River Thames Scheme Flood Modelling Non-Technical Summary

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Project Information

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Glossary

Attenuation	Reduction in peak flows moving downstream
Augmented flow	The small flow through the flood channel in non-flood conditions provided for environmental reasons
Baseline	The river system as it is now, without the River Thames Scheme in place (existing conditions)
Conveying	Passing water downstream
Design flood	Hypothetical floods representing specific flood magnitudes
Drawdown / drawdown effect	The flood channel takes some flow out of the River Thames. This gives lower water levels in the Thames at the flood channel offtake. Lower water levels at the offtake gives a water level reduction in the Thames immediately upstream. This impact is then repeated moving further upstream, although the water level reduction diminishes with distance. Effectively the flood channel draws down the flood levels in the upstream Thames by reducing the downstream obstruction caused by high water levels.
Fluvial flooding	Flooding from rivers and other watercourses
Geomorphology	Changes in the shape of the river channel
Groundwater	Water held or moving beneath the ground surface
Groundwater flooding	Flooding caused by the emergence of groundwater at the ground surface away from the river channel
Hydraulics	Assessing the movement of water within river channels
Hydrology	Assessing the flow at specific points within rivers
Hydrometric data	Records of observed water levels and flows
Model calibration	Adjustments made to the model setup through comparison of recorded data to model predictions for observed floods
No detriment	No increase in flood risk
Surface water flooding	Flooding from rainfall exceeding the capacity of drains and sewers
Topographic data	Survey data representing the elevation of the ground surface
Water supply abstractions	Water removed from the River Thames for storage and treatment to provide drinking water
1D model	One-dimensional model (see Section 3.3(e) for further explanation)
1D-2D model	Linked one-dimensional and two-dimensional model (see Section 3.3(e) for further explanation)

1. Executive Summary

The River Thames Scheme (RTS) design comprises:

- A flood channel in two sections between Egham Hythe and Shepperton;
- Bed lowering downstream of the Desborough Cut;
- Additional gates at Sunbury, Molesey and Teddington weirs;
- New green (land based) and blue (water based) open spaces are being considered associated with the flood channel, with access for local communities and facilities such as sports fields, accessible pathway networks, nature play spaces and sculptural landforms;
- Priority areas for habitat creation enhancement and mitigation, which link with existing and new wildlife corridors, improve fish passage and build upon the network of existing wildlife sites;
- New or improved active travel provision and places for recreational access, which may be along and across the flood channel corridor and new open spaces, with connections to the existing network and two new pedestrian and cycle bridges across the River Thames at Chertsey and Desborough Island;
- Incidental utilities and highways alterations and diversions; and
- Temporary construction features such as site compounds and materials processing and storage sites.

Flood modelling has been used to assess the RTS's impact on fluvial flood risk and to refine the design. The RTS flood modelling between 2014 and 2022 is recorded in a Flood Modelling Report. This Non-Technical Summary is a shorter, simplified version of the Flood Modelling Report, giving an overview of the work undertaken and the key findings.

The Flood Modelling Report and this Non-Technical Summary covers fluvial flooding. That is, flooding that originates from high flows in the River Thames and its tributaries. Other sources of flooding, such as groundwater and surface water runoff, are discussed in the report but this is not the primary focus. Extensive groundwater flood modelling has been undertaken within the RTS study but this is reported separately. Ongoing work is looking at groundwater and surface water flooding, which will be reported separately in due course.

The modelling shows that the RTS will reduce fluvial flood risk from Windsor to Teddington. The impact of the scheme varies by location and flood magnitude. As an overview:

- The greatest reduction in flood levels is in the Egham Hythe and Penton Hook area, near the upstream end of the Runnymede channel (up to 0.9m).
- The reduction parallel to the Spelthorne channel is also considerable (up to 0.8m).
- There is a reduction in flood levels upstream of the flood channel through Staines and beyond. This is due to the Runnymede channel drawing down water levels in the River Thames at the flood channel offtake. The beneficial impact then extends upstream. In Staines, the reduction in flood levels can be significant (up to 0.5m) but

this diminishes moving upstream so that by Datchet and Windsor the benefit provided by the RTS is very small (0.1m or less).

- The benefit downstream of Shepperton is relatively modest (up to 0.2m). The reduction in this area is due to the bed lowering downstream of the Desborough Cut; additional weir gates at Sunbury, Molesey and Teddington; and modified timing of water supply abstractions.
- Downstream of Teddington the benefit is even smaller (0.03m or less) so effectively there is no change in flood risk.
- There is no increase in flood risk predicted at any location in any flood conditions. The RTS will not make flooding worse for anyone.

This summary report records the modelling used to develop the RTS design between 2014 and 2022. This includes:

- Developing and improving the flood models used to represent the River Thames and tributary system as they are now (existing/baseline conditions).
- Model testing with the RTS included to examine its impact. All aspects of the RTS design have been refined including:
    - The flood channel route, structures and operating threshold.
    - The location and configuration of the downstream measures.

The changes made to the design have improved its hydraulic performance and reduced construction costs.

There is ongoing flood modelling work, such as testing the refined landscape design, which continues to inform the RTS design decisions. This will be reported in future updates to the Flood Modelling Report and Non-Technical Summary.

2. Introduction

2.1 River Thames Scheme

The latest River Thames Scheme (RTS) design comprises:

- A flood channel in two sections between Egham Hythe and Shepperton;
- Downstream measures involving:
    - Bed lowering immediately downstream of the Desborough Cut; and
    - Additional gates at Sunbury, Molesey and Teddington weirs.
- New green (land based) and blue (water based) open spaces are being considered associated with the flood channel, with access for local communities and facilities such as sports fields, accessible pathway networks, nature play spaces and sculptural landforms;
- Priority areas for habitat creation enhancement and mitigation, which link with existing and new wildlife corridors, improve fish passage and build upon the network of existing wildlife sites;
- New or improved active travel provision and places for recreational access, which may be along and across the flood channel corridor and new open spaces, with connections to the existing network and two new pedestrian and cycle bridges across the River Thames at Chertsey and Desborough Island;
- Incidental utilities and highways alterations and diversions; and
- Temporary construction features such as site compounds and materials processing and storage sites.

The flood channel provides additional capacity for conveying Thames flows. This reduces flood levels, primarily between Staines and Shepperton, although the drawdown provided by the channel gives some reduction in flood levels further upstream. The flood channel is typically 3-4m deep and 20-50m wide. The two sections of the flood channel are:

- Runnymede channel – from Egham Hythe to Chertsey (4.8km)
- Spelthorne channel – from Laleham to Shepperton (3.2km)

The primary purpose of the downstream measures is to ensure there is no increase in flood risk downstream of the flood channel. However, they also give a small reduction in flood levels in the reach between Shepperton and Teddington.

Figure 2.1 shows an overview of the scheme area, including the two flood channel sections and the downstream compensation measures. This figure shows the RTS Outline Design channel alignments, although note that there is ongoing work looking at refinements to the Spelthorne channel route.

2.2 Purpose of this Non-Technical Summary

The fluvial (river) flood modelling work undertaken for the RTS study between 2014 and 2022 is recorded in the RTS Flood Modelling Report. The Flood Modelling Report is over 400 pages long, covers the model development and results in detail, and is intended for a technical audience that are familiar with modelling terminology.

This report is the Non-Technical Summary of the Flood Modelling Report. It is a shorter version, covering the same material but focusing on the key findings. The objective is to provide an overview of the modelling work for people interested in how the RTS design has been assessed but without a technical background in hydraulic modelling.

The flood modelling described in this report is to assess fluvial (river) flood risk from the River Thames and its tributaries. Throughout the report, unless stated otherwise, when referring to flood risk this means only the fluvial flood risk (the flood risk from rivers). This modelling is based on the Lower Thames river model. Surface water and groundwater flood risk are discussed briefly but that is not the primary purpose of this report. There is ongoing work to assess surface water and groundwater flood risk, which will be reported separately. The Lower Thames river model does not represent surface water and groundwater flooding – alternative modelling approaches are being used for those flood mechanisms.

Further refinement to the RTS design is currently ongoing. This design development continues to be supported by flood modelling to ensure the scheme functions as intended and to compare alternatives. This ongoing flood modelling includes: changes to the landscape design; inclusion of new fish passes on the River Thames at Chertsey, Sunbury and Teddington; further refinement of the Spelthorne channel route; and confirmation of the gate design at Sunbury, Molesey and Teddington. Once this work is complete, reporting of the additional flood modelling will be included in future updates to the Flood Modelling Report and this Non-Technical Summary.

2.3 Report structure

This Non-Technical Summary follows the same structure as the Flood Modelling Report:

- The four parts of the Flood Modelling Report form the sections of this report (sections 3 to 6).
- Each section of the Flood Modelling Report forms a sub-section of this report, retaining the same heading names to help cross-reference between the documents.

