
GHG	Greenhouse Gas
GLA	Greater London Authority
LPA	Local Planning Authority
LB	London Borough
LDA	London Development Agency
LTGDC	London Thames Gateway Development Corporation
MM	Mott MacDonald
NPV	Net Present Value
NVZ	Nitrate Vulnerable Zone (under Nitrates Directive)
OPEX	Operating Expenditure
PE	Population equivalent
PPC	Pollution Prevention and Control
PR09	Ofwat's Periodic Review of charges in 2009
RCD	Raw cake drying
RCI	Raw cake incineration (existing process at Beckton STW and Crossness STWs)
RCI+	As for RCI but assuming a small increase in throughput is achieved through modifications to the existing SPG processes (see Section 5.2 for description of potential modifications).
ROCs	Renewables Obligation Certificates
SAR	Strategic Alternatives Review
SAS	Surplus Activated Sludge (by-product of biological sewage treatment)
SEA	Strategic Environmental Assessment – carried out for TWUL's 'Sludge Strategy'
SPG	Sludge Powered Generators
Sludge Strategy	Thames Water's 25-Year Sludge Strategy, final version published December 2008.
SSM	Safe Sludge Matrix
STR	Sludge Technology Review
STW	Sewage Treatment Works

tDS	Tonnes dry solids. Similarly, tDS/d is tonnes dry solids per day.
THP	Thermal hydrolysis process
TWUL	Thames Water Utilities Limited (Thames Water)
TTQI	Thames Tideway Quality Improvements
UWWTD	Urban Wastewater Treatment Directive
VM	Volatile Matter
VM 1	Value Management meeting nr 1 (appraisal of Long List options)
VM 2	Value Management meeting nr 2 (appraisal of Short List options)

Definitions used in this report

Biosolids	Treated sewage sludge. Product of treatment processes such as digestion or lime stabilisation.
Co-digestion	The digestion of other waste streams with sludge.
Digestion	In the context of this study, the process of decomposing organic matter in sludge by bacteria or by chemical action or heat.
Enhanced digestion	Enhancement of the anaerobic digestion process through use of a pre-digestion stage such as thermal pre-treatment.
Enhanced treated product	Product which meets the requirements for pathogen levels set out in the Safe Sludge Matrix
Gasification	Gasification is the breakdown of hydrocarbons into a gaseous fuel (syngas) by carefully controlling the amount of oxygen present. It uses a similar operating temperature to incineration but with insufficient air to achieve full oxidation. The syngas produced can be used for electricity generation, plus heat recovery (CHP) where cost-effective. Other potential uses of syngas being developed (e.g. conversion to bio-enthanol). Process also generates 'char', discharged from the base of the reactor/furnace, which is classified as a waste and is disposed of to landfill.
Landbank	The area of agricultural land available for recycling treated sewage sludge
Mass burn incineration	In the context of this study, the feeding of sludge cake into a furnace and, by burning, reduction to an ash residual.
Pyrolysis	The thermal degradation of waste in the absence of air. Sludge is heated to a high temperature in an oxygen-free atmosphere. Mainly used as a pre-treatment step to gasification.
Sludge	Sludge is produced as an unavoidable natural by-product of the processes used in both wastewater treatment works and water treatment works, and comprises the solids removed during the treatment processes
Safe Sludge Matrix	Voluntary code identifying minimum acceptable levels of treatment to microbiological standards for wastewater sludge products applied to various agricultural crops, and application windows related to harvesting.
SHARON	Proprietary liquor treatment process.
Thermal destruction	For this report thermal destruction is taken to include any of the following: mass-burn incineration, gasification or pyrolysis.
Thermal pre-treatment	Treatment stage immediately prior to anaerobic digestion. There are various thermal pre-treatment processes including thermal hydrolysis and enzymic hydrolysis.

1 Introduction

1.1 Background and objectives

Thames Water (TWUL), while undertaking a company-wide review of its sludge strategy[1], identified a need for additional sludge treatment capacity in the East London area. In particular, it is expected that the quantity of sludge produced at Beckton STW and Crossness STW will increase due to population growth, tighter environmental regulations and planned upgrades of existing wastewater treatment facilities during AMP 4 and AMP 5.

Currently, the bulk of existing sludge production is treated using the Sludge Powered Generators (SPGs) at each STW. The SPGs do not have the capacity to incinerate all of the sludge produced at each site and therefore rely on other, short term, solutions including lime treatment of sludge cake, to treat the surplus.

TWUL has also carried out a Sludge Technology Review[2] with the aim of investigating in detail the most appropriate 'process routes' to meet the needs of TWUL's company-wide Sludge Strategy. Each process route consists of a combination of process technologies and a disposal route for the resulting treated sludge product. Whilst the Sludge Technology Review commented on the likely suitability of each process route for different sizes of sludge treatment centre – including Beckton STW and Crossness STW - it is necessary for the selection of the appropriate process route for each location to be based on a more detailed site-specific analysis.

TWUL is therefore undertaking a Strategic Alternatives Review (SAR) to investigate site-specific options for dealing with the shortfall in capacities at Beckton STW and Crossness STW. The SAR builds on previous studies and reports on sludge treatment including the company-wide 25-year Sludge Strategy and associated SEA[3], and the Sludge Technology Review. However, it also identifies further site-specific options where appropriate. It is intended that the SAR will establish a platform for preparing necessary planning applications and Environmental Statements specific to these solutions.

The SAR focuses on options for delivery of the additional capacity required to be completed and commissioned for year 1 of AMP 6[4]. However, future technology options – such as alternative treatment processes and co-treatment with alternative waste streams (including co-digestion) will also be considered in outline to ensure that, where feasible, the preferred options identified by the SAR for delivery in AMP 5 and AMP 6 do not preclude adoption of beneficial alternative processes at some later date.

TWUL has commissioned a team of consultants led by Mott MacDonald (MM) and including specialist contributions from Imtech Process and BAMAG GmbH, to undertake the SAR.

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[1] Thames Water's 25-year Sludge Strategy, Thames Water, December 2008 – referred to in this report as the 'Sludge Strategy'. Presents high-level strategic proposals for sludge management/disposal in the region for the 25 years to 2035.

[2] Sludge Technology Review (Draft), Stage 2 - Selected Process Streams, Entec UK Ltd, April 2008.

[3] Strategic Environmental Assessment (SEA) of Thames Water's Draft Strategic Proposals for Sludge Management (Sludge Strategy): Environmental Report, Entec UK Ltd, June 2008, and subsequent SEA Post-Adoption Statement, Entec UK Ltd, December 2008.

[4] The planning, design and construction of the preferred option will need to occur in AMP 5 if completion and commissioning is to be achieved by Year 1 of AMP 6.

1.2 SAR project delivery process

Figure 1.1 shows the overall SAR Project Delivery Process, which closely follows Thames Water's Risk and Value process and ties in with the study timetable and deliverables identified in the Brief for the SAR (contract nr 6QWG/B10, Issue 1, 3rd April 2008).

Based on TWUL's Risk and Value process the SAR is divided into two phases: 'Option Investigation Selection' and 'Option Selection'. Each phase culminates in a Value Management (VM) meeting, VM1 and VM2, respectively - key milestones in the project where options are appraised.

A 'Long-list' of options was developed as part of the 'Option Investigation Selection' phase of the study leading up to VM1. These options include different technologies as well as different locations (within the existing Beckton STW and Crossness STW sites or at other sites). This 'Long-list' of options was appraised at the VM 1 workshop and a 'Short list' of options for each site was derived.

The 'Short-list' options were developed and evaluated during the 'Option Selection' phase and appraised at the subsequent VM 2 workshop where preferred options were identified for both Beckton STW and Crossness STW.

1.3 Appraisal methodology

The appraisal methodology used for this SAR is based on the assessment of each option against a number of objectives - the key aspects which may affect the deliverability of the scheme. Each objective also includes a number of sub-objectives. The objectives and sub-objectives selected must be sufficient and suitable for the differentiation of the options being considered. There is no 'weighting' of objectives used in the option appraisal.

Based on this appraisal method, the options appraisal included the following steps:

1. Description of the options ('Long list' options at the VM 1 meeting and 'Short list' options at the VM 2 meeting)

2. Scoping and agreeing project objectives and sub-objectives that were appropriate to this study.

3. Option appraisal using non-numerical scoring based on the professional judgement of the relevant specialists.

4. Selection of the preferred option(s), taking account of the results of the options appraisal.

5. Outputs from each of the VM meetings included the preferred option(s) and a robust record of the process including the reasoning for the scoring of each option.

In formulating the appraisal methodology a range of objectives were developed to consider technical, practical, social, economic, environmental and planning aspects of each of the options.

The objectives used for the VM 1 and VM 2 workshops are listed in Table 1.1. Appendix A provides further details of the appraisal methodology including a more detailed description of the objectives and sub-objectives used in the appraisal of options for this SAR.

Figure 1.1: SAR Project Delivery Process

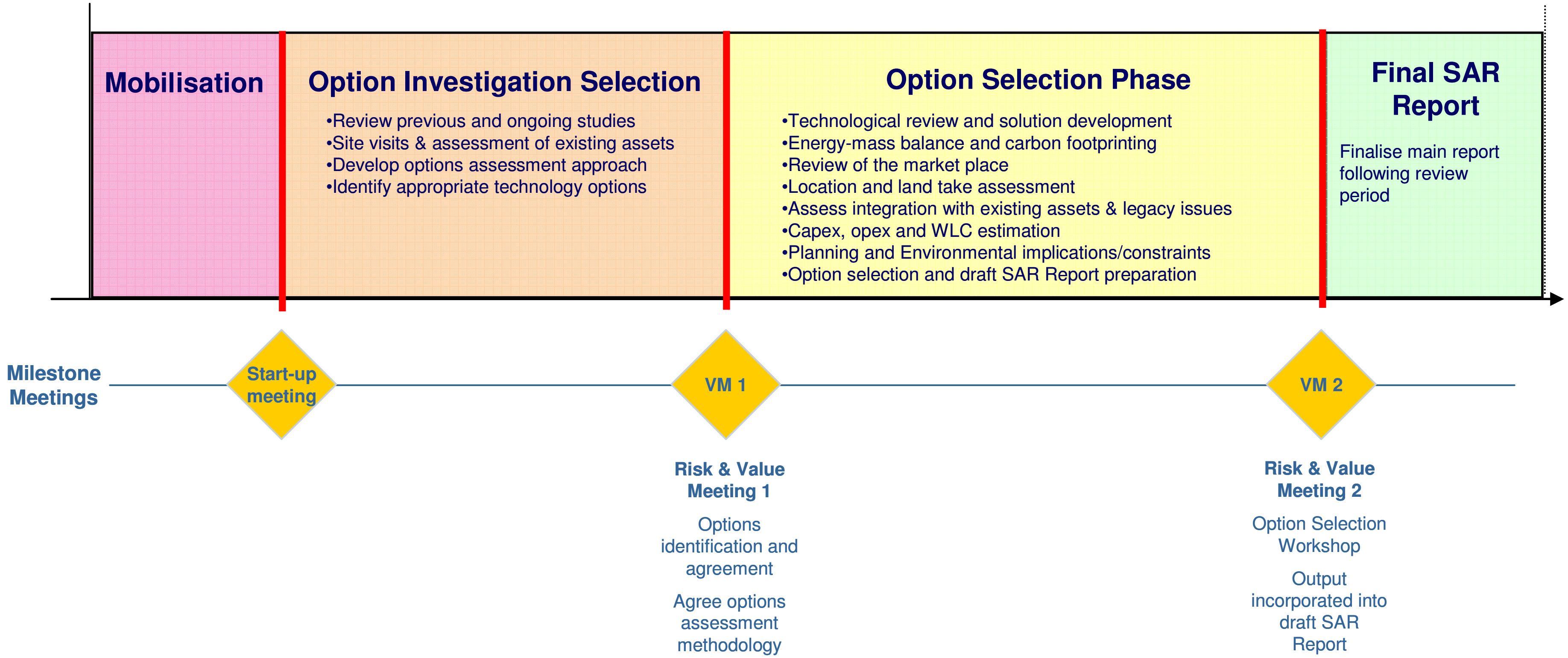

Table 1.1: Objectives used for option appraisal

Objective	Description
Constructability	Constructability is concerned with project related issues encountered during the construction phase of the project. This objective looks at the technical complexity of constructing the project/options, inherent or unforeseen risks to the project programme, including cost and resourcing issues, and consideration of other concurrent schemes. It also considers construction stage environmental impacts through sub-objectives for noise/dust control and traffic management
Technology	The Technology objective assesses whether the proposed technology options are likely to work and provide the required treatment capacity on a reliable basis. The potential for phasing implementation of the proposed plant as well as flexibility for future adaptation are also considered.
Operations	The Operations objective examines how the facility will perform under normal circumstances and conditions, once it becomes operational. ‘Operations’ looks at the likelihood of the scheme specification being achieved with respect to performance, reliability, and flexibility.
Safety	Concerned with reducing the potential for loss of life and injuries resulting from construction and operation.
Integration	The integration objective aims to ensure that all decisions are taken in the context of policies produced by the local authorities, the Greater London Authority, LTGDC (for Beckton and Riverside STWs) and other agencies as well as Thames Water’s strategic policies.
Economy	Concerned with improving the economic efficiency of investment in assets. There are sub-objectives to improve economic efficiency for Thames Water, its customers and the wider economic impacts of the investment.
Environment	The environment objective involves reducing the long term (i.e. during operation) direct and indirect impacts of the scheme facilities on both the local and wider environment. Fourteen sub objectives, including noise, atmospheric pollution of differing kinds, impacts on ecology, climate change and historic buildings – have been identified for the purpose of this optioneering process.
Stakeholder Preferences	Considers the preferences of regulators, Thames Water and other major stakeholders such as the relevant national, regional and local level authorities. Where possible, the assessment is based on stated preferences.

1.4 Purpose and structure of this Report

This report sets out the main components of the option appraisal process including:

- the option identification process,
- the findings of the technical, environmental and land-use planning analysis carried out for each option
- the results of the option appraisal at the VM 1 and VM 2 workshops, including any caveats and limitations identified during the course of the workshops.

This report is divided into the following sections:

- Section 1 provides a brief background to the in the project.
- Section 2 provides the strategic context for the project including the company-wide Sludge Strategy and SEA as well as the environmental and land-use planning context.

- Section 3 provide site specific background information including an assessment of existing sludge treatment processes, details of other schemes at each site and any potential constraints.
- Section 4 describes the solution requirements including the design horizon, required treatment capacities and other parameters for the analysis.
- Sections 5 to 7 describe the development, and evaluation of options as well as the findings of the VM meetings.
- Section 8 presents the conclusions on the preferred option for provision of additional sludge treatment capacity for both Beckton STW and Crossness STW.

Further supporting information is provided in various appendices.

2 Strategic Context

This section sets out the strategic context for the SAR and, in particular, highlights the relationship between the SAR and the Sludge Strategy, associated SEA and the Sludge Technology Review.

2.1 Strategic Direction Statement

TWUL's Strategic Direction Statement[5] proposes the following future for sludge treatment at Beckton STW and Crossness STW:

- In the medium term, to maintain and renew its sludge powered generators, enhance sludge recycling capacity and secure sustainable and varied recycling routes.
- In the longer term, to seek new recycling opportunities (including energy generation), community based waste management solutions, ensure sustainable asset performance and serviceability.

2.2 Sludge Strategy and SEA

2.2.1 Background

During 2007/08 Thames Water (TWUL) developed proposals for the management of sewage sludge in the TWUL region over the 25-year period from 2010 to 2035. These proposals were then published in a draft Sludge Strategy for stakeholder consultation. The draft Sludge Strategy was based upon an assessment of a range of treatment / outlet options, which helped TWUL identify a preferred list of options for each sludge area in the TWUL region.

TWUL prepared these strategic proposals in order to: (1) provide a broad framework for TWUL's specific investment proposals, particularly in the period 2010-2015 for the periodic review of charges in 2009 (PR09), and (2) to review the appropriateness of TWUL's current strategy (i.e. wherever possible recycle sludge to land) going forward, given the increasing costs and regulatory/other constraints arising from this outlet.

TWUL further decided to commission a voluntary, independent Strategic Environmental Assessment (SEA) of its draft Sludge Strategy, carried out by Entec UK Ltd. This was to ensure that potential environmental, economic and social impacts were properly understood and accounted for in all stages of the sludge strategy development.

In developing TWUL's proposals, the following objectives were adopted:

- To manage sludge so as not to endanger human health or harm the environment, by ensuring that all regulatory and legislative controls are met;
- To establish long term, secure and sustainable outlets;
- To ensure that sludge is managed on behalf of customers in a cost-effective and efficient manner, minimising the potential for impact from transport and odour;
- To have due regard to non-statutory Codes of Practice and industry guidance;

[5] *Taking care of water, the next 25 years* (TW's Strategic Direction Statement), Thames Water, December 2007.

- To use the latest available information in formulating and implementing the strategy; and
- To encourage stakeholder participation in the development of the strategy.

The strategic proposals cover all wastewater sludge produced at Thames Water sites and consider predicted sludge production up to 2035, over a 10 year and 25 year horizon.

Towards the end of the 10-year period (2017-2018) TWUL proposes to undertake a further strategic review of the current capacity of treatment/outlets employed, location and number of sludge centres in the Region, in order to inform the next 15-year investment programme.

Following consultation with stakeholders TWUL finalised its Sludge Strategy and prepared an SEA Post Adoption Statement. The SEA Post Adoption Statement describes how the findings of the SEA Environmental Report have been taken into account in the preparation of the Sludge Strategy, as well as the changes made in response to the comments TWUL received during the consultation and as a result of recent changes to legislation. The SEA Post Adoption Statement also covers TWUL's approach to monitoring.

Both the Sludge Strategy and SEA Post Adoption Statement were published in December 2008 and made available on TWUL's website.

2.2.2 Summary of relevant Sludge Strategy conclusions

The main conclusion of TWUL's future sludge strategy is to favour processes which will minimise sludge volumes and maximise energy recovery. Hence, the company intends to invest in sludge treatment technologies which will ensure good product quality and support continued recycling to agricultural land where there is suitable landbank available. However, in areas where it is considered that the landbank available for sludge recycling is already limited or is likely to become insufficient over time then the sludge strategy proposes the use of thermal destruction processes with energy recovery, thus avoiding the increased environmental impact and costs of transporting the treated sludge to increasingly distant agricultural land.

With respect to Beckton and Crossness STWs, the Sludge Strategy states that the preferred 10 year strategy is to provide additional sludge treatment capacity to deal with population growth and refurbishment of existing assets and that this additional capacity is likely to use thermal destruction with energy recovery, though the possibility of enhanced digestion in advance of thermal destruction should also be assessed.

The Sludge Strategy's conclusions and recommendations for Beckton and Crossness STWs are summarised in Table 2.1.

Table 2.1: Sludge Strategy Conclusions and Recommendations – East London (Beckton STW and Crossness STW)

Conclusions	- Processes allowing the efficient extraction of energy and minimising lorry movements are the most suitable. - Recycling to land alone is not a viable option for these sites due to the large volume of sludge produced.
Recommended Strategy – 10-years	- Install additional thermal destruction with energy recovery capacity - Assess whether more efficient energy recovery can be achieved at these sites by carrying out digestion in advance of a thermal destruction process - To help manage short-medium term capacity issues at Beckton STW, install treatment capacity at Riverside STW
Recommended Strategy – 25-years	In the longer term consideration should also be given to co-digestion followed by thermal destruction in order to try to maximise the potential for energy recovery. However this would involve bringing additional material on site and the impact of this activity would need to be fully assessed.

The Sludge Strategy also proposes conversion of other main sludge treatment centres, including Riverside STW, to enhanced digestion to increase renewable energy production and minimise solids for recycling to land.

However, the Sludge Strategy stresses that these preferred treatment/outlet options should not be regarded as site-specific recommendations and that for developments at specific sites, the preferred options would need to be reconsidered in order to check that the assumptions made in the Sludge Strategy are still valid.

A key purpose of this SAR is to review the Sludge Strategy's site specific recommendations for Beckton and Crossness STWs and undertake a detailed site specific appraisal of all options.

2.2.3 Current outlets for sludge

The Sludge Strategy reports that in 2006, some 62% of TWUL's sludge generation was recycled to agriculture, a further 36% was incinerated (in the Beckton and Crossness SPGs) with the resulting ash taken to landfill and the remaining 2% was composted or used for land reclamation. Data for 2007/08 give similar proportions.

Treated sewage sludge has been safely used on agricultural land for a substantial number of years and this is recognised as the best practicable environmental option in most circumstances by the EU and UK Government, at the current time, for dealing with this wastewater residual.

However, a number of issues are impacting on the agricultural land recycling outlet and hence TWUL commissioned a detailed review of landbank availability to inform its Sludge Strategy. The main conclusions of the landbank assessment carried out were as follows:

- In principle, there is sufficient land available for recycling biosolids within the Thames region up to, at least, the project design horizon of 2031. However suitable land is becoming more difficult to secure as demonstrated by the increased volume of biosolids migrated into and out of the region.

- There is a significant urban area within the Thames region and, in particular the east and south-east of the region is likely to become more constrained by the end of the period covered by the Sludge Strategy.
- The security of the landbank is critically dependant on the continuing support and confidence of the farming community and product supply chain. Continued access to arable land growing wheat and oil seed rape is crucial to the continued viability of the outlet in the Thames region.

During the preparation of this SAR, the TWUL Biorecycling team gave further consideration to the availability of landbank for enhanced digestion sludge from East London. They concluded that sufficient landbank would be available for the expected quantities of Beckton and Crossness enhanced digested sludge up to, at least, the design horizon for this SAR.

2.3 Sludge Technology Review

TWUL commissioned a Sludge Technology Review with the aim of investigating in detail the most appropriate 'process routes' to meet the needs of TWUL's company-wide Sludge Strategy. Each process route consisted of a combination of process technologies and a disposal route for the resulting treated sludge product. This review identified several process routes which would meet TWUL's sludge treatment needs and comply with its company wide Sludge Strategy. The suggested process routes are as follows:

- Acid phase digestion (including enzymic hydrolysis) - cake to agriculture.
- Thermal hydrolysis and digestion - cake to agriculture.
- Raw sludge drying – dried sludge to agriculture.
- Enhanced digestion and drying - dried sludge to agriculture.
- Raw sludge cake incineration – ash to landfill (or recycling as building material).
- Enhanced digested cake incineration – ash to landfill (or recycling as building material).

In addition to the above, the following process routes were considered by the review to show promise for the future but were not yet sufficiently proven for implementation in the short and medium term:

- Enhanced digested, dried sludge incineration – ash to landfill (or recycling as building material).
- Raw sludge drying and gasification – ash to landfill.

The Sludge Technology Review dismissed conventional digestion as a solution as enhanced digestion, with its increased solids destruction and higher biogas production, was found to: have significantly lower whole life cost, produce a high quality, enhanced digested product with lower nitrogen content (which is therefore more attractive for agricultural use) and produce lower volumes of material to be transported for recycling.

The Sludge Technology Review commented on the suitability of each process route for different sizes of sludge treatment centre and suggested that thermal destruction by mass-burn incineration was likely to be the most attractive process option at TWUL's largest STWs. The report further highlighted the suitability of this option for sites where there are access issues for sludge transportation by road and limited agricultural landbank for recycling.

The Sludge Technology Review also found that raw sludge drying has the highest energy consumption and Greenhouse Gas (GHG) emissions of the various options.

However, the Sludge Technology Review also concluded that it is necessary for the final selection of the appropriate process route for each location to be based on a more detailed site-specific analysis.

2.4 Alternative technologies and waste streams

The SAR focuses on options for delivery of the additional capacity required to be completed and commissioned by year 1 of AMP 6. However, future technology options – such as alternative treatment processes and co-treatment with alternative waste streams – are also considered in outline to ensure that, where feasible, the preferred options identified by the SAR for delivery in AMP 5 and AMP 6 do not preclude adoption of beneficial alternative processes at some later date.

Gasification and pyrolysis are thermal destruction treatment processes that have been considered in this study as potential alternatives for mass-burn incineration in the longer-term. However, use of these processes for sewage sludge has yet to be demonstrated at commercial scale and using a mixed feed. Despite several pilot schemes for gasification of sewage sludge, no commercial schemes have gone ahead in the UK. Although there are a number of examples operating in Japan these are at a much smaller scale than would be required at Beckton and Crossness STWs. Furthermore, given the long preparation times associated with new SPGs, their cost, and length of operational life once they are commissioned it is unlikely that alternative processes such as gasification would be implemented at either site until towards the end of the period covered by the Sludge Strategy, if at all. Gasification and pyrolysis are therefore only suitable for consideration as options for the longer term.

Gasification may present several advantages including the option (during maintenance shut-downs of the gasification plant) to recycle dried cake to agriculture due to the inclusion of drying in the process stream. However, this process is energy intensive and this potential benefit could only be realised if there is also additional dryer capacity enabling this to also be shut down for maintenance. Other potential advantages include additional energy recovery leading to reduced operating costs compared to incineration. Associated risks arise from the unproven status (with respect to municipal wastewater sludge) and complication of the process.

Co-digestion and co-gasification of other waste types along with wastewater sludge may be commercially attractive options. Co-digestion of sewage sludge with other organic co-substrates – such as food waste – can be considered as a method of enrichment of digester feedstock and improvement of its digestibility. The quantity and quality of biogas can be increased by implementation of co-digestion. This is because certain co-substrates result in production of biogas which is richer in methane than that from the sewage sludge. For instance, biogas from fats can contain up to 70% of methane. On the other hand, wastes rich in carbohydrates are likely to produce more gas but with a lower methane content.

Electrical energy produced from the co-digested portion of the biogas will be eligible for more ROCs than biogas from sewage sludge (post 2011, 2 ROCs/kWh compared to 0.5 ROCs/kWh).

However, the use of co-digestion for sludge treatment is subject to technical and regulatory constraints, which together would effectively preclude significant use of co-digestion at Beckton and Crossness STWs in the short to medium term. These constraints, which are described in detail in Appendix L.3.3, fall into three main areas as follows:

- **Water sector regulation –** specifically Ofwat's limits on the types of activities that can be undertaken by the regulated businesses of water companies. This relates to the use of core, regulated assets (digesters and associated plant) for non-core (and therefore non-regulated) activities such as co-digestion of other wastes. For example, funding for provision or maintenance of any additional assets not required for sewage treatment alone could not be funded by the customers of a water company's regulated business.
- **Environmental Permit Regulations –** these currently adversely impact on the ability of the water companies to recycle sludge to land that is derived from mixing wastewater sludge with food waste. Furthermore, co-digestion activities involving animal by-products (including foods, kitchen wastes) would need to comply with the Animal By-Products Regulations (ABPR) and require pasteurisation.
- **Technical Considerations/Constraints -** Since co-substrates can potentially originate from a variety of sources, their physical and chemical composition will vary considerably. Therefore, the suitability of specific wastes or by-products for co–digestion with sewage sludge would need to be thoroughly assessed and monitored. Some organic compounds have a greater potential for improving digestion as well as generation of biogas than others whilst some substrates can cause operational problems, such as inhibiting digestion, foaming in digesters or deterioration of CHP engines (e.g. due to the presence of siloxanes). A further consideration is the increased potential for odour problems associated with handling easily digestible co-substrates.

Further details and discussion of the potential for alternative technologies and waste streams are provided in Appendix L.3.3.

2.5 Land use planning and Environmental Context

2.5.1 Land use planning

In evaluating options for provision of additional sludge treatment capacity in the East London area it is important to consider their compliance with Government policy on sustainable development, national Planning Policy Guidance (PPGs) Notes and Statements (PPSs), and other regional and local policy guidance documents have been used when evaluating detailed proposals and with planning policy.

The main national policy documents to be considered include:

- Waste Strategy for England 2007 which encourages "less waste, more material recovery, energy from waste and much less landfill".
- PPS1 on 'Delivering sustainable development' describes the important role of the planning system in achieving sustainable development and building sustainable communities.
- PPS10 on 'Planning for sustainable waste management', also encourages more sustainable waste management, moving the management of waste up the 'waste hierarchy' (reduction, reuse, recycling and composting, using waste as a source of energy, and only disposing as a last resort).
- PPS22 'Planning and Pollution control' encourage the incorporation of renewable energy projects in all new developments.

Regional planning policy in London consists of the London Plan – Spatial Development Strategy for Greater London (Consolidated with alterations since 2004) published in February 2008.

LP Policy 4A.18 on 'Water and sewerage infrastructure' states "*Additional capacity for the management of sewage sludge will be needed over the plan period to meet the requirements of growth and tighter environmental standards. The Mayor will work in partnership with the boroughs to ensure timely provision of appropriate new facilities at existing Sewage Treatment Works within London.*".

The East London Sub Regional Development Framework (2006) is also part of the London Plan and states that there is "*the need to manage flood risk and plan carefully for environmental infrastructure including water resources and sewage*".

Other regional policy documents include 'London Thames Gateway Development Corporation – Vision for London Riverside' (March 2008) and 'Rethinking Rubbish in London: The Mayor's Municipal Waste Management Strategy' (September 2003).

Both Beckton and Riverside STWs fall within the London Thames Gateway Development Corporation (LTGDC) area. The LTGDC is not a policy forming body, but relies on the London Plan and borough development plans. The Thames Gateway area has recently been the focus for regeneration and re-development.

With respect to local planning policy documents the various proposed locations for additional sludge treatment capacity lie within local government areas (the London boroughs of Newham, Bexley and Havering and Dartford Borough Council) and these have their own adopted Unitary Development Plans (UDP) and other local plans that need to be considered. Furthermore, a draft Joint Waste Development Plan for East London was published in May 08 and sets out the preferred options for waste disposal up to 2020 across the boroughs of Barking & Dagenham, Havering, Newham and Redbridge.

Appendix J provides a further description of the local, regional and national planning policy and guidance relevant to this study.

2.5.2 Environmental

The options evaluated in this study have the potential to result in impacts during the construction and the operational phases of the project.

The STW locations under consideration lie within highly populated urban areas. All of the sites are located in close proximity to areas which are designated for their amenity or ecological value (e.g. Metropolitan Open Land, sites of importance for nature conservation) in addition to particular local sensitivities such as landscape and visual concerns or proximity to residential neighbours.

It is anticipated that schemes which involve incineration will cause greater concerns for local authorities, key stakeholders and the general public than enhanced digestion options, primarily due to perception issues.

However, the proposed projects would also bring environmental benefits in the form of increased renewable energy generation and efficient sludge management processes with the capacity to treat the increased sludge quantities produced as the unavoidable by-product of increasing wastewater treatment standards and population growth. The projects will also provide additional employment opportunities (during both the construction stage and operation) in areas of high multiple-deprivation with increasing unemployment.

As noted in Section 2.2, an SEA has been undertaken to ensure consideration of all relevant potential environmental, social and economic impacts of the company-wide Sludge Strategy. A Post Adoption Statement, which represents the final step of the SEA process, has also been prepared to document how environmental, social and economic considerations, the views of the consultees and the recommendations of the SEA Environmental Report have been taken into account in the final Sludge Strategy.

However, further consideration of environmental impacts is necessary as preferred options at the sub-regional level are developed into proposals at specific sites such as Beckton and Crossness STWs. Thus site-specific environmental impacts are assessed, in increasing detail, in the following stages:

- Within this SAR the relative environmental impacts of the various options are assessed in sufficient detail to enable comparison and selection of the preferred option.
- Within a detailed Environmental Impact Assessment (EIA) for the selected scheme. Selected schemes may require the submission of a planning application along with an Environmental Impact Assessment (EIA). The need for EIA would be determined with reference to The Town and Country Planning (Environmental Impact Assessment) Regulations 1999 (as amended). Both the planning application and EIA would be subject to consultation with the planning authorities and statutory consultees as well as wider stakeholders..

3 Site Background Information

Potential solutions for providing additional treatment capacity for sludge generated at Beckton STW and Crossness STW involve options constructed wholly at Beckton STW and Crossness STW as well as options in which a proportion of sludge is transferred for treatment at Riverside STW (for Beckton STW sludge) or Long Reach STW (for Crossness STW sludge).

Hence the following sections describe the existing facilities at these STWs including any issues and constraints that may impact on proposed options.

3.1 Overview

Both Beckton STW and Crossness STW provide conventional wastewater treatment processes including primary settlement and secondary biological treatment. These processes produce sludge which is then dewatered and incinerated in the existing SPG at each site.

The following tables summarise the sewage and sludge treatment facilities at each STW.

Table 3.1: Sewage treatment facilities – outline details

Site	Location	Capacity	Processes	Receiving waters
Beckton STW	LB Newham, north bank of the Thames adjacent to Barking Creek.	Population equivalent: **3.4 million** Flow to full treatment: **1,420 Mld**	Fine screens, Grit removal, Primary settlement, Secondary biological treatment (activated sludge).	River Thames
Crossness STW	LB Bexley, south bank of the Thames at Abbey Wood.	Population equivalent: **2.4 million** Flow to full treatment: **778 Mld**	Fine screens, Grit removal, Primary settlement, Secondary biological treatment (activated sludge).	River Thames
Riverside STW	LB Havering, north bank of the Thames.	Population equivalent: **0.5 million**[6] Flow to full treatment: **150 Mld**	Fine screens, Grit removal, Primary settlement, Secondary biological treatment (activated sludge).	River Thames
Long Reach STW	LB Dartford, south bank of the Thames adjacent to Dartford Bridge.	Population equivalent: **1 million** Flow to full treatment: **311 Mld**	Fine screens, Grit removal, Primary settlement, Secondary biological treatment (activated sludge).	River Thames

[6] Value is best estimate. Calculated using total sludge generated and a per capita sludge production of 80 g/head/d.

Table 3.2: Sludge treatment facilities - outline details

Site	Location	Sludge production (2007)	Existing processes	Sludge treated (2007, annual average)
Beckton STW	LB Newham, north bank of the Thames adjacent to Barking Creek	265 tDS/d (includes 25 tDS/d from Riverside STW)	Sludge Powered Generator (incineration, 3 lines)	170 tDS/d
			Lime treatment (lime addition to raw sludge cake)	20 to 30 tDS/d
			Discharged with final effluent	68 tDS/d
Crossness STW	LB Bexley, south bank of the Thames at Abbey Wood	160 tDS/d	Sludge Powered Generator (incineration, 2 lines)	95 tDS/d
			Lime treatment (lime addition to raw sludge cake)	65 tDS/d
Riverside STW	LB Havering, north bank of the Thames.	25 tDS/d	None. Sludge currently transferred by pipeline for treatment at Beckton STW.*	0 tDS/d
Long Reach STW	LB Dartford, south bank of the Thames adjacent to Dartford Bridge.	77 tDS/d	Conventional digestion	77 tDS/d

*TWUL is currently seeking planning permission for scheme 9RTG/A1 which, if approved, would provide 110 tDS/d enhanced digestion capacity at Riverside STW by 2010/11.

3.2 Sludge production forecasts

The sludge production forecasts used in the options analysis are presented in Table 3.3.

As noted previously, sludge from Riverside STW is currently pumped to the inlet works of Beckton STW and treated at Beckton STW. If the proposed enhanced digestion plant at Riverside STW (capacity 110 tDS/d) receives planning permission and is implemented by 2010/11 then this sludge will be treated at Riverside STW along with sludge produced at Beckton STW which exceeds the capacity of the existing SPG (some 70-80 tDS/d of mainly SAS). This will allow TWUL to cease lime treatment at Beckton STW and will provide sufficient capacity until the end of AMP 5. It is anticipated that additional capacity will be needed by year 1 of AMP 6 as a result of further growth and to enable major overhaul of the existing SPGs at each site which is likely to be required in AMP 6, when both SPGs will be approaching 20 years old.

This SAR considers a similar option to that proposed for Riverside-Beckton, involving transfer of Crossness STW sludge to Long Reach STW, for treatment in a proposed enhanced digestion plant at Long Reach STW. As noted previously, Long Reach STW currently provides conventional digestion for indigenous sludge and some local imports.

Table 3.3: Sludge production forecasts

Sludge source	Units	2010	2015	2020	2025	2031
Beckton STW and Riverside STW						
Beckton STW	tDS/d	248	304	320	332	350
Riverside STW	tDS/d	25	27	27	29	30
Total Beckton STW & Riverside STW	**tDS/d**	**273**	**331**	**347**	**361**	**380**
Crossness STW and Long Reach STW						
Crossness STW	tDS/d	165	178	191	205	215
Long Reach STW	tDS/d	72	76	81	85	90
Total Crossness STW & Long Reach STW	**tDS/d**	**237**	**254**	**272**	**290**	**305**

Note: Figures in Table 3.3 are design throughputs which include a peak factor to allow for variability in sludge production and plant availability.

3.3 Sludge treatment facilities

3.3.1 Beckton and Crossness STWs

(i) Sludge treatment processes

As shown in Table 3.4, most sludge produced at Beckton STW and Crossness STW is thickened and then passed to Sludge Powered Generators (SPG) for dewatering and combustion (mass-burn incineration). The residual ash is collected and either recycled or disposed. The SPGs were constructed by a joint venture between Lurgi and Amec and were commissioned in 1998.

Both SPGs have similar processes: thickened raw sludge from the sewage treatment processes is first dewatered using plate filter presses and then burnt in fluidised bed furnaces with energy recovery (steam turbine), ash recovery and flue gas treatment (including further ash and heavy metal recovery systems). Resulting liquid effluents are sent to the STW inlet works for treatment.

Currently, neither of the SPGs can operate at maximum capacity due to bottlenecks within the sludge treatment and handling processes. At Crossness STW, there is an additional issue with discrepancies between actual and design calorific values of the feedstock. It is expected that the existing SPGs at Beckton STW and Crossness STW will require refurbishment and / or modification to optimise their capacities. This is issue is discussed in Section 5.2.

Due to the lack of incinerator capacity at each STW, lime treatment has been installed as a short term measure to provide additional sludge treatment capacity. The product, limed sludge cake is then recycled to agriculture. TWUL reports increasing difficulties in finding farmers who are willing to take the large quantities of limed sludge cake produced at each site due to the current variable product quality. This, together with the high operating costs associated with lime treatment (chemical and cake transport costs) mean that TWUL does not consider this a sustainable treatment option for the long term. In its comments on the Sludge Strategy and SEA the EA has agreed that lime treatment should not be considered as a longer-term primary treatment option for sewage sludge.[7]

[7] EA response, as reported in 'Summary of consultation responses on Thames Water's draft Strategic Proposals for Sludge Management (Sludge Strategy) and the Entec SEA Environmental Report', provided by TWUL, November 2008.

The key parameters for each SPG as well as the design and actual throughputs are summarised in Table 3.4. As discussed below, the actual throughputs are lower than the theoretical design values.

Table 3.4: Beckton STW and Crossness STW SPG – Key Characteristics

Process stage	Units	Beckton STW	Crossness STW
Raw sludge dewatering			
Dewatering plate filter presses	Nr	8	4
Design dry solids content in cake	%DS	32	32
Average achieved dry solids content in cake	%DS	26.8	30.4
Nr of raw cake storage silos	Nr	3	2
Raw cake incineration			
Number of incinerator lines	Nr	3	2
Design capacity per stream (maximum)	tDS/h	4.5	3.5
Design SPG capacity (annual average)	tDS/d	240	110
Actual SPG capacity (annual average)	tDS/d	170	85
Steam turbines	Nr	1	1
Ash content (percentage by weight of total DS)	%	19.4	20.2
Net calorific value of raw sludge	MJ/kg DS	20.85	19.50
Power generation (average) at actual SPG capacity	MW	7.9	3.9

Notes: Each incinerator line also includes dedicated ash and heavy metal recovery systems as well as flue gas scrubbing. Design SPG capacity takes account of 2 weeks planned shutdown each year and "normal" availability of 95%.

(ii) Beckton STW – space constraints

Beckton STW is a relatively congested site with limited space available for additional plant and process units.

As described in Section 3.5, several projects are currently on-going or proposed for construction in AMP5 including:

- Thames Gateway Water Treatment Plant – on-going. Under construction on land to the east of the existing SPG as well as land to the south of the Old Power House (for bio-diesel engines).
- Lee Tunnel and Beckton STW upgrade, to be implemented by June 2014. Will require remaining land between the existing digesters and the Thames Gateway Water Treatment Plant (for tunnel construction as well as permanent tunnel headworks structures including pumping station) as well as land within and to the west of the existing sewage treatment plant.

Land adjacent to the existing SPG would be sufficient for construction of a similar sized structure to the existing SPG. However, the area is crossed by existing services infrastructure including lines to the blower house and overhead power cables which would need to be diverted.

Options including enhanced digestion would require land for additional thickening plant, thermal pre-treatment processes, gas-holders, CHP engines and dewatering plant – all preferably located close to the existing digesters in order to reduce gas and sludge pipework requirements.

An area of some 5,000 m^2 exists between the SPG and the existing digesters (adjacent to the Old Power House and a workshop building) and this, combined with land around the existing SPG, would be sufficient for options where only part of total sludge production would be digested with the rest treated in the existing incinerator. If all the sludge generated at Beckton STW was to be treated using enhanced digestion then this would require additional land including the triangular area immediately to the west of the Old Power House. It is likely that such an option would result in longer sludge and gas pipelines which would be less efficient in terms of both capital and operational pumping costs.

Appendix H includes site plans which show the existing situation at the works, proposed wastewater treatment extensions and other works under the Thames Tideway Quality programme, and remaining land available for any SAR options.

(iii) Crossness STW - space constraints

Crossness STW has limited space available for new plant and process units. Enhancements to existing wastewater treatment processes proposed for AMP 5 will utilise space on site.

At Crossness STW there is land adjacent to the existing SPG which would be sufficient for construction of a similar structure to the existing SPG or enhanced digestion plant. However, the area includes the old disused sludge lagoons which are considered to be contaminated land. There have also been underground fires at this location due to the combustion of components of made ground (e.g. screenings and rags) and this hazard would need to be removed as part of a proposed scheme. The only other area suitable for further development is the strip of land immediately to the north of the existing sludge buffer tanks, east of the existing digesters which has an area of some 2,500 m^2.

Appendix H includes site plans which show the existing situation at the works, proposed wastewater treatment extensions and remaining land available for any SAR options.

3.3.2 Riverside STW

A number of the options considered in this report include transfer of raw sludge from Beckton STW for treatment at Riverside STW.

The sludge from Riverside STW is currently transported by pipeline to Beckton STW sewage works where it is incinerated, however, the Riverside STW site previously provided on-site digestion and has four digesters (effective volume 5,100 m^3, each) which are currently disused as well as two older digesters currently used for liquid storage.

TWUL is currently seeking planning permission for an enhanced digestion plant for Riverside STW which will have a capacity of 110 tDS/d. Further information on this scheme is provided in Section 3.5.2.

Based on a review of the layout plan for the site we consider that there would be sufficient space for an additional enhanced digestion plant (similar to the one already proposed for construction by 2011) as well as, if required, an incinerator. However, construction of the latter structure would probably require relocation of the overhead power cables running across the southern part of the STW site.

3.3.3 Long Reach STW

A number of the options considered in this report include transfer of raw sludge from Crossness STW for treatment at Long Reach STW.

Long Reach STW is located on the south side of the Thames Tideway just to the west of the Littlebrook power station and the Dartford Crossing.

Long Reach STW has a sludge treatment centre which is able to receive liquid imports from other works. The sludge treatment plant comprises thickening, conventional anaerobic digestion, CHP, dewatering and cake storage bays. The cake storage bays are also used for the temporary storage of limed cake from Crossness STW. Eight digesters, each with an effective volume of 2,295 m3 (total effective digester volume 18,400 m^3), are currently used.

Thames Water has considered the feasibility of providing enhanced digestion at Long Reach STW to treat sludge produced by Long Reach STW as well as a proportion of the sludge produced at Crossness STW.

Based on a review of the layout plan for the site we consider that there would be sufficient space for an enhanced digestion plant capable of treating sludge produced at Long Reach STW as well as up to half of the sludge produced by Crossness STW, including additional digesters if required. Provision of an incinerator for digested sludge is considered possible from a space perspective though construction and subsequent operational access would be complicated by the congested nature of the site.

3.3.4 Deephams STW

At the VM 1 workshop it was suggested that Deephams STW might be considered as an alternative location for providing additional treatment capacity for sludge produced at Beckton STW on the grounds that there is an existing pipeline between Beckton STW and Deephams STW.

However, this study has not assessed any options involving transfer of sludge for treatment at Deephams STW. The reasons for this are that transfer options including Deephams STW are likely to be both significantly more expensive (longer pipeline with a number of known defects) and have potentially higher environmental impact (including additional treated effluent discharges to a much smaller water course – the River Lee) than the equivalent options involving Riverside STW. Hence, only transfer options involving Riverside STW are assessed in this study. Section 5.3.1 provides further justification for this approach.

3.4 Existing Beckton STW to Riverside STW pipeline

This section describes the existing pipeline that could potentially be used for transferring sludge between Beckton STW and Riverside STW for treatment.

Potential sludge transfer options, using this pipeline or other options such as road haulage and river transport via barge are evaluated in Section 6.4.

Currently, sludge is pumped from Riverside STW, via a twin pipeline, to the inlet works at Beckton STW for incineration at the Beckton site. The twin pipeline was constructed in 1968-1970 and was originally part of a longer transfer main from Deephams STW to Beckton STW. Each pipe is 305 mm (12 inch) internal diameter and is made of welded steel. The main is approximately 7km in length.

Since construction various sections have been repaired or replaced (e.g. due to diversions for the Channel Tunnel Rail Link (CTRL)). The pipeline is in daily use.

Under the proposed enhanced digestion project at Riverside STW flow through this pipeline will be reversed in order to transfer sludge from Beckton STW to Riverside STW for digestion. As a result the volume of liquid sludge pumped through the pipeline each day will increase (the anticipated maximum flow rate will be 72 l/s, a blend of SAS and primary sludge of between 1.25 – 2 %DS). The twin pipes are used on a duty/standby basis to allow for maintenance.

The route of this pipeline is through highly developed areas, crossing the A13 dual-carriageway, a major railway and dense industrial areas. The CTRL scheme required diversions of the existing pipelines over most of the run between Goresbrook and Riverside STW.

3.5 Other on-going projects

3.5.1 Thames Tideway Project

The Thames Tideway Quality Improvements (TTQI) project is a major programme of work including both tunnel construction and STW upgrades in order to improve river water quality in the Thames Tideway.

A main tunnel (the Thames Tunnel) and a shorter link from Abbey Mills (the Lee Tunnel) will be constructed through London in order to intercept Combined Sewer Overflows (CSOs) and provide storage for the storm water discharged from the CSOs. The contents of the tunnels will then be pumped to Beckton STW when the storm flows abate.

Sewage treatment facilities at five Thames Tideway STWs, including Beckton STW and Crossness STWs, will also be upgraded. The main drivers for these schemes are population growth and compliance with statutory consents.

Construction of the Lee Tunnel and upgrades of Beckton and Crossness STWs are required by June 2014 whilst the Thames Tunnel will be constructed by 2020.

(i) Beckton STW Upgrade and tunnel construction works

Beckton STW is to be extended in order to provide additional treatment capacity for storm water and meet higher consent standards required by the Environment Agency as well as providing for the projected population increase in London up to 2021. A planning application for the Lee Tunnel and Beckton STW upgrade works was submitted on 30th May 2008 and is due to be determined in early 2009.

The Beckton STW upgrade will enable the existing maximum flow to full treatment (FFT) at Beckton STW to be increased from 1420 Ml/day to 2336 Ml/day; an increase of approximately 60 per cent (including capacity for an expected population increase of 10 per cent by 2021).

The Beckton STW upgrade is split into a number of component schemes with the main projects being:

- Refurbishment of the existing sewage treatment works to improve its capacity and effectiveness as well as provision of additional odour control facilities (TWUL project 8QLG).
- Extension of the works to include new preliminary, primary and secondary treatment facilities (activated sludge and final settlement tanks), additional SAS thickening plant and additional odour control facilities (TWUL project 8W8F).

It is expected that the new extended facilities will treat 29% of the total flow to the works.

On completion, the extended works will be required to treat flows up to 2 336 Ml/d and will be subject to tighter consents as follows:

BOD:SS: Amm.N= 18:45:2.5 (95%-ile, >15^{o}C)
BOD:SS: Amm.N= 18:45:3.5 (95%-ile, 13-15^{o}C)
BOD:SS: Amm.N= 18:45:5.0 (95%-ile, <13^{o}C)
BOD:SS: Amm.N= 54:108:13 (Upper tier limits, >15^{o}C)
BOD:SS: Amm.N= 54:108:15.5 (Upper tier limits, 13-15^{o}C)
BOD:SS: Amm.N= 54:108:20 (Upper tier limits, <13^{o}C).

If, at a later date, the works is subject to even tighter consents including a total nitrogen standard, then the new works will receive 34% of the total flow to the works inclusive of return liquors. At that time, the new secondary treatment facilities will be extended further to include additional aeration lanes and final settlement tanks.

(ii) Crossness STW Upgrade

Crossness STW is currently consented to treat flows of up to 777.6 ML/d although it was originally designed to receive flows of up to 982 ML/d. In the future, the works will be required to treat flows of up to 1,117.9 ML/d and will therefore require extensions to existing processes.

The Crossness STW upgrade, which was granted planning permission on 5th November 2008, will include a new inlet pumping station, preliminary, primary and secondary treatment facilities (activated sludge and final settlement tanks) as well as an additional sludge thickening plant (TWUL project 1X8F).

It is expected that the new extended facilities will operate in parallel with the existing treatment stream and treat 38% of the total flow to the works.

On completion, the extended works will be subject to tighter consents as follows:

BOD:SS: Amm.N= 18:45:2.5 (95%-ile, >15^{o}C)
BOD:SS: Amm.N= 18:45:3.5 (95%-ile, 13-15^{o}C)
BOD:SS: Amm.N= 18:45:5.0 (95%-ile, <13^{o}C)
BOD:SS: Amm.N= 54:108:13 (Upper tier limits, >15^{o}C)
BOD:SS: Amm.N= 54:108:15.5 (Upper tier limits, 13-15^{o}C)
BOD:SS: Amm.N= 54:108:20 (Upper tier limits, <13^{o}C).

If, at a later date, the works is subject to even tighter consents including a total nitrogen standard, then the new works will receive 48% of the total flow to the works inclusive of return liquors. At that time, the new treatment facilities will be extended further to included additional PSTs and aeration lanes as well as FSTs.

Sludge generated from the new treatment stream will be pumped to a new raw sludge thickening plant prior to blending with SAS and other sludge from existing wastewater treatment processes. Three existing SAS thickeners will be replaced with larger units.

(iii) Riverside STW Upgrade

At Riverside STW, in order to achieve compliance with the Urban Wastewater Treatment Directive (UWWTD) and the resulting EA discharge limits, an upgrade to the existing works is proposed to achieve higher water quality in the sewage effluent discharged. The Environment Agency requires that the upgrade is constructed and operational by Spring 2012. A planning application has been submitted for the Blower House (application reference U0004.08) and a Flood Defence Consent application has been made to the Environment Agency for the remainder of the scheme.

3.5.2 Riverside Enhanced Digestion

TWUL is currently seeking planning permission for an enhanced digestion plant for Riverside STW which will have a capacity of 110 tDS/d (TWUL scheme 9RTG/A1). The planning application is due to be determined in early 2009.

The reference design for this project indicates that the new plant will include thermal hydrolysis (two streams, each 55 tDS/d) and that the four disused digesters will be brought back into service.

To assist with the capacity shortfall at Beckton STW, it is proposed to use the existing pipeline to transfer surplus sludge from Beckton STW to Riverside STW so that the full 110 tDS/d treatment capacity is used.

In addition to the installation of a thermal hydrolysis plant and refurbishment of the existing digesters, the scope of work for scheme 9RTG/A1 is understood to include construction of new roads, drainage facilities and tanker discharge bays as well as covering of channels and provision of odour control.

3.5.3 Thames Gateway Water Treatment Plant (Beckton)

TWUL is currently constructing the Thames Gateway Water Treatment Plant at Beckton STW, a desalination plant which can treat up to 140 ML/d of brackish water abstracted from the Thames Tideway and will be used during periods of peak water supply demand in London.

As part of this project TWUL is installing bio-diesel fuelled engines to provide power for the desalination process. TWUL currently proposes that these engines will be run throughout the year in order to provide power for sewage treatment processes. The engines are expected to produce some 10 MW of waste heat, 7 MW of which is associated with hot oil (180^{o}C) and the remainder with low pressure hot water.

It may be feasible to re-use this waste heat in any future sludge treatment process – for example, to provide heat for steam generation for the thermal hydrolysis process. However, it can not be guaranteed that the bio-diesel engines will be operated continuously over the long term and hence analysis of sludge treatment options considered in the SAR will assume that an alternative source of heat energy will be required.

3.6 Environmental background

Tables summarising the environmental background for each site are presented in Appendix J of this report. Specific environmental issues identified during evaluation of the options are presented in Section 6.10.

4 Solution Requirements

4.1 Design horizon

TWUL has indicated that any new sludge treatment units, along with the existing SPGs, will need to have sufficient combined capacity to treat sludge generated within the East London area up to 2031.

The design horizon required for the PR09 business plan submission to Ofwat is normally 2021. However, given the size of investment required to provide additional sludge treatment capacity at Beckton and Crossness STWs and the long lead-in times for such projects, TWUL considered it prudent to use a design horizon of 2031 (2021 plus 10 years) for this study.

4.2 Required implementation timescale

Additional sludge treatment capacity is required at each site to meet current shortfalls. Temporary solutions are in place (e.g. lime treatment) or permanent solutions are being implemented (subject to obtaining planning permission, provision of enhanced digestion at Riverside STW which will also treat sludge from Beckton STW) which will provide sufficient capacity until the end of AMP 5. It is anticipated that additional capacity will be needed at the end of AMP 5 as a result of further growth and to enable major overhaul of the existing SPGs at each site which is likely to be required in AMP 6, when both SPGs will be approaching 20 years old.

Hence, a requirement for all options is that planning, design and construction of the preferred option can occur by the end of AMP 5 with completion and commissioning achieved by year 1 of AMP 6. Key issues for an implementation programme will be the time taken to obtain planning permission and the time needed to construct the works.

It is probable that options involving additional incinerator capacity will face more resistance during the planning process and hence may take longer to achieve planning permission. Furthermore, the time to procure and commission a new incinerator or dryer option is likely to be longer than that for an enhanced digestion only plant – typically three to four years compared to two to three years for enhanced digestion – largely due to the relative scale and complexity of incinerator and dryer schemes to procure, construct and commission.

4.3 Sludge production and treatment capacity

Table 4.1 summarises current sludge treatment capacities, forecasted sludge production and estimated shortfalls in treatment capacities. Figures were derived from discussions with TWUL staff and documents provided by TWUL.

Production forecasts for each site include a headroom allowance for both Beckton STW and Crossness STW from 2015. This headroom will serve two purposes:

- It is anticipated that major refurbishment / modification of the existing SPGs will require each furnace to be taken out of service for up to a year – the headroom provided for new facilities available in 2015 will enable total capacity to be maintained for the duration of these rehabilitation works.

- Headroom in the future is required to ensure that sufficient capacity is available for unplanned maintenance of incinerator lines.

As noted previously, sludge from Riverside STW is currently pumped to the inlet works of Beckton STW and treated at Beckton STW. TWUL is currently seeking planning permission for an enhanced digestion plant at Riverside STW (capacity 110 tDS/d), which if approved, would be implemented by 2010/11 enabling Riverside STW sludge to be treated on site.

To assist with the capacity shortfall at Beckton STW it is proposed to use the existing pipeline to transfer surplus sludge from Beckton STW to Riverside STW so that the full 110 tDS/d treatment capacity is used.

A similar scheme, involving transfer of Crossness STW sludge to Long Reach STW, for treatment in a proposed enhanced digestion plant, is considered in this SAR report. As noted previously Long Reach STW currently provides conventional digestion for indigenous sludge and some local imports. As a short-term measure, it also provides temporary storage for limed cake from Crossness STW.

Table 4.1: Sludge production forecasts

Sludge source	Units	2010	2015	2020	2025	2031
Beckton STW						
Beckton STW	tDS/d	248	304	320	332	350
Riverside STW	tDS/d	25	27	27	29	30
Sub-total Beckton STW & Riverside STW	**tDS/d**	**273**	**331**	**347**	**361**	**380**
Proposed headroom	tDS/d		50	50	50	50
Total incl. headroom	**tDS/d**	**226**	**381**	**397**	**411**	**430**
Crossness STW						
Crossness STW	tDS/d	165	178	191	205	220
Long Reach STW	tDS/d	72	76	81	85	90
Sub-total Crossness STW & Long Reach STW	**tDS/d**	**237**	**254**	**272**	**290**	**310**
Proposed headroom	tDS/d		30	30	30	30
Total incl. headroom	**tDS/d**	**237**	**284**	**302**	**320**	**340**

5 Options Development

5.1 Process technology options

5.1.1 Process routes considered

This SAR focuses on options for delivery of the additional capacity required to be completed and commissioned for year 1 of AMP 6.

As noted in Section 2.3, TWUL's Sludge Technology Review identified the most appropriate 'process routes' to meet the needs of TWUL's company-wide Sludge Strategy. Each process route consisted of a combination of process technologies and a disposal route for the resulting treated sludge product.

Based on the findings of the Sludge Technology Review the process routes considered for this SAR are summarised in Table 5.1.

Table 5.1: Process Routes

Process Route	Ref	Final product/disposal
Enhanced digestion (thermal hydrolysis & digestion)	ED	Enhanced digested cake - recycled to agriculture
Drying of raw sludge cake	RCd	Dried sludge - recycled to agriculture
Enhanced digestion followed by conventional drying	EDd	
Incineration of raw sludge cake	RCI	Ash to landfill (or, where feasible, recycled)
Enhanced digestion followed by incineration	EDI	
Enhanced digestion followed by conventional drying and then incineration	EDdI	

The key characteristics of the process technology routes considered for this study are described in Sections 5.1.2 to 5.1.6.

The following process routes identified by the Sludge Technology Review were not considered for this SAR:

- Enhanced digestion (acid phase digestion or enzymic hydrolysis) – cake to agriculture.
- Raw sludge drying and gasification – ash to landfill.

Enhanced digestion using thermal hydrolysis was preferred over other forms of enhanced digestion using acid phase digestion or enzymic hydrolysis for the following reasons:

- thermal hydrolysis pre-treatment processes (THP) were considered to allow treatment of a wider range of sludge types, including sludge with a high SAS content as well as non-sewage sludge slurries which might be used in co-digestion.
- TWUL considered that thermal hydrolysis produced sludge with a lower nitrate content than that produced by enzymic hydrolysis.

- Thermal hydrolysis has a smaller land footprint than acid phase digestion or enzymic hydrolysis processes – an important consideration given the land constrains at both the Beckton and Crossness STWs.

The ‘raw sludge drying and gasification’ process route was not considered for this study because currently, technologies such as gasification are not utilised at full scale for wastewater sludge and therefore do not have a proven track record. Thus it is assumed that mass-burn incineration will continue to be the primary thermal destruction process option though gasification, and to a lesser extent, pyrolysis (due to the reduced disposal options for its char product), may be considered as options in the longer-term.

Future technology options – such as alternative treatment processes and co-treatment with alternative waste streams – are considered in outline for this study to ensure that, where feasible, the preferred options identified by the SAR for delivery in AMP 5 and AMP 6 do not preclude adoption of beneficial alternative processes at some later date.

A description of such alternative treatment processes and the potential for treatment of other waste streams is provided in Appendices L.1, L.2 and L.3.

5.1.2 Enhanced digestion (thermal hydrolysis and digestion)

In enhanced digestion, sludge undergoes pre-treatment to increase volatile matter destruction and hence increase the quantity of biogas produced and the power that can be generated using CHP engines.

Anaerobic digestion is commonly used worldwide for treatment of sewage sludge. Its efficiency, when assessed on the basis of destruction of volatile matter (VM) varies significantly depending not only on the operational parameters but also on the type and composition of sludge. The higher the VM destruction achieved then the lower the amount of solids to be disposed of and the higher the production of biogas.

The performance of anaerobic digestion can be substantially improved by pre-treatment processes which make the sludge (surplus activated sludge in particular) more amenable to digestion – thus greatly increasing solids destruction and biogas production. Increased degree of disinfection, improved sludge dewatering properties and lower odours are other benefits of some of these pre-treatment processes.

There are many types of pre-treatment methods which can be classified into biological, thermal, chemical, physical or combinations of these. Some pre-treatment methods are more effective than others. TWUL has carried out an extensive review of various pre-treatment processes as part of its Sludge Technology Review.

For the purposes of this study only Thermal Hydrolysis (e.g. as provided by Cambi) has been considered for enhanced digestion. This has the lowest area footprint of the various enhanced digestion technologies and therefore is the most likely to be able to fit within the existing STW sites.

Appendix L provides a description of enhanced digestion processes.

5.1.3 Conventional raw sludge drying

Conventional thermal dryers are able to reduce the water content of the sludge such that the dry solids content increases from 25% to more than 90%.

Drying of sludge, whether for use in agriculture or for use in co-firing in cement kilns and power stations, is energy intensive and hence is now usually combined with anaerobic digestion, such that the biogas can be used to fuel the dryer (as opposed to a CHP unit). The low energy value of the sludge compared with the primary fuel has discouraged the uptake of sludge as a fuel for co-firing in cement kilns and power stations.

Fewer raw sludge drying schemes are being implemented due the high energy requirement (and hence high opex) and the lower product quality (compared to digested dried sludge) which may lead to odour problems in recycled to agriculture.

5.1.4 Enhanced digestion and drying

For this process route the enhanced digested sludge is dewatered to a cake and then passed to a conventional thermal dryer to produce a sludge product with a solids content of 85% or more.

As noted in the previous section, the combination with anaerobic digestion allows biogas to be used to provide much of the energy required to heat the dryers and hence reduce the operating costs compared to raw cake drying. It is possible to use biogas in CHP engines and use the resulting heat in belt dryers. However, for drum dryers it would be necessary to use the biogas to heat the dryer directly. If the biogas is not used in a CHP engine the opportunity to earn ROCs for the generation of renewable power is lost.

Digested and dried sludge is a higher quality sludge product that can be recycled to agricultural land. Dried sludge also has lower transport costs than enhanced digested cake.

5.1.5 Raw sludge cake incineration

The existing SPGs at both Beckton and Crossness STWs provide mass-burn incineration of raw cake.

Both SPGs have similar processes: thickened raw sludge from the sewage treatment processes is first dewatered using plate filter presses and then burnt in fluidised bed furnaces with energy recovery (steam turbine), ash recovery and flue gas treatment (including further ash and heavy metal recovery systems). Resulting liquid effluents are sent to the STW inlet works for treatment.

Options evaluated under this study include rehabilitation and modification of the existing SPGs at Beckton and Crossness STWs as well as provision of additional raw sludge incineration capacity.

A number of incinerators currently under construction or in design elsewhere in the UK (for example, Duncrue St Incinerator in Belfast) incorporate a sludge drying stage upstream of incineration in order to increase the auto-thermic level of either raw or digested sludge cake. Hence, it has been assumed that any new incinerators proposed under this study would also include a drying stage (e.g. a thin film type dryer).

Appendix L provides a description of the incineration process assumed for additional sludge incineration options.

5.1.6 Enhanced digestion followed by incineration

This option combines enhanced digestion with mass-burn incineration of the digested cake. Two variants of this option have been proposed:

- Enhanced digestion followed by incineration in the existing SPG – adapted to accept digested cake
- Enhanced digestion followed by incineration in a new, purpose built, incinerator.

Provision of digestion (including enhanced digestion) upstream of the SPGs will reduce the calorific value of the incinerator feedstock and hence will usually require additional dewatering (including partial drying using ‘thin film’ type dryers) to ensure that it is still auto-thermic. Enhanced digestion does however offer benefits such as additional energy recovery in the digestion process which, under current legislation would be eligible for ROCs, as well as a reduction in the incinerator capacity required as a result of the additional destruction of volatile matter in enhanced digestion and subsequent reduction in the tonnage of feed sludge dry solids to the incinerator.

Incineration of enhanced digested sludge is being adopted for at least part of the feed for the proposed extensions to United Utilities’ Shell Green incinerator.

5.1.7 Enhanced digestion followed by conventional drying and then incineration

In section 5.1.6, it was assumed that any new incinerator plant would be likely to include a partial ‘thin film’ type drying stage to ensure autothermic conditions in the furnace even for enhanced digested feed stock.

However, in this option it is assumed that the enhanced digested sludge is thermally dried to 85% dry solids or greater using a conventional belt or drum type dryer. The dried sludge would then be incinerated in the SPG.

The advantage of this approach is that, in the event of incinerator down-time, it would be possible to export the relatively small (compared to enhanced digested cake) quantities of dried sludge for recycling to agriculture.

However, as noted previously, thermal drying is an energy intensive process and hence this process route would probably have the highest opex of all the process routes.

5.1.8 Key technical assumptions

The key technical assumptions supporting the sludge treatment process analysis and subsequent option appraisal are presented in Appendix B.

5.1.9 Market place / track record assessment

(i) Mass-burn incineration

There are a limited number of contractors that would have the necessary track record and capability to refurbish the existing SPGs at Beckton and Crossness STWs or provide new sludge incineration capacity. In Europe, the three firms with the most established track record are:

- Lentjes (previously known as Lurgi)
- Veolia OTV, and
- BAMAG (provided process data analysis and option costs for this SAR).

Lentjes, as Lurgi, designed and constructed the existing SPGs (in JV with AMEC) as well as the existing Duncrue St incinerator. However, their list of reference sites includes only one since the year 2000.

Veolia OTV has recently constructed the Northern Sludge Incineration Plant in St Petersburg. However, they have only constructed three incinerators since the year 2000 of which two were for sewage sludge. Veolia also won the contract for the Shell Green incinerator project, though, the incinerator itself is understood to have been designed by BAMAG.

BAMAG has recently constructed a number of sludge incinerators including the Southern Sludge Incineration Plant in St Petersburg and is currently working on new sludge incineration plants in Northern Ireland (Duncrue St – new stream and refurbishment of existing plant) and for United Utilities (Shell Green).

Thus, there is reasonable potential for competition in provision of new incineration capacity or refurbishment of the existing SPGs. For provision of a new incinerator it is likely that these technology suppliers would combine with any one of a number of civil contractors able to implement this type of project.

(ii) Enhanced Digestion (thermal pre-treatment with anaerobic digestion)

For the enhanced digestion option there are two key supplier types:

- 1st tier - main civil and process contractor, and
- 2nd tier suppliers of the thermal hydrolysis pre-treatment technology (Cambi AS and Veolia).

There are a number of main civil and process contractors that would be potentially capable of implementing the proposed schemes at Beckton and Crossness STWs though some will have a stronger track record than others (Interserve, GallifordTry/Imtech Process, Black & Veatch, etc – all have track records in enhanced digestion schemes). Such contractors are also those currently bidding for projects at the Tideway STWs as well as for TWUL's D&B frameworks and hence their relative capabilities and track records will already be well known to TWUL. In general, it is expected that, partly due to the current economic downturn, there could be increased competition between main contractors and this should ensure that their rates are competitive.

However, as noted previously, the large numbers of projects proposed could lead to a “seller’s market” in enhanced digestion plants with high demand reducing the number of competitors leading to increased capital costs for water companies. This lack of competition will be most pronounced at the 2nd tier plant supplier level.

The 2nd tier plant suppliers offering Thermal Hydrolysis processes are:

- Cambi AS – supplying the Cambi process
- Veolia - supplying the Biothelys process.

