Ham Hydro CIC

Teddington Weir Hydropower Scheme

Flood Risk Assessment

May 2013

Preamble

Amec produced a report covering the results of a Flood Risk Assessment regarding Ham Hydro CIC.'s proposed Hydropower Scheme on Teddington Weir on 28th November 2011. The report was presented to the Environment Agency (EA) for review and comment. Final comments were received by the EA on 14th May 2012. Further to acceptance of the report and clarification by Ham Hydro CIC and its agents, the EA requested that the report be updated. This document constitutes the updated report with the added/amended text in *italics*.

Executive Summary

Purpose of this Report

AMEC was commissioned by Ham Hydro CIC to undertake a Flood Risk Assessment (FRA) for the proposed hydropower scheme at Teddington Weir on the River Thames. *This report has been prepared by Ham Hydro CIC as an update to the FRA produced by AMEC in November 2011, incorporating amendments as reasoned by Ham Hydro CIC and its agents, and the Environment Agency (N.B. all additions and amendments to the original report are provided in italics for ease of reference)*. The FRA conforms to requirements of national planning guidance in the form of Planning Policy Statement 25: Development and Flood Risk (PPS25), and its accompanying practice guide and has been prepared following consultation with the Environment Agency (EA).

The development proposal is to replace 21.3m of weir adjacent to the left bank with a hydropower scheme consisting of a fish pass, three hydropower screws and a guillotine sluice. The proposal also includes the *limited* refurbishment, within the same footprint, of a small ancillary building. This building is currently being used for equipment storage and will be used for housing switch gear associated with the scheme.

The scheme is located in and above the River Thames and therefore is located in Flood Zone 3 according to the Environment Agency's Flood Map. Predicted peak water levels at the weir of 6.80mAOD for a 1 in 100 year plus climate change joint fluvial/tidal event were provided by the Environment Agency (March 2011). The existing Environment Agency 1D-2D hydraulic model of the River Thames has been obtained from the Environment Agency to assess the impact of the proposed scheme on water levels elsewhere. The model results provided predicted a level of 7.01mAOD for the same 1 in 100 year plus climate change event. The baseline model was adjusted to represent the fish passes and piers within the section proposed to be replaced by the scheme. Peak water level for the 1 in 100 year fluvial event (plus climate change) in the modified baseline, is predicted to be 7.03mAOD at the weir.

Other sources of flooding are not considered to present a risk to the scheme or to be impacted by the scheme.

The proposed land use for the site is 'Water Compatible', including the associated plant. The 'Water Compatible' development is appropriate in all Flood Zones.

The River Thames presents a potential fluvial and tidal flood risk to the proposal and the scheme has been designed to manage this risk so that the operating equipment and electronics, where possible, are not damaged during high flow events. The highest predicted water levels are associated with a fluvial event. A 1 in 100 year plus climate change event was identified at 6.80mAOD by the Environment Agency and 7.03mAOD by the modelling undertaken for this project. Flood sensitive equipment at the weir is to be located above 7.554mAOD. It is necessary to site flood sensitive equipment in the ancillary building 'at table height'. The building is being made flood resilient, however, the equipment may be damaged during an extreme flood event. However, there would be no impact on flood risk as the turbines would continue to operate as designed.

The design incorporates mitigation measures including: sluice gates remaining open except for maintenance work and low flow conditions and a replacement guillotine sluice for conveying peak flows. The hydraulic model has been used to assess the impacts of the scheme, including mitigation measures inherent in the design. The results of the modelling suggest that the proposed scheme would have a negligible impact on flood risk elsewhere, i.e. less than +/-0.02m, for either a fluvial or tidal event.

The 'Pulling Order' of the weir will need to be updated to represent the proposed changes to the structure of the weir, ensuring that there is no impact on flood risk.

All known potential flood risks posed to the site have been considered. It is concluded that this site is suitable for the proposed development provided the scheme is constructed as per design which incorporates appropriate mitigation for the fluvial flood risk.

Contents

1. Introduction

1.1 Purpose of this Report

The purpose of this report is to present the Flood Risk Assessment for the proposed low-head hydropower scheme at Teddington Weir, supporting the planning application and *construction and operation phase* Flood Defence Consent applications. This report presents findings based on the fluvial and tidal flood risk modelling that has been undertaken representing both the current situation and with the proposed scheme in place*, and additional information further to liaison with the Environment Agency*.

1.2 Context

The hydropower scheme proposed to be installed within Teddington Weir on the River Thames at Teddington is located within Flood Zone 3. As such Planning Policy 25 – Development and Flood Risk (PPS25) requires a Flood Risk Assessment (FRA) to be undertaken and submitted as part of the planning application. The FRA reports on the assessment of flooding from all sources on the proposed scheme and the potential impacts of the scheme on flood risks elsewhere.

An initial scheme design was developed in March 2011 and interim fluvial modelling was undertaken to inform the final scheme design. A Flood Risk Assessment and Flood Defence Consent Position Statement[1] was produced in April 2011 summarising the flood risk and modelling results to date. Further development of the design has been undertaken and the proposed scheme design has now been finalised. Modelling results representing the current scheme (November 2011) are presented in this report.

1.3 Sources of Data and Consultation

Table 1.1 details the data which has been reviewed and the consultations that have been undertaken as part of this FRA.

[1] Entec. Teddington Weir Hydropower Scheme: Flood Risk Assessment and Flood Defence Consent Position Statement. Revision 1. April 2011.

Table 1.1 Data Reviewed and Consultations Undertaken

Data (received February 2011)
Environment Agency, TH788 Teddington Fluvial Flood Risk 2009 Modelling Report - April 2009 Environment Agency Fluvial Model of the Thames from Molesey Lock to Hammersmith Bridge (ISIS – TUFLOW) Kingston daily mean flows (1970 onwards) – Environment Agency Kingston daily mean levels (1970 onwards) – Environment Agency Teddington downstream mean daily levels – Environment Agency Teddington upstream mean daily levels – Environment Agency Product 4 – Peak water levels upstream and downstream of Teddington Lock – Environment Agency
Consultations (February/March 2011)
Environment Agency – Flood Defence Engineer: Katy Steed Environment Agency – Lock Keepers at Teddington, Peter and Jeff Environment Agency – Project Manager: Stephen Naylor Atkins – Design Engineer, James Smith
Consultations (October/November 2011)
eWaterpower – Technical Advisor for Scheme: Brendan Barrow Environment Agency – regarding the model results and the identification of 'negligible change' in peak water levels. 0.02m elevation changes were agreed to be negligible.

N.B. There have also been meetings between the EA and Ham Hydro CIC where the FRA has been discussed: 16th December 2011; 6th January 2012; 26th March 2012; 24th May 2012; 8th February 2013.

1.4 Structure of this Report

The following points detail the structure of this report is outlined below:

- Section 1 – Introduction and context
- Section 2 – Site description and development proposal
- Section 3 – Assessment of flood risks posed to the development proposal
- Section 4 – Assessment of flood risks impacts elsewhere
- Section 5 – Flood management and mitigation
- Section 6 – Summary

2. Site Description, Development Proposal and Planning Context

2.1 Site Description

2.1.1 The Site

The potential development site is situated at Grid Reference (516995, 171355), which is at the left bank side of Teddington Weir in the River Thames at Teddington. The left bank is that which is on the left when looking downstream. The development is located within the London Borough of Richmond upon Thames.

The weir is currently owned, maintained and operated by the Environment Agency. The Environment Agency asked organisations to tender for the rights to install a hydropower facility on Teddington Weir. Ham Hydro CIC were the successful bidders and as part of this process will be given (subject to all applications being approved) the right to install and operated a hydropower scheme on the weir.

Planning Policy Statement 25 – Development and Flood Risk (PPS25) defines the current structure (i.e. the weir) as Water Compatible Development, Table D.2 in PPS25 Annex D. The development envelope currently includes a small ancillary building adjacent to the river bank approximately 60m upstream of the weir, within the grounds of the Lensbury Club, this is also classified by Table D.2 of PPS25 as Water Compatible Development as associated bankside infrastructure.

A plan illustrating the site boundary and the existing site composition is provided in Figure 3.1 and survey drawings of the existing structure are provided in Appendix A.

2.1.2 Local Topography

The topography of the left and right banks of the River Thames in this area is markedly different. On the right bank, ground levels rise rapidly from the water's edge up towards the high ground occupied by Richmond Park, whereas on the left bank, the ground elevations remain consistently low for several hundred meters away from the river. This difference is manifest in the different flood zone extents on both banks, on the right bank, predicted flood extents are minimal, whereas on the left bank the Environment Agency's flood extent predictions are far more extensive – See Figure 4.1.

A site topographic survey is not currently available.

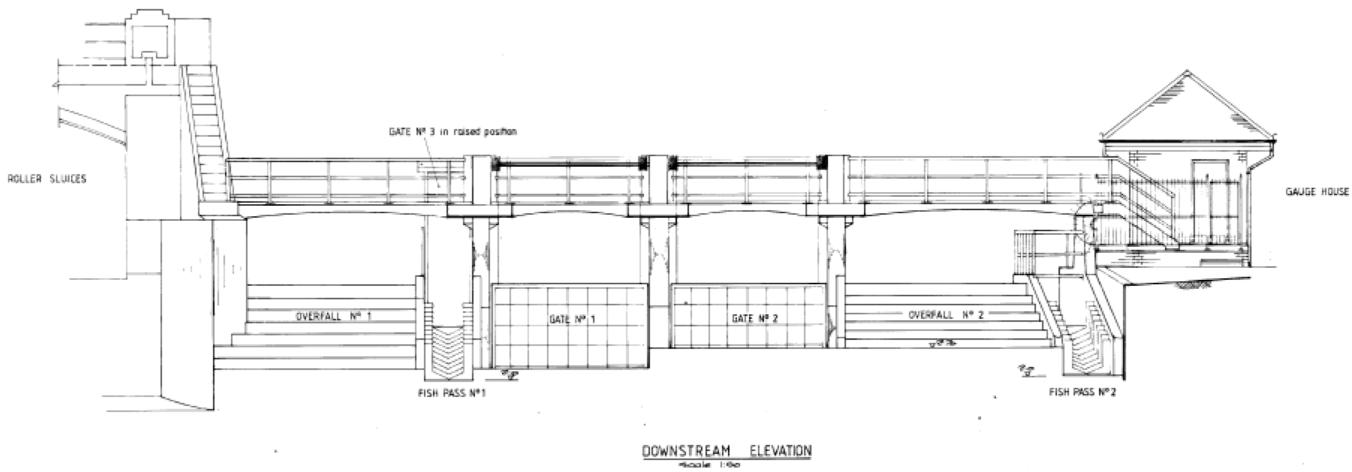
2.1.3 Hydrology and Hydrogeology

The primary hydrological feature in the immediate vicinity is the River Thames. Bedrock geology in the area is Chalk which is overlain by London Clay. Superficial river terrace deposits are present above the London Clay which are identified as being potentially water bearing by the Environment Agency's Aquifer Maps.

2.2 Development Proposal

Development Proposal drawings are presented in Appendix B. In brief, the proposal is to completely replace the first 21.3m length of weir from the left bank. Starting from the left bank, this structure comprises of a fish pass, a fixed weir, two radial gates, another fish pass and another fixed weir section – See Figures 2.1 and 2.2. The proposal is to replace this with a fish pass along the river wall, three helical screws in fixed concrete channels, and a sluice gate – See Figure 2.3.

Figure 2.1 Current Arrangement

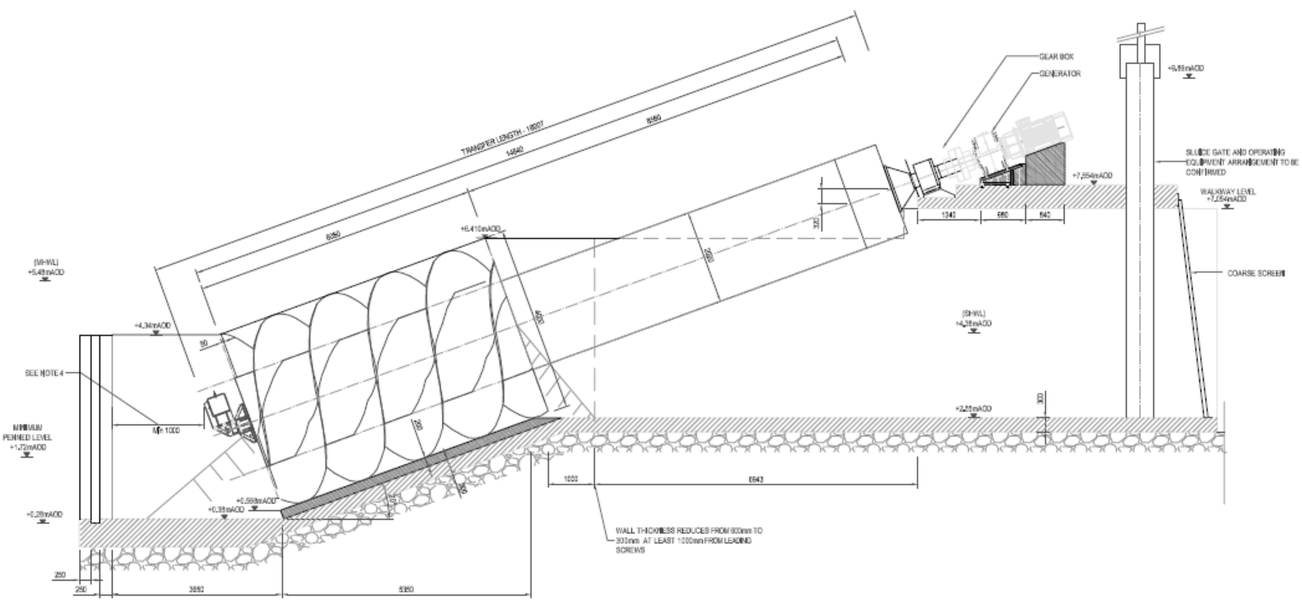


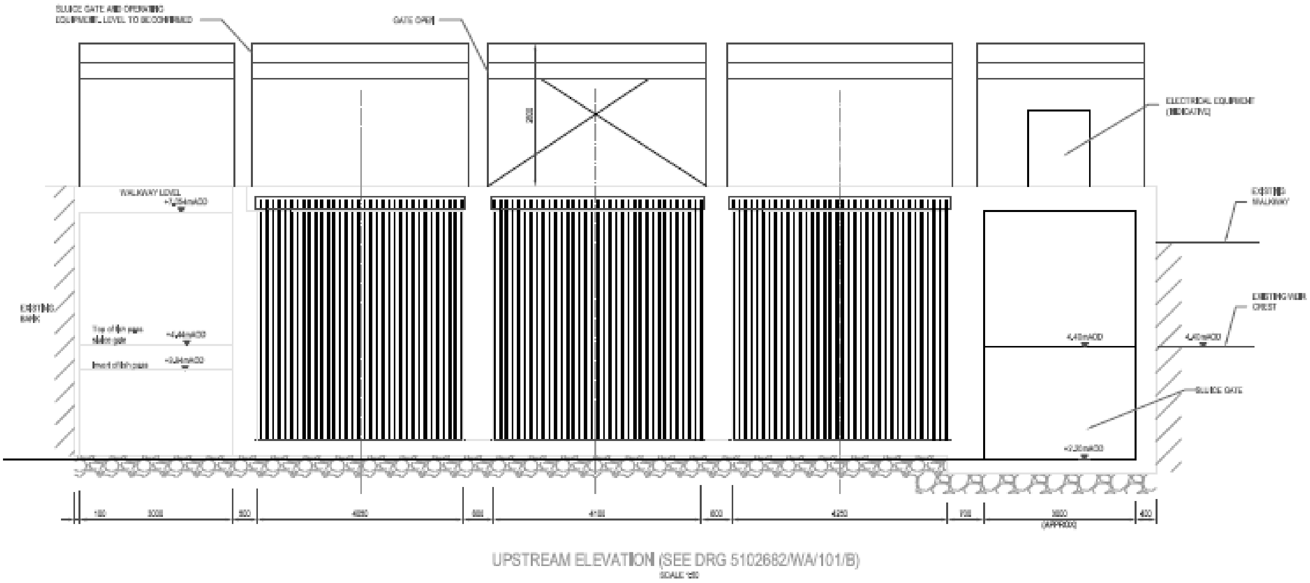
Extract from NRA Drawing 11707 / 209 – full plan is provided in Appendix A.

Figure 2.2 Photo (looking upstream) of the Current Arrangement

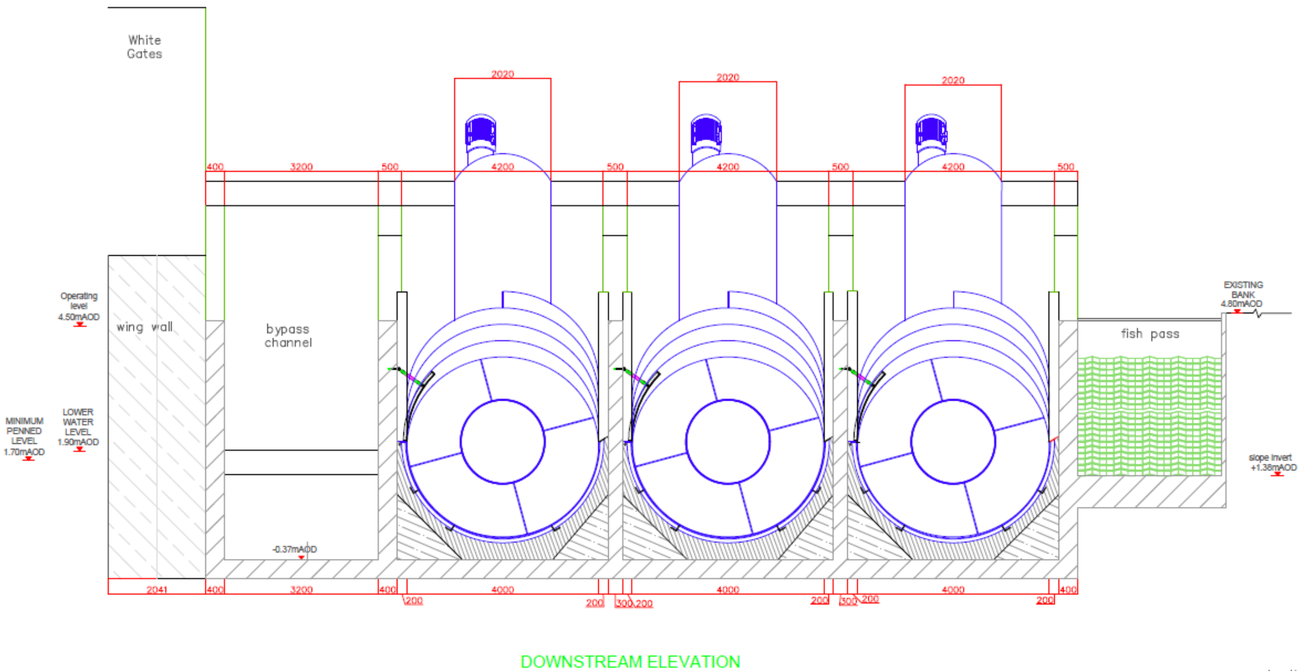
Taken February 2011

Figure 2.3 Proposed Arrangement

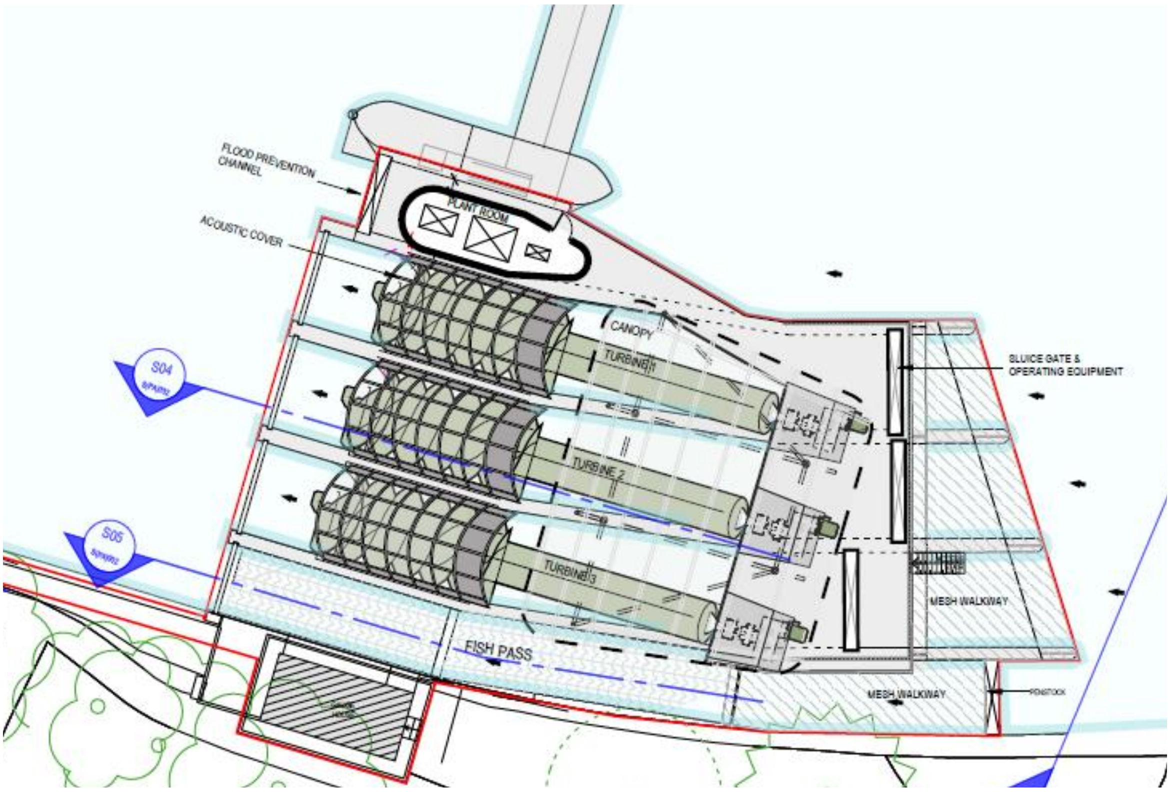




These two images are taken from Drawings 5102682_WA_100C and 5102682_WA_102D which are presented in Appendix B.



This image above is taken from drawing TW Downstream View 1-3 which is presented in Appendix B.



This image above is taken from drawing L(PA)003 (revision 2) which is presented in Appendix B.

As outlined in Section 2.1.1 the current land uses are classified as Water Compatible and Less Vulnerable. The proposed developments, i.e. a hydropower scheme in the weir and the ancillary building are considered to be Water Compatible. There is no increase in the vulnerability classifications within the site boundary.