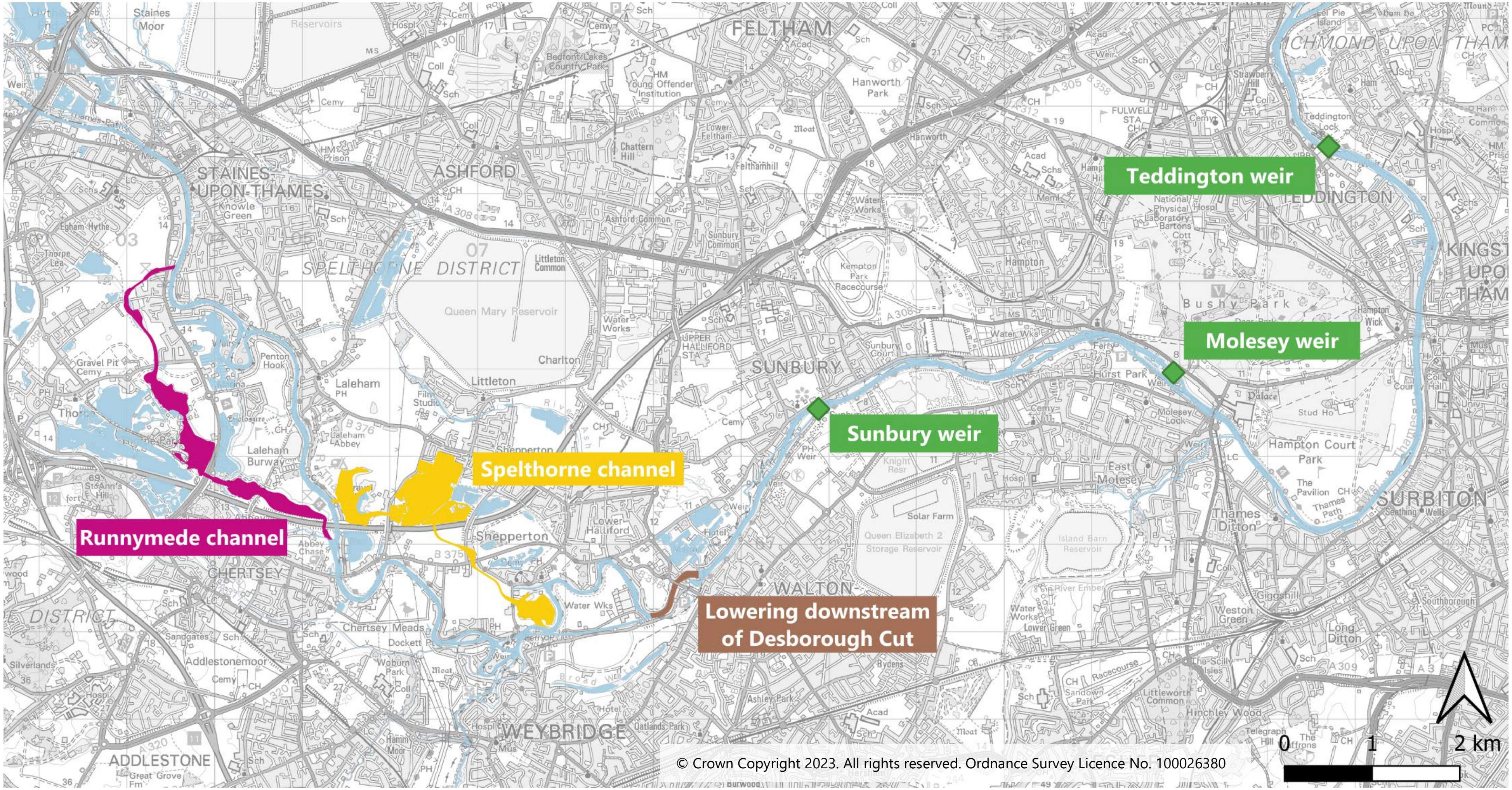


Figure 2.1 Overview of scheme features

3. Background

3.1 How the River Thames Scheme works

(a) Overview

This sub-section of the report provides a description of the components within the RTS design and how they will be operated. This is intended as an introduction to the general concepts of the scheme.

(b) Flood channel

Operation

There are intake gates for each of the two flood channel sections (the Runnymede channel and Spelthorne channel). These intake gates control the flow entering the flood channel.

The flood channel operation is illustrated in Figure 3.1. To summarise:

- **In non-flood conditions** (low and normal flows):
  - The intake gates remain fully closed.
  - The only flow into the flood channel is the augmented flow (0.5-1.0m^3/s) through fish passes around the intake gates. The augmented flow is provided for environmental reasons.
  - A series of control structures (mainly fixed weirs) hold water levels at a constant level and ensure water is retained within the channel, which has environmental and aesthetic benefits. The retained water levels were chosen to match existing lake and groundwater levels – without the control structures the channel would drain down the lakes and groundwater.
  - The River Thames continues to operate as it does now – water levels are controlled by the operation of weir gates at Penton Hook, Chertsey and Shepperton to maintain water levels for navigation and abstractions. There is no change from the current operations, so water levels respond as they do without the RTS.
- **In flood conditions** (high flows):
  - The intake gates are gradually opened as flows in the River Thames rise:
    - Intake gates begin to be opened when the flow in the River Thames exceeds a threshold (230m^3/s).
    - This flow rate is reached on average once a year.
    - The gates are opened progressively to prevent a sudden increase in flow into the flood channel.
    - The objective is to maintain flows in the River Thames at the threshold rate (230m^3/s). This is just below the flow that begins to cause flooding without the RTS.

    - The flow in the existing River Thames channel is always larger than in the new flood channel.
  - When the capacity of the flood channel is reached (150m^3/s), the intake gate openings are gradually reduced:
    - This limits the inflow to the flood channel (to 150m^3/s).
    - The flow in the existing River Thames will begin to increase again. Flooding will occur but the depth and extent are lower than without the RTS.
    - The flow in the River Thames for this to occur is similar to the peak of the 2014 and 2003 observed floods (around 1 in 15 annual chance flood).

The point at which the flood channel capacity is first reached (River Thames flow of 380m^3/s) is illustrated in Figure 3.2 and Figure 3.3. These schematic diagrams show how flow passes through the RTS flood channel area without (Figure 3.2) and with (Figure 3.3) the RTS in place. Note that this representation is simplified for easier comparison since there are hydraulic constraints on the capacity of the Runnymede channel that delay the full 150m^3/s flow being achieved until higher flows in the Thames. Also, the flood extent shown by the blue shading is the 1 in 20 annual chance flood (as the 1 in 15 case has not been modelled).

Reduction in flood risk

The RTS flood channel reduces fluvial flood risk by providing a secondary flow route for water to pass downstream without causing flooding, in addition to the main River Thames channel. This reduces flood risk because:

- **Parallel to the flood channel**:
  - There is less flow in the River Thames channel. Depending on the flood magnitude, this either:
    - Prevents flooding and allows all flow to remain in-bank within the River Thames and flood channel; or
    - Reduces the depth of flooding.
  - Flow that would otherwise pass overland is able to enter the new flood channel sections.
- **Upstream of the flood channel**:
  - The lower flood levels at the Runnymede channel offtake help to draw down upstream water levels in the River Thames. Flood levels in the Thames are primarily determined by the flow arriving from upstream but also by the water level immediately downstream. In this case, the upstream flow remains the same but with lower downstream water levels, flood levels are lower.
  - The positive impact of the RTS flood channel diminishes with distance upstream but there is a small reduction in flood levels as far upstream as Datchet and Windsor.

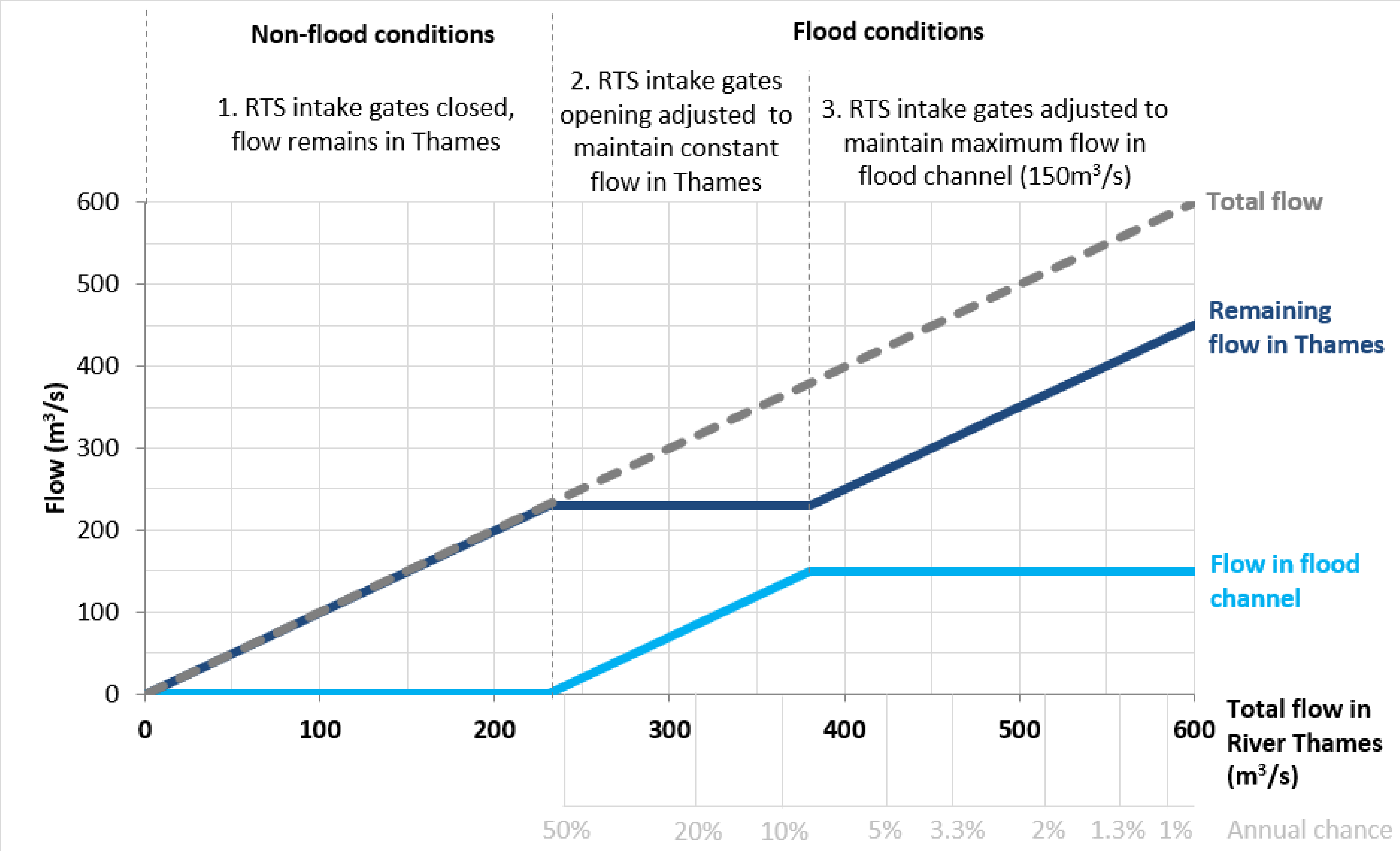


Figure 3.1 Flood channel operation (flows in the River Thames and flood channel)