Cambi has installed over 15 plants for sewage sludge digestion in Europe over the last 10-years (and several more serving the waste treatment market), with a total capacity of nearly 900 tDS/d. These plants include the 100,000 tDS/year Davyhulme scheme currently being constructed for United Utilities.

In contrast, Veolia has only two, relatively small, operating plants in France (dating from 2004, the largest is less than 4 tDS/d), although Veolia has recently won a contract to provide a 10,000 tDS/year plant for Monza (Italy) and has been active in submitting budget prices for larger works in the UK – though Biothelys has not yet been selected for a UK scheme.

Hence, of the two processes Cambi has the greater track record in terms of size and numbers of plant. It should be noted that some of the problems associated with early Cambi plants, such as odour, have now been addressed and there is greater confidence in this technology - as evidenced by the selection of Cambi for the Whitlingham and Cottonvalley schemes for Anglian Water.

5.2 Assessment of existing SPG condition and upgrading options

Currently, neither of the SPGs at Crossness or Beckton can operate at maximum capacity due to ‘bottlenecks’ within the sludge treatment and handling processes. At Crossness STW, there is an additional issue with discrepancies between actual and design calorific values of the feedstock. It is expected that the existing SPGs at Beckton STW and Crossness STW will require refurbishment and / or modification to optimise their capacities.

As part of this SAR, BAMAG has carried out an assessment of the existing SPGs in order to identify any significant problems and recommend potential improvements.

The following are the main issues identified by BAMAG:

- The bag filter housing is subject to corrosion damage leading to excessive air leakage (about 30% of the total air flow). The leakage problem is exacerbated by the compressed air bag cleaning system. Due to the excessive air leakage the Induced Draft (ID) fans for each site run at maximum capacity. Whilst this problem does not prevent the safe operation of the SPGs it does constrain further increases in throughput.
- The furnaces were designed to receive cake with a dry solids content of 32%, however, the plate filter presses at each SPG are unable to achieve more than 26 – 27 %DS. This necessitates utilisation of supplementary fuel (natural gas).

BAMAG propose short–term improvements to the existing SPG as follows:

- minimising ingress of cold air to the flue gas system
- improvement to trace heating,

- reduction of cold bridges,
- reduction in pulse duration
- operating the bag house with higher inlet temperature

More comprehensive refurbishment of the plant should include:

- upgrading the plant to avoid ingress of air into the filter
- improvement to compartment covers
- doubling the thickness of insulation
- considering addition of small amounts of lime ($Ca(OH)_2$ into the front of the bag house to reduce condensation of sulphuric acid
- improvement of plant control and early detection of leakages by installation of oxygen measurement downstream of the boiler and a thermo couple downstream of the bag house.

BAMAG recommends that as a result of the proposed improvements to the bag filter housing at each SPG, overall SPG operation could be improved which could in turn allow throughput to be increased by some 0.5 tDS/hour per incinerator line at each site.

It is acknowledged that implementing such improvements would require extensive repair of the bag filter housing – requiring significant investment and complex planning - and thus is not considered to be a “quick fix”.

However, if this increased throughput could be achieved, BAMAG estimates that total throughputs of 3.5 tDS/h and 2.95 tDS/h per incinerator stream could be achieved for Beckton and Crossness SPGs, respectively. Assuming operating hours of 6700 h/year, the total annualised average capacity would be:

- 193 tDS/d at Beckton SPG, and
- 108 tDS/d at Crossness SPG[8].

The term RCI+ has been used in this report to describe process options which continue the current process at each SPG (raw cake incineration) but assume that modifications to the bag filter housing at each SPG result in improved throughputs.

At Beckton SPG, assuming a DS concentration in the cake of 27%, the combustion will be autothermic, however at Crossness SPG 536 000 m3/year (61 m3/h) of natural gas would be required even though the DS concentration in the cake is higher than at Beckton (28.5%).

To further increase the throughput of the existing incinerators, BAMAG considered two methods of increasing DS concentration in the sludge fed to the incinerators:

(a) install thermal dryers which would pre-dry all of the sludge cake to the required DS concentration

[8] i.e. for Beckton SPG, 3.5 tDS/h/treatment stream for 6700 hours/year gives a total (3 streams) annual SPG capacity of 70,350 tDS/year. Division by 365 days/year gives a total daily capacity, on an annual average basis, of 193 tDS/d for all three streams. Similarly for Crossness SPG, 2.95 tDS/h/treatment stream gives a total (2 streams) annual average capacity of 39,530 tDS/year – equivalent to a total daily capacity, on an annual (365 day) average basis, 108 tDS/d.

(b) install a thermal dryer which would dry a proportion of the sludge cake to, say 90%DS and blend this dried sludge with the wet cake to achieve about 32%DS in the feed to the incinerators.

Option (a) is thought to be impractical as it would require significant space and a complex mechanical transfer system to and from the dryers. In addition, the existing sludge silos are not suitable to be used for hot sludge. Option (b), is more feasible than option (a) because the dried sludge could be transferred pneumatically. However, BAMAG consider that achieving a consistent blend of dried sludge and wet cake would be difficult given the lack of space for effective blending. The integration of a dryer into an existing installation has not been undertaken previously. Mechanical systems and control integration would add significant complexity to any such project. On this basis, the project team decided not to consider installation of a dryer for either of the existing SPGs.

When considering various treatment options, a conservative approach was adopted and the capacities of the existing incinerators when used for mixed raw sludge were assumed to be lower than the potential capacities estimated by BAMAG:

- for Beckton SPG, 170 tDS/d and 190 tDS/d values were used for RCI and RCI+, respectively
- for Crossness SPG, 95 tDS/d and 105 tDS/d values were used for RCI and RCI+, respectively.

5.3 Location options

5.3.1 Beckton STW options

A number of the options considered in this report include transfer of raw sludge from Beckton STW for treatment at Riverside STW. This would maximise use of the enhanced digestion plant planned for construction at Riverside STW by 2011 and, for some options, would require additional enhanced digestion capacity to be built.

Furthermore, at the VM 1 workshop it was suggested that Deephams STW might be considered as an alternative location for providing additional treatment capacity for sludge produced at Beckton STW on the grounds that there is an existing pipeline between Beckton STW and Deephams STW.

However, this study has not assessed any options involving transfer of sludge for treatment at Deephams STW. The reasons for this are as follows:

- Riverside STW has an existing pipeline which is in use and therefore transfer issues are known. The pipeline to Deephams STW is significantly longer (20 km rather than 7 km) and it is considered likely that several sections will require rehabilitation before they can be brought into use (a description of this pipeline is included in Appendix E).
- Part of the existing Beckton to Deephams sludge main is going to be relined and used for transferring raw water from Stratford to the Lea Valley reservoirs.
- The capacity of the remaining existing pipelines to Riverside and Deephams STWs would be insufficient for most options hence additional transfer capacity will be required – either as an additional pipeline or road transport. As Deephams STW is further away both capital and operating costs associated with sludge transfer will be significantly higher. Furthermore, environmental impacts associated with construction of a pipeline in an urban area are likely to be greater for a Deephams option due to the greater pipe length.

- Deephams STW discharges to the River Lee whereas Riverside STW discharges further downstream on the Thames Tideway. Transfer of sludge to Deephams STW would increase the volume of treated sewage discharged to the River Lee. Whilst all discharges would meet EA quality consent requirements there is less dilution available in the River Lee than in the Thames Tideway and hence the potential environmental impacts may be greater.
- Riverside STW has space for the additional sludge treatment plant anticipated under the options considered in this study – hence there is less need to consider an alternative location.

Hence, by inspection, transfer options including Deephams STW are likely to be both significantly more expensive and have potentially higher environmental impact than the equivalent options involving Riverside STW. Hence, only transfer options involving Riverside STW are assessed in this study.

Furthermore, all options assessed provide some or all of the total sludge treatment at Beckton STW. Hence, no options have been assessed that transfer all sludge away from Beckton STW for treatment elsewhere as this would entail:

- high capital costs including provision of new sludge treatment and transfer infrastructure,
- high operating costs including transfer costs (pumping power or transport costs),
- additional liquor treatment costs (on the grounds that other STWs will be smaller and hence less able to absorb additional biological loads on the sewage treatment processes - thus additional liquor treatment capacity will need to be provided)
- insufficient additional land is available at other STWs in the vicinity.
- environmental impact of transfer if by road as well as construction of new treatment facilities.
- it is preferable to treat sludge at source (‘Proximity rule’).

Hence, only the following location combinations have been assessed:

- All additional capacity provided at Beckton STW, with design headrooms of 50 tDS/d at Beckton STW and strategic headroom of 70 tDS/d at Riverside STW.
- Additional capacity provided at both Beckton STW and Riverside STW with design headroom of 50 tDS/d at either Beckton STW or Riverside STW.

Options for transferring sludge are assessed in Section 6.4.

5.3.2 Crossness STW options

All options assessed provide some or all of the total sludge treatment at Crossness STW. Hence, no options have been assessed that transfer all sludge away from Crossness STW for treatment elsewhere. The justification for this is the same as that cited for not relocating all sludge treatment from Beckton STW.

A number of the options considered in this report include transfer of raw sludge from Crossness STW for treatment at Long Reach STW.

Hence, only the following location combinations have been assessed:

- All additional capacity provided at Crossness STW, with design headroom of 30 tDS/d at Crossness STW.
- Additional capacity provided at both Crossness STW and Long Reach STW with design headroom of 30 tDS/d at either Crossness STW or Long Reach STW.

5.3.3 Other locations

In principle, it would be possible to locate additional sludge treatment capacity at locations other than existing TWUL STWs. In practice, such an option would present a number of practical difficulties, including the following:

- Transfer of untreated sludge to the new location – depending on location this could be achieved by new transfer pipeline, barge or road transport.
- Transport of treated sludge product for recycling or disposal – depending on location this could be achieved by barge or road transport. Whilst this applies to all potential locations, including existing STWs, any new location would have to have suitable transport links.
- Treatment of return liquors arising from dewatering of sludge, effluent from flue gas treatment and other processes. If located at a STW then there is the potential for these to be treated by the existing wastewater treatment works. At a new site a dedicated liquor treatment plant would be required which would then need to have its own discharge consent.
- Land ownership and consents – to provide a dedicated sludge treatment facility on a non-operation site would require land ownership to be obtained and submission and approval of additional regulatory consents. Given the timeframe for providing the additional treatment capacity, there is a high risk that the programme to deliver the capacity would not be met due to the potential for protracted landownership and consent negotiations. Furthermore, unless allocated for sludge treatment use in Development Plan Documents, the development of new facilities outside an existing STW is likely to be contrary to the Development Plan.

It is considered that sufficient land exists at TWUL's existing STW assets – either at Beckton STW and Crossness STW or at other (relatively) near STWs. Hence, options including other, non-STW, locations have not been proposed for this SAR.

5.4 Selection of the 'Long List' options

The Long List options were identified prior to the VM 1 workshop. At the VM 1 workshop, the Long List was appraised and less feasible options were discarded in order to derive a Short List of options for further evaluation.

This section describes how the Long List of options was derived.

5.4.1 Identification of potential options

(i) Option matrices

For the purposes of the VM 1 workshop, all the potential process options (described in Section 5.1) were split into two categories, as follows:

- **'Existing'**: Treatment process options for the existing sludge production currently treated using the SPGs
- **'Growth'**: Treatment process options for the additional sludge expected to be produced at each STW due to growth in population served and stricter treated sewage discharges standards **(prefix 'G' for growth)**. This stream also includes current sludge production which exceeds the capacities of the existing SPGs and is therefore treated with lime.

Table 5.2 present the 'Option Matrix' for each STW which indicates the theoretical process route combinations or options for the 'Existing' and 'Growth' sludge treatment streams. The process combinations selected for the Long List are indicated by 'LL'. The reasons for selection of these process combinations are presented in the following sections.

Table 5.2: Matrix showing potential option combinations for Beckton and Crossness STWs

'Existing' treatment stream	**'Growth' stream at Beckton or Crossness**						**'Growth' stream at Riverside or Long Reach**			
	RCI	RCd	ED	EDd	EDI	EDdI	ED	EDd	EDI	EDdI
RCI	LL		LL	LL	LL		LL		LL	
RCI+	LL		LL	LL	LL		LL		LL	
RCd										
EDI					LL				LL	
EDdI										
ED			LL				LL			
EDd				LL						

Key

RCI	Raw cake incineration
RCI+	Raw cake incineration (including optimisation of existing SPG throughput)
RCd	Conventional drying of raw sludge cake
EDI	Enhanced digestion followed by incineration
EDdI	Enhanced digestion followed by conventional drying and then incineration
ED	Enhanced digestion (thermal hydrolysis & digestion)
EDd	Enhanced digestion followed by conventional drying
LL	Option combination selected for Long List

(ii) Basis for selection of Long List options

The combination options in Table 5.2 were evaluated qualitatively in order to reduce the large number of possible combination options to a list of potentially more feasible options for inclusion in the Long list.

It can be seen that similar process route combinations were selected for the Long List for both Beckton STW and Crossness STW through the scale and cost of each option would vary for each site.

The basis for selecting the Long List options is described by process route option for the Existing stream.

Raw sludge incineration (RCI)

Process routes RCI and RCI+ are similar – both consist of raw sludge incineration. However, RCI+ assumes that modifications are made to the existing process (for example, improvements to the bag filters as identified by BAMAG) to optimise throughput, thus reducing the capacity required for the new additional process stream.

As both Beckton and Crossness already have existing raw sludge incinerators it was considered reasonable to include most combinations involving process routes RCI and RCI+ in the Long List of options. These options assume that the life of the existing incinerator stream can be prolonged beyond the beginning of AMP6 though overhaul of key process equipment.

The **exceptions** to this approach were:

- options involving raw cake drying (RCd) for the additional sludge (Growth) stream. In general, if a dried product is required then digestion prior to drying is usually the lower opex solution – particularly as there would not be any biogas production with this option. The Sludge Technology Review reports that enhanced digestion and drying (EDd) also has a lower opex and whole life cost than RCd.
- Options whereby the existing SPG was replaced by an alternative process for the 'Existing' stream and yet a new RCI plant was constructed for the 'Growth' stream. It was considered by the workshop that this option would not be logical as the existing SPG can be rehabilitated to prolong its operational life.
- combinations involving EDd and EDdI at Riverside and Long Reach STWs as these were considered to be relatively less feasible (due to large footprint and greater capex) than ED and EDI at those locations.

Raw sludge drying (RCd)

Combinations involving raw cake drying (RCd), for the whole of the existing treatment stream, were rejected on the following grounds:

- There is a limited market for dried raw sludge for agricultural recycling. There are doubts as to whether the product can achieve enhanced treated standards on a consistent basis and furthermore it can be odorous when stockpiled and it has a high nitrate concentration.
- Decommissioning the existing incinerator and provision of a dedicated dryer would involve a large capital investment for little if any opex saving.
- If a raw dried product is required (e.g. for use as a supplementary fuel by 3rd parties for power generation) then digestion prior to drying is usually the lower opex solution due to energy recovery in the enhanced digestion stage. Hence, EDd would be implemented rather than RCd.

Enhanced digestion, with conventional drying followed by thermal destruction (EDdI)

All combinations involving EDdI were rejected on the grounds of high capex and opex compared to, say EDI or EDd options. Given that the sludge was intended for combustion the additional flexibility provided by a conventional dried product (cheaper agricultural recycling if not incinerated) did not justify the significant additional capital and operating cost incurred.

Furthermore, this process was considered to carry greater operational risk (several complex processes operated in series).

Enhanced digestion, with and without drying

All combinations involving enhanced digestion and decommissioning the existing SPG (ED and EDD) would represent a major change in treatment approach at both Beckton and Crossness. Space could be a limiting factor in provision of enhanced digestion for the whole treatment stream.

There are numerous possible combinations of ED, EDI and EDd at different locations that could be selected from the matrix of potential options. It was considered logical to select those options where the same process routes were adopted for both the 'Existing' and 'Growth' treatment streams on the basis that if a new process route (i.e. not RCI) was cost effective for the 'Existing' treatment stream then it would probably be cost effective for the 'Growth' stream as well.

5.4.2 Long list options

Based on the above selection process, Table 5.3 shows the Long List options that were proposed for consideration at the VM 1 workshop.

Table 5.3: Long List options appraised at VM 1 Workshop

Option ref	Process Options		Beckton STW option locations		Crossness STW option locations	
	Existing	Growth	Existing	Growth	Existing	Growth
1.0	RCI	RCI	Beckton	Beckton	Crossness	Crossness
1.1	RCI+	RCI	Beckton	Beckton	Crossness	Crossness
2.0	RCI	EDI	Beckton	Beckton	Crossness	Crossness
2.1	RCI+	EDI	Beckton	Beckton	Crossness	Crossness
2.2	RCI	EDI	Beckton	Riverside	Crossness	Long Reach
2.3	RCI+	EDI	Beckton	Riverside	Crossness	Long Reach
3.0	EDI	EDI	Beckton	Beckton	Crossness	Crossness
3.1	EDI	EDI	Beckton	Riverside	Crossness	Long Reach
4.0	RCI	ED	Beckton	Beckton	Crossness	Crossness
4.1	RCI+	ED	Beckton	Beckton	Crossness	Crossness
4.2	RCI	ED	Beckton	Riverside	Crossness	Long Reach
4.3	RCI+	ED	Beckton	Riverside	Crossness	Long Reach
5.0	ED	ED	Beckton	Beckton	Crossness	Crossness
5.1	ED	ED	Beckton	Riverside	Crossness	Long Reach
5.2	ED	ED	Beckton	Riverside	Crossness	Long Reach
6.0	RCI	EDd	Beckton	Beckton	Crossness	Crossness
6.1	RCI+	EDd	Beckton	Beckton	Crossness	Crossness
7.0	EDd	EDd	Beckton	Beckton	Crossness	Crossness

5.5 Selection of the 'Short List' options

The Long List options were appraised at the VM 1 workshop in order to select the Short list of options. The appraisal was carried out by scoring options against objectives and sub-objectives agreed amongst the participants at the VM 1 workshop. Further details on the appraisal methodology are provided in Appendix A of this report.

The overall option scores for each objective for both Beckton STW and Crossness STW are presented in Table 5.4. The detailed scores for each option (at objective and sub-objective level) are presented in the VM 1 Optioneering Report[9].

It was not possible at the VM 1 stage to derive overall scores for the 'Economy' and 'Stakeholder preference' objectives – hence these objectives are excluded from Tables 5.4. However, for this preliminary option screening stage this was not considered to be a significant obstacle to deriving the Short List of options for appraisal at VM 2.

Table 5.4 was then used to eliminate the worst performing options overall – with the remaining options included within the Short List for VM 2. Options involving drying (i.e. options 6.0, 6.1 and 7.0) were rejected based on their relatively low scores. All other process technologies were taken forward to the Short list. Some options were taken forward even where the scores were relatively low (i.e. options 2.0, including sub-options, and 3.0), as it was known that there was interest from other TWUL and external stakeholders.

The Short list of options (and main sub-options) was then defined in greater detail immediately following the workshop and the results are presented in tables 5.5 and 5.6 for Beckton STW and Crossness STW options, respectively.

It should be noted that in Table 5.6, the total design capacities quoted for Long Reach STW options include the full Design Capacity at Long Reach (including Long Reach STW sludge) – not just the design capacity required for Crossness STW sludge.

[9] East London Additional Sludge Treatment Capacity, 6QWG Strategic Alternatives Review, VM 1 Optioneering Report, Mott MacDonald, August 2008.

Table 5.4: VM 1 Workshop scores by objective

Beckton STW Options

Option	1.0	1.1	2.0	2.1	2.2	2.3	3.0	4.0	4.1	4.2	4.3	5.0	5.1	5.2	6.0	6.1	7.0
Process	RCI	RCI+	RCI	RCI+	RCI	RCI+	EDI	RCI	RCI+	RCI	RCI+	ED	ED	ED	RCI	RCI+	EDD
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	RCI	EDI	EDI	EDI	EDI	EDI	ED	ED	ED	ED	ED	ED	ED	EDD	EDD	EDD
Location	Beckton	Beckton	Beckton	Beckton	Riverside	Riverside	Beckton	Beckton	Beckton	Riverside	Riverside	Beckton	Riverside	Riverside	Beckton	Beckton	Beckton
Objectives																	
Constructability	+	+	-	-	-	-	- -	0	0	0	0	0	0	0	-	-	- -
Technology	+	+	-	-	-	-	-	+	+	+	+	+	+	+	0	0	- -
Operations	0	0	-	-	-	-	-	0	0	0	0	0	0	0	- -	- -	- -
Safety	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Integration	0	0	+	+	+	+	+	+	+	+ +	+ +	+	+ +	+ +	-	-	-
Economy																	
Environment	-	-	-	-	-	-	-	0	0	0	0	0	0	0	- -	- -	- -
Stakeholder Preferences	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Overall Score	+	+	-	-	-	-	-	+	+	+	+	+	+	+	- -	- -	- -

Crossness STW Options

Option	1.0	1.1	2.0	2.1	2.2	2.3	3.0	4.0	4.1	4.2	4.3	5.0	5.1	5.2	6.0	6.1	7.0
Process	RCI	RCI+	RCI	RCI+	RCI	RCI+	EDI	RCI	RCI+	RCI	RCI+	ED	ED	ED	RCI	RCI+	EDD
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	RCI	EDI	EDI	EDI	EDI	EDI	ED	ED	ED	ED	ED	ED	ED	EDD	EDD	EDD
Location	Crossness	Crossness	Crossness	Crossness	Long Reach	Long Reach	Crossness	Crossness	Crossness	Long Reach	Long Reach	Crossness	Long Reach	Long Reach	Crossness	Crossness	Crossness
Objective																	
Constructability	+	0	-	-	-	-	- -	0	0	0	-	0	0	0	-	-	- -
Technology	+	+	-	-	-	-	-	+	+	+	+	+	+	+	0	0	- -
Operations	0	0	-	-	-	-	-	-	-	0	0	0	0	0	- -	- -	- -
Safety	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Integration	0	0	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-
Economy																	
Environment	-	-	-	-	- -	-	-	0	0	-	0	0	0	0	- -	- -	- -
Stakeholder Preferences	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
Overall Score	+	+	-	-	-	-	-	+	+	+	+	+	+	+	- -	- -	- -

Table 5.5: Short-List options for Beckton STW

Option Ref	Option Group	Process option	Sub-options (including Design Capacities)							
			Sub-option ref	Process	Capacity (tDS/d)	Location	Process	Capacity (tDS/d)	Location	Total capacity (tDS/d)
1.0	**Raw Sludge Incineration** Retain existing SPG (RCI) & provide additional treatment capacity using new mass burn incineration of raw cake (RCI). All product in the form of ash.	RCI & RCI	1.0	RCI	170	Beckton	RCI	220	Beckton	390
			1.1	RCI+	190	Beckton	RCI	200	Beckton	390
2.0	**Raw & Digested Sludge Incineration** Retain existing SPG (RCI) & provide additional treatment capacity through provision of new enhanced digestion with mass burn incineration of digested cake (EDI). All product in the form of ash.	RCI & EDI	2.0	RCI	170	Beckton	EDI	220	Beckton	390
			2.1	RCI+	190	Beckton	EDI	200	Beckton	390
			2.2	RCI	170	Beckton	EDI	220	Riverside	390
			2.3	RCI+	220	Beckton	EDI	170	Riverside	390
3.0	**Digested Sludge Incineration** Retain but modify existing SPG to take digested sludge & provide new enhanced digestion (whole works throughput) with mass burn incineration of digested cake **(all EDI).** All product in the form of ash.	EDI & EDI	3.0	EDI	390	Beckton				390
4.0	**Raw Sludge Incineration and Enhanced Digestion** Retain existing SPG **(RCI)** & provide additional treatment capacity using enhanced digestion **(ED).** Both ash and enhanced digested cake produced. Enhanced digested cake recycled to agriculture.	RCI & ED	4.0	RCI	170	Beckton	ED	220	Beckton	390
			4.1	RCI+	190	Beckton	ED	200	Beckton	390
			4.2	RCI	170	Beckton	ED	220	Riverside	390
			4.3	RCI+	190	Beckton	ED	200	Riverside	390
5.0	**Enhanced Digestion** Mothball existing SPG & provide treatment capacity for entire throughput using enhanced digestion **(all ED).** Enhanced digested cake produced which is recycled to agriculture.	ED & ED	5.0	ED	390	Beckton				
			5.1	ED	210	Beckton	ED	180	Riverside	390
			5.2	ED	320	Beckton	ED	70	Riverside	390

Table 5.6: Short-List options for Crossness STW

Option Ref	Option Group	Process option	Sub-options (including Design Capacities)							
			Sub-option ref	Process	Capacity (tDS/d)	Location	Process	Capacity (tDS/d)	Location	Total capacity (tDS/d)
1.0	**Raw Sludge Incineration** Retain existing SPG (RCI) & provide additional treatment capacity using new mass burn incineration of raw cake (RCI). All product in the form of ash.	RCI & RCI	1.0	RCI	95	Crossness	RCI	120	Crossness	215
			1.1	RCI+	105	Crossness	RCI	110	Crossness	215
2.0	**Raw & Digested Sludge Incineration** Retain existing SPG (RCI) & provide additional treatment capacity through provision of new enhanced digestion with mass burn incineration of digested cake (EDI). All product in the form of ash.	RCI & EDI	2.0	RCI	95	Crossness	EDI	120	Crossness	215
			2.1	RCI+	105	Crossness	EDI	110	Crossness	215
			2.2	RCI	95	Crossness	EDI	207	Long Reach	302
			2.3	RCI+	114	Crossness	EDI	188	Long Reach	302
3.0	**Digested Sludge Incineration** Retain but modify existing SPG to take digested sludge & provide new enhanced digestion (whole works throughput) with mass burn incineration of digested cake **(all EDI).** All product in the form of ash.	EDI & EDI	3.0	EDI	215	Crossness				215
4.0	**Raw Sludge Incineration and Enhanced Digestion** Retain existing SPG **(RCI)** & provide additional treatment capacity using enhanced digestion **(ED).** Both ash and enhanced digested cake produced. Enhanced digested cake recycled to agriculture.	RCI & ED	4.0	RCI	95	Crossness	ED	120	Crossness	215
			4.1	RCI+	105	Crossness	ED	110	Crossness	215
			4.2	RCI	95	Crossness	ED	207	Long Reach	302
			4.3	RCI+	105	Crossness	ED	197	Long Reach	302
5.0	**Enhanced Digestion** Mothball existing SPG & provide treatment capacity for entire throughput using enhanced digestion **(all ED).** Enhanced digested cake produced which is recycled to agriculture.	ED & ED	5.0	ED	215	Crossness		0		215
			5.1	ED	115	Crossness	ED	187	Long Reach	302
			5.2	ED	165	Crossness	ED	137	Long Reach	302

6 Evaluation of the Short List Options

6.1 Introduction

Following the VM 1 workshop the Short List options were analysed in sufficient detail to enable the options to be compared at the VM 2 workshop and hence the preferred option(s) for Beckton STW and Crossness STW to be selected.

From tables 5.5 and 5.6 it can be seen that there are five main options (1.0, 2.0, 3.0, 4.0 and 5.0) as well as sub-options which differ from the main option in terms of capacities and locations. However, a number of sub-options are similar to each other with the only difference being the use of RCI or RCI+, i.e. a relatively small difference in the proposed treatment capacity.

Hence, to simplify the presentation of analysis results in this section, as well as the option appraisal at the VM 2 workshop, it was agreed with TWUL to focus this report on the five main options and three location sub-options (2.3, 4.2 and 5.2), i.e. eight Short List options in total. At the VM 2 workshop, the details of sub-options for the preferred option were reviewed for sensitivity purposes.

The findings of the analysis of the eight Short List options are presented under the following sections:

- Option components
- Process design, including key assumptions, mass balance and energy flows
- Transfer infrastructure, required to take flows from Beckton STW to Riverside STW or Crossness STW to Long Reach STW
- Integration with existing assets, including proposed option layouts and interfaces with existing services
- Treated product recycling/disposal
- Carbon footprint
- Land-use planning issues
- Environmental issues
- Construction/implementation issues
- Cost estimates, including capex, opex, revenue and whole life costs.

6.2 Option components

Process design models have been prepared for each of the Short List options in order to determine the capacities and performance of key process units. An overview of the key components for the enhanced digestion and mass-burn incineration streams are provided in Table 6.1. Further details of process unit sizes derived for each option are presented in Appendix B (tables B.1 and B.2 for Beckton STW and Crossness STW, respectively).

Key components for each option are described in the following sections.

Table 6.1: Key components in enhanced digestion and mass-burn incineration

Stage	Equipment
Enhanced Digestion	
Thermal Hydrolysis Process (THP)	THP thickening tanks
	THP thickening centrifuge, including standby
	THP feed silos
	THP, 14 tDS/d per reactor, Streams of 4 to 5 reactors. Nr of streams:
Digestion	Digestion tanks, 14 days hydraulic retention time
Combined heat & power (CHP)	Biogas storage (2 hours) and flare stack
	CHP engines, including standby
Pre-dewatering buffer tanks	Buffer tanks with aeration, 2 days hydraulic retention time
Dewatering	Centrifuges, including standby
Sludge cake storage	Sludge storage building, 25 days total storage time
Liquor treatment plant	Liquor treatment plant. For optioneering purposes, assumed proprietary system (SHARON)
Incineration	
Existing SPG	Fluidised bed type mass-burn sludge incinerator, including dewatering & flue gas treatment
New SPG	Fluidised bed type mass-burn sludge incinerator, including the following process stages: - Sludge storage silos - Dewatering centrifuges, including standby - Thermal dryer - Rotary disc dryer or in a thin film dryer - Vapour Condenser - Sludge feeding system - sludge rotary feeder - Fluidized bed furnace - Waste heat boiler - Heat recovery / Turbine - Flue gas cleaning and stack - Ash handling - Scrubber effluent treatment.

(i) Option 1.0 (RCI & RCI)

Raw sludge cake will be incinerated at both Beckton and Crossness STWs.

Existing incinerators: Some improvements to the existing incinerators will be carried out but their capacity will be similar to that currently achieved.

New incinerators: Two new incineration lines are proposed, each line with a throughput of 5.4 tDS/h and 2.9 tDS/h, at Beckton and Crossness STWs, respectively. The new incinerators will include thermal drying (e.g. thin film type dryer) to increase dry solids content to at least 32% thus ensuring that auto-thermic combustion is achieved.

(ii) Option 2.0 (RCI & EDI)

Raw sludge cake will continue to be directed to the existing incinerator. The remaining sludge will be treated in an enhanced digestion plant, dewatered to cake and then burnt in the new incinerators. Emergency storage for the digested cake will be provided (25 days) for use in the event of incinerator shut downs. The biogas from the enhanced digestion plant will be used in CHP engines to generate heat (for the thermal hydrolysis process) and electricity. It has been assumed that dedicated liquor treatment will be required for liquors arising from thickening and dewatering process stages in the enhanced digestion plant.

Existing incinerators: Minor modifications as per Option 1.0

New incinerators: At Beckton STW, two new incineration lines are proposed, each with a throughput of 2.65 tDS/h. However, at Crossness STW only one line is proposed, with a throughput of 2.7 tDS/h, as provision of two, smaller, lines would not be cost efficient.

In order to compensate for the decrease in the calorific value as a result of digestion and ensure that the process is auto-thermic, pre-drying of the sludge cake to about 36%DS would be needed. It has been assumed that the enhanced digested and dewatered cake will have a DS concentration of 31%.

(iii) Option 2.3 ('RCI+' & EDI)

Whilst similar to Option 2.0, this option has two key differences:

Existing incinerators: Analysis undertaken for this study indicates that if the existing incinerators were fed with primary sludge only, their throughput could be increased to as much as 220 tDS/d and 114 tDS/d at Beckton and Crossness STWs, respectively. This is higher than the potential throughput estimated for the mixed raw sludge. This estimate is based on the assumption that 30%DS concentration could be achieved in the sludge cake without pre-drying. Remaining sludge (predominantly SAS) would be digested in the new enhanced digestion plants and then incinerated in the new SPGs (i.e. EDI) at Riverside and Long Reach STWs. This solution could also be considered for other options as it would help to minimise the size of proposed ED plant and new incinerators.

New enhanced digestion and incinerators: The new enhanced digestion plants, associated cake storage (25 days) and new SPGs will be constructed at Riverside and Long Reach STWs.

This option will also require construction of transfer infrastructure (pipelines and associated pumping stations – see Section 6.4) between Beckton and Riverside STWs (in addition to the existing pipeline) and between Crossness and Long Reach STWs. Hence, additional facilities for receiving and thickening the transferred sludge would be needed at Riverside or Long Reach STWs. Alternatives to pumping would be road tankering of dewatered sludge cake or barge transport. Transport of dewatered cake would require the installation of a new dewatering plant at Crossness STW.

(iv) Option 3.0 (EDI)

All sludge generated at Beckton and Crossness STWs will be treated in new enhanced digestion plants and then incinerated in the existing SPGs.

The THP process will enable nearly half of the total solids content of the sludge to be destroyed thus reducing the amount of sludge that then needs to be combusted in the SPGs. It is considered that, following refurbishment and some modification, the existing incinerators will be able to combust the entire production of digested sludge at each site, which is 193 tDS/d at Beckton STW and 108 tDS/d at Crossness STW, hence no new incinerators would be required.

However, owing to the lower calorific value of the remaining digested sludge, auto-thermic incineration will not be possible. As provision of additional thermal dryers to dewater the sludge to 35-36%DS or more would not be practical (as highlighted in Section 5.2 of this report) it would be necessary to achieve combustion in the furnaces through input of additional natural gas.

Assuming that the enhanced digested cake will achieve a DS concentration of 31%DS, it is estimated that on average, some 245 m^3/h and 454 m^3/h of additional natural gas will be required for Beckton and Crossness SPGs, respectively.

Emergency storage for the digested cake will be provided (25 days) for use in the event of incinerator shut downs. The biogas from the enhanced digestion plant will be used in CHP engines to generate heat (for the thermal hydrolysis process) and electricity. It has been assumed that dedicated liquor treatment will be required for liquors arising from thickening and dewatering process stages in the enhanced digestion plant.

(v) Option 4.0 (RCI & ED)

Raw sludge cake will be directed to the existing incinerator (as for options 1.0). The remaining sludge will be treated in the enhance digestion plant and the digested cake will be recycled to land.

Operational/emergency storage for the digested cake will be provided (60 days). The biogas from the enhanced digestion plant will be used in CHP engines to generate heat (for the thermal hydrolysis process) and electricity. It has been assumed that dedicated liquor treatment will be required for liquors arising from thickening and dewatering process stages in the enhanced digestion plant.

(vi) Option 4.2 (RCI & ED)

This option is similar to Option 4.0, except that the new enhanced digestion plants and associated cake storage (60 days) will be constructed at Riverside and Long Reach STWs.

This option will also require construction of transfer infrastructure (pipelines and associated pumping stations – see Section 6.4) between Beckton and Riverside STWs (in addition to the existing pipeline) and between Crossness and Long Reach STWs. Additional sludge reception and thickening plant would be required at Riverside and Long Reach STWs.

(vii) Option 5.0 (ED)

All sludge generated at Beckton and Crossness STWs will be treated in a new enhanced digestion plant. It has been assumed that the sludge cake will have DS concentration of 31%DS.

Operational/emergency storage for the digested cake will be provided (60 days). The biogas from the enhanced digestion plant will be used in CHP engines to generate heat (for the thermal hydrolysis process) and electricity. It has been assumed that dedicated liquor treatment will be required for liquors arising from thickening and dewatering process stages in the enhanced digestion plant.

The existing SPGs would be shutdown and mothballed (made safe but not demolished).

(viii) Option 5.2 (ED)

This option is similar to Option 5.0, except that a proportion of the new enhanced digestion capacity required will be constructed at Riverside and Long Reach STWs. The proposed capacities are based on the following assumptions:

- **Beckton and Riverside STWs:** Some (70 tDS/d) will be treated at the proposed enhanced digestion plant at Riverside STW (if TWUL's current planning application is successful). A new enhanced digestion plant (320 tDS/d including 50 tDS/d headroom) will treat the remaining sludge at Beckton STW. This option will not require construction of additional transfer infrastructure as the existing pipeline between Beckton and Riverside STWs will be sufficient.
- **Crossness and Long Reach STWs:** Some 50 tDS/d of raw sludge from Crossness will be transferred via pipeline to Long Reach STW, where a new THP plant will be constructed to treat the combined sludge from Crossness and Long Reach STWs. No new digesters at Long Reach will be needed. The remaining 165 tDS/d of sludge will be treated by a new enhanced digestion plant at Crossness. This option will require construction of additional transfer infrastructure (pipelines and associated pumping stations – see Section 6.4) between Crossness and Long Reach STWs.

6.3 Process Design

This section sets out the key technical parameters underlying the process analysis as well as key findings with respect to the Mass and Energy balances for each option.

6.3.1 Key assumptions

The key technical assumptions that form the basis of all the process calculations and subsequent process evaluation for each of the enhanced digestion options are presented in Appendix B (Table B.3). Design parameters for new incineration plant are contained within the preliminary design submissions prepared by BAMAG GmbH and are provided separately[10].

[10] Mott MacDonald report, "6QWG-Thames Sludge SAR_Consolidated Bamag Report-RevA"

6.3.2 Mass balance

Information on throughputs to key process units as well as product disposal after treatment, whether as ash to landfill or cake to agricultural land, are provided in tabular form in Appendix C (tables C.1 and C.2, for Beckton and Crossness STWs, respectively). Simple process flow diagrams (PFDs) depicting key stages in each group of options are also provided in Appendix C. Key sludge lines within each process are assigned numbers, which when read in conjunction with tables C.1 and C.2, provide information on the mass balance for each of the short-listed options.

The values in the mass balance tables provide a basis for estimation of the size of the sludge treatment plant and, hence, Capex and Opex for each option. Table C.1 includes only data related to sludge generated at Beckton STW and makes allowance for headroom. Sludge quantities shown in Table C.2 for transfer options to Long Reach STW include also the sludge generated at Long Reach STW. This is because, TWUL has not identified a separate scheme for enhanced digestion in the Draft Business Plan and hence it assumed that enhanced digestion at Long Reach STW would have to be provided under the Crossness STW scheme.

6.3.3 Energy balance

Key information on energy flows for each process option are presented in tabular form in Appendix D (tables D.1 and D.2 for Beckton and Crossness STWs, respectively) and should be read in conjunction with the energy flow diagram (EFD) also provided in Appendix D . Values provided in the energy tables are the sum of values for the ‘Existing’ and ‘Growth’ process streams. For Beckton STW, energy values are derived for sludge quantities which exclude any headroom allowance as well as any indigenous sludge from Riverside STW. Energy values for Crossness STW are derived for sludge quantities which exclude headroom allowance but include indigenous sludge from Long Reach STW for any transfer options. The energy values in these tables were used for estimation of Opex costs.

6.4 Transfer infrastructure options

6.4.1 Overview

For options 2.3, 4.2 and 5.2, sludge from Beckton STW or Crossness STW would be transported to other STWs where new or extended sludge treatment works would be developed. For this study the following transfer options have been assumed:

- Beckton STW sludge would be transported to Riverside STW.
- Crossness STW sludge would be transported to Long Reach STW.

The three main options for transporting sludge considered in this study are:

- Pipeline (including pumping)
- Road transport by tanker or truck.
- River transport by barge.

As noted previous there is an existing pipeline between Beckton STW and Riverside STW. However, the capacity of this pipeline is limited and most options would require an additional pipeline to be constructed. There is not a pipeline between Crossness STW and Long Reach STW.

Road transport is a common method used by many water and sewerage companies to transport sludge, either as thickened (liquid) sludge or sludge cake.

The proximity of the East London STWs to the Thames Tideway makes barge transport a possibility for transferring sludge from Beckton STW and Crossness STW to other sites. A number of water companies currently use barges and ships to transport sludge, and until 1998 TWUL transported sludge for disposal at sea from both Beckton STW and Crossness STW. Therefore sludge loading facilities are in place at these sites, though these would require rehabilitation for future use.

Each transfer option will also have different environmental impacts. Pipelines have operational energy consumption (though pumping energy may come from a renewable source such as biogas CHP) as well as potential construction stage impacts (traffic disruption, noise dust). Barge transport has potentially lower impacts though this option still requires fuel (and hence emissions) for the barges and energy associated with pumping sludge to and from sludge loading/unloading points. Road transport has potentially the highest long term impacts due to traffic noise and emissions (GHG and particulates). These potential impacts are also considered in this high level assessment of transfer options.

6.4.2 Beckton STW to Riverside STW

The quantities of wet sludge, at various assumed dry solids contents, that would be transported from Beckton STW for treatment at Riverside STW under options 2.3, 4.2 and 5.2 are shown in Table 6.2.

Table 6.2: Raw sludge quantities to be transported from Beckton STW

Option		2.3	4.2	5.2	Dry Solids Content	Assumed transfer options
Tonnes Dry Solids / day	tDS/d	200	220	70	%DS	
Partially thickened sludge	t wet/d	20000	22000	7000	1%	Pipeline
Thickened sludge	t wet/d	4000	4400	1400	5%	Tanker, barge
Dewatered sludge cake	t wet/d	909	1000	318	22%	Truck, barge

The following transfer options have been evaluated for this study:

(i) Pipeline

As noted previous there is an existing pipeline between Beckton STW and Riverside STW. However, the capacity of this pipeline is limited and most options would require an additional pipeline to be constructed (including an additional crossing of a River Thames tributary).

Option 5.2 is the only option in which the total amount of sludge can be carried by the existing pipeline. For other options it has been assumed that the existing pipeline will carry 80 tDS/d (at 1 to 2%DS) and a new pipeline will be constructed along the same route to transport the remaining sludge for each option. A new DN 400 pipeline would give reasonable velocities and head loss.

It is not proposed to pump thickened sludge as the high head losses would result in uneconomic pumping costs. Thus additional sludge thickening plant capacity would need to be provided at Riverside STW for this option.

The existing pipeline from Beckton STW to Riverside STW is described in Section 3.4. It is assumed that repair of the existing 7km pipeline would not be required.

(ii) Tanker

If sludge is to be transported by road it is assumed that it would be either be as thickened sludge (5% DS) or as dewatered raw cake at, say 22% DS. The number of trips to be made every day (assuming a tanker transports 30 m^3 or trucks carrying up to 28 t of cake per load) would range between 11 (option 5.2, for sludge cake) and 157 (for thickened sludge and options 2.3 and 4.2).

(iii) Barge

Riverside STW is some 0.4 km from the Thames Tideway and hence sludge carried by barge from Beckton STW would need to be unloaded on the Thames and transported the remaining distance to the STW by tanker or new pipeline. It is assumed for this analysis that the barge would only transport thickened sludge and not cake.

Typically, a single barge can transport around 500t per trip, which would suggest that between 3 and 9 trips would be required every day for the various options.

In addition to the operating cost of barging the sludge, a number of initial capital costs would be required for new piers, pipelines and sludge handling/loading facilities.

(iv) Evaluation

The capex, opex and NPV were calculated for each transport option and the results are presented in Table 6.3. Further details of the analysis carried out are presented in Appendix E.

Using a pipeline to transport sludge between Beckton STW and Riverside STW (i.e. constructing a new pipeline and using the existing pipeline) is the preferred option in financial terms, having the lowest net present value (£5.5m). This option is also likely to have the lower environmental impact in terms of lower fossil fuel energy use, lower potential for fugitive odour emissions and reduced traffic impacts.

The option with the next lowest NPV (£13.7m) would be to use the existing pipeline and transfer the additional sludge as cake by truck. The least favoured option would be to tanker thickened sludge as the high operational costs involved result in a net present value of £78.7m.

Table 6.3: Capex, Opex and NPV for transfer options between Beckton STW and Riverside STW

Transfer option	Initial CAPEX (£m)	OPEX £m/year)	NPV (£m)
Pipeline @ 1%	8.33	0.15	10.2
Tanker @ 5%	0	8.03	99.2
Truck @ 22%	3.50	1.84	26.2
Pipeline @ 1% and truck @ 22%	3.00	1.27	18.7
Barge & pipeline @ 5%	2.38	3.34	43.7

NPV calculated over 20 years at a discount rate of 5.1% in accordance with TWUL guidelines.

6.4.3 Crossness STW to Long Reach STW

The quantities of wet sludge, at various assumed dry solids contents, that would be transported from Crossness STW for treatment at Long Reach STW under options 2.3, 4.2 and 5.2 are shown in Table 6.4.

Table 6.4: Quantities of sludge to be transported from Crossness STW

Option		2.3	4.2	5.2	Dry Solids Content	Assumed transfer options
Tonnes Dry Solids / day	tDS/d	110	120	50	%DS	
Partially thickened sludge	t wet/d	11000	12000	5000	1%	Pipeline
Thickened sludge	t wet/d	2200	2400	1000	5%	Tanker, barge
Dewatered sludge cake	t wet/d	500	545	227	22%	Truck, barge

(i) Pipeline

There is no existing pipeline between Crossness STW and Long Reach STW. The distance between the two sites is some 9 km, although this crosses densely built up areas, major road networks and across the River Thames.

A potential route for a pipeline would be to follow Eastern Way, Bronze Age Way and Manor Way, going underneath the tributary of the River Thames before cutting across farmland to Marsh Street. This route totals 8.5km in length. A new DN 400 pipeline would give reasonable velocities and head loss. A new pumping station would also need to be constructed at Crossness STW.

(ii) Tanker

If sludge is to be transported by road it is assumed that it would be either be as thickened sludge (5% DS) or as dewatered raw cake at, say 22% DS. The number of trips to be made every day (assuming a tanker transports 30 m^3 or trucks carrying up to 28 t of cake per load) would range between 9 (option 5.2, for sludge cake) and 86 (for thickened sludge and options 2.3 and 4.2).

(iii) Barge

Long Reach STW is located adjacent to the Thames Tideway, some 11 km downstream from Crossness STW.

Typically, a single barge can transport around 500t per trip, which would suggest that between 2 and 5 trips (depending on option) would be required every day for thickened sludge and 1 trip for sludge cake.

In addition to the operating cost of barging the sludge, a number of initial CAPEX costs would be required for rehabilitated and new piers, pipelines and sludge handling/loading facilities. If sludge cake is transferred then this will require additional dewatering plant at Crossness STW as well as cake reception and blending plant at Long Reach STW.

(iv) Evaluation

The capex, opex and NPV were calculated for each transport option and the results are presented in Table 6.5. Further details of the analysis carried out are presented in Appendix E.

Constructing a DN400, 8.5km pipeline to transport sludge between Crossness STW and Long Reach STW is the preferred option in financial terms, having the lowest net present value (£6.1m). However, constructing a new pipeline in a densely developed area will be disruptive and land ownership issues could arise, therefore more analysis of the area would need to be undertaken to confirm a pipeline is the preferred option. This option is also likely to have the lower environmental impact in terms of lower fossil fuel energy use, lower potential for fugitive odour emissions and reduced traffic impacts however, the potential environmental impacts associated with construction of a pipeline through open land should also be considered.

The option with the next lowest NPV (£10.1m) would be to transfer the sludge as cake by truck. The least favoured option would be to tanker thickened sludge (£43.0m NPV).

Table 6.5: Capex, Opex and NPV for transfer options between Crossness STW and Long Reach STW

	Initial CAPEX (£m)	OPEX £m/year)	NPV (£m)
Pipeline @ 1%	5.7	0.41	6.1
Tanker @ 5%	0	4.38	43.0
Tanker @ 22%	0.3	0.99	10.1
Barge @ 5%	0.9	2.20	22.5
Barge @ 22%	0.9	1.11	11.8

NPV calculated over 20 years at a discount rate of 5.1% in accordance with TWUL guidelines.

6.4.4 Conclusions

The analysis carried out for this study indicates that the least cost option would be to transfer sludge by pipeline between Beckton STW and Riverside STW and between Crossness STW and Long Reach STW. This proved to have a lower whole life cost than both road transport and river transport by barge. Hence, the costs of pipelines and other facilities required for transferring sludge have been included in the cost estimates presented for options 2.3, 4.2 or 5.2.

However, this analysis has not considered the relative environmental impacts of each transfer option in detail, taking into account site specific impacts. Hence further analysis would be required if options 2.3, 4.2 or 5.2 were to be selected as the overall preferred option for either Beckton STW or Crossness STW.

6.5 Proposed option layouts (including temporary land take)

Drawings in Appendix F show locations of proposed facilities for options 1.0, 2.2, 2.3, 3.0, 4.0 and 5.0. These drawings also include tables providing dimensions for key structures proposed for each sites. Separate drawings for options 4.2 and 5.2 are not provided since these were judged to be similar to, but smaller than, options 2.3 and 5.0, respectively.

These layouts are preliminary and have been prepared for the purpose of this optioneering assessment. For selected options, proposed layouts would need to be further developed and refined as part of the project development stage prior to submission of any planning application for the proposed schemes.

From the site plans it can be seen that options 3.0 and 5.0 have the largest footprints at Beckton and Crossness – since these options require enhanced digestion capacity for all sludge produced at each site. However, neither option requires construction of additional incinerator capacity.

6.6 Integration with existing assets

6.6.1 Use of existing assets

(i) Background

A number of the proposed options for additional sludge treatment capacity at both Beckton and Crossness STWs include enhanced digestion for some or all of the forecast sludge production. Other options propose transfer of part of this sludge production for enhanced digestion as Riverside and Long Reach STWs, respectively.

(ii) Beckton and Crossness STWs

Both Beckton and Crossness STWs previously provided conventional digestion plants though these were decommissioned on completion of the SPGs at each site 1998/99. The options presented in this study assume that a number of these disused digesters at each site would be renovated and brought back into service. Although the existing digesters are some 50-years old it is considered that their service life can be extended through renovation and that this likely to be more cost effective and lower carbon footprint than constructing new digesters.

Beckton STW originally had some 36 reinforced concrete digesters, each of 24.5 m diameter and volume of 4400 m3 (effective volume taken as 85%, i.e. 3740 m3). Four are currently used as picket fence thickeners and a further eight are used for sludge buffer storage. The remaining 24 digesters are currently being used for emergency sludge storage and hence are partly full.

Crossness STW has 16 nr 25m diameter concrete primary digesters and 12 nr of ~37m diameter concrete secondary sludge digesters. These tanks are currently used for additional sludge storage.

(iii) Renovation of Beckton and Crossness STWs digesters

A brief external visual inspection of some of the digesters at Crossness and Beckton STWs during the site visit for this study did not identify any significant incidences of concrete spalling or exposed reinforcement. This suggests that the digester structures may be in a better structural condition than those at Riverside STW.

However, for the purposes of this study it has been assumed that structural renovation will be required for each digester used and that this work will be similar in scope to that identified for the Riverside STW digesters. The Riverside STW digester structural survey and subsequent budget quotations from specialist contractors for carrying out the recommended repairs have been used to define the potential scope of work and cost for renovating digesters at Beckton and Crossness STWs. External repairs likely to be required include crack/concrete sealing and repair, replacement of roofs, new pipework penetrations, replacement of access metalwork.

In addition, it has been assumed that digester roofs, existing process pipework (gas and sludge) as well as associated pumping and mixing equipment would be replaced.

If the preferred option for this study requires that existing digesters are brought back into service then it is recommended that a detailed structural survey of the digesters at Crossness and Beckton STWs is undertaken during subsequent design development stages. This survey would need to confirm the full extent of any structural renovation required.

Once the digesters have been renovated and are in operation, it is important that regular inspections and maintenance is undertaken to reduce the risk of future degradation.

(iv) Long Reach STW

Long Reach has 8 primary digesters which have recently been configured to allow for the treatment of hydrolysed sludge, enabling them to process a higher percentage of dry solids. They have also recently been insulated and the pipework modified to allow for additional pipes. The only further improvement that these digesters may require under the options proposed in this study is likely to be to the mixing equipment, to enable it to process the thicker sludge produced by the enhanced digestion.

(v) Riverside STW

Riverside STW site previously provided on-site digestion and it has four digesters which are currently disused as well as two older digesters currently used for liquid storage. TWUL is currently seeking planning permission for an enhanced digestion plant for Riverside STW which will have a capacity of 110 tDS/d (TWUL scheme 9RTG/A1). The reference design for this project indicates that the new plant will include thermal hydrolysis (two streams, each 55 tDS/d) and that the four disused digesters will be brought back into service.

An external structural condition survey[11] of the four concrete digesters identified that the 38 year old structures suffer from exposed and rusting reinforcement in a number of areas, spalling concrete and efflorescence at construction joints.

The results of this survey, together with subsequent cost estimates for the structural rehabilitation work required, have been used as a basis for costing the renovation of the Beckton and Crossness STW digesters.

6.6.2 Interfaces with existing processes

At the Beckton and Crossness STWs, primary and secondary sludge is currently thickened separately and then blended prior to passing to existing SPGs. A proportion of sludge at each STW is diverted to lime treatment plants. All the proposed options will require interception of existing sludge flows and diversion to new treatment facilities.

Similarly, return liquors arising from additional thickening and dewatering facilities proposed under each option will need to be returned to the wastewater treatment processes – either with or without dedicated liquor pre-treatment. It has been assumed that all options incorporating enhanced digestion will require dedicated liquor treatment for liquors arising from thickening and dewatering process stages in the enhanced digestion plant.

The most complicated interface to be managed is that for Option 3.0. In this option all the thickened sludge would be diverted to a new enhanced digestion plant. Following digestion sludge would then be diverted back to the existing SPG for dewatering and combustion. The existing SPG would also require some modification to accept digested sludge. Due to capacity constraints this modification along with the scheduled rehabilitation of the SPGs - would occur after completion of the enhanced digestion plant. Hence, there would be a period prior to completion of rehabilitation and modification of the existing SPGs (assuming one incineration line is shut at a time) during which enhanced digested sludge would be recycled to land.

Whilst the extent and complexity of these interfaces do vary between the various proposed options they are not considered to present major technical problems and hence this factor is not considered significant in deciding between options. However, the construction of diversion works for the preferred option will need careful planning in order to avoid disruption of existing treatment processes.

[11] Structural survey by Hyder Consulting: Riverside Digester Survey Structural Survey Report, 23rd May 2008.

6.6.3 Interfaces with existing services

The areas proposed for construction of the various options are crossed by various underground pipelines and cables as well as overhead power cables.

Furthermore, proposed treatment processes will need to be connected to services including power, natural gas and potable water. If surplus power is expected to be generated and exported then the local distribution network may require additional infrastructure.

The most significant services diversion problems are likely to occur at Beckton STW. Location of new plant around the existing SPG may require diversion of overhead power cables as well as underground air lines and the clean water main from the Thames Gateway Water Treatment Plant. Hence, Beckton STW options which do not require use of the land immediately around the existing SPG are considered easier to implement.

6.7 Quantities for treated product recycling/disposal

The values given in tables 6.5 and 6.6 show the quantities of digested sludge and ash that are to be transported for recycling/disposal for the different options at Beckton and Crossness respectively. The tankers are to carry 28t per load and the wet cake to be transported is 31%DS.

Table 6.6: Recycling/disposal quantities for Beckton

	Option 1.0	Option 2.0	Option 2.3	Option 3.0	Option 4.0	Option 4.2	Option 5.0	Option 5.2
Digested sludge								
tDS/year	0	0	0	0	30,650	32,527	61,300	61,300
t wet cake/year	0	0	0	0	98,872	104,925	197,743	197,743
Truck loads/day	0	0	0	0	10	11	20	20
Truck loads/year	0	0	0	0	3,532	3,748	7,063	7,063
Ash								
tDS/year	24,795	24,716	26,578	24,539	12,467	12,467	0	0
Truck loads/day	3	3	3	3	2	2	0	0
Truck loads/year	886	883	950	877	446	446	0	0

Table 6.7: Recycling/disposal quantities for Crossness

Product type	Option 1.0	Option 2.0	Option 2.3	Option 3.0	Option 4.0	Option 4.2	Option 5.0	Option 5.2
Digested sludge								
tDS/year	0	0	0	0	16,073	32,818	33,039	48,561
t wet cake/year	0	0	0	0	51,849	105,864	106,578	156,648
Truck loads/day	0	0	0	0	6	11	11	16
Truck loads/year	0	0	0	0	1,852	3,781	3,807	5,595
Ash								
tDS/year	13,980	13,819	20,020	13,578	7,173	7,173	0	0
Truck loads/day	2	2	2	2	1	1	0	0
Truck loads/year	500	494	715	485	257	257	0	0

6.8 Carbon footprint

Ofwat requires that water companies report the Greenhouse Gas (GHG) emissions arising from proposed investments as well as the monetary valuations associated with these emissions (based on Defra's Shadow Price of Carbon –SPC). The monetary value of these emissions can then be used in each company's CBA analysis.

Ofwat advises companies to report GHG emissions according to the revised Water UK methodologies. Separate methodologies are prepared for both embodied carbon (in construction activities)[12] and operating carbon[13]. These emissions include direct and indirect emissions associated with the provision of water, wastewater and sludge disposal. They exclude emissions from the supply chain (mainly chemicals).

The carbon footprint for each of the short list options has been estimated to enable comparison of the relative carbon emissions associated with each option. These estimates of carbon emissions have then been converted to costs using Defra's Shadow Price of Carbon in order to derive an estimate of the economic cost of each option with respect to climate change mitigation.

In general, operating carbon emissions are usually the more significant factor over the life of typical water sector assets comprising both civil works and mechanical and electrical equipment. However, the impact of operating emissions is reduced in the analysis for this report by the high renewable energy generation associated with all options.

In interpreting the carbon emissions estimates for Crossness options it should be noted that options involving transfer of sludge to Long Reach STW (i.e. 2.3, 4.2 and 5.2) are based on different capacities to those where all Crossness sludge is treated at Crossness.

6.8.1 Embodied carbon footprint

Embodied carbon emission estimates should normally be calculated using the anticipated quantities of key materials used in the construction of the proposed facilities as well as an estimate of the emissions arising from construction plant and related activities.

However, at this strategy stage the key materials quantities are not available for each option and hence a more approximate approach is proposed which assumes that there is a relationship between embodied carbon emissions and capital cost. For this approach, the carbon footprint has been estimated for a specific sludge treatment scheme and compared with the proposed capital cost for each option.

The carbon footprint for the scheme has been based on the following:

- Detailed breakdown of civil works and MEICA equipment for a new 20,000 tDS/d sludge treatment centre, provided by the contractor as part of its target cost calculation
- The UKWIR methodology for embodied carbon calculations
- Emissions factors from published literature and the Defra website.

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[12] Carbon Accounting in the UK Water Industry: Guidelines for Dealing with Embodied Carbon and Whole Life Costing. UKWIR Report Ref No. 08/CL/01/6

[13] Carbon Accounting in the UK Water Industry: Operational Emissions. UKWIR Report Ref No.08/CL/01/5 and subsequent updates to the spreadsheet reporting template (incorporating revised emission factors) issued by UKWIR.

The total embodied carbon footprint estimated in this way was 15,000 tCO2. The contract value for the scheme was £25 million. This gives a value of 0.60 kg CO_2/£1 invested (excluding Client on-costs).

The value has then been used with the total capital costs for each of the proposed options to derive a rough estimate of the potential embodied carbon emissions for each option.

The resulting estimates of embodied carbon emissions for each option (in tonnes CO_2 equivalent) are presented in tables 6.8 and 6.9 for Beckton and Crossness STWs respectively.

6.8.2 Operational carbon footprint

UKWIR's operational carbon accounting guidelines have been used to prepare an estimate of the operational carbon emissions (including the CO_2 equivalent emissions of nitrous oxide and methane) associated with each option. In preparing these carbon emissions estimates, the following data has used:

- Outline process designs and estimated treated sludge quantities for recycling or disposal, for each option
- Predicted raw sludge transport mileage.

In accordance with UKWIR guidelines the carbon emissions associated with chemical consumption have not been included.

The resulting estimate of operational carbon emissions for each option (in tonnes CO_2 equivalent per year) are presented in Table 6.8 and 6.9 for Beckton and Crossness STWs options, respectively. It can be seen that operational carbon emissions for all options are reduced by renewable energy generation.

Table 6.8: CO2 equivalent emissions – Beckton STW options

Carbon Source	Units	Options							
		1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Embodied carbon:									
CAPEX	£'000	159,081	210,481	208,484	187,371	118,779	128,654	137,590	120,719
Total Embodied CO2	tonnes CO2e	95,449	126,288	125,090	112,423	71,268	77,193	82,554	72,431
(Assumed 0.60 $kgCO_2$ = 1£ capex)									
Operating Carbon:									
Sub-total Power	tonnes CO2e/yr	**-34,582**	**-49,720**	**-48,272**	**-53,540**	**-44,777**	**-39,153**	**-48,814**	**-46,851**
Grid	tonnes CO2e/yr	-34,582	-49,720	-48,272	-53,540	-44,777	-39,153	-48,814	-46,851
Renewable	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Green	tonnes CO2e/yr	0	0	0	0	0	0	0	0
CHP	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Sub-total Fuel	tonnes CO2e/yr	**13,751**	**19,525**	**18,185**	**31,498**	**19,525**	**19,936**	**11,549**	**11,549**
Natural Gas	tonnes CO2e/yr	13,751	19,525	18,185	31,498	19,525	19,936	11,549	11,549
Diesel	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Sub-total Process Emissions	tonnes CO2e/yr	**38,086**	**34,261**	**38,269**	**30,436**	**24,855**	**24,855**	**11,623**	**11,623**
Enhanced Digestion	tonnes CO2e/yr	0	5,812	4,102	11,623	5,812	5,812	11,623	11,623
Incineration	tonnes CO2e/yr	38,086	28,450	34,167	18,813	19,043	19,043	0	0
Sub-total Transport	tonnes CO2e/yr	**98**	**98**	**98**	**98**	**522**	**522**	**881**	**881**
Diesel Consumption (sludge cake)	tonnes CO2e/yr	0	0	0	0	457	457	881	881
Diesel Consumption (ash)	tonnes CO2e/yr	98	98	98	98	65	65	0	0
Total Operating Carbon - excl land	tonnes CO2e/yr	**17,353**	**4,165**	**8,280**	**8,492**	**126**	**6,161**	**-24,761**	**-22,798**
Sludge cake CH4 emissions on land	tonnes CO2e/yr	0	0	0	0	352	352	704	704
Total Operating Carbon - incl land	tonnes CO2e/yr	**17,353**	**4,165**	**8,280**	**8,492**	**477**	**6,512**	**-24,057**	**-22,094**

Notes:
1) Quantities of consumables and of sludge product used to derive the operating carbon emissions are taken from the opex calculations.
2) Factors for GHG emissions and Global Warming Potentials taken from the spreadsheet WI_GHG_Estimator_v3.0.xls as used for June Returns 2008/09

Table 6.9: CO2 equivalent emissions – Crossness STW options

Carbon Source	Units	Options							
		1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Embodied carbon:									
CAPEX	£'000	122,384	144,727	191,011	126,796	78,940	114,290	87,363	109,551
Total Embodied CO2	tonnes CO2e	73,431	86,836	114,606	76,077	47,364	68,574	52,418	65,731
(Assumed 0.60 $kgCO_2$ = 1£ capex)									
Operating Carbon:									
Sub-total Power	tonnes CO2e/yr	**-17,316**	**-28,701**	**-37,916**	**-33,735**	**-26,866**	**-34,001**	**-31,576**	**-40,963**
Grid	tonnes CO2e/yr	-17,316	-28,701	-37,916	-33,735	-26,866	-34,001	-31,576	-40,963
Renewable	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Green	tonnes CO2e/yr	0	0	0	0	0	0	0	0
CHP	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Sub-total Fuel	tonnes CO2e/yr	**0**	**3,718**	**6,147**	**7,100**	**3,664**	**6,654**	**6,564**	**9,218**
Natural Gas	tonnes CO2e/yr	0	3,718	6,147	7,100	3,664	6,654	6,564	9,218
Diesel	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Sub-total Process Emissions	tonnes CO2e/yr	**24,084**	**21,321**	**29,957**	**19,134**	**21,321**	**29,495**	**7,350**	**26,869**
Enhanced Digestion	tonnes CO2e/yr	0	4,102	6,424	7,350	4,102	7,073	7,350	10,321
Incineration	tonnes CO2e/yr	24,084	17,219	23,533	11,784	17,219	22,421	0	16,548
Sub-total Transport	tonnes CO2e/yr	**65**	**65**	**98**	**65**	**359**	**588**	**555**	**849**
Diesel Consumption (sludge cake)	tonnes CO2e/yr	0	0	0	0	326	522	555	783
Diesel Consumption (ash)	tonnes CO2e/yr	65	65	98	65	33	65	0	65
Total Operating Carbon - excl land	tonnes CO2e/yr	**6,833**	**-3,597**	**-1,714**	**-7,436**	**-1,522**	**2,735**	**-17,106**	**-4,028**
Sludge cake CH4 emissions on land	tonnes CO2e/yr	0	0	0	0	248	428	445	625
Total Operating Carbon - incl land	tonnes CO2e/yr	**6,833**	**-3,597**	**-1,714**	**-7,436**	**-1,274**	**3,164**	**-16,662**	**-3,403**

Notes:
1) Quantities of consumables and of sludge product used to derive the operating carbon emissions are taken from the opex calculations.
2) Factors for GHG emissions and Global Warming Potentials taken from the spreadsheet WI_GHG_Estimator_v3.0.xls as used for June Returns 2008/09

Two key elements in the operational carbon footprint for enhanced digestion options are (1) the additional (fossil) fuel consumption required to raise sufficient heat for the pre-treatment process and (2) the carbon emissions associated with the anaerobic digestion process. If the supplementary fuel requirement can be reduced through efficient use of other waste heat sources on site (e.g. waste heat from biodiesel engines at Beckton STW) then this could significantly reduce process emissions. The latest UKWIR carbon emissions spreadsheet (WI_GHG_Estimator_v3.0.xls) contains significantly lower emission factors (specifically, process emissions and emissions following recycling to land) for enhanced anaerobic digestion (using THP) than those for conventional MAD – largely due to the elimination of the secondary digestion stage, improved volatile solids destruction and generally better biogas capture. These changes in emission factors contribute to the overall reduction in emissions for ED options compared to RCI options.

6.8.3 Shadow price of carbon

The embodied and operational carbon emissions estimates produced above are then converted into carbon emissions costs, using Defra's 'Shadow Price of Carbon' (SPC).

The SPC was set at £25.4 per tCO_2e in 2007 (central estimate) with upper and lower bound values of £70 and £16 per tCO_2e respectively. The SPC value rises at 2% per year to reflect the expected increasing cost of mitigation of the impacts of climate change. For this estimate construction was assumed to commence in 2011.

The present value (PV) of the expected annual costs of carbon emissions produced over the 20 year analysis period used for this study are then calculated, including an estimate of additional embodied carbon emissions associated with capital maintenance and renewals over the 20 year period. The total annual carbon emission costs are then discounted using the Social Time Preference Rate (STPR, currently 3.5%) as defined in the Treasury's "Green Book".

The results are presented in Table 6.10 and 6.11, for Beckton and Crossness STWs options, respectively.

It can be seen that options 4.0, 5.0 and 5.2 have the lowest NPV carbon cost whilst Options 2.0, 2.3, 3.0 and 4.2 have the highest carbon costs.