The fish pass is proposed to be 3.0m wide with an invert at 4.44mAOD. Three Archimedean screws are proposed, each with a diameter of 4.0m. *The original report stated that '*the screws will be placed within separate concrete channels with widths of 4.05, 4.1 and 4.25m (from left to right as viewed looking downstream) and an inlet invert at each of 2.55mAOD'. *This is true of the upstream elevation drawing detailed above and Brendan Barrow, from Ewaterpower (agent of Ham Hydro CIC), has asserted that 'The initial design was drawn from the bank outwards and the first channel at point C in the image shown can be seen to use the curve of the grouting to gain 50mm. The second channel using both sides curves gains 100mm. However when the person drawing got to the third channel the principle was not carried forward. There was a minor misunderstanding in our communication. The Sluice Gate channel was to be a minimum of 3m wide but as wide as possible. The person completing the drawing set the channel as 3m wide and thus the 50mm saving on that channel was not used. The potential can be seen in the drawing for the sluice gate to be 3.3m wide. Revised drawings will be completed for revised position. The increased channel width will increase the flow potential and consequently reduce the Flood Risk.' The EA has accepted this clarification, acknowledging that image TW Downstream View 1-3 shows screw channels with a maximum 4.4m.*

Trash screens will be constructed in front of each inlet consisting of 34-36 bars, obstructing approximately one

tenth the width of the screen. *The trash screens in the revised design will be angled towards the sluice gate. The screens will be cleared on a regular basis as part of the maintenance regime and covered in the operation phase Flood Defence Consent. It is proposed that the bars will be horizontal rather than vertical sloping slightly upwards from the bank side to the sluice gate.*
The proposed sluice gate at the flood protection channel is approximately 3.0m wide with an invert at 2.2mAOD. The walkway above the screws will be set at 7.054mAOD, the level of the generators and other equipment (in the small plant room over the sluice – not detailed on the design drawings) is yet to be confirmed, however, this will be set above 7.554mAOD. The screws are currently designed to achieve maximum efficiency when conveying $9m^3/s$ each or $27m^3/s$ in total. Flows in excess of $27m^3/s$ can be accommodated, but $27m^3/s$ represents the most efficient energy generating flow through the three screws.

The assumed minimum standing water head at the structure is understood to be that of the existing lowest fixed weir crest which is 4.4mAOD. The 4.4mAOD crest level is defined by NRA (National Rivers Authority) Drawings dated November 1991 (Appendix A).

In March 2011, the Environment Agency provided information on the revised 'zero levels[2]' for the head and tail gauges at Teddington. The 'zero level' for the head gauge was previously thought to be 4.380mAOD, it is now understood to be 4.409mAOD which represents a 0.029m variation.

Sluice gates, which can be lowered from above, will be in place above each of the three inlets. When lowered, the sluice gates will prevent fluvial flows from flowing into the turbine channels until the peak river level exceeds the walkway crest level of 7.554mAOD. It is intended that the sluice gates will remain open, except during periods of low flow or if maintenance work is required when the sluice gates would be temporarily closed. It is not anticipated that maintenance would occur during a flood event. *It is intended that in this scenario all sluice gates will be fully raised so that the bottom of the gate is level with the base of the plinth above the maximum potential flood level.*

The existing small ancillary building adjacent to the river bank, approximately 60m upstream of the weir, will be used to house the control equipment. The building will be made flood resilient, including the installation of new steel doors with rubber seals. No new bankside development is proposed.

[2] 'zero level' is the relative level against which water levels are locally assessed. Under the current operating arrangement, the water levels are intended to be maintained within 15cm or 6 inches of this zero level.

3. Assessment of Flood Risks to the Proposal

3.1 Overview

This report considers the impact of flooding on the proposed scheme and the impacts of the proposed scheme on flooding elsewhere, as required by PPS25. The proposed scheme is located within the River Thames and is a Water Compatible development while the associated plant room is located above the proposed walkway and is a Less Vulnerable development. The objective here is to ensure that the designs account for peak 1 in 100 year plus climate change river levels and peak 1 in 200 year plus climate change tide levels.

3.2 Potential Sources of Risk to the Proposed Development

Table 3.1 provides a summary of the potential sources of flood risk facing the proposed development.

Table 3.1 Potential Sources of Flood Risk

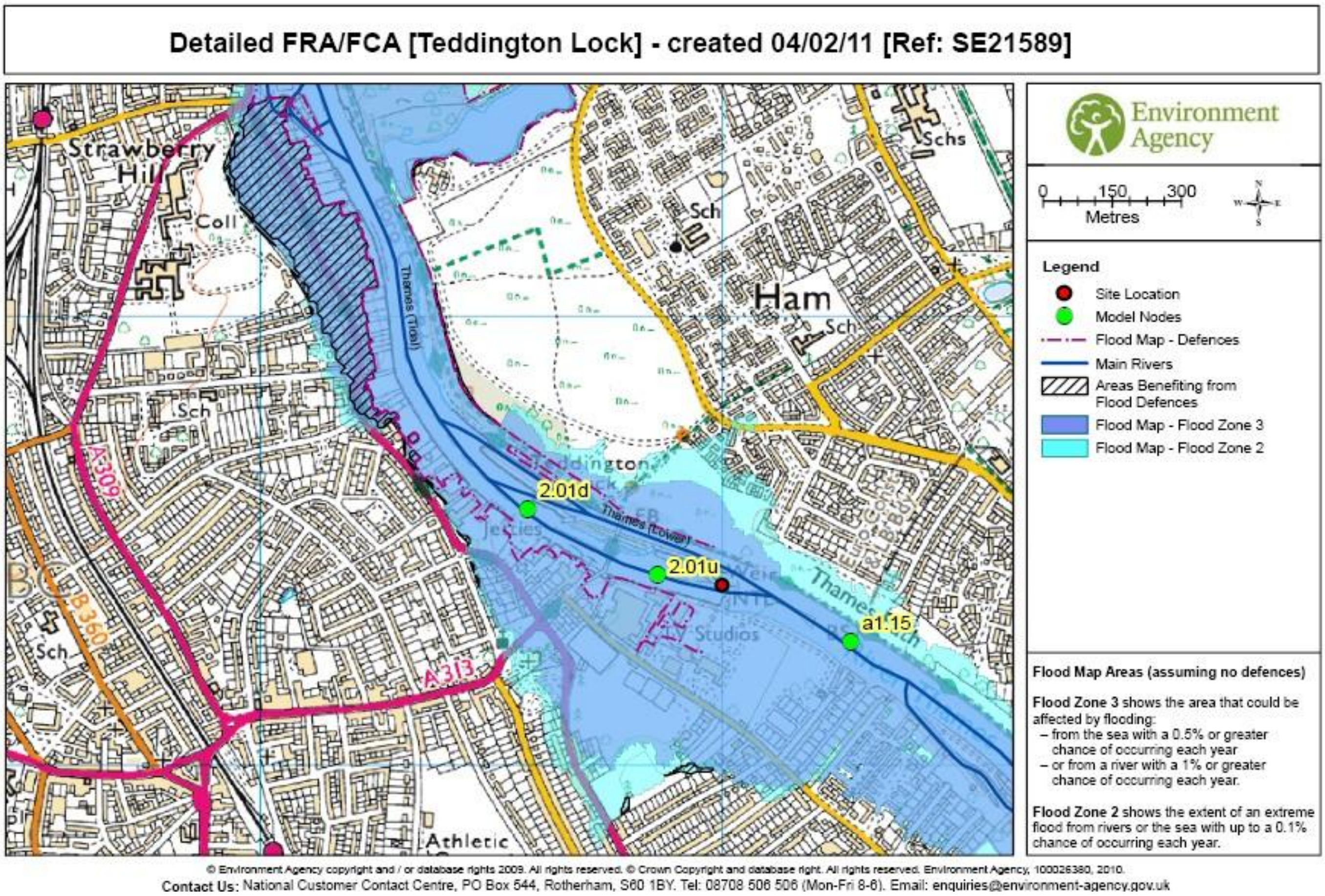
Source of Flooding	Risk Identified	Description of Risk
Fluvial	Yes	Fluvial sources present a risk to the proposed development. There is also a potential for the proposed scheme to increase fluvial flood risk elsewhere.
Tidal	Yes	Tidal sources present a potential risk to the proposed development but less so than the fluvial sources. There is also a potential for the proposed scheme to increase tidal flood risk elsewhere.
Groundwater	Yes	This source is not considered to present a risk to the development proposal given its location in the River Thames. There is a potential risk to the ancillary building.
Sewers	Yes	This source is not considered to present a risk to the development proposal given its location in the River Thames. There is a potential risk to the ancillary building.
Surface water run on	No	This source is not considered to present a risk to the development proposal given its location in the River Thames.
Surface water run-off	No	This source is not considered to present a risk to the development proposal given it's location in the River Thames.
Reservoirs, canals and	No	This source is not considered to present a risk to the development proposal given it's location in the River Thames.

The following section provides additional information for those sources which have been assessed as presenting a risk to the development proposal.

3.2.1 Fluvial and Tidal

All parts of the development are located within Flood Zone 3, indeed the majority of the development is located within the River Thames and is therefore at risk from high river levels during a flood. The extent of the Environment Agency Flood Map is shown in Figure 3.1.

Figure 3.1 Environment Agency Flood Extent Predictions



Supplied by the Environment Agency 24-02-11 Ref SE21589

Teddington Weir is potentially subject to both extreme tidal and fluvial events. The reach upstream of Teddington Weir and downstream of Molesey Lock is predominantly fluvial with a tidal influence during spring tides and extreme tidal events. Whereas the reach downstream of Teddington Weir is significantly more tidal, but still strongly influenced by the fluvial component of the river. Downstream of Richmond Lock, the river can be described as being predominantly tidal. The interplay of both tidal and fluvial influence at Teddington has historically made it challenging to define Annual Probability of Occurrence peak water levels. To this end the Environment Agency embarked on a joint probability modelling exercise to determine single Annual Probability peak water levels for this location (see Appendix C).

Peak flood levels immediately upstream of the weir are cited by the Environment Agency (see Appendix C) as being 6.80mAOD for the 1 in 100 year plus climate change (year 2107) fluvial event. Immediately downstream of the weir the peak levels for the same event are 6.66mAOD. For the same event, the model obtained from the Environment Agency identified a level of 7.01mAOD upstream of the weir and 6.57mAOD downstream of the weir. The revised modelling of the baseline condition predicts that the baseline, in the same 1 in 100 year plus climate change event, is 7.03mAOD. It is noted that the Environment Agency's ISIS-TuFLOW model predicts higher levels upstream of the weir than the reported model levels.

The hydropower screws and all of the associated installations in the river, including the proposed plant room, and the ancillary building are therefore at risk of flooding. Section 5 of this report outlines flood risk mitigation options to manage the identified risks.

3.2.2 Groundwater

Groundwater flooding does not present a risk to any of the proposed installations within the River Thames.

Groundwater may be present within the superficial deposits in the floodplain areas. As such a there is a

potential
for there to be a groundwater flood risk posed to the ancillary building. Nonetheless the impacts of any potential groundwater flooding from localised deposits of sand and gravel are insignificant in comparison to the potential risk associated with an extreme fluvial or tidal event on the River Thames. It is the fluvial and tidal events which form the design standard of the new development and as such the proposed scheme will be safe from any groundwater flood risks.

It is possible that water levels in the ground adjacent to the River Thames my respond to river levels and in local low points in the floodplain this might be expressed as ponded surface water, but this is not considered to present a risk to the ancillary building as it will be designed to manage the 1 in 100 year plus climate change event.

The risk of groundwater flooding is not considered further.

3.2.3 Overland flows, Sewers and Drainage Infrastructure

Overland flows, sewers and other drainage infrastructure do not present a flood risk to any of the proposed installations within the River Thames.

The ancillary building is not assessed to be at risk from this source of flooding either, as if there was localised surface water it would drain into the River Thames which is 10m to the east. There is no topographic or man made barrier between the ancillary building and the River Thames so surface water would not pond in and around the ancillary building. Plans for this ancillary building have not been produced. It is not proposed to increase the footprint of the existing building therefore there is no risk of increasing the rate of surface water run-off.

4. Assessment of Flood Risk Impacts Elsewhere

This section describes the assessment which has been undertaken to review the possible flood risk impacts of the proposed development on the surrounding area. For the proposed scheme to meet the requirements of PPS25 and for it to obtain Flood Defence Consent, any potential increases in flood risk must be reviewed and mitigated where necessary. PPS25 requires all new development to be safe from a flood risk perspective and it requires all new development to ensure that flood risk elsewhere is not increased as a result of development. The process of flood risk assessment and management advocated in PPS25, is to first assess the risks to the development, then consider the impacts the development might have elsewhere and then develop appropriate mitigation measures to manage any identified risk.

Section 5 of this report outlines potential flood risk mitigation options to manage the identified risks.

The proposed scheme is going to replace a section of the weir with a structure which has the potential to increase the resistance to both fluvial flows coming down the river and tidal flows propagating up the river. This is because the two fixed weir sections, two radial gates and two fish passes will be replaced by one fish pass, three Archimedean screws and a new sluice gate. Each screw inlet channel will be fronted by a trash screen. Appendix B presents the design drawings. Above the inlets there is a walkway at 7.054mAOD. Generators and other electrical equipment will be situated above a platform at 7.554mAOD.

At the upstream end of each inlet channel, it is proposed that there will be a sluice gate which will provide a mechanism for preventing river flows from flowing over one or more of the screws. If all the sluice gates were to close the proposed structure will present a present a 14.8m wide barrier, including the piers, to a level of at least 7.554mAOD. In this situation, only the fish pass and sluice gate components of the proposed structure will allow flows to pass through the weir. *The assessment of flood risk has considered a scenario in which all the sluice gates are closed - minimal impacts on upstream water levels were reported as a result of this configuration (a 'closed sluice gate' configuration is a quasi representation of the trash screen/sluice gates being blocked).* However, this situation will not occur as the sluice gates have been design to remain open if there is a power failure or if one of the screws is malfunctioning. The manufacturer has modified the design in light of concerns raised by the Environment Agency earlier in 2011, to ensure that the 'barrier to flow' situation is not the default position. Mechanisms for managing electricity generated during a disconnection from the National Grid have been incorporated into the design. In this way, the sluices can and will remain open in the event of a flood.

Only during extreme low flows or for maintenance purposes (which will be scheduled for the summer months) will the sluice gates be closed. *As part of a revised pulling order agreed with the EA, it is assumed that the Lock Keeper will be responsible for operating all sluice gates (including the flood channel sluice gate) – this will form part of the construction and operation phase Flood Defence Consents.*

*The original report stated that '*the proposed scenario assumes that the sluice gates remain open, although a conservative approach has been taken assuming that no flow is conveyed by the screws. The screws are designed to convey approximately 9m^3/s under optimal energy generating conditions. It has not been possible to obtain confirmation as to how the conveyance through the screws will vary as river levels rise. It is likely that conveyance will remain at a minimum of 9m^3/s, but to review the potential impact of conveyance being reduced, the modelling assessment has simulated a conservative scenario in which no conveyance is assumed.' *Flows through* *the screws will be constant throughout a flood event.*

The model scenario is discussed from both a fluvial and a tidal perspective in Sections 4.1 and 4.2, respectively. Section 3.2.1 introduced the Environment Agency's Joint Probability Fluvial/Tidal model, which the Environment Agency uses for predicting peak water levels along this part of the River Thames. In this model, the water levels for any given location and for any given Annual Occurrence Probability are a product of both tidal and fluvial influences. This model is used in the assessment of both fluvial and tidal flood risks in Sections 4.1 and 4.2.

4.1 Fluvial Flood Risks

4.1.1 Hydraulic Principles

This section sets out what possible impacts the proposed structure might have on fluvial flood risks in this area.

It is proposed to replace the existing Radial Gates 18 and 19, two fixed weir sections and two fish passes with a fish pass, three screws and a new sluice gate. Any reduction in the baseline capacity of the weir has the potential to increase flood risks both upstream and downstream.

To compensate for the resistance to flow presented by the proposed structure, the river can respond in one of three ways. The water level upstream of the structure can increase, more flow can pass through the rest of the structure or additional flows can pass through the floodplain – or a combination of these.

If water levels are elevated or additional flows pass through the floodplain, flood risk could be increased in one of three ways:

- **Deeper Flooding** – An elevated water level means that an area already experiencing flooding will be flooded by deeper water.
- **Flooding New Areas** – The extent of predicted upstream flooding is the product of predicted peak water levels. If the water levels are to rise because of the obstruction then, the extent of flooding will increase. The amount of land currently outside the floodplain which might become at risk is a product of the degree of water level rise and the floodplain topography and gradients.
- **New Flow Routes** – Where the partial obstruction to flow does not extend all the way across the floodplain and is confined to just the river channel (i.e. Teddington Weir) there is a possibility that the obstruction might cause floodplain flows to occupy additional or different flood flow routes in the floodplain adjacent to the obstruction. For example, in an extreme 1 in 100 year plus climate change fluvial event, the land on both banks of the Thames is predicated to be within the floodplain (see Figure 4.1). This water will be flowing water and the route it takes and the amount of water in the floodplain are in part a product of the configuration of Teddington Weir. If the resistance to flow, presented by Teddington Weir, is increased then the floodplain flow routes, depths and velocities either side of the weir may be impacted.

The assessment of flood risk presented in this FRA is based upon these hydraulic principles.

4.1.2 Hydraulic Modelling

Background to the Environment Agency Model

The model provided by the Environment Agency is based on the following key[1] representations (page references are to the Environment Agency Modelling Report April 2009).

- Modelling undertaken using ISIS version 3.1, linked with TUFLOW version 2008-08-AE-iSP (pg11).
- Hydrology: the Thames and Mole represented by full hydrographs where the shape was taken from existing studies and scaled to give the required combined flows and shape at Kingston (pg12). Other tributaries represented by steady state inflows.

Table 4.1 Environment Agency Tributary Hydrology

	Q_2 (m^3/s)	Q_{100+20} (m^3/s)	Notes
Hogsmill	2	5	Set at this because "analysis of event hydrographs showed that the River Hogsmill typically contributes very little flow at the time of peak on the Thames at Kingston" (pg22)
Crane	10	10	"Inflows from the rivers Crane and Brent were kept at the equivalent 1 in 2 year flows" (pg22)
Brent	30	30	"Inflows from the rivers Crane and Brent were kept at the equivalent 1 in 2 year flows" (pg22)

- Downstream Boundary: based on nominal Spring Tide at Southend (2.84mAOD), this same boundary is also applied for the climate change runs.
- Defences: Thames Barrier in operation and continuous linear defences from Teddington Weir to Hammersmith Bridge.
- Teddington Weir representation: several radial gates/gated weirs were represented closed: the two intermediate radial gates between the left bank and the first roller sluice (the layout of the current weir structure is presented in Appendix A, two small radial gates between the roller sluice and the ten radial gates, and two gates weirs closed to 4.23mAOD. Once at a sufficient level water will overtop these structures. The Environment Agency did undertake sensitivity testing and found the model to be insensitive to the operation of these gates, water levels at approximately 1cm higher with the gates represented closed. The fish passes near the left bank were not represented in the model. There is a note in the model indicating that the fish pass will be ignored as it was assumed that they would be insignificant at larger fluvial flows.

[1] Other assumptions are present in the modelling, those identified here are just the key points.

- A “stability patch” has been included covering a large area of the left bank with a roughness value of 0.25.

Model Set Up

The Environment Agency’s ISIS-TUFLOW model of the River Thames has been obtained and manipulated to assess the impacts of the development proposal. Two fluvial scenarios have been run with a further three sensitivity testing scenarios:

- Baseline – current scenario against which the other scenarios will be reviewed. The baseline had to be revised as the existing Environment Agency model did not include the existing fish passes or the obstructions presented by the supporting concrete pillars;

- Proposed – proposed scenario assuming that the screws will not convey flow in flood conditions[2];

- Sensitivity – roughness values in the channel were increased by 20%;

- Sensitivity – Thames Barrier not operational; and

- Sensitivity – screws convey 9m^3/s each.

In each scenario, the 1 in 100 year plus climate change (i.e. 20% increase in river flows) has been simulated combined with the Mean Spring Tide. The only aspect of the Environment Agency’s model that has been altered in these scenarios is the representation of the section of the weir between the left bank and the first roller sluice, all other geometry and flow parameters remain unchanged. The representation of the proposed hydropower scheme in the modelling is described in the Flood Modelling report provided in Appendix D and summarised in the Model Set Up sections below.

Whilst it is possible for an extreme tidal event to propagate up the River Thames from the Thames estuary, the Thames Barrier at Charlton is designed to protect central London from extreme tidal surges. In all flood risk modelling for Flood Risk Assessments and Strategic Flood Risk Assessments upstream of the Thames Barrier the standard guidance is to assume that the Thames Barrier will be operational. This standard procedure has been adopted in the modelling presented in this report, although a sensitivity analysis has been undertaken with the Thames Barrier not in operation.

Model Set Up - Baseline

The baseline model was altered to ensure consistency with the width of river replaced by the proposed scheme. The two fish passes (not included within the existing Environment Agency model) were represented by a width of 1.2m with inverts of 3.29 and 3.32mAOD, and the piers between the existing gates and weirs were represented by a width of 2.9m up to an elevation of at 7.4mAOD from bed level.

[2] *This would only happen in instances where the incoming tide effectively ‘reverses’ the flow of the river and at high flows ‘drowns’ the screws to the point where the screws aren’t turning (as there is no downstream flow).*

Model Set Up – Proposed Scheme

It is proposed that the current weir arrangement is to be replaced with three hydroelectric screws. ISIS does not include a 'hydropower screw' function so it has been necessary to represent the structures using an equivalent unit. Given that the sluice gates at each screw will be open, that flow will pass over the screws and that Teddington Weir will likely drown out during extreme conditions it was considered that the scheme could be represented as a spill unit. As a conservative approach it has been assumed that the screws will not convey flow in flood conditions.

In the model, the units representing the two radial gates and two overflow weirs have been removed and the dimensions of the fish passes and piers removed. An additional spill unit was added incorporating the fish pass, flow over the screws, the new sluice gate, obstruction caused by the piers between the screws, and obstruction caused by the trash screens. See Appendix D for full details of the how the scheme has been represented in the model.