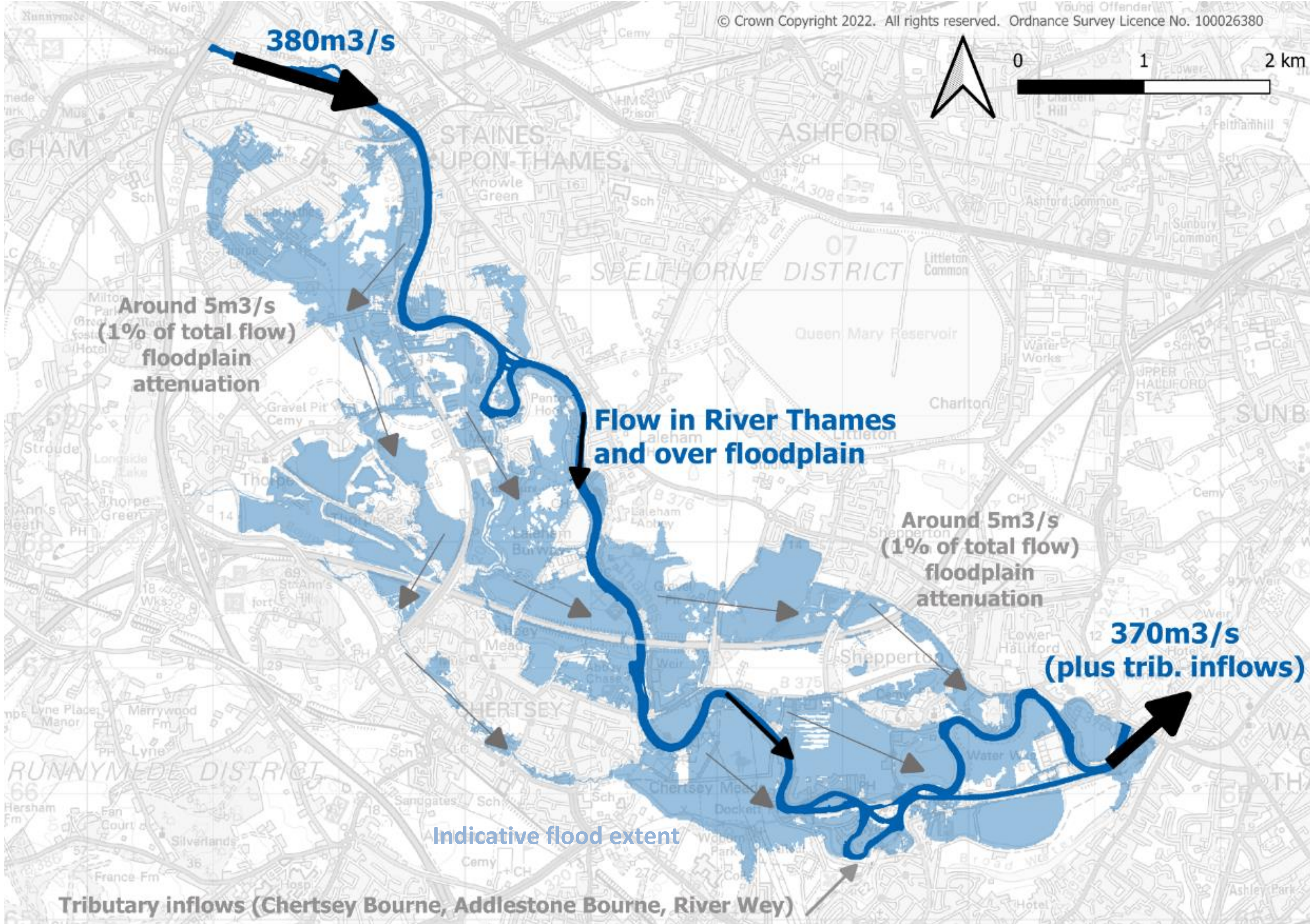


Figure 3.2 Example of existing flow paths (no RTS)

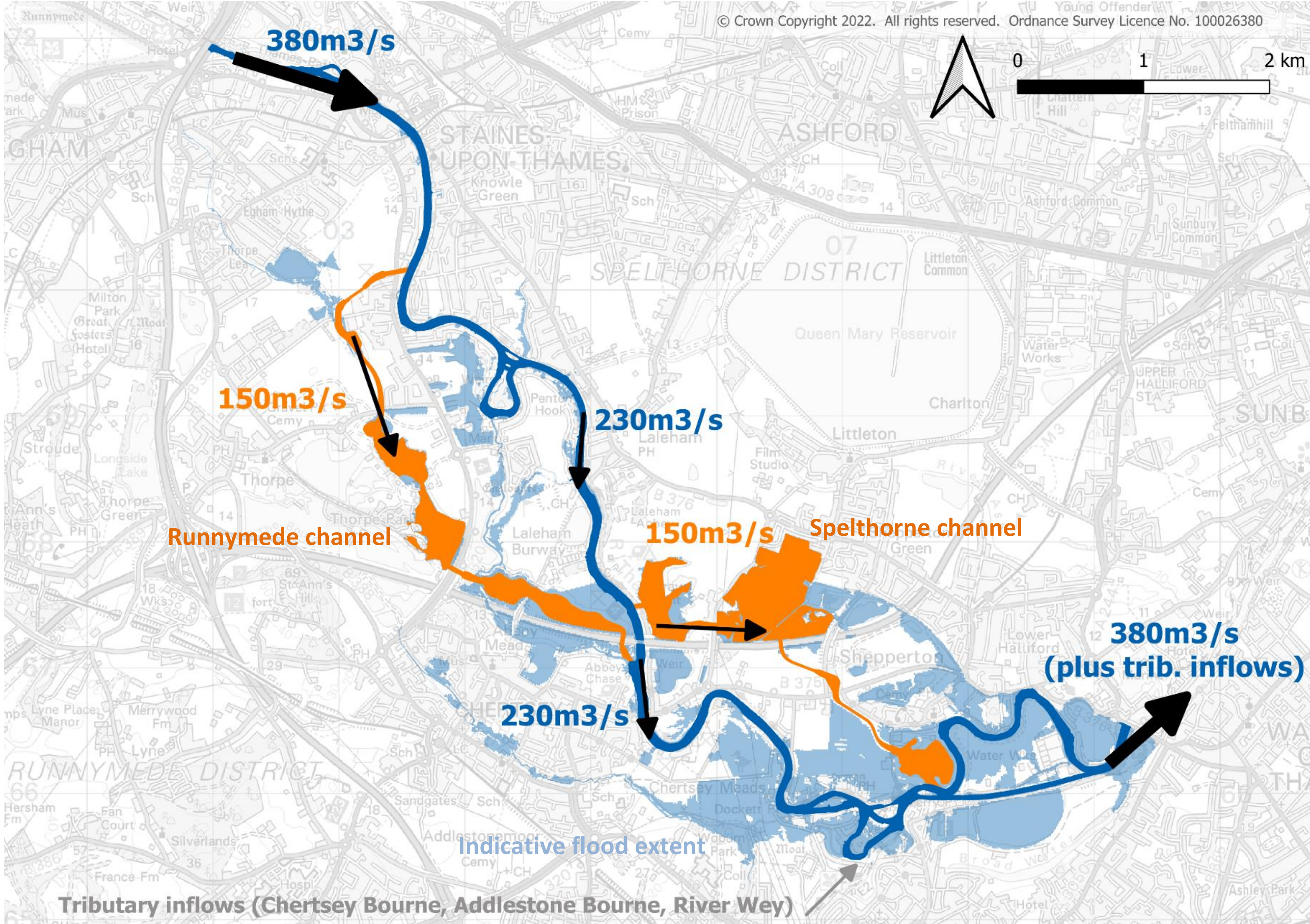


Figure 3.3 Example of flow paths with RTS

Downstream impact

The schematic diagrams (Figure 3.2 and Figure 3.3) show that:

- **In existing conditions** (without the RTS):
  - There is a small amount of attenuation as flow moves downstream. Most of the flow arriving from upstream passes through the system but there is a small reduction in peak flows as the floodplain is activated. The reduction in peak flows can be up to around $10m^3/s$ (2% of the total flow).
  - There is widespread flooding in large magnitude floods. This floodwater continues to flow downstream, albeit slowly, even when passing overland.
- **With the RTS flood channel**:
  - The RTS does not increase the flow volume – this is determined entirely by the flow arriving from upstream.
  - The flood channel provides a more efficient route for floodwater to pass downstream. This means that:
    - Flows downstream rise a bit sooner (by a few hours) because flow moves more quickly through the flood channel (with RTS) than overland (existing).
    - Peak flows leaving the flood channel at its downstream end are the same as the peak flows entering the flood channel.
    - Consequently, compared to existing conditions, peak flows in the River Thames downstream of the flood channel are slightly higher (up to 2%). Note again, the RTS is not creating or increasing flows in the river. The difference is that peak flows no longer reduce moving downstream (by up to around $10m^3/s$), as they do in existing conditions.
    - Downstream compensation measures are required within the RTS design to ensure there is no increase in flood risk at any location. The downstream measures reduce water levels and fully compensate for the small increase in peak flows downstream of the flood channel.
  - The RTS flood channel will not prevent all flooding. The blue shaded areas in Figure 3.3 show a considerably reduced flood extent compared to existing conditions (Figure 3.2) but still some flooded areas, particularly near the downstream end of the Spelthorne channel.

(c) Downstream compensation measures

General

As described above, downstream compensation measures are required within the RTS design to ensure there is no increase in flood risk at any location. The measures compensate for the small (up to 2%) increase in peak flows downstream of the flood channel, relative to existing conditions. In most flood conditions, these downstream works give additional reductions in flood risk beyond existing conditions, although this is not their primary purpose.

The downstream compensation measures comprise:

- River Thames bed lowering downstream of the Desborough Cut; and
- Additional gates at Sunbury, Molesey and Teddington weirs.

Each of these measures works on the same principles:

- They provide additional flow area for water to move downstream. This reduces upstream water levels.
- They do not increase flows. At each location, the flow passing downstream equals the flow arriving from upstream.

Figure 3.4 shows the parts of the river that primarily benefit from each of the downstream compensation measures:

- The bed lowering downstream of the Desborough Cut reduces flood risk up to Shepperton weir.
- The additional gates at Sunbury weir reduce flood levels up to the Desborough bed lowering (there is actually a small benefit upstream to Shepperton, alongside the bed lowering works).
- The additional gates at Molesey weir reduce flood levels up to Sunbury weir.
- The additional gates at Teddington weir reduce flood levels up to Molesey weir.

Bed lowering downstream of the Desborough Cut

Figure 3.5 shows an example river channel cross-section illustrating the depth of bed lowering downstream of the Desborough Cut. Note that the horizontal and vertical scales are different, in order to show the water levels and bed level change more clearly. The river is much wider than it is deep so using equal scales would make the changes in the figure hard to see clearly.

Figure 3.5 shows the additional flow area that would be created in the centre of the river channel. The increased flow area gives a small reduction in flood levels. The water level reduction is only modest, which is one of the reasons why more extensive bed lowering has not been pursued as part of the scheme.