Table 6.10: NPV Cost of carbon emissions – Beckton STW options

SPC Value	Component	PV (£'000)							
		1.0	**2.0**	**2.3**	**3.0**	**4.0**	**4.2**	**5.0**	**5.2**
Central estimate	Embodied Carbon	5,417	7,167	7,099	6,380	4,045	4,381	4,685	4,111
= £25.4 / tCO_2e in 2007	Operating Carbon	14,350	3,444	6,847	7,023	395	5,385	-19,893	-18,270
	Total PV - Carbon emissions	19,767	10,611	13,946	13,403	4,439	9,766	-15,208	-14,160
Upper bound estimate	Embodied Carbon	14,928	19,752	19,564	17,583	11,146	12,073	12,912	11,328
= £70.0 / tCO_2e in 2007	Operating Carbon	39,546	9,491	18,871	19,354	1,088	14,841	-54,824	-50,351
	Total PV - Carbon emissions	54,475	29,243	38,435	36,937	12,234	26,914	-41,913	-39,023
Lower bound estimate	Embodied Carbon	3,412	4,515	4,472	4,019	2,548	2,760	2,951	2,589
= £16.0 / tCO_2e in 2007	Operating Carbon	9,039	2,169	4,313	4,424	249	3,392	-12,531	-11,509
	Total PV - Carbon emissions	12,451	6,684	8,785	8,443	2,796	6,152	-9,580	-8,919

Table 6.11: NPV Cost of carbon emissions – Crossness STW options

SPC Value	Component	PV (£'000)							
		1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Central estimate	Embodied Carbon	4,167	4,928	6,504	4,318	2,688	3,892	2,975	3,730
= £25.4 / tCO_2e in 2007	Operating Carbon	5,651	-2,975	-1,417	-6,149	-1,053	2,616	-13,778	-2,814
	Total PV - Carbon emissions	9,818	1,954	5,087	-1,832	1,635	6,508	-10,803	916
Upper bound estimate	Embodied Carbon	11,485	13,581	17,925	11,899	7,408	10,725	8,198	10,280
= £70.0 / tCO_2e in 2007	Operating Carbon	15,573	-8,198	-3,906	-16,946	-2,903	7,210	-37,971	-7,755
	Total PV - Carbon emissions	27,058	5,384	14,019	-5,048	4,505	17,935	-29,773	2,526
Lower bound estimate	Embodied Carbon	2,625	3,104	4,097	2,720	1,693	2,451	1,874	2,350
= £16.0 / tCO_2e in 2007	Operating Carbon	3,560	-1,874	-893	-3,873	-663	1,648	-8,679	-1,773
	Total PV - Carbon emissions	6,185	1,231	3,204	-1,154	1,030	4,099	-6,805	577

The results indicate the following:

- For the same treatment capacity, operating carbon emissions are lower for options including enhanced digestion – either as the sole treatment process or as a means to reduce the size of a subsequent incineration plant.
- Options 4.0, 5.0 and 5.2 have the lowest NPV cost of carbon emissions for both Beckton and Crossness STW options.

In interpreting the carbon emissions estimates for Crossness options it should be noted that options involving transfer of sludge to Long Reach STW (i.e. 2.3, 4.2 and 5.2) are based on different capacities to those where all Crossness sludge is treated at Crossness.

6.9 Planning and permitting issues

Compliance of the various options with national, regional and local land use policies was discussed at the VM 2 workshop and the findings of this discussion with respect to the proposed options is provided in Section 7.5 (Integration) of this report.

Appendix J provides a further description of the local, regional and national planning policy and guidance relevant to the proposed options.

Hence, this section focuses on key permitting issues associated with the options.

6.9.1 Planning application and requirement for EIA

Options considered under the SAR for each location range from provision of an enhanced digestion plant to new incinerator capacity similar to existing. All options will therefore consist of tanks, buildings and other structures of varying heights and plan areas.

Development will either be Schedule 1 Development, where Environmental Impact Assessment (EIA) is automatically required, or Schedule 2 Development, where it is necessary to seek a Screening Opinion from the planning authority as to whether EIA is required, under the Town and Country Planning (Environmental Impact Assessment) Regulations 1999 (as amended). If an EIA is required, then any permitted development rights under the Town and Country Planning (General Permitted Development) Order 1995 are removed and the entire development will require planning permission. If EIA is not required and the development would be undertaken on operational land, Thames Water would be able to construct plant up to 15m high under their permitted development rights, but the provision of any buildings would require planning permission...

6.9.2 Environmental Permitting Regulations

The Pollution Prevention and Control (PPC) and Waste Management Licensing (WML) regulations have been consolidated under the Environmental Permitting (EP) Regulations which came into force on 6 April 2008.

Sludge incineration and combustion of biogas or other fuels in CHP engines or boilers with between 3 and 50 MW thermal input are covered by the EP Regulations and hence require an Environmental Permit. Such installations must adopt a philosophy of Integrated Pollution Prevention Control (IPPC) as laid down in the IPPC Directive (96/61/EC) and transposed into UK law by the Pollution Prevention Control Regulations (England and Wales) 1999 (PPC Regulations).

Options considered under this study would involve the following activities which would result in modifications of existing Environmental Permits or the requirement for new permits.

- Additional SPG capacity at Beckton and Crossness STWs
- Provision of CHP capacity and directly associated activities (e.g. gas handling systems) as part of provision of enhanced digestion schemes at Beckton or Crossness STWs
- Significant changes to existing CHP capacity and directly associated activities at Riverside[15] or Long Reach STWs.

Transfer of sludge from Beckton STW to Riverside STW by pipeline (as proposed in options 2.3, 4.2 and 5.2) would not be classed as an ‘import’ to Riverside STW because the pipeline would be regarded as a public sewer and the sludge arrives at the head of the works. Hence, such a transfer would not need an Environmental Permit. However, transfer of sludge by truck or barge would probably trigger the requirement for an EP as quantities would exceed 10,000 m^3/year.

Similar requirements would cover options for transfer of sludge from Crossness STW to Long Reach STW.

6.10 Environmental issues

The options have the potential to give rise to both positive and negative environmental effects.

In general, there are environmental sensitivities relating to the individual sites in terms of local ecological or recreational designations, proximity of neighbouring properties and potential cumulative impacts arising from other proposed schemes. An outline summary of the baseline environment at each site is provided in the tables in Appendix J.

The assessment of environmental issues for this SAR has been carried out in sufficient detail to enable selection of a preferred option for each site. The preferred options will be subjected to a more detailed environmental assessment during subsequent project development stages leading up to submission of a planning application at each site. Thus, issues which would be similar for all options, for example,

[15] Assuming that TWUL is successful in obtaining planning permission for the proposed Riverside advanced digestion project.

regeneration / employment creation, flood risk, etc., and would not serve to differentiate between options, are not addressed in detail in this SAR but would be covered by the supporting documents for the subsequent planning application.

Key impacts associated with the different technology options are highlighted below. A comparative assessment of each option against the environmental objectives and sub-objectives for this study is resented in Section 7.8.

6.10.1 Landscape and visual

All options involving incineration will have an increased visual impact due to the height of structure and stacks – although probably no greater than the existing SPGs at each site. Enhanced digestion plant is generally less than 20m high and therefore will have a less significant visual impact.

Despite Beckton STW being situated on predominantly low lying land, the existing SPG does not currently have a large visual impact from outside of the STW boundary. However, if further medium and high rise residential development occurs near the STW then future construction of any structures similar in scale to the SPG will have a greater visual impact.

At Crossness STW, new plant or buildings would need to be in keeping with the modern landmark design of the existing Crossness SPG building.

6.10.2 Air quality (including odour)

An increase in total emissions is expected when increasing the sludge treatment capacity with options including new incineration plants likely to have greater emissions than those producing digested cake. Combustion activities under the selected scheme would operate under an Environmental Permit and all new works will meet the requirements of this permit.

For Crossness STW, the presence of other large emissions in the vicinity (including the new Belvedere Incinerator) may require consideration of the combined effect of these emissions on air quality.

No significant odour emissions would be expected for the proposed process technologies as process equipment with the potential to generate odour will be enclosed and emissions treated to appropriate levels. Furthermore, provision of additional sludge treatment capacity will enable existing lime plants at Beckton and Crossness, a potential source of odour, to be decommissioned thus reducing the overall odour risk for sludge treatment.

6.10.3 Waste management

Options involving enhanced digestion will result in an end product which can be recycled to agriculture and are therefore high on the waste management hierarchy. Incineration options will produce an ash which would be disposed of to landfill (if recycling options are not identified) which is lower on the waste management hierarchy.

6.10.4 Traffic and transport

Roads in the London area are increasingly congested. Given the locations of Beckton and Crossness STWs there are issues relating to increased traffic movements, particularly through relatively confined urban locations. The distances travelled would result in increased emissions from vehicles affecting TWUL's carbon footprint.

Traffic impacts during operation would vary according to option selected: options requiring road transfer of thickened or dewatered sludge or road transport of digested cake would have greater impacts than those producing ash for disposal (assuming landfill capacity is available in reasonable proximity to London). From this perspective, options 1.0, 2.0 and 3.0 would have the lowest impacts. Amongst the options producing a digested sludge product, options 5.0 and 5.2 would have greater impact than Options 4.0 and 4.2 due to the greater volume of digested sludge to be transported.

Elimination of lime treatment at each site would also eliminate traffic movements related to import of lime and export of limed sludge.

All options will result in additional local traffic during construction though there is potential to mitigate this impact through careful management of deliveries.

6.10.5 Ecology

Both Beckton STW and Crossness STW are within areas of Metropolitan Open Land. Riverside STW contains a Site of Borough Importance for Nature Conservation.

Site surveys of Beckton STW have shown that the wildlife and habitats surrounding the development site range from negligible to medium importance.

Crossness STW has 3 statutory designated sites and 18 non-statutory sites within a 2km radius of the site (SSSIs and Local Nature Reserve) and is therefore a sensitive area in terms of terrestrial ecology. TWUL reports that water voles have been found at Crossness STW.

All options would have an impact on the ecology of the sites, and mitigation measures would be required.

6.10.6 Contaminated land

All sites have been used for sewage treatment and associated activities, thus giving the potential for contamination. Previous site investigations have been undertaken and have identified that there is a moderate to high risk with respect to ground contamination, prior to mitigation. Old sludge storage lagoons at Crossness STW are known to be contaminated.

6.10.7 Noise

In terms of operational noise from the STW itself, all plant will be designed to limit boundary noise to required levels and it is unlikely that sensitive receptors would be affected. However, there is potential for increased traffic noise impacts, during construction and, for some options, operation, particularly where road access passes through residential areas (e.g. at Crossness STW). However, as noted below, traffic noise associated with the existing lime treatment operation at Beckton and Crossness STWs will be eliminated.

There is potential for construction noise impacts, resulting from heavy plant operation and increased traffic movements, for all options.

6.11 Cost estimates

Detailed capital and operating cost estimates have been prepared for each of the Short-listed options. Tables 6.11 and 6.12 present a summary of the results for Beckton and Crossness STWs respectively, including NPVs and Average Incremental Costs (AICs) for each option.

Figures 6.1 and 6.2 present the cost data in graphical form for Beckton and Crossness STWs respectively.

6.11.1 Capital expenditure

Capital expenditure estimates have been based on the following sources:

- Contractors target cost estimates for constructing Cambi enhanced digestion plants at Whitlingham STW and Cottonvalley STW and Monsal plants at King's Lynn STW and Great Billing STW.
- Cambi quotes for provision of a thermal hydrolysis plant at Riverside STW.
- BAMAG cost estimates for construction of new incinerator capacity and rehabilitation of the existing SPG at each STW.

The capital expenditure estimates for options which retain the existing SPG at each site include a cost estimate for major refurbishment of the existing SPGs. This major refurbishment is assumed to enable the SPGs to operate continue to operate for a further 20 years.

Option 3.0 includes an additional £10 million estimate (for each site) for adapting the existing SPGs to take advanced digested cake.

A more detailed breakdown of the Capex estimate for each option is provided in Appendix G.

6.11.2 Operating expenditure

Operating expenditure estimates have been based on the following sources:

- Expected performance data for Cambi enhanced digestion plants based on detailed process analysis carried out for Whitlingham STW and Cottonvalley STW supplemented by further discussions with Cambi, during this study.
- Expected performance data for proposed incinerators estimated by BAMAG.

- Historic performance data for existing incinerators provided by TWUL.

Operating costs exclude revenue from electricity sales and ROCs (which are provided separately in the tables) and are presented without Business Rates (though an estimate of business rates is provided).

A value for ‘Change in Opex due to Project’ has been calculated for each option and is equal to the future opex minus the estimated "without project" opex.

Table 6.12: Cost estimate summary for Beckton STW

Option		Units	Option 1.0	Option 2.0	Option 2.3	Option 3.0	Option 4.0	Option 4.2	Option 5.0	Option 5.2
Process route - Existing stream			RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Process route - Additional stream			RCI	EDI	EDI	0	ED	ED		ED
Location - Existing stream			Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Location - Additional stream			Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Throughput (tDS/d) - Existing stream			170	170	220	390	170	170	390	320
Throughput (tDS/d) - Additional stream			220	220	170	0	220	220	0	70
Initial CAPEX										
Civil Works		£'000	27,476	40,697	43,135	37,472	24,057	30,658	39,510	34,549
MEICA		£'000	90,000	114,736	110,825	100,896	63,658	64,349	62,096	54,599
Sub-total - Base Cost		£'000	**117,477**	**155,434**	**153,959**	**138,368**	**87,715**	**95,007**	**101,606**	**89,148**
Contractor's on-costs		£'000	41,604	55,047	54,525	49,003	31,064	33,647	35,984	31,572
Sub-total - Design & Construction Costs		£'000	**159,081**	**210,481**	**208,484**	**187,371**	**118,779**	**128,654**	**137,590**	**120,719**
TWUL Costs (incl TWUL risk allowance)		£'000	38,100	50,500	45,800	41,100	28,500	31,000	33,100	29,100
Total Project Cost		£'000	**197,181**	**260,981**	**254,284**	**228,471**	**147,279**	**159,654**	**170,690**	**149,819**
Proposed OPEX										
Staff Costs		£'000/year	1,696	1,984	2,175	1,664	1,536	1,087	639	639
Chemicals		£'000/year	2,464	2,447	2,478	2,431	2,163	2,176	1,862	1,784
Operational Maintenance		£'000/year	3,506	3,659	3,575	2,845	2,570	2,602	769	676
Electricity consumption	STC, Liquor treatment	£'000/year	3,056	2,853	3,224	2,807	2,233	2,614	1,395	1,607
Electricity generated by CHP & consumed by STC/WwTW		£'000/year	-7,251	-8,539	-9,057	-8,493	-7,919	-7,087	-7,081	-7,378
CHP Engine Maintenance (incl periodic overhaul)		£'000/year	0	540	353	1,081	540	508	1,081	1,081
Fuel (supplementary)		£'000/year	1,320	2,123	1,955	3,166	2,123	2,175	1,449	1,449
Business Rates		£'000/year	1,669	1,879	2,103	1,673	1,392	1,730	1,692	1,608
Sludge Transport - Biosolids Recycling		£'000/year	0	0	0	0	4,054	4,302	9,294	9,294
Sludge Transport - Ash disposal		£'000/year	1,587	1,582	1,701	1,571	798	798	0	0
Potable Water (for steam, poly make-up/dilution)		£'000/year	121	179	163	237	179	181	237	237
Total OPEX - excluding Business Rates and Income		£'000/year	**6,499**	**6,829**	**6,568**	**7,307**	**8,277**	**9,354**	**9,645**	**9,388**
Income										
ROCs		£'000/year	-1,617	-2,691	-3,067	-3,946	-2,545	-3,027	-2,763	-3,328
Electricity Exports		£'000/year	0	-683	-278	-2,876	-245	-315	-1,151	-950
Total Income		£'000/year	**-1,617**	**-3,374**	**-3,345**	**-6,822**	**-2,790**	**-3,342**	**-3,914**	**-4,278**
Total Net OPEX - excluding Business Rates, including Income		£'000/year	**4,882**	**3,455**	**3,223**	**485**	**5,486**	**6,013**	**5,731**	**5,110**
Existing Opex										
Existing Opex at commissioning - including income		£'000/year	7,684	7,684	7,684	7,684	7,684	7,684	7,684	7,684
Change in Opex due to Project										
Excluding ROCs & electricity exports (excluding Business Rates)		£'000/year	-1,186	-856	-1,116	-377	592	1,670	1,960	1,703
Including ROCs & electricity exports (excluding Business Rates		£'000/year	-2,803	-4,230	-4,461	-7,199	-2,198	-1,672	-1,953	-2,574
NPV										
20 years at 8%	Total Capex NPV	£'000	239,927	315,475	306,920	276,392	177,514	190,217	200,183	175,751
	Total Opex NPV	£'000	80,305	76,085	72,765	90,293	102,276	115,593	119,183	116,006
	Total Cost NPV	£'000	**320,231**	**391,560**	**379,685**	**366,685**	**279,790**	**305,810**	**319,365**	**291,757**
	Total Income NPV	£'000	**19,979**	**41,695**	**41,336**	**84,301**	**34,480**	**41,294**	**48,364**	**52,859**
	Net NPV	£'000	**300,252**	**349,865**	**338,348**	**282,384**	**245,310**	**264,516**	**271,002**	**238,898**
Average Incremental Cost (AIC)										
20 years at 8%	**Throughput (discounted)**	tDS	**1,533,531**	**1,533,531**	**1,533,531**	**1,533,531**	**1,533,531**	**1,533,531**	**1,533,531**	**1,533,531**
	Total Cost AIC	£/tDS	**209**	**255**	**248**	**239**	**182**	**199**	**208**	**190**
	Net AIC	£/tDS	**196**	**228**	**221**	**184**	**160**	**172**	**177**	**156**

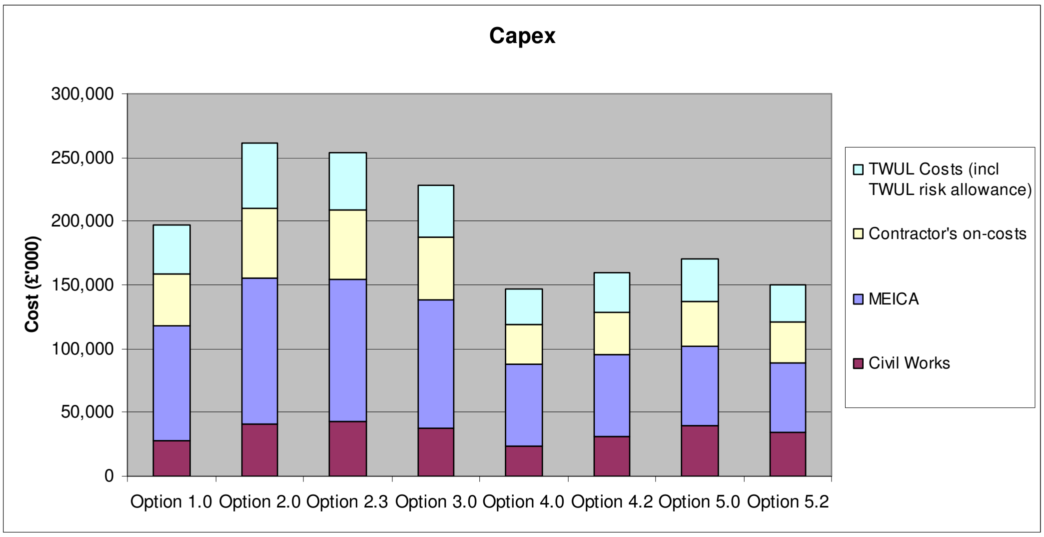
Note: Capex includes refurbishment (capital maintenance) of existing SPG.

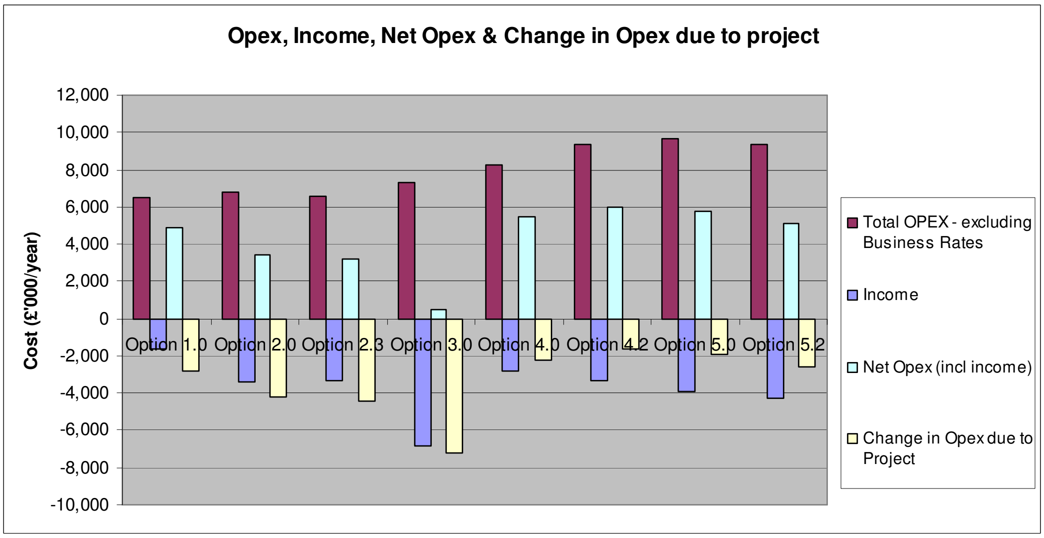
Table 6.13: Cost estimate summary for Crossness STW

Option	**Units**	**Option 1.0**	**Option 2.0**	**Option 2.3**	**Option 3.0**	**Option 4.0**	**Option 4.2**	**Option 5.0**	**Option 5.2**
Process route - Existing stream		RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Process route - Additional stream		RCI	EDI	EDI	0	ED	ED		ED
Location - Existing stream		Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Location - Additional stream		Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Throughput (tDS/d) - Existing stream		95	95	114	215	95	95	215	165
Throughput (tDS/d) - Additional stream		120	120	188	0	120	207	0	137
Initial CAPEX									
Civil Works	£'000	21,775	28,894	43,258	22,727	15,158	29,295	24,607	36,906
MEICA	£'000	68,603	77,983	97,798	70,908	43,137	55,105	39,908	43,994
Sub-total - Base Cost	£'000	**90,377**	**106,877**	**141,056**	**93,635**	**58,295**	**84,400**	**64,515**	**80,900**
Contractor's on-costs	£'000	32,007	37,850	49,955	33,161	20,645	29,890	22,848	28,651
Sub-total - Design & Construction Costs	£'000	**122,384**	**144,727**	**191,011**	**126,796**	**78,940**	**114,290**	**87,363**	**109,551**
TWUL Costs (incl TWUL risk allowance)	£'000	29,400	34,800	41,900	27,800	19,000	27,500	21,000	26,400
Total Project Cost	£'000	**151,784**	**179,527**	**232,911**	**154,596**	**97,940**	**141,790**	**108,363**	**135,951**
Proposed OPEX									
Staff Costs	£'000/year	1,312	1,600	1,919	1,600	1,216	1,023	511	511
Chemicals	£'000/year	1,340	1,329	1,971	1,317	1,180	1,663	1,011	1,486
Operational Maintenance	£'000/year	2,593	2,587	2,862	2,024	1,828	2,001	491	578
Electricity consumption STC, Liquor treatment	£'000/year	1,943	1,718	2,755	1,551	1,253	1,923	706	1,366
Electricity generated by CHP & consumed by STC/WwTW	£'000/year	-4,051	-5,781	-8,062	-6,673	-5,078	-7,144	-5,607	-6,614
CHP Engine Maintenance (incl periodic overhaul)	£'000/year	0	385	577	690	385	639	690	968
Fuel (supplementary)	£'000/year	5	465	770	858	465	840	824	1,157
Business Rates	£'000/year	1,499	1,605	2,022	1,363	1,210	1,613	1,385	1,679
Sludge Transport - Biosolids Recycling	£'000/year	0	0	0	0	2,126	4,340	5,009	7,362
Sludge Transport - Ash disposal	£'000/year	1,040	1,026	1,431	1,010	459	459	0	0
Potable Water (for steam, poly make-up/dilution)	£'000/year	66	105	160	138	105	167	138	198
Total OPEX - excluding Business Rates and Income	£'000/year	**4,248**	**3,435**	**4,383**	**2,515**	**3,939**	**5,912**	**3,773**	**7,013**
Income									
ROCs	£'000/year	-794	-1,581	-2,203	-2,318	-1,525	-2,175	-1,763	-2,476
Electricity Exports	£'000/year	0	0	-185	-634	0	0	0	-850
Total Income	£'000/year	**-794**	**-1,581**	**-2,388**	**-2,953**	**-1,525**	**-2,175**	**-1,763**	**-3,326**
Total Net OPEX - excluding Business Rates, including Income	£'000/year	**3,454**	**1,854**	**1,995**	**-438**	**2,414**	**3,737**	**2,009**	**3,687**
Existing Opex									
Existing Opex at commissioning - including income	£'000/year	6,961	6,961	6,961	6,961	6,961	6,961	6,961	6,961
Change in Opex due to Project									
Excluding ROCs & electricity exports (excluding Business Rates)	£'000/year	-2,713	-3,526	-2,578	-4,446	-3,022	-1,049	-3,188	53
Including ROCs & electricity exports (excluding Business Rates	£'000/year	-3,507	-5,107	-4,966	-7,399	-4,547	-3,224	-4,952	-3,274
NPV									
20 years at 8% Total Capex NPV	£'000	184,367	216,565	279,360	188,274	118,428	167,963	127,318	156,847
Total Opex NPV	£'000	52,493	36,584	44,690	31,075	48,679	73,055	46,620	86,666
Total Cost NPV	£'000	**236,860**	**253,149**	**324,051**	**219,348**	**167,107**	**241,018**	**173,938**	**243,512**
Total Income NPV	£'000	**9,813**	**19,538**	**29,508**	**36,489**	**18,846**	**26,877**	**21,790**	**41,106**
Net NPV	£'000	**227,048**	**233,611**	**294,543**	**182,859**	**148,260**	**214,141**	**152,148**	**202,406**
Average Incremental Cost (AIC)									
20 years at 8% Throughput (discounted)	tDS	**834,421**	**834,421**	**1,226,428**	**834,421**	**834,421**	**1,226,428**	**834,421**	**1,226,428**
Total Cost AIC	£/tDS	**284**	**303**	**264**	**263**	**200**	**197**	**208**	**199**
Net AIC	£/tDS	**272**	**280**	**240**	**219**	**178**	**175**	**182**	**165**

Note: Capex includes refurbishment (capital maintenance) of existing SPG.

Figure 6.1: Summary Capital and Operating Costs for Beckton





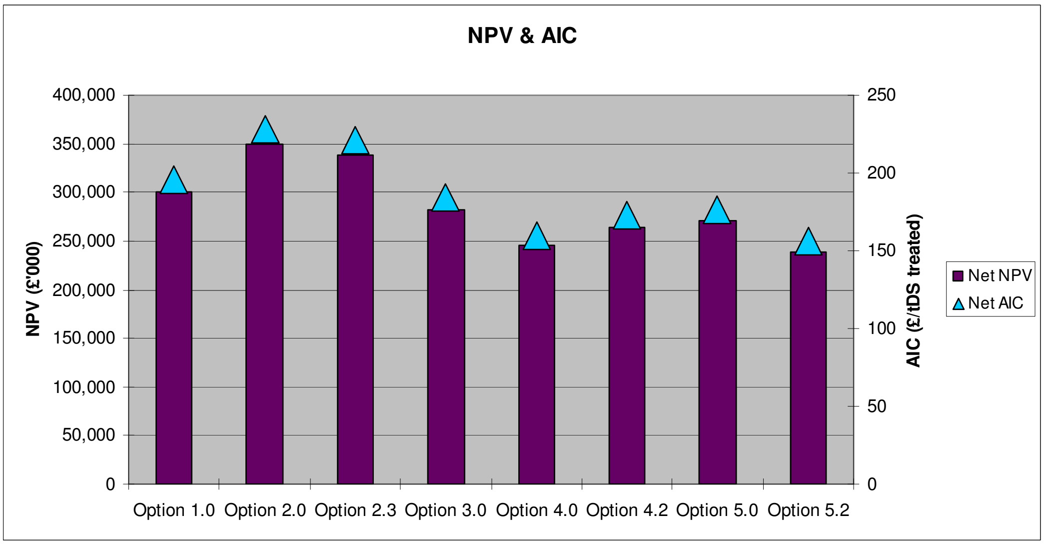
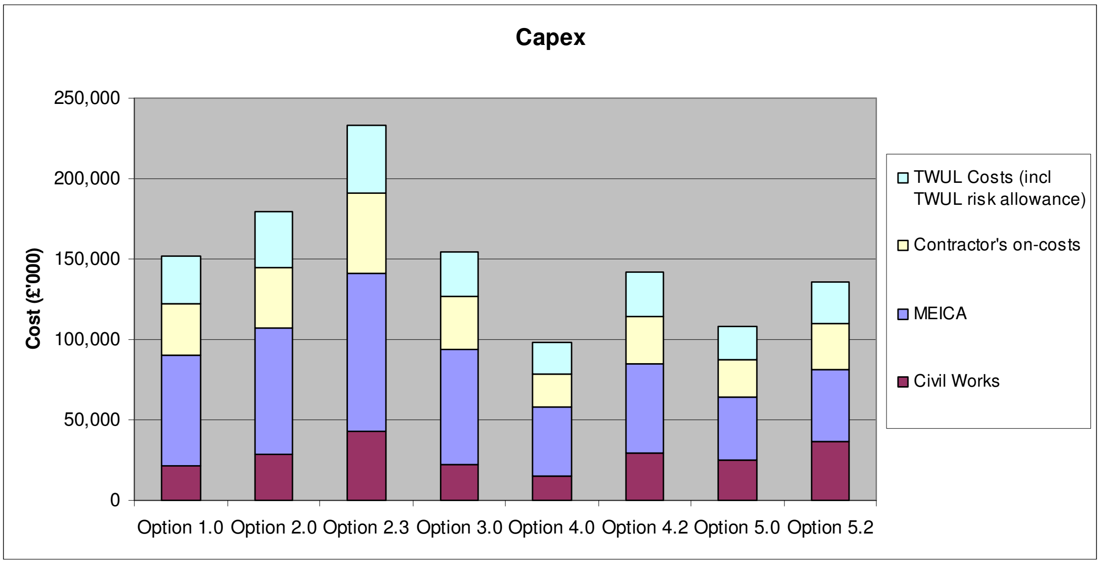
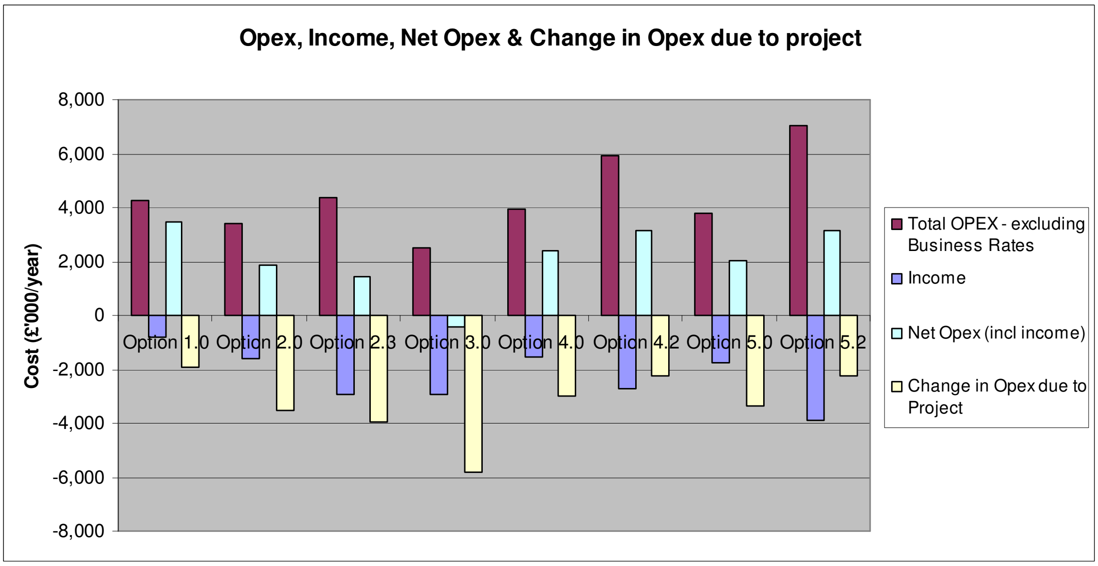
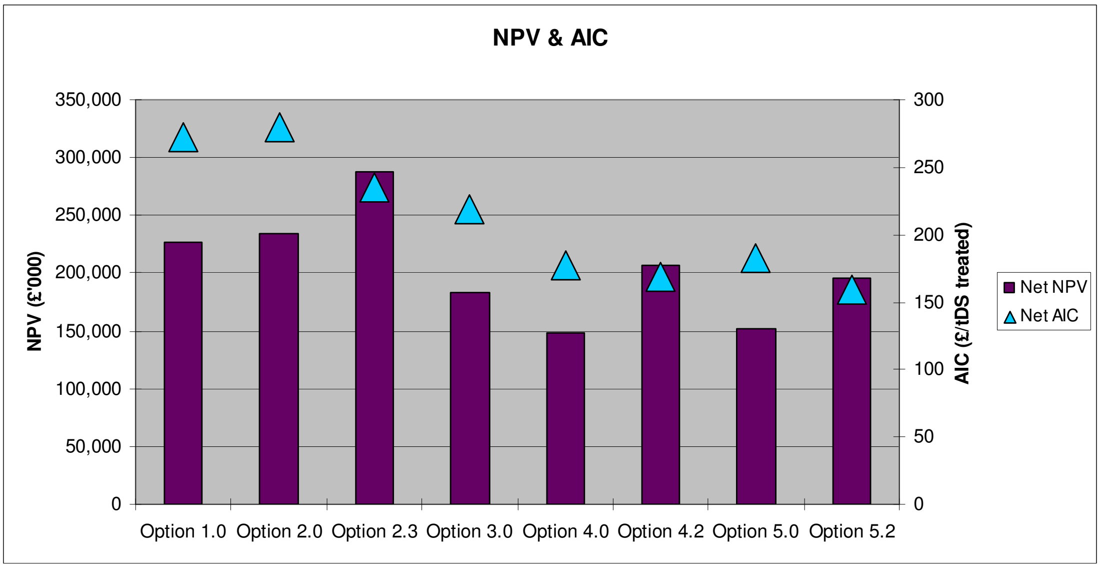


Figure 6.2: Summary Capital and Operating Costs for Crossness







6.11.3 Revenue

The following sources of revenue have been assumed in the cost estimates:

- Sale of Renewables Obligation Certificates (ROCs) for electricity generated by burning biogas in the CHP engines. It has been assumed that 1.0 ROCs/MWh will be available for all CHP engines fully accredited with Ofgem before April 2011 (assumed to be those under the proposed enhanced digestion project at Riverside STW and the existing CHP engines at Long Reach STW) but only 0.5 ROCs/MWh for all additional CHP engines installed under the proposed options for additional sludge capacity.
- Sale of Renewables Obligation Certificates (ROCs) for electricity generated by the SPG steam turbines. It has been assumed that 1.0 ROCs/MWh will be available for all capacity installed before 2011 (i.e. the existing SPGs) but only 0.5 ROCs/MWh for all additional steam turbines installed under the proposed options for additional sludge capacity.
- Sale of surplus electricity generated by CHP engines or steam turbines.

Unit rates for ROCs and electricity sales have been provided by TWUL.

6.11.4 Net present value and AIC

NPVs for each option have been calculated based on the capex, opex and revenue estimates, discounted at 5.1% over a 20-year design horizon.

Average Incremental Costs (AIC) for each option are calculated as the NPV divided by the 'present value' of all sludge throughputs over the 20 year design horizon, discounted at 5.1%.

6.11.5 Conclusions on cost estimates

It can be seen from the tables and graphs presented that options 4.0 and 5.0 have the lowest capital expenditure for both Beckton and Crossness (25% and 13%, respectively, lower than Option 1.0 for Beckton STW; 35% and 30%, respectively, lower than Option 1.0 for Crossness STW) demonstrating that provision of enhanced digestion capacity is considerably cheaper in capex terms than new incineration capacity.

If the refurbishment costs for the existing SPGs are excluded then the capex for options 3.0 and 5.0 would be similar whilst the capex for Option 4.0 would be between 30% and 40% lower than options 1.0, 3.0 and 4.0.

Option 3.0 has the lowest net opex (opex minus income) due to having the highest potential income. The whole throughput would be digested, creating biogas for use in CHP (i.e. similar to options 5.0 and 5.2) but incineration of the resulting sludge cake would also generate power from the existing SPG steam turbine. This analysis takes into account the additional natural gas consumption required to achieve combustion of the (lower calorific value) enhanced digested sludge.

Options 4.0, 4.2, 5.0 and 5.2 have relatively higher net opex due to the supplementary fossil fuel required to heat the thermal pre-treatment stage and additional sludge recycling costs (large volumes of cake rather than relatively small quantities of ash). It is possible that the fossil fuel consumption can be reduced through further process optimisation, for example, using more biogas in a steam boiler and less in CHP engines (creating more heat though less power) or through use of other waste heat sources (e.g. waste heat from the Beckton Thames Gateway Water Treatment Plant biodiesel engines).

Overall, options 4.0, 4.2, 5.0 and 5.2 have the lowest NPV and AIC – due to their moderately higher opex being mitigated by significantly lower capital costs.

7 Option Selection Workshop

The Short List options were appraised at the VM 2 workshop in order to select the preferred option. The appraisal methodology included the scoring of options against agreed objectives and sub-objectives as described in Section 1.3.

The scores take the form of three grades of positive performance (one, two or three plus signs); three grades of negative performance (one, two or three minus signs); and a neutral i.e. a seven point score.

Thus, the scoring system used was as follows:

Score	Meaning
+ + +	Very strong positive effect of the option on the objective
+ +	Moderately strong positive effect of the option on the objective
+	Positive effect of the option on the objective
0	Overall neutral effect of the option on the objective
-	Negative effect of the option on the objective
- -	Moderately strong negative effect of the option on the objective
- - -	Very strong negative effect of the option on the objective
?	Uncertain effect of the option on the objective
n/a	No relation between the option and the objective.

Whilst the scoring of sub-objectives was a 'qualitative' assessment it was based on the experience of the specialists in the workshop as well as the thorough analysis of the options presented in Section 6.0 of this report.

It should be noted that the overall scores for each objective (and the overall consolidated score for all objectives) presented in the following sections were selected based on the consensus of the experts present at the value management workshops, taking into account the scores for the underlying sub-objectives. The overall scores were not based on any numerical analysis of the scores for the underlying sub-objectives.

Further details on the appraisal methodology are provided in Section 1.3 of this report.

This section presents the key findings and conclusions of the VM 2 Option Selection workshop including the scores assigned for each option against the agreed objectives and sub-objectives.

7.1 Constructability

7.1.1 Discussion

Constructability is concerned with project related issues encountered during the construction phase of the project – including construction phase environmental impacts.

Hence, this objective looks at the relative technical complexity of building the options, inherent or unforeseen risks to the project programme, including cost and resourcing issues, consideration of other concurrent schemes and environmental impacts.

The assessment of options was based on the following sub-objectives:

- Implementation programme (whether an option can be implemented in time to meet demand)
- Utilities interfaces
- Noise / dust control (potential to impact on nearby developments)
- Traffic management (including potential requirement for road closures / diversions)
- Construction access (within site)
- Other major interface issues
- Technical complexity
- Availability of land for contractor's site compound and laying down area, and
- Maintaining existing treatment processes during construction & commissioning.

These objectives were assessed on the basis of design review and engineering judgement (in the context of available information and level of design development at this stage). Table 7.1 summarises the discussions on each sub-objective that occurred at the VM 2 workshop. In general, the findings were similar for both Beckton STW and Crossness STW options, however, where differences between the sites were identified these are presented in Table 7.1.

Appendix I of this report presents the scores for each sub-objective in more detail and also highlights where scores for an option changed between VM 1 and VM 2.

Table 7.1: Constructability – Basis for sub-objective scores

Implementation programme (whether an option can be implemented in time to meet demand)
A requirement for each option is that it can be implemented by the end of AMP 5. Key issues for an implementation programme will be the time taken to achieve planning application and the time needed to construct the works. At the VM2 workshop it was considered that only Option 3.0 (where the existing SPG had to be modified to accept enhanced digested sludge) had a greater risk of programme delay and therefore justified a lower score. Other options had greater scope for -off-line work and hence lower risk.
Utilities interfaces
In general, options requiring diversion of significant existing services were given a lower score. For Beckton STW this resulted in options requiring diversion of the overhead cables next to the existing SPG being given a lower score (-) compared to 0 for other options. No significant differences were identified between options at Crossness STW and hence all were scored 0.
Noise / dust control (constraints posed by nearby developments)
It was considered that at all options had an equal potential for construction noise or dust impacts on nearby developments and that these would need to be mitigated by good construction practice (noise and dust suppression) - hence all Beckton STW and Crossness STW options were scored the same (-).
Traffic management (including potential for road closures / diversions)
Construction traffic management was considered likely to be a significant impact for all options involving construction of additional capacity at Beckton STW or Crossness STW - hence options where all works are located at Beckton STW or Crossness STW were given negative scores. In contrast, options where most additional capacity was provided at Riverside STW or Long Reach STW were considered to have lower construction traffic impacts and hence were given neutral scores (0). It was considered that traffic impacts could be partly mitigated by good site management (lorry load optimisation, timing of deliveries, etc).
Construction access (within site)
Options which had a larger land 'footprint' were considered likely to cause greater construction management issues within each STW site and were therefore given lower scores. Thus options involving EDI and ED at Beckton or Crossness STWs were given the lowest scores whilst options where additional assets were constructed at Riverside STW or Long Reach STWs, so reducing the overall intensity of construction at each site) achieved neutral scores (0). For Beckton STW options it was considered that there would be an additional impact as construction would coincide with construction of the Tideway Tunnel headworks.
Other major interface issues
Some options involved more complex interfaces with existing processes including the existing SPG (e.g. RCI+) and these were awarded more negative scores as a result.
Technical complexity
Options involving a single process type and location were considered to be less technically complex. Conversely, options involving two different process types combined with treatment being divided between two sites, were considered to be the most complex and therefore were given the lowest scores.
Availability of land for contractor's site compound and laying down area
All sites are constrained, to varying extent, by the availability of space for construction of the permanent works (treatment plant) as well as space required for a contractor's temporary site compound and laying down area. It was considered that less land would be required for enhanced digestion plant construction as main components are fabricated off-site. Hence, process options including new incineration were given a more negative score.
Maintaining existing treatment processes during construction & commissioning
Works involving modification to existing treatment streams, particularly where this involves adaptation of the existing incinerators to burn digested sludge cake (i.e. where an existing incinerator is converted to EDI) or other enhancements to the existing incinerator (i.e. RCI+) were considered to have the highest risk of impacting on operation of existing process streams and hence were scored lowest.

7.1.2 Optioneering results

MM proposed scores that were then debated by the workshop. Tables 7.2 and 7.3 present the scores for each sub-objective and the overall scores that were agreed for the Constructability objective for Beckton STW and Crossness STW options, respectively.

It can be seen from the tables that, in terms of the constructability objective, options which provided both additional mass-burn incinerator and enhanced digestion were judged least attractive whilst those likely to have a lower footprint and interface issues (i.e. less complex) were given the highest scores. The overall option scores for the VM1 and VM2 workshops are broadly similar, with minor differences largely due to greater understanding of the contractor's working area requirements.

In conclusion, it was agreed that in terms of constructability, there are no "show stoppers" and that further detailed study was required to differentiate between the options.

The overall option scores for the VM1 and VM2 workshops are broadly similar.

Table 7.2: Scores: Constructability – Beckton

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Implementation programme (whether an option can be implemented in time to meet demand)**							
VM 2 Score	0	0	0	-	0	0	0	0
Sub-objective	**Utilities interfaces**							
VM 2 Score	-	-	-	-	0	-	-	-
Sub-objective	**Noise / dust control (constraints posed by nearby developments)**							
VM 2 Score	-	-	-	-	-	-	-	-
Sub-objective	**Traffic management (incl potential road closures / diversions)**							
VM 2 Score	- -	- -	0	- -	- -	0	- -	- -
Sub-objective	**Construction access (within site)**							
VM 2 Score	-	- -	0	- -	- -	0	- -	-
Sub-objective	**Other major interface issues**							
VM 2 Score	0	0	-	-	0	0	-	-
Sub-objective	**Technical complexity**							
VM 2 Score	0	- -	- - -	- -	-	- - -	-	-
Sub-objective	**Availability of land for contractor's site compound and laying down area**							
VM 2 Score	-	-	-	-	-	+	0	0
Sub-objective	**Maintaining existing treatment processes during construction & commissioning**							
VM 2 Score	+ + +	+	+	+	+ + +	+ + +	+ + +	+ + +
Overall Score for Constructability Objective								
VM 2 Score	+	-	- -	-	0	0	0	+

Table 7.3: Scores: Constructability – Crossness

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Implementation programme (whether an option can be implemented in time to meet demand)**							
VM 2 Score	0	0	0	-	0	0	0	0
Sub-objective	**Utilities interfaces**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Noise / dust control (constraints posed by nearby developments)**							
VM 2 Score	-	-	-	-	-	-	-	-
Sub-objective	**Traffic management (incl potential road closures / diversions)**							
VM 2 Score	- -	- -	0	- -	- -	0	- -	- -
Sub-objective	**Construction access (within site)**							
VM 2 Score	-	- -	0	- -	- -	0	- -	-
Sub-objective	**Other major interface issues**							
VM 2 Score	0	0	-	-	0	0	-	-
Sub-objective	**Technical complexity**							
VM 2 Score	0	- -	- - -	- -	-	- - -	-	-
Sub-objective	**Availability of land for contractor's site compound and laying down area**							
VM 2 Score	-	-	-	-	-	+	0	0
Sub-objective	**Maintaining existing treatment processes during construction & commissioning**							
VM 2 Score	+ + +	+	+	+	+ + +	+ + +	+ + +	+ + +
Overall Score for Constructability Objective								
VM 2 Score	+	-	- -	-	0	0	0	+

7.2 Technology

7.2.1 Discussion

The Technology objective assessed whether the proposed technology options were likely to work and provide the required treatment capacity on a reliable basis. The potential flexibility for future adaptation was also considered.

The assessment of options was based on the following sub-objectives:

- Reliability of process
- Track record (established process)
- Track record (implemented at similar scale)
- Availability of suppliers (plant, chemicals and materials)
- Footprint (availability of land)
- Potential for future upgrading through additional or alternative process stages
- Marketability/recycling/ disposal of final product.

These objectives were assessed on the basis of design review and engineering judgement (in the context of available information and level of design development at this stage). Table 7.4 summarises the discussions on each sub-objective that occurred at the VM 2 workshop.

Table 7.4: Technology – Basis for sub-objective scores

Reliability of process (ability to operate on a consistent basis)
Following discussion on the reliability of the various processes, based on the experience of the workshop participants, a consensus was reached that enhanced digestion options were likely to be the most reliable, followed by mass-burn incineration options. Hence options comprising ED were scored more positively than RCI or EDI options. These scores were the same for both Beckton STW and Crossness STW options.
Track record (established process)
This sub-objective assessed whether there was a sufficient track record for the process technologies to provide comfort that the option was feasible. The workshop consensus was that both enhanced digestion and mass-burn incineration were both established processes and therefore scored highest (2 pluses). However, the participants were not aware of existing examples of enhanced digestion followed by incineration and hence this was scored lower (-). However, it was noted that this solution was being adopted by United Utilities for at least part of its throughput for the proposed extension to the Shell Green incinerator.
Track record (implemented at similar scale)
This sub-objective assessed whether there was a sufficient track record for the process technologies being implemented at a similar scale to provide comfort that the option was feasible. The existing Beckton STW and Crossness STW SPGs are already amongst the largest in Europe and given TWUL's reliance on these two sites for much of their sludge treatment capacity it is essential that processes are proven at this size. The workshop consensus was that raw cake incineration was already proven at scale given that this was the existing process at each site - hence this scored the highest (+++). For enhanced digestion it was considered that although there were no existing sites at this scale the modularity of the process meant that scaling up was not an issue - hence this scored the next highest (++). However, for EDI options it was noted that there were no existing examples and hence these were given lower scores.
Availability of suppliers (plant, chemicals and materials)
This sub-objective considered the availability of suppliers from the point of view of technical capability to provide working facilities (technical ability and manufacturing capacity). The workshop consensus was that all processes could be supplied in the timescale and quality required - hence most options were scored equally (++). However, it was felt that the larger number of suppliers available for incineration technology, compared to enhanced digestion, gave this a small edge. Hence, raw cake incineration was given the highest score (+++).
Footprint (availability of land)
This sub-objective considered the potential footprint for each option against the likely availability of land at each site. It was considered that options involving raw cake incineration (RCI) would have the lowest footprint and hence scored highest (++). Scores for other options fell between (+) and (- -) based on the combination of processes and hence the expected footprint.
Potential for future upgrading through additional or alternative process stages
This sub-objective considered the potential for future adaptation of the process option in the event that new processes - such as gasification - become more technically and economically attractive. The consensus was that options culminating in incineration had less potential for adaptation than options providing only enhanced digestion. Hence enhanced digestion options were scored one minus and other options two minuses.
Marketability/recycling/ disposal of final product
It was considered that an enhanced digested cake product would have the most potential market. Ash was given the lowest score (-) due to the lack of recycling outlets currently available for this product. Furthermore, the outlet for an incinerated ash product is severely constrained. TW estimates a maximum of 3 to 4 years of available landfill capacity in the London region.

7.2.2 Optioneering results

MM proposed scores that were then debated by the workshop. Table 7.5 present the scores for each sub-objective and the overall scores that were agreed for the Technology objective for both Beckton STW and Crossness STW options (options at each site were scored the same hence only one table is presented).

It can be seen from the table that, in terms of the technology objective, options which provided an additional mass-burn incinerator or which provided enhanced digestion, were the most favoured at the workshop. These options were considered to represent 'tried and tested' technologies with a probability of meeting the technical requirements. It was noted that whilst this was the case for the processes when considered individually, the combination of the two processes (i.e. EDI) was less proven.

Enhanced digestion processes were also considered to have the most potential for future adaptation, for example, through additional process stages.

In conclusion, it was agreed that in terms of Technology, there are no "show stoppers".

The overall option scores for the VM1 and VM2 workshops are broadly similar.

Table 7.5: Scores: Technology – Beckton and Crossness options

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Reliability of process**							
VM 2 Score	+	+	+	+	+	+	+ +	+ +
Sub-objective	**Track record (established process)**							
VM 2 Score	+ +	-	-	-	+ +	+ +	+ +	+ +
Sub-objective	**Track record (implemented at similar scale)**							
VM 2 Score	+ + +	-	- -	- -	+ +	+ +	+ +	+ +
Sub-objective	**Availability of Suppliers (plant)**							
VM 2 Score	+ + +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
Sub-objective	**Footprint (land take)**							
VM 2 Score	+ +	+	0	-	0	+	-	-
Sub-objective	**Potential for future upgrading through additional or alternative process stages**							
VM 2 Score	- -	- -	- -	- -	-	-	-	-
Sub-objective	**Marketability/recycling/ disposal of final product**							
VM 2 Score	-	-	-	-	+	+	+	+
Overall Score for Technology Objective								
VM 2 Score	+ +	-	-	-	+	+	+	+
Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach

7.3 Operations

7.3.1 Discussion

The Operations objective assessed how the facility will perform under normal circumstances and conditions, once it becomes operational. Operations looks at the likelihood of the scheme specification being achieved with respect to performance, reliability, and flexibility.

The assessment of options was based on the following sub-objectives:

- Staffing – (numbers needed & availability, expertise/ experience required for the different technologies)
- Maintenance requirements
- Operational flexibility e.g. able to handle variations in feed quantity and quality)
- Operational Complexity
- Risk of losing disposal route for product.

These objectives were assessed on the basis of design review and engineering judgement (in the context of available information and level of design development at this stage). Table 7.6 summarises the discussions on each sub-objective that occurred at the VM 2 workshop.

Table 7.6: Operations – Basis for sub-objective scores

Staffing – (numbers needed & availability, expertise/ experience required for the different technologies)
In scoring this sub-objective it was considered that options which resulted in more than one type of sludge treatment technology at each site should have a lower score on the grounds that additional staff (numbers and expertise) would be required to operate each type of process. Scores in this case were one minus. Conversely, options with only one process technology at each site were scored higher (0). Where technologies were used at different sites (e.g. RCI at Beckton STW and ED at Riverside STW) then this was treated as a single technology at each site and scored accordingly.
Maintenance requirements
Scores for this sub-objective reflected the perceived reliability of the processes, and thus the potential maintenance effort required, as well as the number of processes involved - which would impact on the range of skills that would be needed at each site. Options involving incineration were considered to have a high maintenance requirement - particularly if in combination with a different technology at the same location (e.g. RCI and ED at Beckton STW, score --). The highest scoring options were those only using enhanced digestion or where different technologies were used at separate sites.
Operational flexibility e.g. able to handle variations in feed quantity and quality)
All options were considered to be reasonable similar for this sub-objective though options including enhanced digestion were considered to have a small advantage and hence were scored marginally higher (0 compared to one minus for other options). Option 2.0 and 2.3 which include both RCI and EDI process streams, were considered to be the least flexible as it would not be possible to mix digested and raw cake in the feed to the existing SPG due to the risk of biogas production in the furnace feed silos.
Operational Complexity
This sub-objective was intended to capture process complexity from an operations point of view. Options 1.0 and 5.0 scored the most positively as they each comprise a single process type at a single location.
Risk of losing disposal route for product

The outlet for an incinerated ash product is constrained due to a lack of landfill capacity. TW staff at the workshop reported that only 3 to 4 years of landfill capacity remaining in the London region. Treating a large proportion of sludge using enhanced digestion would also increase TW's vulnerability with respect to potential disruption of agricultural recycling following, for example, further outbreaks of Foot and Mouth'. On this basis Options 5.0 and 5.2 were given more negative scores. The risks associated with enhanced digestion of just half of the sludge produced at Beckton or Crossness STWs (options 4.0 and 4.2) were considered to be lower and comparable to those associated with ash disposal.

7.3.2 Optioneering results

MM proposed scores that were then debated by the workshop. Table 7.7 present the scores for each sub-objective and the overall scores that were agreed for the Operations objective for both Beckton STW and Crossness STW options (options at each site were scored the same hence only one table is presented).

It can be seen from the table that, in terms of the Operations objective, options involving two different processes on one site (e.g. ED and RCI) were considered to be more complex from an operational viewpoint than single process sites e.g. all ED or all RCI).

In conclusion, it was agreed that in terms of Operations, there are no “show stoppers”.

The overall option scores for the VM1 and VM2 workshops are broadly similar.

Table 7.7: Scores: Operations Beckton and Crossness options

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Staffing – (numbers needed & availability, expertise/ experience required for the different technolog**							
VM 2 Score	0	-	-	-	-	0	0	0
Sub-objective	**Maintenance requirements**							
VM 2 Score	- -	- -	- -	- -	- -	-	-	-
Sub-objective	**Operational flexibility (e.g. able to handle variations in feed quantity and quality)**							
VM 2 Score	-	- -	- -	-	0	-	0	0
Sub-objective	**Operational Complexity**							
VM 2 Score	+ +	- -	- -	-	-	0	+ +	+
Sub-objective	**Risk of losing disposal route for product**							
VM 2 Score	0	0	0	0	0	0	- - -	- - -
Overall Score for Operations Objective								
VM 2 Score	+	- -	- -	-	0	0	- - -	- - -
Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach

7.4 Safety

7.4.1 Discussion

The safety objective is concerned with reducing the loss of life, injuries and damage to property resulting from construction and operation.

This objective consisted of just one sub-objective – to 'Reduce risk of illness or injury to employees, contractors and public'. Table 7.8 summarises the discussion on this sub-objective that occurred at the VM 2 workshop.

Table 7.8: Safety – Basis for sub-objective scores

Reduce risk of illness or injury to employees, contractors and public
It was considered that TWUL would not promote nor allow construction of a new treatment facility that was not 'safe' and hence all options should be scored with a zero. It was noted that enhanced digestion options could include thermal hydrolysis which uses high pressure steam. However, it was considered that any additional safety risk will be minimised through operator training and regular inspections of the pressure systems. Incineration options may, depending on design, include thin-film type dryers. However, these were considered not to suffer from the same potential safety risks as conventional dryers. In conclusion it was decided to give all options a neutral score.

7.4.2 Optioneering results

MM proposed scores that were then debated by the workshop. Table 7.9 present the scores for each sub-objective and the overall scores that were agreed for the Safety objective for both Beckton STW and Crossness STW options (options at each site were scored the same hence only one table is presented).

In conclusion it was agreed that as all options would be designed to operate safely there was little differentiation between the options.

Table 7.9: Overall Scores: Safety

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Reduce risk of illness or injury to employees, contractors and public**							
VM 2 Score	0	0	0	0	0	0	0	0
Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach

7.5 Integration

7.5.1 Discussion

The integration objective aims to ensure that all decisions are taken in the context of Thames Water strategic policies and policies produced by local authorities, Greater London Authority and national agencies.

The assessment of options was therefore based on integration with the following policies and strategies:

- Greater London Authority (GLA) objectives and ambitions
- London Thames Gateway Development Corporation (LTGDC) objectives and ambitions
- Land use policy
- Other local and national government policies
- Thames Water's strategic policies and documents including Strategic Direction Statement, Thames Water's 25-year Sludge Strategy and the Strategic Environmental Assessment (SEA - including subsequent SEA Post Adoption Statement) for the Sludge Strategy.

These objectives were assessed on the basis of design review and engineering judgement (in the context of available information and level of design development at this stage). Table 7.10 summarises the discussions on each sub-objective that occurred at the VM 2 workshop.

Table 7.10: Integration – Basis for sub-objective scores

LTGDC objectives and ambitions
Both Beckton and Riverside STWs fall within the area covered by LTGDC. It was considered that development within the operational boundaries of the site would not conflict with LTGDC's objectives and improvement of and provision of additional sewerage and sludge treatment infrastructure was considered critical to bringing about more growth within the London Thames Gateway area and adverse impacts such as increased traffic movements would not be significant. Hence, all options were scored neutral. The LTGDC has regeneration objectives for more employment and housing development near Beckton and Riverside STWs and any impacts would be considered under environment sub-objectives. This sub-objective was not relevant to Crossness STW options.
Other national government policies
Scoring focussed on sustainability and renewable energy which were considered relevant and favoured enhanced digestion options as these reduced sludge volume (and hence disposal transport), produced renewable energy and enabled treated sludge to be recycled to agricultural land. Sub-options involving treatment of a proportion of sludge at either Riverside or Long Reach STWs scored lower than those where all sludge was treated at origin (i.e. Beckton or Crossness STWs) due to consideration of the 'proximity principle' as well as the additional energy use required in transporting sludge to these sites compared to 'in-situ' treatment.
Other regional government policies (London Plan)
Scoring took into account the London Plan policies on water and sewage infrastructure replacement to meet population growth and climate change requirements as well as the GLA consultation response on the Sludge Strategy and associated SEA. The GLA, in its consultation response on the Sludge Strategy, accepted that recycling sewage sludge to land is the Best Practicable Environmental Option (BPEO) and in accordance with Mayoral recycling policies. The GLA also expressed support the adoption of advanced conversion technologies (including pyrolysis and gasification) over conventional incineration. Hence options including enhanced digestion were scored higher than those involving incineration as the final treatment stage.
Land use policy (Unitary Development Plans / Local Development Plan Documents)
This sub-objective considered local policy issues such as sustainability and renewable energy. It also took into account various land use designations, such as 'Metropolitan open land' at Beckton and Crossness STWs and the Site of Borough Importance for Nature Conservation at Riverside STW. The Beckton and Crossness sites are the most heavily designated and this influence scoring for these options. However, options involving transfer of sludge to Riverside and Long Reach could also affect designated sites and, furthermore, would require greater energy use (in sludge transfer). Hence, options were scored the same (neutral).
Integration with Thames Water's Strategic Direction Statement, Sludge Strategy and associated SEA
The Strategic Direction Statement and the Sludge Strategy set out Thames Water's outline proposals for future sludge treatment in the East London region and these are assessed in the SEA. It was considered that options including mass-burn incineration, with or without pre-treatment using enhanced digestion, were consistent with the recommendations in these documents and hence all scored (+). Options which only included enhanced digestion were given more negative scores due to the increased transport impacts and greater risk associated with reliance on the agricultural recycling route for all sludge produced at Beckton STW.

7.5.2 Optioneering results

MM proposed scores that were then debated by the workshop. Tables 7.11 and 7.12 present the scores for each sub-objective and the overall scores that were agreed for the Integration objective for Beckton STW and Crossness STW options, respectively.

It can be seen from the table that, in terms of the Integration objective, options which provided enhanced digestion and incineration, or enhanced digestion followed by incineration, were favoured.

In conclusion, it was agreed that in terms of Integration, there are no "show stoppers".

Table 7.11: Scores: Integration - Beckton

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**LTGDC (London Thames Gateway Development Corporation) objectives and ambitions**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Other national government policies (PPS)**							
VM 2 Score	-	0	-	+	+	0	+	0
Sub-objective	**Other regional government policies (London Plan)**							
VM 2 Score	-	-	-	-	+	+	+	+
Sub-objective	**Land use policy (Unitary Development Plans / Local Development Plan Documents)**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Thames Water Strategic Direction Statement, Sludge Strategy and associated SEA (including SEA Post Adoption Statement)**							
VM 2 Score	+	+	+	+	0	0	-	-
Overall Score for Integration Objective								
VM 2 Score	0	+	0	+	+	+	0	0

Table 7.12: Scores: Integration - Crossness

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**National government policies (PPS)**							
VM 2 Score	-	0	-	+	+	0	+	0
Sub-objective	**Regional government policies (London Plan)**							
VM 2 Score	-	-	-	-	+	+	+	+
Sub-objective	**Land use policy (Unitary Development Plans / Local Development Plan Documents)**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Thames Water Strategic Direction Statement, Sludge Strategy and associated SEA (including SEA Post Adoption Statement)**							
VM 2 Score	+	+	+	+	0	0	-	-
Overall Score for Integration Objective								
VM 2 Score	-	0	-	0	+	0	0	0

7.6 Economy

7.6.1 Discussion

Economy is concerned with improving the economic efficiency of investment in assets. There are sub-objectives to improve economic efficiency for Thames Water, customers and to improve reliability and the wider economic impacts. Economy is considered to be a key objective with respect to achieving Ofwat approval for the proposed investment given Ofwat's responsibility to ensure that proposed investments are affordable for customers.

The assessment of options was based on the following sub-objectives:

- Construction costs
- Operating and maintenance costs (excluding electricity sales & ROCs)
- Revenue (sludge product recycling, on-site power generation and ROCs)
- Net Opex, including revenue
- WLC.

These sub-objectives were assessed on the basis of the cost estimates prepared using the available information and level of design development at this stage. Table 7.13 summarises the discussions on each sub-objective that occurred at the VM 2 workshop.

Table 7.13: Economy – Basis for sub-objective scores

Construction costs
The scores for this sub-objective were based on analysis of option capital costs prepared by the SAR Consultant. Options were scored relative to Option 1.0 which was considered the reference option. Based on the cost analysis it could be seen that options providing enhanced digestion with incineration were significantly more expensive to construct than the other options. Options providing additional capacity using just enhanced digestion were generally the cheapest. The cost for Option 4.2 was relatively higher than the other ED options due to the cost of the additional pipeline and associated thickening plant capacity required to transfer sludge to Riverside STW.
Operating and maintenance costs (excluding electricity sales & ROCs)
The scores for this sub-objective were based on preliminary analysis of option operating costs prepared by the SAR Consultant. This analysis was based on the predicted process performance for each option and unit cost data for similar schemes elsewhere. The operating cost data exclude potential income from electricity sales and ROCs but include the value of electricity generated and consumed on-site. Options were scored relative to Option 1.0 which was considered the reference option. Based on the analysis the high sludge transport and recycling costs associated with options 4.0, 4.2, 5.0 and 5.2 are a significant factor and result in these options having the highest overall opex. Option 3.0 also has a high opex due to high power and fossil fuel consumption.
Revenue (sludge product recycling, on-site power generation and ROCs)
Scoring for this sub-objective focussed on the potential for sale of surplus electricity generated and the ability to earn ROCs for the power produced. In general, options using enhanced digestion were considered to have greater potential for energy generation and earning ROCs - hence these were awarded two pluses. Option 3.0 allows electricity to be generated and ROCs earned for the ED stage as well as generating power in the SPG.
Net Opex, including (net of existing opex and revenue incl ROCs)
This analysis takes into account both future net opex and income. It can be seen that Option 3.0 has the most favourable net opex.
WLC
Whole life costs were derived using the construction and operating costs presented. The WLC included the initial capital, capital maintenance/renewals, net operating costs and income and were derived using a discount rate of 5.1% of 20 years in accordance with TW policy. The analysis indicates that options 4.0 and 5.2 have the lowest WLC, followed by options 1.0, 3.0, 4.2 and 5.0. The options were scored accordingly.

7.6.2 Optioneering results

MM proposed scores that were then debated by the workshop. Tables 7.14 and 7.15 present the scores for each sub-objective and the overall scores that were agreed for the Economy objective for Beckton STW and Crossness STW options, respectively.

The scores for this sub-objective were based on analysis of option costs prepared by the SAR Consultant. Options were scored relative to Option 1.0 which was considered the reference option. The WLC included the initial capital, capital maintenance/renewals, net operating costs and income and has therefore been used as the overall score for the economy objective.

Options 4.0 and 5.2 were awarded the best scores overall for the Economy objective.

Table 7.14: Scores: Economy – Beckton

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Construction costs**							
VM 2 Score	0	- -	- -	-	+ +	+	+	+ +
Sub-objective	**Operating and maintenance costs (excluding electricity sales & ROCs)**							
VM 2 Score	0	0	0	0	-	- -	- -	- -
Sub-objective	**Revenue (sludge product recycling, on-site power generation and ROCs)**							
VM 2 Score	0	+ +	+ +	+ + +	+ +	+ +	+ +	+ +
Sub-objective	**Net Opex, including revenue**							
VM 2 Score	0	+	+	+ + +	0	0	0	0
Sub-objective	**Whole Life Costs**							
VM 2 Score	0	-	-	0	+	0	0	+
Overall Score for Economy Objective								
VM 2 Score	0	-	-	0	+	0	0	+

Table 7.15: Scores: Economy - Crossness

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Construction costs**							
VM 2 Score	0	- -	- - -	0	+ +	0	+	0
Sub-objective	**Operating and maintenance costs (excluding electricity sales & ROCs)**							
VM 2 Score	0	+	0	+	0	- -	0	- - -
Sub-objective	**Revenue (sludge product recycling, on-site power generation and ROCs)**							
VM 2 Score	0	+	+ +	+ +	+	+ +	+	+ +
Sub-objective	**Net Opex, including revenue**							
VM 2 Score	0	+	+	+ +	+	0	+	0
Sub-objective	**Whole Life Costs**							
VM 2 Score	0	0	-	+	+ +	0	+ +	+
Overall Score for Economy Objective								
VM 2 Score	0	0	-	+	+ +	0	+ +	+

7.7 Property and Land

Although initially included in the Objectives prior to the VM 1 meeting, "Property and Land" was not scored in the meeting in order to avoid double counting as it was considered that potential impacts on neighbouring land uses were already covered by the "Constructability" (includes sub-objectives for temporary impacts on property and land) and the "Environment" objectives (includes sub-objectives for permanent impacts on property and land such as noise, cultural heritage, community, etc.).