4.1.3 Fluvial Flood Risk Modelling Results

The baseline model predicts a peak water level of 7.03mAOD for the 1 in 100 year plus climate change (year 2107) fluvial event. The impacts of the proposed scheme are assessed in terms of water levels and flood extent predictions, as these are key flood risk indicators. Peak water levels upstream of Teddington Weir are shown in Table 4.2. The impact of the proposed scheme on peak water levels during a fluvial event is described in the Flood Modelling report provided in Appendix D and is summarised in Table 4.3. *Regarding tables 4.2 and 4.3, ass clarification 'with Thames Barrier' is the same as 'Thames Barrier operational'; and 'without Thames Barrier' is the same as 'Thames Barrier not operational'.*

Table 4.2 Fluvial Flood Risk Modelling – Predicted Peak Water Levels

Scenario	Peak Water Level Upstream of Teddington Weir
Baseline with Thames Barrier	7.03mAOD
Baseline without Thames Barrier	7.11mAOD
Proposed Scheme with Thames Barrier	7.05mAOD
Proposed Scheme without Thames Barrier	7.12mAOD
Proposed Scheme with Thames Barrier including 27m^3/s conveyance through screws	7.04mAOD

Peak water level taken from model node: a1.15, immediately upstream of the weir

Table 4.3 Fluvial Flood Risk Modelling – Impact of Proposed Scheme

Scenario	Average impact over 2km upstream reach	Impact immediately upstream of weir
Thames Barrier operational	Negligible	Negligible
Thames Barrier not operational	Negligible	Negligible
Thames Barrier operational, Manning's n+20%	Negligible	Negligible
Thames Barrier operational, screw conveyance of $27m^3/s$ included	Negligible	Negligible

Note: negligible is considered to be +/-0.02m or less. This is based on the" unexpected longitudinal variations" in the comparison of model results which predict an oscillating and inconsistent +/- 0.02m variation in locations where the scheme would not be expected to impact, i.e. more than 6km upstream of the weir beyond two major structures. This variation is inherent in the model, rather than as a result of the scheme and may be a result of the reporting interval of six minutes, the complex nature of the model, the large distances between model nodes or other reason. In addition, early modelling predicted a 0.03m variation in predicted results with only a change in model timestep.

The predicted impact (Table 4.3 and Appendix E) indicate that the proposed hydropower scheme will have negligible impact on the upstream water levels. All the variation is within the tolerances of the model accuracy, considered to be +/-0.02m for this model. The Flood Modelling report (Appendix D) states that the baseline simulation for the Thames Barrier operational scenario "exhibited some unexpected longitudinal variations which make direct comparison with the proposed scenario less than straightforward" and suggest the average impact over the 2km upstream reach may be more representative.

Figures 1 and 2 in Appendix E present peak water level predictions for the Baseline, with the scheme represented, with and without conveyance through the screws and with and without the Thames barrier being operational. The Water level predictions in Table 4.2 describe the water level predictions in the River Thames channel, Figures 1 and 2 in Appendix E illustrate that there is negligible water level impacts in the floodplain. There are however two small areas 2km to the south on the right bank floodplain where peak levels are predicted to increase by 0.1m in the scenario where no screw conveyance is assumed. The same areas are predicted to decrease by 0.1m when the Thames Barrier is assumed to not be working. These areas do not reflect the behaviour of the rest of the modelled floodplain, in which negligible change is predicted in all scenarios. These areas were flagged during provisional modelling in April 2011 and the conclusion remains that predicted change is not a product of the proposed scheme at Teddington Weir. Unexpected discrepancies exist in the baseline scenario (Figure 1) near this location in that the water levels do not follow the general pattern of the wider floodplain, this suggests some model instability within this area. If the scheme were predicted to impact floodplain levels then these would be observed within the 2km reach between Teddington and Richmond. Increased in floodplain water levels are not predicted.

4.2 Tidal Flood Risks

4.2.1 Hydraulic Modelling

As identified in Section 3.2.1, this reach of the River Thames is tidally influenced. As such the assessment of flood risk needs to consider the impact of the development proposal on the propagation of an extreme tide up the River Thames and over the weir.

Background to the Environment Agency Model

The Environment Agency does not currently provide flood extents for just a tidal event. The flood extent predictions presented in Appendix C are from the joint probability Fluvial and Tidal model. To this end, there are no direct 'tidal only' peak levels of flood extent predictions to review.

Model Set Up

The Environment Agency's ISIS-TUFLOW model of the River Thames has been obtained and manipulated to assess the impacts of the development proposal. The same scenarios as the fluvial assessment have been run, two fluvial scenarios and three sensitivity testing scenarios:

- Baseline – current scenario against which the other scenarios will be reviewed;
- Proposed – proposed scenario assuming that the screws will not convey flow in flood conditions[3];
- Sensitivity – roughness values in the channel were increased by 20%;
- Sensitivity – Thames Barrier not operational; and
- Sensitivity – screws convey $9m^3/s$ each.

In each scenario, the 1 in 200 year plus climate change (for the year 2107) tidal boundary has been applied to the ISIS model at Southend[4] with a 1 in 2 year fluvial event. As with the fluvial event, the only aspect of the Environment Agency's model that has been altered in these scenarios is the representation of the section of the weir between the left bank and the first roller sluice, all other geometry and flow parameters remain unchanged. The representation of the proposed hydropower scheme in the modelling is described in the Flood Modelling report provided in Appendix D and summarised in the Model Set Up Baseline and Model Set up Proposed Scheme sections in Section 4.1.2.

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[3] *This would only happen in instances where the incoming tide effectively 'reverses' the flow of the river and at high flows 'drowns' the screws to the point where the screws aren't turning (as there is no downstream flow).*

[4] Southend is the downstream limit of the Thames model and it is at this location where alternative tidal scenarios can be applied. The model then routes the flow up the River Thames, accounting for both the Thames Barrier and other flood defences.

4.2.2 Tidal Flood Risk Modelling Results

The impacts of the proposed scheme are assessed in terms of water levels and flood extent predictions, as these are key flood risk indicators. Peak water levels upstream of Teddington Weir are shown in Table 4.4. The impact of the proposed scheme on peak water levels during a tidal event is described in the Flood Modelling report provided in Appendix D and is summarised in Table 4.5.

Table 4.4 Tidal Flood Risk Modelling – Predicted Peak Water Levels

Scenario	Peak Water Level Upstream of Teddington Weir
Baseline with Thames Barrier	4.74mAOD
Proposed Scheme with Thames Barrier	4.73mAOD

Table 4.5 Tidal Flood Risk Modelling – Impact of Proposed Scheme

Scenario	Average impact over 2km upstream reach	Impact immediately upstream of weir
Thames Barrier operational	Negligible	Negligible
Thames Barrier not operational	n/a	n/a
Thames Barrier operational, Manning's n+20%	Negligible	Negligible
Thames Barrier operational, screw conveyance of $27m^3/s$ included	n/a	n/a

Note: negligible is considered to be +/-0.01m or less

The predicted impact (Table 4.5) indicates that the proposed hydropower scheme will have a negligible impact on the upstream water levels. Indeed the variation is well within +/-0.01m. The tidal model did not show the same "unexpected longitudinal variations". There was no predicted change downstream of Teddington Weir as a result of the proposed scheme.

Figure 3 in Appendix E present peak water level predictions for the Baseline and with the scheme represented, with the Thames barrier being operational. The Water level predictions in Table 4.3 describe the water level predictions in the River Thames channel, Figures 3 in Appendix E illustrates that there is negligible water level impacts in the floodplain.

4.3 Climate Change

Climate change has been accounted for in the assessment of fluvial and tidal flood risks by using predicted river flows and tidal surge profiles for the year 2107.

5. Flood Risk Management and Mitigation

5.1 Introduction

The assessment of fluvial flood risk (Section 4.1) indicates that the development proposal is predicted to have a negligible impact both upstream and downstream of the weir, *even when* assuming *there is* no flow through the screws *(sluice gates remaining open). This would only happen in instances where the incoming tide effectively 'reverses' the flow of the river and at high flows 'drowns' the screws to the point where the screws aren't turning (as there is no downstream flow).* The assessment of tidal flood risk (Section 4.2) indicates that the development proposal is predicted to have a negligible impact both upstream and downstream of the weir during a tidal event, assuming no flow through the screws. As outlined in Section 4.1.3 and 4.2.2 these impacts are considered to be within the tolerances of the ISIS-TUFLOW model and thus negligible and not requiring mitigation measures. The small impacts on water level and flood extent predictions are described in Section 4.1.3 and 4.2.2.

Only the 1 in 100 year plus climate change fluvial flow has been simulated as part of the fluvial assessment. Smaller flood flows have not been represented in the model as it is considered that any impacts would be of a smaller magnitude than that predicted in the 1 in 100 year plus climate change event.

5.2 Flood Risk Management

This section of the report identifies the design measures which have been incorporated into the scheme to manage flood risk both to the installation and elsewhere. These are the design responses. This section also details the management responses which will need to be implemented as part of future water level and flood risk management at the weir. These measures are considered to satisfy the requirements of PPS25. *It is acknowledged (as alluded to earlier in this report) that more details are required for both the construction and operation phase Flood Defence Consents.*

These management measures are discussed in the following sections.

5.3 Management Through Design

5.3.1 Design of the Hydropower Scheme

The hydropower scheme has been designed so that the sluice gates remain open during normal operation and are closed only during low flow conditions or during maintenance work. It is not intended to carry out maintenance work during a flood event. A Flood Management Plan or similar will be incorporated to ensure maintenance work is planned for periods of low flow and considers the rainfall forecast and flood warnings before work is undertaken. This mitigation measures has been purposefully design as part of the current scheme so that the screws can continue to operate in the event of a power failure on the grid, and thus not requiring closure of the sluice gates, through wasting the energy via an air heat dump. This design feature represents a significant revision of the early designs to manage the potential risk of closure which was identified by the Environment Agency.

5.3.2 Installation of Additional Capacity in the Weir

The scheme has been designed to include a new sluice which can be considered as a 'flood relief channel', which will provide a new flow area between 2.2mAOD (invert) and the existing weir crest at 4.4mAOD over its 3.0m width. *The provision of additional capacity, to convey flows within the weir structure, beyond that of the 'flood relief channel' already incorporated into the design* is not considered necessary. *The* hydraulic modelling undertaken as part of the FRA does not predict measurable increases upstream of the structure (observed differences have been considered negligible and within model tolerances).

5.3.3 Management of Risk to the Scheme through Design

The design plans are presented in Appendix B. Peak flood levels immediately upstream of the weir are cited by the Environment Agency (see Appendix C) as being 6.80mAOD for the 1 in 100 year plus climate change (year 2107) fluvial event. The modelling undertaken for this study predicts a level of 7.03mAOD for the same event. The walkway above the screws will be set at 7.054mAOD *(which has sufficient freeboard above the 1% plus climate change modeled water level)*, the level of the generators and other equipment is yet to be confirmed, however, this will be set above 7.554mAOD. This will ensure that the plant room housing water sensitive equipment is at least 1.0m above the predicted 1 in 100 year plus climate change fluvial event identified by the Environment Agency or 0.52m above levels predicted by this study. The predicted water levels are highest at the weir during a fluvial event.

5.3.4 The Ancillary Building

The control equipment is proposed to be located in the existing building in the Lensbury Club grounds. In compliance with the requirements of PPS25, the refurbishment of the building has been designed so that the building footprint does not increase. The building will be made flood resilient with sensitive equipment being set as high as practicable above the current floor level at 'table height'. It is recognised that there is a risk that sensitive equipment may be damaged during an extreme event, however, the screws would remain in operation and therefore no impacts are anticipated to flood risk elsewhere.

5.4 Management through Revised Operating Procedures

A 'Pulling Order' sheet is retained in the Lock Keeper's office at Teddington Weir which dictates the order in which the gates and sluices are opened to manage rising water levels, a copy of which is provided in Appendix F.

It will be necessary to adopt an alternative 'Pulling Order' once the scheme is in place to remove Radial Gates 18 and 19 and incorporate operation of the sluice at the flood protection channel. This would also ensure the most efficient operation of the new hydropower screws. Currently the first gates to open, as water levels rise, are the fish passes and the flap gates. During the 1 in 100 year flood event, the weir will be fully drawn, by which time the order in which the gates are drawn is less significant. The 'Pulling Order' is likely to be more significant for the management of high frequency low magnitude events which require some of the gates to be drawn, but not all. It is therefore recommended that a revised pulling order be established to manage water levels during high frequency low magnitude events so as to ensure that for any given event, the flood risk elsewhere is not increased. The operation of the weir is the responsibility of the Environment Agency, and therefore has not been refined as part of the proposed scheme. *Ham Hydro CIC acknowledges that the pulling order and gate operating procedure has to be fully discussed and agreed with the EA; and the Lock Keepers informed and trained in the new methodology. It is understood that revised pulling orders and gate operating procedures will form a part of the construction and operation phase Flood Defence Consents.*

5.5 Flood Risk Management During Construction

To construct the scheme it will be necessary to build a cofferdam on the up and downstream sides of the left bank portion of the weir. The purpose of which will be to provide dry working conditions. When building the cofferdam, consideration should be given to the potential water levels which could occur if there was an extreme event on the River Thames.

The installation of a temporary cofferdam will effectively remove part of Teddington Weir from service and thus reduce the width of the weir. As established in Section 4.1.3, the reduction in conveyance potential of this part of the weir is not predicted to have a significant impact on the upstream peak water levels during the 1 in 100 year (plus climate change) fluvial event. Flow through other sections of the weir has been found to increase, compensating for the loss of part of the weir. It is therefore likely that the impact of the cofferdam will also be small.

It should be noted that climate change considerations are not appropriate for reviewing the risks during the construction phase, which *is anticipated to occur in 2013*. Therefore peak water levels are likely to be lower than 7.03mAOD which was predicted for the 1 in 100 year fluvial event which is inclusive of a climate change allowance.

Even when conveyance through the screws is not facilitated, the hydraulic river model adapted for use in this FRA does not predict measurable increases in peak water level upstream of the weir. The height of the cofferdam will be informed by construction method statement and health and safety assessments. The hydraulic modelling undertaken in this FRA can be used to conclude that if the cofferdam was installed with a crest level of 7.554mAOD or less then it would unlikely result in any measurable increases in water level upstream.

To reduce risks to the construction and to further minimise the impacts of the cofferdam on flood risks elsewhere it is recommended that construction is undertaken between late spring and early autumn as these are typically low flow periods on the River Thames.

During construction the existing weir 'Pulling Order' (Appendix F) will not be applicable as radial gates 18 and 19 will be taken out of service. It is therefore recommended that an interim 'Pulling Order' be established to manage high flows during the construction period.

Ham Hydro acknowledges that more details are required for a construction phase Flood Defence Consent. An option to mitigate flood risk may include the inclusion of flaps in the cofferdam to facilitate conveyance through the structure should flood water levels get too high.

6. Summary

This Flood Risk Assessment for the proposed hydropower scheme at Teddington Weir has been undertaken according to the requirements of PPS25.

The River Thames presents a potential fluvial and tidal flood risk to the proposal and the scheme has been designed to manage this risk so that the operating equipment and electronics, where possible, are not damaged during high flow events. The flood sensitive equipment will be housed in the plant room (located on the structure), located above 7.554mAOD, or in the ancillary building. The plant room (located on the structure) is at least 0.75m higher than the 6.80mAOD cited by the Environment Agency (see Appendix C) for the 1 in 100 year plus climate change (year 2107) fluvial event immediately upstream of the weir. This is 0.52m above the level predicted by the modelling undertaken for this assessment, however, it should be noted that the equipment will be housed above 7.554mAOD and that failure of the equipment is not anticipated to impact third parties. It is recommended to site the flood sensitive equipment above 7.63mAOD. At the ancillary building it has not been practicable to site the flood sensitive equipment above 'table level'. However, while the flood sensitive equipment may be damaged during an extreme event, the screws have been designed to continue operating and therefore no impact to flood risk is anticipated. It is proposed that a pump is installed within the ancillary building to discharge any flood water that does enter the building. Other sources of flooding are not considered to present a risk to the scheme.

The potential impacts of the scheme, including the mitigation inherent in the design, on flood risk elsewhere have been assessed by modifying the Environment Agency's river model of the lower Thames. The average fluvial and tidal peak water level increase in the River Thames was predicted to be negligible both at Teddington Weir and for 2km upstream of the weir. This was the case both with and without conveyance through the screws. On this basis, further mitigation measures are not considered necessary.

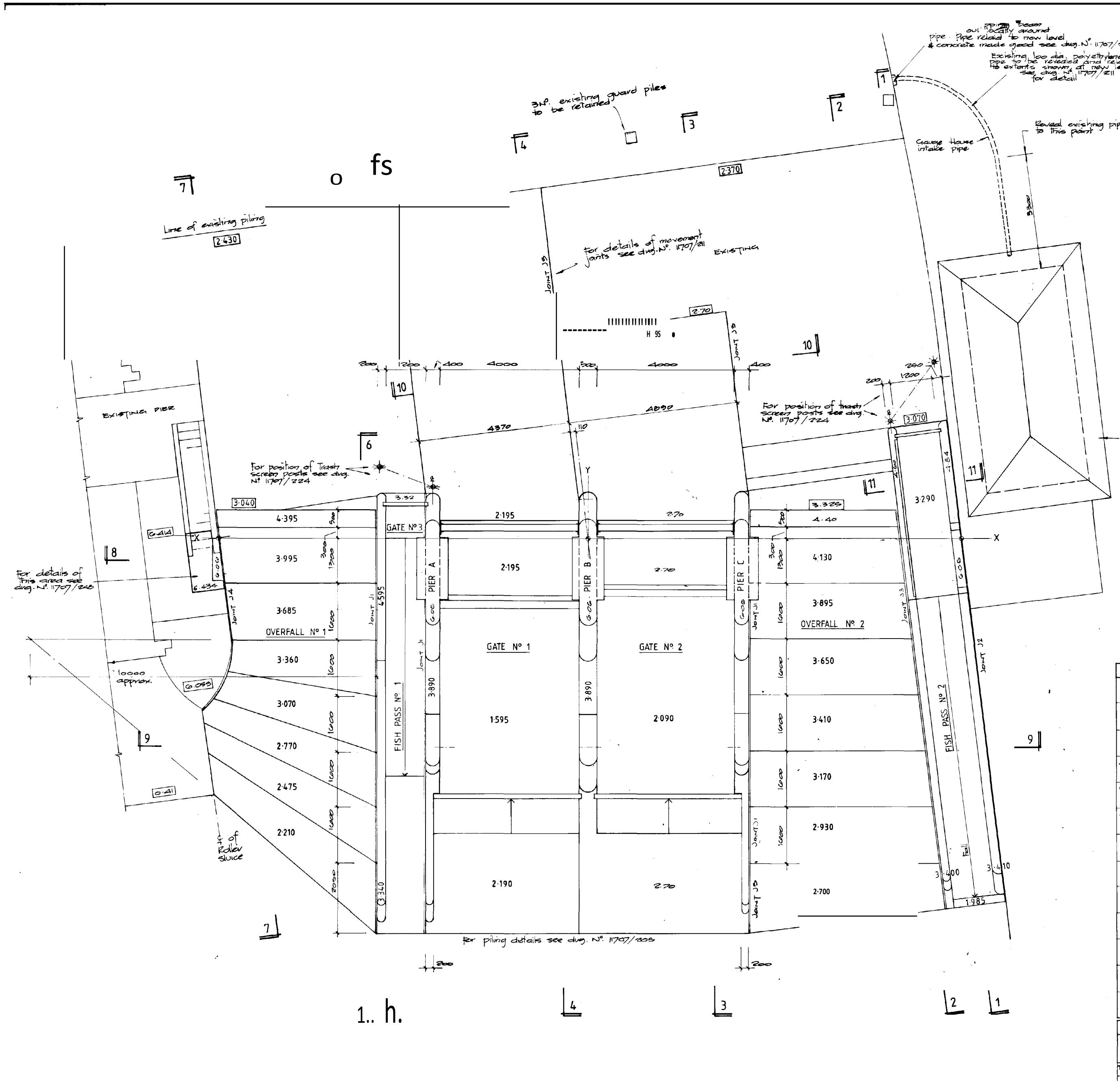
The scheme has been designed to incorporate the following mitigation measures:

- Sluice gates remain open expect during low flow conditions and for maintenance work (undertaken during low flow conditions);
- New flood protection channel incorporated as part of the design; and
- Sensitive equipment located above 7.554mAOD.

In addition the 'Pulling Order' will need to be adjusted to ensure the most efficient operation of the new hydropower screws and introduce the operation of the sluice at the flood protection channel. The revised 'Pulling Order' will need to ensure that flood risk is not increased elsewhere.

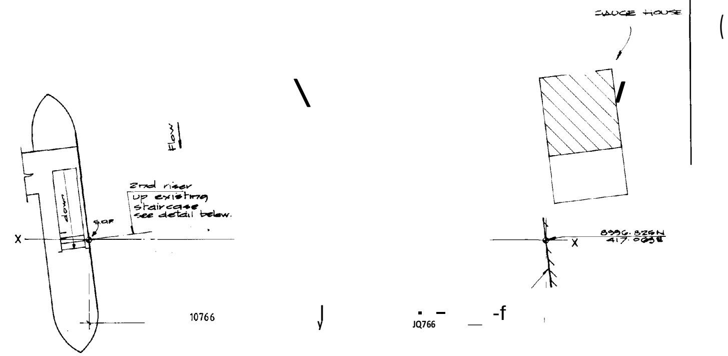
All known potential flood risks posed to the site have been considered. It is concluded that this site is suitable for the proposed development provided the scheme is constructed as per design which incorporates appropriate mitigation for the fluvial flood risk.

Appendix A
Current Weir Configuration

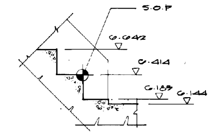


PLAN

Scale 1:50.
All metalwork omitted for clarity



SETTING OUT



LOCATION OF SETTING OUT POINT ON ROLLER SLUICE

HOLDING DOWN BOLT SCHEDULE

	Location	No. off	dia	type	Comments
1	corbel on Piers: A B C	4 12 10 10	20 10 20 20	2	
2	GANGWAY: Roller sluice Lensbury club stair	2 2 2	16 16 12	2	
3	GATES 1 & 2 PIVOTS	18 18	32 32	–	see drg. Nº. 11707/234.
4	STANKING CHANNELS on Piers A, B & C.	48	20	1	
5	FISH PASS Nº 2 Flooring support RSA.	10	10	1	
6	FISH PASS Nº 2 H/R end fixing	4	10	2	
7	FISH PASS Nº 2 H/R base fixing	8	12	2	
8	GATE ARC RUBBING STRIPS	64	6	–	see drg. Nº. 11707/225
9	GATE SILL PLATES	12	20	2	
10	GATE Nº 3	[illegible] 2	6 12	3	Nº of bolts depends upon design which forms part of
11	GATE Nos 1 & 2 TIMBER SILL BOARDS	8	12	3	tender ∴ approx only given

Type	Holding Down Bolt Details
1	Cast in socket
2	Post drilled chemical anchor by 'Hilti' H.V.A. type HAS-R. or sim. approved.
3	Post drilled 'thru bolt' by Rawlplug or sim. approved

NOTES

All levels are in Metres above O.D(N).
All dimensions are in millimetres

All exposed edges to have 25 x 25 chamfers.