In non-flood conditions, there will be no change in water levels because they are controlled by the operation of gates downstream at Sunbury weir.

There is no increase in peak flow or volume due to the bed lowering. The lowered part of the channel is always under water so this volume cannot be ‘released’. The additional flow area just allows slightly lower water levels in flood conditions.

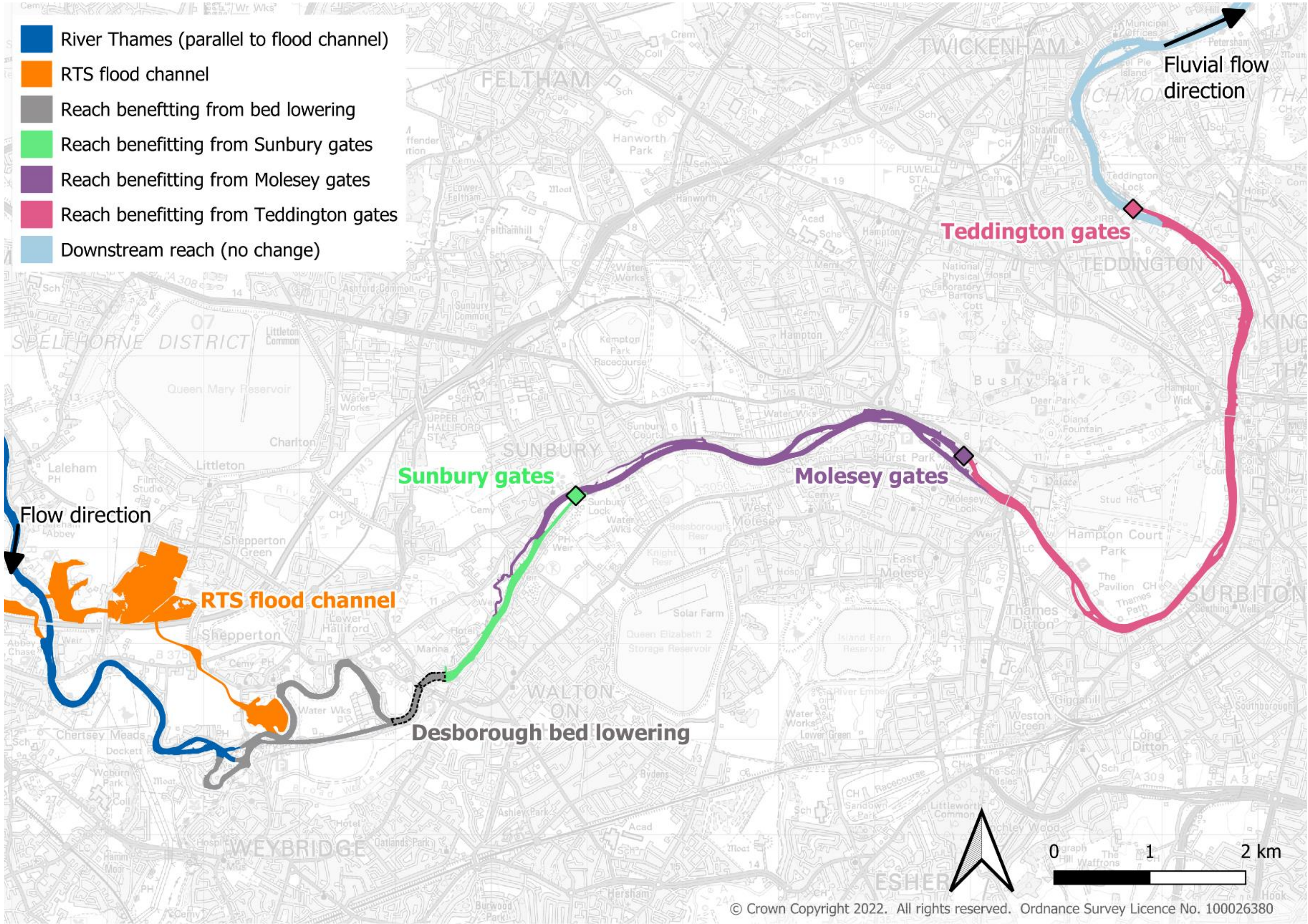


Figure 3.4 Downstream compensation measures

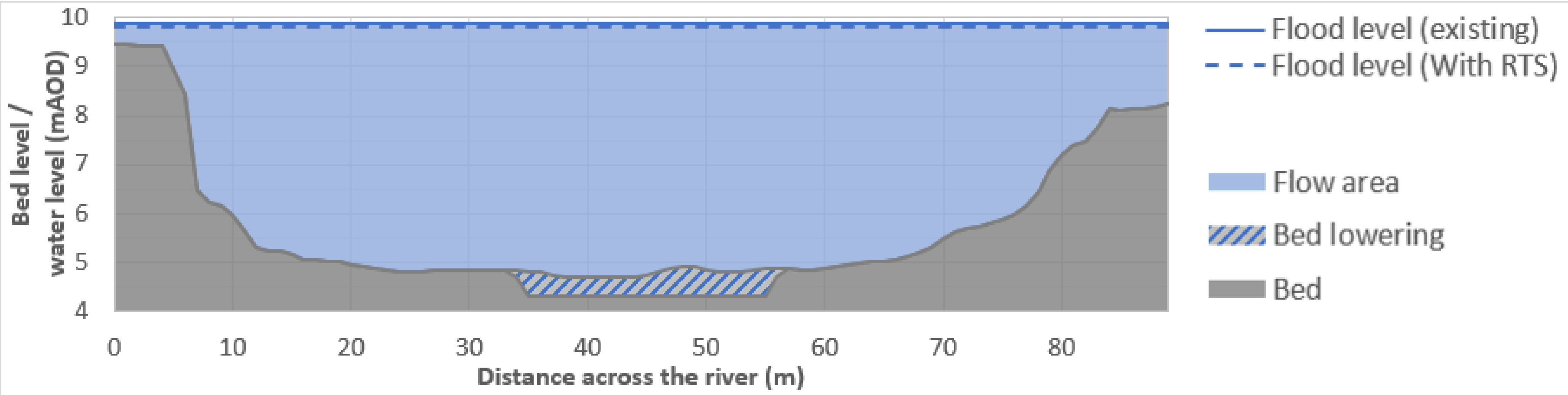


Figure 3.5 Example cross-section showing bed lowering near Desborough Cut (with exaggerated vertical scale to show changes)

Note: Figure 3.5 shows a small reduction in flood levels with the RTS compared to existing conditions. This difference is difficult to see on the figure because it is small in comparison to the overall water depth but the peak flood level is lower with the RTS than without.

Additional weir gates at Sunbury, Molesey and Teddington

Figure 3.6 is a plan view of Sunbury weir, using this as an example for the additional weir gates. As shown in the figure:

- The additional gates provide an extra flow route across the weir complex, to supplement the existing gates and weirs.
- With the additional gates, less flow passes through the existing gates and weirs. This works more efficiently hydraulically, giving a reduction in upstream water levels.
- The flow passing downstream is equal to the flow arriving from upstream. This doesn’t change with the additional gates. Hence there is no increase in downstream flow due to the additional gates.

The additional gates will only be opened in high flow (flood) conditions. In normal and low flows, the gates will remain closed and upstream water levels will be controlled by the existing gates as they are now.

The additional gates will be opened following the same principles as the existing gates. The gates will be opened gradually as river flows increase, to maintain upstream water levels at their normal retention level as long as possible. This ensures that the additional gates will always be open when required to compensate for the impact of the flood channel.

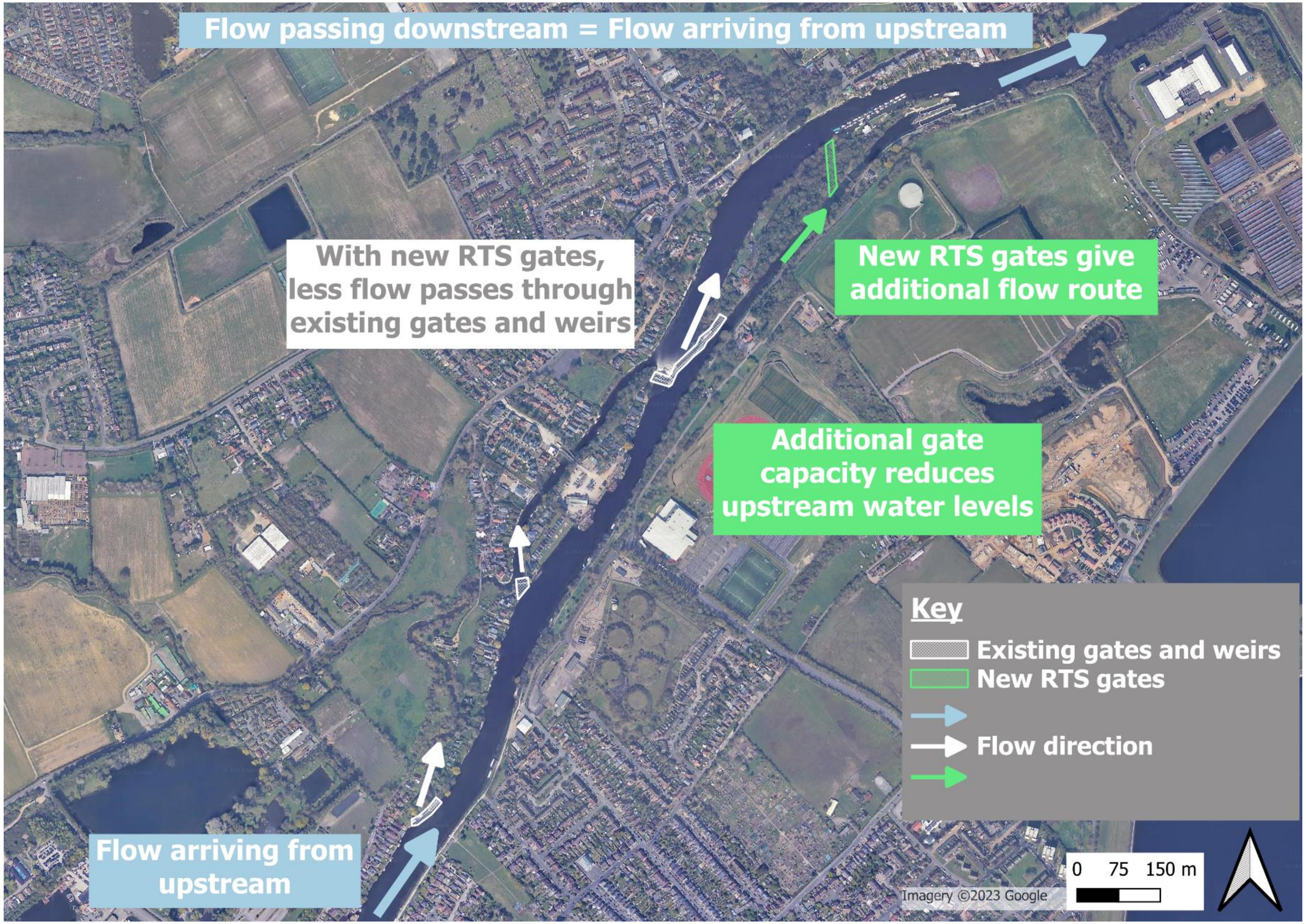


Figure 3.6 Additional weir gates (Sunbury example)

Downstream of Teddington

There is minimal impact from the RTS downstream of Teddington weir.