7.8 Environment

7.8.1 Discussion

The environment objective involves reducing the direct and indirect impacts of the scheme facilities on the environment. Fifteen sub objectives, including noise, air quality, impacts on ecological resources and landscape/visual impact – were identified for the purpose of the VM 2 workshop.

For the purposes of this VM 2 workshop, readily available desk based data was referenced and the judgement and experience of various specialists was used to develop the results and outline justifications listed in Table 7.16.

Table 7.16: Environment – Basis for sub-objective scores

Landscape/ Townscape & Visual
At the VM2 workshop scores were based on the following principles: - Incinerator facilities are likely to have a greater visual impact than enhanced digestion facilities which are smaller in scale and similar to existing treatment facilities. - The construction of sludge treatment facilities in low lying areas with several vantage points, such as at Crossness or Riverside, is likely to have greater potential landscape/visual impacts than developments within the Beckton STW site. Based on these principles options including provision of incineration plant at Riverside or Crossness were awarded the lowest scores.
Air Quality incl. odour
It was assumed that any of the processes discussed would be designed and operated to meet regulatory requirements and standards laid out in any operating permit. At the VM2 workshop, it was considered appropriate to include other issues which may lead to a reduction in air quality (such as increased traffic movements and dust generation during construction) which would be associated with the scheme. It was therefore decided that there was a potential for a reduction in air quality although it was not possible to differentiate between proposed options.
Waste
Incinerator ash: It was assumed that end product from the incineration process would require disposal to landfill (low on the waste hierarchy). It was noted that lack of landfill capacity in the region was becoming an issue. Hence, options producing ash were given lower scores. **Enhanced digestion:** At the VM2 workshop, it was considered that enhanced digested cake would be recycled to agriculture providing it was of a suitable quality. Hence, options producing enhanced digested product were scored higher. It was considered that treatments which provided both ash and enhanced digested sludge were effectively neutral in there impact.
Water resources
The workshop participants considered that there was little differentiation between the options with respect to water resources.
Archaeology
It was considered that there is a potential negative impact on archaeological resources due to ground disturbance during construction of new facilities but the impact was likely to be similar for all options.

Traffic and Transport
All options would require incinerator ash and/or digested sludge to be transported off site for disposal or re-use. Incineration options produce the least quantities of material requiring disposal and therefore fewer traffic movements – hence these scored (-). Enhanced digestion options would produce greater quantities of digested sludge cake requiring recycling and therefore require more vehicle movements – hence a more negative score was awarded to enhanced digestion options. The type of road network used to access the proposed facilities was also taken into account with lower scores being given the options giving rise to greater traffic movements on local roads prior to reaching the strategic road network.
Ecology
Previous EIA work carried out at Beckton considered the site to be of fairly low ecological value. At the VM2 workshop it was identified that for the Riverside site, the proposed site for any development (the disused sludge lagoons) are designated a Grade 2 Site of Borough Importance for Nature Conservation and therefore proposals which involved Riverside received a more negative score. The Crossness site is located in a sensitive location with respect to ecology with a number of designated nature reserves in close proximity to the site and the larger the footprint of the development the greater the potential impact on ecological resources. There are no ecological designations on the Long Reach STW site but the surrounding area contains a number of nationally and regionally important areas. Options involving construction of a pipeline to Long Reach STW could lead to impact on ecologically sensitive areas.
Cultural heritage
It was considered that there would be a neutral effect on Cultural Heritage resources as a result of the proposals. There are no Scheduled Ancient Monuments, Listed Buildings, Conservation Areas, Registered Historic Parks and Gardens, Protected Wreck Sites, Ancient Woodland or Historic Battlefields present within the proposed development sites although listed buildings are found elsewhere with the Crossness STW site.
Health
Indicators used to assess health impacts include traffic and associated emissions, nuisance issues during construction – noise, dust etc and operational issues such as odour but at this stage there were no discernable differences between options.. At the VM2 workshop it was decided to capture some of these issues under the air quality objective (resulting in a more negative air quality score) and, in the absence of any specific information, it was decided to score health as neutral across all options.
Contaminated Land
It was considered that all the options would potentially bring contaminated land improvements as land contamination in the areas proposed for construction of new facilities may need to be removed/cleaned during the redevelopment process.
Community
It was considered that the impact on community resources was likely to be similar across the options (e.g. through increased traffic and associated emissions, nuisances issues during construction – noise, dust etc, or operational issues such as odours or through restricted access to community facilities). At this stage of the project development there were no discernable differences between Beckton options. However, it was noted that there are a number of housing developments in close proximity to the Long Reach STW site and therefore there could be a greater impact on sensitive receptors at these facilities - hence the options involving work at Long Reach STW were given a more negative score.
Noise
It was considered that there would be no significant difference in the background noise levels from the options proposed. Design measures would ensure that elevated noise sources were mitigated.
Socio-economic
It was considered that additional sludge treatment facilities within the boundaries of existing STWs would be unlikely to affect economic investment if an odour neutral or better situation is achieved – though there may be perception issues as well as issues apart from odour. There was no discernable differences between options and all were scored equally (neutral).
Renewable energy
Calculations indicated that enhanced digestion, or enhanced digestion followed by incineration, provided the greatest potential for renewable energy generation and hence these options received the most positive scores.
Climate change (relative GHG emissions for each option)

Based on analysis carried out for this SAR, it was concluded that options based on enhanced digestion alone were likely to have lower operational greenhouse gas emissions than those using incineration, for the same sludge throughput. Hence, incineration options were given a more negative score than enhanced digestion options.

7.8.2 Optioneering results

MM proposed scores that were then debated by the workshop. Tables 7.17 and 7.18 present the scores for each sub-objective and the overall scores that were agreed for the Environment objective for Beckton STW and Crossness STW options, respectively.

From these tables it can be seen that the overall assessments for each site, taking into account the sub-objective assessments, are as follows:

- Beckton STW options: Options 4.0, 5.0 and 5.2 are preferable to the other options.
- Crossness STW options: Option 5.0 had the highest score.

However, different options score better against different sub-objectives and hence there is no obviously 'best' option based on the environmental objective.

Table 7.17: Scores: Environment – Beckton

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Landscape/ Townscape & Visual**							
VM 2 Score	-	-	- -	-	0	-	0	0
Sub-objective	**Air quality (incl. odour)**							
VM 2 Score	-	-	-	-	-	-	-	-
Sub-objective	**Waste**							
VM 2 Score	- -	- -	- -	- -	0	0	+	+
Sub-objective	**Water Resources**							
VM 2 Score	0	0	-	0	0	-	0	-
Sub-objective	**Archaeology**							
VM 2 Score	-	-	-	-	-	-	-	-
Sub-objective	**Traffic & Transport**							
VM 2 Score	-	-	-	-	- - -	- -	- - -	- -
Sub-objective	**Ecology**							
VM 2 Score	0	0	-	0	0	-	0	-
Sub-objective	**Cultural Heritage**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Health**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Contaminated Land**							
VM 2 Score	+	+	+	+	+	+	+	+
Sub-objective	**Community**							
VM 2 Score	-	-	-	-	-	-	-	-
Sub-objective	**Noise**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Socio economic**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Renewable energy**							
VM 2 Score	+	+ +	+ +	+ + +	+ +	+ +	+ +	+ +
Sub-objective	**Climate change (relative GHG emissions for each option).**							
VM 2 Score	- -	- -	- -	- -	-	-	-	-
Overall Score for Environment Objective								
VM 2 Score	-	-	-	-	0	-	0	0

Table 7.18: Scores: Environment – Crossness

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Landscape/ Townscape & Visual**							
VM 2 Score	- -	- -	- -	-	-	0	-	0
Sub-objective	**Air quality (incl. odour)**							
VM 2 Score	-	-	-	-	-	-	-	-
Sub-objective	**Waste**							
VM 2 Score	- -	- -	- -	- -	0	0	+	+
Sub-objective	**Water Resources**							
VM 2 Score	-	-	-	-	-	-	-	-
Sub-objective	**Archaeology**							
VM 2 Score	-	-	- -	-	-	- -	-	- -
Sub-objective	**Traffic & Transport**							
VM 2 Score	-	-	-	-	- - -	-	- - -	- -
Sub-objective	**Ecology**							
VM 2 Score	-	- -	- -	- -	-	- -	-	- -
Sub-objective	**Cultural Heritage**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Health**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Contaminated Land**							
VM 2 Score	+	+	+	+	+	+	+	+
Sub-objective	**Community**							
VM 2 Score	-	-	- -	-	-	- -	-	- -
Sub-objective	**Noise**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Socio economic**							
VM 2 Score	0	0	0	0	0	0	0	0
Sub-objective	**Renewable energy**							
VM 2 Score	+	+ +	+ +	+ + +	+ +	+ +	+ +	+ +
Sub-objective	**Climate change (relative GHG emissions for each option).**							
VM 2 Score	- -	- -	- -	- -	-	-	-	-
Overall Score for Environment Objective								
VM 2 Score	- -	- -	- -	-	-	-	0	-

7.9 Stakeholder preferences

The stakeholder objective should include preferences of clients and any other major stakeholders which should also include the opinion of relevant national, regional and local level authorities.

The following were considered to be the key external (i.e. non Thames Water) stakeholders for this project:

- Ofwat (regulatory) objectives
- DEFRA / EA Government Department
- Local authorities
- Agricultural Sector
- Public, including customers.

Table 7.19 summarises the discussions on each sub-objective that occurred at the VM 2 workshop.

Given that the various stakeholders had not yet had the opportunity to comment on the various options considered in the SAR it was considered premature to score this objective. Hence, only the results of the discussions are presented here.

Table 7.19: Stakeholder preferences – Basis for sub-objective scores

Ofwat (regulatory) objectives
Ofwat's objectives were interpreted from guidance provided for PR09 business plan submissions. These include a requirement to report on the carbon footprint associated with proposed investments. In general, all options were considered to be consistent with Ofwat's objectives for provision of effective sludge treatment services. However, options where at least part of the additional sludge treatment capacity was provided using enhanced digestion were considered likely to be more acceptable due to lower whole life cost.
DEFRA / EA Government Department
For sludge treatment it was considered that Defra and the EA would have similar objectives to Ofwat.
Local authorities
It was considered that it would be premature to speculate on the local authorities' preferences until they have had the opportunity to comment on the various options considered in the SAR.
Agricultural Sector
The agricultural sector preference is relevant for options where recycling of digested sludge cake to agriculture is proposed. As the preference of the agricultural sector is strongly influenced by the attitudes and policies of their customers it was considered appropriate to judge the likely agricultural stakeholder preferences based on the current policy of the British Retail Consortium (BRC). The current situation is that the BRC will accept use of sludge on agricultural land based on the Safe Sludge Matrix.
Public including customers
It was considered that it would be premature to speculate on the public's preferences until they have had the opportunity to comment on the various options considered in the SAR. However, based on previous experience, it was considered likely that the public would prefer enhanced digestion options rather than new incineration capacity.

7.10 Consolidated results

At the end of the VM2 workshop the scores for each objective were consolidated in separate tables for Beckton STW options and Crossness STW options. The workshop participants then reached a consensus on the overall score to award to each of the Short List options for each location.

Tables 7.20 and 7.21 present the consolidated objective scores and agreed 'overall score' for Beckton STW options and Crossness STW options, respectively (note: the stakeholder preference objective was not scored for this analysis as the various stakeholders had not yet had an opportunity to comment on the proposed options).

Taking these overall scores into account, the workshop participants then reached a consensus on the preferred option for each site. The key decision factors and conclusions are presented in Section 8.

Table 7.20: Overall Scores - Beckton STW options

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Objective	**Constructability**							
VM 2 Score	+	-	- -	-	0	0	0	+
Objective	**Technology**							
VM 2 Score	+ +	-	-	-	+	+	+	+
Objective	**Operations**							
VM 2 Score	+	- -	- -	-	0	0	- - -	- - -
Objective	**Safety**							
VM 2 Score	0	0	0	0	0	0	0	0
Objective	**Integration**							
VM 2 Score	0	+	0	+	+	+	0	0
Objective	**Economy**							
VM 2 Score	0	-	-	0	+	0	0	+
Objective	**Environment**							
VM 2 Score	-	-	-	-	0	-	0	0
Objective	**Stakeholder Preferences**							
VM 2 Score	?	?	?	?	?	?	?	?
Objective	**Overall Score**							
VM 2 Score	+	- -	- -	-	+	0	-	0

Table 7.21: Overall Scores – Crossness STW options

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Objective	**Constructability**							
VM 2 Score	+	-	- -	-	0	0	0	+
Objective	**Technology**							
VM 2 Score	+ +	-	-	-	+	+	+	+
Objective	**Operations**							
VM 2 Score	+	- -	- -	-	0	0	- - -	- - -
Objective	**Safety**							
VM 2 Score	0	0	0	0	0	0	0	0
Objective	**Integration**							
VM 2 Score	-	0	-	0	+	0	0	0
Objective	**Economy**							
VM 2 Score	0	0	-	+	+ +	0	+ +	+
Objective	**Environment**							
VM 2 Score	- -	- -	- -	-	-	-	0	-
Objective	**Stakeholder Preferences**							
VM 2 Score	?	?	?	?	?	?	?	?
Objective	**Overall Score**							
VM 2 Score	0	- -	- -	-	+ +	0	0	0

8 Preferred Option

This section describes the selection of the preferred option for provision of additional sludge treatment capacity at Beckton and Crossness STWs. The section also compares the preferred solution of this SAR with that identified in TWUL's company-wide Sludge Strategy.

This section also presents an outline delivery programme for the preferred solution.

8.1 Selection of the Preferred Option for each site

The VM2 workshop participants reached a consensus on the preferred option for each site, taking into account the overall scores for each objective.

Overall, the workshop concluded that **Option 4.0** was the preferred solution at both Beckton STW and Crossness STW. This option combines the refurbishment and continued use of the existing SPGs with additional sludge treatment capacity provided by new enhanced digestion (thermal hydrolysis) plants.

This section describes the key decision factors in the selection of the preferred option.

8.1.1 Key factors in selection of the preferred option for each site

From tables 7.20 and 7.21 it can be seen that the overall option scores for each location favoured option 4.0 (and Option 1.0 for Beckton). Options 2.0 and 2.3 were least favoured for both sites.

A review of the overall scores for each of the appraisal objectives presented in sections 7.1 to 7.8 of this report shows that no single option consistently outperformed the other options – different options, or groups of options, performed best for different objectives. However, Option 4.0 was the only option to consistently achieve either a neutral or positive score for all objectives (all other options achieved at least one negative score). Option 4.0 also performed better than Option 1.0, the other higher scoring option, for those objectives which are considered to be the most relevant to achieving Ofwat approval for the proposed investment (Economy) and local authority planning permission (Integration and Environment).

The project appraisal objectives are listed below and factors which had a significant influence on the selection of Option 4.0 are highlighted.

Constructability – Option 4.0 can be constructed largely 'off-line' and therefore has a lower risk of interfering with the operation of the existing SPG. Enhanced digestion also requires a relatively smaller footprint, both for the plant itself and the contractor's compound (much of the plant can be fabricated off-site and brought in as required) – a key consideration given the congested nature of the Beckton STW site. Larger footprint options, such as options 2.0, 2.2, 3.0, 5.0 and 5.2 would pose greater construction challenges.

Technology – Both thermal hydrolysis and mass-burn incineration can be considered proven technologies – though there are few examples of enhanced digestion followed by incineration. Hence, Option 4.0 represents proven technology, as did options 1.0, 4.2, 5.0 and 5.2. Enhanced digestion can also be considered to be a more flexible solution in that, if required, it can be supplemented by addition of a thermal destruction stage in the future (see Section 8.1.2).

Operations – Option 1.0 was considered to be the least complex from an operational perspective (largely as it involves an extension of the existing treatment technology at each site). However, Option 4.0, with its two parallel treatment technologies was considered the next highest option.

Despite also using enhanced digestion, options 5.0 and 5.2 achieved a low overall score for this objective due to the higher operational risk associated with treating the entire output of Beckton STW and/or Crossness STW using enhanced digestion. Thames Water operations staff were particularly concerned that options 5.0 and 5.2 would create significant operational difficulties in the event of any loss of the agricultural outlet, for example, following an outbreak of Foot and Mouth disease.

Safety – it was considered that TWUL would not promote nor allow construction of a new treatment facility that was not 'safe' and hence all options were scored the same.

Integration – it was concluded that options that treated at least part of the sludge produced at Beckton and Crossness STWs using enhanced digestion, such as Option 4.0, were more closely aligned with local, regional and national government policies with respect to sustainability and renewable energy generation.

Economy – Option 4.0 was amongst the higher scoring options for economy due to the low relatively capital cost and whole life cost – and therefore potentially more likely to achieve Ofwat approval for funding as it would be the more affordable solution for customers. Furthermore, it is considered that enhanced digestion options, including Option 4.0, also offer greater scope for further opex optimisation.

Environment – Overall Option 4.0 achieved a neutral score for Beckton STW options and a slightly negative score for Crossness STW options. In both cases, Option 4.0 scored slightly higher than Option 1.0. However, overall scores for all options for the environment objective were within a narrow range (neutral to single minus) indicating that, overall, the environmental impacts for each option were similar.

Stakeholder Preferences – as stakeholders have not yet had the opportunity to comment on the options presented in this SAR it was decided it would be premature to score this objective (see Section 7.9). However, based on previous experience, as well as comments received from stakeholders on the draft Sludge Strategy and SEA, it was considered likely that both local authorities and the public would favour enhanced digestion options rather than provision of new incineration capacity.

8.1.2 Implications for future sludge treatment provision at Beckton and Crossness STWs

Option 4.0 provides a flexible solution that, if required, it can be supplemented by a second thermal destruction stage in the future.

In the Sludge Strategy, enhanced digestion followed by thermal destruction of the remaining sludge, was amongst the best performing options, based on the assumption that it is an efficient way of extracting energy from the sludge and, at the same time, minimising the volume of sludge requiring further treatment.

As noted in Section 2.2, towards the end of the 10-year period (2017-2018) following publication of its current Sludge Strategy, TWUL proposes to undertake a further strategic review of its sludge treatment needs and the availability of appropriate treatment technologies, in order to inform the next 15-year investment programme. By this date emerging thermal destruction technologies, such as sewage sludge gasification or pyrolysis, may have become more established and it may be prove cost-effective to provide these as a second stage following enhanced digestion.

8.1.3 Alignment with company-wide Sludge Strategy and SEA

As reported in Section 2.2, TWUL's Sludge Strategy concluded that the recommended 10-year strategy for Beckton and Crossness STWs is to install additional thermal destruction capacity with energy recovery (Option 1.0 in this SAR). The Sludge Strategy also recommended that an assessment should be carried out to determine whether more efficient energy recovery can be achieved at these sites by carrying out digestion in advance of a thermal destruction process (options 2.0, 2.3 and 3.0 in this SAR).

Thus, the preferred option identified by this SAR, which proposed enhanced digestion for additional sludge produced at each site (whilst retaining existing thermal destruction capacity), would appear to be contrary to the recommendations of the Sludge Strategy.

However, the following points should be noted when comparing the SAR and Sludge Strategy recommendations:

Site specific analysis

The Sludge Strategy stresses that the preferred treatment/outlet options contained in the Sludge Strategy should not be regarded as site-specific recommendations and that for developments at specific sites, the preferred options would need to be subjected to detailed assessment in order to check that the assumptions made in the Sludge Strategy are still valid.

A key purpose of this SAR has been to review the Sludge Strategy's site specific recommendations for Beckton and Crossness STWs and undertake a more detailed site specific appraisal of all options. This more detailed analysis has identified that, at least in the 10-year design period, enhanced digestion in parallel with refurbishment of the existing SPGs is a more cost effective solution.

Condition of existing digester assets

The Sludge Strategy identified the poor condition of the existing digesters at each site as one reason for not proposing an enhanced digestion solution. However, recent experience of renovating digesters has provided additional cost data which has been used in this SAR. Even when the cost of digester renovation is included in the cost analysis Option 4.0 was still found to be cost effective.

Potential for staged achievement of Sludge Strategy recommendations

As highlighted in Section 8.1.2, Option 4.0 keeps open the option of providing thermal destruction (following enhanced digestion) in the future, allowing time for alternative thermal destruction processes such as gasification of sewage sludge to become technically proven and cost effective.

Compatibility with overall conclusions of the Sludge Strategy

The Sludge Strategy also concluded (see Table 2.1 in this report) that:

- *Processes allowing the efficient extraction of energy and minimising lorry movements are the most suitable.*
- *Recycling to land alone is not a viable option for these sites due to the large volume of sludge produced.*

The enhanced digestion process used for Option 4.0 is efficient at producing energy using biogas CHP and allows the recycling of sludge to agriculture, thus helping to reduce the consumptions of fossil fuel based fertilisers. Furthermore, in Option 4.0 only around half of the sludge produced at Beckton and Crossness STWs would be treated using enhanced digestion with the remainder continuing to be treated in the existing SPGs which will be refurbished – reducing the risk of relying solely on agricultural recycling of treated sludge. For Option 4.0, at full design capacity the proposed enhanced digestion plant at Beckton STW would generate less than 10 vehicle loads of sludge cake per day (6 vehicle loads at Crossness STW).

Compatibility with waste management hierarchy

The Sludge Strategy also recognises that recovering energy from sludge (using thermal destruction) is lower down the waste management hierarchy than recycling to land, but where recycling is less secure or problematic, this route can offer a sustainable outlet (Section 4.3 of the Sludge Strategy). The more detailed analysis undertaken for this SAR has highlighted that using enhanced digestion, in parallel with existing SPGs, can bring significant renewable energy benefits and enable sustainable recycling to agriculture.

Conclusions on alignment with TWUL's Sludge Strategy

The Sludge Strategy's stated recommendations for Beckton and Crossness STWs are for provision of additional thermal destruction – though the Sludge Strategy also states that these high level recommendations need to be confirmed by detailed site-specific analysis.

The detailed analysis undertaken for this SAR, which has included detailed process sizing and cost estimation as well as assessment against a broad range of appraisal criteria, has identified that provision of enhanced digestion capacity in parallel with refurbishment of the existing SPGs is the most appropriate solution for these sites in the medium term.

In the longer term, this solution could constitute the first part of a phased implementation of the Sludge Strategy recommendations. This longer term option would be assessed as part of the 10-year review of the current Sludge Strategy in 2017/18.

8.1.4 Potential for further optimisation of the preferred option

There are a number of possibilities for further optimisation of Option 4.0 at Beckton STW and Crossness STW and these should be explored during subsequent project development prior to submission of a planning application for any schemes.

Potential measures include:

- **Further optimisation of site layouts to minimise environmental impacts.** A detailed review of each STW and potential layouts for the proposed enhanced digestion plant will take place to ensure the optimal layout and location is chosen, ensuring environmental impacts are minimised.
- **Phased implementation of enhanced digestion capacity.** Taking advantage of the modularity of the thermal hydrolysis process to provide capacity in phases to match demand. This approach could be used in combination with continued (i.e. beyond AMP5) passing of Beckton STW sludge to the proposed enhanced digestion plant at Riverside STW, potentially delaying the need for implementation of additional enhanced treatment phases at Beckton STW.
- **Treating primary and secondary sludge in separate waste streams.** Using the existing SPG to take predominantly primary sludge and the new enhanced digestion plant to take predominantly secondary sludge (SAS). This would potentially allow the performance of the SPG to be optimised and would take advantage of the ability of thermal hydrolysis processes to treat sludge with high SAS content.
- **Potential to use waste heat.** The bio-diesel engines being installed under the Thames Gateway Water Treatment Plant will produce both high and low grade waste heat. This waste heat could potentially be used in the thermal hydrolysis process (e.g. to heat steam) thus reducing the use of supplementary fossil fuel. However, the feasibility of such an arrangement would depend on a number of issues such as plant layout as well as the temperature, quantity and consistency of the available waste heat.
- **Explore Co-digestion opportunities.** Co-digestion with other wastes could become a sustainable solution in the future once the significant existing technical and regulatory hurdles are overcome. Co-digestion would require provision of additional enhanced digestion capacity above that needed to treat indigenous sewage sludge, in order to provide capacity for other wastes (additional thermal pre-treatment capacity, digesters and other associated plant). Further design development of the preferred option could consider measures to improve flexibility for incorporating such additional capacity in the future.

8.2 Delivery Programme

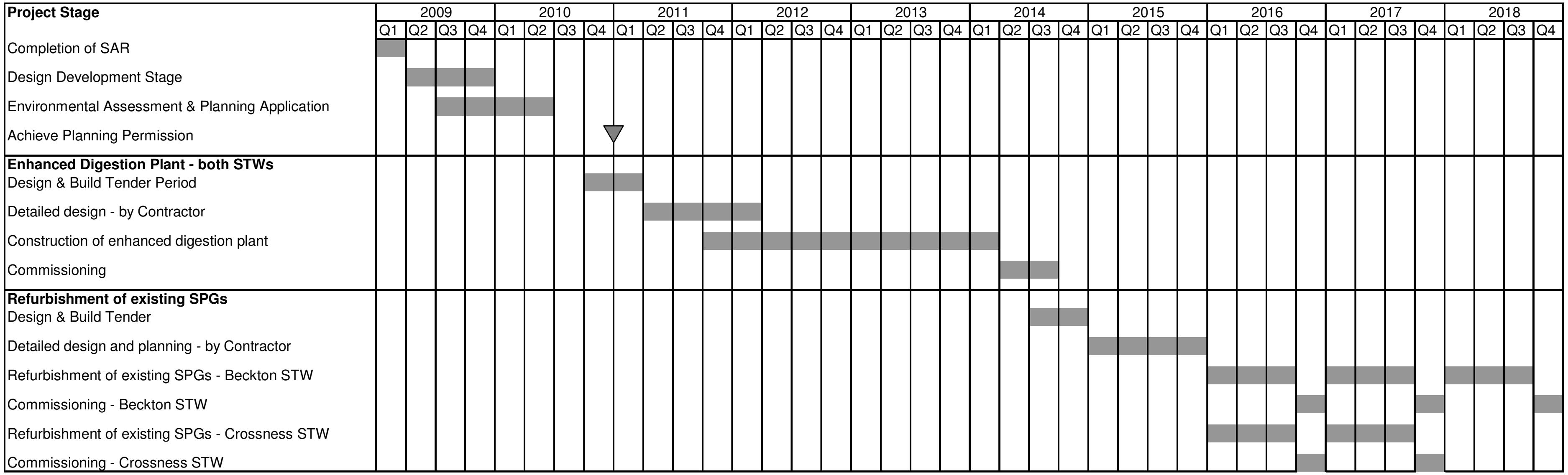
Figure 8.1 provides an outline delivery programme for Option 4.0 (note, each year is divided into quarters).

The programme is based on the following assumptions and data:

- A planning application is submitted in the first half of 2010 and that planning permission is obtained by the end of 2010.
- Construction of the enhanced digestion plant, including refurbishment of the existing digesters, is completed in 30 months followed by a 6 month commissioning period. This is some 6 months longer than the programme achieved for Anglian Water’s Cottonvalley and Whitlingham thermal hydrolysis plants and reflects the additional scale of the proposed plants for Beckton and Crossness STWs.
- Major refurbishment of the existing SPGs will be carried out once the enhanced digestion plant capacity is available but not before Q1 2016 (assuming the funding requirement for refurbishment is obtained in AMP6).
- It is assumed that only one incinerator line will be refurbished at a time at each site and that the complex nature of the work may result in only one line at each site being refurbished each year.

The programme indicates that completion of the enhanced digestion plant could be achieved in mid 2014 (assuming planning permission is granted at the end of 2010). Subject to funding availability, this could enable the refurbishment of the existing SPGs to be brought forward such that refurbishment of the first line commenced in Q3, 2014.

Figure 8.1: Outline Delivery Programme for Preferred Option



Appendix A Appraisal Methodology and Criteria

A.1 Methodology

The appraisal methodology used for this SAR is based on the assessment of each option against a number of objectives - the key aspects which may affect the deliverability of the scheme. Each objective also includes a number of sub-objectives. The objectives and sub-objectives selected must be sufficient and suitable for the differentiation of the options being considered. There is no 'weighting' of objectives used in the option appraisal.

Based on this appraisal method, the options appraisal included the following steps:

1. Description of the options ('Long list' options at the VM 1 meeting and 'Short list' options at the VM 2 meeting)

2. Scoping and agreeing project objectives and sub-objectives that were appropriate to this study.

3. Option appraisal using non-numerical scoring based on the professional judgement of the relevant specialists.

4. Selection of the preferred option(s), taking account of the results of the options appraisal.

5. Outputs from each of the VM meetings included the preferred option(s) and a robust record of the process including the reasoning for the scoring of each option.

An experienced facilitator chaired both the VM 1 and VM 2 meetings to assist with directing the proceedings and with documenting and recording the outcomes.

In formulating the appraisal methodology a range of objectives were developed to consider technical, practical, social, economic, environmental and planning aspects of each of the options.

A.2 Objectives and sub-objectives

The appraisal process requires the assessment of each option against a number of objectives - the key aspects which may affect the deliverability of the scheme. Each objective also includes a number of sub-objectives.

The following objectives were used in this study.

- Constructability
- Technology
- Operations
- Safety
- Integration
- Economy
- Environment

- Stakeholder Preferences.

Further definition of each objective as well as lists of sub-objectives are provided in Table A.1.

Table A.1: Objectives and sub-objectives used for this SAR

Constructability Constructability is concerned with project related issues encountered during the construction phase of the project. This objective looks at the technical complexity of constructing the project/options, inherent or unforeseen risks to the project programme, including cost and resourcing issues, and consideration of other concurrent schemes. It also considers construction stage environmental impacts through sub-objectives for noise/dust control and traffic management. **Sub objectives:** • Implementation programme (whether an option can be constructed in time to meet demand) • Utilities interfaces • Noise / dust control (constraints posed by nearby developments) • Traffic management (including potential road closures / diversions) • Construction access (within site) • Other major interface issues • Technical complexity • Availability of land for contractor's site compound and laying down area • Maintaining existing treatment processes during construction & commissioning.
Technology The Technology objective assesses whether the proposed technology options are likely to work and provide the required treatment capacity on a reliable basis. The potential for phasing implementation of the proposed plant as well as flexibility for future adaptation are also considered. **Sub objectives:** • Reliability of process • Track record (established process) • Track record (implemented at similar scale) • Availability of suppliers (plant) • Footprint (land take) • Potential for future upgrading through additional process stages • Marketability/recycling/disposal of final product.
Operations The Operations objective examines how the facility will perform under normal circumstances and conditions, once it becomes operational. Operations looks at the likelihood of the scheme specification being achieved with respect to performance, reliability, and flexibility. **Sub objectives:** • Staffing – (numbers needed & availability, expertise/experience required for the different technologies)

- Maintenance requirements
- Operational flexibility (variations in feed quantity and quality)
- Operational complexity
- Risk of losing disposal route for product

Safety

The safety objective is concerned with reducing the loss of life and injuries resulting from construction and operation. The sub objective is to reduce accidents.

Sub objectives:

Reduce risk of illness or injury to employees, contractors and public (sources of injury or illness may include contact with sludge and treated sludge products, contact with toxic substances used in the treatment process, injury due to operator accidents or plant malfunction).

Integration

The integration objective aims to ensure that all decisions are taken in the context of policies produced by the local authorities, the Greater London Authority, LTGDC (for Beckton and Riverside STWs) and other agencies as well as Thames Water's strategic policies.

Sub objectives:

- LTGDC (London Thames Gateway Development Corporation) objectives
- National government policies
- Regional government policies (London Plan)
- Local land use policies
- Thames Water Strategic Direction Statement, Sludge Strategy and SEA.

Economy

Economy is concerned with improving the economic efficiency of investment in assets. There are sub-objectives to improve economic efficiency for Thames Water, customers and to improve reliability and the wider economic impacts.

Sub objectives:

- Construction costs
- Operating and maintenance costs (excluding revenue)
- Revenue (power export and ROCs)
- Net opex, including revenue
- Whole life costs

Environment The environment objective involves reducing the long term (i.e. during operation) direct and indirect adverse impacts of the scheme facilities on both the local and wider environment. **Sub objectives:** • Landscape/Townscape & Visual • Air quality (incl. odour) • Waste • Water resources • Archaeology • Traffic & Transport • Ecology • Cultural Heritage • Health • Contaminated Land • Community • Noise • Socio economic • Renewable energy & Climate change (relative carbon emissions)
Stakeholder Preferences Considers the preferences of regulators and other major stakeholders such as the relevant national, regional and local level authorities and the public. The assessment was based on perceived preferences judged from recent communications and documents. **Sub objectives** • Ofwat (regulatory) objectives • Defra / EA • Local and regional authorities • Agricultural sector • Public, including customers.

A.3 Option appraisal (scoring)

Option appraisal (Step 3) is carried out by specialists in each objective – preferably those specialists who may have to ultimately defend the decision making process at public inquiry.

The focus of comparison in the VM 1 and VM 2 meetings was the score applied to the performance of each option against the agreed sub-objectives. The scores took the form of three grades of positive performance (one, two or three plus signs); three grades of negative performance (one, two or three minus signs); and a neutral i.e. a seven point score.

Thus, the scoring system used at both the VM 1 and VM 2 meetings was as follows:

Table A.2: Scoring system for option appraisal

Score	Meaning
+ + +	Very strong positive effect of the option on the objective
+ +	Moderately strong positive effect of the option on the objective
+	Positive effect of the option on the objective
0	Overall neutral effect of the option on the objective
-	Negative effect of the option on the objective
- -	Moderately strong negative effect of the option on the objective
- - -	Very strong negative effect of the option on the objective
?	Uncertain effect of the option on the objective
n/a	No relation between the option and the objective.

The seven point scale used for the VM 1 and VM 2 meetings was similar to the (five point) scoring system adopted for the SEA for evaluating the various options presented in the TWUL Sludge Strategy against environmental objectives. However, MM considered a seven-point scoring system more appropriate for a site specific analysis such as the SAR on the grounds that the potential impacts of each option on the objectives (and sub-objectives) can be identified more clearly than is possible for the broader, company-wide sludge strategy, and hence it is possible to identify more subtle differences between the option impacts.

In the case of 'Economy', quantitative data (capex, opex and whole life cost) was used to help determine the thresholds between the seven point scale. For other topic areas, the process was reliant on professional judgement.

At the workshop, participants debated the scores initiated by the experts in each topic area until consensus was reached of what were fair and defensible conclusions in respect of each option. The results were captured in tables for each objective (see Appendix I for the scores for each sub-objective at the VM1 and VM2 meetings).

A.4 Selection of preferred option(s)

At the end of the VM 1 meeting overall scores were awarded for each Long List option and a consensus was obtained on the Short list of preferred options to take forward to VM 2.

At the end of the VM 2 meeting overall scores were awarded for each Short List option and a consensus was obtained on the preferred option at Beckton STW and at Crossness STW. .

Appendix B Option Components & Key Technical Assumptions

The Option Components for Beckton and Crossness options are presented in Tables B.1 and B.2 respectively.

The key technical assumptions that form the basis of all the enhanced digestion process calculations and subsequent process evaluation of each of the options are presented in Table B.3.

Key technical assumptions with respect to incinerator design are provided in Bamag's submissions which are provided separately ("6QWG-Thames Sludge SAR_Consolidated Bamag Report-RevA").

Table B.1: Option Components – Beckton STW

Stage	Equipment	Details	Options							
			1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Enhanced Digestion										
Thermal Pre Treatment (THP)	THP thickening tanks	*4 hr retention time; Aspect ratio (H:D)=1; Assumed 7140 operational hours/year; 1 mixer per tank*	/	2 nr. @ 367m^3, 7.8m Ø	2nr. @ 833m^3, 10.2mØ	2nr. @ 650m^3, 9.4mØ	2nr. @ 367m^3, 7.8mØ	2nr. @ 833m^3, 10.2mØ	2nr. @ 650m^3, 9.4mØ	2nr. @ 533m^3, 8.8mØ
	THP thickening centrifuge	*Nr. Includes 2 standby centrifuges*	/	4 nr. @ 93.7 m^3/hr	7 nr. @ 85.2 m^3/hr	6 nr. @ 83.1 m^3/hr	4 nr. @ 93.7 m^3/hr	9 nr. @ 85.2 m^3/hr	6 nr. @ 83.1 m^3/hr	5 nr. @ 90.9 m^3/hr
	THP feed silos	*Volume of one tank = 60m^3*	/	4 nr. 4.19hrs retention time	2 nr. 4.61hrs retention time	6 nr. 3.54hrs retention time	4 nr. 4.19hrs retention time	3 nr. 4.61hrs retention time	6 nr. 3.54hrs retention time	5 nr. 3.60hrs retention time
	THP	*14 tDS/d per reactor, Streams of 4 to 5 reactors. Nr of streams:*	/	4 streams	2 streams	6 streams	4 streams	3 streams	6 streams	5 streams
Digestion	Digestion plant	*14 days retention time; 1 mixer in each tank; 7,300 operational hours/year*	/	9 nr. Existing @ 3,740m^3	3 nr. New @ 5,150m^3	15 nr. Existing @ 3,740m^3	9 nr. Existing @ 3,740m^3	5 nr. New @ 5,150m^3	15 nr. Existing @ 3,740m^3	12 nr. Existing @ 3,740m^3
Degasing (provisional)	Degasing tanks	*Existing digesters. 2 days retention time; 2 duty&1 standby compressor; 7,300 operational hrs/yr*	/	2 nr. @ 3,740 m^3 using existing digester	1 nr. @ 5,150 m^3	2 nr. @ 3,740 m^3 using existing digester	2 nr. @ 3,740 m^3 using existing digester	1 nr. @ 5,150 m^3	2 nr. @ 3,740 m^3 using existing digester	4nr. @ 3,740 m^3 using existing digester
Combined heat & power (CHP)	Biogas plant and flare stack	*4 nr. cylinder gas holder; 2hrs retention time. 0.9m^3 NTP/Kg VM destroyed*	/	Total volume 8,350m^3	Total volume 3,573m3	Total volume 14,802m3	Total volume 8,350m3	Total volume 5,418m3	Total volume 14,802m3	Total volume 12,145m3
	CHP engines	*Total nr. includes 1 standby*	/	6 nr. 1.9MW CHP output 8.9MWe	3 nr. 1.9MW CHP output 3.8MWe	8 nr. 2.4MW CHP output 15.7MWe	6 nr. 1.9MW CHP output 8.9MWe	5 nr. 1.9MW CHP output 5.8MWe	8 nr. 2.4MW CHP output 15.7MWe	7 nr. 2.4MW CHP output 12.9MWe
Dewatering	Centrifuges	*Nr. includes 1 standby centrifuges*	4 nr.	3 nr.	2 nr.	4 nr.	3 nr.	2 nr.	4 nr.	3nr.
Sludge cake storage	Sludge storage building	*Storage time short term = 5 days; additional long term = 20 days*	/	/	/	/	10,310m^3; plan area 4,124m^2	7,377m^3; plan area 2,951m^2	18,277m^3; plan area 7,311m^2	14,997m^3; plan area 5,999m^2
Liquor treatment plant	Liquor treatment plant	*Proprietary system SHARON; Bioreactor: 2.7days reaction time*	/	2 nr. @ 2,864m^3; 23m Ø	2nr. @ 1,299m^3; 15mØ	3nr. @ 3,384m^3; 25mØ	2nr. @ 2,864m^3; 23mØ	2nr. @ 1,949m^3; 19mØ	3nr. @ 3,384m^3; 25mØ	3nr. @ 2,777m^3; 22mØ
Incineration			Existing 170 tDS/d New 220 tDS/d	Existing 170 tDS/d New 109 tDS/d	Existing 220 tDS/d New 110 tDS/d (including Riverside sludge)	Existing 193 tDS/d	Existing 170 tDS/d	Existing 170 tDS/d	/	/
Existing SPG	Furnace	*Fluidised bed type mass-burn sludge incinerator, including dewatering & flue gas treatment*	3 Nr lines, 3.0 tDS/h (furnace area = 20m^2)	3 Nr lines, 3.0 tDS/h (furnace area = 20m^2)	3 Nr lines, 3.8 tDS/h (furnace area = 20m^2)	3 Nr lines, 3.8 tDS/h (furnace area = 20m^2)	3 Nr lines, 3.0 tDS/h (furnace area = 20m^2)	3 Nr lines, 3.0 tDS/h (furnace area = 20m^2)	None	None
New SPG	Furnace	*Fluidised bed type mass-burn sludge incinerator, including dewatering, thermal drying & flue gas treatment*	2 Nr 5.4 tDS/h, (furnace area = 30m^2)	2 Nr 5.3 tDS/h, (furnace area = 25m^2)	2 Nr 5.1 tDS/h, (furnace area = 25m^2)	None	None	None	None	None

Table B.2: Option Components – Crossness STW

Stage	Equipment	Details	Options							
			1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Enhanced Digestion										
Thermal Pre Treatment (THP)	THP thickening tanks	*4 hr retention time; Aspect ratio (H:D)=1; Assumed 7140 operational hours/year; 1 mixer per tank*	/	2nr. @ 200m^3, 6.3mØ	5nr. @ 626m^3. 9.3mØ	2nr. @ 358m^3, 7.7mØ	2nr. @ 200m^3, 6.3mØ	5nr. @ 690m^3, 9.6mØ	2nr. @ 358m^3, 7.7mØ	2nr. @ 275m^3. 7.0mØ; 4nr. @ 570m^3, 9.0mØ
	THP thickening centrifuge	*Nr. Includes 2 standby centrifuges*	/	4nr. @ 51.1 m^3/hr	11nr. @ 88.9 m^3/hr	4nr. @ 91.6 m^3/hr	4nr. @ 51.1 m^3/hr	11nr. @ 97.9 m^3/hr	4nr. @ 91.6 m^3/hr	4nr. @ 70.3 m^3/hr; 8nr. @ 97.2 m^3/hr
	THP feed silos	*Volume of one tank = 60m^3*	/	2 nr. 3.84hrs retention time	3 nr. 3.68hrs retention time	4 nr. 4.29hrs retention time	2 nr. 3.84hrs retention time	3 nr. 3.34hrs retention time	4 nr. 4.29hrs retention time	3 nr. 4.19hrs retention time; 2 nr. 3.37hrs retention time
	THP	*14 tDS/d per reactor, Streams of 4 to 5 reactors. Nr of streams:*	/	2 streams	3 streams	4 streams	2 streams	3 streams	4 streams	5 streams
Digestion	Digestion plant	*14 days retention time; 1 mixer in each tank; 7,300 operational hours/year*	/	5 nr. Existing @ 3,740m^3	12 nr. New @ 2,295m^3	9 nr. Existing @ 3,740m^3	5 nr. Existing @ 3,740m^3	13 nr. New @ 2,295m^3	9 nr. Existing @ 3,740m^3	15 nr. Existing @ 3,740m^3; 15 nr. New @ 2,295m^3
Degasing (provisional)	Degasing tanks	*Existing digesters. 2 days retention time; 2 duty&1 standby compressor; 7,300 operational hrs/yr*	/	1 nr. @ 3,740 m^3 using existing digester	1 nr. @ 3,600 m^3	1 nr. @ 3,740 m^3 using existing digester	1 nr. @ 3,740 m^3 using existing digester	1 nr. @ 3,600 m^3	1 nr. @ 3,600 m^3 using existing digester	1nr. @ 3,740 m^3 using existing digester + 1nr. @ 3,600 m^3
Combined heat & power (CHP)	Biogas plant and flare stack	*0.9m^3 NTP/Kg VM destroyed*	/	Total volume 4,596m^3	Total volume 8,600m^3	Total volume 8,235m^3	Total volume 4,596m^3;	Total volume 8,600m^3	Total volume 8,235m^3	Total volume 6,320m^3; Total volume 6,450m^3
	CHP engines	*Total nr. includes 1 standby*	/	3 nr. 1.9MW CHP output 4.9MWe	4 nr. 1.9MW CHP output 7.4MWe	4 nr. 2.4MW CHP output 8.7MWe	3 nr. 1.9MW CHP output 4.9MWe	5 nr. 1.9MW CHP output 8.2MWe	4 nr. 2.4MW CHP output 8.7MWe	3 nr. 2.4MW CHP output 6.7MWe 3 nr. 2.4MW CHP output 5.6MWe
Dewatering	Centrifuges	*Nr. includes 1 standby centrifuges*	3 nr.	2 nr.	3 nr.	3 nr.	2 nr.	3 nr.	3 nr.	Existing 3nr. Additional 2nr.
Sludge cake storage	Sludge storage building	*Storage time short term = 5 days; additional long term = 20 days*	/	/	/	/	5,571m^3; plan area 2,228m^2	9,923m^3; plan area 3,969m^2	9,981m^3; plan area 3,992m^2	7,660m^3; plan area 3,064m^2; 6,356m^3; plan area 2,542m^2
Liquor treatment plant	Liquor treatment plant	*Proprietary system SHARON; Bioreactor: 2.7days retention time*	/	1nr. @ 3,125m^3; 24mØ	2nr. @ 2,444m^3; 21mØ	2nr. @ 2,800m^3; 23mØ	1nr. @ 3,125m^3; 24mØ	2nr. @ 2,691m^3; 22mØ	2nr. @ 2,800m^3; 23mØ	2nr. @ 2,149m^3; 20mØ; 1nr. @ 3,566m3; 25mØ
Incineration			Existing 95 tDS/d New 120 tDS/d	Existing 95 tDS/d New 59 tDS/d	Existing 114 tDS/d New 95 tDS/d	Existing 105 tDS/d	Existing 95 tDS/d	Existing 95 tDS/d	/	/
Existing SPG	Furnace	*Fluidised bed type mass-burn sludge incinerator, including dewatering & flue gas treatment*	2 Nr lines, 2.67 tDS/h (furnace area = 15m^2)	2 Nr lines, 2.67 tDS/h (furnace area = 15m^2)	2 Nr lines, 2.95 tDS/h (furnace area = 15m^2)	2 Nr lines, 2.9 tDS/h (furnace area = 15m^2)	2 Nr lines, 2.67 tDS/h (furnace area = 15m^2)	2 Nr lines, 2.67 tDS/h (furnace area = 15m^2)	None	None
New SPG	Furnace	*Fluidised bed type mass-burn sludge incinerator, including dewatering, thermal drying & flue gas treatment*	2 Nr 2.9 tDS/h (furnace area = 20m^2)	1 Nr 2.9 tDS/h (furnace area = 20m^2)	2 Nr 2.4 tDS/h (furnace area = 12.5m^2)	None	None	None	None	None

Table B.3: Key Technical Assumptions – Enhanced Digestion Options

Parameter		Units	Value	Comments
1	**Solids/VM Production rates**			
	Proportion of primary VM in primary DS	% of DS	84	
	Proportion of secondary VM in secondary DS	% of DS	75	
2	**Sludge Pumping Stations (PD)**			
	Type of pump		Progressive cavity	Seepex
	Number of standby pumps	Nr	1	
	Pumping efficiency of pumps	%	60	Depends on pump type and condition
3	**Mechanical Mixing in Holding Tanks**			**Apply to holding tanks in general**
	Type		External jet mixing	Jet-mixing with external pump
	Specific mixing power	W/m³	20	
	Jet configuration	M	N/A	Determined by supplier. Tanks greater than approx 10 m deep require two levels of jets.
4	**THP Thickening Feed Tank**			
	Retention time	H	4	
	Type of mixing		External jet mixing	
5	**Sludge Thickening with Centrifuge**			
	Performance			
	Maximum solids concentration of thickened sludge	w/w%	14 to 16	
	maximum capacity of individual unit	m³/h	100	
	Loading Rate			
	Minimum number of duty machines	Nr	2	
	Number of standby machines	Nr	1	
	Polyelectrolyte Consumption	kg/tSS	5	
	Power Consumption of Centrifuge			
	G-force of centrifuge	G-force	2000	
	Diameter of centrifuge	M	0.65	
	Effective head	mH_2O	325	
6	**THP Feed Silos**			
	Volume of one tank	m³	60	
	Type of mixing			No mixing required for THP feed.
7	**Anaerobic Digestion**			
	Digestion Tanks			
	Minimum retention time		14	At 11 w/w% digester feed sludge after pre-treatment in THP
	Effective volume as a fraction of total	Nr	0.85	

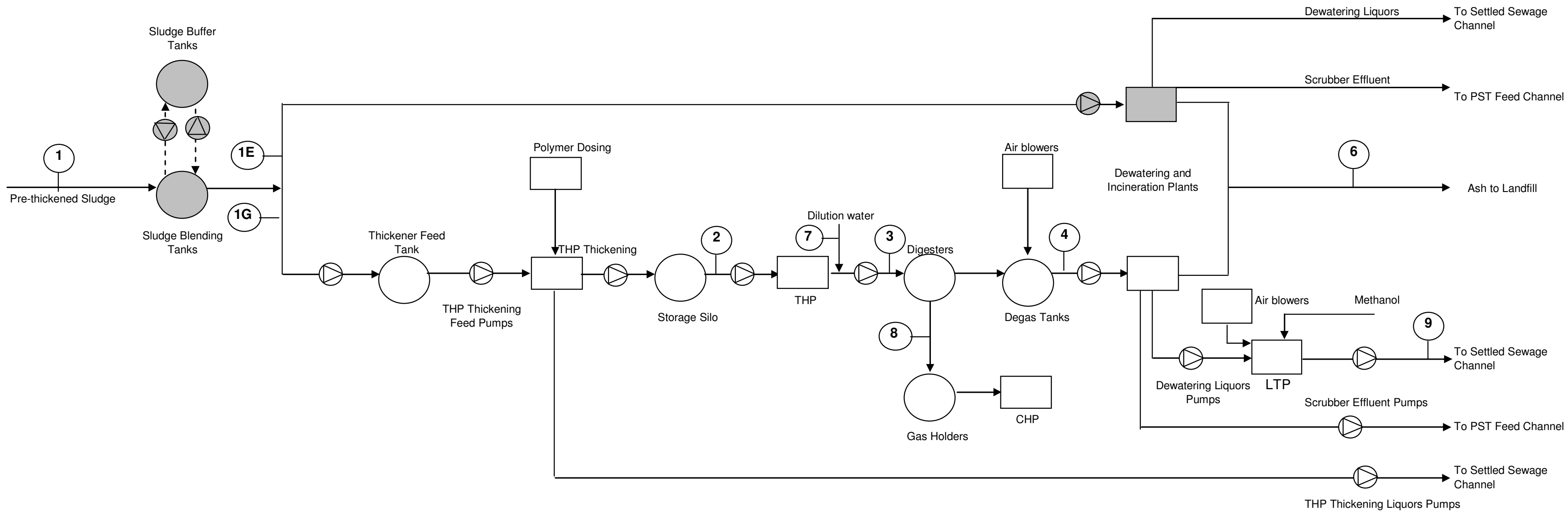
Parameter	Units	Value	Comments
Mixing			
Preferred type	Jet mixing	External jet mixing	
Absorbed power consumption	W/m^3	10	
Destruction of VM			
Thermal Pre-treatment at 165C (THP)			
Destruction of primary VM	% of VM	65	
Destruction of secondary VM	% of VM	60	
Biogas Production			
Biogas per kg VM destroyed	m3 NTP/kg	0.90	Methane concentration is approximately 70 v/v%
Maximum gas utilisation	% of total	95	
Gas Holder			
Minimum retention time	hours of gas production	2	Gas holder capacity must be sufficient to maintain running of CHP engine for continuous periods of at least 5 hours
CHP Engines			
Number of standby engines	Nr	1	
8 Degas Tanks			
Retention Time	Days	2	Applicable to conventional storage with mechanical or jet
Preferred mixing type		External jet mixing	
Specific mixing power	W/m^3	20	
9 Sludge Dewatering with Centrifuge			
Performance			Could use Klampresses. However, centrifuges assumed for this Optioneering stage.
Maximum solids concentration of sludge cake following	w/w%	31	
Loading Rate			
Minimum number of duty machines	Nr	1	
Minimum number of standby machines	Nr	1	
Maximum volumetric loading rate per machine	m^3/hour	70	
Maximum operational time	hours per day	24	
Polyelectrolyte Consumption			
Dose of polyelectrolyte	kg/tSS	7	
Power Consumption of Centrifuge			
G-force of centrifuge	G-force	2000	
Diameter of centrifuge	M	0.75	
Effective head	mH_2O	375	
10 Sludge Liquor Strength			
Digested sludge dewatering (after THP)			
Amm-N	mg/l	2 500	Ammonia concentration has been shown not to impair digestion
Alkalinity	mg $CaCO_3$/l	7 500	

Appendix C Process Flow Diagrams & Mass Balances for each Option

Beckton STW

RCI:RCI
Options 1.0 and 1.1

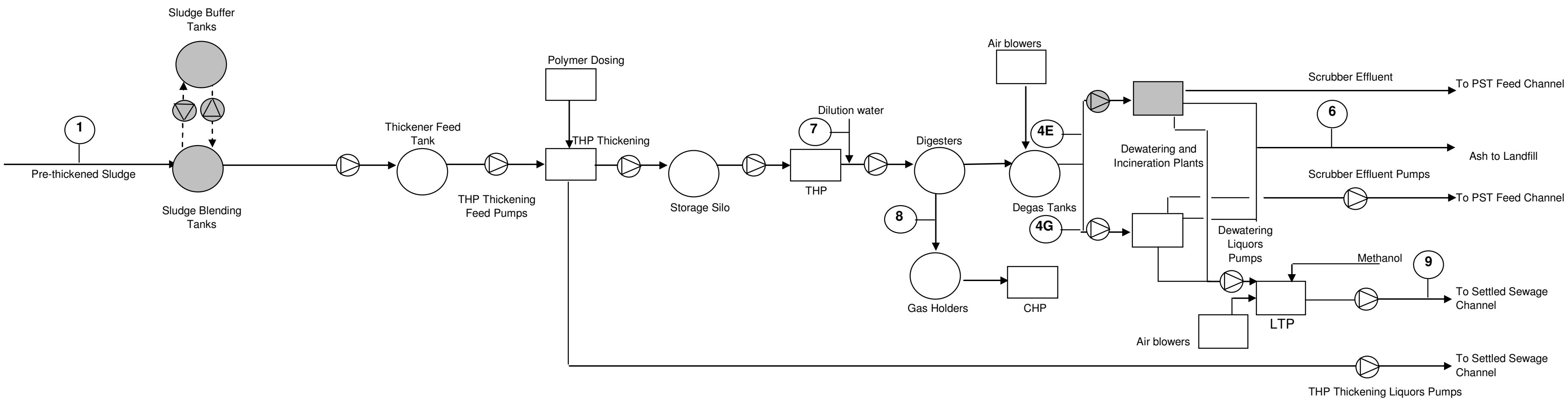
RCI: EDI
Options 2.0 and 2.1
Options 2.2 and 2.3 Options are same as 2.0 and 2.1 but with enhanced digestion plant and new incineration plant located at Riverside (liquid rather than pre-thickened Beckton sludge transferred to Riverside).



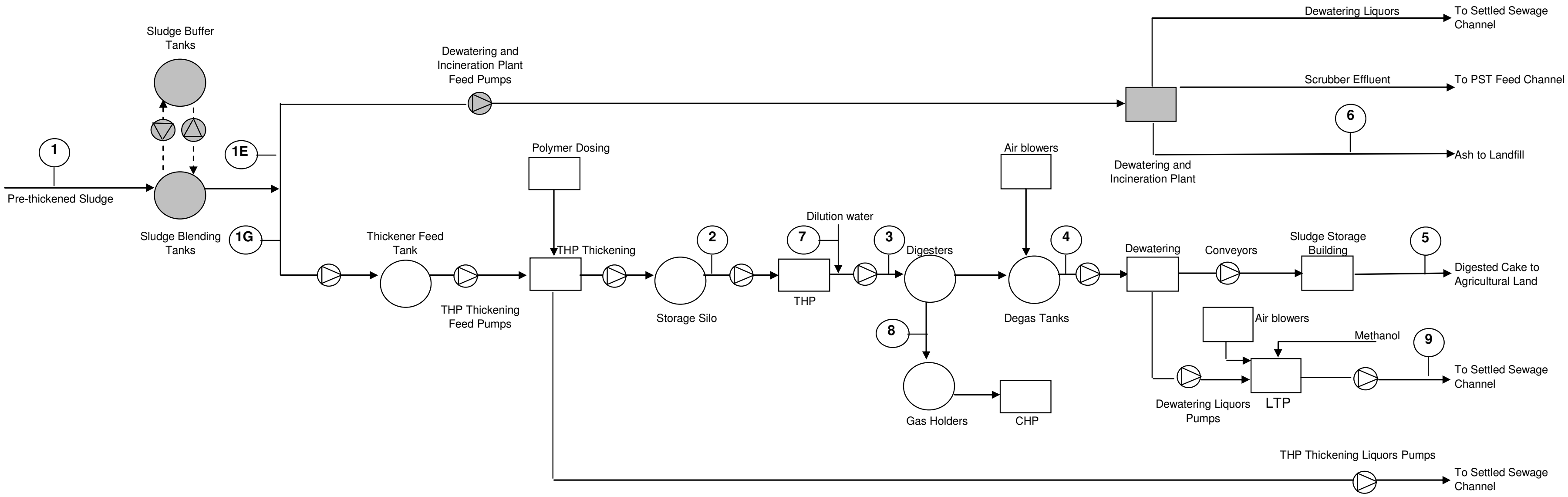
EDI: EDI

Option 3.0

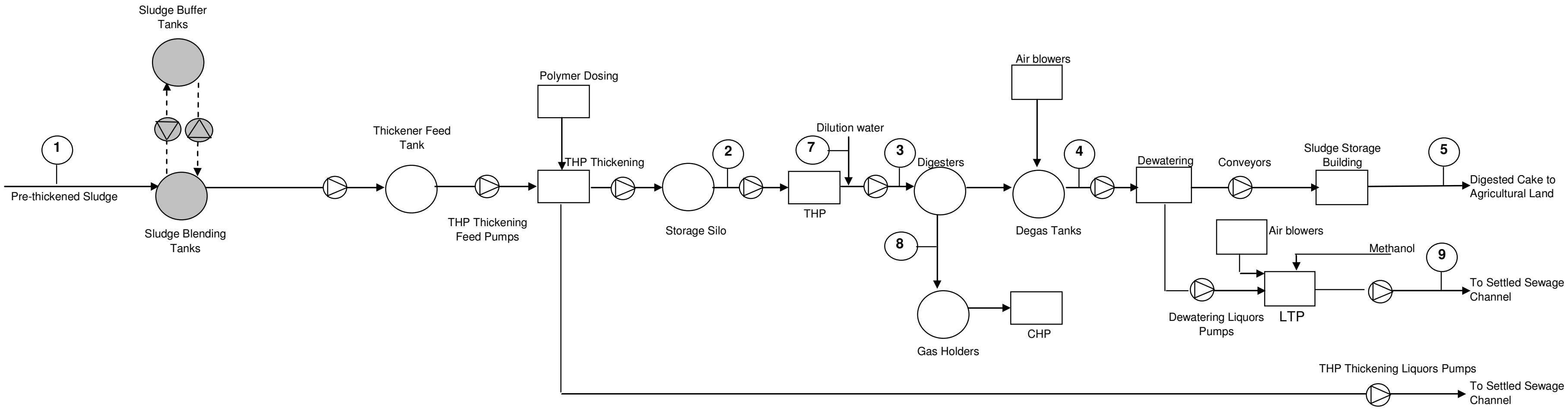
Option 3.1 Option is same as option 3.0 but liquid rather than pre-thickened Beckton sludge transferred to Riverside for enhanced digestion and incineration.



RCI: ED
Options 4.0 and 4.1
Options 4.2 and 4.3 Options are same as 4.0 and 4.1 but with liquid rather than pre-thickened Beckton sludge transferred to Riverside for enhanced digestion



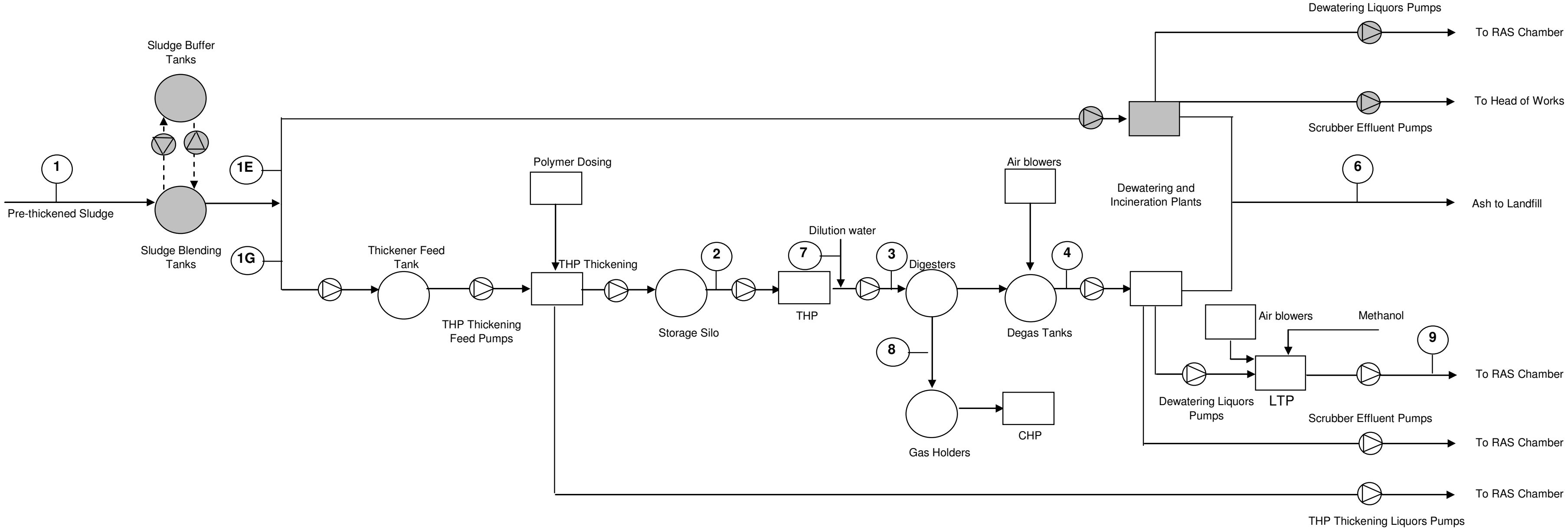
ED: ED
Option 5.0
Options 5.1 and 5.2 Options are the same as 5.0 but with liquid sludge rather than pre-thickened Beckton sludge transferred to Riverside for enhanced digestion.



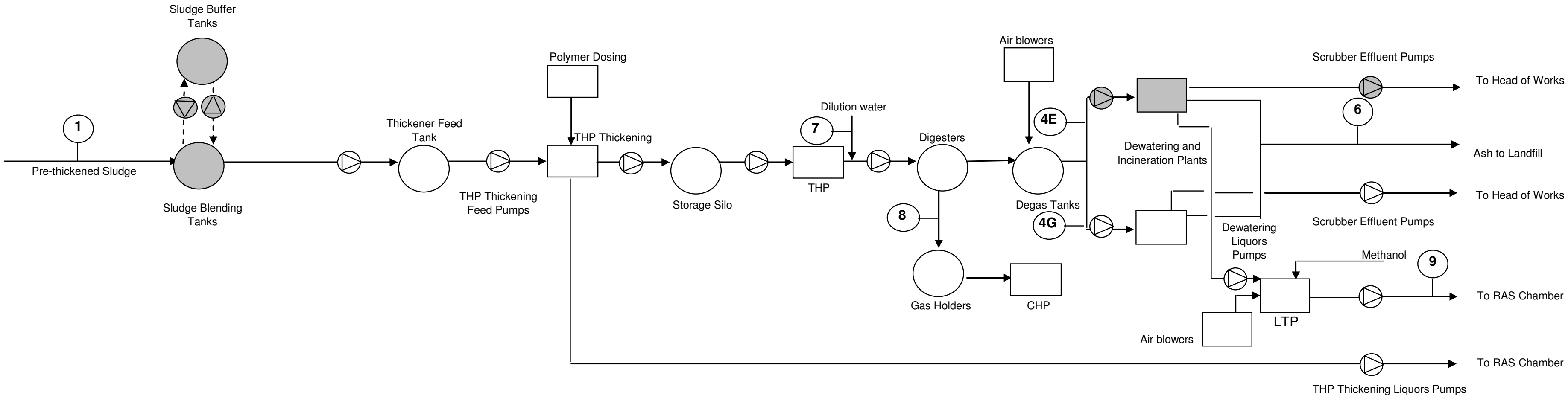
Crossness STW

RCI:RCI
Options 1.0 and 1.1

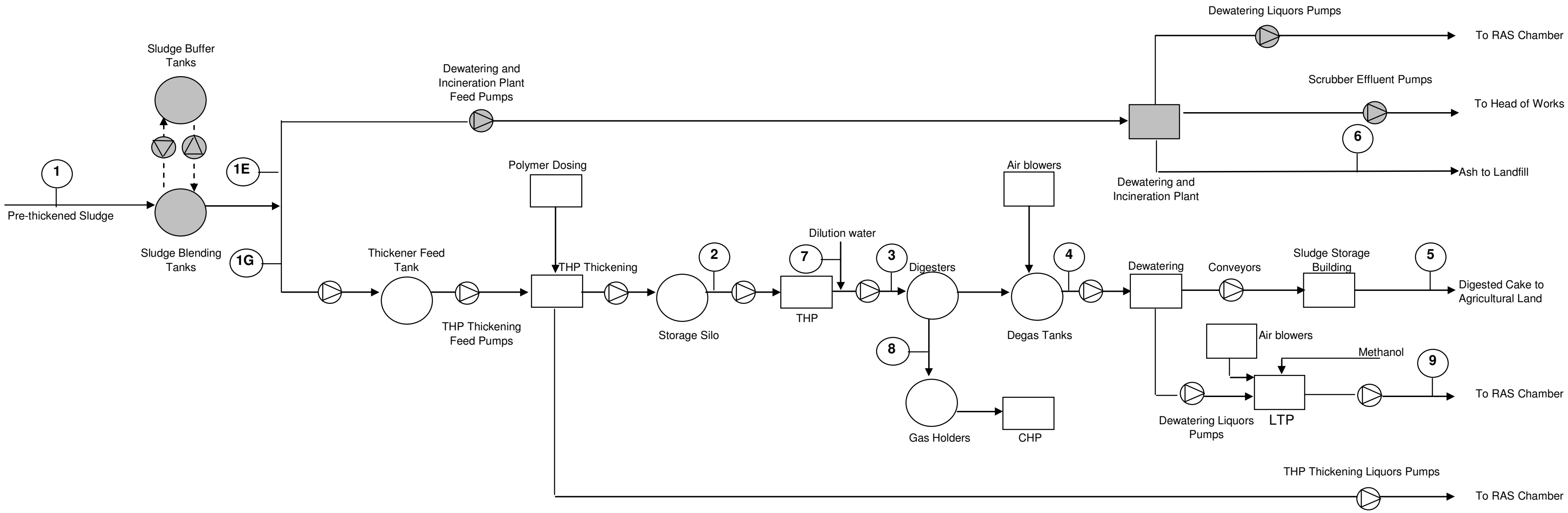
RCI: EDI
Options 2.0 and 2.1
Options 2.2 and 2.3 Options are same as 2.0 and 2.1 but with enhanced digestion plant and new incineration plant located at Long Reach (liquid rather than pre-thickened Crossness sludge transferred to Long Reach).



EDI: EDI
Option 3.0
Option 3.1 Option is same as option 3.0 but liquid rather than pre-thickened Crossness sludge transferred to Long Reach for enhanced digestion and incineration.