This drawing is to be read in conjunction with drg. Nºs. :- 11707/205 to 212 incl.

Existing levels shown thus : 6.414
New levels shown thus : 6.414

5 ALL DIMENSIONS SHOWN ARE AS BUILT WITHIN BUILDERS TOLERANCE.

Revision	Date	Amendment
AC	NOV. 92	AS CONSTRUCTED
J		ISSUED FOR CONSTRUCTION
G.	6-11-91	ISSUED FOR TENDER (REVS D-F NOT USED)

NRA
National Rivers Authority
Thames Region

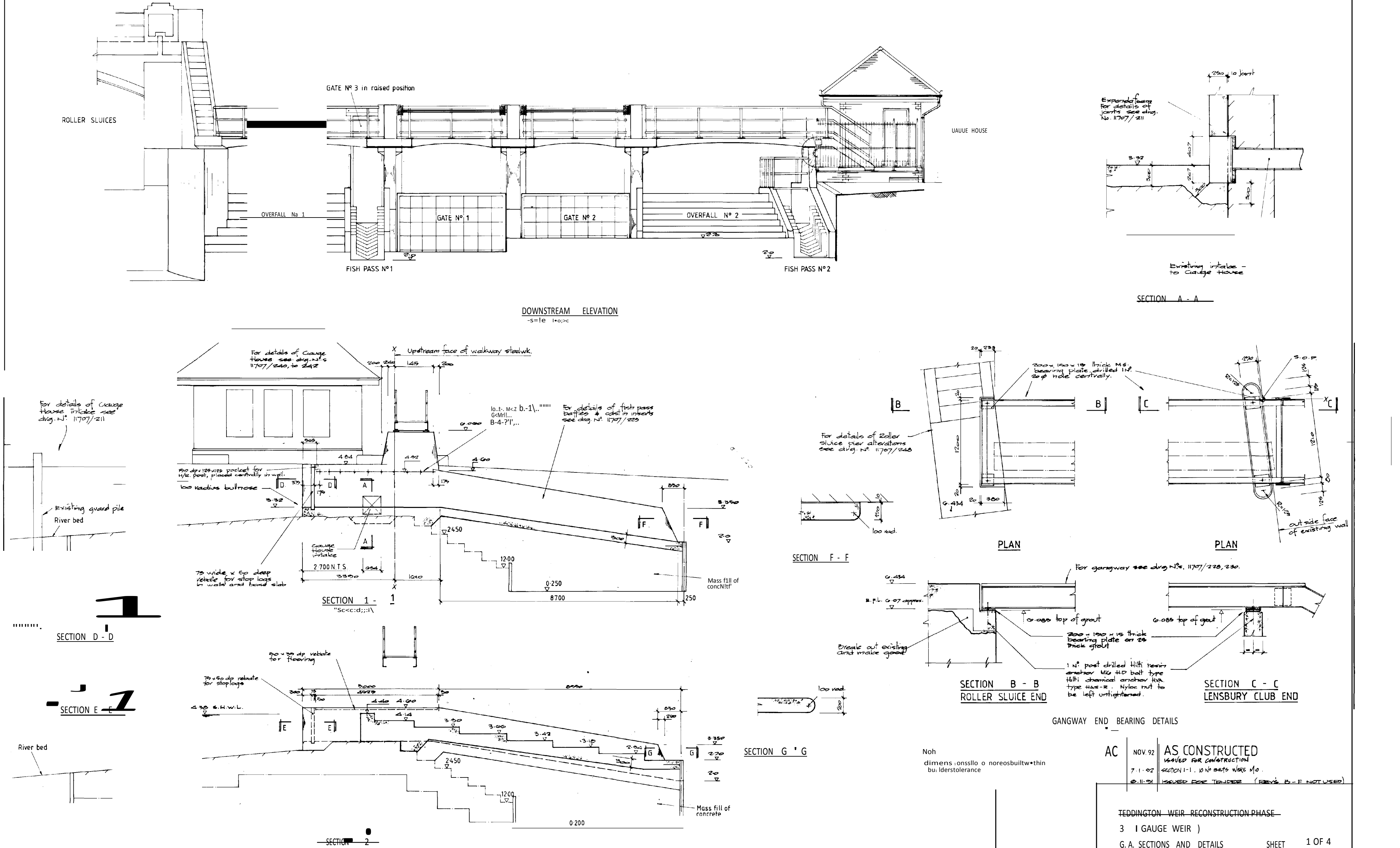
TEDDINGTON WEIR RECONSTRUCTION
PHASE 3 (GAUGE WEIR)
GENERAL ARRANGEMENT. PLAN & SETTING OUT

DRN. A.P.M.	CHKD. [illegible]	APP. CRP	ORIGINAL SCALE: 1:50	PROJECT REF: 3354
DATE: JAN. '91	DATE: Nov 91	DATE: Nov 91		
SECTION PROJECTS:				

L. D. JONES, I.P.F.A, F.C.C.A, M.B.I.M, M.I.W.E.M.
REGIONAL GENERAL MANAGER,
KINGS MEADOW HOUSE,
KINGS MEADOW ROAD,
READING RG1 8DQ.

ENGINEER:
N. J. SMITH C.Eng., M.I.C.E., M.I.W.E.M.

DRAWING NUMBER 11707 / 208 REV AC



AC | NOV. 92 | AS CONSTRUCTED

ISSUED FOR CONSTRUCTION

ISSUED FOR TENDER

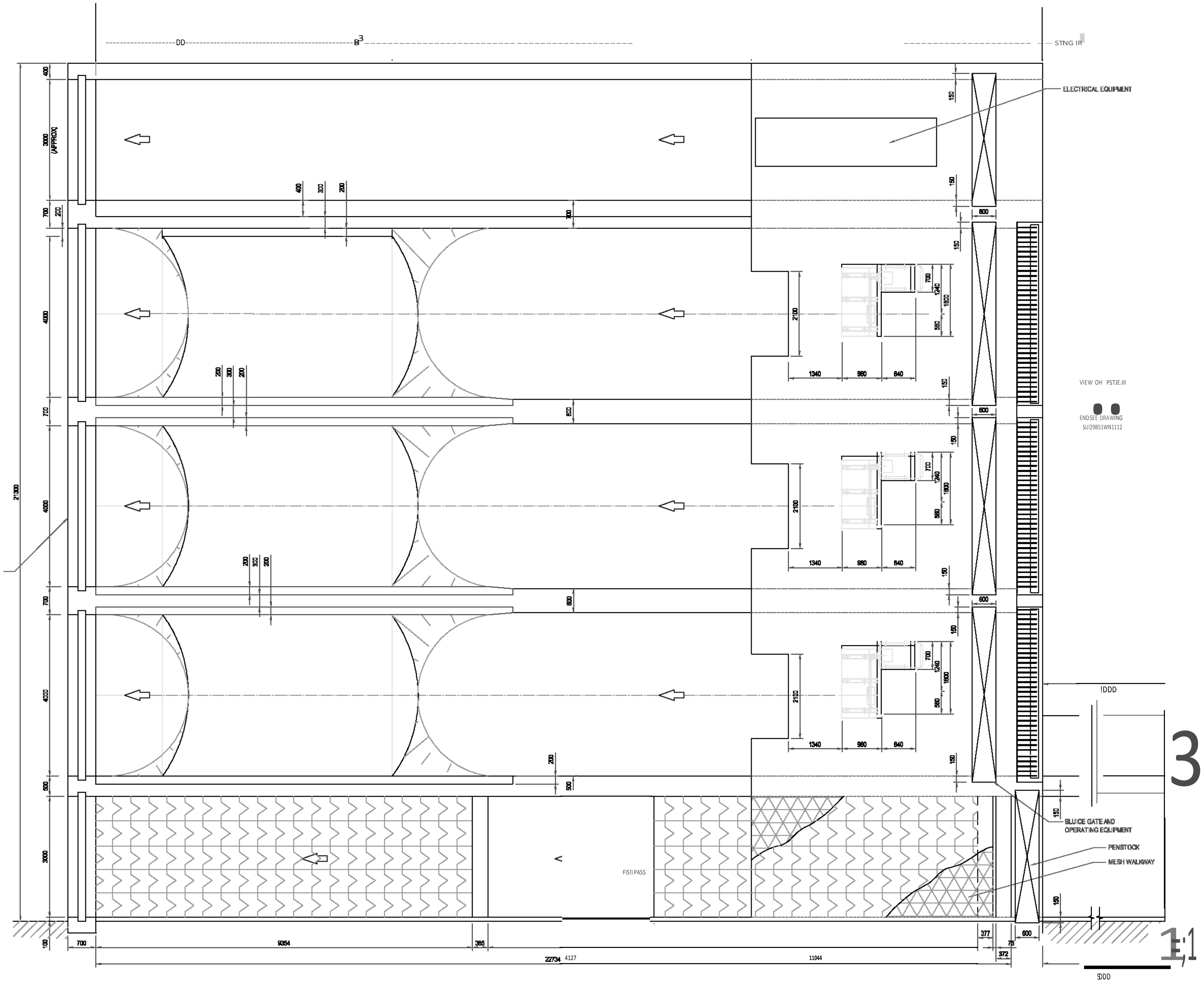
TEDDINGTON WEIR RECONSTRUCTION PHASE 3 (GAUGE WEIR)

G. A. SECTIONS AND DETAILS

SHEET 1 OF 4

11707 /209

Appendix B Proposed Plans



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Peterborough, Cambo, Fax. +44(0)1733 355999
England, PE2. 6YS. Tel. +44(0)1733 366900

Client
HAM HYDRO CIC

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TEDDINGTONWEIR HYDROPOWER SCHEME

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HYDROPOWER SCREW PLAN
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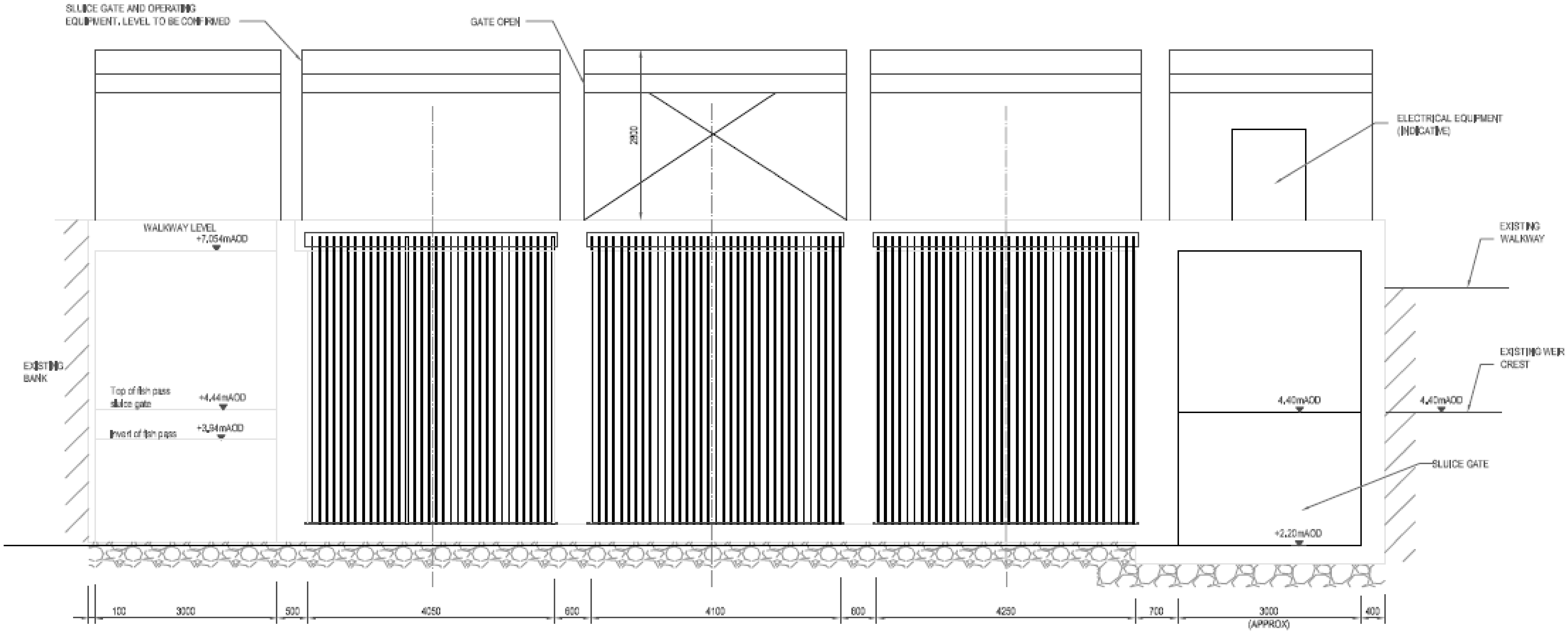
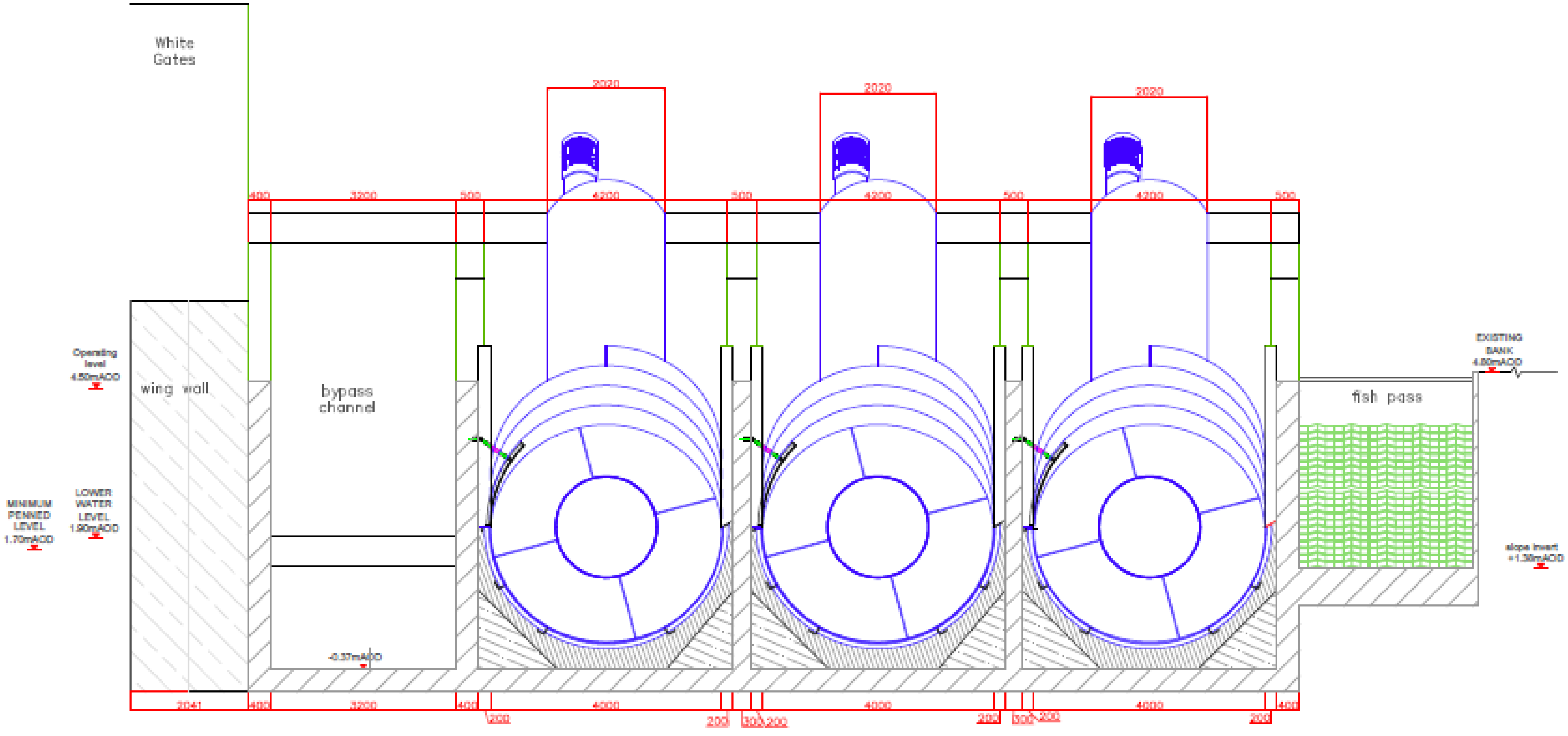


UPSTREAM ELEVATION (SEE DRG 5102682/WA/101/B)



DOWNSTREAM ELEVATION
(SLUICE GATES NOT SHOWN)
SCALE 1:100

Indicative drawing only
Subject to design approval

eWaterpower Ltd.

Project	Teddington Weir	
Client	Ham Hydro CIC	
Date	29/02/2012	
Drawn by	Steve Tickner	
File name	TW Downstream View1-3	
Layout	A3	PDF
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Viewports	1	

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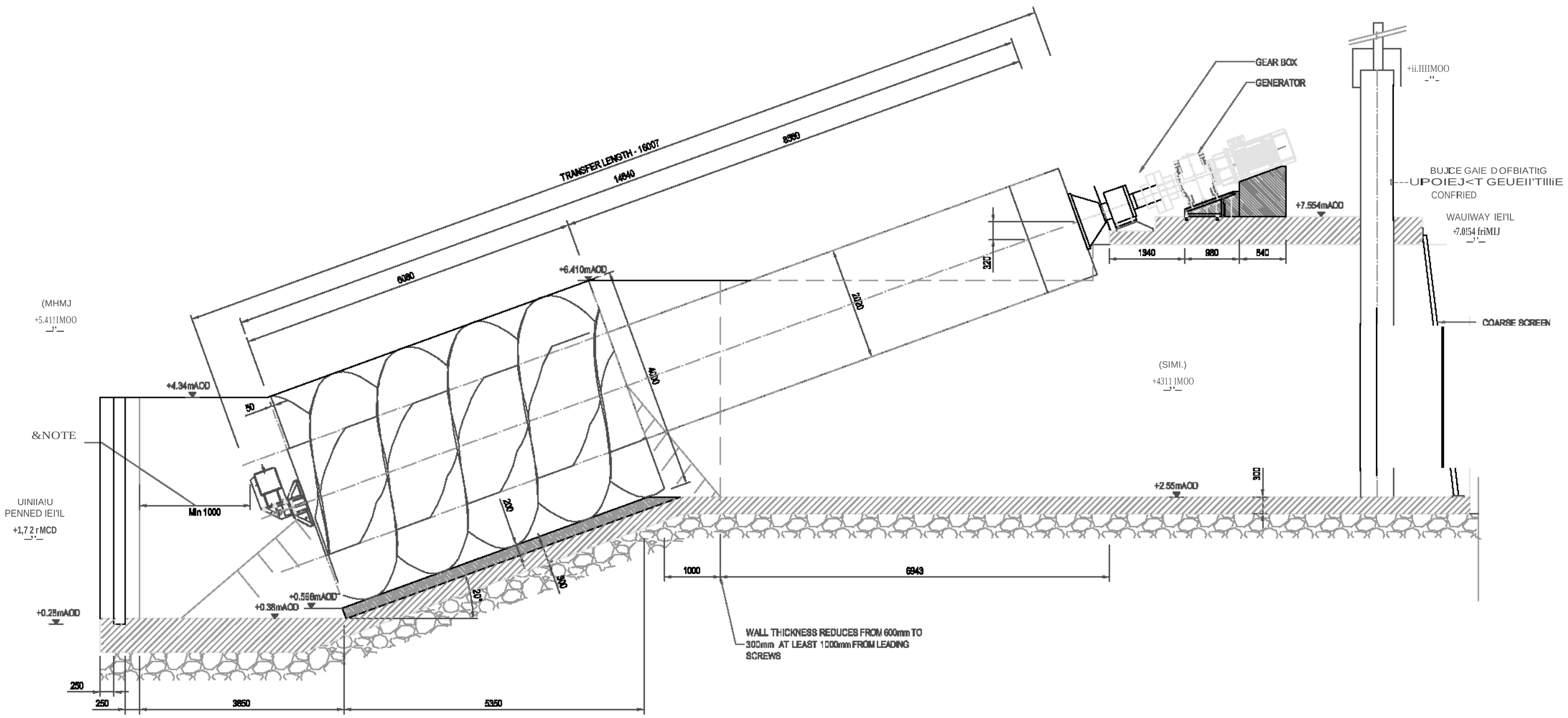

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Tel. +44(0)1733 366900

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HAM HYDRO CIC

TEDDINGTON WEIR
HYDROPOWER SCHE E

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HYDROPOWER SCREW
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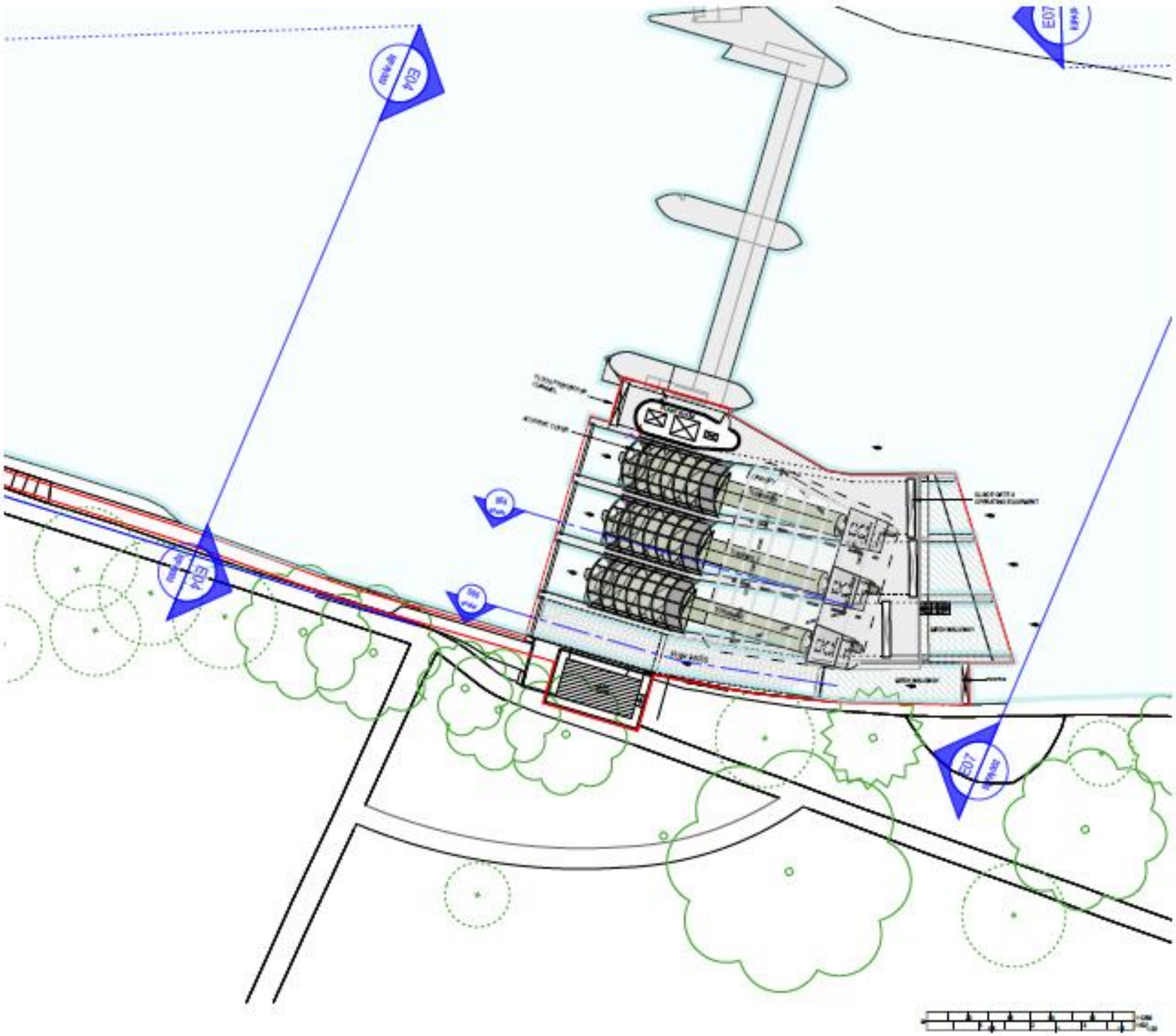
Drawfna

5102682 / WA / 100 C



P2	PLAN AMENDED		
P1	ISSUED FOR PLANNING		HLM

Revisions

Project

TEDDINGTON WEIR

Client

HAM HYDRO CIC

Title

PROPOSED PLAN

Drawing No.	Revision
L(PA)003	P2

Scale @ A2	Drawn
1:200	HLM

Date	Checked
25/11/2011	HLM

HLM

Appendix C
Environment Agency Correspondence

Product 4 (Detailed Flood Risk) for Teddington Lock

Our ref: **SE21589**

Product 4 is designed for developers where Flood Risk Standing Advice FRA (Flood Risk Assessment) Guidance Note 3

i) "all applications in Flood Zone 3, other than non-domestic extensions less than 250 sq meters; and all domestic extensions", and

ii) "all applications with a site area greater than 1 ha" in Flood Zone 2.