In this part of the river there is a clear tidal influence apparent even during fluvial (river) floods, with distinct high and low tides. The peak flood level is determined by both the fluvial flow and the tidal conditions. Moving downstream the tidal influence becomes stronger and the fluvial component of the total flow volume becomes smaller.

The additional gates at Teddington work most efficiently at low tide, when the drop in water levels across the gates/weir is greatest. By releasing more flow at low tide, this gives a small reduction in flows and water levels at high tide, although the change is very small. The downstream compensation measures do, however, fully mitigate the impact of the RTS flood channel and there is no increase in flood risk.

Modified timing of water supply abstractions

An additional measure to reduce flood levels downstream of the RTS flood channel is to modify the timing of water supply abstractions during floods. These abstractions are not taken at a constant rate – there is always some fluctuation in abstraction rates over days and weeks. Aligning higher periods of abstractions to the river flood peak, gives a modest reduction in flood levels. The total volume of the abstractions remains the same.

The Environment Agency (EA) have already begun working with Thames Water to implement this approach, including successful trials in winter 2019/20. However, it is important to note that this is undertaken on a best endeavours basis so it cannot be guaranteed to be available. There could be operational reasons (such as maintenance or water quality) that mean the modified abstraction approach may not be possible in particular floods.

Even without the modified abstractions implemented, there is no increase in flood risk at any location due to the RTS. Modified abstractions provide an additional benefit to the downstream reach without requiring any capital works but are not essential to ensure no detriment from the RTS.

3.2 Previous flood modelling reports

There were 33 flood modelling reports written as part of the RTS study between 2015 and 2021. Many of these were fully or partly superseded by later work as the RTS modelling and design developed. The overall Flood Modelling Report was compiled from the parts of those previous reports that remained applicable. The intention is that the Flood Modelling Report provides a single source to refer to, without needing to revisit the previous modelling reports.

The RTS study builds on the Lower Thames Strategy, which also included considerable flood modelling and is reported separately.

3.3 Terminology

(a) General

This sub-section provides some explanation for the terminology used in the report. We have avoided using technical terms and jargon wherever possible.

(b) Flood magnitude

There are several different ways to state flood magnitudes. For example, the following terms all refer to the same flood magnitude:

- 1 in 20 annual chance flood.
- 5% annual exceedance probability (AEP).
- 1 in 20 year flood.
- 20-year flood.
- 20 year return period.

Through this report, we have primarily used the form "1 in 20 annual chance flood". Sometimes this is shortened to just "1 in 20" for brevity.

'Design floods' are hypothetical floods representing specific flood magnitudes that are used in the flood modelling, along with observed floods such as Jan/Feb 2014.

(c) Design standard

Often a flood alleviation scheme will have a 'design standard'. That is, the largest flood magnitude that the scheme protects all properties against. For a defence like a flood wall/embankment or flood storage reservoir, this is straightforward to define and design to.

The River Thames Scheme does not have a specific design standard. This is because the benefit provided by the scheme varies depending on location. There is not a single standard of protection provided to properties within the study area. The presence of the flood channel sections and downstream measures will reduce flood risk but the benefit can only be categorised when looking at individual properties and locations. To give just a few illustrative examples, the RTS will reduce the frequency of flooding at some properties from the:

- 1 in 5 to the 1 in 10 annual chance flood;
- 1 in 5 to the 1 in 50 annual chance flood;
- 1 in 10 to the 1 in 50 annual chance flood; and
- 1 in 100 to the 1 in 1000 annual chance flood.

Whilst there will be groups of properties in these bands (and many other combinations), they are not necessarily even in the same geographic location.

The flood channel will work most effectively in moderate flood magnitudes such as the 1 in 20 annual chance flood, which is similar to the observed 2003 and 2014 floods. These are the conditions where the channel will give the greatest reductions in water levels and begin to operate close to its capacity. However, the channel will continue to reduce flood depths and extent in much more extreme floods. Again, this is unlike a flood wall or storage area, where once the capacity is exceeded there may no longer be any benefit provided.

These factors mean that there is not a simple explanation for the design standard of the RTS.

(d) Flood channel names

There were originally three flood channel sections within the RTS design:

- Berkshire channel, formerly known as channel section 1 (CS1) – no longer part of the RTS design
- Runnymede channel, formerly known as channel section 2 (CS2)
- Spelthorne channel, formerly known as channel section 3 (CS3)

(e) Software

The modelling described in this report was undertaken using:

- **1D** (one-dimensional) models. In 1D models, water can only flow in one direction (forwards or backwards) along flow paths pre-determined by the modeller when building the model. This modelling approach represents both the rivers and floodplain as 1D elements with:
  - The river channel as cross-sections of the channel shape.
  - Structures such as bridges, culverts, gates and weirs.
  - The floodplain as storage units representing relatively large areas, linked to the river with pre-defined units for the river banks and other flow paths.
- **1D-2D** (linked one-dimensional and two-dimensional) models. In this approach:
  - The river channel and structures are represented as 1D units, as with 1D-only models.
  - The floodplain is represented in 2D. For the Lower Thames, this is a regular grid of, generally, 10m by 10m squares. In a 2D model, water is able to find its own way through the model grid (rather than this being pre-determined by the modeller).
  - The 1D and 2D domains are dynamically linked so flow can pass between them in both directions.

3.4 Qualitative description of flood response

The fluvial flood mechanism within the study area can be described using the source-pathway-receptor approach:

- Source
  - Fluvial flows in the River Thames and its tributaries (see Figure 3.7).
  - Tidal influence in the Thames downstream of Molesey weir. The normal tidal limit is at Teddington weir but high tides can influence water levels up to Molesey in some conditions.

- Pathway
  - The River Thames.
  - The new RTS flood channel (after it is constructed).
  - Overland flow across the floodplain and through other watercourses and lakes.
  - Groundwater connections via the gravels below ground can lead to floodplain inundation when river levels are high.
- Receptors
  - Include dwellings, community facilities, businesses, sites designated for biodiversity and cultural heritage importance, and locally, regionally and nationally important infrastructure.
  - There are properties alongside the river and within its floodplain throughout the study area as the river passes by Datchet, Old Windsor, Wraysbury, Hythe End, Staines-upon-Thames, Egham Hythe, Laleham, Chertsey, Shepperton, Walton, Sunbury, Hampton, Molesey, Thames Ditton, Kingston and Teddington. This includes properties on a number of islands within the Thames. If flows are high enough, the river will overtop its banks and cause flooding.
  - The existing standard of protection varies widely due to the local topography, variation in raising of property thresholds and lack of formal flood defences. This will still be true with the RTS in place. The flood channel does not provide a consistent standard of protection – rather it reduces the frequency of flooding at each property benefitting from the scheme.