RCI: ED
Options 4.0 and 4.1
Options 4.2 and 4.3 Options are same as 4.0 and 4.1 but with liquid rather than pre-thickened Crossness sludge transferred to Long Reach for enhanced digestion



ED: ED
Option 5.0
Options 5.1 and 5.2 Options are the same as 5.0 but with liquidsludge rather than pre-thickened Crossness sludge transferred to Long Reach for enhanced digestion.

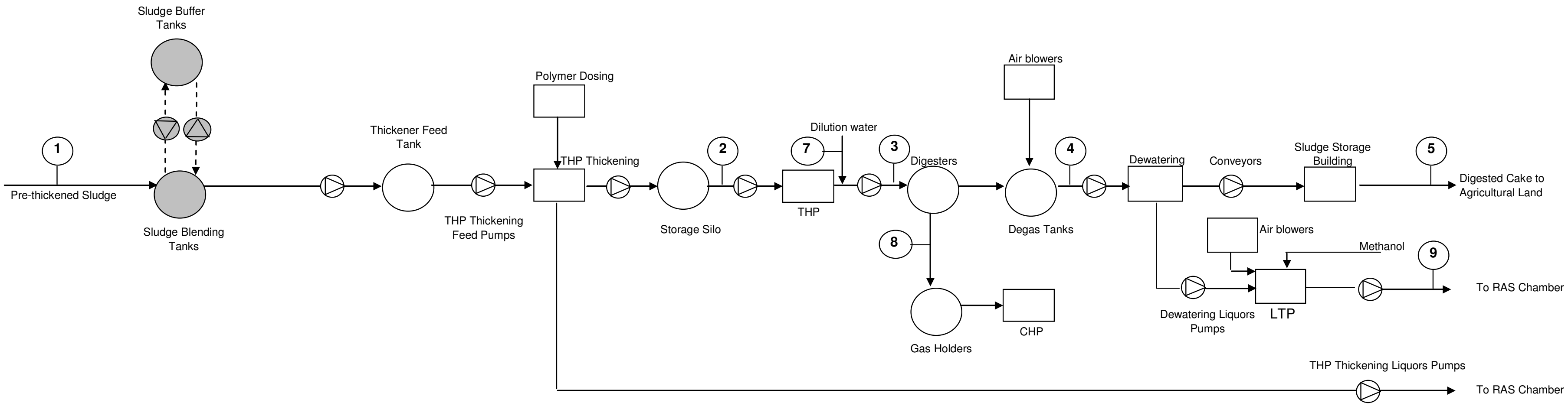


Table C.1: Beckton Mass Balance – 2031 Annual Average (Headroom Included, Sludge from Riverside Excluded)

		PFD Ref No	1		2	3	4		5		6	7	8	9
			1E	1G			4E	4G	5E	5G				
		Units	pre-thickened sludge	pre-thickened or liquid sludge	thickened sludge	sludge to digesters	sludge from digesters	sludge from digesters	sludge cake	sludge cake	ash	dilution water	biogas m³/h	sludge liquors from LTP
Option 1.0	**RCI & RCI**													
DS mass rate		tDS/d	170	220					170	220	78			
Sludge mass rate		t/d	3400	4400					3400	4400	78			
Flow rate		m³/d	3400	4400					3400	4400				
DS concentration		%	5	5					5	5				
VM content in DS		%	80	80					80	80				
Option 2.0	**RCI+ & EDI**													
DS mass rate		tDS/d	170	220	220	220		109	170	109	78			
Sludge mass rate		t/d	3400	4400	1375	2200		2200	630	351	78			
Flow rate		m³/d	3400	4400	1375	2200		2200	583	325		825	4175	2121
DS concentration		%	5	5	16	10		5	27	31				
VM content in DS		%	80	80	80	80		60	80	60				
Option 2.3	**RCI[&] & EDI**													
DS mass rate		tDS/d	220	170	170	170		89	220	89	75			
Sludge mass rate		t/d	4400	17000	1063	1700		1700	815	287	75			
Flow rate		m³/d	4400	17000	1063	1700		1700	754	156		375	1787	42882
DS concentration		%	5	1.0	16	10		5	27	31				
VM content in DS		%	84	77	77	77		57	84	57				
Option 3.0	**EDI & EDI**													
DS mass rate		tDS/d	390		390	390	193		193		77			
Sludge mass rate		t/d	7800		2438	3900	3900		621		77			
Flow rate		m³/d	7800		2438	3900	3900		575			1463	7401	177620
DS concentration		%	5		16	10	5		31					
VM content in DS		%	80		80	80	60		60					
Option 4.0	**RCI & ED**													
DS mass rate		tDS/d	170	220	220	220		109	170	109	34			
Sludge mass rate		t/d	3400	4400	1375	2200		2200	630	351	34			
Flow rate		m³/d	3400	4400	1375	2200		2200	583	325		825	4175	100196
DS concentration		%	5	5	16	10		5	27	31				
VM content in DS		%	80	80	80	80		60	80	60				
Option 4.2	**RCI & ED**													
DS mass rate		tDS/d	170	220	220	220		114	170	114	34			
Sludge mass rate		t/d	3400	22000	1375	2200		2200	630	368	34			
Flow rate		m³/d	3400	22000	1375	2200		2200	583	232		563	2709	65018
DS concentration		%	5	1	16	10		5	27	31				
VM content in DS		%	84	78	84	78		57	84	57				
Option 5.0	**ED & ED**													
DS mass rate		tDS/d	390		390	390	193		193					
Sludge mass rate		t/d	7800		2438	3900	3900		621					
Flow rate		m³/d	7800		2438	3900	3900		575			1463	7401	177620
DS concentration		%	5		16	10	5		31					
VM content in DS		%	80		80	80	60		60					
Option 5.2 - total	**ED & ED**													
DS mass rate		tDS/d	390		390	390	193		193					
Sludge mass rate		t/d	13400		2438	3900	3900		621					
Flow rate		m³/d	13400		2438	3900	3900		575			1463	7401	177620
DS concentration		%			16	10	5		31					
VM content in DS		%			80	80	60		60					

Table C.2: Crossness Mass Balance - 2031 Average Values for Crossness (Includes Indigenous Sludge from Long Reach)

		PFD Ref No	1		2	3	4		5		6	7	8	9
			1E	1G			4E	4G	5E	5G				
		Units	pre-thickened sludge	pre-thickened or liquid sludge	thickened sludge	sludge to digesters	sludge from digesters	sludge from digesters	sludge cake	sludge cake	ash	dilution water	biogas m³/h	sludge liquors from LTP
Option 1.0	**RCI & RCI**													
DS mass rate		tDS/d	95	120					95	120	45			
Sludge mass rate		t/d	1,900	2,400					1,900	2,400	45			
Flow rate		m³/d	1,900	2,400					1,900	2,400				
DS concentration		%	5	5					5	5				
VM content in DS		%	81	81					81	81				
Option 2.0	**RCI & EDI**													
DS mass rate		tDS/d	95	120	120	120		59	95	59	44			
Sludge mass rate		t/d	1,900	2,400	750	1,200		1,200	352	189	44			
Flow rate		m³/d	1,900	2,400	750	1,200		1,200	326	175		450	2,298	1,157
DS concentration		%	5	5	16	10		5	27	31				
VM content in DS		%	81	81	81	81		60	81	60				
Option 2.3	**RCI+ &EDI**													
DS mass rate		tDS/d	114	188	188	188		95	114	95	61			
Sludge mass rate		t/d	2,280	18,791	1,174	1,879		1,879	422	308	61			
Flow rate		m³/d	2,280	18,791	1,174	1,879		1,879	391	285		705	3,467	83,214
DS concentration		%	5	1.0	16	10		5	27	31				
VM content in DS		%	84	79	79	79		58	84	58				
Option 3.0	**EDI & EDI**													
DS mass rate		tDS/d	215		215	215	105		105		43			
Sludge mass rate		t/d	4300		1,344	2,150	2150		339		43			
Flow rate		m³/d	4300		1,344	2,150	2150		314			806	4,118	98,822
DS concentration		%	5		16	10	5		31					
VM content in DS		%	81		81	81	60		60					
Option 4.0	**RCI & ED**													
DS mass rate		tDS/d	95	120	120	120		59	95	59	20			
Sludge mass rate		t/d	1,900	2,400	750	1,200		1,200	352	189	20			
Flow rate		m³/d	1,900	2,400	750	1,200		1,200	326	175		450	2,298	55,157
DS concentration		%	5	5	16	10		5	27	31				
VM content in DS		%	81	81	81	81		60	81	60				
Option 4.2	**RCI & ED**													
DS mass rate		tDS/d	95	207	207	207		105	95	105	20			
Sludge mass rate		t/d	1,900	20,691	1,293	2,069		2069	352	337	20			
Flow rate		m³/d	1,900	20,691	1,293	2,069		2069	326	312		776	3,837	92,090
DS concentration		%	5	1	16	10		5	27	31				
VM content in DS		%	84	79	84	79		59	84	59				
Option 5.0	**ED & ED**													
DS mass rate		tDS/d	215		215	215	105		105					
Sludge mass rate		t/d	4300		1,344	2,150	2150		339					
Flow rate		m³/d	4300		1,344	2,150	2150		314			806	4,118	98,822
DS concentration		%	5		16	10	5		31					
VM content in DS		%	81		81	81	60		60					
Option 5.2 - total	**ED & ED**													
DS mass rate		tDS/d	302		302	302	148		148					
Sludge mass rate		t/d	16991		1,887	3,019	3019		477					
Flow rate		m³/d	16991		1,887	3,019	3019		441			1132	5,782	138,771
DS concentration		%			16	10	5		31					
VM content in DS		%			81	81	60		60					

Appendix D Energy Flow Diagram and Energy Balance for each option

Energy Flow Diagram

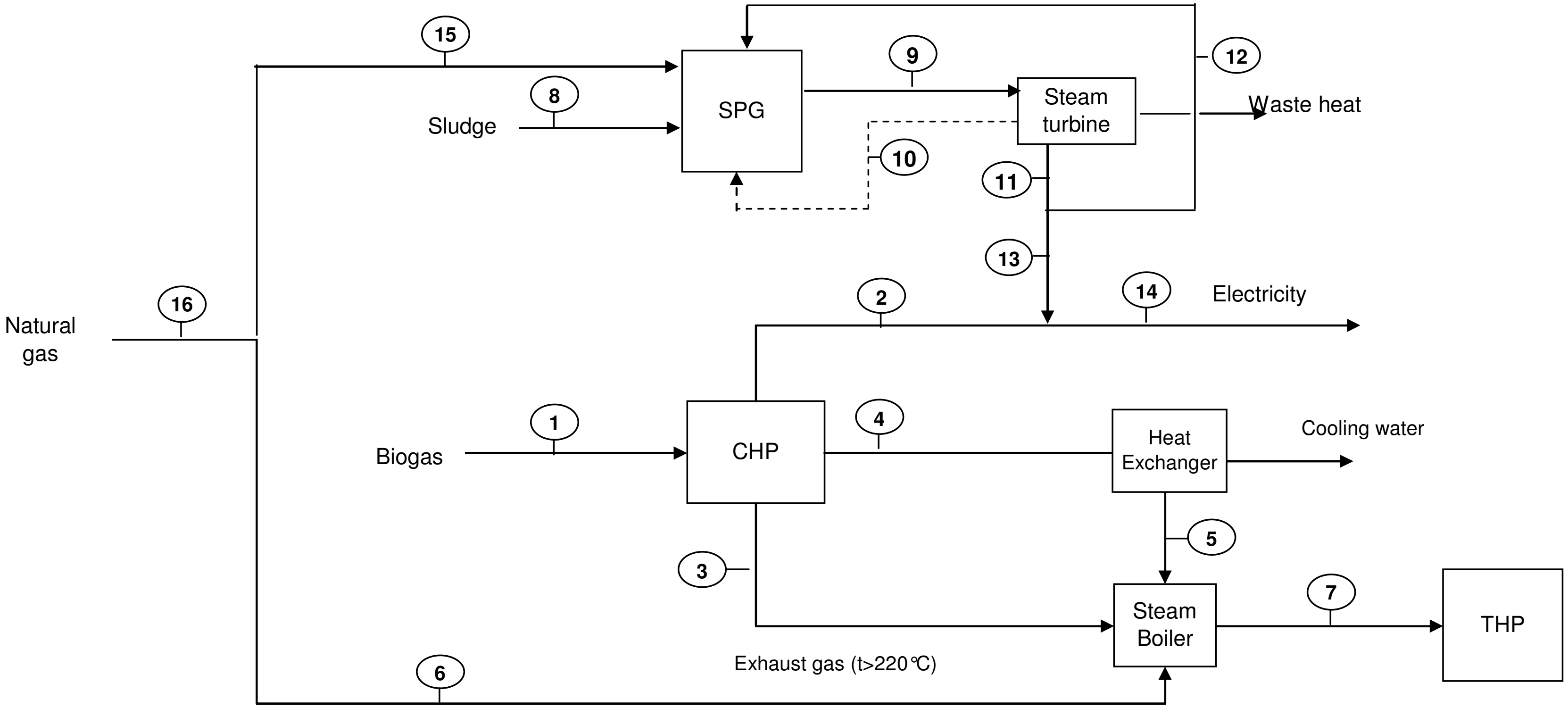


Table D.1: Energy Balance for Beckton STW options

Sub- Option Reference		**Units**	**1.0**	**2.0**	**2.3**	**3.0**	**4.0**	**4.2**	**5.0**	**5.2**
Process option			**RCI:RCI**	**RCI:EDI**	**RCI+:EDI**	**EDI:EDI**	**RCI:ED**	**RCI:ED**	**ED:ED**	**ED:ED**
1	Energy in biogas to CHP	MW	0	19.6	12.8	39.2		18.4	39.2	39.2
1	Biogas to CHP flow rate	Nm³/h	0	3,065	2,004	6,129	3,065	2,882	6,129	6,129
2	Electrical energy generated by CHP	MW	0	6.85	4.48	13.71	6.85	6.44	13.71	13.71
3	Heat from CHP exhaust gas to THP boiler	MW	0	2.86	1.87	5.71	2.86	2.69	5.71	5.71
4	Heat from CHP cooling water	MW	0	3.99	2.61	7.99	3.99	3.76	7.99	7.99
5	Heat from CHP cooling water used by THP boiler	MW	0	0.65	0.46	1.29	0.65	0.65	1.29	1.29
6	Energy in natural gas to THP boiler	MW	0	3.20	2.46	6.40	3.20	3.43	6.40	6.40
6	Flow rate of natural gas to THP boiler	Nm³/h	0	298	229	597	298	320	597	597
7	Heat to THP	MW	0.0	5.90	4.17	11.81	5.90	5.90	11.81	11.81
8	Energy in sludge to SPG	MW	67.6	47.7	62.5	26.3	36.0	36.0	0	0
8	Sludge DS rate	tDS/d	340	254	305	167.9	170	170	0	0
9	Energy from boiler to steam turbine	MW	60.9	43.7	53.1	26.7	32.9	32.9	0	0
10	Energy in steam to the dryer	MW	3.5	1.8	2.0	0.0	0.0	0.0	0	0
11	Gross electrical energy generated by SPG steam turbine	MW	14.06	10.24	13.21	8.1	7.93	7.93	0.00	0.00
12	Parasitic electrical energy of SPG	MW	5.26	3.88	4.35	2.5	2.78	2.78	0.00	0.00
13	Net electrical energy from SPG steam turbine	MW	8.80	6.36	8.85	5.6	5.15	5.15	0.00	0.00
14	Total electrical energy available from CHP and SPG	MW	8.80	13.21	13.33	19.33	12.00	11.59	13.7	13.71
15	Energy in natural gas to SPG	MW	0.00	0.00	0.00	2.29	0.00	0.00	0.00	0.00
15	Flow rate of natural gas to SPG	Nm³/h	0	0	0	214	0	0	0	0
16	Energy in natural gas to THP and SPG	MW	0.00	3.20	2.46	8.69	3.20	3.43	6.40	6.40
16	Flow rate of natural gas to THP and SPG	Nm³/h	0	298	229	810	298	320	597	597
	Net energy (item 14 - item16)	MW	**8.80**	**10.01**	**10.87**	**10.64**	**8.80**	**8.17**	**7.31**	**7.31**

Table D.2: Energy Balance for Crossness STW options

Sub- Option Reference		Units	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process option			**RCI:RCI**	**RCI:EDI**	**RCI+:EDI**	**EDI:EDI**	**RCI:ED**	**RCI:ED**	**ED:ED**	**ED:ED**
1	Energy in biogas to CHP	MW	0	10.5	17.6	21.5		19.8	21.5	31.6
1	Biogas to CHP flow rate	Nm³/h	0	1,637	2,749	3,366	1,637	3,099	3,366	4,947
2	Electrical energy generated by CHP	MW	0	3.66	6.15	7.53	3.66	6.93	7.53	11.06
3	Heat from CHP exhaust gas to THP boiler	MW	0	1.64	2.76	3.37	1.64	3.11	3.37	4.96
4	Heat from CHP cooling water	MW	0	2.13	3.58	4.39	2.13	4.04	4.39	6.45
5	Heat from CHP cooling water used by THP boiler	MW	0	0.34	0.60	0.70	0.34	0.67	0.70	1.03
6	Energy in natural gas to THP boiler	MW	0	1.52	2.84	3.13	1.52	3.15	3.13	4.60
6	Flow rate of natural gas to THP boiler	Nm³/h	0	142	265	292	142	294	292	429
7	Heat to THP	MW	0	3.13	5.48	6.42	3.13	6.14	6.42	9.44
8	Energy in sludge to SPG	MW	34.37	24.54	34.22	11.23	19.10	19.10	0.00	0.00
8	Sludge DS rate to SPG	tDS/d	185	139	195	0	95	95	0	0
9	Energy from boiler to steam turbine	MW	30.38	21.81	29.76	14.58	16.77	16.77	0.00	0.00
10	Energy in steam to the dryer	MW	1.9	1.0	1.7	0.0	0.0	0.0	0.0	0.0
11	Gross electrical energy generated by SPG steam turbine	MW	6.85	4.94	11.01	3.5	3.97	3.97	0.00	0.00
12	Parasitic electrical energy of SPG	MW	2.87	2.13	4.59	1.3	1.55	1.55	0.00	0.00
13	Net electrical energy from SPG steam turbine	MW	3.98	2.80	6.43	2.2	2.42	2.42	0.00	0.00
14	Total electrical energy available from CHP and SPG	MW	3.98	6.46	13.36	9.71	6.09	9.35	7.5	11.06
15	Energy in natural gas to SPG	MW	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
15	Flow rate of natural gas to SPG	Nm³/h	67	67	0	381	67	67	0	0
16	Energy in natural gas to THP and SPG	MW	0.00	1.52	2.84	3.14	1.52	3.15	3.13	4.60
16	Flow rate of natural gas to THP and SPG	Nm³/h	67	209	265	673	209	361	292	429
	Net energy (item 14 - item16)	MW	**3.98**	**4.94**	**10.52**	**6.58**	**4.56**	**6.20**	**4.40**	**6.46**

Appendix E Transfer Option Assessment

E.1 Overview

For options 2.3, 4.2 and 5.2, sludge from Beckton STW or Crossness STW would be transported to other locations where there is potentially more land available for development of new or extended sludge treatment works. For this study the following transfer options have been assumed:

Beckton STW sludge would be transported to Riverside STW.

Crossness STW sludge would be transported to Long Reach STW.

The three main options for transporting sludge considered in this study are:

Pipeline (including pumping)

Road transport by tanker or truck.

River transport by barge.

As noted previous there is an existing pipeline between Beckton STW and Riverside STW. However, the capacity of this pipeline is limited and most options would require an additional pipeline to be constructed. There is not a pipeline between Crossness STW and Long Reach STW.

Road transport is a common method used by many water and sewerage companies to transport sludge, either as thickened (liquid) sludge or sludge cake.

The proximity of the East London STWs to the Thames Tideway makes barge transport a possibility for transferring sludge from Beckton STW and Crossness STW to other sites. A number of water companies currently use barges and ships to transport sludge, and until 1998 TWUL transported sludge for disposal at sea from both Beckton STW and Crossness STW. Therefore sludge loading facilities are in place at these sites, though these would require rehabilitation for future use.

E.2 Beckton STW to Riverside STW

E.2.1 Pipeline option

The existing main is 7 km long and comprises two pipes, each 305 mm diameter.

It has been assumed that an additional pipeline will be required for options 2.3 and 4.2 but not for Option 5.2. In sizing the additional pipeline it has been assumed that the existing pipeline will carry 80tDS/d and a new pipeline will b constructed along the same route to transport the remainder of the sludge to be transferred under each option. A new DN400 pipeline would give the following velocities and pressure heads for the additional sludge in each option.

Table E.1: Potential pipeline velocities and pressure heads for pipeline between Beckton STW and Riverside STW

Option	Additional sludge quantity (1% DS)	Velocity (m/s)	Head loss (m)
2.3	12,000	1.11	21.0
4.2	14,000	1.29	28.2

This option would also require additional pumping capacity at Beckton STW. As the sludge pumped to Riverside STW would have a low dry solids concentration (1 to 2 %DS) additional (compared to transferring thickened sludge by tanker) pre-thickening sludge storage and thickening plant would be required at Riverside STW.

The existing 7km pipeline is in use and is assumed to be in adequate condition and hence would not need rehabilitation.

Estimated component costs for the pipeline option are summarised in Table E.2.

Table E.2: Estimated construction costs for pipeline option between Beckton STW and Riverside STW

Option	Capex (£m)				Opex (£'000/yr)
	Pipeline	Pump Stn	Thickening	Total	Power
2.3	6.75	1.35	0.23	8.33	23.3
4.2	6.75	1.35	0.23	8.33	36.6
5.2	0	0	0	0	0

Note: Construction costs exclude TWUL on-costs.

E.2.2 Road transport

The road distance between Beckton STW and Riverside STW is some 12 km. The route would incorporate Jenkins Road, Spur Road, A13/Alfred's Way, A1306, Marsh Way, A1306, Cherry Tree Lane and Manor Way

If sludge is to be transported by road it is assumed that it would either be as thickened sludge (5% DS) or as dewatered raw cake at, say 22% DS. The number of trips to be made every day (assuming a tanker transports 30 m^3 or trucks carrying up to 28 t of cake per load) would range between 11 and 157, depending on the option chosen and the % DS carried, as shown in Table E.3.

Assuming a typical cost rate for bulk sludge transport of £5/tonne wet sludge would result in an annual transport cost ranging from £2.6m to £8.0m/year for thickened sludge and £0.6 to £1.8m/year for cake. Apart from transport costs the transport of thickened sludge would also result in significantly greater liquor production from the pre-thermal hydrolysis thickening plant at Riverside STW. Transport of dewatered cake would potentially allow blending with indigenous Riverside STW to produce a 16%DS sludge and hence reduce the cost of thickening at Riverside STW.

Table E.3: Trips and costs of transporting sludge by road between Beckton STW and Riverside STW

Option	Number of tanker movements 28 tonne/trip		Operating cost @ £5.00 /t sludge			
			Per day (£'000/d)		Per year £'000/yr)	
	5% DS	22%DS	5% DS	22%DS	5% DS	22%DS
2.3	143	32	20.0	4.5	7,300	1,659
4.2	157	36	22.0	5.0	8,030	1,825
5.2	50	11	7.0	1.6	2,555	581

Transport of dewatered sludge cake would require construction of dewatering plant and cake export facility (odour controlled silo, roadworks and weigh bridge) at Beckton STW and cake reception facilities at Riverside STW. These additional works would cost an estimated £3.5m.

If the existing pipeline was rehabilitated to carry 80tDS/d, tankers could be used to transport the remainder. Assuming 22% DS is transported, between 6 and 23 trips would be required every day, depending on the option chosen, and the transport cost would fall to between £800,000 and £1.2m/year for options 2.3 and 4.2.

E.2.3 Barge and pipeline

Until 1998 Beckton STW disposed of its sludge at sea and therefore there is a pier on site with reception facilities. However, this is believed to be in constant use for works to the inlet and is therefore considered unavailable for other use.

Riverside STW is 0.4km from the Thames and therefore if the sludge was to be barged a pipeline would be required to transport the sludge from the Thames to the treatment works. Research shows that a barge can transport around 500t per trip. Table E.4 shows how many trips would be required every day for the various options.

Table E.4: Trips and costs of transporting sludge by barge between Beckton STW and Riverside STW

Option	Number of barge movements		Operating Cost (£'000) @ £3000/barge/day	
	500 t/trip		Per day	Per year
	5% DS	5% DS	5% DS	5% DS
2.3	8	2	9.0	3,285
4.2	9	2	9.0	3,285
5.2	3	1	3.0	1,095

It is has been assumed that sludge would be pumped from the barge to the treatment works (tankering is unlikely to be as cost effective). Therefore it is assumed for this analysis that the barge would only transport thickened sludge and not cake.

In addition to the cost of barging the sludge, a number of initial capital costs would be required, including construction of a new pier close to Riverside STW, land purchase for the sludge reception area, new thickened sludge pumping station and new 0.4 km DN400 pipeline to transport the thickened sludge from the reception area to Riverside STW.

The government and British Waterways supports the use of waterways to transport freight and because of this there may be grants available to help with capital costs required.

E.2.4 Evaluation

Reusing the existing pipeline to transport sludge between Beckton STW and Riverside STW is the preferred option in financial terms, having a net present value of £10.2m. The least favoured option would be to tanker thickened sludge as the high operational costs involved result in a net present value of £99.2m.

Table E.5: Capex, Opex and NPV for transfer options between Beckton STW and Riverside STW

Transfer option	Initial Capex (£m)	Opex £m/year)	NPV (£m)
Pipeline @ 1%	8.33	0.15	10.2
Tanker @ 5%	0	8.03	99.2
Truck @ 22%	3.50	1.84	26.2
Pipeline @ 1% and truck @ 22%	3.00	1.27	18.7
Barge & pipeline @ 5%	2.38	3.34	43.7

NPV calculated over 20 years at a discount rate of 5.1% in accordance with TWUL guidelines.

E.3 Crossness STW to Long Reach STW

The quantities of thickened sludge (5% DS) that could be transported to Long Reach STW from Crossness STW for treatment are shown in Table E.6.

Table E.6: Quantities of sludge to be transported from Crossness STW

Option	Sludge Quantities			
	tDS/d	t/d (% DS)		
		1%	5%	22%
2.3	110	11,000	2,200	500
4.2	120	12,000	2,400	545
5.2	50	5,000	1,000	227

There is no existing pipeline between Crossness STW and Long Reach STW. This study has assessed three options: construct a pipeline from Crossness STW to Long Reach STW, transfer by road and transfer by river barge.

E.3.1 Pipeline

The proposed pipeline route would follow Eastern Way, Bronze Age Way and Manor Way, going underneath a tributary of the River Thames before cutting across Dartford Marshes to Marsh Street. This route totals 9 km in length (an alternative route completely along roads would be some 11 km long). It has been estimated that a DN400 pipeline of 9 km in length would have a construction cost of £9.5m. A new pumping station would need to be constructed costing in the region of £1.3m. Capital and operating costs for this option are presented in Table E.7.

Table E.7: Pumping costs for new pipeline between Crossness STW and Long Reach STW

Option	Sludge quantity (1% DS)	Flow (l/s)	Velocity (m/s)	Pressure head (m)	Cost of pumping (£)
2.3	11,000	127.3	1.01	21.3	21,711
4.2	12,000	138.9	1.11	25.4	28,243
5.2	5,000	N/A	N/A	N/A	N/A

As the sludge pumped to Long Reach STW would have a low dry solids concentration (1 to 2 %DS) additional (compared to transferring thickened sludge by tanker) pre-thickening sludge storage and thickening plant would be required at Long Reach STW.

E.3.2 Road transport

The likely route of a tanker would be 11 km. The route would follow Belvedere Road, Harrow Manor Way, A2041, A2016, A206, and Marsh Street.

Tankering sludge would require between 9 and 86 trips per day, depending on the option chosen and the %DS carried.

Table E.8: Trips and costs of transporting sludge by road between Crossness STW and Long Reach STW

Option	Number of tanker movements		Cost @ £5 /t sludge			
	28 t/trip		Per day (£'000/d)		Per year £'000/yr)	
	5% DS	22%DS	5% DS	22%DS	5% DS	22%DS
2.3	79	18	11.0	2.5	4,015	912.5
4.2	86	20	12.0	2.7	4,380	995.5
5.2	36	9	5.0	1.1	1,825	414.8

Transport of dewatered sludge cake would require construction of dewatering plant and cake export facility (odour controlled silo, roadworks and weigh bridge) at Crossness STW and cake reception facilities at Long Reach STW. These additional works would cost an estimated £2.5m.

E.3.3 Barge

The distance along the River Thames between Crossness STW and Long Reach STW is approximately 9 km. If each barge carries 500t, the following table shows the number of trips required every day for both thickened sludge and cake.

Table E.9: Trips and costs of transporting sludge by barge between Crossness STW and Long Reach STW

Option	Number of barge movements		Operating Cost (£'000) @ £3000/barge/day			
	500	t/trip	Per day		Per year	
	5% DS	22%DS	5% DS	22%DS	5% DS	22%DS
2.3	4	1	12.0	3.0	4,380	1,095
4.2	5	1	15.0	3.0	5,475	1,095
5.2	2	1	6.0	3.0	2,190	1,095

Although more trips are required to transport thickened sludge between the two STWs, transporting this medium would be preferred because the reception area would be less complex. It would also prevent the need for dewatering at Crossness STW prior to transporting and blending/diluting at Long Reach STW to make it suitable for the thermal pre-treatment.

Crossness STW used to dispose of its sludge at sea and therefore has a pier in place. However, this pier has been disused since sea disposal ceased in 1998 and would therefore require a thorough survey and potential repair work to enable it to be used in the future. An estimate of £0.2m has been allowed for this in the option costs.

A reception area for the sludge would also need to be constructed with a conveyor to transport the sludge to the enhanced digestion plant.

E.3.4 Evaluation

As Table E.10 shows, constructing a new DN400 pipeline of 9 km length is the preferred option in financial terms. Although it has a very high capital cost, the operating costs are significantly lower than any other option, resulting in an NPV of £6m. However, constructing the new pipeline along a major highway and across marshland will not be easy and land ownership issues could arise. More analysis of the area would need to be undertaken to confirm an appropriate pipeline route.

Table E.10: Capex, Opex and NPV for transfer options between Crossness STW and Long Reach STW

Transfer option	Initial Capex (£m)	Opex £m/year)	NPV (£m)
Pipeline @ 1%	10.8	.04	6.11
Tanker @ 5%	0	4.4	0.04
Tanker @ 22%	2.5	1.0	0.01
Barge @ 5%	0.9	2.2	0.02
Barge @ 22%	0.9	1.1	0.01

NPV calculated over 20 years at a discount rate of 5.1% in accordance with TWUL guidelines.

E.4 Conclusions

The analysis carried out for this study indicates that the least cost option would be to transfer sludge by pipeline between Beckton STW and Riverside STW and between Crossness STW and Long Reach STW. This proved to have a lower whole life cost than both road transport and river transport by barge. Hence, the costs of pipelines and other facilities required for transferring sludge have been included in the overall cost estimates presented for options 2.3, 4.2 or 5.2.

However, this analysis has not considered the relative environmental impacts of each transfer option. Hence further analysis would be required if options 2.3, 4.2 or 5.2 were to be selected as the overall preferred option for either Beckton STW or Crossness STW.

E.5 Description of existing Beckton STW to Deephams STW

At the VM 1 workshop it was suggested that Deephams STW might be considered as an alternative location for providing additional treatment capacity for sludge produced at Beckton STW, partly because there is an existing pipeline between Beckton STW and Deephams STW.

This section describes the existing pipeline and considers the potential work that may be required if this option is pursued.

The pipeline consists of twin DN 305 (12 inch) cast iron pipes, approximately 20 km long. The majority of this pipeline is currently unused and hence is potentially available for transporting sludge between Beckton STW and Deephams STW. However, where the pipeline has already been turned over to other uses, such as potable water supply, then it is assumed that these sections would need to be replaced or new pipes built for the alternative uses.

Table E.11: lists the sections of the existing twin pipeline, their conditions and the obstacles it passes through. From this it can be seen that Section 1 of the pipeline is either in use (Pipe 1) or an alternative use is being considered (Pipe 2).

Section 2 of the pipeline has been unused for eight years and is likely to require significant rehabilitation prior to re-use. This section of the pipeline crosses a number of major roads and railways, and hence pipe repairs risk being both costly and potentially disruptive to traffic.

Section 3 of the pipeline would require a detailed survey and potential repair work to be carried out prior to future use, again, potentially affecting a number of major transport links.

Sections 4 and 5 are reported to be in reasonable condition though additional CCTV inspection would be needed to confirm this status.

Table E.11: Beckton STW to Deephams STW – Existing pipeline condition

Section	Distance (km)	Pipe 1	Pipe 2	Obstacles
1	1.7	Used for potable water supply to the Beckton SPG	Being considered for fibre optic main	Crosses the A1020
2	4.4	Not in use since 2008. Bursts recorded in past.	Being considered for fibre option main	Crosses A13, A112, A124 and A1011 as well as major railway
3	2.2	Unused. Condition unknown.	Unused. Condition unknown.	Crosses Docklands Light Railway and A115
4	4.9	Pipe intact, can be reused.	Pipe intact, can be reused.	Crosses A12, A104 Crosses railway in two locations
5	6.8	Pipe intact, can be reused.	Pipe intact, can be reused.	Crosses A503, A406

It is estimated that if a third of the pipeline would need to be rehabilitated and this would result in a capital cost of some £2.5 million (assuming slip lining). Furthermore, it is assumed that a new pipeline and associated pumping station would cost in the region of £22 million and additional pumping power costs would be around £110,000/year.

Hence, this study has not assessed any options involving transfer of sludge for treatment at Deephams STW on the grounds that such options are likely to be both significantly more costly and have potentially higher environmental and traffic impacts than the equivalent options involving Riverside STW.

Appendix F Carbon Footprint Assessment

Table F.1: Carbon Footprint Calculations – Beckton STW options

Carbon Source	Emissions Factor	Global Warming Potential	Units	Options							
				1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Embodied carbon:											
CAPEX	**£**		£'000	159,081	210,481	208,484	187,371	118,779	128,654	137,590	120,719
Total Embodied CO2	**kgCO_2/£**		tonnes CO2e	95,449	126,288	125,090	112,423	71,268	77,193	82,554	72,431
(Assumed 0.60 kgCO_2 = 1£ capex)	0.6										
Operating Carbon:											
Sub-total Power			tonnes CO2e/yr	**-34,582**	**-49,720**	**-48,272**	**-53,540**	**-44,777**	**-39,153**	**-48,814**	**-46,851**
Grid	Grid_EF_CO2	None	tonnes CO2e/yr	-34,582	-49,720	-48,272	-53,540	-44,777	-39,153	-48,814	-46,851
Renewable	Renewable_EF_CO2	None	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Green	Green_EF_CO2	None	tonnes CO2e/yr	0	0	0	0	0	0	0	0
CHP	CHP_Power_EF_CO2	None	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Sub-total Fuel			tonnes CO2e/yr	**13,751**	**19,525**	**18,185**	**31,498**	**19,525**	**19,936**	**11,549**	**11,549**
Natural Gas	NGas_EF_CO2	None	tonnes CO2e/yr	13,751	19,525	18,185	31,498	19,525	19,936	11,549	11,549
Diesel	Diesel_EF_CO2	None	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Sub-total Process Emissions			tonnes CO2e/yr	**38,086**	**34,261**	**38,269**	**30,436**	**24,855**	**24,855**	**11,623**	**11,623**
Enhanced Digestion	Sludge_THP_EF_CH4	CH4_CO2eq_GWP	tonnes CO2e/yr	0	5,812	4,102	11,623	5,812	5,812	11,623	11,623
Incineration	Sludge_Incin_N2O	N2O_CO2eq_GWP	tonnes CO2e/yr	38,086	28,450	34,167	18,813	19,043	19,043	0	0
Sub-total Transport			tonnes CO2e/yr	**98**	**98**	**98**	**98**	**522**	**522**	**881**	**881**
Diesel Consumption (sludge cake)	Diesel_EF_CO2	None	tonnes CO2e/yr	0	0	0	0	457	457	881	881
Diesel Consumption (ash)	Diesel_EF_CO2	None	tonnes CO2e/yr	98	98	98	98	65	65	0	0
Total Operating Carbon - excl land			tonnes CO2e/yr	**17,353**	**4,165**	**8,280**	**8,492**	**126**	**6,161**	**-24,761**	**-22,798**
Sludge cake CH4 emissions on land	Sludge_THP_Land_EF_CH4	CH4_CO2eq_GWP	tonnes CO2e/yr	0	0	0	0	352	352	704	704
Total Operating Carbon - incl land			tonnes CO2e/yr	**17,353**	**4,165**	**8,280**	**8,492**	**477**	**6,512**	**-24,057**	**-22,094**

Notes:
1) Quantities of consumables and of sludge product used to derive the operating carbon emissions are taken from the opex calculations.
2) Factors for GHG emissions and Global Warming Potentials taken from the spreadsheet WI_GHG_Estimator_v3.0.xls as used for June Returns 2008/09.

Table F.2: Carbon Footprint Calculations – Crossness STW options

Carbon Source	Emissions Factor	Global Warming Potential	Units	Options							
				1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Embodied carbon:											
CAPEX	**£**		£'000	122,384	144,727	191,011	126,796	78,940	114,290	87,363	109,551
Total Embodied CO2	**$kgCO_2$/£**		tonnes CO2e	73,431	86,836	114,606	76,077	47,364	68,574	52,418	65,731
(Assumed 0.60 $kgCO_2$ = 1£ capex)	0.6										
Operating Carbon:											
Sub-total Power			tonnes CO2e/yr	**-17,316**	**-28,701**	**-37,916**	**-33,735**	**-26,866**	**-34,001**	**-31,576**	**-40,963**
Grid	Grid_EF_CO2	None	tonnes CO2e/yr	-17,316	-28,701	-37,916	-33,735	-26,866	-34,001	-31,576	-40,963
Renewable	Renewable_EF_CO2	None	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Green	Green_EF_CO2	None	tonnes CO2e/yr	0	0	0	0	0	0	0	0
CHP	CHP_Power_EF_CO2	None	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Sub-total Fuel			tonnes CO2e/yr	**0**	**3,718**	**6,147**	**7,100**	**3,664**	**6,654**	**6,564**	**9,218**
Natural Gas	NGas_EF_CO2	None	tonnes CO2e/yr	0	3,718	6,147	7,100	3,664	6,654	6,564	9,218
Diesel	Diesel_EF_CO2	None	tonnes CO2e/yr	0	0	0	0	0	0	0	0
Sub-total Process Emissions			tonnes CO2e/yr	**24,084**	**21,321**	**29,957**	**19,134**	**21,321**	**29,495**	**7,350**	**26,869**
Enhanced Digestion	Sludge_THP_EF_CH4	CH4_CO2eq_GWP	tonnes CO2e/yr	0	4,102	6,424	7,350	4,102	7,073	7,350	10,321
Incineration	Sludge_Incin_N2O	N2O_CO2eq_GWP	tonnes CO2e/yr	24,084	17,219	23,533	11,784	17,219	22,421	0	16,548
Sub-total Transport			tonnes CO2e/yr	**65**	**65**	**98**	**65**	**359**	**588**	**555**	**849**
Diesel Consumption (sludge cake)	Diesel_EF_CO2	None	tonnes CO2e/yr	0	0	0	0	326	522	555	783
Diesel Consumption (ash)	Diesel_EF_CO2	None	tonnes CO2e/yr	65	65	98	65	33	65	0	65
Total Operating Carbon - excl land			tonnes CO2e/yr	**6,833**	**-3,597**	**-1,714**	**-7,436**	**-1,522**	**2,735**	**-17,106**	**-4,028**
Sludge cake CH4 emissions on land	Sludge_THP_Land_EF_CH4	CH4_CO2eq_GWP	tonnes CO2e/yr	0	0	0	0	248	428	445	625
Total Operating Carbon - incl land			tonnes CO2e/yr	**6,833**	**-3,597**	**-1,714**	**-7,436**	**-1,274**	**3,164**	**-16,662**	**-3,403**

Notes:
1) Quantities of consumables and of sludge product used to derive the operating carbon emissions are taken from the opex calculations.
2) Factors for GHG emissions and Global Warming Potentials taken from the spreadsheet WI_GHG_Estimator_v3.0.xls as used for June Returns 2008/09.

Appendix G Option Capex Estimates

This appendix provides a detailed breakdown of the Option capex estimates presented in Section 6.11.

Table G.1: Capex Breakdown by Option – Beckton STW options

Process stage	**Option 1.0**			**Option 2.0**			**Option 2.3**			**Option 3.0**		
Main stream (Process, capacity (tDS/d), location)	RCI	170	Beckton	RCI	170	Beckton	RCI+	220	Beckton	EDI	390	Beckton
Additional capacity (Process, capacity (tDS/d), location)	RCI	220	Beckton	EDI	220	Beckton	EDI	170	Riverside	0	0	0
	Civil	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**
Transfer pumping station and main												
Pumping Station (Transfer to Riverside)	0	0	0	0	0	0	400	600	1,000	0	0	0
Transfer main to Riverside	0		0	0		0	5,000		5,000	0		0
Thickening Pre-TPT												
Transfer main (Existing thickeners feed to Pre-TPT thickening)				90		90	60		60	90		90
Thickener feed tanks - (2 Nr new coated steel tanks)				146	97	243	178	118	296	167	111	278
Thickening feed pumps (incl pipework, base, suction manifold, cover)				40	260	300	30	195	225	60	390	450
Sludge Thickening (centrifuges & transfer pumps to cake silo)				803	1,825	2,628	365	1,570	1,935	1,424	2,036	3,459
Pumping Station incl pipework (Liquors to PST inlet channel)				162	72	234	285	149	434	212	101	313
Transfer main (Liquors to PST inlet channel)				90		90	60		60	90		90
Pumping Station incl pipework (Delivery of thickened sludge to sludge cake silo)				99	29	128	85	24	109	131	40	171
Transfer main (Delivery of thickened sludge to sludge cake silo)				28		28	28		28	28		28
Cake Reception & Silo (imported cake stream)												
Cake blending												
Cambi Feed Cake Silo (including transfer pumps)				100	inc	100	75	inc	75	150	inc	150
Odour Biofilter				64	440	504	48	330	378	96	660	756
Thermal Pre-Treatment						19,567			14,661			29,267
Thermal pre-treatment stage (process units)				0	17,200	17,200	0	12,900	12,900	0	25,800	25,800
Foundations and hardstanding				1,800	0	1,800	1,350	0	1,350	2,700	0	2,700
Pumping Station (Delivery of pretreated sludge to digesters)				100	300	400	75	225	300	150	450	600
Transfer main (Delivery of pretreated sludge to digesters)				167		167	111		111	167		167
Anaerobic Digestion						21,405			19,359			37,429
Digestion Tanks - existing (empty, clean/degritting & refurbish)				5,400	inc	5,400	0	inc	0	9,000	inc	9,000
Temporary Lime treatment incl loss of ROCs				n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Digestion Tanks - new, including gas mixing				0	inc	0	5,150	inc	5,150	0	inc	0
Boiler / plant building (including pipework around digesters)				4,015	5,220	9,235	3,103	4,033	7,136	7,118	9,253	16,370
Gas Holder - Beckton				167	746	913	0	0	0	296	1,323	1,619
Gas Holder - Riverside				0	0	0	120	534	654	0	0	0
CHP engines				238	4,750	4,988	190	3,800	3,990	420	8,400	8,820
Surplus/Waste Gas Burner				40	inc	40	40	inc	40	70	inc	70
Biogas treatment (Siloxanes)				30	300	330	30	300	330	50	500	550
Degas Tanks - existing (empty, clean/degritting & refurbish)				500	0	500	0	0	0	1,000	0	1,000
Degas Tanks - new				0	0	0	1,030	1,030	2,060	0	0	0
Dewatering & cake handling (post digestion, where cake not incinerated)												
Pumping Station (Feed to dewatering)												
Transfer mains (Feed to dewatering)												
Dewatering												
Pumping Station incl pipework (Liquors to treatment)												
Transfer main (Liquors to treatment)												
Cake Handling (conveyors)												
Cake Handling (storage building)				2,848	0	2,848	3,085	0	3,085	6,580	0	6,580
Mass-burn Incineration (including sludge dewatering, where cake is incinerated)												
Pumping Station (Raw or digested sludge feed to incinerator)	79	50	130	79	50	130	73	43	117	99	70	169
Transfer mains (Raw or digested sludge feed to incinerator)	167		167	167		167	111		111	167		167
Dewatering incl in incinerator	inc	inc	inc	inc	inc	inc	inc	inc	inc	1,424	2,036	3,459
Pumping Station incl pipework (Liquors to treatment)	inc	inc	inc	inc	inc	inc	inc	inc	inc	152	66	217
Transfer main (Liquors to STW or dedicated LTP)	90	0	90	45		45	30		30	45		45
Mass-burn incineration - new (BAMAG estimate)	26,040	63,000	89,040	19,344	51,600	70,944	18,352	51,000	69,352			
Mass-burn incineration - overhaul/enhance existing (BAMAG estimate)		24,000	24,000		24,000	24,000		28,800	28,800		38,800	38,800
Liquor treatment plant												
Liquor treatment plant (including air blowers & methanol dosing plant)				1,840	4,007	5,847	1,418	3,088	4,506	3,262	7,103	10,365
Pumping Station incl pipework (Treated liquors to Settled Sewage Channel)				105	41	146	93	35	128	137	58	194
Transfer main (Treated liquors to Settled Sewage Channel)				90		90	60		60	90		90
Other												
Misc. small pumps, pipelines		250	250		500	500		250	250		500	500
Misc Civils (Drainage, Manholes, Ducts, Drawpits)	500		500	1,000		1,000	1,000		1,000	1,000		1,000
MCC, Kiosk, (Starters & Cabling in Mech items)	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc
Transformers & LV Switchboards	100	500	600	100	1,000	1,100	100	1,000	1,100	100	1,000	1,100
Diversion of existing services		2,000	2,000		2,000	2,000		500	500		2,000	2,000
Misc civil/temporary works	500		500	1,000		1,000	1,000		1,000	1,000		1,000
SCADA		200	200		300	300		300	300		200	200
						0			0			0
(a) Total Base Cost	**27,476**	**90,000**	**117,477**	**40,697**	**114,736**	**155,434**	**43,135**	**110,825**	**153,959**	**37,472**	**100,896**	**138,368**
Contractor's on-costs												
(b) Contractor's Risk Allowance 8.0% of (a)			9,398			12,435			12,317			11,069
(c) Construction Management & Commissioning 6.0% of (a) + (b)			7,612			10,072			9,977			8,966
(d) Contractor's Design 5.0% of (a) + (b)			6,344			8,393			8,314			7,472
(e) Contractor's General Items 6.0% of (a) + (b)			7,612			10,072			9,977			8,966
(f) Management Fee 6.0% of (a) to (e)			8,907			11,784			11,673			10,491
(g) Insurances 1.1% of (a) to (f)			1,731			2,290			2,268			2,039
(h) Total Solution Cost	135%	of base cost	**159,081**	135%	of base cost	**210,481**	135%	of base cost	**208,484**	135%	of base cos	**187,371**
TWUL Costs & Risk Allowance												
D&PG	11.50%	of (h)	20,000			26,400			26,200			23,500
D&PT	2.50%	of (h)	4,000			5,300			5,300			4,700
OPC 1	6.85%	of (h)	10,900			14,500			14,300			12,900
Other TW implementation costs	2.00%	of (h)	3,200			4,300			4,200			3,800
TWUL Costs & Risk Allowance			**38,100**			**50,500**			**45,800**			**41,100**
Total Project Cost/Affordability Estimate	168%	of base cost	**197,181**	168%	of base cost	**260,981**	165%	of base cost	**254,284**	165%	of base cos	**228,471**

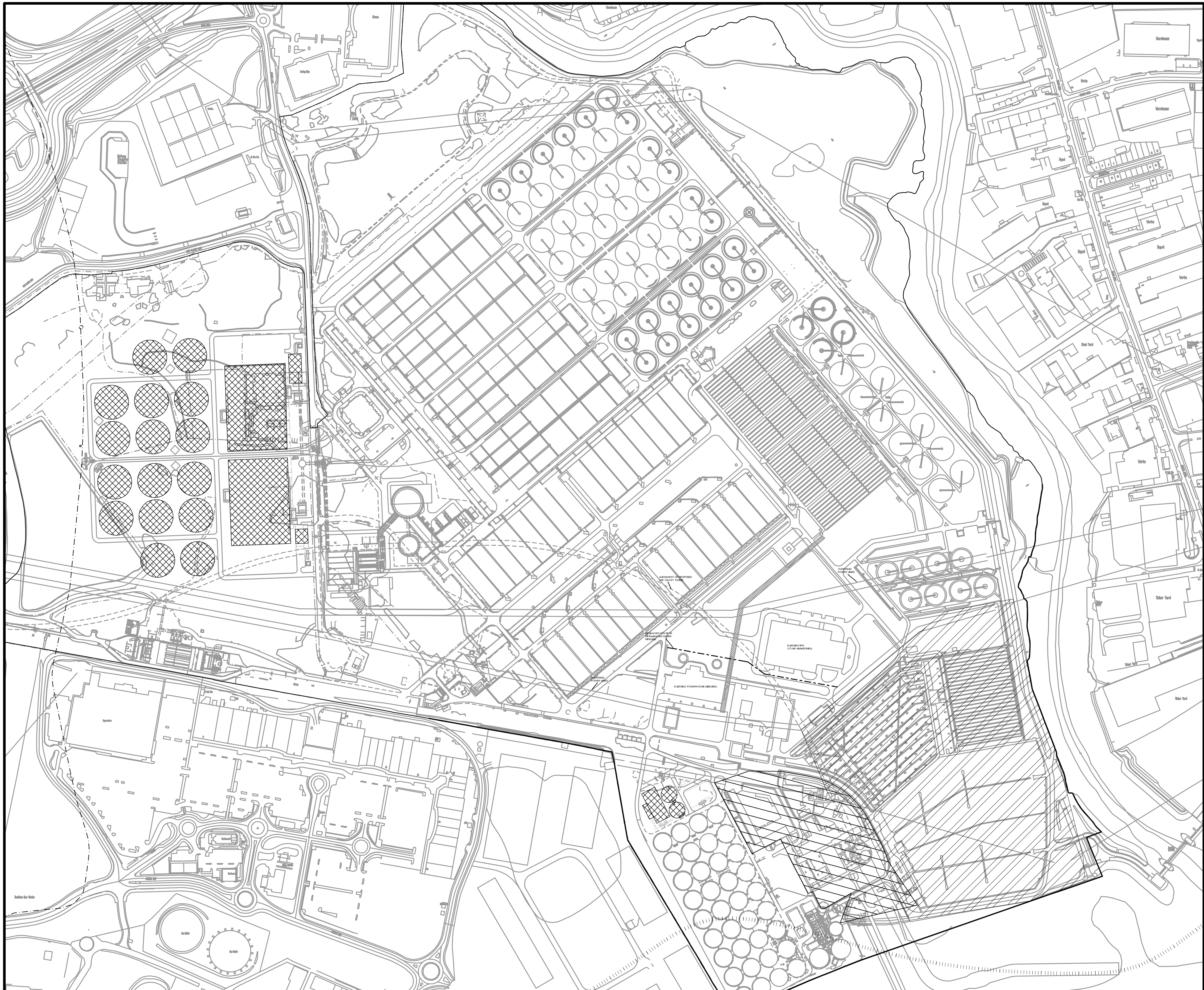
Process stage	**Option 4.0**			**Option 4.2**			**Option 5.0**			**Option 5.2**		
Main stream (Process, capacity (tDS/d), location)	RCI	170	Beckton	RCI	170	Beckton	ED	390	Beckton	ED	320	Beckton
Additional capacity (Process, capacity (tDS/d), location)	ED	220	Beckton	ED	220	Riverside	0	0	0	ED	70	Riverside
	Civil	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**
Transfer pumping station and main												
Pumping Station (Transfer to Riverside)	0	0	0	400	600	1,000	0	0	0	0	0	0
Transfer main to Riverside	0		0	5,000		5,000	0		0	0		0
Thickening Pre-TPT												
Transfer main (Existing thickeners feed to Pre-TPT thickening)	90		90	60		60	90		90	90		90
Thickener feed tanks - (2 Nr new coated steel tanks)	146	97	243	178	118	296	167	111	278	160	107	266
Thickening feed pumps (incl pipework, base, suction manifold, cover)	40	260	300	40	260	300	60	390	450	50	325	375
Sludge Thickening (centrifuges & transfer pumps to cake silo)	803	1,825	2,628	548	1,696	2,243	1,424	2,036	3,459	1,168	1,960	3,128
Pumping Station incl pipework (Liquors to PST inlet channel)	162	72	234	321	174	495	212	101	313	193	90	283
Transfer main (Liquors to PST inlet channel)	90		90	60		60	90		90	90		90
Pumping Station incl pipework (Delivery of thickened sludge to sludge cake silo)	99	29	128	96	28	124	131	40	171	119	36	155
Transfer main (Delivery of thickened sludge to sludge cake silo)	28		28	28		28	28		28	28		28
Cake Reception & Silo (imported cake stream)												
Cake blending												
Cambi Feed Cake Silo (including transfer pumps)	100	inc	100	100	inc	100	150	inc	150	125	inc	125
Odour Biofilter	64	440	504	64	440	504	96	660	756	80	550	630
Thermal Pre-Treatment			19,567			19,511			29,267			24,417
Thermal pre-treatment stage (process units)	0	17,200	17,200	0	17,200	17,200	0	25,800	25,800	0	21,500	21,500
Foundations and hardstanding	1,800	0	1,800	1,800	0	1,800	2,700	0	2,700	2,250	0	2,250
Pumping Station (Delivery of pretreated sludge to digesters)	100	300	400	100	300	400	150	450	600	125	375	500
Transfer main (Delivery of pretreated sludge to digesters)	167		167	111		111	167		167	167		167
Anaerobic Digestion			21,405			23,691			37,429			31,401
Digestion Tanks - existing (empty, clean/degritting & refurbish)	5,400	inc	5,400	0	inc	0	9,000	inc	9,000	7,200	inc	7,200
Temporary Lime treatment incl loss of ROCs	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Digestion Tanks - new, including gas mixing	0	inc	0	6,180	inc	6,180	0	inc	0	0	inc	0
Boiler / plant building (including pipework around digesters)	4,015	5,220	9,235	4,015	5,220	9,235	7,118	9,253	16,370	5,840	7,592	13,432
Gas Holder - Beckton	167	746	913	0	0	0	296	1,323	1,619	243	1,085	1,328
Gas Holder - Riverside	0	0	0	157	702	859	0	0	0	53	237	291
CHP engines	238	4,750	4,988	238	4,750	4,988	420	8,400	8,820	360	7,200	7,560
Surplus/Waste Gas Burner	40	inc	40	40	inc	40	70	inc	70	50	inc	50
Biogas treatment (Siloxanes)	30	300	330	30	300	330	50	500	550	40	500	540
Degas Tanks - existing (empty, clean/degritting & refurbish)	500	0	500	0	0	0	1,000	0	1,000	1,000	0	1,000
Degas Tanks - new	0	0	0	1,030	1,030	2,060	0	0	0	0	0	0
Dewatering & cake handling (post digestion, where cake not incinerated)												
Pumping Station (Feed to dewatering)	79	50	130	79	50	130	99	70	169	91	62	153
Transfer mains (Feed to dewatering)	167		167	111		111	167		167	167		167
Dewatering	803	1,825	2,628	548	1,696	2,243	1,424	2,036	3,459	1,168	1,960	3,128
Pumping Station incl pipework (Liquors to treatment)	116	47	163	116	47	163	152	66	217	138	58	197
Transfer main (Liquors to treatment)	45		45	60		60	90		90	90		90
Cake Handling (conveyors)	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc
Cake Handling (storage building)	5,533	0	5,533	5,788	0	5,788	8,543	0	8,543	7,855	0	7,855
Mass-burn Incineration (including sludge dewatering, where cake is incinerated)												
Pumping Station (Raw or digested sludge feed to incinerator)												
Transfer mains (Raw or digested sludge feed to incinerator)												
Dewatering incl in incinerator												
Pumping Station incl pipework (Liquors to treatment)												
Transfer main (Liquors to STW or dedicated LTP)												% adjustm
Mass-burn incineration - new (BAMAG estimate)												
Mass-burn incineration - overhaul/enhance existing (BAMAG estimate)		24,000	24,000		24,000	24,000						
Liquor treatment plant												
Liquor treatment plant (including air blowers & methanol dosing plant)	1,840	4,007	5,847	1,836	3,998	5,834	3,262	7,103	10,365	3,262	7,103	10,365
Pumping Station incl pipework (Treated liquors to Settled Sewage Channel)	105	41	146	105	41	146	137	58	194	137	58	194
Transfer main (Treated liquors to Settled Sewage Channel)	90		90	70		70	120		120	110		110
Other												
Misc. small pumps, pipelines		250	250		250	250		500	500		500	500
Misc Civils (Drainage, Manholes, Ducts, Drawpits)	600		600	750		750	1,000		1,000	1,000		1,000
MCC, Kiosk, (Starters & Cabling in Mech items)	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc
Transformers & LV Switchboards	100	1,000	1,100	100	1,000	1,100	100	1,000	1,100	100	1,000	1,100
Diversion of existing services		1,000	1,000		250	250		2,000	2,000		2,000	2,000
Misc civil/temporary works	500		500	500		500	1,000		1,000	1,000		1,000
SCADA		200	200		200	200		200	200		300	300
			0			0			0			0
(a) Total Base Cost	**24,057**	**63,658**	**87,715**	**30,658**	**64,349**	**95,007**	**39,510**	**62,096**	**101,606**	**34,549**	**54,599**	**89,148**
Contractor's on-costs												
(b) Contractor's Risk Allowance 8.0% of (a)			7,017			7,601			8,128			7,132
(c) Construction Management & Commissioning 6.0% of (a) + (b)			5,684			6,156			6,584			5,777
(d) Contractor's Design 5.0% of (a) + (b)			4,737			5,130			5,487			4,814
(e) Contractor's General Items 6.0% of (a) + (b)			5,684			6,156			6,584			5,777
(f) Management Fee 6.0% of (a) to (e)			6,650			7,203			7,703			6,759
(g) Insurances 1.1% of (a) to (f)			1,292			1,400			1,497			1,313
(h) Total Solution Cost	135%	of base cos	**118,779**	135%	of base cos	**128,654**	135%	of base cos	**137,590**	135%	of base cos	**120,719**
TWUL Costs & Risk Allowance												
D&PG			14,900			16,200			17,300			15,200
D&PT			3,000			3,300			3,500			3,100
OPC 1			8,200			8,900			9,500			8,300
Other TW implementation costs			2,400			2,600			2,800			2,500
TWUL Costs & Risk Allowance			**28,500**			**31,000**			**33,100**			**29,100**
Total Project Cost/Affordability Estimate	168%	of base cos	**147,279**	168%	of base cos	**159,654**	168%	of base cos	**170,690**	168%	of base cos	**149,819**

Table G.2: Capex Breakdown by Option – Crossness STW options

Process stage	Option 1.0			Option 2.0			Option 2.3			Option 3.0			Option 4.0			Option 4.2			Option 5.0			Option 5.2		
Main stream (Process, capacity (tDS/d), location)	RCI	95	Crossness	RCI	95	Crossness	RCI+	114	Crossness	EDI	215	Crossness	RCI	95	Crossness	RCI	95	Crossness	ED	215	Crossness	ED	165	Crossness
Additional capacity (Process, capacity (tDS/d), location)	RCI	120	Crossness	EDI	120	Crossness	EDI	188	.ong Reac	0	0	0	ED	120	Crossness	ED	207	Long Reach	0	0	0	ED	137	Long Reach
	Civil	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**	**Civil**	**MEICA**	**Total**
Transfer pumping station and main																								
Pumping Station (Transfer to Riverside)	0	0	0	0	0	0	300	700	1,000	0	0	0	0	0	0	300	700	1,000	0	0	0	300	600	900
Transfer main to Riverside	0		0	0		0	7,000		7,000	0		0	0		0	7,000		7,000	0		0	6,000		6,000
Thickening Pre-TPT												4,284												
Transfer main (Existing thickeners feed to Pre-TPT thickening)				90		90	60		60	90		90	90		90	60		60	90		90	90		90
Thickener feed tanks - (2 Nr new coated steel tanks)				126	84	210	206	137	343	145	97	241	126	84	210	211	141	351	145	97	241	201	134	335
Thickening feed pumps (incl pipework, base, suction manifold, cover)				20	130	150	30	195	225	40	260	300	20	130	150	30	195	225	40	260	300	30	195	225
Sludge Thickening (centrifuges & transfer pumps to cake silo)				438	1,625	2,063	686	1,771	2,456	785	1,817	2,601	438	1,625	2,063	755	1,803	2,559	785	1,817	2,601	1,102	1,938	3,040
Pumping Station incl pipework (Liquors to PST inlet channel)				123	50	173	298	159	457	161	71	232	123	50	173	312	168	480	161	71	232	142	61	203
Transfer main (Liquors to PST inlet channel)				90		90	60		60	90		90	90		90	60		60	90		90	90		90
Pumping Station incl pipework (Delivery of thickened sludge to sludge cake silo)				57	15	72	67	18	84	77	21	98	57	15	72	70	19	89	77	21	98	86	24	110
Transfer main (Delivery of thickened sludge to sludge cake silo)				28		28	28		28	28		28	28		28	28		28	28		28	28		28
Cake Reception & Silo (imported cake stream)																								
Cake blending																								
Cambi Feed Cake Silo (including transfer pumps)				50	inc	50	75	inc	75	100	inc	100	50	inc	50	75	inc	75	100	inc	100	75	inc	75
Odour Biofilter				32	220	252	48	330	378	64	440	504	32	220	252	48	330	378	64	440	504	48	330	378
Thermal Pre-Treatment						9,867			14,661			19,567			9,867			14,661			19,567			14,717
Thermal pre-treatment stage (process units)				0	8,600	8,600	0	12,900	12,900	0	17,200	17,200	0	8,600	8,600	0	12,900	12,900	0	17,200	17,200	0	12,900	12,900
Foundations and hardstanding				900	0	900	1,350	0	1,350	1,800	0	1,800	900	0	900	1,350	0	1,350	1,800	0	1,800	1,350	0	1,350
Pumping Station (Delivery of pretreated sludge to digesters)				50	150	200	75	225	300	100	300	400	50	150	200	75	225	300	100	300	400	75	225	300
Transfer main (Delivery of pretreated sludge to digesters)				167		167	111		111	167		167	167		167	111		111	167		167	167		167
Anaerobic Digestion						13,400			18,922			22,745			13,400			21,176			22,745			32,339
Digestion Tanks - existing (empty, clean/degritting & refurbish)				3,000	inc	3,000	2,400	inc	2,400	5,400	inc	5,400	3,000	inc	3,000	2,400	inc	2,400	5,400	inc	5,400	6,600	inc	6,600
Temporary Lime treatment incl loss of ROCs				n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Digestion Tanks - new, including gas mixing				0	inc	0	1,836	inc	1,836	0	inc	0	0	inc	0	2,295	inc	2,295	0	inc	0	0	inc	0
Boiler / plant building (including pipework around digesters)				2,190	2,847	5,037	3,429	4,458	7,888	3,924	5,101	9,025	2,190	2,847	5,037	3,776	4,909	8,685	3,924	5,101	9,025	5,510	7,163	12,673
Gas Holder - Crossness				92	411	503	0	0	0	165	736	901	92	411	503	0	0	0	165	736	901	126	565	691
Gas Holder - Long Reach				0	0	0	172	769	941	0	0	0	0	0	0	172	769	941	0	0	0	129	576	705
CHP engines				190	3,800	3,990	238	4,750	4,988	300	6,000	6,300	190	3,800	3,990	285	5,700	5,985	300	6,000	6,300	480	9,600	10,080
Surplus/Waste Gas Burner				40	inc	40	40	inc	40	70	inc	70	40	inc	40	40	inc	40	70	inc	70	50	inc	50
Biogas treatment (Siloxanes)				30	300	330	30	300	330	50	500	550	30	300	330	30	300	330	50	500	550	40	500	540
Degas Tanks - existing (empty, clean/degritting & refurbish)				500	0	500	500	0	500	500	0	500	500	0	500	500	0	500	500	0	500	1,000	0	1,000
Degas Tanks - new				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dewatering & cake handling (post digestion, where cake not incinerated)																								
Pumping Station (Feed to dewatering)													66	33	98	74	45	119	75	46	121	84	55	139
Transfer mains (Feed to dewatering)													167		167	111		111	167		167	167		167
Dewatering													438	1,625	2,063	755	1,803	2,559	785	1,817	2,601	1,102	1,938	3,040
Pumping Station incl pipework (Liquors to treatment)													88	32	120	113	45	158	115	46	161	102	39	141
Transfer main (Liquors to treatment)													45		45	60		60	90		90	90		90
Cake Handling (conveyors)													inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc
Cake Handling (storage building)				1,786	0	1,786	3,282	0	3,282	3,593	0	3,593	3,469	0	3,469	5,397	0	5,397	5,398	0	5,398	6,984	0	6,984
Mass-burn Incineration (including sludge dewatering, where cake is incinerated)																								
Pumping Station (Raw or digested sludge feed to incinerator)	66	33	98	66	33	98	72	42	115	75	46	121												
Transfer mains (Raw or digested sludge feed to incinerator)	167		167	167		167	111		111	167		167												
Dewatering incl in incinerator	inc	inc	inc	inc	inc	inc	inc	inc	inc	785	1,817	2,601												
Pumping Station incl pipework (Liquors to treatment)	inc	inc	inc	inc	inc	inc	inc	inc	inc	115	46	161												
Transfer main (Liquors to STW or dedicated LTP)	90	0	90	45		45	30		30	45		45												% adjustm
Mass-burn incineration - new (BAMAG estimate)	19,952	47,520	67,472	15,544	35,904	51,448	18,096	42,240	60,336															
Mass-burn incineration - overhaul/enhance existing (BAMAG estimate)		20,000	20,000		20,000	20,000		24,000	24,000		31,000	31,000		20,000	20,000		20,000	20,000						
Liquor treatment plant																								
Liquor treatment plant (including air blowers & methanol dosing plant)				1,004	2,186	3,190	1,570	3,418	4,988	1,799	3,917	5,716	1,004	2,186	3,190	1,729	3,765	5,493	1,799	3,917	5,716	2,526	5,501	8,027
Pumping Station incl pipework (Treated liquors to Settled Sewage Channel)				79	28	108	98	37	135	104	40	144	79	28	108	102	39	141	104	40	144	122	49	171
Transfer main (Treated liquors to Settled Sewage Channel)				90		90	60		60	90		90	90		90	70		70	120		120	110		110
Other																								
Misc. small pumps, pipelines		250	250		500	500		250	250		500	500		200	200		250	250		500	500		500	500
Misc Civils (Drainage, Manholes, Ducts, Drawpits)	200		200	400		400	400		400	400		400	200		200	400		400	400		400	400		400
MCC, Kiosk, (Starters & Cabling in Mech items)	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc	inc
Transformers & LV Switchboards	100	400	500	100	400	500	100	400	500	100	400	500	100	400	500	100	400	500	100	400	500	100	400	500
Diversion of existing services		200	200		400	400		400	400		400	400		200	200		400	400		400	400		400	400
Misc civil/temporary works	200		200	400		400	400		400	400		400	200		200	400		400	400		400	400		400
SCADA		200	200		300	300		300	300		200	200		200	200		200	200		200	200		300	300
Contaminated land remediation	1,000		1,000	1,000		1,000			0	1,000		1,000	1,000		1,000			0	1,000		1,000	1,000		1,000
(a) Total Base Cost	**21,775**	**68,603**	**90,377**	**28,894**	**77,983**	**106,877**	**43,258**	**97,798**	**141,056**	**22,727**	**70,908**	**93,635**	**15,158**	**43,137**	**58,295**	**29,295**	**55,105**	**84,400**	**24,607**	**39,908**	**64,515**	**36,906**	**43,994**	**80,900**
Contractor's on-costs																								
(b) Contractor's Risk Allowance 8.0% of (a)			7,230			8,550			11,284			7,491			4,664			6,752			5,161			6,472
(c) Construction Management & Commissioning 6.0% of (a) + (b)			5,856			6,926			9,140			6,068			3,778			5,469			4,181			5,242
(d) Contractor's Design 5.0% of (a) + (b)			4,880			5,771			7,617			5,056			3,148			4,558			3,484			4,369
(e) Contractor's General Items 6.0% of (a) + (b)			5,856			6,926			9,140			6,068			3,778			5,469			4,181			5,242
(f) Management Fee 6.0% of (a) to (e)			6,852			8,103			10,694			7,099			4,420			6,399			4,891			6,134
(g) Insurances 1.1% of (a) to (f)			1,332			1,575			2,078			1,380			859			1,244			951			1,192
(h) Total Solution Cost	135%	of base cost	**122,384**	135%	of base cost	**144,727**	135%	of base cost	**191,011**	135%	of base cos	**126,796**	135%	of base cos	**78,940**	135%	of base cos	**114,290**	135%	of base cos	**87,363**	135%	of base cos	**109,551**
TWUL Costs & Risk Allowance																								
D&PG	11.50%	of (h)	15,400			18,200			24,000			15,900			9,900			14,400			11,000			13,800
D&PT	2.50%	of (h)	3,100			3,700			4,800			3,200			2,000			2,900			2,200			2,800
OPC 1	6.85%	of (h)	8,400			10,000			13,100			8,700			5,500			7,900			6,000			7,600
Other TW implementation costs	2.00%	of (h)	2,500			2,900			3,900			2,600			1,600			2,300			1,800			2,200
TWUL Costs & Risk Allowance			**29,400**			**34,800**			**41,900**			**27,800**			**19,000**			**27,500**			**21,000**			**26,400**
Total Project Cost/Affordability Estimate	168%	of base cost	**151,784**	168%	of base cost	**179,527**	165%	of base cost	**232,911**	165%	of base cos	**154,596**	168%	of base cos	**97,940**	168%	of base cos	**141,790**	168%	of base cos	**108,363**	168%	of base cos	**135,951**