Product 4 includes the following information:

Ordnance Survey 1:25k colour raster base mapping;

Flood Zone 2 and Flood Zone 3;

Relevant model node locations and unique identifiers (for cross referencing to the water levels, depths and flows table);

Model(s) extents;

FRA site boundary (where a suitable GIS layer is supplied);

Flood defence locations (where available/relevant) and unique identifiers; (supplied separately)

Flood Map areas benefiting from defences (where available/relevant);

Flood Map flood storage areas (where available/relevant);

Historic flood events outlines (where available/relevant, not the Historic Flood Map) and unique identifiers;

Statutory (Sealed) Main River (where available within map extents);

A table showing:

i) model node X/Y coordinate locations, unique identifiers, levels, flows and JFLOW depths;

ii) Flood defence locations unique identifiers and attributes; (supplied separately)

iii) Historic flood events outlines unique identifiers and attributes; and

iv) local flood history data (where available/relevant).

Please note:

If you will be carrying out computer modelling as part of your Flood Risk Assessment, please read the enclosed guidance which sets out our requirements and best practice for computer river modelling.

This information is based on that currently available as of the date of this letter. You may feel it is appropriate to contact our office at regular intervals, to check whether any amendments/ improvements have been made. Should you re- contact us after a period of time, please quote the above reference in order to help us deal with your query.

This information is provided subject to the enclosed notice which you should read. This letter is not a Flood Risk Assessment. The information supplied can be used to form part of your Flood Risk Assessment. Further advice and guidance

http://www.environment-agency.gov.uk/research/planning/82584.aspx

If you would like advice from us regarding your development proposals you can complete our pre application enquiry form which can be found at

http://www.environment-agency.gov.uk/research/planning/33580.aspx

Modelled in-channel levels

SE21589

Modelled water levels in the Thames for locations close to your site are shown in the tables below. All levels are provided in **metres above Ordnance Datum Newlyn (mAODN)** In modelling the levels, three main factors were considered; the astronomical tide, the surge tide and the flow coming from the non-tidal Thames. The location, or node, closest to your site is 2.01u.

Modelled River Levels (mAODN)
Location node a1.15
Grid ref: TQ 17278 71275

Year	Annual Probability of Occurrence						
	10%	5%	2%	1%	0.5%	0.2%	0.1%
2005	5.93	6.15	6.42	6.61	6.79	7.04	7.22
2055	6.12	6.33	6.61	6.82	7.02	7.28	7.45
2107	6.07	6.29	6.58	6.80	6.99	7.24	7.41

Modelled River Levels (mAODN)
Location node 2.01u
Grid ref: TQ 16859 71425

Year	Annual Probability of Occurrence						
	10%	5%	2%	1%	0.5%	0.2%	0.1%
2005	5.87	6.06	6.30	6.50	6.67	6.91	7.08
2055	6.04	6.23	6.48	6.68	6.88	7.13	7.29
2107	5.98	6.18	6.46	6.66	6.85	7.10	7.24

Modelled River Levels (mAODN)
Location node 2.01d
Grid Ref: TQ 16578 71570

Year	Annual Probability of Occurrence						
	10%	5%	2%	1%	0.5%	0.2%	0.1%
2005	5.70	5.86	6.07	6.24	6.39	6.60	6.75
2055	5.85	6.00	6.22	6.40	6.57	6.79	6.93
2107	5.78	5.95	6.19	6.37	6.53	6.75	6.87

Model notes

SE21589

Model: **Tidal Thames Extreme Water Levels 2008**

Notes:

Our water levels are created from a 2-D joint-probability computer hydraulic model. As this is a joint-probability model the confluence of different factors such as astronomical tides, tide surge and river flows have been taken into account. In summary, the calculation of extreme water levels involves two main stages:
1) Estimating a matrix of water levels at various locations (or model nodes) along the estuary 2) Calculating the statistical frequency (return period) with which a particular water level might be expected to occur at each of the model nodes.

This study modelled water levels to various annual probabilities (10%, 5%, 2%, 1%, 0.5%, 0.2% and 0.1%) Each of these probabilities have been modelled for present day (2005) and future years (2055 and 2107) taking into account DEFRA's climate change allowances as set out in the Planning Policy Statement 25 (PPS25)

Climate change allowances:

Some of the levels are lower for the more extreme probabilities when including climate change because the hydraulic model used to produce these levels takes into account the Thames Barrier closure rule (circumstances/conditions of closure) and assumes that it remains unchanged up to 2107. Increased sea levels and fresh water flows mean that the Thames Barrier closure rule will be met more often. This means that a smaller number of tides will be allowed to flow up into central London each year. The highest tides experienced upstream of the Thames Barrier occur when the circumstances are within a fine margin of meeting the closure rule, and the decision is taken not to close (a near closure event). As there will be fewer tides per year upstream of the Barrier, and the ratio of near closure levels to regular tidal levels within this smaller number of tides remains constant, the number of near closure events will decrease, and therefore so do the modelled levels.

Thames Barrier, Eastmoor Street, Charlton, London, SE7 8LX
Customer services line: 08708 506 506
Email: enquiries@environment-agency.gov.uk

Historic flood data

SE21589

Our records show that the area of your site has not been affected by tidal flooding.
Information on floods that have affected areas near your site is provided in the table below, and is shown on the attached map

Historic Flood Events Unique ID	Flood Event Code	Flood Event Name	Start Date	End Date	Source of Flooding	Cause of Flooding

Extra historic flood information:

Please note the Environment Agency maps show flooding to land not individual properties. Floodplain extents are an indication of the geographical extent of a historic flood. They do not provide information regarding levels of individual properties, nor do they imply that a property has flooded internally.

Thames Barrier, Eastmoor Street, Charlton, London, SE7 8LX
Customer services line: 08708 506 506
Email: enquiries@environment-agency.gov.uk

Flood Defences SE21589

General description:

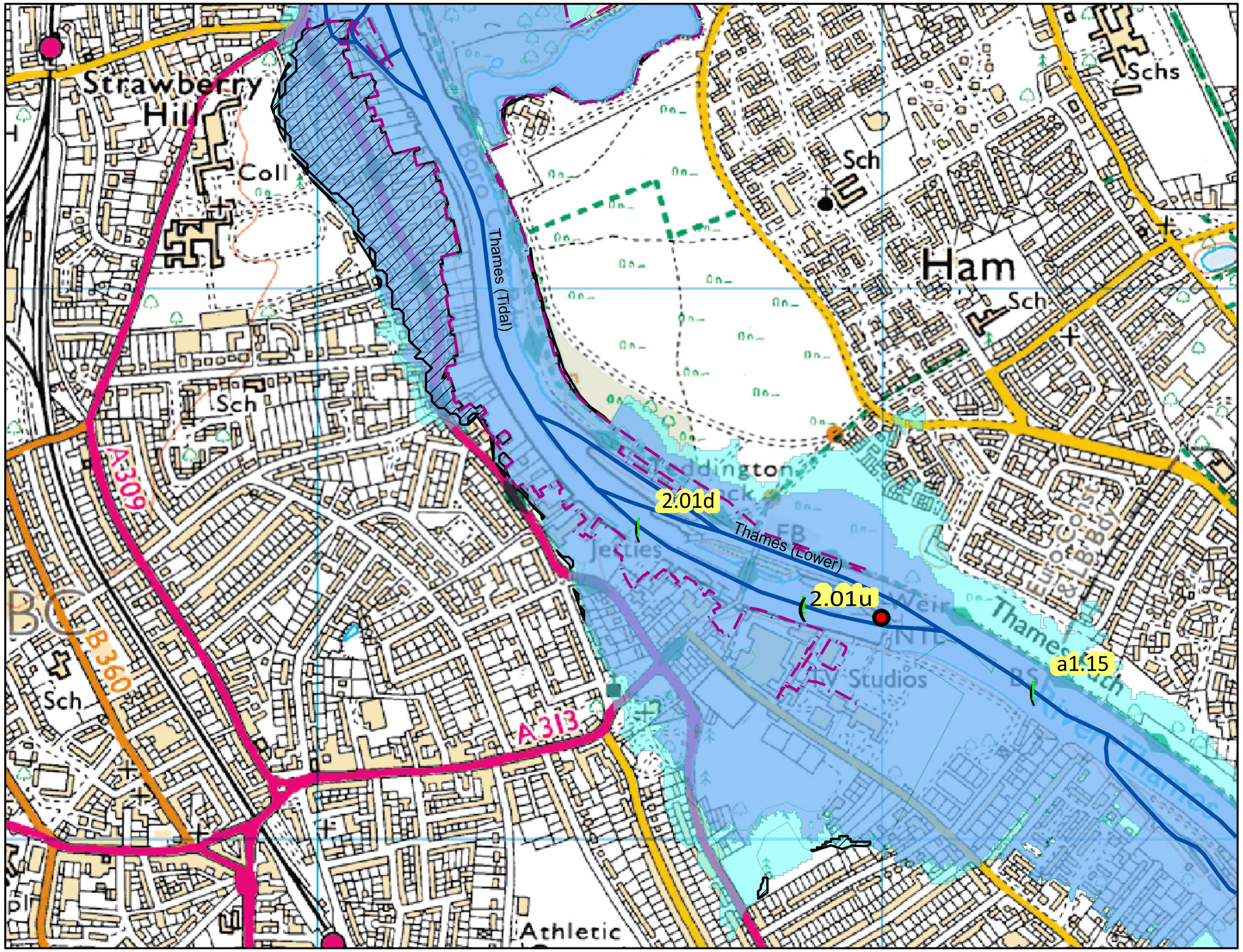
The defences along the tidal Thames in this area are all raised, man-made and privately owned. We inspect them twice a year to ensure that they remain fit for purpose. They must be maintained by their owners to the flood defence level in the area (6.1 mAODN along the Thames). The overall condition grade for defences in the area is 2 (good), on a scale of 1 (very good) to 5 (very poor)

Standard of protection provided by the tidal defences

The river Thames defences along this section of the river provide a standard of protection of 1 in 1000. This means that the defences protect against a tidal flooding event that has a 0.1% annual probability of occurring. This remains true up to the year 2070. After 2070 the standard of protection will decrease over time. However the Thames Estuary 2100 project has studied options to manage flood risk in the Thames estuary up to the year 2100. Public consultation of this study has finished, but you can access all the information here: http://www.environment-agency.gov.uk/research/library/consultations/106100.aspx

Thames Barrier, Eastmoor Street, Charlton, London, SE7 8LX
Customer services line: 08708 506 506
Email: enquiries@environment-agency.gov.uk

Detailed FRA/FCA [Teddington Lock] - created 04/02/11 [Ref: SE21589]



Environment Agency

0 150 300
Metres

Legend

- Site Location
- Model Nodes
- Flood Map - Defences
- Main Rivers
- Areas Benefiting from Flood Defences
- Flood Map - Flood Zone 3
- Flood Map - Flood Zone 2

Flood Map Areas (assuming no defences)

Flood Zone 3 shows the area that could be affected by flooding:
– from the sea with a 0.5% or greater chance of occurring each year
– or from a river with a 1% or greater chance of occurring each year.

Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to a 0.1% chance of occurring each year.

Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 08708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

RE: Ham Hydro (Teddington Weir) FRA - Flood Risk Query
Brines, Luis to: john.rampley@amec.com 25/11/2011 14:08
Cc: "Glynn, Justine", "lianne.grogan@amec.com"

History: This message has been forwarded.

Hi all,

Please see attached our final version of the model review.

We have included in the conclusions answers to your questions below. In regards to the first query about the 0.02m increase upstream can be considered negligible. The second query relates to the decrease in freeboard of the sensitive equipment (presumed to be electronic equipment associated with screw operation). The revised freeboard level of 0.52m above the 100yrCC is still significant. If you have already run some simulations to demonstrate that preventing flow through the screws has no impact on flood risk, then the design level of 7.554mAOD (0.52m above the 100yrCC level) should be accepted.

Please note we would need you to provide some feedback for the text highlighted in red. Kind

regards

Luis

Luis Brines
Flood Risk Mapping and Data Management Team
Environment Agency

From: john.rampley@amec.com [mailto:john.rampley@amec.com]
Sent: 25 November 2011 10:00
To: Brines, Luis
Cc: Glynn, Justine; lianne.grogan@amec.com
Subject: RE: Ham Hydro (Teddington Weir) FRA - Flood Risk Query

Morning Luis,

Thank you for the update. We look forward to hearing from you.

Many Thanks

John

John Rampley Principal Consultant AMEC
AMEC Environment & Infrastructure UK Limited
17 Angel Gate, City Road, London, EC1V 2SH Tel +44 (0)20 7843 1400
Direct +44 (0)20 7843 1448, mobile +44 (0)7712 663200
john.rampley@amec.com
amec.com/ukenvironment

From: "Brines, Luis" <luis.brines@environment-agency.gov.uk>
To: "lianne.grogan@amec.com" <lianne.grogan@amec.com>
Cc: "john.rampley@amec.com" <john.rampley@amec.com>, "Glynn, Justine" <justine.glynn@environment-agency.gov.uk>
Date: 25/11/2011 09:56
Subject: RE: Ham Hydro (Teddington Weir) FRA - Flood Risk Query

---

Good morning Lianne,

I just received the review this morning from Halcrow and I need to do some tweaks. I will give you an answer as soon as possible.

Thanks

Regards Luis

From: lianne.grogan@amec.com [mailto:lianne.grogan@amec.com]
Sent: 24 November 2011 15:02
To: Brines, Luis
Cc: john.rampley@amec.com; Glynn, Justine
Subject: RE: Ham Hydro (Teddington Weir) FRA - Flood Risk Query

Good afternoon Luis/Justine,

I am assuming that you are still expecting to hear back from Halcrow today. Could you please ensure that John Rampley is included in the response regarding my queries about the FRA approach to consider +/-0.02m change as negligible and the design levels for the proposal.

Thank you.

Kind regards,

Lianne Grogan, BASc, MCIWEM, C.WEM
Senior Consultant
AMEC
AMEC Environment & Infrastructure UK Limited
Northumbria House, Regent Centre, Gosforth, Newcastle upon Tyne, NE3 3PX, UK Tel +44 (0)1912 726100
Direct +44 (0)1912 726446, mobile +44 (0)7817 275606
lianne.grogan@amec.com
amec.com/ukenvironment

From:	"Brines, Luis" <luis.brines@environment-agency.gov.uk>
To:	"lianne.grogan@amec.com" <lianne.grogan@amec.com>, "Glynn, Justine" <justine.glynn@environment-agency.gov.uk>
Cc:	"john.rampley@amec.com" <john.rampley@amec.com>
Date:	22/11/2011 11:30
Subject:	RE: Ham Hydro (Teddington Weir) FRA - Flood Risk Query

Hello Lianne,

Halcrow assures me they will send us the review by the end of Thursday. I've asked them to take into account your comments below, so this should hopefully bring some light to your report.

Regards Luis

Luis Brines
Flood Risk Mapping and Data Management Team
Environment Agency

From: lianne.grogan@amec.com [mailto:lianne.grogan@amec.com]
Sent: 21 November 2011 15:42
To: Glynn, Justine
Cc: john.rampley@amec.com; Brines, Luis
Subject: RE: Ham Hydro (Teddington Weir) FRA - Flood Risk Query

Hi Justine,

I'm trying to follow up on my email from last week regarding the Ham Hydro query, but was told you were working from home this afternoon and on leave tomorrow. As I mentioned in the email we're trying to finalise the report today. I appreciate that it has only been two days, but I don't suppose you have heard anything back from Halcrow yet? We're keen to get a response on our proposed approach before submitting the report. Thank you in advance for your help in resolving this matter.

Kind regards,

Lianne Grogan, BASc, MCIWEM, C.WEM
Senior Consultant
AMEC
AMEC Environment & Infrastructure UK Limited
Northumbria House, Regent Centre, Gosforth, Newcastle upon Tyne, NE3 3PX, UK Tel +44 (0)1912 726100
Direct +44 (0)1912 726446, mobile +44 (0)7817 275606
lianne.grogan@amec.com
amec.com/ukenvironment

Be more sustainable - think before you print

From:	"Glynn, Justine" <justine.glynn@environment-agency.gov.uk>
To:	"john.rampley@amec.com" <john.rampley@amec.com>

Cc: "lianne.grogan@amec.com" <lianne.grogan@amec.com>, "Brines, Luis" <luis.brines@environment-agency.gov.uk>

Date: 18/11/2011 13:33

Subject: RE: Ham Hydro (Teddington Weir) FRA - Flood Risk Query

---

Hello John,

Luis has forwarded the questions below to Barrie Grice at Halcrow as they are currently dealing with the model review for us. Barrie will give you a ring if he needs more information.
Best regards

Justine Glynn
Development & Flood Risk
West Thames Area - South East Region

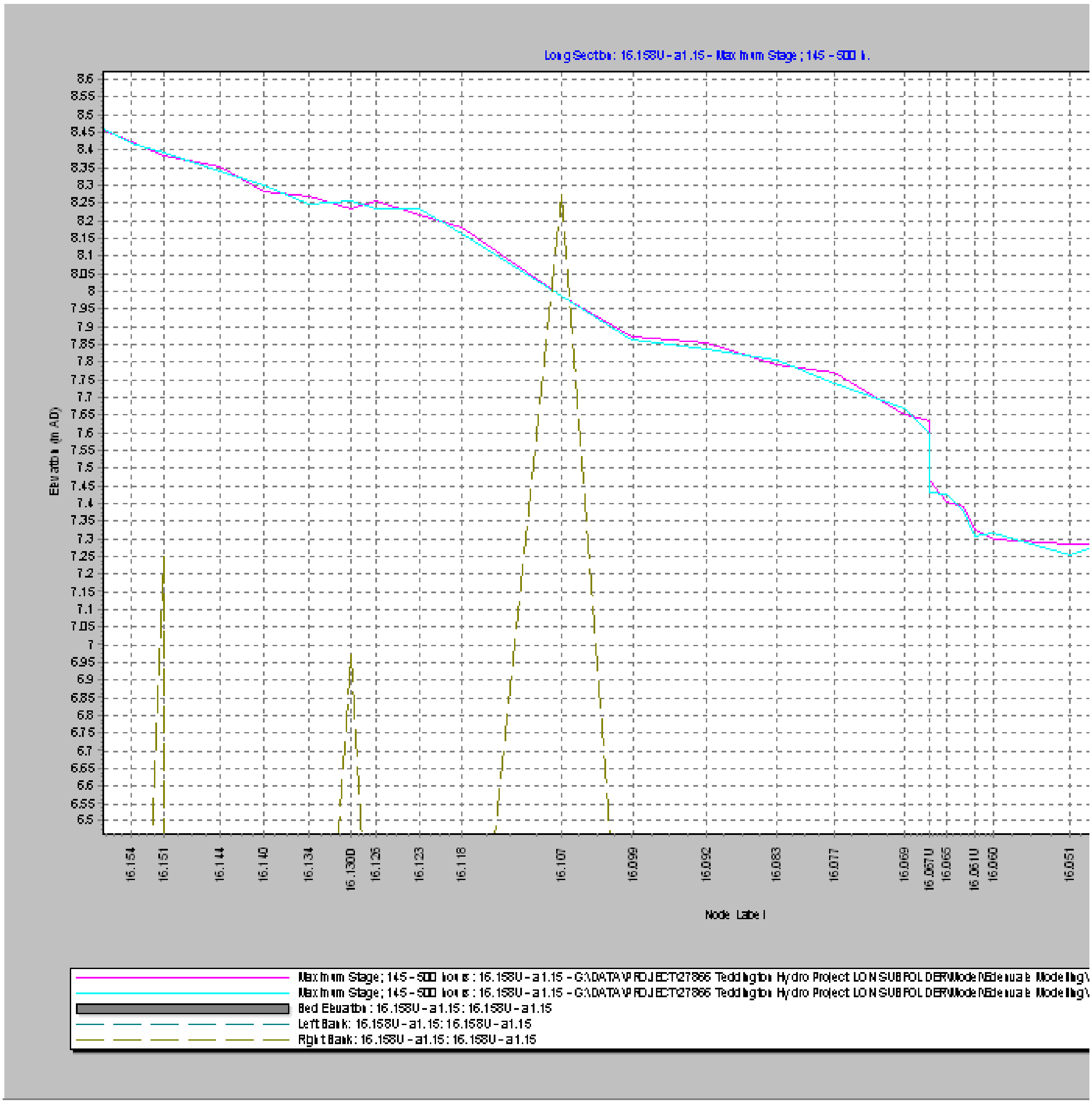
From: lianne.grogan@amec.com [mailto:lianne.grogan@amec.com]
Sent: 17 November 2011 15:32
To: Glynn, Justine
Cc: john.rampley@amec.com
Subject: Ham Hydro (Teddington Weir) FRA - Flood Risk Query

Good afternoon Justine,

I tried to call this morning, but was told you were on leave. I believe you are aware of the proposed hydropower scheme for Teddington Weir on the River Thames. I have been writing the Flood Risk Assessment based on the recent modelling undertaken by Edenvale Young and would like to discuss our findings before the report is officially submitted as part of a planning application.