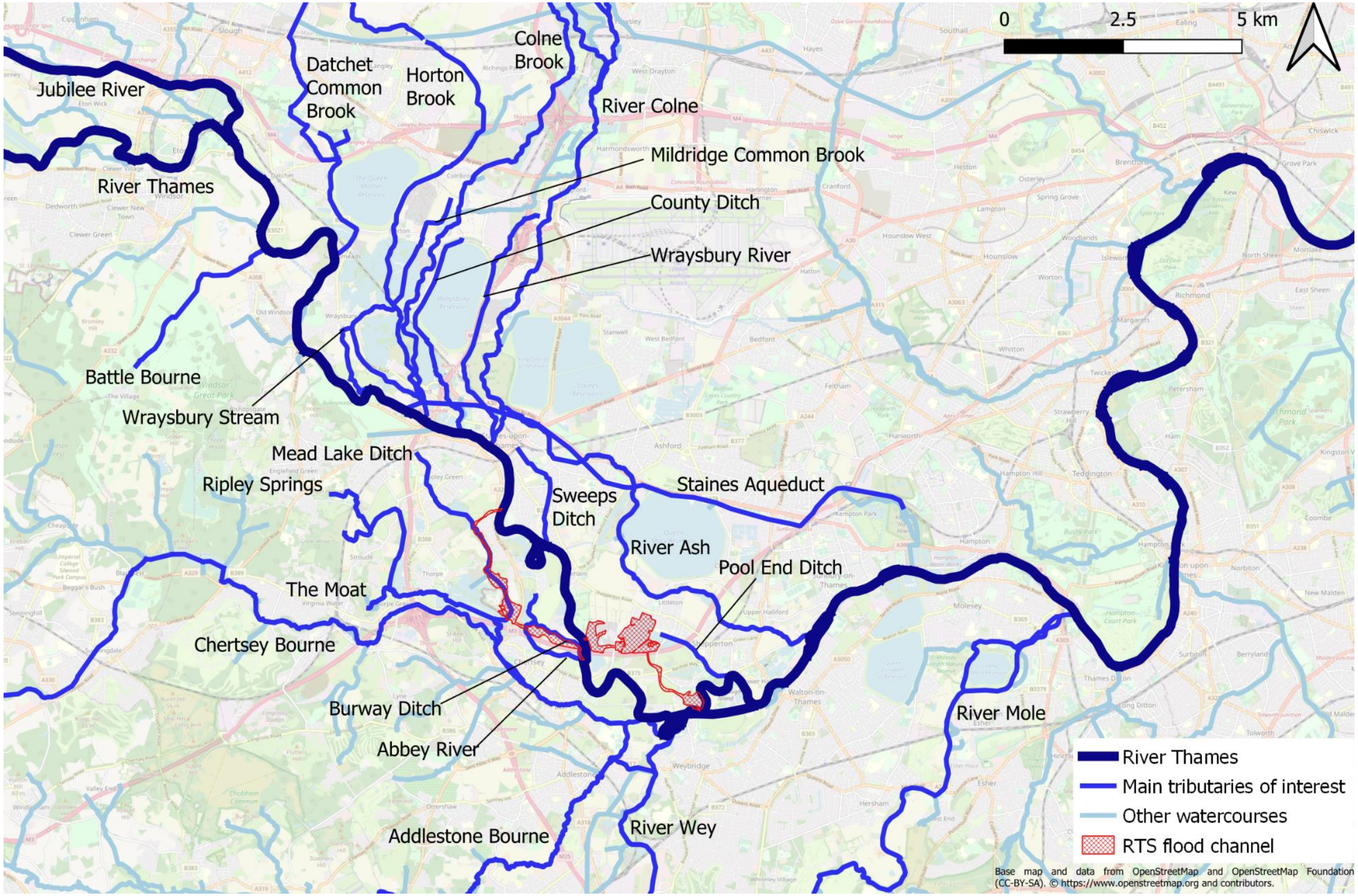


Figure 3.7 Watercourses in study area

3.5 Hydrology

(a) Approach

Hydrological analysis was used to define the inflows used in the flood model. These flood inflows were calculated using the extensive flow and water level records available for the lower Thames. The primary data source is the gauging station at Teddington/Kingston, which has the longest continuous flow record in the UK, beginning in 1883. This was augmented with historical information about large floods that occurred before the gauging station record began. In addition, analysis was undertaken on lock keeper records of flood levels along the Thames dating back to the 1890s.

(b) Fluvial flood history

The two largest floods in recent years on the lower Thames occurred in January 2003 and December 2013 to February 2014. The peak flows in these two floods were of similar magnitude to each other at each of the four gauging stations in the study area. Both floods are estimated as approximately 1 in 15 annual chance floods (as the magnitude of their peak flows generally lie in-between the 1 in 10 and 1 in 20 annual chance design flood peaks).

Figure 3.8 shows the annual maximum peak flows at the Kingston, based on data in the National River Flow Archive (NRFA). This illustrates that the 2003 and 2014 floods were the largest gauged since November 1974. However, prior to that, significantly higher peak flows were recorded in November 1894, March 1947, September 1968 and January 1915.

The winter 2013-14 flows were exceptional in the duration that the high flows lasted, with separate peaks in December, January and February. The volume recorded over a 90 day period, as shown in Figure 3.9, was significantly larger than at any other time in the Kingston record, which began in 1883. In contrast, the 1894 and 1947 floods rose and fell more quickly from their higher flood peaks. The impact in 2013-14 of the very long duration of high flows was for sustained river flooding to some properties and, also, greater opportunity for groundwater flooding originating from the river and passing via the gravels beneath the adjacent floodplain.

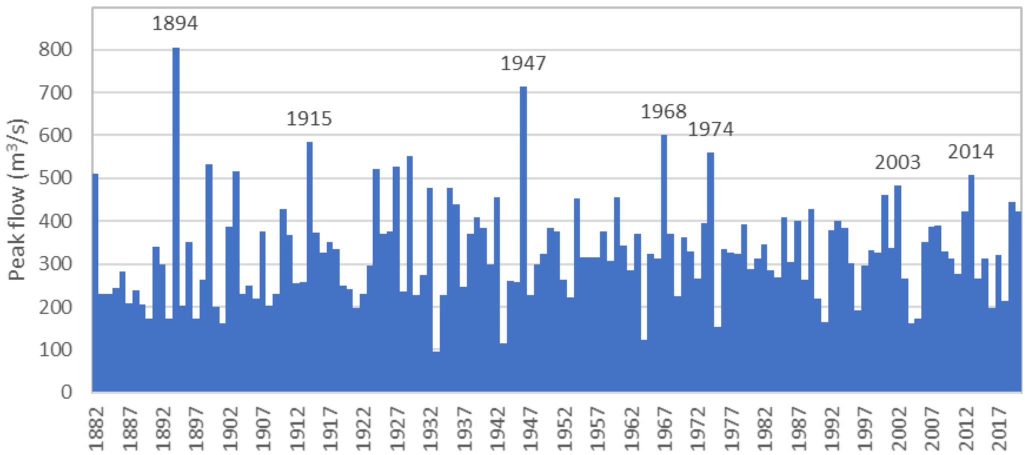


Figure 3.8 Annual maximum flows at River Thames gauging stations in the study area

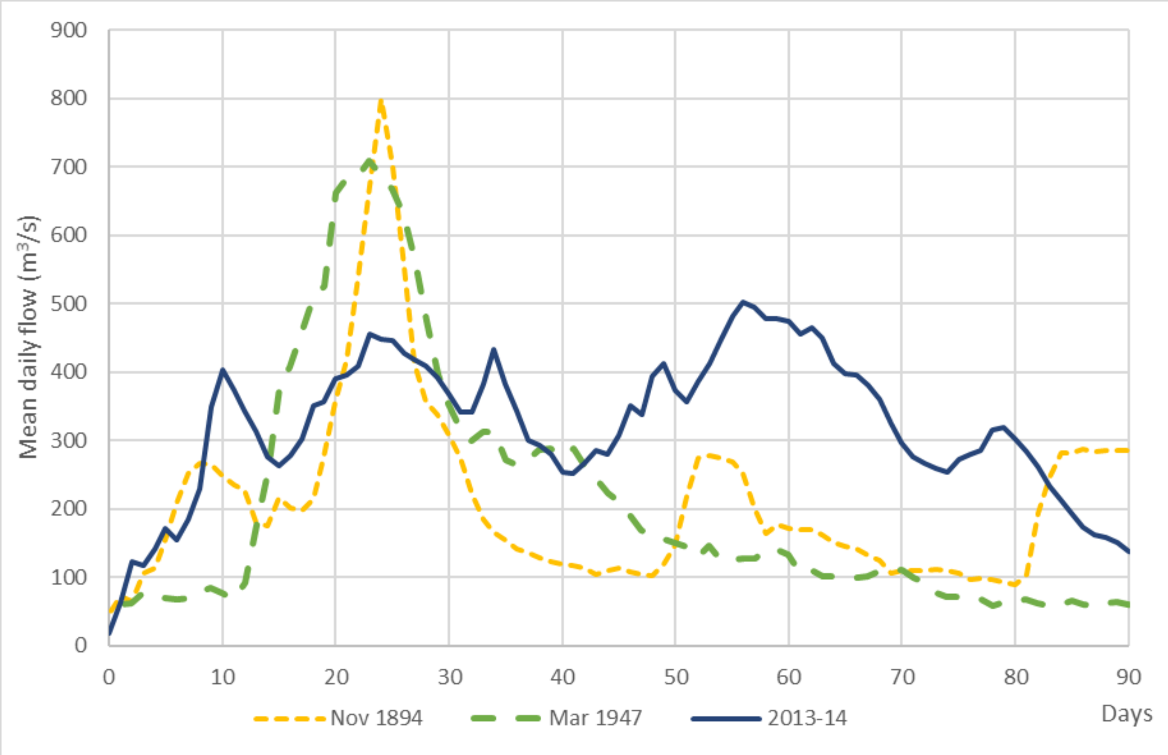


Figure 3.9 Comparison of gauged flow hydrographs at Kingston

(c) Design floods

Two types of floods have been simulated in the model:

- Thames dominated floods. This case has design flood conditions in the River Thames but lower magnitude inflows in the tributaries. This is the primary design case for the RTS.

- Tributary dominated floods. This case has design flood conditions in the tributaries but only a moderate flow in the River Thames. This is of interest when considering the impact of the RTS on the Chertsey Bourne.

(d) Tidal boundary conditions

The downstream limit of the model is at Southend, with the model including the whole of the tidal Thames through London and the Thames estuary. The model includes the Thames Barrier. The Thames Barrier is operated by the EA considering operational thresholds of fluvial flow and tidal water level combinations.

The tidal boundary condition used at Southend represents a reasonable worst case for a fluvial flood:

- For lower flood magnitudes, a mean spring tidal cycle was used. This is a standard modelling assumption for a downstream tidal boundary in fluvial flood scenarios.

- For higher flood magnitudes (above the 1 in 50 annual chance flood), the Thames Barrier would close with a mean spring tide. For these floods, the modelling uses the largest tide that the Barrier would remain open for. This approach gives higher flood levels upstream of the Barrier than taking a higher tide and closing the Barrier.

- We have followed the Thames Barrier operational thresholds to define the downstream tide levels. The operational thresholds define the conditions for which the Barrier must be closed.

The Thames Barrier is open for all the design flood simulations but Thames Barrier closures have also been simulated when testing observed floods (when the Barrier was closed, such as 2014), along with other sensitivity testing for the tidal boundary conditions and Thames Barrier operations.

The tidal boundary conditions were discussed and agreed in consultation between the RTS project team, the EA's Thames Barrier operational team and the Thames Estuary 2100 (TE2100) team. This includes consideration of planned changes to the Barrier's operation in the 2030s following the TE2100 outcomes.

3.6 Model versions

As described in Section 3.3(e), both 1D-only and 1D-2D versions of the Lower Thames flood model were used for the work described in this report.

The general philosophy is that:

- The 1D-only model was used for testing and refining multiple options.
- The 1D-2D model was used to:
    - understand floodplain flows and water levels;
    - as a cross-check of the 1D-only model results; and
    - for final model outputs such as flood maps, animations and economic appraisal.

The 1D-only model generally takes 1-2 hours to run a design event simulation. This makes it a useful tool for quickly testing and comparing multiple different options. The 1D-only model is appropriate for this task, since the design development was predominantly focused on channel structures and alignment, which are represented as 1D elements in both versions of the model and there is no loss of accuracy compared to the 1D-2D model. Due to the complexity of the 1D-2D model, it takes between 2 and 14 days to complete each model simulation, depending on the flood magnitude (and amount of flooding into the 2D domain). The 1D-2D model represents the floodplain in more detail than the 1D-only model. Therefore, the 1D-2D model was used for the final model outputs and tasks investigating floodplain flows and water levels.

3.7 Model review and quality assurance

The Lower Thames flood model was developed by two consultants – JBA and Galliford Binnies (GB). This was subject to a comprehensive quality assurance process. The quality assurance of JBA's work is described in Section 13 of their Modelling Report (2019). The key aspects of that are reproduced below, along with the additional aspects of the GB work:

- Standard internal checks and reviews by JBA and GB on their own work.