Appendix H Drawings

H.1 Locations of other proposed schemes in AMP 4 and AMP 5



KEY

- TW site boundary
- Proposed AMP 4 development
- Desalination plant site investigation
- Lee Tunnel working areas
- Existing services (incuding Air, Mains and Water)
- DLR extension

Rev	Date	Drawn	Description	Ch'k'd	App'd
A	08/09/08	AS	FOR INFORMATION	JN	JN

Thames Water Utilities
ENGINEERING
Gainsborough House
Manor Farm Road, Reading RG2 0JN

Mott MacDonald
Demeter House
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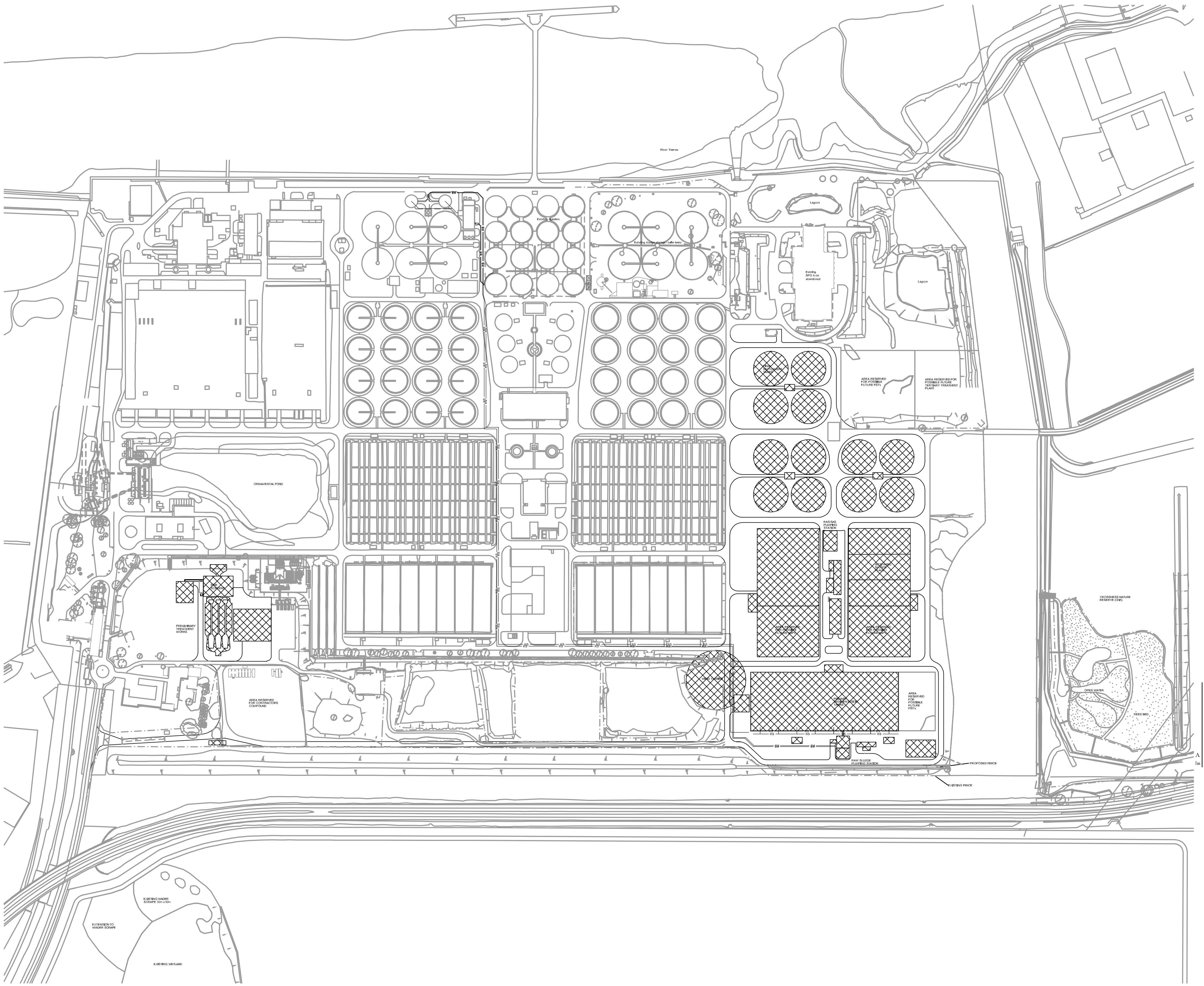
Tel +44 (0)1223 460 660
Fax +44 (0)1223 461 007
Web www.mottmac.com

Project Title
EAST LONDON ADDITIONAL
SLUDGE TREATMENT CAPACITY
STRATEGIC ALTERNATIVES REVIEW

Drawing Title
BECKTON STW
SITE PLAN

Designed	AS		Eng.Chk.	GM	
Drawn	AS		Coordination	AS	
Dwg.Chk.	JN		Approved	JN	
Scale	1:5000 @ A3	Project	246969	Status	INF
		CAD file			
Drawing No	246969/BECKTON/SITE PLAN			Rev	A



KEY

Proposed AMP 4 development

Desalination plant site investigation

Rev	Date	Drawn	Description	Ch'k'd	App'd
A	08/09/08	AS	FOR INFORMATION	JN	JN

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Project Title

EAST LONDON ADDITIONAL
SLUDGE TREATMENT CAPACITY
STRATEGIC ALTERNATIVES REVIEW

Drawing Title

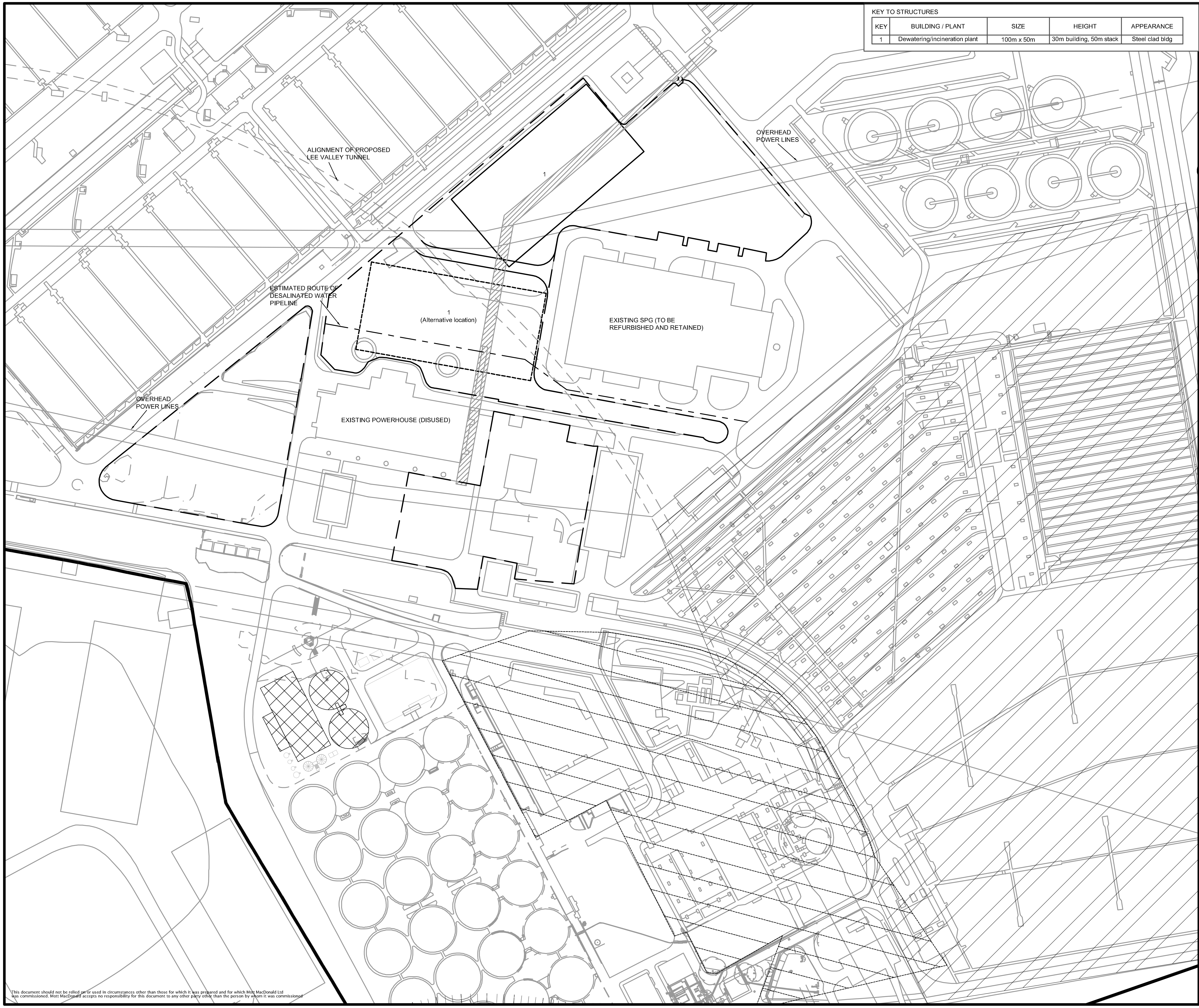
CROSSNESS STW
SITE PLAN

Designed	AS		Eng.Chk.	GM
Drawn	AS		Coordination	AS
Dwg.Chk.	JN		Approved	JN
Scale 1:5000 @ A3	Project 246969	CAD file		Status INF
Drawing No 246969/CROSSNESS/SITE PLAN				Rev A

H.2 Beckton STW Options

KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	Dewatering/incineration plant	100m x 50m	30m building, 50m stack	Steel clad bldg



KEY

- Border of potential land available for post AMP4 development
- Initial layout for post AMP4 development
- Proposed AMP 4 development
- Desalination plant site investigation
- Lee Tunnel working areas
- Existing services (incuding Air, Mains and Water)
- DLR extension

1:2000 @ A3

0m 10 20 30 40 50 100m

Rev	Date	Drawn	Description	Ch'k'd	App'd
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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Project Title

EAST LONDON ADDITIONAL
SLUDGE TREATMENT CAPACITY
STRATEGIC ALTERNATIVES REVIEW

Drawing Title

BECKTON STW
PROPOSED LAYOUT FOR BECKTON OPTION 1.0

Designed	AS		Eng.Chk.	GM	
Drawn	AS		Coordination	AS	
Dwg.Chk.	JN		Approved	JN	
Scale	SEE SCALE		Project 246969		Status INF
			CAD file		
Drawing No	246969/BECKTON/1.0				Rev C

KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	THP thickener feed tank	2 nr. 7.8m Ø	8m	Steel clad bldg
2	THP thickening plant	36m x 13m	15m	Steel clad bldg
3	THP and pumps	45m x 41m	9m	Steel tank
4	Digesters	9 nr (existing)	10m	Concrete
5	Gas holders	4 nr. 13m Ø	18m	Steel tank
6	CHP	16m x 51m	8m	Steel clad bldg
7	Degas tanks	2 nr (existing)	10m	Concrete
8	Dewatering/incineration plant	90m x 30m	30m building, 50m stack	Steel clad bldg
9	LTP	30m x 60m	8m	Steel clad bldg/GRP kiosk
		2nr. 23Ø	8m	Steel tank
10	Sludge storage	85m x 30m	10m	Steel clad bldg

KEY

- Border of potential land available for post AMP4 development
- Initial layout for post AMP4 development
- Proposed AMP 4 development
- Desalination plant site
- Lee Tunnel working areas
- Existing services (incuding Air, Mains and Water)
- DLR extension

1:2000 @ A3

0m 10 20 30 40 50 100m

Rev	Date	Drawn	Description	Ch'k'd	App'd
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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Project Title

EAST LONDON ADDITIONAL
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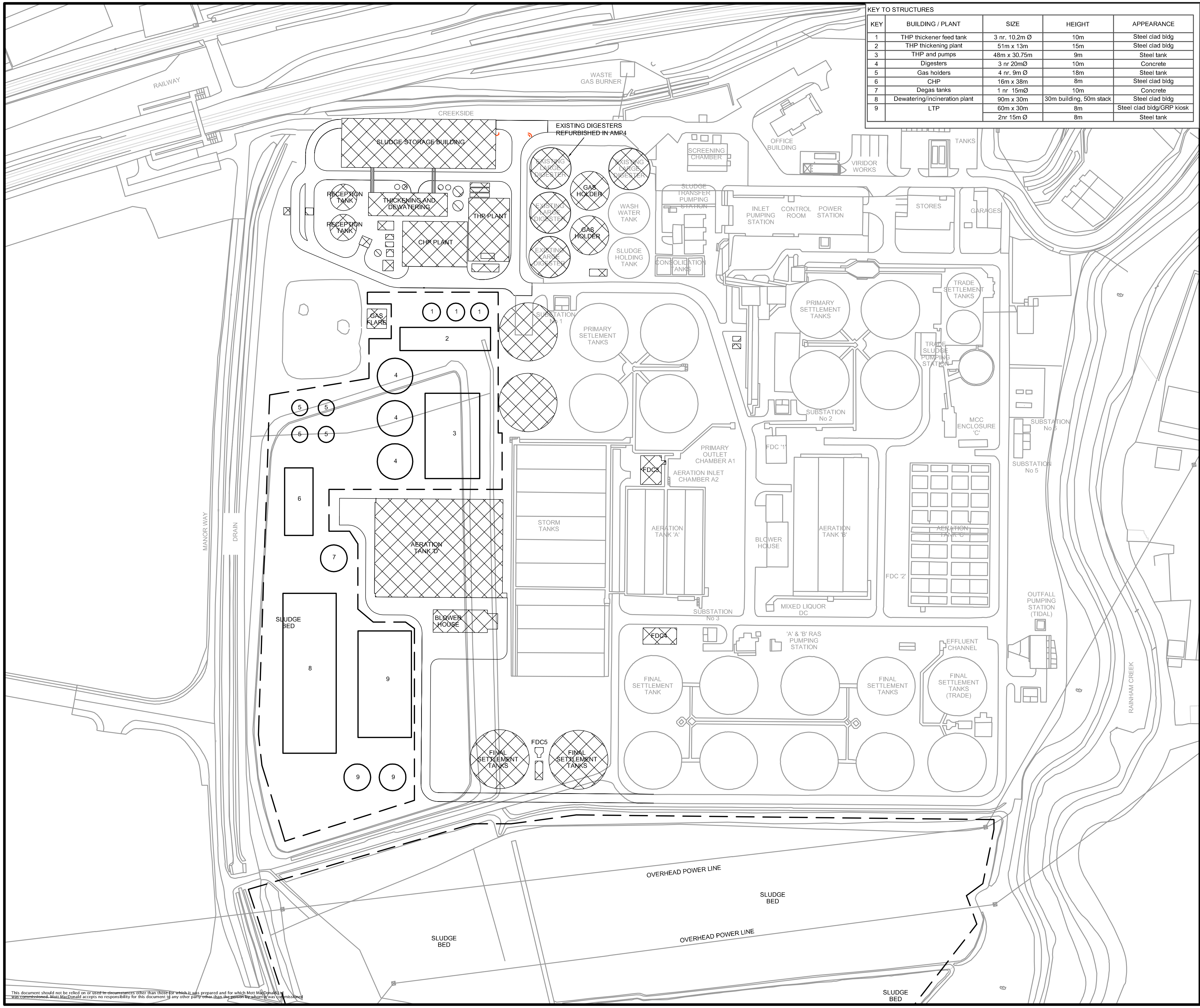
Drawing Title

BECKTON STW
PROPOSED LAYOUT FOR BECKTON OPTION 2.0

Designed	AS		Eng.Chk.	GM	
Drawn	AS		Coordination	AS	
Dwg.Chk.	JN		Approved	JN	

Scale: SEE SCALE
Project: 246969
CAD file
Status: INF

Drawing No: 246969/BECKTON/2.0
Rev: C



KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	THP thickener feed tank	3 nr. 10.2m Ø	10m	Steel clad bldg
2	THP thickening plant	51m x 13m	15m	Steel clad bldg
3	THP and pumps	48m x 30.75m	9m	Steel tank
4	Digesters	3 nr 20mØ	10m	Concrete
5	Gas holders	4 nr. 9m Ø	18m	Steel tank
6	CHP	16m x 38m	8m	Steel clad bldg
7	Degas tanks	1 nr 15mØ	10m	Concrete
8	Dewatering/incineration plant	90m x 30m	30m building, 50m stack	Steel clad bldg
9	LTP	60m x 30m	8m	Steel clad bldg/GRP kiosk
		2nr 15m Ø	8m	Steel tank

KEY

- Border of potential land available for post AMP4 development
- Initial layout for post AMP4 development
- Proposed AMP 4 development

1:2000 @ A3

0m 10 20 30 40 50 100m

Rev	Date	Drawn	Description	Ch'k'd	App'd
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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Project Title

EAST LONDON ADDITIONAL SLUDGE TREATMENT CAPACITY STRATEGIC ALTERNATIVES REVIEW

Drawing Title

RIVERSIDE STW
PROPOSED LAYOUT FOR BECKTON OPTION 2.3

Designed	AS		Eng.Chk.	GM	
Drawn	AS		Coordination	AS	
Dwg.Chk.	JN		Approved	JN	
Scale	SEE SCALE	Project	246969		Status INF
		CAD file			
Drawing No	246969/BECKTON/2.3				Rev C

KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	THP thickener feed tank	2 nr. 9.4m Ø	8m	Steel clad bldg
2	THP thickening plant	42m x 13m	15m	Steel clad bldg
3	THP and pumps	3 nr. 45m x 20.5m	9m	Steel tank
4	Digesters	15 nr existing	10m	Concrete
5	Gas holders	4 nr. 18m Ø	18m	Steel tank
6	CHP	25m x 61m	8m	Steel clad bldg
7	Degas tanks	2 nr existing	10m	Concrete
8	LTP	90m x 30m	8m	Steel clad bldg/GRP kiosk
		3nr. 25m Ø	8m	Steel tank
9	Sludge storage	85m x 30m	10m	Steel clad bldg

KEY

- Border of potential land available for post AMP4 development
- Initial layout for post AMP4 development
- Proposed AMP 4 development
- Desalination plant site investigation
- Lee Tunnel working areas
- Existing services (incuding Air, Mains and Water)
- DLR extension

Rev	Date	Drawn	Description	Ch'k'd	App'd
A	24/03/09	AS	FOR INFORMATION	JN	JN

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Project Title
EAST LONDON ADDITIONAL
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STRATEGIC ALTERNATIVES REVIEW

Drawing Title
BECKTON STW
PROPOSED LAYOUT FOR BECKTON OPTION 3.0

Designed	AS		Eng.Chk.	GM
Drawn	AS		Coordination	AS
Dwg.Chk.	JN		Approved	JN

Scale: SEE SCALE
Project: 246969
CAD file
Status: INF
Drawing No: 246969/BECKTON/3.0
Rev: A

KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	THP thickener feed tank	2 nr. 7.8m Ø	8m	Steel clad bldg
2	THP thickening plant	36m x 13m	15m	Steel clad bldg
3	THP and pumps	45m x 41m	9m	Steel tank
4	Digesters	9 nr (existing)	10m	Concrete
5	Gas holders	4 nr. 13m Ø	18m	Steel tank
6	CHP	16m x 51m	8m	Steel clad bldg
7	Degas tanks	2 nr (existing)	10m	Concrete
8	LTP	30m x 60m	8m	Steel clad bldg/GRP kiosk
		2nr. 23Ø	8m	Steel tank
9	Sludge storage	90m x 30m	10m	Steel clad bldg

KEY

- Border of potential land available for post AMP4 development
- Initial layout for post AMP4 development
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1:2000 @ A3

0m 10 20 30 40 50 100m

Rev	Date	Drawn	Description	Ch'k'd	App'd
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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Project Title

EAST LONDON ADDITIONAL
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STRATEGIC ALTERNATIVES REVIEW

Drawing Title

BECKTON STW
PROPOSED LAYOUT FOR BECKTON OPTION 4.0

Designed	AS	Eng.Chk.	GM
Drawn	AS	Coordination	AS
Dwg.Chk.	JN	Approved	JN

Scale: SEE SCALE | Project: 246969 | CAD file | Status: INF

Drawing No: 246969/BECKTON/4.0 | Rev: C

KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	THP thickener feed tank	2 nr. 9.4m Ø	8m	Steel clad bldg
2	THP thickening plant	42m x 13m	15m	Steel clad bldg
3	THP and pumps	3 nr. 45m x 20.5m	9m	Steel tank
4	Digesters	15 nr existing	10m	Concrete
5	Gas holders	4 nr. 18m Ø	18m	Steel tank
6	CHP	25m x 61m	8m	Steel clad bldg
7	Degas tanks	2 nr existing	10m	Concrete
8	LTP	90m x 30m	8m	Steel clad bldg/GRP kiosk
		3nr. 25m Ø	8m	Steel tank
9	Sludge storage	90m x 30m	10m	Steel clad bldg

KEY

- Border of potential land available for post AMP4 development
- Initial layout for post AMP4 development
- Proposed AMP 4 development
- Desalination plant site investigation
- Lee Tunnel working areas
- Existing services (incuding Air, Mains and Water)
- DLR extension

1:2000 @ A3

0m 10 20 30 40 50 100m

Rev	Date	Drawn	Description	Ch'k'd	App'd
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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Project Title

EAST LONDON ADDITIONAL
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STRATEGIC ALTERNATIVES REVIEW

Drawing Title

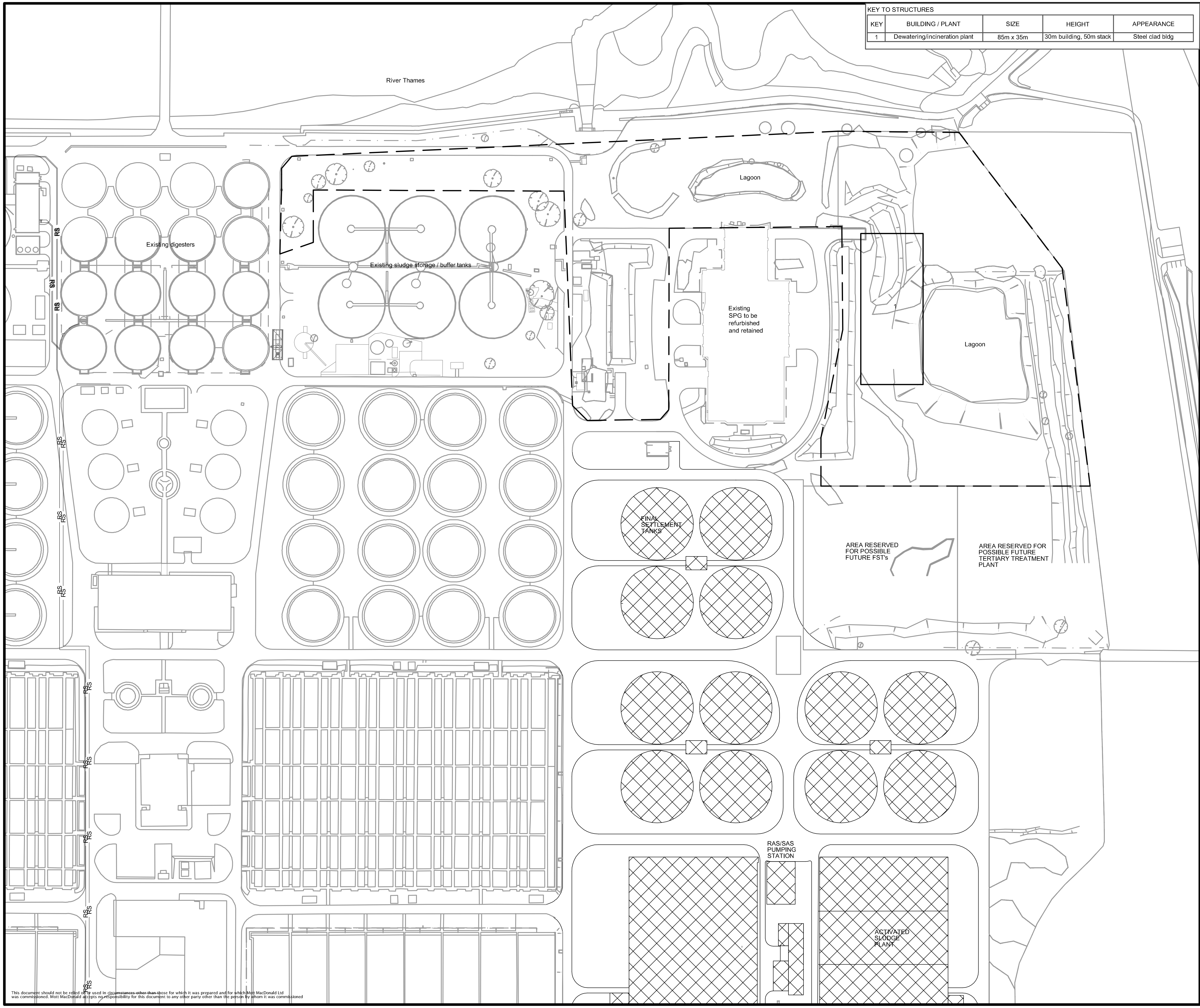
BECKTON STW
PROPOSED LAYOUT FOR BECKTON OPTION 5.0

Designed	AS		Eng.Chk.	GM	
Drawn	AS		Coordination	AS	
Dwg.Chk.	JN		Approved	JN	
Scale	SEE SCALE	Project 246969			Status INF
		CAD file			
Drawing No	246969/BECKTON/5.0				Rev C

H.3 Crossness STW Options

KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	Dewatering/incineration plant	85m x 35m	30m building, 50m stack	Steel clad bldg



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KEY

- Border of potential land available for post AMP4 development
- Initial layout for post AMP4 development
- Proposed AMP 4 development

1:2000 @ A3

0m 10 20 30 40 50 100m

Rev	Date	Drawn	Description	Ch'k'd	App'd
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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Project Title

EAST LONDON ADDITIONAL
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STRATEGIC ALTERNATIVES REVIEW

Drawing Title

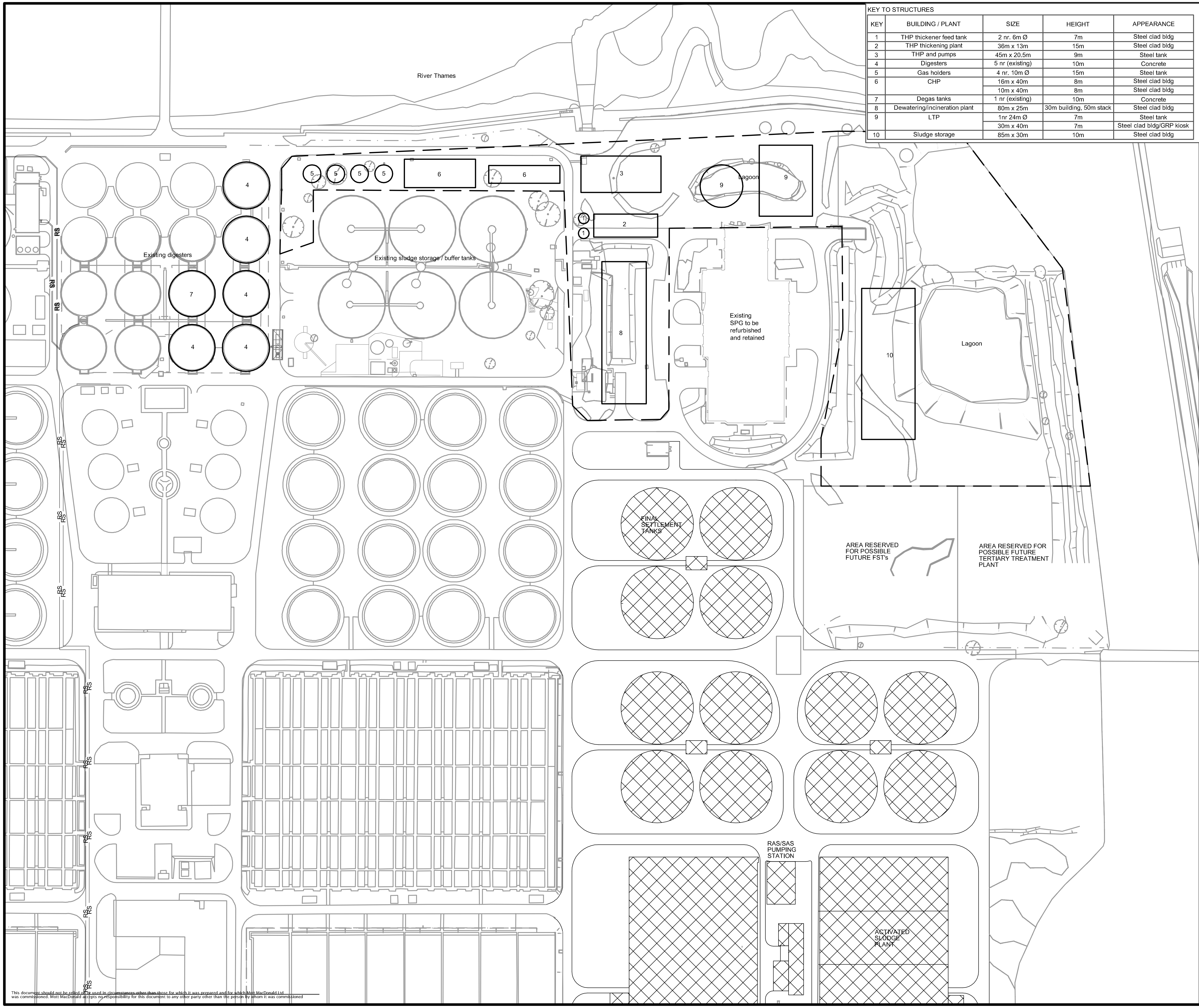
CROSSNESS STW
PROPOSED LAYOUT FOR CROSSNESS OPTION 1.0

Designed	AS		Eng.Chk.	GM	
Drawn	AS		Coordination	AS	
Dwg.Chk.	JN		Approved	JN	

Scale: SEE SCALE	Project: 246969 CAD file	Status: INF
Drawing No: 246969/CROSSNESS/1.0		Rev: C

KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	THP thickener feed tank	2 nr. 6m Ø	7m	Steel clad bldg
2	THP thickening plant	36m x 13m	15m	Steel clad bldg
3	THP and pumps	45m x 20.5m	9m	Steel tank
4	Digesters	5 nr (existing)	10m	Concrete
5	Gas holders	4 nr. 10m Ø	15m	Steel tank
6	CHP	16m x 40m	8m	Steel clad bldg
		10m x 40m	8m	Steel clad bldg
7	Degas tanks	1 nr (existing)	10m	Concrete
8	Dewatering/incineration plant	80m x 25m	30m building, 50m stack	Steel clad bldg
9	LTP	1nr 24m Ø	7m	Steel tank
		30m x 40m	7m	Steel clad bldg/GRP kiosk
10	Sludge storage	85m x 30m	10m	Steel clad bldg



KEY

Border of potential land available for post AMP4 development

Initial layout for post AMP4 development

Proposed AMP 4 development

Rev	Date	Drawn	Description	Ch'k'd	App'd
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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Project Title

EAST LONDON ADDITIONAL SLUDGE TREATMENT CAPACITY STRATEGIC ALTERNATIVES REVIEW

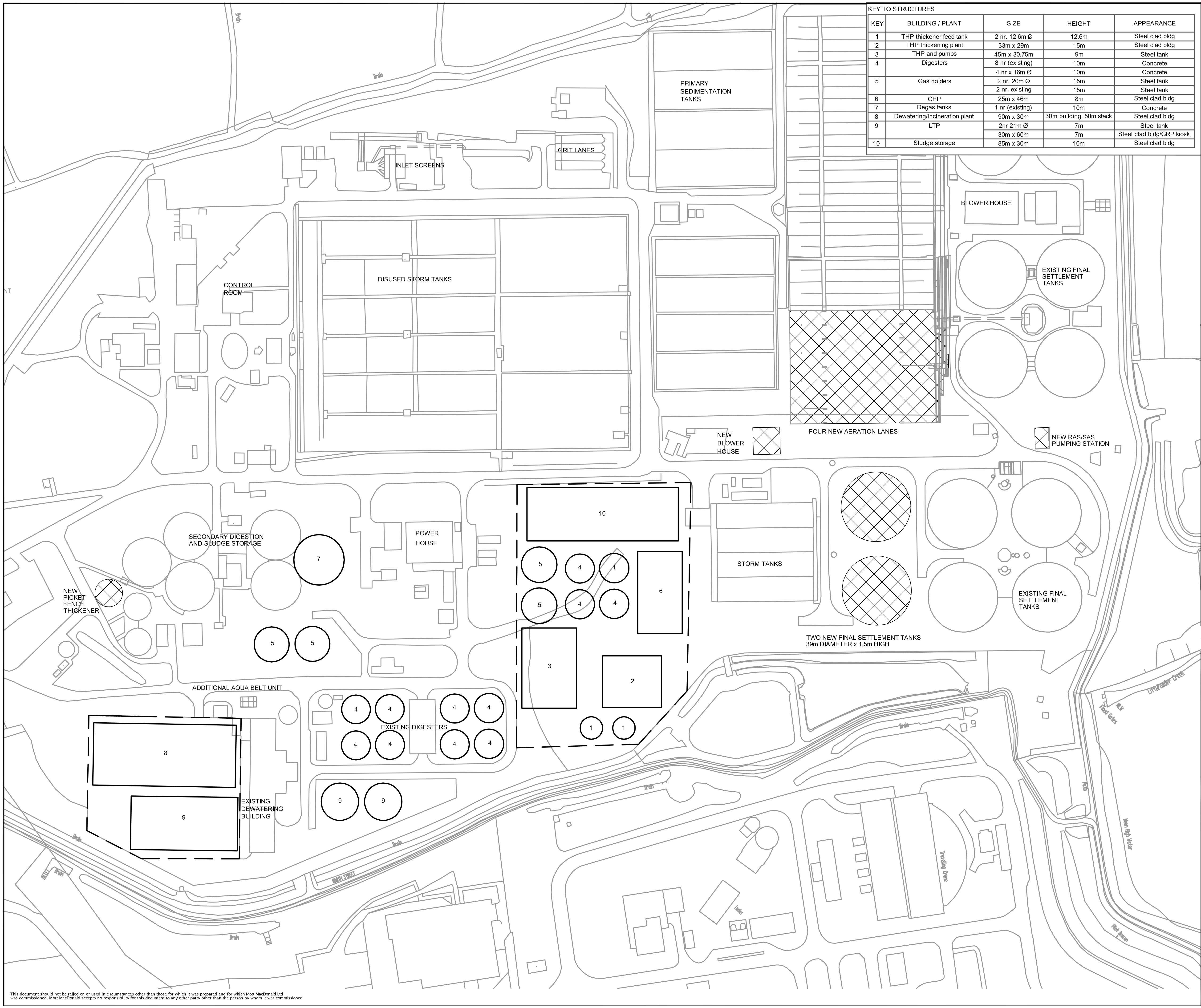
Drawing Title

CROSSNESS STW
PROPOSED LAYOUT FOR CROSSNESS OPTION 2.0

Designed	AS	Eng.Chk.	GM
Drawn	AS	Coordination	AS
Dwg.Chk.	JN	Approved	JN

Scale: SEE SCALE | Project: 246969 | CAD file | Status: INF

Drawing No: 246969/CROSSNESS/2.0 | Rev: C



KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	THP thickener feed tank	2 nr. 12.6m Ø	12.6m	Steel clad bldg
2	THP thickening plant	33m x 29m	15m	Steel clad bldg
3	THP and pumps	45m x 30.75m	9m	Steel tank
4	Digesters	8 nr (existing)	10m	Concrete
		4 nr x 16m Ø	10m	Concrete
5	Gas holders	2 nr. 20m Ø	15m	Steel tank
		2 nr. existing	15m	Steel tank
6	CHP	25m x 46m	8m	Steel clad bldg
7	Degas tanks	1 nr (existing)	10m	Concrete
8	Dewatering/incineration plant	90m x 30m	30m building, 50m stack	Steel clad bldg
9	LTP	2nr 21m Ø	7m	Steel tank
		30m x 60m	7m	Steel clad bldg/GRP kiosk
10	Sludge storage	85m x 30m	10m	Steel clad bldg

KEY

Border of potential land available for post AMP4 development

Initial layout for post AMP4 development

Proposed AMP 4 development

1:2000 @ A3

0m 10 20 30 40 50 100m

Rev	Date	Drawn	Description	Ch'k'd	App'd
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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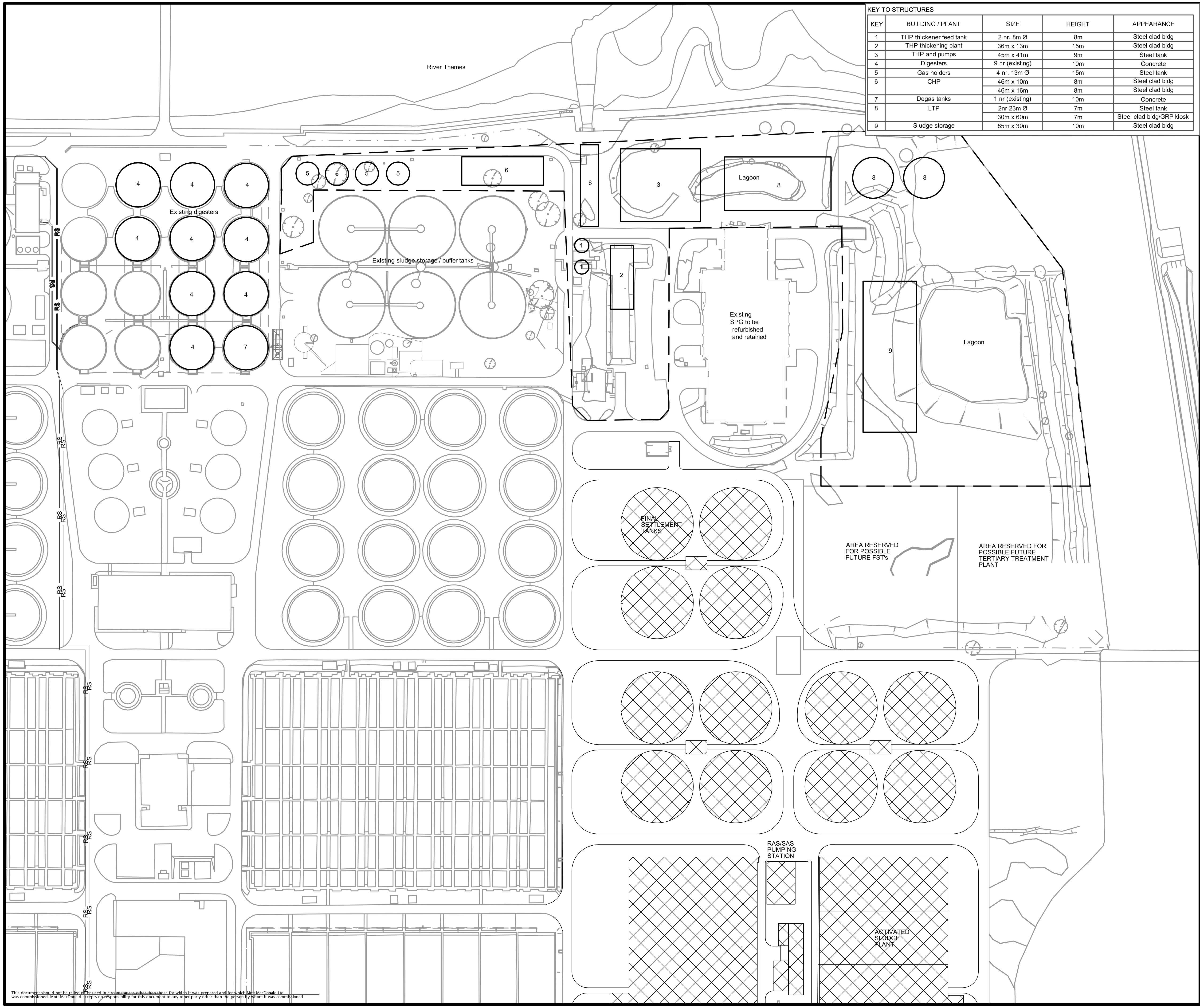
Project Title

EAST LONDON ADDITIONAL SLUDGE TREATMENT CAPACITY STRATEGIC ALTERNATIVES REVIEW

Drawing Title

LONG REACH STW
PROPOSED LAYOUT FOR CROSSNESS OPTION 2.3

Designed	AS	Eng.Chk.	GM
Drawn	AS	Coordination	AS
Dwg.Chk.	JN	Approved	JN
Scale	SEE SCALE	Project	246969
		CAD file	
Status	INF		
Drawing No	246969/CROSSNESS/2.3	Rev	C



KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	THP thickener feed tank	2 nr. 8m Ø	8m	Steel clad bldg
2	THP thickening plant	36m x 13m	15m	Steel clad bldg
3	THP and pumps	45m x 41m	9m	Steel tank
4	Digesters	9 nr (existing)	10m	Concrete
5	Gas holders	4 nr. 13m Ø	15m	Steel tank
6	CHP	46m x 10m	8m	Steel clad bldg
		46m x 16m	8m	Steel clad bldg
7	Degas tanks	1 nr (existing)	10m	Concrete
8	LTP	2nr 23m Ø	7m	Steel tank
		30m x 60m	7m	Steel clad bldg/GRP kiosk
9	Sludge storage	85m x 30m	10m	Steel clad bldg

KEY

Border of potential land available for post AMP4 development

Initial layout for post AMP4 development

Proposed AMP 4 development

Desalination plant site investigation

1:2000 @ A3

0m 10 20 30 40 50 100m

Rev	Date	Drawn	Description	Ch'k'd	App'd
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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Project Title

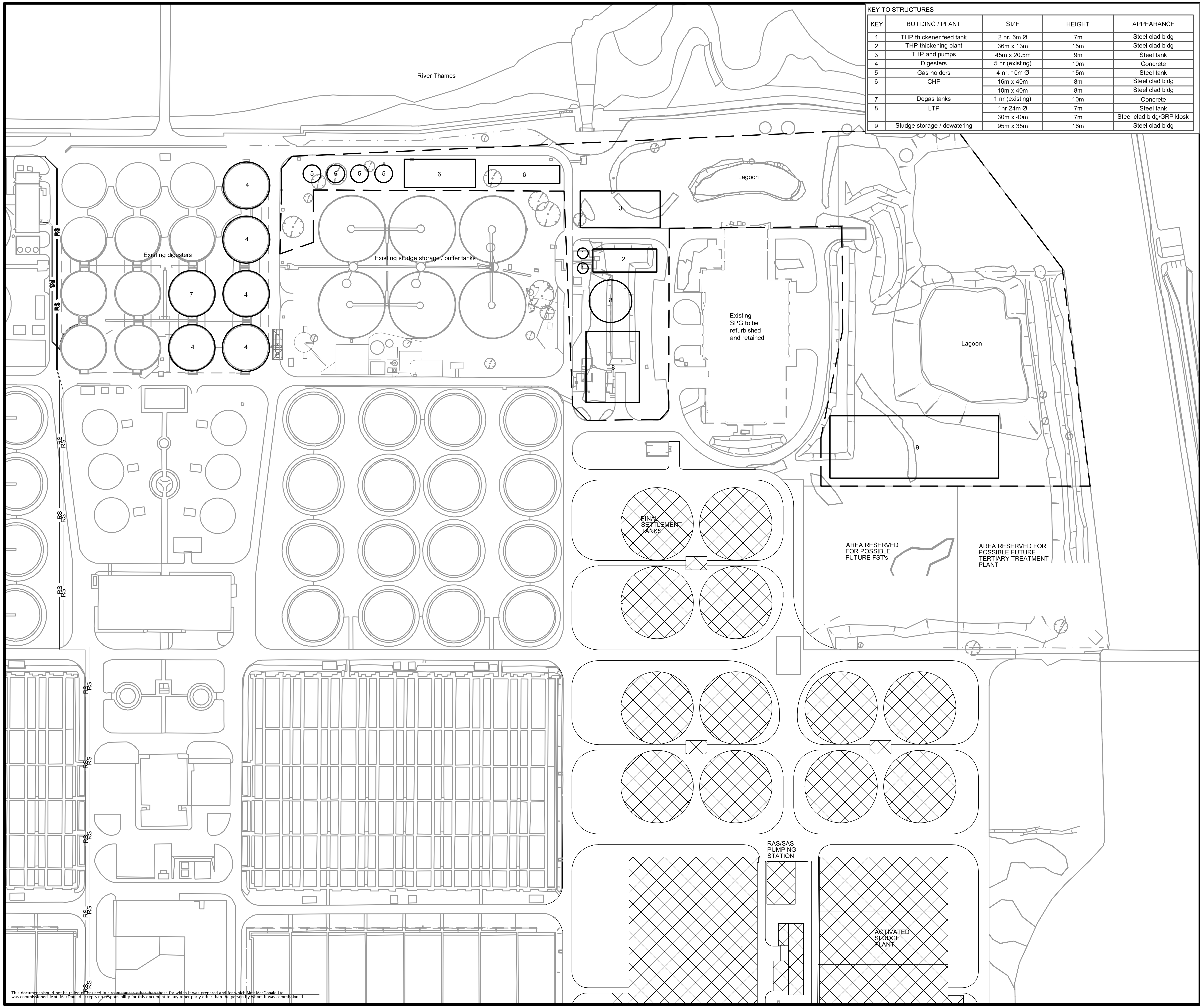
EAST LONDON ADDITIONAL SLUDGE TREATMENT CAPACITY STRATEGIC ALTERNATIVES REVIEW

Drawing Title

CROSSNESS STW
PROPOSED LAYOUT FOR CROSSNESS OPTION 3.0

Designed	AS	Eng.Chk.	GM
Drawn	AS	Coordination	AS
Dwg.Chk.	JN	Approved	JN

Scale: SEE SCALE
Project: 246969
CAD file
Status: INF
Drawing No: 246969/CROSSNESS/3.0
Rev: C



KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	THP thickener feed tank	2 nr. 6m Ø	7m	Steel clad bldg
2	THP thickening plant	36m x 13m	15m	Steel clad bldg
3	THP and pumps	45m x 20.5m	9m	Steel tank
4	Digesters	5 nr (existing)	10m	Concrete
5	Gas holders	4 nr. 10m Ø	15m	Steel tank
6	CHP	16m x 40m	8m	Steel clad bldg
		10m x 40m	8m	Steel clad bldg
7	Degas tanks	1 nr (existing)	10m	Concrete
8	LTP	1nr 24m Ø	7m	Steel tank
		30m x 40m	7m	Steel clad bldg/GRP kiosk
9	Sludge storage / dewatering	95m x 35m	16m	Steel clad bldg

KEY

Border of potential land available for post AMP4 development

Initial layout for post AMP4 development

Proposed AMP 4 development

Rev	Date	Drawn	Description	Ch'k'd	App'd
E	18/12/08	AS	FOR INFORMATION	JN	JN
D	28/11/08	AS	FOR INFORMATION	JN	JN
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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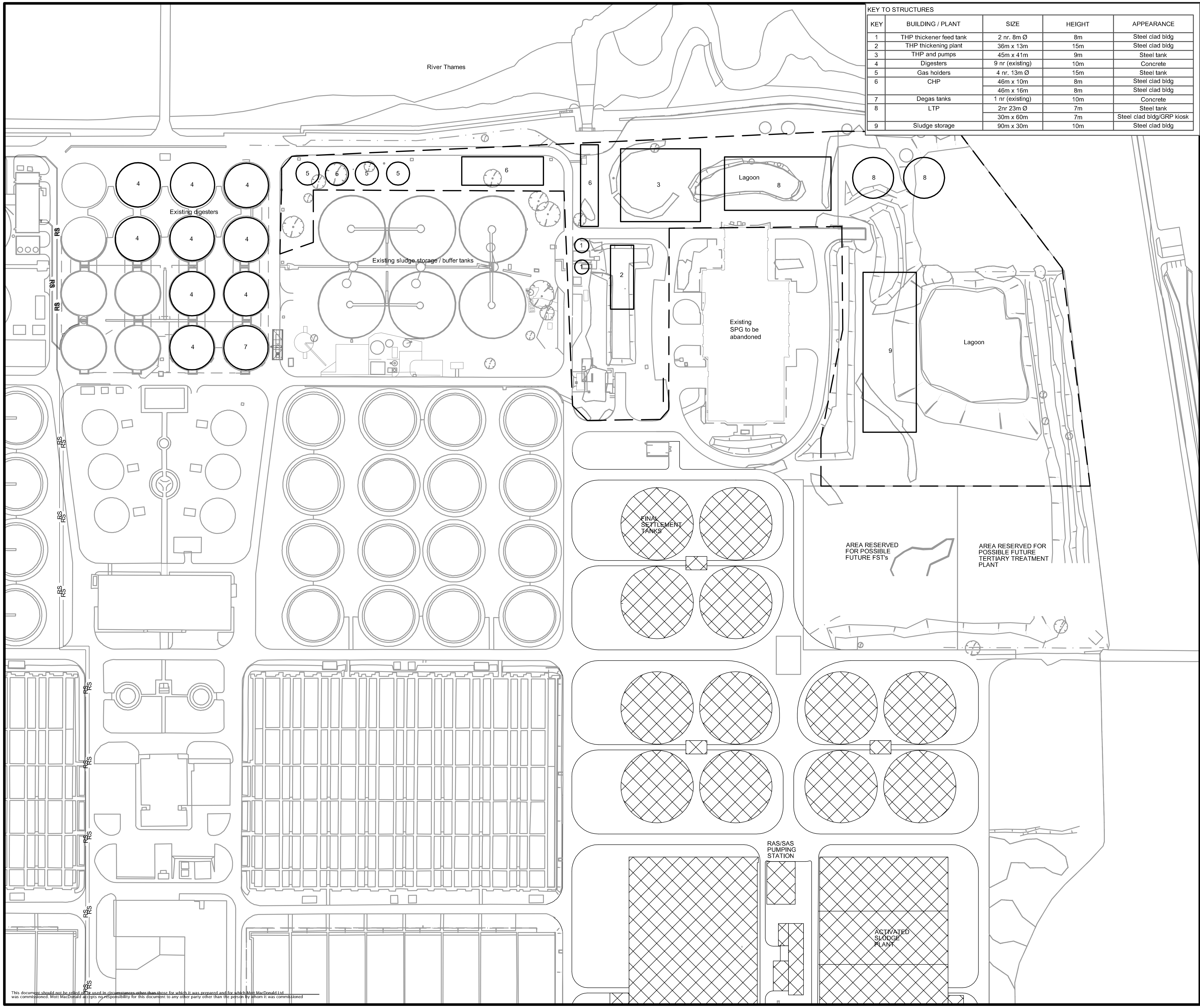
Project Title

EAST LONDON ADDITIONAL
SLUDGE TREATMENT CAPACITY
STRATEGIC ALTERNATIVES REVIEW

Drawing Title

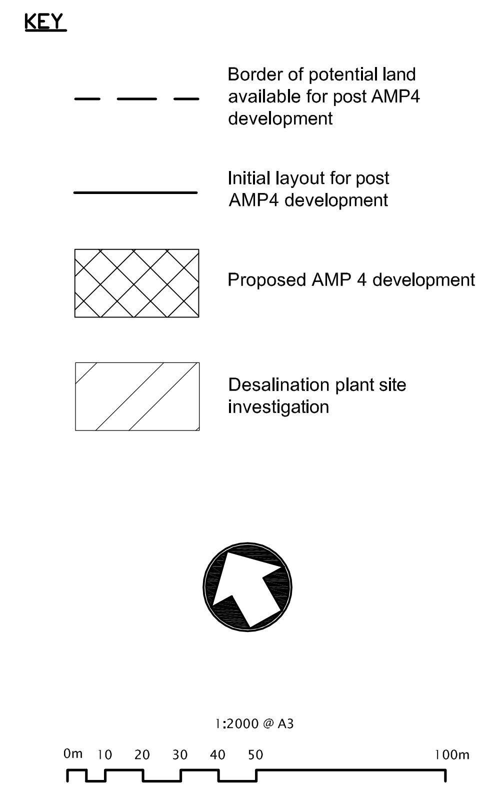
CROSSNESS STW
PROPOSED LAYOUT FOR CROSSNESS OPTION 4.0

Designed	AS	Eng.Chk.	GM
Drawn	AS	Coordination	AS
Dwg.Chk.	JN	Approved	JN
Scale: SEE SCALE	Project: 246969	CAD file	Status: INF
Drawing No: 246969/CROSSNESS/4.0			Rev: E



KEY TO STRUCTURES

KEY	BUILDING / PLANT	SIZE	HEIGHT	APPEARANCE
1	THP thickener feed tank	2 nr. 8m Ø	8m	Steel clad bldg
2	THP thickening plant	36m x 13m	15m	Steel clad bldg
3	THP and pumps	45m x 41m	9m	Steel tank
4	Digesters	9 nr (existing)	10m	Concrete
5	Gas holders	4 nr. 13m Ø	15m	Steel tank
6	CHP	46m x 10m	8m	Steel clad bldg
		46m x 16m	8m	Steel clad bldg
7	Degas tanks	1 nr (existing)	10m	Concrete
8	LTP	2nr 23m Ø	7m	Steel tank
		30m x 60m	7m	Steel clad bldg/GRP kiosk
9	Sludge storage	90m x 30m	10m	Steel clad bldg



Rev	Date	Drawn	Description	Ch'k'd	App'd
C	08/09/08	AS	FOR INFORMATION	JN	JN
B	29/08/08	AS	FOR INFORMATION	JN	JN
A	22/08/08	AS	FOR INFORMATION	JN	JN

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Project Title

EAST LONDON ADDITIONAL
SLUDGE TREATMENT CAPACITY
STRATEGIC ALTERNATIVES REVIEW

Drawing Title

CROSSNESS STW
PROPOSED LAYOUT FOR CROSSNESS OPTION 5.0

Designed	AS		Eng.Chk.	GM	
Drawn	AS		Coordination	AS	
Dwg.Chk.	JN		Approved	JN	

Scale: SEE SCALE	Project: 246969 CAD file	Status: INF
Drawing No: 246969/CROSSNESS/5.0		Rev: C

Appendix I Option Scores agreed at VM 1 and VM2 Workshops

The following sections present the results of the option appraisal and scoring carried out at the VM 1 and VM 2 workshops.

The justification for the option scores are presented as well as, where appropriate, the reasons for changes in option scores between VM 1 and VM 2 workshops.

I.1 Beckton STW option scores

Scoring of Objectives - Constructability **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Implementation programme (whether an option can be implemented in time to meet demand)**							
VM 1 Score	0	-	-	- -	0	0	-	-
VM 2 Score	0	0	0	-	0	0	0	0
Discussion	A requirement for each option is that it can be implemented by the end of AMP 5. Key issues for an implementation programme will be the time taken to achieve planning application and the time needed to construct the works. The VM1 workshop concluded that all options could be implemented in the required timescale (hence scored 0) but that options involving more complex processes such as EDI had a greater risk of programme delay. Hence, options including EDI were given lower scores (- or --). At the VM2 workshop it was considered that only Option 3.0 (where the existing SPG had to be modified to accept enhanced digested sludge) had a greater risk and therefore justified a lower score. Other options had greater scope for -off-line work.							
Sub-objective	**Utilities interfaces**							
VM 1 Score	-	-	-	-	0	-	-	-
VM 2 Score	-	-	-	-	0	-	-	-
Discussion	In general, options requiring diversion of significant existing services were given a lower score. For Beckton STW, all options except Option 4 would potentially require diversion of the overhead cables next to the existing SPG and hence these were given a lower score (-) compared to 0 for Option 4.0.							
Sub-objective	**Noise / dust control (constraints posed by nearby developments)**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	-	-	-	-	-	-	-	-
Discussion	It was considered that at all options had an equal potential for construction noise or dust impacts on nearby developments and that these would need to be mitigated by good construction practice (noise and dust suppression) - hence all options were scored the same (-).							
Sub-objective	**Traffic management (incl potential road closures / diversions)**							
VM 1 Score	- -	- -	0	- -	- -	0	- -	- -
VM 2 Score	- -	- -	0	- -	- -	0	- -	- -
Discussion	Construction traffic management was considered likely to be a significant impact for all options involving construction of additional capacity at Beckton STW - hence options where all works are located at Beckton STW were given negative scores. In contrast, options where additional capacity was provided at Riverside STW were considered to have lower construction traffic impacts and hence were given neutral scores (0). The exception was Option 5.2 where most of the additional capacity would be provided at Beckton STW and hence this was also given a low score. It was considered that traffic impacts could be partly mitigated by good site management (lorry load optimisation, timing of deliveries, etc).							
Sub-objective	**Construction access (within site)**							
VM 1 Score	-	- -	0	- -	- -	0	- -	-
VM 2 Score	-	- -	0	- -	- -	0	- -	-
Discussion	Options which had a larger land 'footprint' were considered likely to cause greater construction management issues within each STW site and were therefore given lower scores. Thus options involving EDI and ED at Beckton STW were given the lowest scores whilst options where additional assets were constructed at Riverside STW, so reducing the overall intensity of construction at each site) achieved neutral scores (0). For Beckton STW options it was considered that there would be an additional impact as construction would coincide with construction of the Tideway Tunnel headworks.							
Sub-objective	**Other major interface issues**							
VM 1 Score	0	0	-	-	0	0	-	-
VM 2 Score	0	0	-	-	0	0	-	-
Discussion	Some options involved more complex interfaces with existing processes including the existing SPG (e.g. RCI+) and these were awarded more negative scores as a result.							

Scoring of Objectives - Constructability **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Technical complexity**							
VM 1 Score	0	- -	- - -	- -	-	- - -	- -	- - -
VM 2 Score	0	- -	- - -	- -	-	- - -	-	-
Discussion	Options involving a single process type and location were considered to be less technically complex. Conversely, options involving two different process types combined with treatment being divided between two sites, were considered to be the most complex and therefore were given the lowest scores. The scores for Option 5 and 5.2 were reduced compared to VM1 as these options involve single processes with all new construction located at Beckton STW.							
Sub-objective	**Availability of land for contractor's site compound and laying down area**							
VM 1 Score	+ +	+	- -	+	+	-	+	-
VM 2 Score	-	-	-	-	-	+	0	0
Discussion	All sites are constrained, to varying extent, by the availability of space for construction of the permanent works (treatment plant) as well as space required for a contractor's temporary site compound and laying down area. A review of contractor land requirements, subsequent to the VM1 workshop, suggests that as much as 4 hectares may be required for construction of new incinerators. This area is unlikely to be available in a single location and hence will probably need to be split into several areas around the STW sites - which is less efficient. Less land would be required for enhanced digestion plant construction. Hence, process options including new incineration were given a more negative score.							
Sub-objective	**Maintaining existing treatment processes during construction & commissioning**							
VM 1 Score	+ + +	+	+	-	+ + +	+ + +	+	+
VM 2 Score	+ + +	+	+	+	+ + +	+ + +	+ + +	+ + +
Discussion	Works involving modification to existing treatment streams, particularly where this involves adaptation of the existing incinerators to burn digested sludge cake (i.e. where an existing incinerator is converted to EDI) or other enhancements to the existing incinerator (i.e. RCI+) were considered to have the highest risk of impacting on operation of existing process streams and hence were scored lowest.							
Overall Score for Construcability Objective								
VM 1 Score	+	-	-	- -	0	0	0	0
VM 2 Score	+	-	- -	-	0	0	0	+
Rational	It can be seen from the table that, in terms of the constructability objective, options which provided both additional mass-burn incinerator and enhanced digestion were judged least attractive whilst those likely to have a lower footprint and interface issues (i.e. less complex) were given the highest scores. The overall option scores for the VM1 and VM2 workshops are broadly similar, with minor differences largely due to greater understanding of the contractor's working area requirements. In conclusion: it was agreed that in terms of constructability, there are no "show stoppers" and that further detailed study was required to differentiate between the options.							

Scoring of Objectives - Technology **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Reliability of process**							
VM 1 Score	+	+	+	+	+ +	+ +	+ +	+ +
VM 2 Score	+	+	+	+	+	+	+ +	+ +
Discussion	Following discussion on the reliability of the various processes, based on the experience of the workshop participants, the following consensus was reached: Enhanced digestion options were considered to be the most reliable, followed by mass-burn incineration options. Hence options including ED scores 2 plusses whilst RCI or EDI scored 1 plus. These scores were the same for both Beckton STW and Crossness STW options. Option appraisal during the VM1 workshop was based on the new components of the process only. During the VM2 workshop, it was decided that options should be assessed on the entire process (both old and new components) - hence the scores for options 4.0 and 4.2 were reduced slightly.							
Sub-objective	**Track record (established process)**							
VM 1 Score	+ +	-	-	-	+ +	+ +	+ +	+ +
VM 2 Score	+ +	-	-	-	+ +	+ +	+ +	+ +
Discussion	This sub-objective assessed whether there was a sufficient track record for the process technologies to provide comfort that the option was feasible. The workshop consensus was that both enhanced digestion and mass-burn incineration were both established processes and therefore scored highest (2 pluses). However, the participants were not aware of existing examples of enhanced digestion followed by incineration and hence this was scored lower (-). However, it was noted that this solution was being adopted by United Utilities for at least part of its throughput for the proposed extension to the Shell Green incinerator.							
Sub-objective	**Track record (implemented at similar scale)**							
VM 1 Score	+ + +	-	- -	- -	+ +	+ + +	+	+
VM 2 Score	+ + +	-	- -	- -	+ +	+ +	+ +	+ +
Discussion	This sub-objective assessed whether there was a sufficient track record for the process technologies being implemented at a similar scale to provide comfort that the option was feasible. The existing Beckton STW and Crossness STW SPGs are already amongst the largest in Europe and given TWUL's reliance on these two sites for much of their sludge treatment capacity it is essential that processes are proven at this size. The workshop consensus was that raw cake incineration was already proven at scale given that this was the existing process at each site - hence this scored the highest (+++). For enhanced digestion it was considered that although there were no existing sites at this scale the modularity of the process meant that scaling up was not an issue - hence this scored the next highest (++). However, for EDI it was noted that there were no existing examples and hence these were both given low scores for track record.							
Sub-objective	**Availability of Suppliers (plant)**							
VM 1 Score	+ + +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
VM 2 Score	+ + +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
Discussion	This sub-objective considered the availability of suppliers from the point of view of technical capability to provide working facilities (technical ability and manufacturing capacity). The workshop consensus was that all processes could be supplied in the timescale and quality required - hence most options were scored equally (++). However, it was felt that the larger number of suppliers available for incineration technology, compared to enhanced digestion, gave this a small edge. Hence, raw cake incineration was given the highest score (+++).							
Sub-objective	**Footprint (land take)**							
VM 1 Score	+ +	+	0	- -	0	+	-	+
VM 2 Score	+ +	+	0	-	0	+	-	-
Discussion	This sub-objective considered the potential footprint for each option against the likely availability of land at each site. It was considered that options involving raw cake incineration (RCI) would have the lowest footprint and hence scored highest (++). Scores for other options fell between (+) and (- -) based on the combination of processes and hence the expected footprint.							

Scoring of Objectives - Technology **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Potential for future upgrading through additional or alternative process stages**							
VM 1 Score	- -	- -	- -	- -	-	-	-	-
VM 2 Score	- -	- -	- -	- -	-	-	-	-
Discussion	This sub-objective considered the potential for future adaptation of the process option in the event that new processes - such as gasification - become more technically and economically attractive. The consensus was that options culminating in incineration had less potential for adaptation than options providing only enhanced digestion. Hence enhanced digestion options were scored one minus and other options two minuses.							
Sub-objective	**Marketability/recycling/ disposal of final product**							
VM 1 Score	-	-	-	-	+	+	+	+
VM 2 Score	-	-	-	-	+	+	+	+
Discussion	It was considered that an enhanced digested cake product would have the most potential market. Ash was given the lowest score (-) due to the lack of recycling outlets currently available for this product. Furthermore, the outlet for an incinerated ash product is severely constrained. TW estimates a maximum of 3 to 4 years of available landfill capacity in the London region.							
Overall Score for Technology Objective								
VM 1 Score	+	-	-	-	+	+	+	+
VM 2 Score	+ +	-	-	-	+	+	+	+
Rational	It can be seen from the table that, in terms of the technology objective, options which provided an additional mass-burn incinerator or which provided enhanced digestion, were the most favoured at the workshop. These options were considered to represent 'tried and tested' technologies with a probability of meeting the technical requirements. It was noted that whilst this was the case for the processes when considered individually, the combination of the two processes (i.e. EDI) was less proven. Enhanced digestion processes were also considered to have the most potential for future adaptation, for example, through additional process stages. However, there was concern over whether the greater space required for enhanced digestion at Beckton and Crossness STWs under options 5.0 and 5.2 would be available.							