Flood Risk Elsewhere
The results of the modelling indicate that the there is an increase of less than 0.01m representing flow through the screws and an increase of less than 0.02m if for some reason there is no conveyance through the screws. Basically flow through other parts of the weir increase slightly to compensate for the reduction of flow over the replaced section of the weir so that there isn't a significant impact on predicted water levels. We are proposing to identify all changes less than +/-0.02m as 'negligible'. This is based on a comparison of model results which predict an oscillating and inconsistent +/- 0.02m variation in locations where the scheme would not be expected to impact, i.e. more than 6km upstream of the weir beyond two major structures. See attached long-section plot below (blue-current, pink-proposed scheme with no conveyance through the screws). In addition, early modelling predicted a 0.03m variation in predicted results with only a change in model timestep, which suggests there is some variation inherent in the model. There are other factors which might also influence this such as the reporting interval of six minutes, the complex nature of the model, the large distances between model nodes or other.

Is this approach acceptable to the EA? The modelling suggests that the impact of the scheme is negligible and that no further mitigation (other than what is already incorporated in the design) is required.



Flood Risk at the Proposal

The EA provided modelled levels in the River Thames which indicates a level of 6.8mAOD (node: a1.15) upstream of the weir for a 1 in 100year plus climate change (2107) event. The modelling for this project, which includes representation of two fish passes and the piers between structures that were not in the model provided, predicts a level of 7.03mAOD for the same event. The sensitive equipment is located above 7.554mAOD. This is provides an allowance for uncertainty of 0.75m based on the provided level, but only 0.52m for the modelling undertaken for the project. Given there is a disparity in the predicted results and that failure of the equipment is not expected to impact third parties, would this be acceptable to the EA?

We are aiming to finish the FRA on Monday (Nov 21st) and so would appreciate a response as soon as possible. I am on leave tomorrow, so if you need to discuss any of these issues, please contact John Rampley in my absence.

Kind regards,

Lianne Grogan, BASc, MCIWEM, C.WEM
Senior Consultant
AMEC
AMEC Environment & Infrastructure UK Limited
Northumbria House, Regent Centre, Gosforth, Newcastle upon Tyne, NE3 3PX, UK Tel +44 (0)1912 726100
Direct +44 (0)1912 726446, mobile +44 (0)7817 275606
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Model Review Teddington_Weir_Hydropowerv2.pdf

Appendix D
Flood Modelling Report

Teddington Weir Hydropower Scheme

Flood Modelling

November 2011

Final

Edenvale Young
The Wool Hall
12 St Thomas Street
Bristol
BS1 6JJ

AMEC Environment & Infrastructure UK Ltd
17 Angel Gate, City Road
London, EC1V 2SH

VERSION HISTORY

Version	Action	Name	Date	Detail
1.4	Prepared by	A Gilbert	09 November 2011	Final Report for Issue
1.4	Checked by	C Whitlow	09 November 2011	

REPORT ISSUED TO

Issued to	Version	Method
AMEC Environment & Infrastructure (John Rampley, Lianne Grogan and Claire Penny)	1.4	Digital by Email

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TABLE OF CONTENTS

LIST OF FIGURES

1 INTRODUCTION

1.1 Background to Study

Edenvale Young Associates (EVY) have been commissioned by AMEC Environment & Infrastructure to progress a flood modelling study being undertaken on the Thames at Teddington Weir. The flood modelling is required to simulate the potential impacts of a low-head hydropower scheme at the weir, which is being proposed by Ham Hydro Community Interest Company (CIC).

The proposals comprise the development of three Archimedes Screws, each of 4m diameter; positioned adjacently. These will be flanked by a fish pass and a sluice gate, both 3m wide, on the left and right respectively.

The results of the modelling study will inform the Flood Risk Assessment that is being prepared in support of a forthcoming planning application for the development being made by Ham Hydro CIC. Specifically, EVY have been asked to progress the following tasks:

(i) Reviewing the baseline data and proposed scheme data to familiarise the modeller with the previous work and to identify any data gaps.

(ii) Updating of the baseline model to reflect any changes in the baseline condition as per plans provided to AMEC by Ham Hydro CIC.

(iii) Reviewing the existing representation of the proposed scheme and amending if appropriate.

(iv) Updating the model representing the proposed scenario based on the scheme details provided.

(v) Re-running both the baseline scenario and with-scheme scenario for the 1-in-100 year plus climate change fluvial event.

(vi) Re-running both the baseline scenario and with-scheme scenario for the 1-in-200 year plus climate change tidal event.

(vii) Sensitivity testing of the key variables, provisionally expected to include: roughness, crest heights, flows and tide levels.

(viii) Production of mapped outputs showing spatially varying depth, velocity and hazard in the study area for all scenarios.

(ix) Production of ISIS long section plots illustrating peak water levels across the study reach for all scenarios.

(x) Production of a report documenting the work undertaken, highlighting changes made to the models and all assumptions.

1.2 Information Provided

Information that was made available to EVY to progress the study included:

- An ISIS-TUFLOW model of the Lower Thames, originally developed by Halcrow and featuring amendments made by AMEC at Teddington Weir. The inflow and downstream boundary conditions were already defined in the model. It is noted that the tidal model had not run when it was supplied.
- Photographs and a survey drawing from 1991 illustrating the current weir and gate arrangement at Teddington Weir.
- Data from the EA concerning the ‘pulling order’ for the existing radial gates at Teddington Weir and their flood map for the Thames at this locality.
- Drawings prepared by Atkins illustrating the design arrangement of the proposed scheme (ref: *5102682_WA_100-102_B*); subsequently superseded (in places) by scheme

dimensions offered by Brendan Barrow, the scheme advisor.

2 MODEL SCHEMATISATION

The following section describes the geometry of the model at Teddington Weir to simulate the design events: 1-in-100 year fluvial and 1-in-200 year tidal floods, with climate change allowance.

2.1 Baseline Scenario

2.1.1 Previous Representation

The existing arrangement at Teddington Weir is represented in the 1D domain of the ISIS- TUFLOW model; a schematic identifying the various units is shown in **Figure 2-1**.

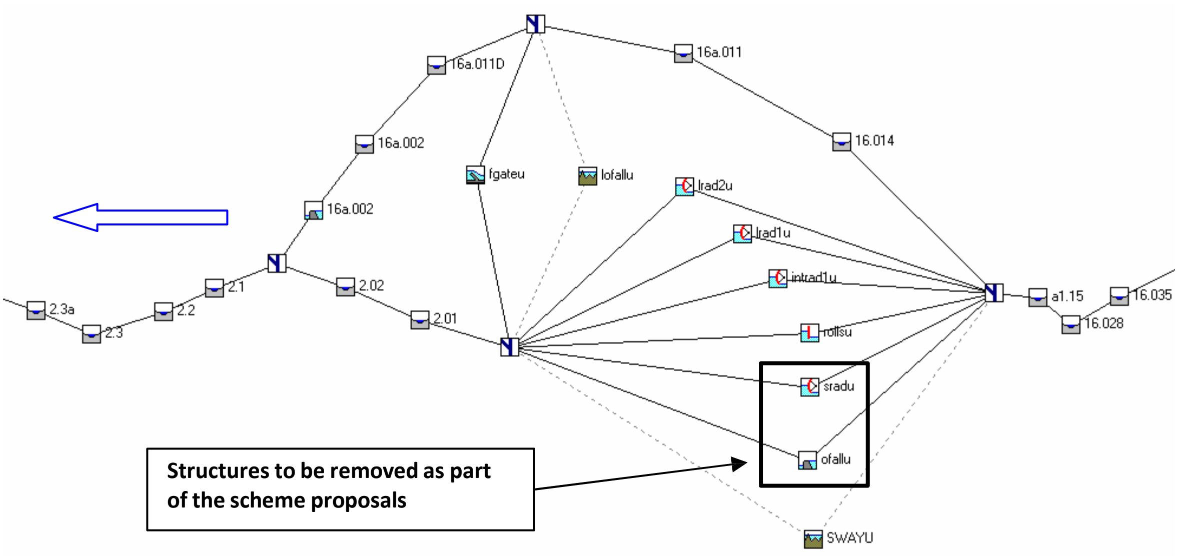


Figure 2-1 Schematic of ISIS model at Teddington Weir in baseline scenario

Of principle importance to the current study is the representation of the weir and gate arrangement near the left bank since the proposed scheme will replace all structures south of the roller sluices. A photograph illustrating the model representation in this area is shown in **Figure 2-2**.

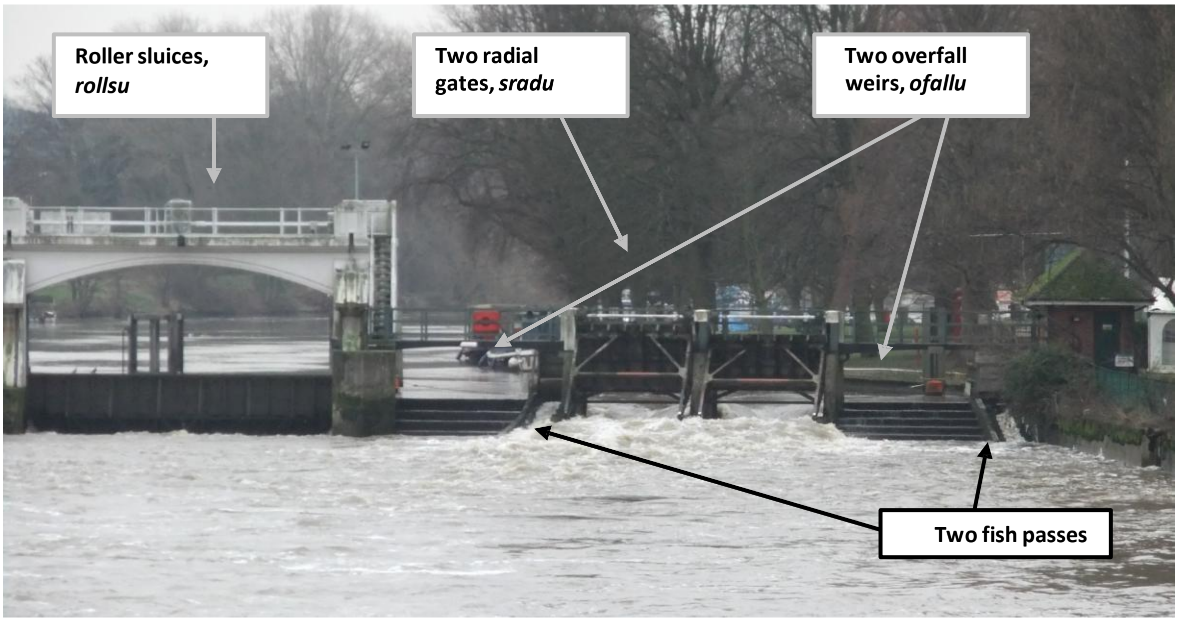


Figure 2-2 View upstream of existing arrangement at site of proposed scheme

2.1.2 Changes to Model

The two fish passes highlighted in **Figure 2-2** were not included in the original model set-up. In order to ensure consistency with the width of river replaced by the new scheme, it was considered appropriate to include these within the baseline scenario.

The dimensions of two fish passes were added as an extension to the existing spill *SWAYU*, these are both of width 1.2m with inverts of 3.29mAOD and 3.32mAOD. An obstruction of width 2.9m and was also added to represent the piers between the existing gates and weirs, which had also not previously been included. This obstruction was defined at an elevation of 7.4mAOD, corresponding to the top of the white boxes that are positioned at the top of the piers (inclusive of the thickness of the bridge deck). The current arrangement is illustrated in **Figure 2-3**.

Figure 2-3 Picture illustrating position of white boxes above piers in baseline scenario

The new spill added to the baseline scenario is shown in **Figure 2-4**.

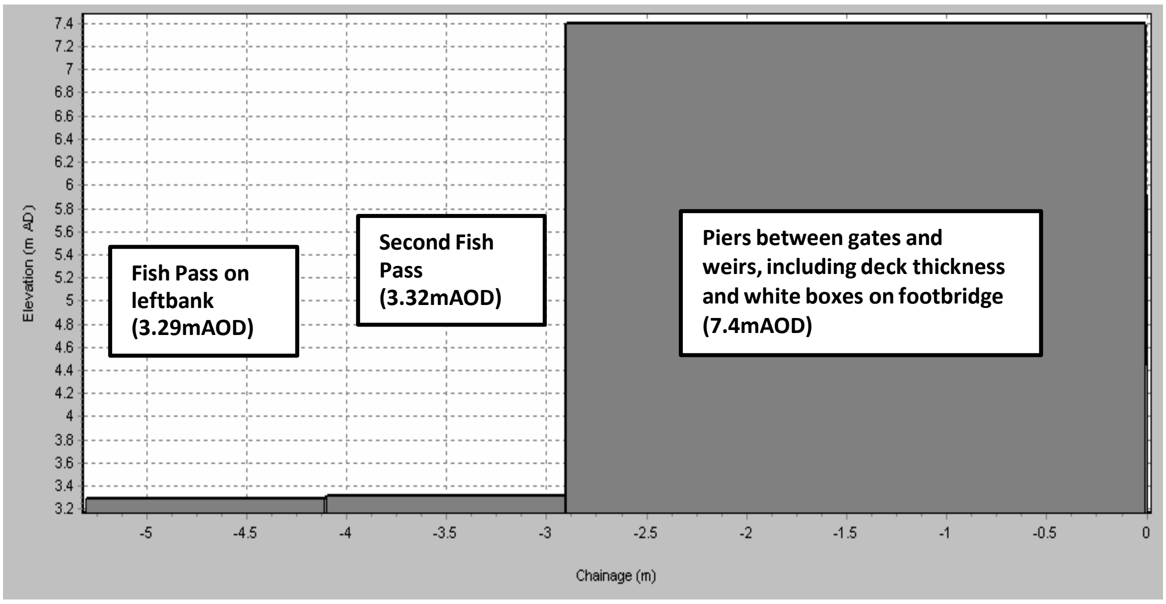


Figure 2-4 Profile of extension to spill 'SWAYU' in baseline scenario

The combined width of the new additions (5.3m), the two weirs (8m) and the two gates (8m) now match the width over which the scheme is being designed, 21.3m, enabling a meaningful comparison to be made.

It is noted that the fence across the footbridge is not explicitly included within the baseline model. This is considered to present a very minor obstruction to high flows, although it is acknowledged that there is the potential for the structure to entrap debris; thereby reducing available conveyance.

It is further noted that the controls for all the sluices and radial gates in the model were not altered from their existing definitions, apart from changing the modular limits at these structures from 0.9 to 0.7 in an effort to make the model more stable through the simulation.

The only change to the boundary conditions concerned the nature of the head-time boundary used in the tidal scenario. This was because the existing boundary was out-of-phase with the operation of the Thames Barrier, causing reflection waves to be created upstream and downstream of the barrier. As a fix, the head-time boundary adopted for the fluvial scenario was used for the tidal scenario, with the maximum tide adjusted to replicate the 1-in-200 year plus climate change design event; coincident with the maximum inflow.

2.2 Proposed Scenario

2.2.1 Scheme Details

The modelling for the development in place has tried to best represent the impact of the scheme on the flood regime; this has been informed by correspondence with Brendan Barrow. In design flood conditions we understand that:

(i) The gates for the screws will be open. These are only intended to be shut either during periods of low flow, or if maintenance work is required (which would not occur during a flood situation),

(ii) The screws are not enclosed units; hence water passing through the trash screen will pass over the top of the screw as it flows downstream.

(iii) Teddington Weir will drown under such extreme conditions and thus there will be limited or no head loss to generate power from the screws during the flood wave. As a conservative measure, it has been assumed that the screws will not convey flow in flood conditions. However a sensitivity test was also run assuming a constant flow of 9m^3/s per screw, described in **Section 2.3.3.**

In light of the above, it is considered that the impact of the scheme can be represented as a spill unit which incorporates: the obstruction caused by the top of the screws, the obstruction caused by the piers between the screws, and the obstruction caused by the trash screen (defined as one tenth the width of the screen).

2.2.2 Changes to Model

In order to model the proposed scenario, the following changes were made:

(i) The two radial gates (*sradu*) and the two overfall weirs (*ofallu*) were removed.

(ii) The dimensions of the fish passes and piers added to spill *SWAYU* were removed.

(iii) An additional spill was added (*Screws_u*) to represent the scheme design; this is illustrated in **Figure 2-5**. (This was given a coefficient of 1.0 to be consistent with that used for *SWAYU.*)

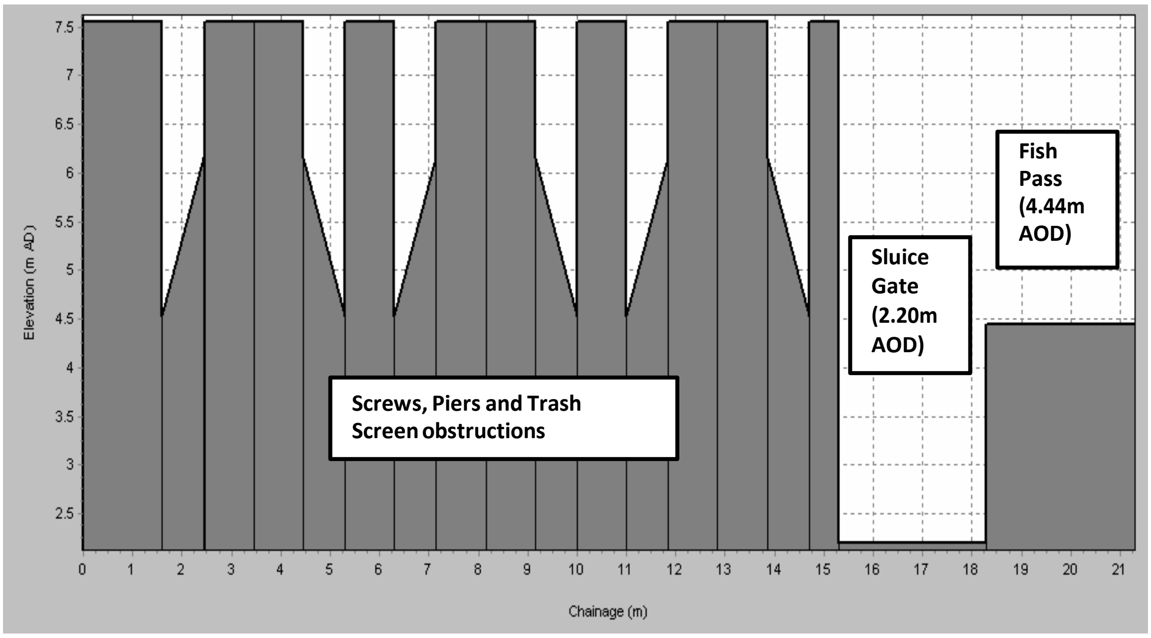


Figure 2-5 Geometry of spill unit used to represent the scheme design

The schematic of the model at Teddington Weir in the proposed scenario is shown in **Figure 2-6**.

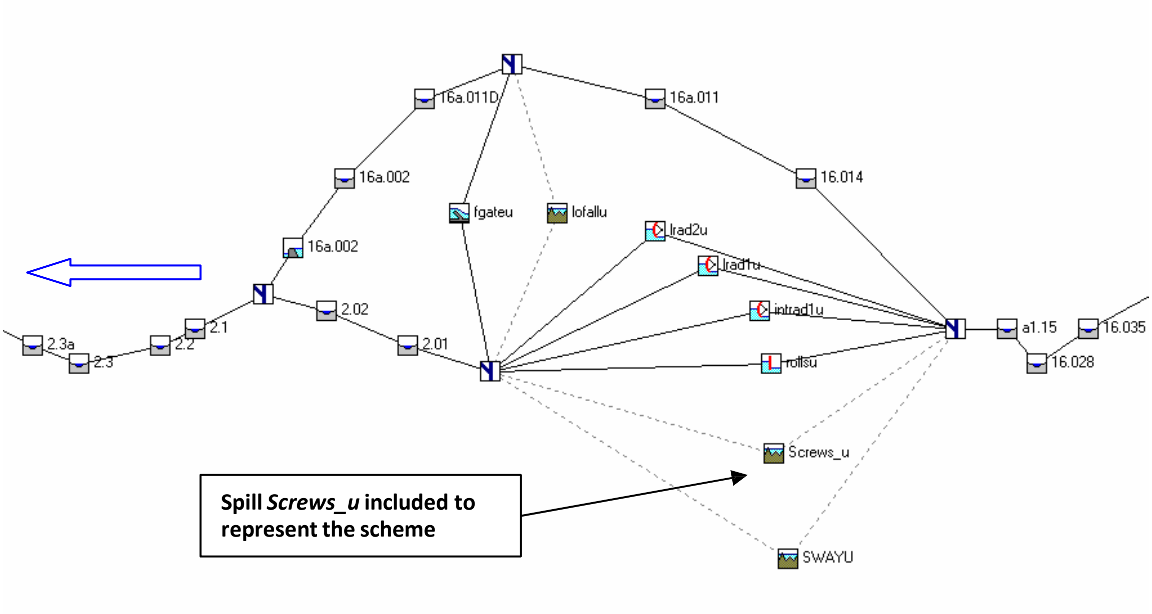


Figure 2-6 Schematic of ISIS model at Teddington Weir in proposed scenario

2.3 Sensitivity Testing

2.3.1 Roughness

The sensitivity of the simulations to roughness was tested by increasing the Manning's *n* values (as defined in the existing ISIS model) by 20% in both the baseline and proposed scheme scenarios. Immediately downstream of Teddington Weir, the in-channel roughness has been defined using a Manning's *n* value of 0.028; henceforth the sensitivity testing has considered a higher value of 0.034.

A sensitivity simulation using a lower roughness value was also attempted however the model did not run for this scenario.

2.3.2 Thames Barrier

The Thames Barrier was assumed to be operational during both the fluvial and tidal design floods, since it is in precisely these conditions where it is intended to be used. Nevertheless, recognising the potential fallibility of flood defence infrastructure, the fluvial flood was also simulated without the Thames Barrier in operation as a sensitivity run.