- Independent peer review of JBA's hydrology report and calculations by Hyder Consulting (now Arcadis) in November 2014.
- Independent peer review of JBA's flood modelling by CH2M Hill (now Jacobs) in 2014 to 2016. This covered review of the 1D model, review of the 1D-2D model and review of model outputs.
- EA review of JBA's model outputs by technical and catchment specialists.
- GB review of JBA's models at each handover point:
    - Initial 1D model in 2015.
    - Interim and Recalibrated 1D models in 2016.
    - Handover 1D-2D model in 2016.
    - Final 2019 1D-2D model in 2020.
- Independent peer review of GB's flood modelling by CH2M Hill in 2015 to 2017. This involved all modelling deliverables and related to the design of the RTS.
- Review of all GB modelling outputs by EA technical and catchment specialists (2015, 2016, 2017, 2020, 2021, 2022 and 2023). This includes review by EA specialists both within the RTS team (with expert knowledge of the scheme) and outside of the RTS team (independent to the project). Specialists were drawn from different EA teams including the national Incident Management and Resilience team (Strategic Delivery / Evidence & Risk) and the relevant area Partnership and Strategic Overview teams (Thames; Kent, South London and East Sussex; and Hertfordshire & North London).

The modelling peer review by CH2M Hill:

- Involved a series of meetings and workshops hosted by the EA and attended by CH2M Hill and the flood mapping and RTS project teams (JBA, GB, and EA experts).
- Provided extensive feedback on the flood model and deliverables.
- Led to many improvements and refinements to the flood model setup to more accurately represent flood risk.

4. Baseline model development

4.1 General

The baseline model referred to in the section heading is the model without the RTS included, representing the river system as it is now (existing conditions).

The development of the latest version of the Lower Thames model was started by JBA in 2013, as described in their Lower Thames Flood Modelling Study Report (JBA, 2020). Their update combined a number of separate existing models into a single model, whilst also incorporating new survey data and new 2D floodplain representation.

The model was calibrated and verified using observed data from high flow events in January 2003, February 2007, February 2009, November 2012 and January/February 2014.

Over the course of the RTS modelling work, there have been multiple flood models developed, including several iterations of most models. Table 4.1 shows the timeline of the model development:

- GB's modelling began in 2015 from a handover version of JBA's 1D-only flood model.
- The GB and JBA flood model development then continued in parallel.
- GB's 1D-only model was finalised in 2016. That model version has continued to be used for further testing and refinement of the RTS design up to the present time (2023). However, the underlying model – in terms of existing channel geometry, schematisation and roughness – has not changed, just aspects of the RTS design within it.
- GB's first 1D-2D modelling was undertaken in 2017. For the latest model update, in 2021, the model was primarily based on JBA's final 2019 1D-2D model (River Ash variant). We also used aspects of our 2017 model to improve the model schematisation.

The following sub-sections give a brief summary of GB's work in developing and improving the Lower Thames model.

Table 4.1 Model development timeline

Year	JBA 1D-only	GB 1D-only	JBA 1D-2D	GB 1D-2D
2015	2015 JBA 1D	2015 Initial 1D	-	-
2016	-	2016 Interim 1D 2016 Recalibrated 1D	2016 JBA 1D-2D	-
2017	-	-	-	2017 1D-2D
2018	-	-	-	-
2019	-	-	2019 JBA 1D-2D Lower Thames 2019 JBA 1D-2D Hammersmith 2019 JBA 1D-2D River Ash	-
2020	-	-	-	-
2021	-	-	-	2021 1D-2D

4.2 2015 Initial 1D model

The 1D-only model of the Lower Thames was developed by JBA, primarily as a tool to aid model calibration. JBA provided a version of the 1D model to GB in June 2015. This 1D model had been reviewed by CH2M Hill, with the focus on the model calibration for the observed flood events in 2007, 2009, 2012, 2003 and 2014.

GB undertook an initial review of the model in July 2015, focusing on the schematisation around the RTS flood channel route. A second more extensive review was undertaken in August-September 2015 when the model began to be used for the Concept Design testing. Following these reviews, GB adjusted the model to improve its accuracy and reduce its run time. An updated version was returned to JBA and CH2M Hill in October 2015. That version is referred to as the 2015 Initial model in this report.

The 2015 Initial model was superseded by the 2016 Recalibrated 1D model.

4.3 2016 Recalibration of 1D model

GB found that the 2015 Initial 1D model tended to underestimate flood levels in the 2003 and 2014 calibration events and the more extreme design flood events. This was based on comparison to recorded hydrometric data and results from the previous Lower Thames Strategy model. Water levels predicted by the Initial model were typically 0.1-0.2m lower than observed water levels in the 2003 and 2014 floods.

We undertook a recalibration exercise to obtain a better match between modelled and recorded flood levels. The changes to the model resulted in a significant improvement in the calibration results. Peak levels, peak flows and hydrograph shapes give a much better match with the recorded hydrometric data. The recalibration halved the average difference between modelled and observed peak water levels, with only 15% of sites/events outside the ±0.15m calibration target accuracy (compared to 47% with the Initial model).

The 2016 Recalibrated 1D model remains the latest 1D model version and is still being used for the RTS.

Figure 4.1 shows the calibration results for the 2014 flood (December 2013 to February 2014). The recorded water levels are shown in blue and the model results for the 2016 Recalibrated 1D model are shown in dashed red. The results show a close match between the recorded data and the model predictions. A similarly good fit was obtained for the other four calibration events.

4.4 2017 1D-2D model

GB adapted the 2016 JBA 1D-2D handover model to create the GB 2017 1D-2D model. This model version was used for developing the Outline Design of the RTS in 2017. This work comprised:

- Amendments to the model setup to improve accuracy and model stability.
- Cutting down the 2D domain in the model to focus on the main RTS study area.
- Creating a version of the 1D-2D model that included the RTS flood channel and downstream compensation measures.

- Modelling the Do Nothing scenario, used in the economic appraisal to assess what would happen if watercourse maintenance were to cease and structures were abandoned.

The 2017 1D-2D modelling is superseded by the 2021 model update.

4.5 Review of 2019 1D-2D model

GB undertook a review of JBA's 2019 1D-2D model, which was developed in parallel to the GB 2017 1D-2D model. The original intention was to use the 2019 1D-2D model to assess the RTS for consistency with the EA's flood mapping outputs such as their online Flood Map.

The review identified that the 2019 1D-2D model was not suitable to assess the RTS and that further model development was required.

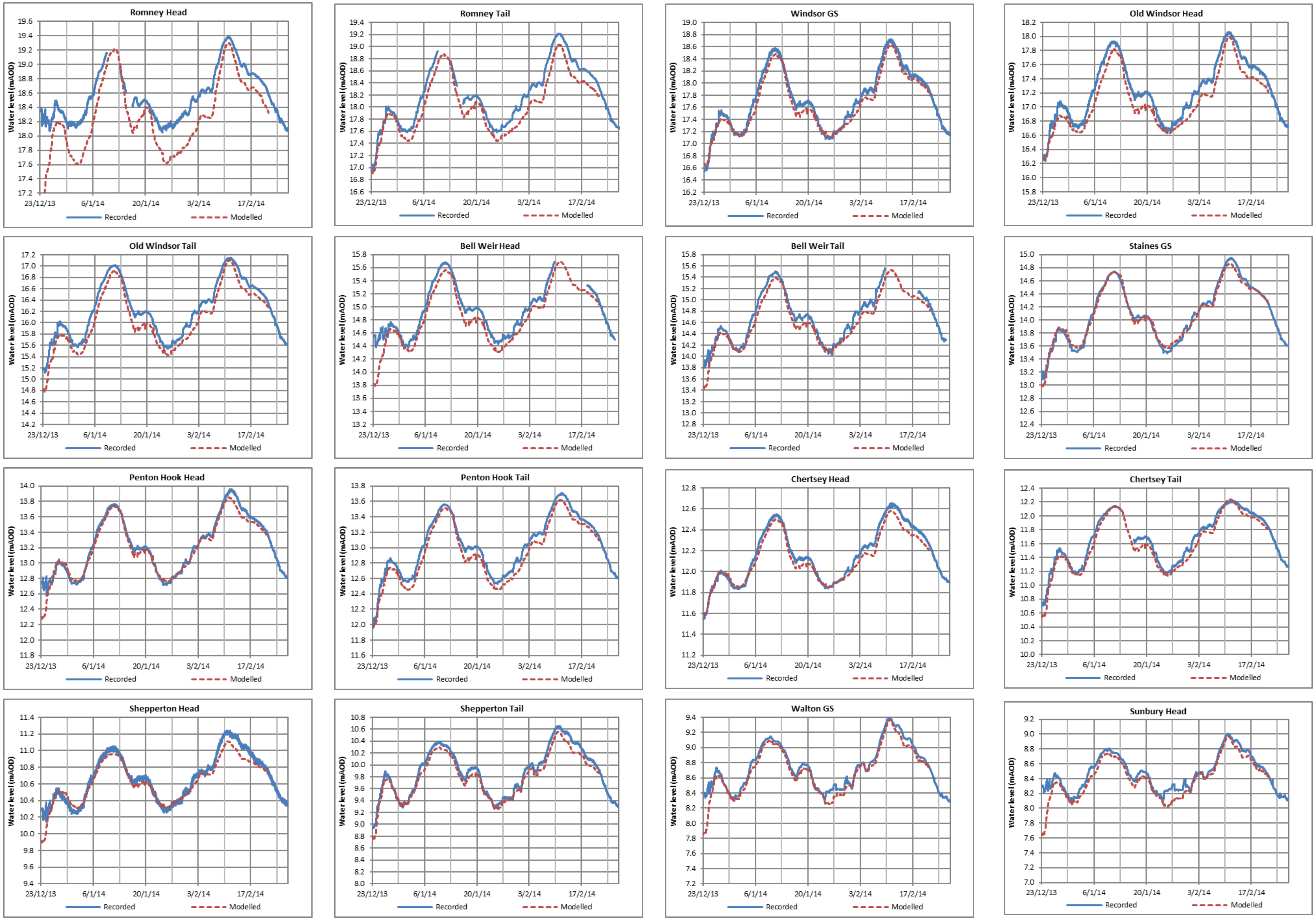
4.6 2021 1D-2D model

The 2021 1D-2D model is a revised version of the 2019 1D-2D model, incorporating changes made for the GB 2017 1D-2D model and some additional refinements to the model geometry using additional topographic data and information that was not available in 2017.