Scoring of Objectives - Operations **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Staffing – (numbers needed & availability, expertise/ experience required for the different technologi**							
VM 1 Score	0	-	-	-	-	0	0	0
VM 2 Score	0	-	-	-	-	0	0	0
Discussion	In scoring this sub-objective it was considered that options which resulted in more than one type of sludge treatment technology at each site should have a lower score on the grounds that additional staff (numbers and expertise) would be required to operate each type of process. Scores in this case were one minus. Conversely, options with only one process technology at each site were scored higher (0). Where technologies were used at different sites (e.g. RCI at Beckton STW and ED at Riverside STW) then this was treated as a single technology at each site and scored accordingly. Options which required implementation of a new technology were also scored lower because staff will require additional training.							
Sub-objective	**Maintenance requirements**							
VM 1 Score	- -	- -	- -	- -	- -	-	-	-
VM 2 Score	- -	- -	- -	- -	- -	-	-	-
Discussion	Scores for this sub-objective reflected the perceived reliability of the processes, and thus the potential maintenance effort required, as well as the number of processes involved - which would impact on the range of skills that would be needed at each site. Options involving incineration were considered to have a high maintenance requirement - particularly if in combination with a different technology at the same location (e.g. RCI and ED at Beckton STW, score --). The highest scoring options were those only using enhanced digestion or where different technologies were used at separate sites.							
Sub-objective	**Operational flexibility (e.g. able to handle variations in feed quantity and quality)**							
VM 1 Score	-	-	-	-	0	-	0	0
VM 2 Score	-	- -	- -	-	0	-	0	0
Discussion	At VM2, all options were considered to be reasonable similar for this sub-objective though options including enhanced digestion were considered to have a small advantage and hence were scored marginally higher (0 compared to one minus for other options). Option 2.0 and 2.3 which include both RCI and EDI process streams, were considered to be the least flexible as it would not be possible to mix digested and raw cake in the feed to the existing SPG due to the risk of biogas production in the furnace feed silos.							
Sub-objective	**Operational Complexity**							
VM 1 Score	- -	- -	0	- -	- -	0	- -	- -
VM 2 Score	+ +	- -	- -	-	-	0	+ +	+
Discussion	This sub-objective was added to capture process complexity from an operations point of view. Further discussion at VM2 led to a significant change in the scoring approach for this sub-objective. Options 1.0 and 5.0 scored the most positively as they each comprise a single process type at a single location.							
Sub-objective	**Risk of losing disposal route for product**							
VM 1 Score	0	0	0	0	0	0	-	-
VM 2 Score	0	0	0	0	0	0	- - -	- - -
Discussion	The outlet for an incinerated ash product is severely constrained due to a lack of landfill capacity. TW staff at the workshop reported that only 3 to 4 years of landfill capacity remaining in the London region. However, doubts were also expressed as to the feasibility of treating large proportions of Beckton and Crossness STWs' sludge using enhanced digestion given the location of the STWs (urban areas with congested transport networks) and the availability of agricultural landbank within reasonable range of East London. Treating a large proportion of sludge using enhanced digestion would also increase TW's vulnerability with respect to potential disruption of agricultural recycling following, for example, further outbreaks of Foot and Mouth'. On this basis Options 5.0 and 5.2 were given negative scores. The risks associated with enhanced digestion of just half of the sludge produced at Beckton or Crossness STWs (options 4.0 and 4.2) were considered to be lower and comparable to those associated with ash disposal.							

Scoring of Objectives - Operations **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Overall Score for Operations Objective								
VM 1 Score	+	-	-	- -	0	0	0	0
VM 2 Score	+	- -	- -	-	0	0	- - -	- - -
Rational	In terms of the operations objective, options involving two different processes on one site (e.g. ED and RCI or EDI) were considered to be more complex from an operational viewpoint than single process sites e.g. all ED or all RCI). Option involving just raw cake incineration or enhanced digestion were considered to be the best from an operational perspective. It was felt by the workshop participants that providing enhanced digestion capacity for all sludge generated at Beckton STW would present too great an opporational risk and hence this option was scored with three negatives overall.							

Scoring of Objectives - Safety **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Reduce risk of illness or injury to employees, contractors and public**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that TWUL would not promote nor allow construction of a new treatment facility that was not 'safe' and hence all options should be scored with a zero. It was noted that enhanced digestion options could include thermal hydrolysis which uses high pressure steam. However, it was considered that any additional safety risk will be minimised through operator training and regular inspections of the pressure systems. Incineration options may, depending on design, include thin-film type dryers. However, these were considered not to suffer from the same potential safety risks as conventional dryers. In conclusion it was decided to give all options a neutral score.							

Scoring of Objectives - Integration **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**GLA objectives and ambitions**							
VM 1 Score	-	-	-	-	+	+	-	+
VM 2 Score								
Discussion	The GLA favours waste treatment options which maximise energy recovery and recycling potential. Hence options including enhanced digestion were scored higher than those involving incineration as the final treatment stage. This sub-objective was not scored at VM2 as it was considered the same as that for "Other regional government policies (London Plan)".							
Sub-objective	**LTGDC (London Thames Gateway Development Corporation) objectives and ambitions**							
VM 1 Score	-	-	0	-	-	0	-	0
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that development within the operational boundaries of the site would not conflict with LTGDC's objectives and improvement of and provision of additional sewerage and sludge treatment infrastructure was considered critical to bringing about more growth within the London Thames Gateway area and adverse impacts such as increased traffic movements would not be significant. Hence, all options were scored neutral. This sub-objective was not relevant to Crossness STW options.							
Sub-objective	**Other national government policies (PPS)**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	-	0	-	+	+	0	+	0
Discussion	This sub-objective was not scored during the VM 1 workshop as it was felt that there were a number of national government policies that should be scored separately. Scoring at VM 2 stage focussed on Sustainability and Energy Renewal which were considered relevant and favoured enhanced digestion options as these increased renewable energy, reduced sludge volume and traffic to disposal.							
Sub-objective	**Other regional government policies (London Plan)**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	-	-	-	-	+	+	+	+
Discussion	This sub-objective was not scored during the VM 1 workshop as it was felt that there were a number of regional policies that should be scored separately. Scoring at VM 2 stage focussed on London Plan policies on water and sewage infrastructure replacement to meet population growth and climate change requirements.							

Scoring of Objectives - Integration **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Land use policy (Unitary Development Plans / Local Development Plan Documents)**							
VM 1 Score	-	-	+	-	-	+	-	+
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	At VM 1, development on designated 'Metropolitan open land' was a considered the key issue for land use planning purposes and hence options involving additional facilities at Beckton STW were scored lower than options where additional capacity was provided at Riverside STW. However, at VM 2, sustainability and energy issues, as well as the conservation area designation at Riverside, were considered further and resulted in overall neutral scores for each option.							
Sub-objective	**Thames Water Strategic Direction Statement, Sludge Strategy and associated SEA (including SEA Post Adoption Statement)**							
VM 1 Score	+	+	+	+	+	+	+	+
VM 2 Score	+	+	+	+	0	0	-	-
Discussion	The Strategic Direction Statement and the Sludge Strategy set out Thames Water's outline proposals for future sludge treatment in the East London region and these are assessed in the SEA. It was considered that options including mass-burn incineration, with or without a preceding enhanced digestion stage, were consistent with the recommendations in these documents and hence all scored (+). Options 5.0 and 5.2, providing only enhanced digestion, were scored lowest.							
Overall Score for Integration Objective								
VM 1 Score	0	+	+	+	+	+ +	+	+ +
VM 2 Score	0	+	0	+	+	+	0	0
Rational	It can be seen from the table that, in terms of the Integration objective, options which provided enhanced digestion and incineration, or enhanced digestion followed by incineration, were favoured. Options which provided at least part of the additional sludge treatment capacity at Riverside STW, thus also avoiding Metropolitan Open Land, were favoured over those where all the development was at Beckton STW.							

Scoring of Objectives - Economy **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Construction costs**							
VM 1 Score	- -	- - -	- - -	- - -	-	-		-
VM 2 Score	0	- -	- -	-	+ +	+	+	+ +
Discussion	The scores for this sub-objective were based on analysis of option capital costs prepared by the SAR Consultant. Options were scored relative to Option 1.0 which was considered the reference option. Based on the cost analysis it could be seen that options providing enhanced digestion with incineration were significantly more expensive to construct than the other options. Options providing additional capacity using just enhanced digestion were generally the cheapest.							
Sub-objective	**Operating and maintenance costs (excluding electricity sales & ROCs)**							
VM 1 Score	- -	- -	- -	- -	-	-		-
VM 2 Score	0	0	0	0	-	- -	- -	- -
Discussion	The scores for this sub-objective were based on preliminary analysis of option operating costs prepared by the SAR Consultant. This analysis was based on the predicted process performance for each option and unit cost data for similar schemes elsewhere. The operating cost data exclude potential income from electricity sales and ROCs but include the value of electricity generated and consumed on-site. Options were scored relative to Option 1.0 which was considered the reference option. Based on the analysis the high sludge transport and recycling costs associated with options 4.0, 4.2, 5.0 and 5.2 are a significant factor and result in these options having the highest overall opex.							
Sub-objective	**Revenue (sludge product recycling, on-site power generation and ROCs)**							
VM 1 Score	-	+	+	+ +	+ +	+ +	+ +	+ +
VM 2 Score	0	+ +	+ +	+ + +	+ +	+ +	+ +	+ +
Discussion	Scoring for this sub-objective focussed on the potential for sale of surplus electricity generated and the ability to earn ROCs for the power produced. In general, options using enhanced digestion were considered to have greater potential for energy generation and earning ROCs - hence these were awarded two pluses. Option 3.0 allows electricity to be generated and ROCs earned for the ED stage as well as generating power in the SPG.							
Sub-objective	**Net Opex, including revenue**							
VM 1 Score	- -	- -	0	- -	- -	0	- -	- -
VM 2 Score	0	+	+	+ + +	0	0	0	0
Discussion	This analysis takes into account both future net opex and income. It can be seen that Option 3.0 has the most favourable net opex.							
Sub-objective	**Whole Life Costs**							
VM 1 Score	-	- -	0	- -	- -	0	- -	-
VM 2 Score	0	-	-	0	+	0	0	+
Discussion	Whole life costs were derived using the construction and operating costs presented. The WLC included the initial capital, capital maintenance/renewals, net operating costs and income and were derived using a discount rate of 5.1% for 20 years in accordance with TW policy. The analysis indicates that options 4.0 and 5.2 have the lowest WLC, followed by options 1.0, 3.0, 4.2 and 5.0. The options were scored accordingly.							
Overall Score for Economy Objective								
VM 1 Score								
VM 2 Score	0	-	-	0	+	0	0	+
Rational	The scores for this sub-objective were based on analysis of option costs prepared by the SAR Consultant. Options were scored relative to Option 1.0 which was considered the reference option. The WLC included the initial capital, capital maintenance/renewals, net operating costs and income and have therefore been used as the overall score for the economy objective.							

Scoring of Objectives - Environment **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Landscape/ Townscape & Visual**							
VM 1 Score	-	-	- -	-	-	-	-	-
VM 2 Score	-	-	- -	-	0	-	0	0
Discussion	**Beckton STW:** The construction of a sludge treatment facility at Beckton STW has the potential to impact on the landscape/visual quality of the area although it is realised that such a facility will be positioned within an already industrial setting and therefore there was no differentiation between the Beckton STW proposals. Scores at VM2 for options 4 and 5 were slightly more positive than those awarded at VM1 as these options were considered to have a low visual impact (compared to the high stack required for an incinerator). **Riverside STW:** It was assumed that any proposals involving the construction of incinerators at Riverside STW rather than enhanced digestion drying beds would have a greater visual impact as Riverside is positioned within a relatively low lying area with a number of vantage points. Hence, Option 2.3 was given the lowest score.							
Sub-objective	**Air quality (incl. odour)**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	-	-	-	-	-	-	-	-
Discussion	It was assumed that any of the processes discussed would be designed and operated to meet regulatory requirements and standards laid out in any operating permit. At the VM2 workshop, it was considered appropriate to include other issues which may lead to a reduction in air quality (such as increased traffic movements and dust generation during construction) which would be associated with the scheme. It was therefore decided that there was a potential for a reduction in air quality (hence the lower score compared to VM1) although it was not possible to differentiate between proposed options.							
Sub-objective	**Waste**							
VM 1 Score	- -	- -	- -	- -	-	-	-	-
VM 2 Score	- -	- -	- -	- -	0	0	+	+
Discussion	**Incinerator ash:** It was assumed that end product from the incineration process would require disposal to landfill (low on the waste hierarchy). It was noted that landfill capacity in the region was becoming an issue. Hence, options producing ash were given lower scores. **Enhanced digestion:** At the VM2 workshop, it was considered that enhanced digested cake would be recycled to agriculture providing it was of a suitable quality. Hence, options producing enhanced digested product were scored higher than at the VM1 workshop. It was considered that treatments which provided both ash and enhanced digested sludge were effectively neutral in there impact.							
Sub-objective	**Water Resources**							
VM 1 Score	0	0	-	0	0	-	0	-
VM 2 Score	0	0	-	0	0	-	0	-
Discussion	Beckton STW options: No differentiation regarding water resources for options located only at Beckton STW. However, it was thought that the Riverside STW site lay in a flood compensation area (needs clarification) and therefore proposals at this location could have a greater impact.							
Sub-objective	**Archaeology**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	-	-	-	-	-	-	-	-
Discussion	It was considered that there is a potential negative impact on archaeological resources due to ground disturbance during construction of new facilities but the impact was likely to be similar for all options.							

Scoring of Objectives - Environment **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Traffic & Transport**							
VM 1 Score	-	-	-	-	- -	- -	- -	- -
VM 2 Score	-	-	-	-	- - -	- -	- - -	- -
Discussion	All options would require incinerator ash and/or digested sludge to be transported off site for disposal or re-use. **Incineration options:** Quantities of material requiring disposal are lower and therefore fewer traffic movements for disposal – hence a score of (-) was given for incineration options. **Enhanced digestion options:** Quantities of material requiring recycling as agricultural product are greater and therefore require more vehicle movements – hence a more negative score was awarded to enhanced digestion options. At the VM2 workshop is was considered that enhanced digestion options at Beckton STW would give rise to greater negative impacts as the traffic movements would be on local roads prior to reaching the strategic road network and therefore these combinations were given a (- - -) score.							
Sub-objective	**Ecology**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	0	-	0	0	-	0	-
Discussion	At the VM1 it was considered that there would be a neutral effect on ecological resources as a result of the proposed options. This assumed that works to the river frontage would not be undertaken (e.g. to promote transportation by barge). Previous EIA work carried out at Beckton considered the site to be of fairly low ecological value. At the VM2 workshop it was identified that for the Riverside site, the proposed site for any development (the disused sludge lagoons) are designated a Grade 2 Site of Borough Importance for Nature Conservation and therefore proposals which involved Riverside received a more negative score.							
Sub-objective	**Cultural Heritage**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that there would be a neutral effect on Cultural Heritage resources as a result of the proposals. There are no Scheduled Ancient Monuments, Listed Buildings, Conservation Areas, Registered Historic Parks and Gardens, Protected Wreck Sites, Ancient Woodland or Historic Battlefields present within the proposed development sites.							
Sub-objective	**Health**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that there could be an impact on health of the wider community (e.g. through increased traffic and associated emissions, nuisance issues during construction – noise, dust etc, or operational issues such as odours) but at this stage of the assessment there were no discernable differences between options. At the VM2 workshop it was decided to capture some of these issues under the air quality objective (resulting in a more negative air quality score) and, in the absence of any specific information, it was decided to score health as neutral across all options.							
Sub-objective	**Contaminated Land**							
VM 1 Score	+	+	+	+	+	+	+	+
VM 2 Score	+	+	+	+	+	+	+	+
Discussion	It was considered that all the options would potentially bring contaminated land improvements as land contamination in the areas proposed for construction of new facilities may need to be removed/cleaned during the redevelopment process.							

Scoring of Objectives - Environment **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Community**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	-	-	-	-	-	-	-	-
Discussion	It was considered that the impact on community resources was likely to be similar across the options (e.g. through increased traffic and associated emissions, nuisances issues during construction – noise, dust etc, or operational issues such as odours) or through restricted access to community facilities (e.g. Riverside STW access) but at this stage of the assessment there were no discernable differences between options.							
Sub-objective	**Noise**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that there would be no significant difference in the background noise levels from the options proposed. Design measures would ensure that elevated noise sources were mitigated.							
Sub-objective	**Socio economic**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that additional sludge treatment facilities within the boundaries of existing STWs would be unlikely to affect economic investment if an odour neutral or better situation is achieved – though there may be perception issues as well as issues apart from odour. There was no discernable differences between options and all were scored equally (neutral).							
Sub-objective	**Renewable energy**							
VM 1 Score	+	+	+	+ + +	+ +	+ +	+ +	+ +
VM 2 Score	+	+ +	+ +	+ + +	+ +	+ +	+ +	+ +
Discussion	Preliminary calculations indicated that enhanced digestion, or enhanced digestion followed by incineration, provided the greatest potential for renewable energy generation and hence these options received the most positive scores.							
Sub-objective	**Climate change (relative GHG emissions for each option).**							
VM 1 Score	- -	- -	- -	- -	-	-	-	-
VM 2 Score	- -	- -	- -	- -	-	-	-	-
Discussion	Based on analysis carried out for this SAR, it was concluded that enhanced digestion only options were likely to have lower operational greenhouse gas emissions than those using incineration. Hence, incineration options were given a more negative score than enhanced digestion options.							
Overall Score for Environment Objective								
VM 1 Score	-	-	-	-	0	0	0	0
VM 2 Score	-	-	-	-	0	-	0	0
Rational	The overall assessment, taking into account the sub-objective assessments, is that options 2.0, 3.0, 4.0 and 5.2 are preferrable to the other options. However, different options score better against differnt sub-objectives and hence there is no obviously 'best' option based on the environmental objective.							

Scoring of Objectives - Stakeholder preferences **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Sub-objective	**Thames Water objectives**							
VM 1 Score	+ +	+ +	+	+ +	+ +	+	+ +	+
VM 2 Score	+ +	+ +	+	+ +	+ +	+	+ +	+
Discussion	Scoring for this criteria was based on Thames Water's own objectives as expressed in the Strategic Direction Statement and draft company-wide Sludge Strategy. In general, all options were considered to be consistent with TWUL's objectives for provision of sludge treatment capacity in the East London region. However, options where all additional sludge treatment capacity was provided at the STW where the sludge							
Sub-objective	**Ofwat (regulatory) objectives**							
VM 1 Score	+	+	+	+	+ +	+ +	+ +	+ +
VM 2 Score	+	+	+	+	+ +	+ +	+ +	+ +
Discussion	Scoring for these criteria was based on Ofwat's perceived objectives as interpreted from guidance provided for PR09 business plan submissions. These include a requirement to report on the carbon footprint associated with proposed investments. In general, all options were considered to be consistent with Ofwat's objectives for provision of effective sludge treatment services. However, options where at least part of the							
Sub-objective	**DEFRA / EA Government Department**							
VM 1 Score	+	+	+	+	+ +	+ +	+ +	+ +
VM 2 Score	+	+	+	+	+ +	+ +	+ +	+ +
Discussion	For sludge treatment it was considered that Defra and the EA would have similar objectives to Ofwat. Hence, options were given the same scores as for the Ofwat sub-objective.							
Sub-objective	**Local authorities**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	?	?	?	?	?	?	?	?
Discussion	It was considered that it would be premature to score this sub-objective until the results of the SEA consultation were received (expected end-August 2008). Hence, the effect of the option on the objective was left as unknown.							
Sub-objective	**Agricultural Sector**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	0	0	0	0	+	+	+	+
Discussion	At the VM1 workshop it was considered that it would be premature to score this sub-objective until the results of the SEA consultation were received (expected end-August 2008). Hence, the effect of the option on the objective was left as unknown. At VM2 it was considered possible to score the sub-objective based on the current policy of the British Retail Consortium (BRC). The current situation is that the BRC will accept use of sludge on agricultural land based on the Safe Sludge Matrix.							
Sub-objective	**Public including customers**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	?	?	?	?	?	?	?	?
Discussion	It was considered that it would be premature to score this sub-objective until the results of the SEA consultation were received (expected end-August 2008). Hence, the effect of the option on the objective was left as unknown.							
Overall Score for Stakeholder preferences Objective								
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	?	?	?	?	?	?	?	?
Rational	As noted above, it was felt premature to score the sub-objectives for ‘Local authorities’, ‘Agricultural Sector’ and ‘Public, including customers’ until the results of the SEA consultation were received. As a result it was not considered possible to assign an overall score for each option for this objective.							

Scoring of Objectives - Overall Scores **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Objective	**Constructability**							
VM 1 Score	+	-	-	- -	0	0	0	0
VM 2 Score	+	-	- -	-	0	0	0	+
Discussion	It can be seen from the table that, in terms of the constructability objective, options which provided both additional mass-burn incinerator and enhanced digestion were judged least attractive whilst those likely to have a lower footprint and interface issues (i.e. less complex) were given the highest scores. The overall option scores for the VM1 and VM2 workshops are broadly similar, with minor differences largely due to greater understanding of the contractor's working area requirements. In conclusion: it was agreed that in terms of constructability, there are no “show stoppers” and that further detailed study was required to differentiate between the options.							
Objective	**Technology**							
VM 1 Score	+	-	-	-	+	+	+	+
VM 2 Score	+ +	-	-	-	+	+	+ +	+ +
Discussion	It can be seen from the table that, in terms of the technology objective, options which provided an additional mass-burn incinerator or which provided enhanced digestion, were the most favoured at the workshop. These options were considered to represent ‘tried and tested’ technologies with a probability of meeting the technical requirements. It was noted that whilst this was the case for the processes when considered individually, the combination of the two processes (i.e. EDI) was less proven. Enhanced digestion processes were also considered to have the most potential for future adaptation, for example, through additional process stages.							
Objective	**Operations**							
VM 1 Score	+	-	-	- -	0	0	0	0
VM 2 Score	+	- -	- -	-	0	0	- - -	- - -
Discussion	In terms of the operations objective, options involving two different processes on one site (e.g. ED and RCI or EDI) were considered to be more complex from an operational viewpoint than single process sites e.g. all ED or all RCI). Option involving just raw cake incineration or enhanced digestion were considered to be the best from an operational perspective. It was felt by the workshop participants that providing enhanced digestion capacity for all sludge generated at Beckton STW would present too great an opporational risk and hence this option was scored with three negatives overall.							
Objective	**Safety**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that TWUL would not promote nor allow construction of a new treatment facility that was not 'safe' and hence all options should be scored with a zero. It was noted that enhanced digestion options could include thermal hydrolysis which uses high pressure steam. However, it was considered that any additional safety risk will be minimised through operator training and regular inspections of the pressure systems. Incineration options may, depending on design, include thin-film type dryers. However, these were considered not to suffer from the same potential safety risks as conventional dryers. In conclusion it was decided to all options a neutral score.							
Objective	**Integration**							
VM 1 Score	0	+	+	+	+	+ +	+	+ +
VM 2 Score	0	+	0	+	+	+	0	0
Discussion	It can be seen from the table that, in terms of the Integration objective, options which provided enhanced digestion and incineration, or enhanced digestion followed by incineration, were favoured. Options which provided at least part of the additional sludge treatment capacity at Riverside STW, thus also avoiding Metropolitan Open Land, were favoured over those where all the development was at Beckton STW.							
Objective	**Economy**							
VM 1 Score								
VM 2 Score	0	-	-	0	+	0	0	+

Scoring of Objectives - Overall Scores **Beckton STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton	Beckton
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Beckton	Beckton	Riverside	Beckton	Beckton	Riverside	Beckton	Riverside
Discussion	The scores for this sub-objective were based on analysis of option costs prepared by the SAR Consultant. Options were scored relative to Option 1.0 which was considered the reference option. The WLC included the initial capital, capital maintenance/renewals, net operating costs and income and have therefore been used as the overall score for the economy objective.							
Objective	**Environment**							
VM 1 Score	-	-	-	-	0	0	0	0
VM 2 Score	-	-	-	-	0	-	0	0
Discussion	The overall assessment, taking into account the sub-objective assessments, is that options 2.0, 3.0, 4.0 and 5.2 are preferrable to the other options. However, different options score better against differnt sub-objectives and hence there is no obviously 'best' option based on the environmental objective.							
Objective	**Stakeholder Preferences**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	?	?	?	?	?	?	?	?
Rational	As noted above, it was felt premature to score the sub-objectives for ‘Local authorities’, ‘Agricultural Sector’ and ‘Public, including customers’ until the results of the SEA consultation were received. As a result it was not considered possible to assign an overall score for each option for this objective.							
Objective	**Overall Score**							
VM 1 Score	+	-	-	-	+	+	+	+
VM 2 Score	+	- -	- -	-	+	0	-	0
Discussion	The overall scores, based on the objective level scores, suggest that the best options overall are 1.0 and 4.0. Given that the solution should also have the lowest whole life cost this would suggest that Option 4.0 is the preferred option overall.							

I.2 Crossness STW option scores

Scoring of Objectives - Constructability **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Implementation programme (whether an option can be implemented in time to meet demand)**							
VM 1 Score	0	-	-	- -	0	0	-	-
VM 2 Score	0	0	0	-	0	0	0	0
Discussion	A requirement for each option is that it can be implemented by the end of AMP 5. Key issues for an implementation programme will be the time taken to achieve planning application and the time needed to construct the works. The VM1 workshop concluded that all options could be implemented in the required timescale (hence scored 0) but that options involving more complex processes such as EDI had a greater risk of programme delay. Hence, options including EDI were given lower scores (- or --). At the VM2 workshop it was considered that only Option 3.0 (where the existing SPG had to be modified to accept enhanced digested sludge) had a greater risk and therefore justified a lower score. Other options had greater scope for -off-line work.							
Sub-objective	**Utilities interfaces**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	In general, options requiring diversion of significant existing services were given a lower score. No significant differences were identified between options at Crossness STW and hence all were scored 0.							
Sub-objective	**Noise / dust control (constraints posed by nearby developments)**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	-	-	-	-	-	-	-	-
Discussion	It was considered that at all options had an equal potential for construction noise or dust impacts on nearby developments and that these would need to be mitigated by good construction practice (noise and dust suppression) - hence all options were scored the same (-).							
Sub-objective	**Traffic management (incl potential road closures / diversions)**							
VM 1 Score	- -	- -	0	- -	- -	0	- -	- -
VM 2 Score	- -	- -	0	- -	- -	0	- -	- -
Discussion	Construction traffic management was considered likely to be a significant impact for all options involving construction of additional capacity or Crossness STW - hence options where all works are located at Crossness STW were given negative scores. In contrast, options where additional capacity was provided at Long Reach STW were considered to have lower construction traffic impacts and hence were given neutral scores (0). The exception was Option 5.2 where most of the additional capacity would be provided at Crossness STW and hence this was also given a low score. It was considered that traffic impacts could be partly mitigated by good site management (lorry load optimisation, timing of deliveries, etc).							
Sub-objective	**Construction access (within site)**							
VM 1 Score	-	- -	0	- -	- -	0	- -	-
VM 2 Score	-	- -	0	- -	- -	0	- -	-
Discussion	Options which had a larger land 'footprint' were considered likely to cause greater construction management issues within each STW site and were therefore given lower scores. Thus options involving EDI and ED at Crossness STW were given the lowest scores whilst options where additional assets were constructed at Long Reach STW, so reducing the overall intensity of construction at each site) achieved neutral scores (0).							
Sub-objective	**Other major interface issues**							
VM 1 Score	0	0	-	-	0	0	-	-
VM 2 Score	0	0	-	-	0	0	-	-
Discussion	Some options involved more complex interfaces with existing processes including the existing SPG (e.g. RCI+) and these were awarded more negative scores as a result.							

Scoring of Objectives - Constructability **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Technical complexity**							
VM 1 Score	0	- -	- - -	- -	-	- - -	- -	- - -
VM 2 Score	0	- -	- - -	- -	-	- - -	-	-
Discussion	Options involving a single process type and location were considered to be less technically complex. Conversely, options involving two different process types combined with treatment being divided between two sites, were considered to be the most complex and therefore were given the lowest scores. The scores for Option 5 and 5.2 were reduced compared to VM1 as these options involve single processes with all new construction located at Crossness STW.							
Sub-objective	**Availability of land for contractor's site compound and laying down area**							
VM 1 Score	+ +	+	- -	+	+	-	+	-
VM 2 Score	-	-	-	-	-	+	0	0
Discussion	All sites are constrained, to varying extent, by the availability of space for construction of the permanent works (treatment plant) as well as space required for a contractor's temporary site compound and laying down area. A review of contractor land requirements, subsequent to the VM1 workshop, suggests that as much as 4 hectares may be required for construction of new incinerators. This area is unlikely to be available in a single location and hence will probably need to be split into several areas around the STW sites - which is less efficient. Less land would be required for enhanced digestion plant construction. Hence, process options including new incineration were given a more negative score.							
Sub-objective	**Maintaining existing treatment processes during construction & commissioning**							
VM 1 Score	+ + +	+	+	-	+ + +	+ + +	+	+
VM 2 Score	+ + +	+	+	+	+ + +	+ + +	+ + +	+ + +
Discussion	Works involving modification to existing treatment streams, particularly where this involves adaptation of the existing incinerators to burn digested sludge cake (i.e. where an existing incinerator is converted to EDI) or other enhancements to the existing incinerator (i.e. RCI+) were considered to have the highest risk of impacting on operation of existing process streams and hence were scored lowest.							
Overall Score for Constructability Objective								
VM 1 Score	+	-	-	- -	0	0	0	0
VM 2 Score	+	-	- -	-	0	0	0	+
Rational	It can be seen from the table that, in terms of the constructability objective, options which provided both additional mass-burn incinerator and enhanced digestion were judged least attractive whilst those likely to have a lower footprint and interface issues (i.e. less complex) were given the highest scores. The overall option scores for the VM1 and VM2 workshops are broadly similar, with minor differences largely due to greater understanding of the contractor's working area requirements. In conclusion: it was agreed that in terms of constructability, there are no "show stoppers" and that further detailed study was required to differentiate between the options.							

Scoring of Objectives - Technology **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Reliability of process**							
VM 1 Score	+	+	+	+	+ +	+ +	+ +	+ +
VM 2 Score	+	+	+	+	+	+	+ +	+ +
Discussion	Following discussion on the reliability of the various processes, based on the experience of the workshop participants, the following consensus was reached: Enhanced digestion options were considered to be the most reliable, followed by mass-burn incineration options. Hence options including ED scores 2 plusses whilst RCI or EDI scored 1 plus. These scores were the same for both Beckton STW and Crossness STW options. Option appraisal during the VM1 workshop was based on the new components of the process only. During the VM2 workshop, it was decided that options should be assessed on the entire process (both old and new components) - hence the scores for options 4.0 and 4.2 were reduced slightly.							
Sub-objective	**Track record (established process)**							
VM 1 Score	+ +	-	-	-	+ +	+ +	+ +	+ +
VM 2 Score	+ +	-	-	-	+ +	+ +	+ +	+ +
Discussion	This sub-objective assessed whether there was a sufficient track record for the process technologies to provide comfort that the option was feasible. The workshop consensus was that both enhanced digestion and mass-burn incineration were both established processes and therefore scored highest (2 pluses). However, the participants were not aware of existing examples of enhanced digestion followed by incineration and hence this was scored lower (-). However, it was noted that this solution was being adopted by United Utilities for at least part of its throughput for the proposed extension to the Shell Green incinerator.							
Sub-objective	**Track record (implemented at similar scale)**							
VM 1 Score	+ + +	-	- -	- -	+ +	+ + +	+	+
VM 2 Score	+ + +	-	- -	- -	+ +	+ +	+ +	+ +
Discussion	This sub-objective assessed whether there was a sufficient track record for the process technologies being implemented at a similar scale to provide comfort that the option was feasible. The existing Beckton STW and Crossness STW SPGs are already amongst the largest in Europe and given TWUL's reliance on these two sites for much of their sludge treatment capacity it is essential that processes are proven at this size. The workshop consensus was that raw cake incineration was already proven at scale given that this was the existing process at each site - hence this scored the highest (+++). For enhanced digestion it was considered that although there were no existing sites at this scale the modularity of the process meant that scaling up was not an issue - hence this scored the next highest (++). However, for EDI it was noted that there were no existing examples and hence these were both given low scores for track record.							
Sub-objective	**Availability of Suppliers (plant)**							
VM 1 Score	+ + +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
VM 2 Score	+ + +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
Discussion	This sub-objective considered the availability of suppliers from the point of view of technical capability to provide working facilities (technical ability and manufacturing capacity). The workshop consensus was that all processes could be supplied in the timescale and quality required - hence most options were scored equally (++). However, it was felt that the larger number of suppliers available for incineration technology, compared to enhanced digestion, gave this a small edge. Hence, raw cake incineration was given the highest score (+++).							
Sub-objective	**Footprint (land take)**							
VM 1 Score	+ +	+	0	- -	0	+	-	+
VM 2 Score	+ +	+	0	-	0	+	-	-
Discussion	This sub-objective considered the potential footprint for each option against the likely availability of land at each site. It was considered that options involving raw cake incineration (RCI) would have the lowest footprint and hence scored highest (++). Scores for other options fell between (+) and (- -) based on the combination of processes and hence the expected footprint.							

Scoring of Objectives - Technology **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Potential for future upgrading through additional or alternative process stages**							
VM 1 Score	- -	- -	- -	- -	-	-	-	-
VM 2 Score	- -	- -	- -	- -	-	-	-	-
Discussion	This sub-objective considered the potential for future adaptation of the process option in the event that new processes - such as gasification - become more technically and economically attractive. The consensus was that options culminating in incineration had less potential for adaptation than options providing only enhanced digestion. Hence enhanced digestion options were scored one minus and other options two minuses.							
Sub-objective	**Marketability/recycling/ disposal of final product**							
VM 1 Score	-	-	-	-	+	+	+	+
VM 2 Score	-	-	-	-	+	+	+	+
Discussion	It was considered that an enhanced digested cake product would have the most potential market. Ash was given the lowest score (-) due to the lack of recycling outlets currently available for this product. Furthermore, the outlet for an incinerated ash product is severely constrained. TW estimates a maximum of 3 to 4 years of available landfill capacity in the London region.							
Overall Score for Technology Objective								
VM 1 Score	+	-	-	-	+	+	+	+
VM 2 Score	+ +	-	-	-	+	+	+	+
Rational	It can be seen from the table that, in terms of the technology objective, options which provided an additional mass-burn incinerator or which provided enhanced digestion, were the most favoured at the workshop. These options were considered to represent 'tried and tested' technologies with a probability of meeting the technical requirements. It was noted that whilst this was the case for the processes when considered individually, the combination of the two processes (i.e. EDI) was less proven. Enhanced digestion processes were also considered to have the most potential for future adaptation, for example, through additional process stages.							

Scoring of Objectives - Operations **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Staffing – (numbers needed & availability, expertise/ experience required for the different technologi**							
VM 1 Score	0	-	-	-	-	0	0	0
VM 2 Score	0	-	-	-	-	0	0	0
Discussion	In scoring this sub-objective it was considered that options which resulted in more than one type of sludge treatment technology at each site should have a lower score on the grounds that additional staff (numbers and expertise) would be required to operate each type of process. Scores in this case were one minus. Conversely, options with only one process technology at each site were scored higher (0). Where technologies were used at different sites (e.g. RCI at Beckton STW and ED at Riverside STW) then this was treated as a single technology at each site and scored accordingly. Options which required implementation of a new technology were also scored lower because staff will require additional training.							
Sub-objective	**Maintenance requirements**							
VM 1 Score	- -	- -	- -	- -	- -	-	-	-
VM 2 Score	- -	- -	- -	- -	- -	-	-	-
Discussion	Scores for this sub-objective reflected the perceived reliability of the processes, and thus the potential maintenance effort required, as well as the number of processes involved - which would impact on the range of skills that would be needed at each site. Options involving incineration were considered to have a high maintenance requirement - particularly if in combination with a different technology at the same location (e.g. RCI and ED at Beckton STW, score --). The highest scoring options were those only using enhanced digestion or where different technologies were used at separate sites.							
Sub-objective	**Operational flexibility (e.g. able to handle variations in feed quantity and quality)**							
VM 1 Score	-	-	-	-	0	-	0	0
VM 2 Score	-	- -	- -	-	0	-	0	0
Discussion	At VM2, all options were considered to be reasonable similar for this sub-objective though options including enhanced digestion were considered to have a small advantage and hence were scored marginally higher (0 compared to one minus for other options). Option 2.0 and 2.3 which include both RCI and EDI process streams, were considered to be the least flexible as it would not be possible to mix digested and raw cake							
Sub-objective	**Operational Complexity**							
VM 1 Score	- -	- -	0	- -	- -	0	- -	- -
VM 2 Score	+ +	- -	- -	-	-	0	+ +	+
Discussion	This sub-objective was added to capture process complexity from an operations point of view. Further discussion at VM2 led to a significant change in the scoring approach for this sub-objective. Options 1.0 and 5.0 scored the most positively as they each comprise a single process type at a single location.							
Sub-objective	**Risk of losing disposal route for product**							
VM 1 Score	0	0	0	0	0	0	-	-
VM 2 Score	0	0	0	0	0	0	- - -	- - -
Discussion	The outlet for an incinerated ash product is severely constrained due to a lack of landfill capacity. TW staff at the workshop reported that only 3 to 4 years of landfill capacity remaining in the London region. However, doubts were also expressed as to the feasibility of treating large proportions of Beckton and Crossness STWs' sludge using enhanced digestion given the location of the STWs (urban areas with congested transport networks) and the availability of agricultural landbank within reasonable range of East London. Treating a large proportion of sludge using enhanced digestion would also increase TW's vulnerability with respect to potential disruption of agricultural recycling following, for example, further outbreaks of Foot and Mouth'. On this basis Options 5.0 and 5.2 were given negative scores. The risks associated with enhanced digestion of just half of the sludge produced at Beckton or Crossness STWs (options 4.0 and 4.2) were considered to be lower and comparable to those associated with ash disposal.							
Overall Score for Operations Objective								
VM 1 Score	+	-	-	- -	0	0	0	0
VM 2 Score	+	- -	- -	-	0	0	- - -	- - -

Scoring of Objectives - Operations **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Rational	In terms of the operations objective, options involving two different processes on one site (e.g. ED and RCI or EDI) were considered to be more complex from an operational viewpoint than single process sites e.g. all ED or all RCI). Option involving just raw cake incineration or enhanced digestion were considered to be the best from an operational perspective. It was felt by the workshop participants that providing enhanced digestion capacity for all sludge generated at Beckton STW would present too great an opporational risk and hence this option was scored with three negatives overall.							

Scoring of Objectives - Integration **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**GLA objectives and ambitions**							
VM 1 Score	-	-	-	-	+	+	-	+
VM 2 Score								
Discussion	The GLA favours waste treatment options which maximise energy recovery and recycling potential. Hence options including enhanced digestion were scored higher than those involving incineration as the final treatment stage. This sub-objective was not scored at VM2 as it was considered the same as that for "Other regional government policies (London Plan)".							
Sub-objective	**Other national government policies (PPS)**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	-	0	-	+	+	0	+	0
Discussion	This sub-objective was not scored during the VM 1 workshop as it was felt that there were a number of national government policies that should be scored separately. Scoring at VM 2 stage focussed on Sustainability and Energy Renewal which were considered relevant and favoured enhanced digestion options as these increased renewable energy, reduced sludge volume and traffic to disposal.							
Sub-objective	**Other Regional government policies (London Plan)**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	-	-	-	-	+	+	+	+
Discussion	This sub-objective was not scored during the VM 1 workshop as it was felt that there were a number of regional policies that should be scored separately. Scoring at VM 2 stage focussed on London Plan policies on water and sewage infrastructure replacement to meet population growth and climate change requirements.							
Sub-objective	**Land use policy (Unitary Development Plans / Local Development Plan Documents)**							
VM 1 Score	-	-	+	-	-	+	-	+
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	At VM 1, development on designated 'Metropolitan open land' was a considered the key issue for land use planning purposes and hence options involving additional facilities at Crossness STW were scored lower than options where additional capacity was provided at Long Reach STW. However, at VM 2, sustainability and energy issues were considered further and resulted in overall neutral scores.							
Sub-objective	**Thames Water Strategic Direction Statement, Sludge Strategy and associated SEA (including SEA Post Adoption Statement)**							
VM 1 Score	+	+	+	+	+	+	+	+
VM 2 Score	+	+	+	+	0	0	-	-
Discussion	The Strategic Direction Statement and the Sludge Strategy set out Thames Water's outline proposals for future sludge treatment in the East London region and these are assessed in the SEA. It was considered that options including mass-burn incineration, with or without a preceding enhanced digestion stage, were consistent with the recommendations in these documents and hence all scored (+). Options 5.0 and 5.2, providing only enhanced digestion, were scored lowest.							
Overall Score for Integration Objective								
VM 1 Score	0	+	+	+	+	+	+	+
VM 2 Score	-	0	-	0	+	0	0	0
Rational	It can be seen from the table that, in terms of the Integration objective, options which provided an enhanced digested product for recycling were favoured - although retaining thermal destruction as well as enhanced digestion achieved a higher overall score. Options which provided at least part of the additional sludge treatment capacity at Long Reach STW, thus also avoiding Metropolitan Open Land, were favoured over those where all the development was at Crossness STW.							

Scoring of Objectives - Safety

Crossness STW Options

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Reduce risk of illness or injury to employees, contractors and public**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that TWUL would not promote nor allow construction of a new treatment facility that was not 'safe' and hence all options should be scored with a zero. It was noted that enhanced digestion options could include thermal hydrolysis which uses high pressure steam. However, it was considered that any additional safety risk will be minimised through operator training and regular inspections of the pressure systems. Incineration options may, depending on design, include thin-film type dryers. However, these were considered not to suffer from the same potential safety risks as conventional dryers. In conclusion it was decided to give all options a neutral score.							

Scoring of Objectives - Economy **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Construction costs**							
VM 1 Score	- -	- - -	- - -	- - -	-	-		-
VM 2 Score	0	- -	- - -	0	+ +	0	+	0
Discussion	The scores for this sub-objective were based on analysis of option capital costs prepared by the SAR Consultant. Options were scored relative to Option 1.0 which was considered the reference option. Based on the cost analysis it could be seen that options providing enhanced digestion with incineration were significantly more expensive to construct than the other options. Options providing additional capacity using just enhanced digestion were generally the cheapest. The cost for Option 4.2 was relatively higher than the other ED options due to the cost of the additional pipeline and associated thickening plant capacity required to transfer sludge to Riverside STW.							
Sub-objective	**Operating and maintenance costs (excluding electricity sales & ROCs)**							
VM 1 Score	- -	- -	- -	- -	-	-		-
VM 2 Score	0	+	0	+	0	- -	0	- - -
Discussion	The scores for this sub-objective were based on preliminary analysis of option operating costs prepared by the SAR Consultant. This analysis was based on the predicted process performance for each option and unit cost data for similar schemes elsewhere. The operating cost data exclude potential income from electricity sales and ROCs but include the value of electricity generated and consumed on-site. Options were scored relative to Option 1.0 which was considered the reference option. Based on the analysis the high sludge transport and recycling costs associated with options 4.0, 4.2, 5.0 and 5.2 are a significant factor and result in these options having the highest overall opex. Option 3.0 also has a high opex due to high power and fossil fuel consumption.							
Sub-objective	**Revenue (sludge product recycling, on-site power generation and ROCs)**							
VM 1 Score	-	+	+	+ +	+ +	+ +		+ +
VM 2 Score	0	+	+ +	+ +	+	+ +	+	+ +
Discussion	Scoring for this sub-objective focussed on the potential for sale of surplus electricity generated and the ability to earn ROCs for the power produced. In general, options using enhanced digestion were considered to have greater potential for energy generation and earning ROCs - hence these were awarded two pluses. Option 3.0 allows electricity to be generated and ROCs earned for the ED stage as well as generating power in the SPG.							
Sub-objective	**Net Opex, including revenue**							
VM 1 Score	- -	- -	0	- -	- -	0	- -	- -
VM 2 Score	0	+	+	+ +	+	0	+	0
Discussion	This analysis takes into account both future net opex and income. It can be seen that Option 3.0 has the most favourable new opex.							
Sub-objective	**Whole Life Costs**							
VM 1 Score	-	- -	0	- -	- -	0	- -	-
VM 2 Score	0	0	-	+	+ +	0	+ +	+
Discussion	Whole life costs were derived using the construction and operating costs presented. The WLC included the initial capital, capital maintenance/renewals, net operating costs and income and were derived using a discount rate of 7% of 20 years in accordance with TW policy. The analysis indicates that options 4.0 and 5.2 have the lowest WLC, followed by options 1.0, 3.0, 4.2 and 5.0. The options were scored accordingly.							
Overall Score for Economy Objective								
VM 1 Score								
VM 2 Score	0	0	-	+	+ +	0	+ +	+
Rational	The scores for this sub-objective were based on analysis of option costs prepared by the SAR Consultant. Options were scored relative to Option 1.0 which was considered the reference option. The WLC included the initial capital, capital maintenance/renewals, net operating costs and income and have therefore been used as the overall score for the economy objective.							

Scoring of Objectives - Environment **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Landscape/ Townscape & Visual**							
VM 1 Score	- -	- -	- -	- -	-	-	-	-
VM 2 Score	- -	- -	- -	-	-	0	-	0
Discussion	At VM1, it was considered that the construction of a sludge treatment facility at Crossness has the potential to impact on the landscape/visual quality of the area as it lies within a fairly open area. It was considered that an incinerator facility would have a greater visual impact than enhanced digestion facilities which are smaller in scale and in keeping with the existing facilities. At the VM2 workshop it was agreed that options 3.0, 4.2 and 5.2 are similar to the current configurations present at these sites and scoring was therefore reduced.							
Sub-objective	**Air quality (incl. odour)**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	-	-	-	-	-	-	-	-
Discussion	It was assumed that any of the processes discussed would be designed and operated to meet regulatory requirements and standards laid out in any operating permit. At the VM2 workshop, it was considered appropriate to include other issues which may lead to a reduction in air quality (such as increased traffic movements and dust generation during construction) which would be associated with the scheme. It was therefore decided that there was a potential for a reduction in air quality (hence the lower score compared to VM1) although it was not possible to differentiate between proposed options.							
Sub-objective	**Waste**							
VM 1 Score	- -	- -	- -	- -	-	-	-	-
VM 2 Score	- -	- -	- -	- -	0	0	+	+
Discussion	**Incinerator ash:** It was assumed that end product from the incineration process would require disposal to landfill (low on the waste hierarchy). It was noted that landfill capacity in the region was becoming an issue. Hence, options producing ash were given lower scores. **Enhanced digestion:** At the VM2 workshop, it was considered that enhanced digested cake would be recycled to agriculture providing it was of a suitable quality. Hence, options producing enhanced digested product were scored higher than at the VM1 workshop. It was considered that treatments which provided both ash and enhanced digested sludge were effectively neutral in there impact.							
Sub-objective	**Water Resources**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	-	-	-	-	-	-	-	-
Discussion	No differentiation regarding water resources for the option combinations proposed. Crossness lies within a floodplain and there are a number of drainage lines and water features in the vicinity of the site which could be impacted by the proposals.							
Sub-objective	**Archaeology**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	-	-	- -	-	-	- -	-	- -
Discussion	It was considered that there is a potential negative impact on archaeological resources due to ground disturbance during construction of new facilities but the impact was likely to be similar for all options. Options which require access to Long Reach STW could have greater negative impacts due to a potential need to construct a pipeline to Long Reach STW.							

Scoring of Objectives - Environment **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Traffic & Transport**							
VM 1 Score	-	-	- -	-	- -	- - -	- -	- - -
VM 2 Score	-	-	-	-	- - -	-	- - -	- -
Discussion	All options would require incinerator ash and/or digested sludge to be transported off site for disposal or re-use. **Incineration options:** Quantities of material requiring disposal are lower and therefore fewer traffic movements for disposal – hence a score of (-) was given for incineration options. **Enhanced digestion options:** Quantities of material requiring recycling as agricultural product are greater and therefore require more vehicle movements – hence these options were generally given more negative scores than incinerator options. Changes in specific options scores between the VM1 and VM2 workshops were based on more detailed evaluation of sludge quantities and traffic impacts since the VM1 workshop. Option 4.0 and 5.0 were increased as it was considered these two options would have a greater volume of material for disposal from Crossness STW and hence there could be greater traffic movements through a local housing area and the local road network. Scores for options 4.2 and 5.2 were made less negative as is it now proposed that sludge will be transferred to Long Reach STW via pipeline and this will reduce the ro							
Sub-objective	**Ecology**							
VM 1 Score	-	- -	?	- -	-	?	-	?
VM 2 Score	-	- -	- -	- -	-	- -	-	- -
Discussion	The Crossness site is located in a sensitive location with respect to ecology with a number of designated nature reserves in close proximity to the site and the larger the footprint of the development the greater the potential impact on ecological resources. There are no ecological designations on the Long Reach STW site but the surrounding area contains a number of nationally and regionally important areas. Options involving construction of a pipeline to Long Reach STW could lead to impact on ecologically sensitive areas.							

Scoring of Objectives - Environment **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Cultural Heritage**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that there would be a neutral effect on Cultural Heritage resources as a result of the proposals. There are no Scheduled Ancient Monuments, Listed Buildings, Conservation Areas, Registered Historic Parks and Gardens, Protected Wreck Sites, Ancient Woodland or Historic Battlefields present within the proposed development sites although listed buildings are found elsewhere within the Crossness STW site.							
Sub-objective	**Health**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that there could be an impact on health of the wider community (e.g. through increased traffic and associated emissions, nuisance issues during construction – noise, dust etc, or operational issues such as odours) but at this stage of the assessment there were no discernable differences between options. At the VM2 workshop it was decided to capture some of these issues under the air quality objective (resulting in a more negative air quality score) and, in the absence of any specific information, it was decided to score health as neutral across all options.							
Sub-objective	**Contaminated Land**							
VM 1 Score	+	+	+	+	+	+	+	+
VM 2 Score	+	+	+	+	+	+	+	+
Discussion	It was considered that all the options would potentially bring contaminated land improvements as land contamination in the areas proposed for construction of new facilities may need to be removed/cleaned during the redevelopment process.							
Sub-objective	**Community**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	-	-	- -	-	-	- -	-	- -
Discussion	It was considered that the impact on community resources was likely to be similar across the options (e.g. through increased traffic and associated emissions, nuisances issues during construction – noise, dust etc, or operational issues such as odours) or through restricted access to community facilities. At VM2 it was noted that there are a number of housing developments in close proximity to the Long Reach STW site and therefore there could be a greater impact on sensitive receptors at these facilities - hence the options involving work at Long Reach STW were given a more negative score.							
Sub-objective	**Noise**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that there would be no significant difference in the background noise levels from the options proposed. Design measures would ensure that elevated noise sources were mitigated.							
Sub-objective	**Socio economic**							
VM 1 Score	-	-	-	-	-	-	-	-
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that additional sludge treatment facilities within the boundaries of existing STWs would be unlikely to affect economic investment if an odour neutral or better situation is achieved – though there may be perception issues as well as issues apart from odour. There was no discernable differences between options and all were scored equally (neutral).							
Sub-objective	**Renewable energy**							
VM 1 Score	+	+	+	+ + +	+ +	+ +	+ +	+ +
VM 2 Score	+	+ +	+ +	+ + +	+ +	+ +	+ +	+ +
Discussion	Calculations indicated that enhanced digestion, or enhanced digestion followed by incineration, provided the greatest potential for renewable energy generation and hence these options received the most positive scores.							
Sub-objective	**Climate change (relative GHG emissions for each option).**							
VM 1 Score	- -	- -	- -	- -	-	-	-	-
VM 2 Score	- -	- -	- -	- -	-	-	-	-

Scoring of Objectives - Environment **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Discussion	Based on analysis carried out for this SAR, it was concluded that options based on enhanced digestion alone were likely to have lower operational greenhouse gas emissions than those using incineration. Hence, incineration options were given a more negative score than enhanced digestion options.							
Overall Score for Environment Objective								
VM 1 Score	-	-	-	-	0	-	0	0
VM 2 Score	- -	- -	- -	-	-	-	0	-
Rational	The overall assessment, taking into account the sub-objective assessments, is that options 3.0 and 5.0 are preferable to the other options. Option 2.3 and 4.2 have the worst overall scores largely due to constraints associated with providing sludge treatment at Long Reach STW. However, different options score better against different sub-objectives and hence there is no obviously 'best' option based on the environmental objective.							

Scoring of Objectives - Stakeholder preferences **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Sub-objective	**Thames Water objectives**							
VM 1 Score	+ +	+ +	+	+ +	+ +	+	+ +	+
VM 2 Score	+ +	+ +	+	+ +	+ +	+	+ +	+
Discussion	Scoring for this criteria was based on Thames Water's own objectives as expressed in the Strategic Direction Statement and draft company-wide Sludge Strategy. In general, all options were considered to be consistent with TWUL's objectives for provision of sludge treatment capacity in the East London region. However, options where all additional sludge treatment capacity was provided at the STW where the sludge is generated (i.e. at Beckton STW or Crossness STW) scored higher than those where additional capacity was provided by transferring sludge to another site.							
Sub-objective	**Ofwat (regulatory) objectives**							
VM 1 Score	+	+	+	+	+ +	+ +	+ +	+ +
VM 2 Score	+	+	+	+	+ +	+ +	+ +	+ +
Discussion	Scoring for these criteria was based on Ofwat's perceived objectives as interpreted from guidance provided for PR09 business plan submissions. These include a requirement to report on the carbon footprint associated with proposed investments. In general, all options were considered to be consistent with Ofwat's objectives for provision of effective sludge treatment services. However, options where at least part of the additional sludge treatment capacity was provided using enhanced digestion was scored higher on the grounds that these options would be likely to have a lower whole life carbon footprint.							
Sub-objective	**DEFRA / EA Government Department**							
VM 1 Score	+	+	+	+	+ +	+ +	+ +	+ +
VM 2 Score	+	+	+	+	+ +	+ +	+ +	+ +
Discussion	For sludge treatment it was considered that Defra and the EA would have similar objectives to Ofwat. Hence, options were given the same scores as for the Ofwat sub-objective.							
Sub-objective	**Local authorities**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	?	?	?	?	?	?	?	?
Discussion	It was considered that it would be premature to score this sub-objective until the results of the SEA consultation were received (expected end-August 2008). Hence, the effect of the option on the objective was left as unknown.							
Sub-objective	**Agricultural Sector**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	0	0	0	0	+	+	+	+
Discussion	At the VM1 workshop it was considered that it would be premature to score this sub-objective until the results of the SEA consultation were received (expected end-August 2008). Hence, the effect of the option on the objective was left as unknown. At VM2 it was considered possible to score the sub-objective based on the current policy of the British Retail Consortium (BRC). The current situation is that the BRC will accept use of sludge on agricultural land based on the Safe Sludge Matrix.							
Sub-objective	**Public including customers**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	?	?	?	?	?	?	?	?
Discussion	It was considered that it would be premature to score this sub-objective until the results of the SEA consultation were received (expected end-August 2008). Hence, the effect of the option on the objective was left as unknown.							
Overall Score for Stakeholder preferences Objective								
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	?	?	?	?	?	?	?	?
Rational	As noted above, it was felt premature to score the sub-objectives for ‘Local authorities’, ‘Agricultural Sector’ and ‘Public, including customers’ until the results of the SEA consultation were received. As a result it was not considered possible to assign an overall score for each option for this objective.							

Scoring of Objectives - Overall Scores **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Objective	**Constructability**							
VM 1 Score	+	-	-	- -	0	0	0	0
VM 2 Score	+	-	- -	-	0	0	0	+
Discussion	It can be seen from the table that, in terms of the constructability objective, options which provided both additional mass-burn incinerator and enhanced digestion were judged least attractive whilst those likely to have a lower footprint and interface issues (i.e. less complex) were given the highest scores. The overall option scores for the VM1 and VM2 workshops are broadly similar, with minor differences largely due to greater understanding of the contractor's working area requirements. In conclusion: it was agreed that in terms of constructability, there are no “show stoppers” and that further detailed study was required to differentiate between the options.							
Objective	**Technology**							
VM 1 Score	+	-	-	-	+	+	+	+
VM 2 Score	+ +	-	-	-	+	+	+ +	+ +
Discussion	It can be seen from the table that, in terms of the technology objective, options which provided an additional mass-burn incinerator or which provided enhanced digestion, were the most favoured at the workshop. These options were considered to represent ‘tried and tested’ technologies with a probability of meeting the technical requirements. It was noted that whilst this was the case for the processes when considered individually, the combination of the two processes (i.e. EDI) was less proven. Enhanced digestion processes were also considered to have the most potential for future adaptation, for example, through additional process stages.							
Objective	**Operations**							
VM 1 Score	+	-	-	- -	0	0	0	0
VM 2 Score	+	- -	- -	-	0	0	- - -	- - -
Discussion	In terms of the operations objective, options involving two different processes on one site (e.g. ED and RCI or EDI) were considered to be more complex from an operational viewpoint than single process sites e.g. all ED or all RCI). Option involving just raw cake incineration or enhanced digestion were considered to be the best from an operational perspective. It was felt by the workshop participants that providing enhanced digestion capacity for all sludge generated at Beckton STW would present too great an opporational risk and hence this option was scored with three negatives overall.							
Objective	**Safety**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	0	0	0	0	0	0	0
Discussion	It was considered that TWUL would not promote nor allow construction of a new treatment facility that was not 'safe' and hence all options should be scored with a zero. It was noted that enhanced digestion options could include thermal hydrolysis which uses high pressure steam. However, it was considered that any additional safety risk will be minimised through operator training and regular inspections of the pressure systems. Incineration options may, depending on design, include thin-film type dryers. However, these were considered not to suffer from the same potential safety risks as conventional dryers. In conclusion it was decided to all options a neutral score.							
Objective	**Integration**							
VM 1 Score	0	+	+	+	+	+ +	+	+ +
VM 2 Score	-	0	-	0	+	0	0	0
Discussion	It can be seen from the table that, in terms of the Integration objective, options which provided an enhanced digested product for recycling were favoured - although retaining thermal destruction as well as enhanced digestion achieved a higher overall score. Options which provided at least part of the additional sludge treatment capacity at Long Reach STW, thus also avoiding Metropolitan Open Land, were favoured over those where all the development was at Crossness STW.							
Objective	**Economy**							
VM 1 Score								
VM 2 Score	0	0	-	+	+ +	0	+ +	+

Scoring of Objectives - Overall Scores **Crossness STW Options**

Option	1.0	2.0	2.3	3.0	4.0	4.2	5.0	5.2
Process	RCI	RCI	RCI+	EDI	RCI	RCI	ED	ED
Location	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness	Crossness
Process	RCI	EDI	EDI	EDI	ED	ED	ED	ED
Location	Crossness	Crossness	Long Reach	Crossness	Crossness	Long Reach	Crossness	Long Reach
Discussion	The scores for this sub-objective were based on analysis of option costs prepared by the SAR Consultant. Options were scored relative to Option 1.0 which was considered the reference option. The WLC included the initial capital, capital maintenance/renewals, net operating costs and income and have therefore been used as the overall score for the economy objective.							
Objective	**Environment**							
VM 1 Score	-	-	-	-	0	0	0	0
VM 2 Score	- -	- -	- -	-	-	-	0	-
Discussion	The overall assessment, taking into account the sub-objective assessments, is that options 2.0, 3.0, 4.0 and 5.2 are preferrable to the other options. However, different options score better against differnt sub-objectives and hence there is no obviously 'best' option based on the environmental objective.							
Objective	**Stakeholder Preferences**							
VM 1 Score	?	?	?	?	?	?	?	?
VM 2 Score	?	?	?	?	?	?	?	?
Rational	As noted above, it was felt premature to score the sub-objectives for ‘Local authorities’, ‘Agricultural Sector’ and ‘Public, including customers’ until the results of the SEA consultation were received. As a result it was not considered possible to assign an overall score for each option for this objective.							
Objective	**Overall Score**							
VM 1 Score	0	0	0	0	0	0	0	0
VM 2 Score	0	- -	- -	-	+ +	0	0	0
Discussion	The overall scores, based on the objective level scores, suggest that the best option is 4.0. This solution also has the lowest whole life cost.							

Appendix J Environmental Context

J.1 Background - Beckton STW

Key Issues	Comment (Beckton STW)
Air Quality (incl. odour)	The LB of Newham is designated as an Air Quality Management Area (AQMA) – primarily as a result of traffic emissions. The selected scheme will operate under an Environmental Permit (PPC) and all new works will meet the requirements of this permit.
Cultural Heritage and Archaeological	There are no Scheduled Ancient Monuments, Listed Buildings, Conservation Areas, Registered Historic Parks and Gardens, Protected Wreck Sites, Ancient Woodland or Historic Battlefields present within the area proposed for development. The existing Pumping Station chimney is now Grade II listed, however, this lies outside of the proposed development area. The site lies in an Archaeological Priority area as designated by the LB Newham UDP. Previous studies undertaken on the site and in the surrounding area have identified various items of archaeological interest from early medieval periods to the Neolithic and bronze ages. Future development options are likely to require a detailed site survey due to the historic nature of the site, regardless of the option chosen.
Ecology	Beckton STW is designated as an area of Metropolitan Open Land by LB Newham UDP. Site surveys for invasive plants, reptiles, amphibians, bats, breeding birds, wintering birds, invertebrates and water voles have been carried out previously at Beckton STW for other schemes proposed at the site. The Beckton STW site is considered to be of negligible to low value for bats, amphibians and water voles, low to medium value for reptiles and breeding birds, and medium value for invertebrates. The foreshore is considered to be of low to medium value for wintering birds. Habitats at Beckton STW are considered to be of negligible to low value with the exception of tall ruderals, swamp and rough grassland habitats, which are considered to be of low to medium importance.
Contaminated Land	The site has been used for sewage treatment and associated activities, thus giving the potential for contamination. Previous site investigations have been undertaken to assess the risks associated with the development at the site and have identified that there is a moderate to high risk with respect to ground contamination, prior to mitigation. The primary source of any potential contamination is the elevated concentrations of lead within areas used for grit screenings handling and storage. Widespread sewage-related contamination, including microbes, ammoniacal nitrogen, nitrate and chloride has been identified within the grit screenings. There is a presence of Made Ground with contamination hotspots, which are derived from the extended historical use of the land as a sewage treatment works. There are also potential off-site sources of contamination including the gas works to the south-west of the site.
Landscape and visual	Beckton STW is the largest sewage treatment works in the UK, treating wastewater for much of north and northeast London with substantial areas of plant machinery, tanks, and buildings, including a large Sludge Powered Generator (SPG). The site is traversed by a network of roads and interspersed with open areas, such as car parks

Key Issues	Comment (Beckton STW)
	and vacant land. Despite Beckton STW being such a large development situated on predominantly low lying land, the existing SPG does not currently have a large visual impact from outside of the STW boundary. However, if further medium and high rise residential development occurs near the STW boundary then future construction of any structures similar in scale to the SPG will have a greater visual impact.
Noise	Beckton STW lies in a predominantly industrial / commercial area. To the east lies Barking Reach Industrial estate, to the north lies further commercial and industrial developments and the A13, and to the south-west lies an area of expanding retail and commercial developments, including Galleons Reach and Beckton STW Triangle, and the A1020 Royal Docks Road. There are areas of residential development to the north-east, to the south-west beyond the A1020 and to the south across the river in Greenwich. The former represent the most sensitive receptors with respect to any noise and vibration impacts associated with the development. It is unlikely that sensitive receptors would be affected due to operational noise at the STW but there could be issues with construction noise, resulting from heavy plant operation and increased traffic movements. Other significant noise sources in the area include: ▪ the A13 to the north; ▪ the A1020 (Royal Docks Road) to the west; ▪ DLR Depot to the south-west; and ▪ Barking Reach Industrial Estate to the east.
Traffic and Transport	Vehicular access to the Beckton STW from the strategic road network is gained via the junction of the A406 North Circular Road, the A13 and the A1020. Depending on the option taken forward, the local highways authority will need to be consulted to ensure that adequate notice of any disruption due to construction works, or any increase in traffic related to operation, can be placed on the surrounding network. All options will result in additional local traffic during construction though there is potential to mitigate this impact through careful management of deliveries. Traffic impacts during operation will vary according to option selected: options requiring road transfer of thickened or dewatered sludge or road transport of digested cake will have greater impacts than those producing ash for disposal. However, elimination of lime treatment as a result of the proposed project will eliminate significant traffic movements associated with lime imports and exports of limed sludge.
Water	<u>Surface Water</u> Beckton STW lies adjacent to Barking Creek at the point where is meets the Thames Tideway. There are a series of drainage ditches on the Beckton STW site which are thought to be part of a relic drainage system of the site. The EA reports that the Thames Tideway is cleaner and healthier than it has been for nearly 200 years. As a result it is now able to support a wide variety of wildlife, including over 120 different species of fish. <u>Flood Risk</u> A flood risk assessment for Beckton STW concluded that it is defended against a 1-in-1000-year return period fluvial or tidal event. The main flood risk posed to the site is from residual risk from a breach event in the Roding (Barking Creek) embankment 750m upstream of the site.