2.3.3 Screw Conveyance

A sensitivity scenario was run to test the effect of allowing each screw to convey a flow of $9m^3/s$ during the flood wave, as advised would occur by Brendan Barrow. This would provide an additional $27m^3/s$ of conveyance in addition to the flow passing over the screws.

In order to include this extra conveyance within the model, an abstraction unit was defined at the location of the scheme, as shown in the schematic given in **Figure 2-7**.

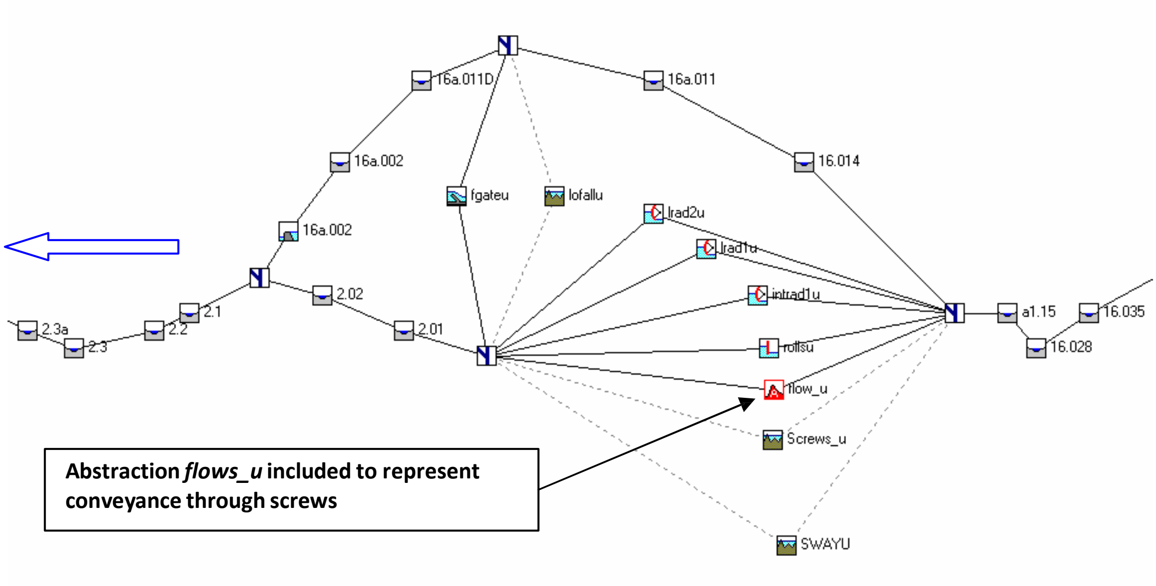


Figure 2-7 Schematic of ISIS model for proposed scenario with abstraction unit included

3 MODEL RESULTS

3.1 Model Convergence

The ISIS model convergence plots for the baseline and with-scheme scenarios are shown for the design fluvial (**Figure 3-1**) and design tidal (**Figure 3-2**) events; assuming the Thames Barrier is operational.

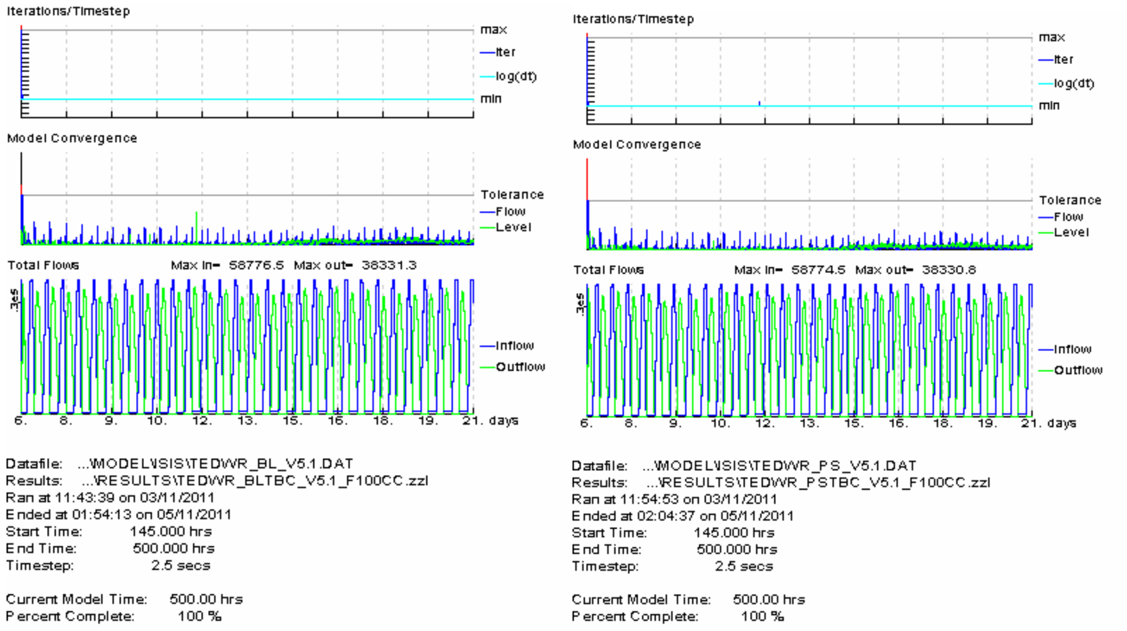


Figure 3-1 ISIS convergence plots for the design fluvial flood in the baseline (left) and proposed scheme (right) scenarios

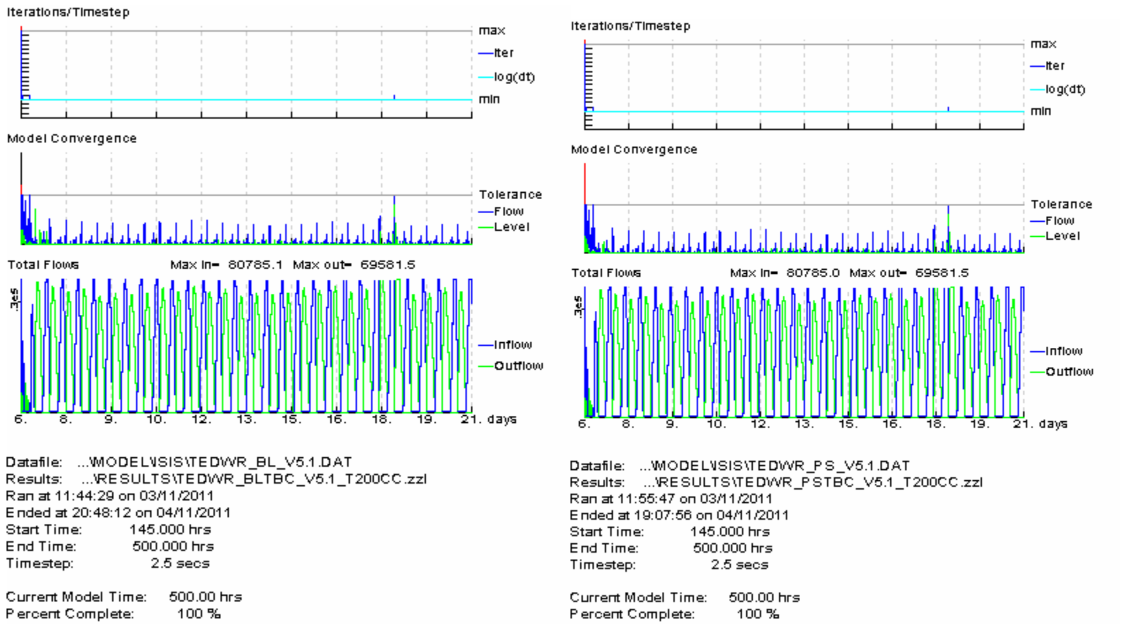


Figure 3-2 ISIS convergence plots for the design tidal flood in the baseline (left) and proposed scheme (right) scenarios

These plots indicate that, with the exception of some minor instability at the start of the model, there are no areas of non-convergence during the simulation.

3.2 Fluvial Design Event

The design 1-in-100 year fluvial flood with an allowance for climate change, and including the operational Thames Barrier was simulated for both baseline and proposed scenarios. Long profile plots through the gauged reach are given in **Figure 3-3** and **Figure 3-4**.

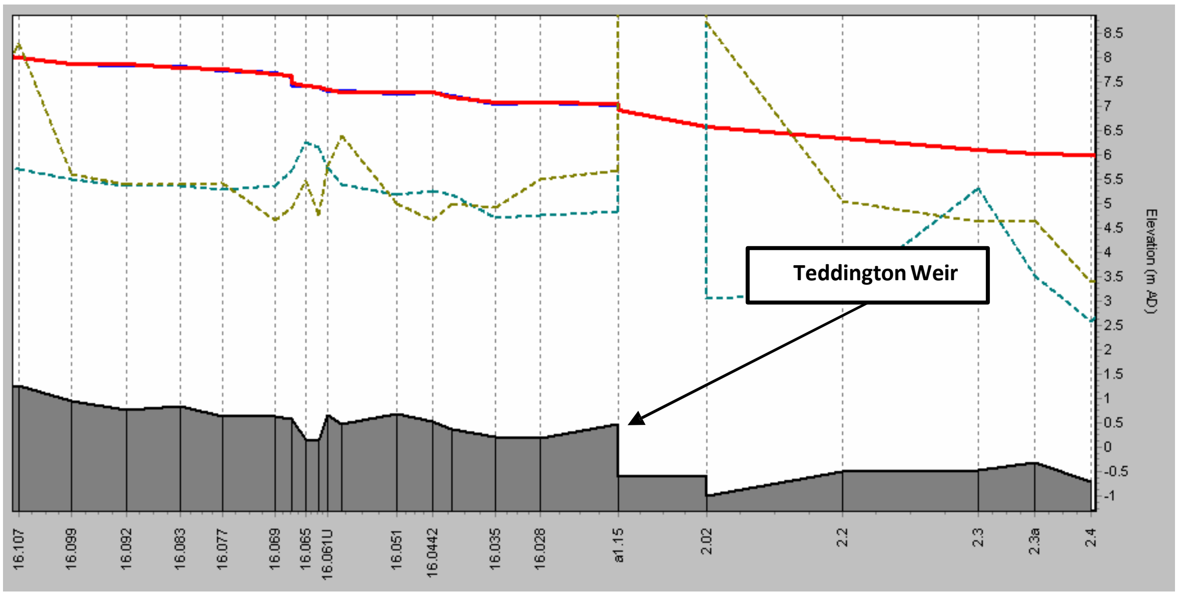


Figure 3-3 Long section of the baseline (blue) and proposed scheme (red) maximum water level

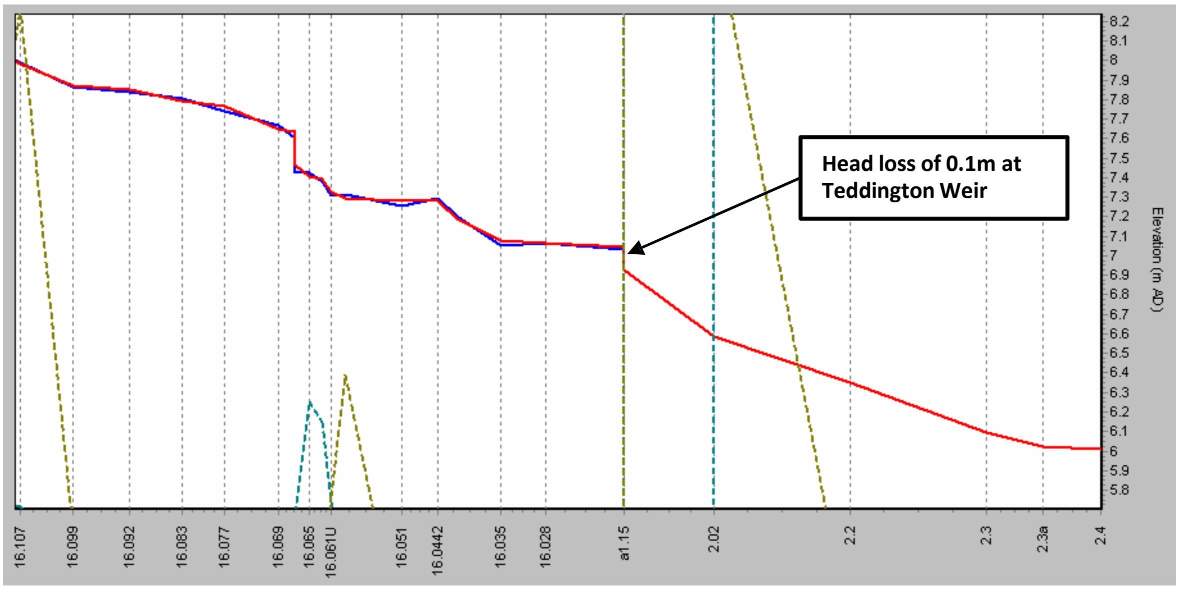


Figure 3-4 Zoomed in long section of the baseline (blue) and proposed scheme (red) maximum water level

The profiles shown in **Figure 3-4** indicate that the differences between the baseline and proposed scheme predicted maximum water levels are around the tolerance of the model accuracy of +/- 10mm. The baseline scenario also exhibits some unexpected longitudinal variation in peak water level, making a direct comparison between the scenarios less than straightforward.

In light of the variations seen in maximum water level of the baseline scenario, the differences between the two scenarios are presented as follows:

(i) at the cross-section immediately upstream of Teddington Weir, and;

(ii) as an average of the differences at seven model cross-sections over a 2km upstream of the weir (averaging the influence of longitudinal variations on the estimation of the impact).

In this simulation, the impact immediately upstream of the weir is estimated to be +16mm, whilst the average impact over the 2km reach is +4mm. The latter is within the accepted model tolerance of +/-10mm, whilst the former is only a slight departure from this tolerance, and must be considered in light of the variations exhibited in the baseline scenario.

3.2.1 Sensitivity to the Thames Barrier

The effect of not operating the Thames Barrier on the baseline fluvial flood scenario is presented in **Figure 3-5**. The omission of the Thames Barrier closures in the model increase maximum water level in the baseline simulation by 80mm immediately upstream of Teddington Weir.

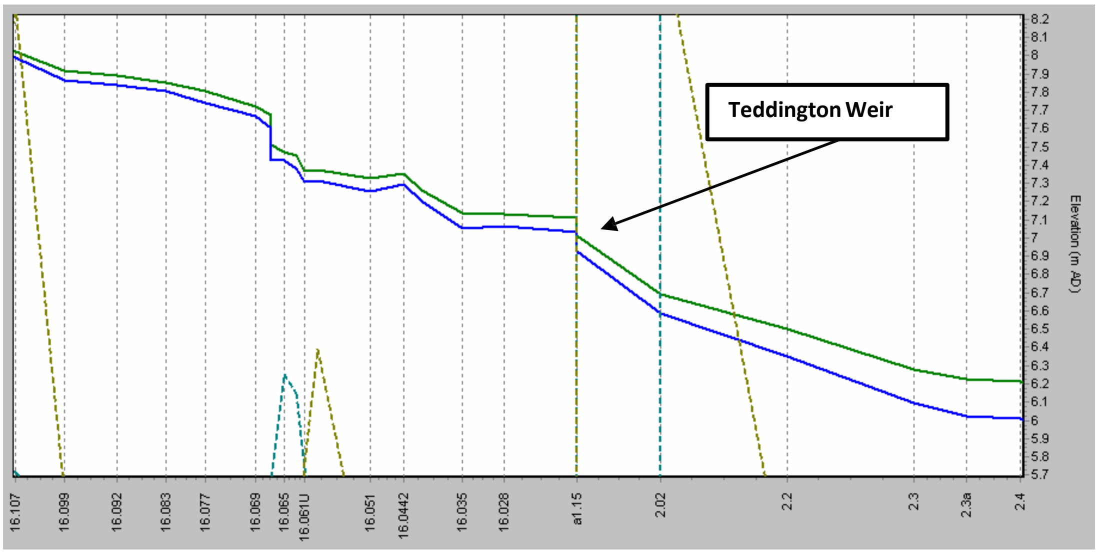


Figure 3-5 Zoomed in long section of the maximum water level for the baseline scenario with (blue) and without (green) the Thames Barrier in operation

The modelled impact on the maximum water surface is shown in **Figure 3-6**.

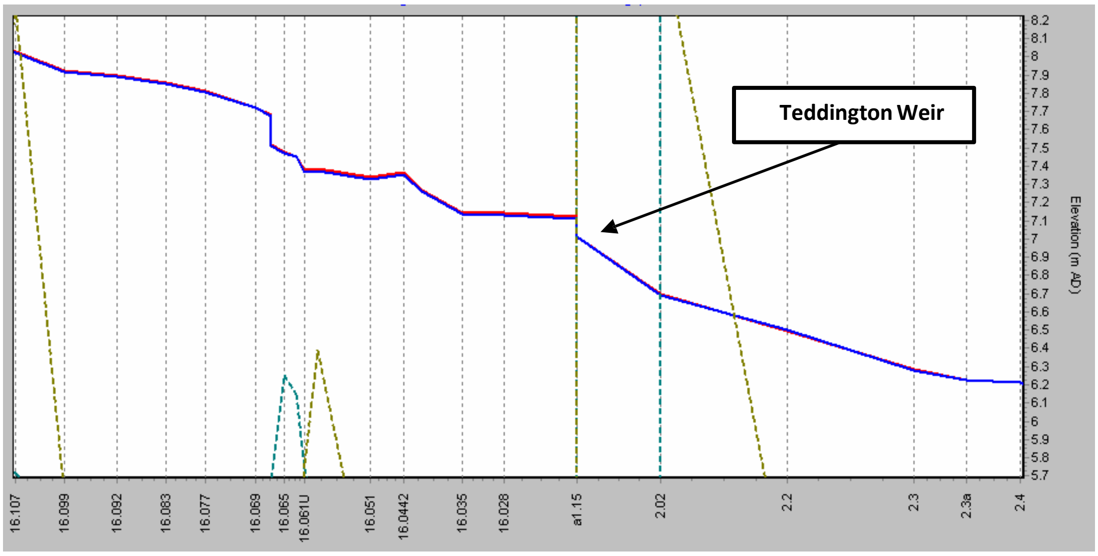


Figure 3-6 Zoomed in long section of the maximum water level for the baseline scenario (blue) and proposed scheme (red) without the Thames Barrier

Omitting the Thames Barrier gives an impact immediately upstream of the weir of +11mm, and an average predicted impact over the 2km upstream reach of +9mm.

3.2.2 Sensitivity to Roughness

The profiles of maximum water levels upstream of the Teddington Weir are shown for the fluvial flood using existing roughness values and the variations of +20% in **Figure 3-7**.

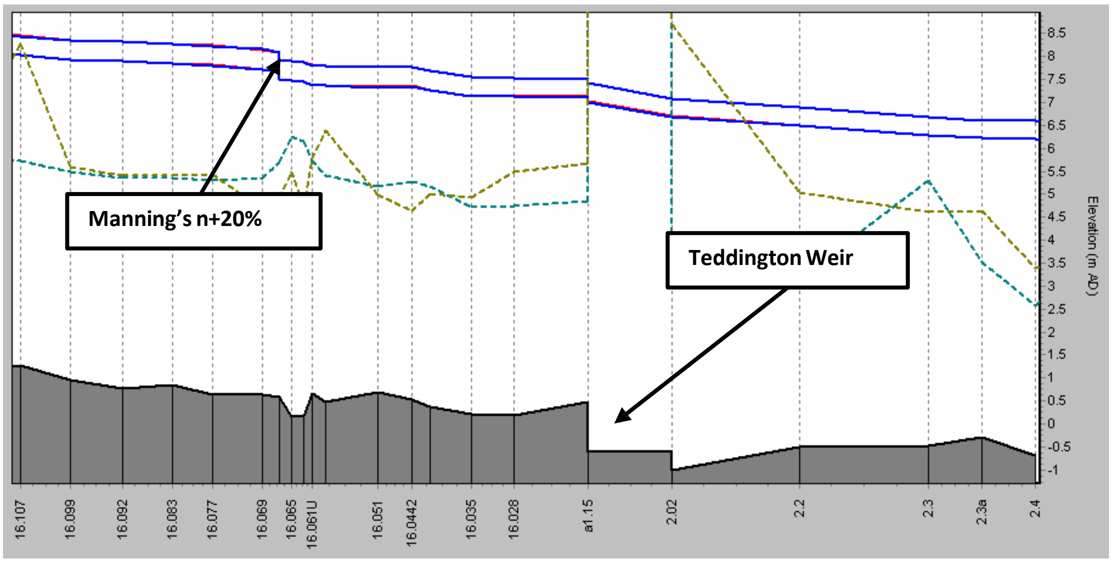


Figure 3-7 Maximum water level in baseline (blue) and proposed (red) scenarios with different roughness

The above plot illustrates that the maximum water levels are increased by approximately 0.4m when *n* is increased by 20%. The impact immediately upstream of the weir is predicted to be +8mm, whilst the average impact over the 2km reach upstream is +4mm.

3.2.3 Sensitivity to Screw Conveyance

As expected the allowance for conveyance through the screws during the fluvial flood event has reduced the maximum water level with the scheme in place, albeit only slightly. A plot of the maximum water level in baseline and the proposed scenario is shown in **Figure 3-8**.

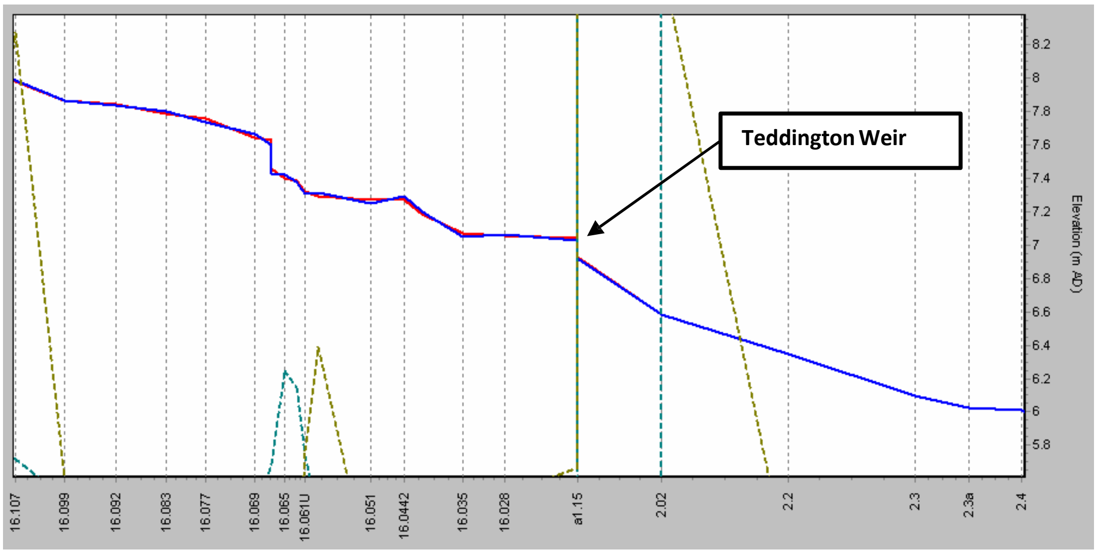


Figure 3-8 Zoomed in plot of maximum water level in the baseline (blue) and proposed scenario (red) with an allowance for conveyance through the screws

The effect of the screw conveyance is to reduce the impact immediately upstream of the weir to an increase of +9mm. When impacts across the 2km upstream reach are considered, there is an average predicted reduction of -2mm when compared to the baseline.