Key Issues	Comment (Beckton STW)
	Geology & Hydrogeology The published geological mapping (BGS Sheet 257 for Romford, 1:50,000, drift and solid, dated 1974) along with borehole data taken from Site Investigations indicates that the site is underlain by the following geological formations; ▪ Made ground ▪ Alluvium ▪ River Terrace gravels (Minor Aquifer) ▪ London Clay (impermeable layer) ▪ Woolwich Formation of the Lambeth Beds - the clay layers nearer the top of the formation are considered as impermeable; ▪ Thanet Sands (Minor Aquifer) ▪ Upper Chalk (Major Aquifer)

J.2 Background - Crossness STW

Key Issues	Comment (Crossness STW)
Air Quality (incl. odour)	The LB of Bexley is designated as an Air Quality Management Area (AQMA) – primarily as a result of traffic emissions. In 2005 Crossness STW was issued with an abatement notice for odour. However, a lime plant has resolved this by removing the need for raw cake storage. The selected scheme will operate under an Environmental Permit (PPC) and all new works will meet the requirements of this permit. However, the other large emissions in the vicinity, including the new Riverside STW (Belvedere) Incinerator, means that it may be necessary to consider the combined effect of these emissions on air quality.
Cultural Heritage and Archaeological	Crossness STW is partially located in an Area of Archaeological Search as defined by the London Borough of Bexley's UDP. Within the area proposed for development, there are no Scheduled Monuments and no Listed Buildings. However, there are three Listed Buildings within the STW site, all situated c. 500m to the north-west of the main development site, namely: • Crossness STW Pumping Station – Beam Engine House (Grade I); • Workshop to south-east of Beam Engine House (Grade II); and • Workshop to south-west of Beam Engine House (Grade II). The Listed Buildings lie within a Conservation Area designated in February 1997. Previous investigations have shown that the Crossness STW site is located in an area of archaeological and historical significance.
Ecology	Crossness STW lies within an area of Metropolitan Open Land and an area of Metropolitan importance for nature conservation. Aquatic ecology The Thames Tideway and its tributaries in the vicinity of Crossness STW contain a number of valuable habitats that are rare in London: mudflats, shingle beach, saltmarsh, inter-tidal vegetation, reedbeds, islands and the river channel itself. The area is particularly important for wildfowl and wading birds and for birds such as the black redstart. A number of nationally rare snails occur, including the brackish water snail *Pseudamnicola confusa*. The river is known to support more than 100 species of fish, including dace in the freshwater reaches, and smelt, sea bass and Twaite shad in the estuarine reaches. Terrestrial ecology The site lies in a sensitive location with respect to terrestrial ecology. There are 3

Key Issues	Comment (Crossness STW)
	statutory designated sites within a 2km radius of the site (SSSIs and Local Nature Reserve) and 18 non-statutory designated sites within a 2km radius – including the Crossness STW Nature Reserve (partially on site) which was established in response to a previous Section 106 Agreement for the Sludge Powered Generator. It extends east of the operational STW boundary, with approximately one third lying within a fenced area immediately east of the site boundary fence, and approximately two thirds unfenced, further east. The land immediately east of the eastern STW boundary fence, known as the 'protected area' is managed principally for nature conservation and educational resource and is subjected to restricted access. The area supports extensive areas of reedbed and scrub to the south, whilst a new wader scrape has been established to the north. A bird hide and a bat cave have recently been constructed within the wader scrape. Although Crossness STW does not lie within a protected area itself, care must be taken during the design and construction for any of the options to mitigate potential effects on the wildlife and nearby areas.
Contaminated Land	The site has been used for sewage treatment and associated activities, thus giving the potential for contamination. Previous site investigations have been undertaken and have identified that there is a moderate to high risk with respect to ground contamination, prior to mitigation. The primary source of any potential contamination is the presence of extensive areas of Made Ground with contamination hotspots, which are derived from the extended historical use of the land as a sewage treatment works.
Landscape and visual	Crossness STW lies on the south bank of the tidal River Thames. Its context is defined principally by the A2016 Eastern Way to the south with the Crossness STW Southern Marshes (CSM) beyond, and the River Thames to the north. To the east is Crossness STW Nature Reserve with Belvedere Industrial Estate beyond, and to the west is Riverside STW Golf Course and driving range beyond which is the North Thamesmead residential area. The STW is highly visible from the west and from part of the A2016 - Bronze Age Way - to the south-east of the site. The London Borough of Bexley UDP shows that there are two site lines that cross through the STW which need to be taken into consideration: 1. The view from Eaglesfield recreation ground to Bexley and the Lower Thames; and 2. The view from Beckton STW Alps (Newham) of the East London Panorama.
Noise	In the immediate surroundings of the STW are the River Thames to the north, Crossness STW Nature Reserve (CNR) to the east, Crossness STW Southern Marshes (CSM) to the south and a golf course to the west. Residential areas are located approximately 300m west of the STW, 700m south-west and 770m south-east. The River Thames footpath is located to the north-west. Whichever option is taken forward will have noise suppression built into the design. According to the LB Bexley UDP, Crossness STW lies within a Special Industrial Zone. It is considered that sensitive receptors are unlikely to be impacted by operational noise from the STW itself but there could be issues with construction noise, resulting from heavy plant operation. However, there is greater potential for traffic noise impacts, during construction and, for some options, operation, as road access for the STW passes through residential areas.
Traffic and Transport	Vehicular access to Crossness STW and the proposed development site is gained from the A2041 Harrow Manorway and the A2016 Eastern Way – both dual carriageways. The principal strategic connection to the national motorway network is via the A2016

Key Issues	Comment (Crossness STW)
	Eastern Way, which provides links to the M25 motorway. The local roads off of the A2041 are predominantly used by local traffic. Belvedere Road is adjacent to the STW and traffic includes current operational traffic from the Crossness STW and local traffic. Access to Crossness STW from the A2016 'Eastern Way' passes through the Crossness STW Nature Reserve (CNR), a Local Nature Reserve and an area designated by the Borough and GLA as of Metropolitan Importance for Nature Conservation. As such, routing of construction and operational traffic via this route is not considered appropriate. Elimination of lime treatment as a result of the proposed project will eliminate significant traffic movements associated with lime imports and exports of limed sludge.
Water	<u>Surface Water</u> Crossness STW is situated on the southern bank of the Thames Tideway and north of the Crossness STW Southern Marshes (CSM), part of a wider area known as the 'Erith Marshes'. A series of ditch networks run adjacent to the STW site's southern and eastern boundaries. These ditches link Erith Marshes and Belvedere (including its industrial estates) to the south, the Thames Tideway to the north and the industrial works to the east. Groundwater sources at the site comprise of two minor aquifers (River Terrace Deposits and Thanet Sands) and a major aquifer (Chalk). <u>Flood Risk</u> The whole site is located within the EA's Indicative Floodplain. This indicates areas at risk from flooding from a 1 in 200 year return period tidal flood, or 1 in 100 year return period fluvial flood. However, the site is considered to be protected from flooding by the Tidal Thames Defence (TTD) flood protection walls, protecting against a 1 in 1000 year return period flood event. <u>Geology & Hydrogeology</u> A number of ground investigations on the STW site and surroundings had encountered peat and alluvial deposits.

J.3 Background - Riverside STW

Key Issues	Comment (Riverside STW)
Air Quality (incl. odour)	The entire LB Havering is an Air Quality Management Area based on Nitrogen dioxide (NO_2) and Particulate Matter < 10 µm (PM_{10}).
Cultural Heritage and Archaeological	There are no Scheduled Ancient Monuments, Listed Buildings, Conservation Areas, Registered Historic Parks and Gardens, Protected Wreck Sites, Ancient Woodland or Historic Battlefields present within the site or study area. The site does not lie in an Archaeology Protection Area.
Ecology	Disused sludge lagoons are located in the south and west of the operational STW site. These are designated as a Grade 2 Site of Borough Importance for Nature Conservation (SBINC). Rainham Marshes, a SSSI, lies approximately 1km east of the site.
Contaminated Land	The site has been used for sewage treatment and associated activities, thus giving the

Key Issues	Comment (Riverside STW)
	potential for contamination.
Landscape and visual	The Riverside STW occupies a site of approximately 24 hectares. It is characterised by typical sewage treatment plant and structures. These comprise concrete, brick and steel structures including inlet works, settlement tanks, aeration lanes, an existing blower house buildings and ancillary buildings. There is a network of concrete roads and areas of hard standing, interlaced with areas of amenity grass with a limited number of trees. Ancillary offices, parking and storage facilities are predominantly located to the north-east of the operational STW site. The surrounding landscape is predominantly flat and low-lying marshland. The character of the surrounding landscape is dominated by industry and commerce, with large industrial estates, depots, factories and works to the north, east and south of the STW. South-east of the STW, beyond the industrial areas, the open marsh character of the Rainham Marshes is more intact, leading down towards the River Thames.
Noise	The closest residential properties are at Creekside, which is adjacent to the northern boundary of the STW. Whilst now privately occupied, these properties were once part of the works and housed water company employees. Beyond the A1306, approximately 250m from the STW site boundary, is the residential area of South Hornchurch.
Traffic and Transport	Access to the site is via Lamson Road, off Ferry Lane. The access from Manor Way is no longer in use following the construction of the Channel Tunnel Rail Link. The A1306 lies to the north of the site and the A13 lies to the south.
Water	Rainham Creek runs north to south near the eastern STW boundary and there are other smaller surface water features both on the STW site and in its vicinity, including drainage channels leading to Rainham Creek, which flows into the River Thames. The Havering New Sewer is located outside the northern and western site boundary. The site lies in an area which is liable for flooding.

J.4 Background - Long Reach STW

Key Issues	Comment (Long Reach STW)
Air Quality (incl. odour)	Dartford Borough Council is designated as an Air Quality Management Area. Generally, the air quality is good and the majority of the borough is not expected to have any problems meeting the Government set Air Quality Objectives. A small area adjacent to the A282 Tunnel Approach Road is likely to have difficulties achieving the Objectives for nitrogen dioxide and fine particles. An Action Plan is being drawn up in order to improve air quality within the area. Pollution comes mainly from traffic emissions and the current reading for Dartford is low and has a pollution index of 1. The area surrounding the A282 Tunnel Approach Road (east of the site) has an index of 2. Dartford Council is concerned about odour from the Long Reach STW site which is mainly due to storage of limed cake from Crossness STW. The council has threatened an odour abatement notice at the site. Elimination of lime treatment and storage will therefore reduce this risk – though action may be required in the short term.
Cultural Heritage and Archaeological	There are no Scheduled Ancient Monuments, Listed Buildings, Conservation Areas, Registered Historic Parks and Gardens, Protected Wreck Sites, Ancient Woodland or Historic Battlefields present within the site or study area.

Key Issues	Comment (Long Reach STW)
	The site does not lie in an Archaeological priority area and there are no listed buildings on site.
Ecology	Dartford and Crayford Marshes together form the largest remnants of coastal grazing marsh without a statutory designation in Greater London. They hold significant amounts of the UK Biodiversity Action Plan ‘priority habitats’, including grazing marsh and mudflat. Dartford Marshes are designated as a Kent Site of Nature Conservation Interest, and parts of Dartford Marshes are within a Local Nature Reserve. The saltmarshes and tidal mudflats are also of key significance for the species they support. Populations of water voles recorded on all three marshes are nationally important, especially with the apparent absence of mink. The watercourses and banks are also inhabited by rare invertebrates. The areas support good populations of farmland and wetland birds and the River Thames is internationally significant for bird passage. The River Darent and the ditch network have a diverse range of fish, although the characteristic eel populations have undergone significant decline. There are no nationally designated ecological sites in the vicinity of the sewage works.
Contaminated Land	The site has been used for sewage treatment and associated activities, thus giving the potential for contamination.
Landscape and visual	Long Reach STW lies on the south bank of the tidal River Thames. The site lies adjacent to Dartford Salt Marshes to the west and to the north-west are Aveley, Wellington and Rainham marshes. The general area is fairly low lying in character. The Littlebrook Power Station and associate structures is present to the east of the sewage works.
Noise	In the immediate surroundings are; the River Thames to the north, Dartford Salt Marshes to the west, Littlebrook Power Station to the east and a disused hospital to the south. The closest residential area is approximately 750m south of the site.
Traffic and Transport	Vehicular access to the site is gained via the B-road Marsh Street which is off the A206 (Bob Dunn Way), a dual carriageway. This is the only vehicular access to the site. The main connections to the national motorway network are via the A206 which links to the M25 Motorway via the A282.
Water	Long Reach STW is located in East London on the south bank of the Thames. The likelihood of flooding from rivers or the sea in this area is low and unlikely to flood except in extreme circumstances. The area is at risk from flooding 0.5% each year (1 in 200 years). The site is protected by flood defences which reduces but does not eliminate the risk of flooding. The River Thames lies to the immediate north of the site and the River Darent lies approximately 1km west. The Dartford Salt Marshes contain an extensive system of drainage ditches.

Appendix K Planning Context

K.1 Introduction

This appendix identifies the local, regional and national planning policy and guidance relevant to the proposed options for provision of additional sludge treatment for sludge produced at Beckton and Crossness STWs.

As a number of the options considered in this report include transfer of raw sludge from Beckton STW to Riverside STW and from Crossness STW to Long Reach STW, the local planning guidance associated with these other STWs is also presented.

K.2 National planning policy

Planning policy at a national level is delivered through Planning Policy Guidance notes (PPGs) and Planning Policy Statements (PPSs). All regional and local planning documents should be in compliance with these guidance notes and statements. The key PPGs and PPSs of relevance to this SAR are identified below:

- PPS1: Delivering Sustainable Development (January 2005);
- PPS9: Biodiversity and Geological Conservation (August 2005);
- PPS10: Planning for Sustainable Waste Management (July 2005);
- PPG16: Archaeology and Planning (August 2001);
- PPS22: Renewable Energy (August 2004);
- PPS23: Planning and Pollution Control (November 2004); and
- PPS25: Development and Flood Risk (December 2006).

K.2.1 Planning Policy Statement 1: Delivering Sustainable Development (PPS1)

PPS1 sets out the Government overarching planning policies on the delivery of sustainable development through the planning system, including protecting the environment and using natural resources prudently.

In December 2007, a supplement to PPS1 specifically addressing Climate Change was published. This sets out how planning processes should contribute to reducing emissions and stabilising climate change. The document sets out key planning objectives and decision making principles for regional planning bodies.

The Beckton and Crossness STWs proposals could be considered to accord with the principles in PPS1 though contributing to sustainable economic development and ensuring that the essential infrastructure is provided to support existing and future communities and contributes to the creation of safe, sustainable, liveable communities. Furthermore, all options include generation of renewable energy and hence could be considered to contribute to reducing carbon emissions.

In PPS1, the Government requires planning authorities to ensure the achievement of high quality and inclusive design for all development, including individual buildings, public and private spaces and wider area development schemes. The Government encourages good design, which should:

- be integrated into the existing urban form and the natural and built environments; and
- be an integral part of the processes for ensuring successful, safe and inclusive villages, towns and cities.

In addition, paragraph 20 of PPS1 highlights *'development plan policies should take account of environmental issues such as:*

- *the management of waste in ways that protect the environment and human health,*

including producing less waste and using it as a resource wherever possible'.

The proposed schemes would provide the necessary capacity for the treatment and disposal of sludge arising from sewage treatment facilities serving over 5 million people in London. This issue is also addressed under PPS10 below.

K.2.2 Planning Policy Statement 9: Biodiversity and Geological Conservation (August 2005);

There are sites of nature conservation nearby such as the 20 hectare nature reserve on the eastern side of Crossness STW. Advice in paragraph 12 is that *'networks of natural habitats provide a valuable resource. They can link sites of biodiversity importance and provide routes or stepping stones for the migration, dispersal and genetic exchange of species in the wider environment. Local authorities should aim to maintain networks by avoiding or repairing the fragmentation and isolation of natural habitats through policies in plans'.*

Crossness STW lies within designated Metropolitan Open Land (MOL) and the adjacent nature reserve is an Area of Metropolitan Importance for Nature Conservation (and also a Site of Borough Importance for Nature Conservation). Hence, LB Bexley wishes to protect the Crossness STW site and associated nature reserve from further development.

There is an existing Thames footpath and cycle route within MOL which passes along the Thames to the north of Crossness STW.

Some options involve construction at Long Reach STW which is classed as a Thames Water Biodiversity site. The biodiversity schedule lists two specific areas of interest through it is considered that neither would be affected by the options being considered in this SAR for the provision of additional sludge treatment infrastructure at the STW[16].

K.2.3 Planning Policy Statement 10: Planning for Sustainable Waste Management (PPS10)

The Beckton STW and Crossness STW proposals need to take account of the requirements of PPS10 and the National Waste Strategy 2007. The quantities of sludge generated at Beckton and Crossness STWs will increase in the future and will require treatment.

[16] See Thames Water report "PR09 Sludge Asset Report – Long Reach STW" (S1161 F907 Long Reach Sludge Report.doc)

Processes which allowed beneficial recycling of treated sludge products (e.g. to agricultural land) are higher on the Waste Hierarchy and would be preferable to landfilling. However, there are limits to both agricultural land bank availability and opportunities for recycling incinerator ash as a building material. At least, TWUL should aim to minimise the amount of waste ash sent to landfill.

The Beckton and Crossness STWs proposals would need to demonstrate that they comply with local and regional waste policies such as the Mayors' Municipal Waste Strategy (see below). Transfer of more than 10,000 m^3/year of sludge cake between sewage treatment works (e.g. from Crossness STW to Long Reach STW) would fall under Waste Management legislation and require a licence from the EA (the waste management authority).

A Waste Management Plan (WMP) covering construction stage activities would also be produced for both schemes. WMPs became mandatory for all construction projects over £250,000 on the 6th April 2008, under Section 54 of the Clean Neighbourhood and Environment Act 2005.

K.2.4 Planning Policy Guidance Note 15: Planning and the Historic Environment (PPG15)

PPG15 states that developments close to, but outside a Conservation Area, which would affect views into or out of the area, should be a material consideration in determining development applications. It also states that, when considering planning applications, detailed plans and drawings of proposed new development are required.

There are two line of sight views from landscape features and historic positions, such as the Eaglesfield Recreation Ground to Bexley and Lower Thames; the view from Beckton Alps (Newham) East London panorama. These view cross in the middle of the site.

The Crossness STW proposals would be near the Crossness Beam Engine House, a Grade I Listed Building on this site and within a Conservation Area. New plant or buildings at Crossness STW would need to be in keeping with the modern landmark design of the existing Crossness SPG building.

K.2.5 Planning Policy Guidance 16: Archaeology and Planning (PPG16)

Paragraph 12 states that '*when important remains are known to exist or when archaeologists have good reason to believe that important remains exist, developers will be able to help by preparing sympathetic designs using, for example, foundations which avoid disturbing the remains altogether or minimise damage by raising ground levels under a proposed new structure, or by the careful siting of landscaped or open areas. There are techniques available for sealing archaeological remains underneath buildings or landscaping, thus securing their preservation for the future even though they remain inaccessible for the time being.*'

All sludge treatment infrastructure options may involve substantial underground excavation for sludge treatment facilities. Crossness STW is located within an Area of Archaeological Search.

K.2.6 Planning Policy Statement 22: Renewable Energy (PPS22)

The Government policy on renewable energy is set out in PPS22, which states '*Increased development of renewable energy resources is vital to facilitating the delivery of the Government's commitments on both climate change and renewable energy.*'

PPS22 also states that when making planning decisions on proposed developments, the planning authorities should take into account '*special circumstances, which may include the wider environmental benefits associated with increased production of energy from renewable sources'.*

Renewable energy requirements are considered further in sections of the London Plan below.

K.2.7 Planning Policy Statement 23: Planning and Pollution Control (PPS23)

This policy statement outlines the relationship between the planning system and pollution control. Paragraph 11 states that '*close co-ordination between planning authorities, transport authorities and pollution control regulators is essential to meet the common objective that where development takes place, it is sustainable.'*

Advice in paragraph 17 is that '*where land is affected by contamination, development can provide an opportunity to address the problem for the benefit of the wider community and bring the land back into beneficial use.*' The proposals at Crossness may seek to utilise land to the east of the existing Sludge Powered Generator that was formerly used as sewage lagoons, which is contaminated.

Advice in paragraph 20 is that PPS23 Annex 2: Development on Land Affected by Contamination gives brief details of the roles of the different parties in the development process, on the relationship between planning control and the contaminated land regime and on the requirements and good practice in dealing with these issues through planning control.

Advice in paragraph 26 highlights the local authority responsibilities for integrating land use planning with plans and strategies for the control, mitigation and removal of pollution. Contaminated land is defined by the Environment Act 1995 in terms of substances in, on, or under land where significant harm is or would be caused. The Act sets down a regime for dealing with contaminated land, to treat past contamination problems and prevent its occurrence in the future.

K.2.8 Planning Policy Statement 25: Development and Flood Risk (PPS25)

PPS25 on development and flood risk was published in December 2006. The policy states that flood risk should be considered as part of any planning application in order to limit risk of future damage to property and life due to flooding. Paragraph 3 of the background to the guidance states that: *"All forms of flooding and their impact on the natural and built environment are material planning considerations. Planning Policy Statement 1: Delivering Sustainable Development sets out the Government's objectives for the planning system, and how planning should facilitate and promote sustainable patterns of development, avoiding flood risk and accommodating the impacts of climate change."*

In relation to development control decisions, advice in paragraph 26 seeks to ensure that *'local planning authorities (LPAs), advised by the Environment Agency and other relevant organisations, should determine applications for planning permission taking account of all material considerations, including the issue of flood risk, the Flood Risk Assessments (FRA) prepared by the developer (when required) and proposals for reducing or managing that risk'*.

All sites affected by the options fall within flood zones, since they are both located close to the River Thames. Flood risk assessments would be carried out and the results would inform the design of the tanks and other structures required. The EA may require flood compensation for the volume of the new structures.

K.3 Regional Planning Policy

The key regional planning documents of relevance to the Beckton and Crossness STWs proposals are the adopted London Plan (February 2008), the Mayor's Energy Strategy, the Mayor's Waste Strategy and the East London Sub-regional Development Framework.

K.3.1 The London Plan (LP)

The London Plan (LP) functions as regional planning policy. It is a statutory document that has development plan status and forms a primary policy document for assessing development applications. It was adopted in February 2008 (with consolidated alterations since 2004) and sets the direction for local planning policy, (developed by London Borough Councils). The most relevant proposals are:

- Objective 3: to make London a more prosperous city with strong and diverse long term economic growth; and
- Objective 6: to make London an exemplary world city in mitigating and adapting to climate change and a more attractive, well-designed and 'green' city.

Options for additional sludge treatment capacity will generally accord with these objectives though different options will have varying carbon footprints. The proposed developments would support sustainable economic growth in the London area by providing essential infrastructure.

Sustainable development

Policy 2A.1 (Sustainability criteria) states criteria to be used in developing sub-regional development frameworks and to be considered in UDPs and planning applications. These include:

- using a design-led approach to optimise the potential of sites and improve the quality of life; and
- ensuring that development takes account of the capacity of existing or planned infrastructure including public transport, utilities and community infrastructure.

The various options would have differing local traffic impacts depending on the volume of treated sludge product generated.

Improving the Use of Energy

LP policy 4A.7 (Renewable Energy) states that the Mayor's Climate Change Mitigation and Energy Strategy which includes *'facilitating and encouraging the use of all forms of renewable energy where appropriate, and giving consideration to the impact of new development on existing renewable energy schemes'*.

This policy also states '*The Mayor will [...] adopt a presumption that developments will achieve a reduction in carbon dioxide emissions of 20% from on site renewable energy generation (which can include sources of decentralised renewable energy) unless it can be demonstrated that such provision is not feasible*'.

As noted previously, the proposed options include power generation using biogas powered CHP engines and steam turbines. There is also the potential to use waste heat from the biodiesel engines installed under the Thames Gateway Water Treatment Plant at Beckton. However, the options vary in the quantity of renewable energy generated and the energy consumed by the treatment process.

Improving Water and Sewage Infrastructure

LP policy 4A.18 (Water and sewage infrastructure) states that *'the Mayor expects developers and local planning authorities to work together with water supply and sewerage companies to enable the inspection, repair or replacement of water supply and sewerage infrastructure. Water and wastewater infrastructure requirements should be put in place in tandem with planned growth to avoid adverse environmental impacts'.*

With regards to provision of additional sludge treatment capacity, LP policy 4A.18 states that *'additional capacity for the management of sewage sludge will be needed over the plan period to meet the requirements of growth and tighter environmental standards. The Mayor will work in partnership with the boroughs to ensure timely provision of appropriate new facilities at existing sewage treatment works within London'.*

Advice in LP paragraph 4.52 is that *'in March 2007 the government announced that Thames Water would build an overflow sewer tunnel to comprehensively address the long term problems of sewage overflows into the River Thames and Lower River Lee. The project will be constructed in two phases, the first phase being from the Lee Valley to Beckton Waste Water Treatment Works. The second phase will be from Hammersmith to Beckton. The project will involve a large diameter sewer tunnel with connecting shafts, access shafts, the expansion of Beckton Waste Water Treatment Works and an increase in the capacity for sewage sludge treatment at Beckton. The Mayor supports the timely implementation of the project, which is expected to take up to 2020. Boroughs will need to resolve local matters, for example, design, construction, traffic management, remediation and mitigation. The project directly affects some 12 London boroughs. The principle of the project is strategically important to delivering a more sustainable London'.*

One of the principles to the Blue Ribbon Network (Rivers/canals/streams) in paragraph 4.140 is that '*London must also have reliable and sustainable supplies of water and methods of sewage disposal and a precautionary approach must be taken to the risks created by global warming and the potential for flooding'*. Advice in LP policy 4A.14 is that '*the Mayor will encourage multi agency collaboration (GLA Group, Environment Agency, Thames Water) to identify sustainable solutions to strategic surface water and combined sewer drainage flooding/overflows*'.

K.3.2 The Mayor’s Energy Strategy (2004)

The Mayor’s policy, as stated within the Energy Strategy, is that “*To contribute to meeting London’s targets for the generation of renewable energy, the Mayor will expect applications referable to him to generate at least 10% of the site’s energy needs (power and heat) from renewable energy on the site where feasible*”.

Further relevant proposals included the following - Proposal 6, “*London should generate at least 665GWh of electricity and 280GWh of heat, from up to 40,000 renewable energy schemes by 2010. [...] To help achieve this, London should install [...] more anaerobic digestion plants with energy recovery and biomass-fuelled combined heat and power plants.*”

K.3.3 The Mayor’s Municipal Waste Management Strategy: Rethinking Rubbish in London (September 2003)

The Mayor’s Municipal Waste Strategy document of 2004, makes a number of statements relevant to this study.

The following proposals outline the GLA’s view towards Anaerobic Digestion (AD) plant:

Proposal 29: ‘*The Mayor will support proposals for and work with key stakeholders to introduce new and emerging advanced conversion technologies for waste (for example, anaerobic digestion, gasification or pyrolysis) which satisfy the requirements of the Renewables Obligation Order 2002, supplying electric power and wherever possible also heat, and minimise the quantity of hazardous solid residues.’*

Proposal 31: ‘*The Mayor will encourage the development of anaerobic digestion plants, which treat segregated biodegradable waste and produce a digestate suitable for agricultural and horticultural use.*’

There is also a direct reference to the potential re-use of the anaerobic digestion assets at both Beckton and Crossness STWs (Paragraph 4E.19).

Paragraph 4E.19 states that *‘anaerobic digestion was use in London for many years for the treatment of sewage sludge prior to the dumping of the residue at sea. When sea disposal was discontinued in 1998 the two East London anaerobic digestion plants were no longer needed and have remained idle since then. However, part of the plant could be converted for the digestion of biodegradable waste at lower cost than the construction of new facilities. The main sites are at Beckton in the London Borough of Newham and Crossness in the London Borough of Bexley’.*

With respect to incineration plants the Mayor’s Strategy also states in paragraph 3.59 that *‘the inclusion of equalities issues within waste management is an underdeveloped but evolving agenda. One of the few examples is the report of the Select Committee on Environment, Transport and Regional Affairs in their Fifth Report Delivering Sustainable Waste Management. The Committee was concerned that incineration plants ‘...may end up in those areas where it is anticipated that resistance will be least. In practice, this is likely to be poorer areas…’*

Advice in paragraph 4Q.18 is that the 'Fifth Report' also emphasised that *'important factors affecting the location for an incinerator should include that they are best able to meet the demand for heat and power. It should be ensured that there is an open process when siting facilities and that communities are publicly funded to examine the details of proposals, thus ensuring that there are no inequalities in the siting of facilities'*.

The Mayor of London would expect boroughs to apply these policy provisions in considering development projects. UDP policies should also adopt the following criteria in selecting sites for waste management and disposal:

- proximity to source of waste;
- the nature of the activity proposed and its scale;
- the environmental impact on surrounding areas, particularly noise, emissions, odour and visual impact;
- the transport impact, particularly the use of rail and water transport; and
- using sites that are located in industrial areas and on existing waste management locations.

K.4 Local Planning Policy

K.4.1 LB Bexley Adopted Unitary Development Plan

The LB Bexley has an adopted Unitary Development Plan (UDP) (adopted 24 April 2004), which is a material planning consideration and therefore must be taken into account in determining applications for development. The Crossness STW is located on land designated on the UDP proposals map as Metropolitan Open Land which is also a Site of Borough Importance for Nature Conservation (SBINC).

Policy ENV15 states that *'within Metropolitan Open Land, there will be a presumption against permitting the construction of new buildings, or the change of use of land or buildings for purposes other than other uses which would maintain the open character or visual amenities of Metropolitan Open Land'*. Hence, any proposed construction at Crossness would need to be sensitively designed in order to match the modern landmark design of the existing SPG building and to enhance the character and appearance of the area.

The advice in Policy ENV 24 is that *'in the Sites of Borough Importance for Nature Conservation,(such as Crossness) the Council will have particular regard to the effects of development on wildlife habitats, or the need to protect rare species. Planning permission may be refused if development is likely to cause the loss of a valuable habitat or conditions will be used, where appropriate, to protect, enhance, create or restore habitats'*. Options for new infrastructure at Crossness would be on land within the Crossness site and are considered unlikely to result in any serious or unacceptable loss of habitat. Furthermore, there is a 20 hectare nature reserve on the eastern boundary of the site, which would adequately compensate for any loss of habitant on the existing site.

Crossness STW is considered UDP under policy TS16 which states that *'the Council will prepare a Planning Brief to consider a redevelopment compatible with surrounding land uses; promote the extension of the riverside public footpath and the conservation and enhancement of the Crossness Beam Engine House; and all proposals for development should comply with the provisions of Policy ENV23 and make a positive contribution to the management, in the interests of nature conservation, of the sewage works and its surroundings.'*

UDP under policy TS17 *'the Council will have regard to the following:*

1. *the requirement for Thames Water to enhance and modernise its facilities in line with government directives;*
2. *the need to reduce significant adverse environmental impacts, such as airborne or waterborne pollution, noise, smells and unreasonable traffic generation;*
3. *the need to ensure that development in that part of the area designated as Metropolitan Open Land minimises the impact on the predominantly open character of the land; and*
4. *the need to minimise the effects of development on wildlife habitats and the need to protect rare species'.*

K.4.2 LB Newham Adopted Unitary Development Plan

The LB Newham has an adopted Unitary Development Plan (UDP) (with saved policies beyond 2007), which is a material planning consideration and therefore must be taken into account in determining applications for development. The Beckton STW is located on land designated on the UDP proposals map as Metropolitan Open Land which is also a Site of Nature Conservation Importance (SNCI).

Advice in paragraph 3.46 is that *'developers are requested to identify the nature and extent of the existing wildlife resource by carrying out appropriate surveys of flora and fauna during the field season and before developing proposals for the site. Mitigation measures to ensure the conservation or enhancement of the site's biodiversity should be included as an integral part of any proposal for development of the site. Habitats preserved, enhanced, created or relocated as a result of development will be protected and the provisions of Policy EQ9 will apply to them'.*

The Beckton STW proposals would not significantly affect the habitats within the site including the protected Site of Nature Conservation Importance (SNCI) bordering the site to the east along Barking Creek. There is normally a presumption against development as outlined in Appendix AQ1 on *'protected sites of nature conservation importance where development will not be permitted'* which lists Beckton STW's non-operational land at Northern Lagoon.

Advice in paragraph 3.46 is that *'with regard to railside land, sewage works and water transport facilities already located on or adjoining SNCIs listed in Appendix 2, applications for improvements or redevelopment necessary for continued operational use of the land will normally be permitted as the Council recognises the primary role of such land in the provision of important public services'.*

Policy EQ57 seeks to control the disposal of hazardous waste by imposing strict planning conditions. Advice in paragraph 3.147 is that *'the Council recognises that waste (including sewage sludge) must be dealt with efficiently to minimise the environmental impact associated with its transfer, processing storage and disposal. In addition, effective waste management can help reduce the amount of land needed for landfill and promote recycling'.*

Policy EQ62 seeks to flood risk protection and advice in paragraph 3.159 is that '*Newham's flood plains are defined by the Environment Agency. In areas where flood information is unavailable, but where the Environment Agency suspects there is a risk of flooding, developers will be expected to evaluate the flood risk and identify measures to mitigate such risk on site and elsewhere*'.

Flood risk assessments would be carried out since the site falls within a flood zone close to the River Thames and the results would inform the design of the tanks and other structures required. The EA may require flood compensation for the volume of the new structures.

Policy S4 of the London Borough of Newham (LBN) UDP states that development proposals will be assessed in terms of how they are compatible with the aims of sustainable development, including '*detailed project design, building materials, the environmental impact and mitigation of construction activities, the re-use and recycling of excavated material and construction waste and the energy efficiency of the operational proposals*.'

This policy is developed further by Policy S9, which states '*high standards of design that address function and appearance will be required in all new development… Community safety and energy efficiency considerations will also be required to be addressed in the siting and layout and orientation of new development*'.

Beckton STW falls within the London Thames Gateway Development Corporation (LTGDC) area, and therefore any major applications for new development in this area will be determined by them. The purposes, powers and responsibilities of the LTGDC are explained in more detail at the end of Section 10, Implementation and Monitoring of the Core Strategy and Development Control Policies Development Plan Document, and its boundary is shown in Figure 2 of the Core Strategy.

K.4.3 Dartford Borough Council

Long Reach STW is located to the east of Dartford Marshes, which are designated as Metropolitan Green Belt and also as a Site of Local Nature Conservation Interest. The site is adjacent to Littlebrook Power Station located to the east of the Dartford crossing at the Queen Elizabeth II Bridge. The land to the south of the site is designated for Employment and Economic Development uses. The land to the south-west is designated for the provision of Community Facilities. Long Reach STW treats the sewage from a 'population equivalent' of nearly 1 million people.

It is considered that the Long Reach STW are 'essential facilities' under policy GB2 (New Buildings in the Green Belt), which can be located within the Green Belt as stated in paragraph 6.5.2 of the Dartford Local Plan Review Second Deposit Draft (2004), which states that these should *'should be genuinely required for uses of land which preserve the openness of the Green Belt and do not conflict with the purposes of including land within it'.*

Advice in paragraph 13.3.6 of the Dartford Local Plan Review Second Deposit Draft (2004) is that *'the character of the western end of the riverside frontage within Dartford Borough is open grazing marsh. Eastwards, the character changes to one of a more industrial nature - the Longreach Sewage Treatment Works and the Littlebrook Power Station. The Dartford Crossing, the associated infrastructure and movement of traffic are the dominating features approximately mid way along the Dartford stretch of the Thames'*. It is considered that the proposals at Long Reach would be consistent with the overall objectives of the landscape character along the Thames riverside.

The Dartford Local Plan Review Second Deposit Draft (2004) gives strong protection to nature conservation areas such as Dartford Marshes and states under 'Natural Environment' in paragraph 13.9.2 that *'the ecology and nature conservation value must be fully taken into account in any proposals for landscape enhancement of green spaces, particularly in areas of marshland, such as Dartford Marshes, where tree planting would be inappropriate, for example. The foreshore and inter-tidal zone have a particular importance for nature conservation'*. It is considered that the proposals at Long Reach would be consistent with the requirements of policy TR5 on Nature Conservation, since there would be no landtake from Dartford Marshes which is also a Thames Water Biodiversity site.

The Kent and Medway Structure Plan (2006) states in paragraph 4.37 that one of the ten functions of the urban-rural fringe is that *'the countryside around towns plays an important part in the sustainable management of the waste, water and pollution generated in urban areas'*. It is considered that the proposals at Long Reach would be consistent with the requirements of policy EN11 (Planning and Managing the Urban Fringe), since sludge would be managed more efficiently.

The Kent and Medway Structure Plan (2006) policy NR9 (Water Supply and Wastewater Treatment) seeks to ensure that *'land required for expanded or new facilities for water resource management or wastewater treatment will be identified and safeguarded in Local Development Documents'*.

K.4.4 LB Havering

The LB Havering has an adopted Unitary Development Plan (UDP) (with saved policies beyond 2007), which is a material planning consideration and therefore must be taken into account in determining applications for development. TWUL's Riverside STW is the main wastewater treatment works for Havering Borough and serves a population equivalent of approximately 400,000. Riverside STW is one of TWUL's main strategic operational STWs for dealing with wastewater in London.

An upgrade of Riverside STW is required in order to comply with a new Environment Agency discharge consent for the works. The Riverside STW will need to be increased to the west of the works as it currently forms part of the existing operational site and was previously used for the sewage treatment processes. This area has small scrub vegetation and has previously been used for landfill. New SWT plant and equipment would be located adjacent to existing site, in order to facilitate efficient operations.

The Riverside STW is located within an area designated in the UDP as Rainham Employment Area under policy EMP1, to the east of Rainham Creek, with the railway line to the north and the new A13 trunk road to the south. Nearby land-uses include Fairview industrial estate to the south, the Midlands industrial estate to the north across the railway line and Albright industrial estate to the east across Rainham Creek.

Havering's Local Development Framework (LDF) is a portfolio of different documents which will set out the future planning of the borough up to 2020. Following Examinations in 2007, a Planning Inspector has decided that all three of the following documents, the Core Strategy, Development Control Policies and Site Specific Allocations are 'sound', subject to her recommendations.

The area identified for the Riverside STW upgrade/expansion is part of a larger area to the west and south of the site that is designated on the Core Strategy DPD proposals map as a Borough Site of Nature Conservation Importance. This land is not considered to be of a particularly high environmental quality for nature conservation.

The Core Strategy policy CP15 (Environmental Management) seeks to ensure that new development should *'reduce their environmental impact and to address the causes and adapt to and mitigate the affects of climate change in their location, construction and use; have a sustainable water supply and drainage infrastructure; and take the necessary measures to address contaminated land issues'*.

The Development Control Policies DPD policy DC9 (Strategic Industrial Locations) considers that waste uses are acceptable in these locations, such as Rainham Employment *Area (which was designated EMP1 in the UDP).*

The Development Control Policies DPD policy DC51 (Water Supply, Drainage and Quality) seeks to ensure that *'development or expansion of water supply or waste water facilities necessary to serve existing or planned future development will need to ensure that there is no adverse impact on other land uses or the environment'*. The sludge treatment options at Riverside will safeguard the environment and will also come under the Environmental Permit (Pollution Prevention & Control – PPC) licensing scheme as they will have over 3MW of thermal input.

The Development Control Policies DPD policy DC58 (Biodiversity and Geodiversity) states that planning permission for development that adversely affects a Borough Site of Nature Conservation Importance *'will not be granted unless the economic or social benefits of the proposals clearly outweigh the nature conservation importance of the site and only then if adequate mitigation can be provided and no alternative site is available'*.

Appendix L Technology Options (including alternative technologies and waste streams)

This appendix provides further description of the processes used within the proposed options evaluated for this SAR. It also describes alternative technologies and waste streams that, although not promoted in this study, should be considered further in future studies.

L.1 Overview

This SAR report focuses on options for delivery of the additional capacity required to be completed and commissioned for year 1 of AMP 6. However, future technology options – such as alternative treatment processes and co-treatment with alternative waste streams – are also considered in outline to ensure that, where feasible, the preferred options identified by the SAR for delivery in AMP 5 and AMP 6 do not preclude adoption of beneficial alternative processes at some later date.

In the long term existing incineration at both sites could be replaced by new and upcoming technologies such as gasification and pyrolysis. However, currently, these technologies are not utilised at full scale for wastewater sludge and therefore do not have a proven track record. Furthermore, the long lead in times associated with new SPGs, their cost, and length of operational life once they are commissioned makes the replacement of incineration with alternative processes such as gasification unlikely within the time period covered by the Sludge Strategy. However, if options producing an enhanced digested cake are adopted for this SAR then this will provide greater flexibility for addition of alternative processes such as gasification in the future.

TWUL's Sludge Strategy considers predicted needs up to 2035, over a 10 year and 25 year horizon. Towards the end of the 10-year period (2017-2018) TWUL proposes to undertake a further strategic review of the sludge management needs across the region in order to inform the next 15-year investment programme (from 2020 to 2035). This review is expected to also consider progress in the development of alternative sludge treatment technologies.

Co-digestion of other waste types along with wastewater sludge may be a commercially attractive option. Co-digestion of other waste streams – such as food waste – provides an additional source of volatile organic matter that can be converted to biogas. Electrical energy produced from the co-digested portion of the biogas will be eligible for more ROCs than biogas from sewage sludge (post 2011, 2 ROCs/kWh compared to 0.5 ROCs/kWh). However, there are issues associated with using core assets (digesters and associated plant) for such activities – for example, funding for provision or maintenance of any additional assets not required for sewage treatment alone. There are also waste licensing implications attached to mixing wastewater sludge with food waste.

L.2 Processes used in options considered for this SAR

L.2.1 Enhanced digestion

Anaerobic digestion preceded by pre-treatment is referred to in this report as enhanced digestion (ED).

Anaerobic digestion (AD) is commonly used worldwide for treatment of sewage sludge. Its efficiency, when assessed on the basis of destruction of volatile matter (VM) varies significantly depending not only on the operational parameters but also on the type and composition of sludge. Secondary sludge generated by activated sludge systems (as in Beckton STW and Crossness STW) is known to be less amenable to digestion than other types of sludge, such as primary sludge. In conventional digesters approximately 30% of secondary VM can be destroyed compared to 50% of VM present in primary sludge. With final effluent discharge requirements becoming more stringent, the proportion of secondary sludge in sludge generated by wastewater treatment works increases. Secondary sludge constitutes about 40% of the total sludge generated at Beckton STW and about 35% at Crossness STW [17].

The higher the VM destruction, the lower the amount of solids to be disposed of and the higher the production of biogas. The calorific value of the sludge does however decrease as a result of digestion. This makes digested sludge a less attractive feedstock for processes such as such as incineration. The nutrient content (nitrogen in particular) of the sludge is also depleted as a result of digestion, resulting in decreased fertiliser value of the sludge but enabling the maintenance of relatively high sludge dosing rates per hectare of agricultural land. This is important if the increasingly stringent requirements of the Nitrate Directive are to be met.

The performance of AD can be substantially improved by pre-treatment processes which make the sludge (surplus activated sludge in particular) more amenable to digestion – thus greatly increasing solids destruction and biogas production. Increased degree of disinfection and improved dewatering properties are other benefits of some of these pre-treatment processes.

There are many types of pre-treatment methods which can be classified into biological, thermal, chemical, physical or combinations of these. Some pre-treatment methods are more effective than others. TWUL carried out an extensive review of various pre-treatment processes (Sludge Technology Review, December 2007). The table below concentrates on the few that increase the solids destruction as well as the overall degree of disinfection. The table also summarises the performance of the pre-treatment methods in terms of VM reduction and achievable sludge standards.

[17] Percentages based on monitoring data provided by TWUL. In MM's experience, these values are considered to be relatively low compared to typical values for other wastewater treatment plants.

Table L.1: Summary Performance of AD plants with pre-treatment

Pre-treatment	VM Reduction %	Sludge standard[a]	Other benefits
None (conventional mesophilic AD)	40 to 45	None	-
Homogenisation (Crown, Bugbuster)	~ 60	Conventional	
Acid phase digestion (APD) - single tank at 35°C	~ 50 to 55	Conventional	-
Enzymic hydrolysis (EH) - Monsal six-tank system at 42°C	~ 55 to 60	Conventional	- Possible small improvement in dewaterability of digested sludge.
Monsal EEH three + three tank system at 42°C and 55°C	~ 55 to 60	Enhanced	
TPAD/ASTM[b] systems at 55°C to 60°C	~ 55 to 60	Enhanced	-
Thermal Hydrolysis plant (THP) (Cambi, Biothelys) at 165°C for 30 mins	~ 60 to 65	Enhanced	- Dewaterability of digested sludge is greatly improved. - Capacity of existing digesters may be increased by factor of two or so

Note

a) ‘Conventionally-treated’ and ‘enhanced-treated’ refer to the standards given in the UK draft regulations for use of sludge in agriculture.

b) ASTM - Anaerobic Stabilisation Thermophilic/Mesophilic (Germany) and TPAD - Temperature-Phased Anaerobic Digestion (USA)

With regard to VM reduction, all the pre treatment methods work in a similar way; the hydrolysis of the organic solids is carried out in the pre treatment reactor, although the biological and thermal mechanisms are different. THP also shears the sludge, which may have additional benefits in that it causes lyses of bacterial cells. In all cases, the increased pathogen kill is obtained using the pasteurisation principle, possibly enhanced by low pH values in the mesophilic biological pre treatment.

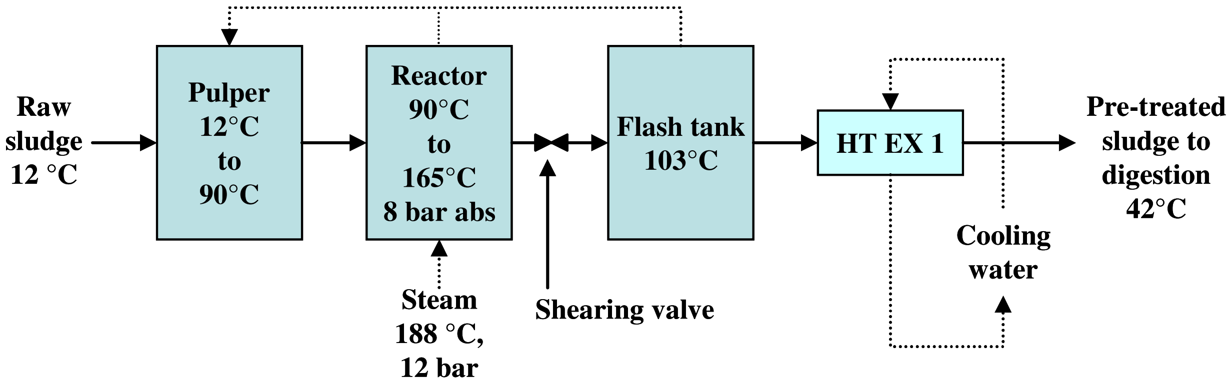
The increased biogas produced is cost-effectively consumed in CHP systems producing exportable electricity and heat. In all the pre-treatment methods listed in the table above, apart from THP, the heat generated by the CHP is sufficient to meet treatment needs. Supplementary fuel would be required for THP plants.

As identified in Section 5.1, THP was selected as the preferred pre-treatment process for enhanced digestion for this study.

Thermal pre-treatment promotes hydrolysis and acidification, which are rate limiting steps in conventional anaerobic digestion. Pre-treatment produces hydrolysis products and volatile fatty acids (VFAs) which are readily decomposed in the digesters.

THP is described below using the Cambi process as an example. The diagram below shows the pre treatment as comprising three stages, each with a capacity of about 1.5 hours sludge production. The stages operate batch wise in a cycle. The cycle involves flashing steam from batches of sludge in the Reactor and Flash Tank to the next batch of sludge in the Pulper. In this way, some of the heat is recycled. Batches of sludge are hydrolysed in the Reactor at 165°C for around 30 minutes.

Figure L.1: Diagram of Thermal Pre-treatment System



The steam injected into the Reactor is the single source of heat used by the pre-treatment process, apart from pumping losses. Most of this heat is sourced from the exhaust of the CHP engine, although some has to be sourced directly from supplementary fuel, either biogas or fossil fuel[18].

The Pulper produces an off-gas that contains no methane but is highly odorous owing mainly to the presence of volatile organics. This off-gas is treated by transferring it to digesters where most of the odorous compounds in the off-gas dissolve in the sludge and are then biologically destroyed.

Not only is THP effective at increasing solids destruction in downstream digesters but it also radically changes the rheological properties of the sludge, allowing mixed sludge at solids' concentrations of up to 12 w/w% to be digested. Furthermore, THP considerably improves the dewatering properties of the digested sludge, allowing the production of sludge cake at solids' concentrations of over 30 w/w%. 31%DS has been assumed in the process calculations, which form the basis of cost estimations for this study.

As a result of increased VM destruction during digestion, it is expected that there will be an ammonia load in the liquors separated from the sludge during dewatering (especially where digested sludge is predominantly made up of secondary sludge). As the sludge liquors will be returned to the main wastewater treatment process, more investigation would be needed to determine the available treatment headroom in the existing wastewater treatment plants. To err on the safe side, the cost estimates for all ED options include costs of dedicated sludge liquor treatment using the SHARON process.

[18] Alternative solutions, such as use of steam from the incinerators in THP and use of biogas for purposes other than CHP (e.g. biogas cleaning and export to the natural gas grid) could be considered if feasible and cost-effective.

Given the current state of development, the THP pre-treatment system can handle mixed sludges at DS concentrations up to 16 w/w% [19] although the sludge has to be diluted with water to a DS concentration less than 12 w/w% before entering the digester. THP can handle such thick sludge because the treatment changes the rheological properties of the sludge, making the it more fluid.

Injecting steam into the sludge for heating provides some dilution, reducing the DS concentration by about 2 w/w%. The dilution water may be potable water or treated effluent.

It is recommended that retention time in digesters downstream of THP is a minimum of 14 days.

The heating requirement for THP is higher than for biological pre-treatment methods (such as the enzymic hydrolysis), since the sludge has to be heated to a much higher temperature, even though much of the heat is recovered through steam flashing. Furthermore, not all the waste heat produced by the CHP engine is available to the THP, since only the heat extracted from the exhaust gas can be used to raise steam, although some jacket heat is used to heat the boiler feed water.

The net effect is that the THP usually requires supplementary fuel for raising steam; the fuel may be biogas or fossil fuel. The amount of supplementary fuel depends on several factors, of which the most important is the DS concentration of the feed sludge and the specific design of the CHP engine. Supplementary fuel requirement is typically 15% to 25% of biogas production.

The following tables list the sites where thermal hydrolysis has been implemented or is under construction.

L.2.2 Mass-burn incineration

The existing SPGs at both Beckton and Crossness STWs provide mass-burn incineration of raw cake.

Both SPGs have similar processes: thickened raw sludge from the sewage treatment processes is first dewatered using plate filter presses and then burnt in fluidised bed furnaces with energy recovery (steam turbine), ash recovery and flue gas treatment (including further ash and heavy metal recovery systems). Resulting liquid effluents are sent to the STW inlet works for treatment.

Options evaluated under this study include rehabilitation and modification of the existing SPGs at Beckton and Crossness STWs as well as provision of additional raw sludge incineration capacity.

BAMAG GmbH has provided outline design details for options where additional mass-burn incineration capacity is proposed (options 2.0 and 2.3). The following is a summary of the proposed process. Figure L.2 provides a sketch of the proposed process.

The proposed plant would be designed to incinerate sewage sludge and would comply with 2000/76/EC emissions standards.

Each plant would normally consist of two or more incineration lines, each including sludge storage, drying, incineration, waste heat recovery and flue gas cleaning. In addition, there would be common equipment such as the steam turbine, scrubber effluent treatment plant, ash silos, stack and utilities.

Each plant would include the following main process stages items:

[19] The higher the DS concentration in the sludge fed to THP, the lower the energy requirement of the process.

Sludge silo – 2 Nr, containing agitators to ensure a homogenous sludge mix.

Dewatering – the option design assumed centrifuges but could also use Klampresses or similar.

Buffer Silo - for dewatered cake.

Thermal dryer – a sludge dryer will dry the sludge up to the point where the incineration will take place autothermic - normally in the range of 28 – 35%DS. Sludge drying can be accomplished in a rotary disc dryer or in a thin film dryer using the steam from the steam boiler or the backpressure steam from the turbine. The dryer is a horizontal unit consisting of several sections heated with steam.

Vapour Condenser - The vapours from the dryer are condensed with cooling water in the vapour condenser. The air is separated from the vapours in the condenser and routed to the incinerator. The resulting condensate is routed back to the STW for further treatment.

Sludge feeding system - Dried cake from the thermal dryer is discharged to a sludge rotary feeder. This sludge feeder is equipped with a fast rotating adjustable paddle that throws the sludge into the incinerator and distributes it over the fluidised bed. The shaft of the sludge feeder is cooled by cooling water.

Fluidized bed furnace - The fluidised bed incinerator would be designed to incinerate municipal sewage sludge. The range of economic operation will allow controlled throughput of the incinerator as specified, down to 70% of maximum flow. Below this level additional excess air would be necessary to maintain fluidisation. The sludge lumps fed to the fluidised bed disintegrate: The contained water evaporates, and the sludge then ignites and the volatile components burn during the retention time of the ash and flue gases in the combustion zone. The flue gas (containing ash) leaves the incinerator at the top.

Waste heat boiler - Flue gas leaving the incinerator will be drawn through a dedicated waste heat recovery system in which it will be cooled from its normal inlet temperature of 870°C – 920°C to a temperature of approximately 180 - 2000C. The recovered heat in the form of high pressure steam is used to run a steam turbine.

Heat recovery / Turbine – the high pressure steam from the waste heat boilers is routed to the steam turbine connected to a generator for electricity production.

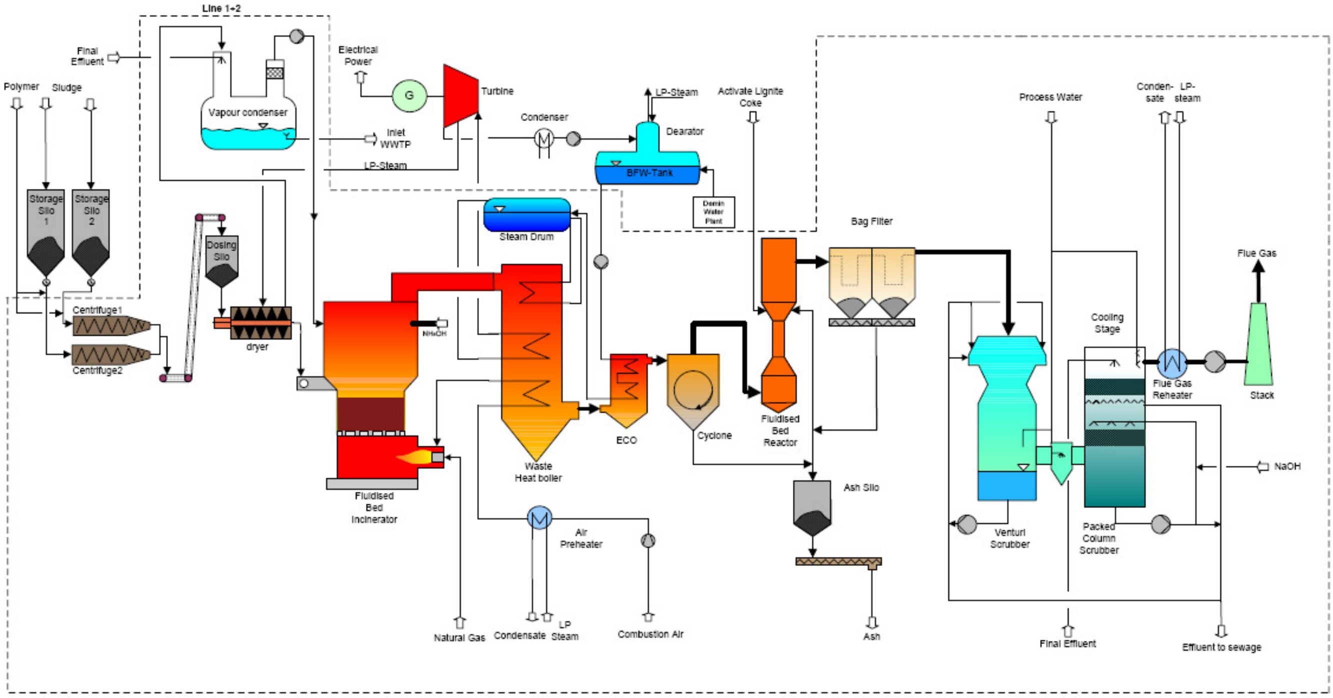
Flue gas cleaning - Flue gas would leave the waste heat boiler at a temperature of approximately 1900C and would contain combustion products and contaminants from the sludge including acidic gases and ash. The flue gas treatment system would comprise a dust removal step in an electrostatic precipitator (ESP), a heat exchanger, a wet scrubber system and a fixed bed adsorber. Section L.2.3 provides further details of Bamag’s proposed approach to flue gas treatment.

Flue gas stack - A flue gas stack would be provided to discharge the final flue gas flow to atmosphere. The internal diameter of the duct is designed for a flue gas discharge velocity of 10 - 15 m/s into the atmosphere.

Ash handling - Ash will be collected in an ash silo from which it can then be loaded into trucks for disposal.

Scrubber effluent treatment - Effluent from the flue gas scrubber is treated in order to neutralise the effluent and remove heavy metal impurities and suspended solids in the water to below the specified concentration limits for discharge to the STW.

Figure L.2: Diagram illustrating the sludge incineration process



L.2.3 Flue gas treatment

There are a number of process combinations that can be used to achieve the EC guidelines on atmospheric emissions from incinerators.

BAMAG has reviewed the flue gas treatment plants at the existing Beckton and Crossness SPGs and found that:

- The existing treatment processes are able to meet current EC Guidelines following some refurbishment will continue to meet the requirements in the future.
- The same treatment processes would perform satisfactorily if used for any new incineration streams at each site.
- There may be advantages in plant operation (particularly with respect to process familiarity) if the same flue gas treatment processes were used for all incinerators in the East London area.

The following atmospheric discharge parameters are, in the main, controlled by setting the values of key furnace design parameters including temperature, oxygen concentration and gas retention time:

- carbon monoxide
- hydrocarbons

- dioxins & furans
- oxides of nitrogen which may include nitrous oxide nitric oxide, nitrogen dioxide and dinitrogen tetroxide.

Nitrogen oxides emission is controlled typically by the injection of a chemical which releases ammonia into the furnace off-gases, such as ammonia solution (ammonium hydroxide, NH_4OHaq) or urea solution ($CO(NH_2)_2$ aq). BAMAG propose to use the moss common method, which is currently used at Beckton and Crossness SPGs, i.e. Selective Non Catalytic Reduction (SNCR), by injecting ammonia solution into the freeboard of the furnace.

BAMAG proposes to remove particulates (dust or fly ash, which include the refractory metals, such as iron, nickel, tin, copper, zinc etc) in an initial dry process using cyclone (electrostatic precipitator, ESP are used in other applications) followed by second stage dry process in a bag house (wet scrubbing is an alternative process).

Incinerator flue gases contain oxides of sulphur, SOx, hydrogen chloride or hydrochloric acid gas, HCl, formed from the combustion of sludges containing chlorinated compounds.

Typically, these acid gases have been removed in a final wet scrubbing stage of the flue gas treatment. In recirculating water flows to the wet scrubbers, the pH value is corrected using an alkali, typically caustic soda, NaOH, which neutralises the acids.

There is also a dry acid gas removal technique (not proposed by BAMAG for these schemes) but which is considered to be relatively expensive, i.e. the injection of dry sodium bicarbonate power into the flue gas stream. The bicarbonate reacts with the SOx and the HCl to form solid sodium sulphate and sodium chloride, which are in powder form and are usually removed in a bag filter. In such cases, a wet scrubbing stage can be avoided.

Unlike the refractory heavy metals which are largely present in the ash, elemental mercury and mercuric salts generally remain in the flue gases and pass through the dust removal processes.

The elemental mercury vapour will react with elemental sulphur. Hence, filters comprising activated carbon impregnated with sulphur will react with and fix the mercury as mercuric sulphide.

The type of mercury filter in use at Beckton and Crossness SPGs comprises a fluidised bed of Activated Lignite Coke onto which SOx in the flue gases adsorb, reduce top elemental sulphur and proceed to capture elemental mercury vapour. This process is proposed by BAMAG to be used also in new incineration plants. The coke is diluted with ash to reduce fire risk and spent coke is renewed on an as-needed basis by a media blow-down procedure.

Other, alternative methods of removal of mercury include:

- Fixed granular beds of activated carbon with a preceding layer of inert media such as pumice; these can also work well but can be subject to blockage.
- A dry process for elemental mercury removal by injection of powdered activated carbon impregnated with TMT-15, a mercaptan, which reacts with the mercury to for mercuric sulphide. The reacted powder is removed in a bag filter.

Mercuric salts can be removed by dosing of TMT-15 into the final wet scrubbing stage, where mercuric sulphide solids are precipitated and the scrubber liquor treated in a scrubber effluent treatment plant including neutralisation with caustic soda, coagulation with a ferric salt, settlement of solids and dewatering into a sludge cake for off-site disposal. The treated scrubber effluent can be returned to the STW for treatment.

L.3 Alternative processes and waste streams for future study

L.3.1 Gasification

Gasification and pyrolysis technologies are potential alternatives to incineration but have yet to be proven either at large scale, or using sludge as a feedstock. In gasification the sludge is heated (but not burnt) to produce a synthetic gas (‘syn-gas’) which can be used either as a fuel source in a gas turbine, or in a boiler to raise steam for a steam turbine. The fuel value of syngas is not typically as high as that of digester gas, perhaps 60% of digester gas energy values. Pre-drying of the sludge is necessary, which takes most of the available energy unless a supplementary fuel is co-gasified with the sludge (such as a secondary recovered fuel (SRF) from municipal waste operations).

Gasification may present several advantages including the option (during maintenance shut-downs of the gasification plant) to recycle dried cake to agriculture due to the inclusion of drying in the process stream. However, this process is energy intensive and this potential benefit would only be realised if these is additional dryer capacity available during the maintenance shut downs. Other potential advantages include additional energy recovery leading to reduced operating costs compared to incineration. Associated risks arise from the relatively unproven status (with respect to large scale application for municipal wastewater sludge) and complication of the process.

L.3.2 Pyrolysis

Pyrolysis is similar to gasification with the main difference being that sludge is thermally treated in an oxygen free atmosphere. The sludge is not actually burnt, but brought to a temperature of typically 500°C. The process generates three residues: solids containing mineral matter/carbon, water, and pyrolysis gases (the main constituent is carbon dioxide). The pyrolysis gases may be condensed to produce oil which, in turn can be used to generate energy or in an engine. Pyrolysis is not an end disposal route for sludge and it is mainly used as a pre-treatment step to gasification or combustion.

L.3.3 Co-digestion

L.i Background

Co-digestion is the simultaneous digestion of a homogenous mixture of two or more substrates. The most common situation is when a major amount of a main basic substrate (e.g. sewage sludge) is mixed and digested together with minor amounts of a single, or a variety of, additional substrates referred to as co-substrates.

Co-digestion of sewage sludge with other organic co-substrates can be considered as a method of enrichment of digester feedstock and improvement of its digestibility.

The quantity and quality of biogas can be increased through co-digestion. This is because certain co-substrates result in production of biogas which is richer in methane than that from the sewage sludge. For instance, biogas from fats can contain up to 70% of methane. On the other hand, wastes rich in carbohydrates are likely to produce more gas but with a lower methane content

The use of co-digestion for sludge treatment is subject to technical, regulatory and economical constraints.

L.ii Technical considerations/constraints

Since co-substrates can potentially originate from a variety of sources, their physical and chemical composition may vary considerably. Some organic compounds have greater potential for generation of biogas than others. In addition, some feedstocks may result in the introduction of an additional limiting step to the digestion process. It is possible that where this is the case, some pre-treatment methods which are typically designed to assist the hydrolysis step of the digestion process, may be ineffective for wastes which impede other subsequent digestion steps. Composition of the digestion feedstock may also reduce the number of disposal routes available for the sludge. The following are the main considerations in terms of co-substrate composition.

addition of co-substrates which are poor in nutrients may result in a nutrient deficiency in the feedstock. Typically, the optimum ratio of C:N:P for growth of bacteria is 15:1:0.2. Failure to meet this ratio may hamper the digestion process. In addition, there may be a requirement to dose nutrients if there is a shortage of macro and micro nutrients.

presence of large solids

presence of impurities may have adverse affect on the digestion or biogas system, e.g. wastes from the cosmetic industry may contain high level of siloxanes.

presence of substances which may be toxic or inhibitory to digestion, e.g. pharmaceutical wastes.

potential for odour problems associated with handling of easily digestible co-substrates.

inability to dispose of co-digested sludge to agriculture if it contains certain waste types (dealing with source separated wastes is desirable).

change in rheological properties of the digestion feedstock may adversely or beneficially affect pumping and mixing.

animal by-products (including foods, kitchen wastes) need to comply with ABPR and require pasteurisation.

analysis of toxic substances (e.g. levels of red list substances) will need to be determined and demonstrated (Hatton C., 2007)

increased transport impacts (for additional waste imports)

Significant changes to the existing system may be required such as:

provision of pre-treatment for co-substrates which may require a range of processes such as screening, maceration, thickening, chemical conditioning and hydrolysis of large solids provision of blending facilities to ensure that the digester feedstock is homogenous

possible extensions/modifications to existing plant if digesters and auxiliary plant are unsuitable due to changes in feedstock rheology or increased biogas production.

Handling and pre-treatment requirements will have to be evaluated carefully, since the overall economy of co-digestion is severely influenced by additional running costs of pre-treatment plants (Braun R., 2005).

Table L.1 gives examples of various co-substrates which can be used in co-digestion and indicates how easily and cost effectively (see "Value" column) these substrates can be digested (Braun R., 2005, based on Austrian experience).

Table L.2: Examples of co-substrates and their value in co-digestion

Type of wastes	Value	Comments
Animal products		
Chicken manure	+ +	Risk of NH_3 inhibition
Liquid piggery manure	+ + +	Risk of NH_3 inhibition
Cow manure	+ +	
Food industry		
Food beyond expiry date	+ +	Expensive unpacking required
Confectionary wastes	+ +	Liquefaction required
Whey	+ + +	No pre-treatment required
Residues from fruit juice production	+ +	Chopping may be required
Yeast products		
Yeast and sludge from breweries	+ + +	Increased H_2S formation possible
Sludge from distilleries	+ + +	Increased H_2S formation possible
Other fermentation wastes	+ + +	
Wastes from plant and animal fat		
Oils	+ + +	Scum in digester may occur
Fat trap contents	+ +	Scum in digester may occur

Note: +++ - excellent co-substrate

++ - good co-substrate.

L.iii Regulatory considerations/constraints

The following highlight some the regulatory considerations/constraints that would need to be resolved:

the use of Ofwat regulated assets for treatment of non-sewage wastes.

sewage sludge is subject to land recycling requirements and regulations (Safe Sludge Matrix, Nitrate Directive)

the receiving sewage treatment works may require an environmental permit

risk that the end-product may be classified as waste and have to be disposed of at licensed landfill sites.

implications for where the digestate can be recycled if the digestate contains high levels of N and P or PTEs.

additional local government authority planning implications

ABPR may necessitate pre-pasteurisation of the co-substrate. The ABPRs divide animal by-products into three categories according to their risk (Defra, 2006):

- Category 1 - Very high risk material, including the carcasses of animals suspected or confirmed of being infected with Transmissible Spongiform Encephalopathy (TSE, the family of diseases which includes Bovine Spongiform Encephalopathy - BSE), specified risk material (SRM, i.e. the riskiest parts of an animal's body) and catering waste from international transport.
- Category 2 - High risk material which consists of animals which die on a farm, animal by-products that are contaminated, manure and the digestive tract content.
- Category 3 - Any material which has previously been fit for human consumption, including catering waste, raw meat and fish.

According to the ABPR, biogas plants can treat materials in category 3, if hygienised (70 ºC, 1 hour, particle size <12 mm) before or after digestion and materials in category 2, if sterilised (133 ºC, 20 min, 3 bar, particle size <50 mm) before digestion. Practically, co-substrates of category 3 are likely to be the viable candidates for co-digestion at sewage sludge digestion plants.

Catering waste, former foodstuffs and raw meat and raw fish from food manufacturers and food retailers will usually be category 3 materials.

L.iv Applications

On the continent, a number of sewage sludge digesters are increasingly using co–substrates. Also, new sewage treatment plant designs, or plant extensions, increasingly cater for alternative co–substrates, like source separated bio-waste, kitchen wastes, fat wastes, flotation sludges and various other materials. By this means, the energy balance is usually considerably improved (Braun R., 2005). Co-digestion of sewage sludge with other wastes is less common practice in the UK although there are some companies (e.g. Thames Water and Viridor- Waste Management), which use co-digestion.

A full scale plant was constructed at Maple Lodge STW in late 1995 and operated between February and October 1996. The reactor was an on-line sludge digester of 3400 m^3 capacity, capable of treating some 120 m^3/day of sewage sludge. The process had four stages namely, mechanical pre-separation, slurrying with sludge, settlement/screening and digestion.

Other examples include a co-digestion plant installed at Rye Meads STW with a population equivalent of 330 000.

L.3.4 Co-incineration

Incineration as applied within the UK water industry is exclusively dedicated to sludge disposal. In other European Countries (e.g. Germany) co-incineration of sludge and municipal waste is also practiced. The sludge, either as dewatered cake, but generally as dried pellets, can be burnt in a specifically built plant with refuse derived fuel. It is possible to burn wastewater sludge with municipal waste however; the furnace technology used needs to be capable of handling both fuels because the municipal fraction tends to dominate both the design and operation.

Discussions with BAMAG have confirmed that the existing furnace design used for the Beckton and Crossness SPGs would not be suitable for use with non-sludge wastes such as MBT residues.