3.3 Tidal Design Event

The tidal scenario was simulated with the Thames Barrier in operation. As a result, the maximum flood levels at Teddington Weir are significantly lower than predicted during the design fluvial flood. Both baseline and proposed simulations include an allowance for climate change. The maximum water levels are shown in **Figure 3-9**.

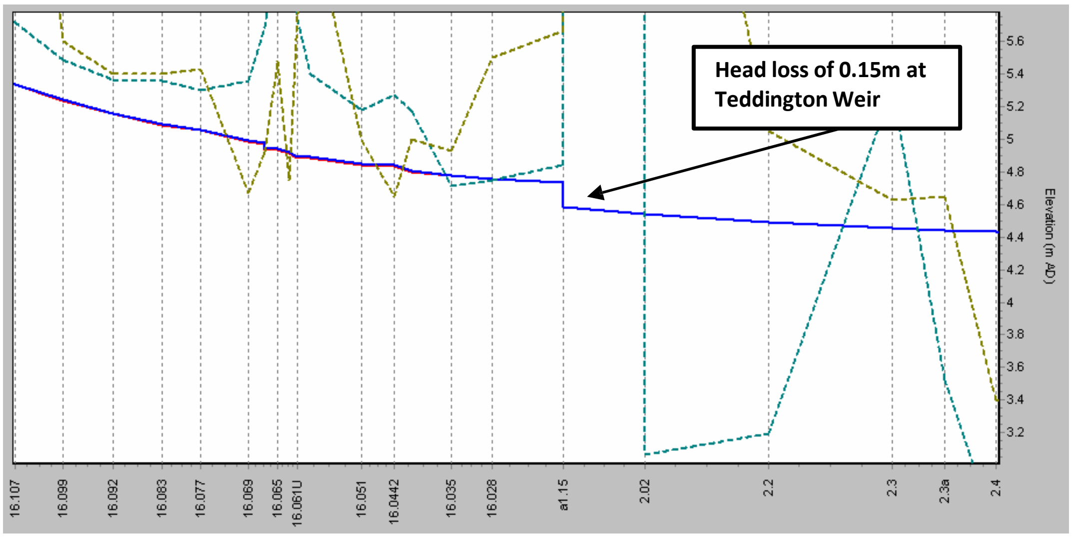


Figure 3-9 Zoomed in long section of the baseline (blue) and proposed scheme (red) maximum water level during design tidal event

The impact in the design tidal event is to reduce the maximum water level -1mm immediately upstream of the weir, and over the 2km upstream reach by -4mm.

3.3.1 Sensitivity to Roughness

The profiles of maximum water levels upstream of the Teddington Weir are shown for the tidal flood using existing roughness values and the variations of +20% in **Figure 3-10**.

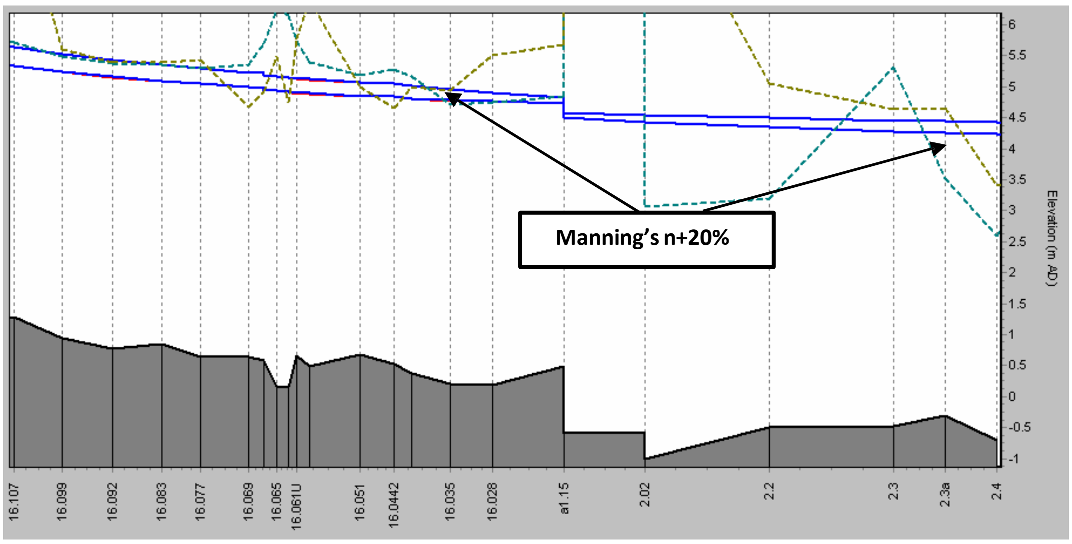


Figure 3-10 Maximum water level in baseline (blue) and proposed (red) scenarios with different roughness

Interestingly, the higher roughness value leads to an increase in maximum water level upstream of Teddington Weir, whilst downstream there is a corresponding decrease. Upstream of the weir the impact is predicted to be a reduction in peak level of -2mm, whilst the average impact of the scheme over the 2km upstream reach is predicted to be a reduction by -1mm.

3.4 Summary of Impacts

The table below lists the impacts on the maximum water level of the proposed scheme relative to the baseline scenario in both design fluvial and design tidal events.

	Average impact over 2km upstream reach		**Impact immediately upstream of weir**	
	Fluvial	**Tidal**	**Fluvial**	**Tidal**
Thames Barrier included.	+4mm	-4mm	+16mm	-1mm
Thames Barrier not included.	+9mm	n/a	+11mm	n/a
Thames Barrier included. Manning's n+20%	+4mm	-1mm	+8mm	-2mm
Thames Barrier included; screw conveyance of 27m^3/s allowed for.	-2mm	n/a	+9mm	n/a

As an overview, the modelling indicates that the scheme will not cause an increase in flood levels during the design tidal event, whilst in the fluvial event the predicted increase in levels will be negligible and generally within the tolerance limit of the model, +/-10mm.

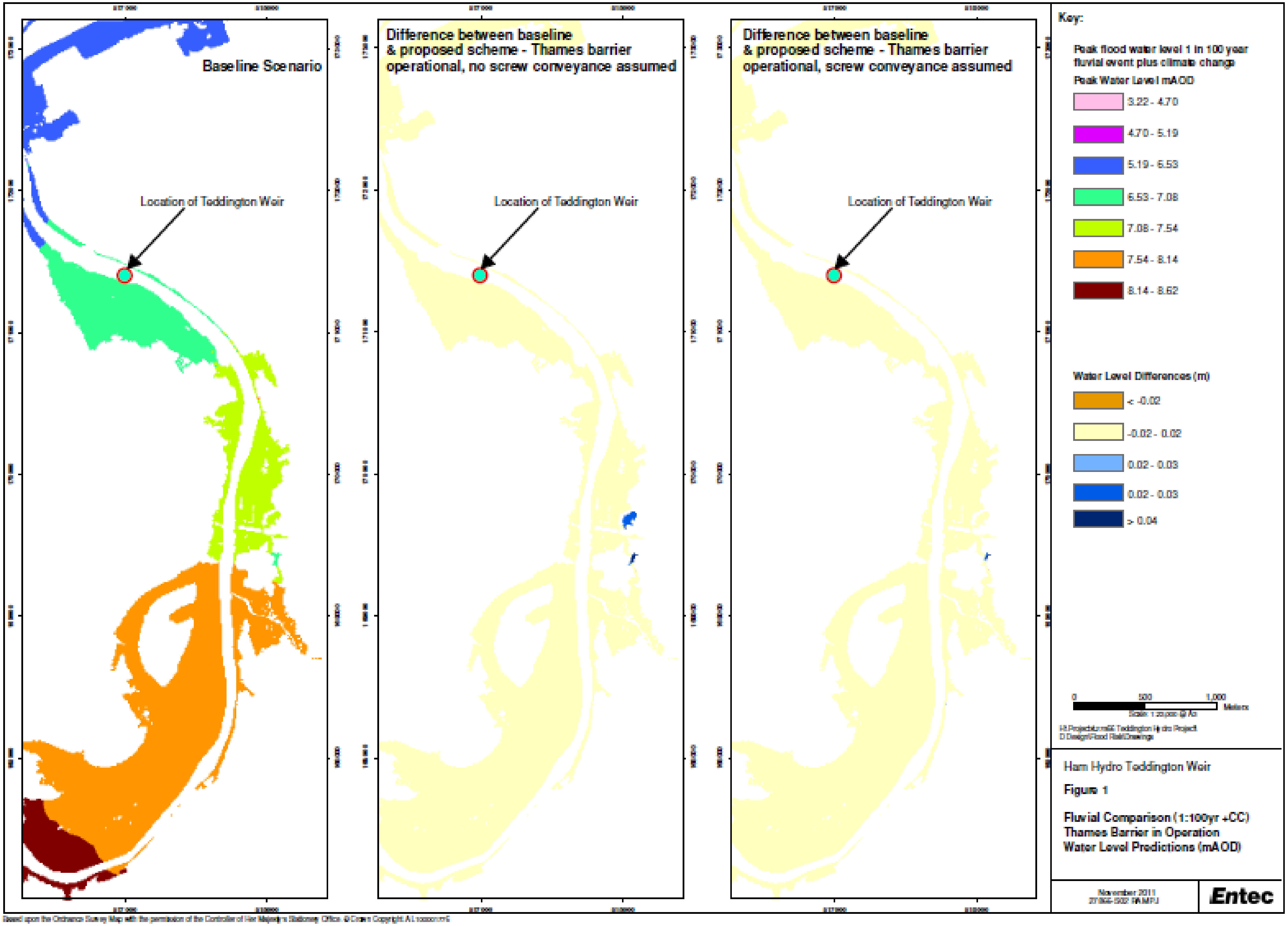
For the largest impact of +16mm, it should be recognised that the baseline simulation for this scenario exhibited some unexpected longitudinal variations which make direct comparison with the proposed scenario less than straightforward. Indeed this was the driver for presenting the average impact predicted over the 2km upstream reach, which may be considered more representative.

The +16mm increase is also under the assumption that no water will pass along the screw during flood conditions. Whereas when adopting an estimated conveyance of 9m^3/s per screw (as advised by Brendan Barrow) the predicted impacts fall within the tolerance limit of +/-10mm and are as such considered negligible.

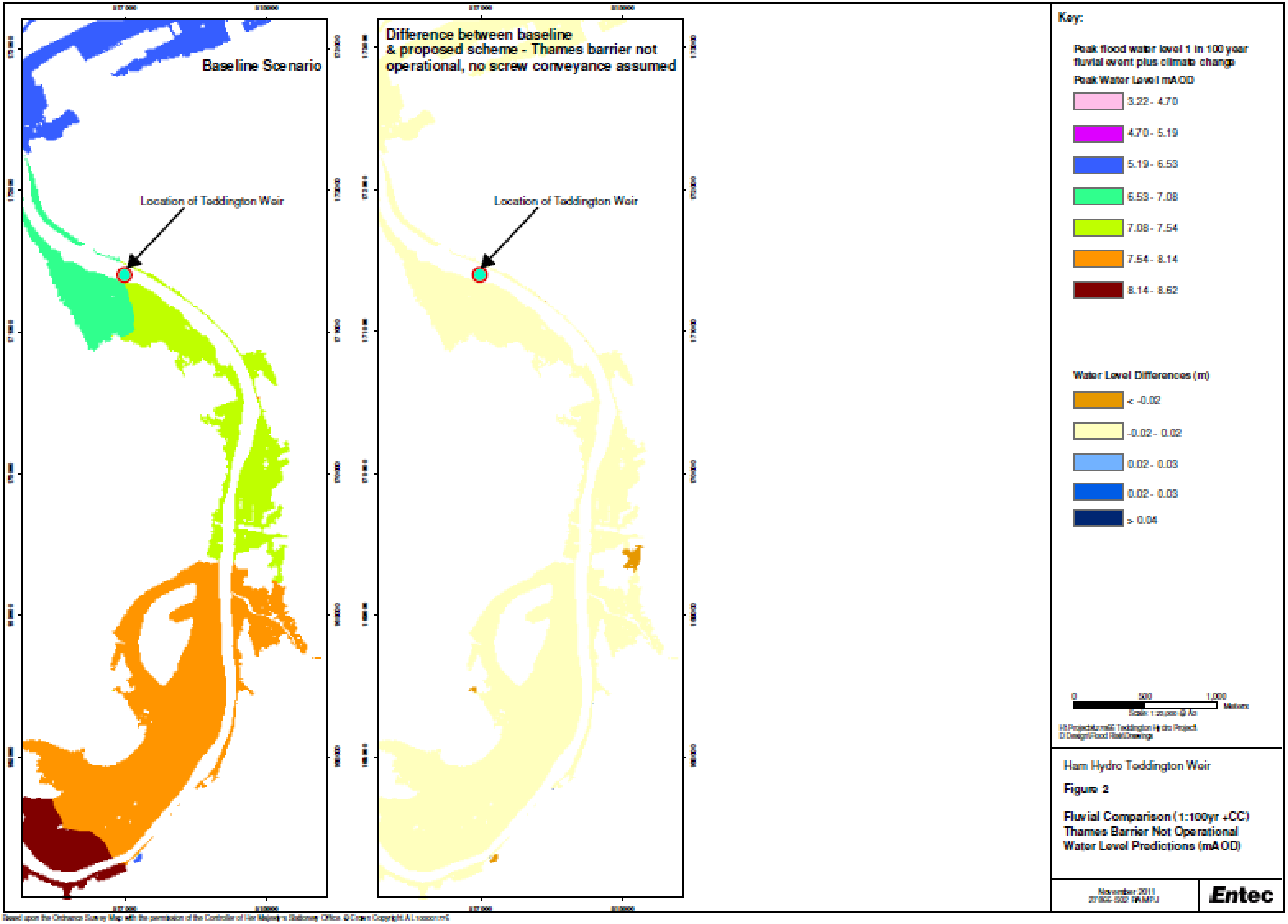
The implication is that the proposed scheme is not predicted to have an impact above the model tolerance on flooding on the Thames, and therefore will not increase flood risk to third parties. As such, the development of the hydropower scheme at Teddington Weir is considered to comply with PPS25, the current planning policy pertaining to development and flood risk.

Appendix E
Hydraulic Modelling Results

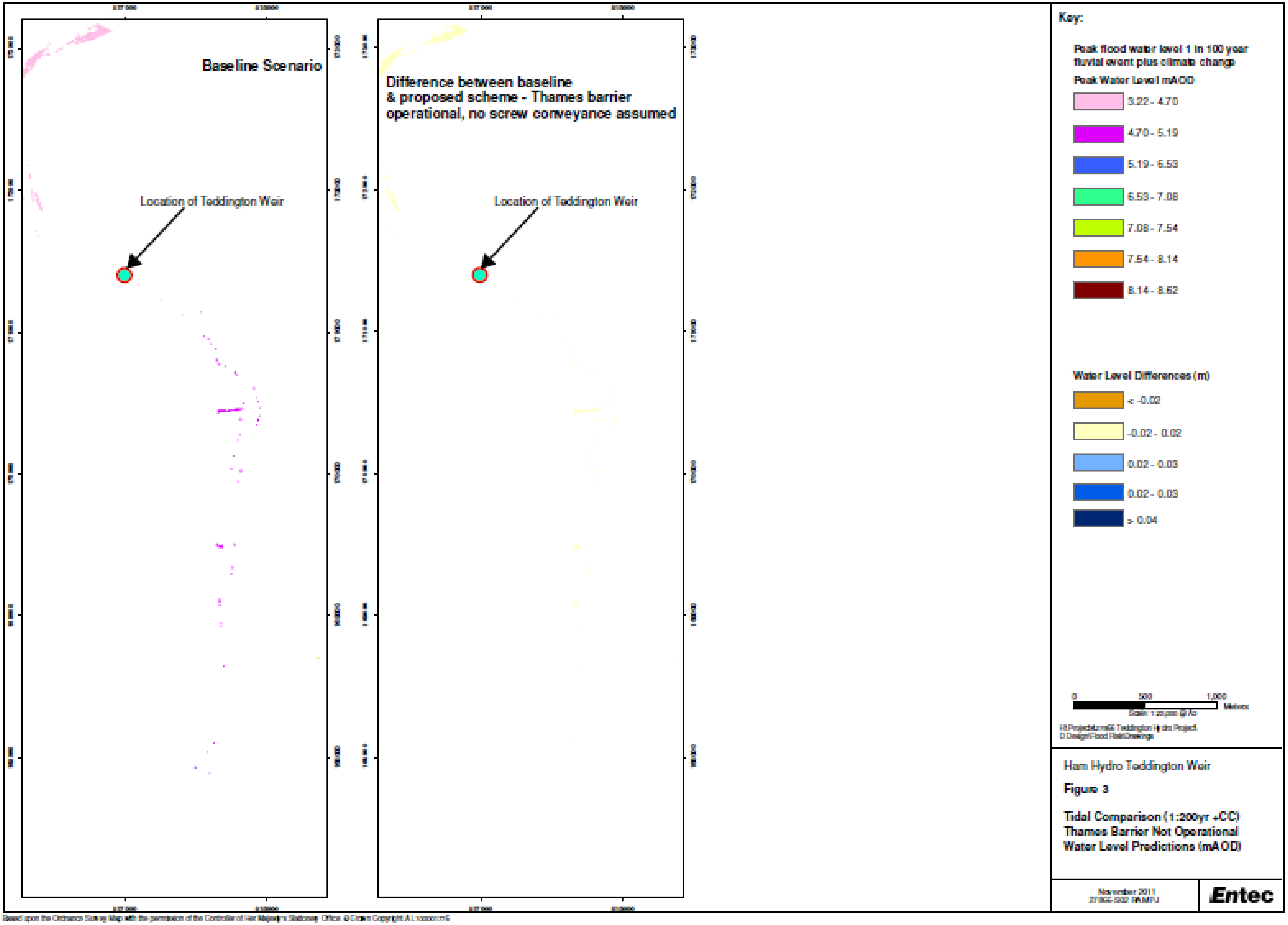
The variations/oscillations in water level at locations upstream are present in the baseline model supplied by the Environment Agency. The adaptation of Teddington Weir simulated in this study has not included the alteration of other aspects of the model to fix localised oscillations.



Baseline Scenario
Location of Teddington Weir
Difference between baseline & proposed scheme - Thames barrier operational, no screw conveyance assumed
Location of Teddington Weir
Difference between baseline & proposed scheme - Thames barrier operational, screw conveyance assumed
Location of Teddington Weir
Key:
Peak flood water level 1 in 100 year fluvial event plus climate change
Peak Water Level mAOD
3.22 - 4.70
4.70 - 5.19
5.19 - 6.53
6.53 - 7.08
7.08 - 7.54
7.54 - 8.14
8.14 - 8.62
Water Level Differences (m)
< -0.02
-0.02 - 0.02
0.02 - 0.03
0.02 - 0.03
> 0.04
0
500
1,000
Metres
Ham Hydro Teddington Weir
Figure 1
Fluvial Comparison (1:100yr +CC)
Thames Barrier in Operation
Water Level Predictions (mAOD)
November 2011
Entec



Baseline Scenario
Difference between baseline & proposed scheme - Thames barrier not operational, no screw conveyance assumed
Location of Teddington Weir
Location of Teddington Weir
Key:
Peak flood water level 1 in 100 year fluvial event plus climate change
Peak Water Level mAOD
3.22 - 4.70
4.70 - 5.19
5.19 - 6.53
6.53 - 7.08
7.08 - 7.54
7.54 - 8.14
8.14 - 8.62
Water Level Differences (m)
< -0.02
-0.02 - 0.02
0.02 - 0.03
0.02 - 0.03
> 0.04
0
500
1,000
Meters
Ham Hydro Teddington Weir
Figure 2
Fluvial Comparison (1:100yr +CC)
Thames Barrier Not Operational
Water Level Predictions (mAOD)
November 2011


Baseline Scenario
Location of Teddington Weir
Difference between baseline
& proposed scheme - Thames barrier
operational, no screw conveyance assumed
Location of Teddington Weir
Key:
Peak flood water level 1 in 100 year
fluvial event plus climate change
Peak Water Level mAOD
3.22 - 4.70
4.70 - 5.19
5.19 - 6.53
6.53 - 7.08
7.08 - 7.54
7.54 - 8.14
8.14 - 8.62
Water Level Differences (m)
< -0.02
-0.02 - 0.02
0.02 - 0.03
0.02 - 0.03
> 0.04
0
500
1,000
Metres
Ham Hydro Teddington Weir
Figure 3
Tidal Comparison (1:200yr +CC)
Thames Barrier Not Operational
Water Level Predictions (mAOD)
November 2011
Entec

Appendix F
Weir Pulling Order Sheet

TEDDINGTON WEIR PULLING ORDER

From Fully Closed

Next Move	Headwater Range
No.1&2 Fish Pass Opefl No.1 Flap Gate Open Radials to Crest as Required	6" above H.W
No.2 Flap Gate Open No.3 Radial drawn No.19 Radia No.4 Radial Drawn **No.18 Radial Drawn**	4" to 6" above H.W **YELLOW WARNING BOARDS**
No.14 Radial Drawn No.12 Radial Drawn **No.10. Radial Drawn**	2,to 4" above H.W **RED WARNING BOARDS**
Roller Sluices from 0' to 1' each No.8 Radial Drawn Roller Sluices from 1' to 2' each	H.W to 2" above H.W
No.6 Radial Drawn Roller Sluices from 2' to 3' each No.13 Radial Drawn	2" below to H.W
Roller Sluices from 3' to 4' each No.11 Radial Drawn Roller Sluices from 4' to 5' each	4" below to 2" below H.W
No.9 Radial Drawn Roller Sluices from 5' to 6' each No.7 Radial Drawn Roller Sluices from 6' to 7' each No.5 Radial Drawn Roller Sluices from 7' to 8' each Continue until Roller Sluices to 15' each	6"below to 4" below H.W **WEiR FULLY DRAWN**

Radials can be drawn to half way if required. Roller Sluices can be drawn in 6" lots if required. When shutting in Radials go to Crest.
Radials are fully closed at 2" above SHWL marker,