The 2021 1D-2D model was verified by comparison to earlier model versions to ensure the model calibration still applied.

The latest (2021) climate change guidance from the EA was used to define the model simulations required. Climate change factors of +10%, +15%, +20%, +25%, +35%, +45% and +81% were applied for the 1 in 100 annual chance flood.

The 2021 1D-2D model is the latest 1D-2D model version and provides the best representation of flood risk for the Lower Thames between Windsor and Teddington.


Romney Head
Water level (mAOD)
19.6 19.4 19.2 19.0 18.8 18.6 18.4 18.2 18.0 17.8 17.6 17.4 17.2
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Romney Tail
Water level (mAOD)
19.4 19.2 19.0 18.8 18.6 18.4 18.2 18.0 17.8 17.6 17.4 17.2 17.0 16.8 16.6
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Windsor GS
Water level (mAOD)
19.0 18.8 18.6 18.4 18.2 18.0 17.8 17.6 17.4 17.2 17.0 16.8 16.6 16.4 16.2
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Old Windsor Head
Water level (mAOD)
18.2 18.0 17.8 17.6 17.4 17.2 17.0 16.8 16.6 16.4 16.2 16.0 15.8
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Old Windsor Tail
Water level (mAOD)
17.2 17.0 16.8 16.6 16.4 16.2 16.0 15.8 15.6 15.4 15.2 15.0 14.8 14.6 14.4 14.2
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Bell Weir Head
Water level (mAOD)
15.8 15.6 15.4 15.2 15.0 14.8 14.6 14.4 14.2 14.0 13.8 13.6 13.4 13.2
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Bell Weir Tail
Water level (mAOD)
15.8 15.6 15.4 15.2 15.0 14.8 14.6 14.4 14.2 14.0 13.8 13.6 13.4 13.2 13.0 12.8
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Staines GS
Water level (mAOD)
15.0 14.8 14.6 14.4 14.2 14.0 13.8 13.6 13.4 13.2 13.0 12.8 12.6 12.4
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Penton Hook Head
Water level (mAOD)
14.0 13.8 13.6 13.4 13.2 13.0 12.8 12.6 12.4 12.2 12.0 11.8
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Penton Hook Tail
Water level (mAOD)
13.8 13.6 13.4 13.2 13.0 12.8 12.6 12.4 12.2 12.0 11.8 11.6
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Chertsey Head
Water level (mAOD)
12.8 12.6 12.4 12.2 12.0 11.8 11.6 11.4 11.2
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Chertsey Tail
Water level (mAOD)
12.4 12.2 12.0 11.8 11.6 11.4 11.2 11.0 10.8 10.6 10.4 10.2 10.0
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Shepperton Head
Water level (mAOD)
11.4 11.2 11.0 10.8 10.6 10.4 10.2 10.0 9.8 9.6 9.4
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Shepperton Tail
Water level (mAOD)
10.8 10.6 10.4 10.2 10.0 9.8 9.6 9.4 9.2 9.0 8.8 8.6 8.4 8.2 8.0
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Walton GS
Water level (mAOD)
9.4 9.2 9.0 8.8 8.6 8.4 8.2 8.0 7.8 7.6 7.4 7.2
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled
Sunbury Head
Water level (mAOD)
9.2 9.0 8.8 8.6 8.4 8.2 8.0 7.8 7.6 7.4 7.2 7.0
23/12/13 6/1/14 20/1/14 3/2/14 17/2/14
Recorded
Modelled

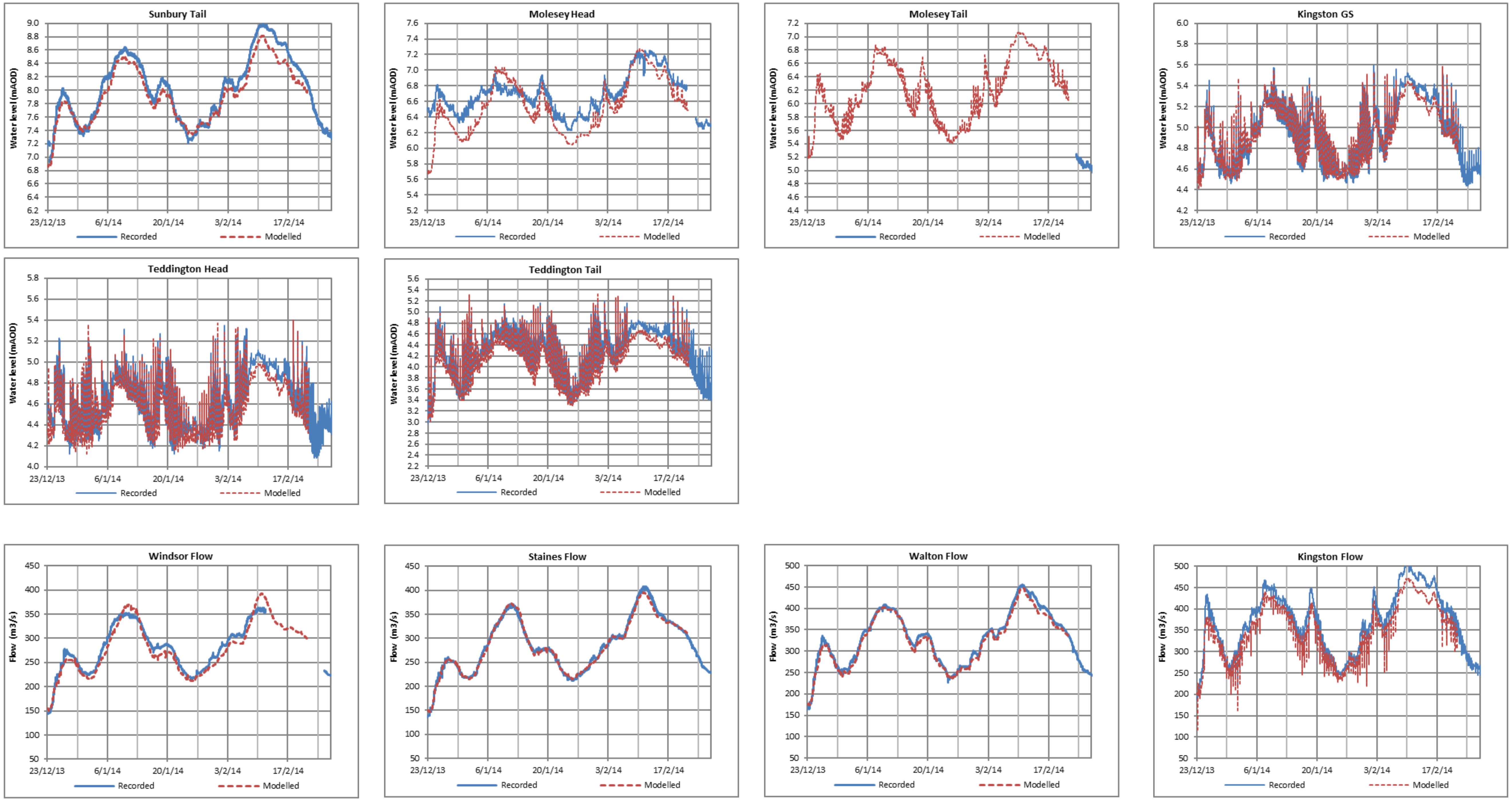


Figure 4.1 Model calibration results (2016 Recalibrated 1D model)

5. Model testing

5.1 General

This section describes the model testing to assess and improve the RTS design.

5.2 Representation of RTS flood channel

In all versions of the flood model, the RTS flood channel (and downstream compensation measures) is represented as 1D cross-sections and structures. The representation is much more detailed than in previous modelling – with cross-sections at 100m spacing.

5.3 Overview of design development

The RTS design has been tested and refined using the flood model over several years. Each stage has looked at particular aspects of the evolving design. The key steps, which remain relevant in the latest design, are shown on the timeline within Table 5.1. Each of the steps shown in Table 5.1 are covered briefly in the following sub-sections. The order of the sub-sections is determined by geographic location rather than just chronology so that, for example, the Runnymede channel sub-sections are grouped together.

Table 5.1 Timeline of flood modelling used for design development

Year	Runnymede channel	Spelthorne channel	Desborough Cut	Sunbury, Molesey and Teddington
2016	Concept Design	Concept Design Review Spelthorne channel route	Concept Design Desborough alternatives	Concept Design
2017	Chertsey Bourne option testing Outline Design	Outline Design	Outline Design	Outline Design
2018	-	-	-	-
2019	-	-	-	-
2020	Flood risk without Berkshire channel	Flood risk without Berkshire channel	Flood risk without Berkshire channel	Flood risk without Berkshire channel
2021	Flood channel operating criteria	Flood channel operating criteria	Optimisation of downstream measures	Optimisation of downstream measures
2022	Validation of design using 1D-2D model	Validation of design using 1D-2D model	Validation of design using 1D-2D model	Validation of design using 1D-2D model

5.4 Runnymede channel Concept Design (2016)

This was the first iteration of 1D modelling used to develop the Runnymede channel design from the Lower Thames Strategy design. This included:

- Refining the location and size of structures on the flood channel.

- Changes to the channel shape, including past Thorpe Hay Meadow and through landfill areas.
- Adjustments to flood banks.

This work identified that the biggest constraint on hydraulic capacity of the channel are the culverts under the M3 at the downstream end of the Runnymede channel.

5.5 Chertsey Bourne option testing (2017)

The 1D model was used to:

- Understand existing flood risk in Chertsey from both the River Thames and the Chertsey Bourne, including analysis of joint probability of concurrent extreme floods in both watercourses.
- Test options and refine the design of the four structures within the Thorpe Park lakes that allow some flow to be diverted from the Chertsey Bourne into the Runnymede channel.

The refined design achieves reductions to flood risk in Chertsey from both River Thames and Chertsey Bourne floods.

5.6 Spelthorne channel Concept Design (2016)

As with the Runnymede channel Concept Design modelling, this was the first iteration of 1D modelling used to develop the Spelthorne channel design. This covered refinements to structures, channel shape and flood banks.

5.7 Revised Spelthorne channel route (2016)

This 1D modelling led to a significant change to the Spelthorne channel route – moving from a split route with two outlets utilising existing M3 culverts to a single route with a new M3 underbridge. This option gave greater water level reductions than the original design.

5.8 Outline Design (2017)

The 1D-2D model was used to test the RTS Outline Design. This work focused on:

- Changes to the channel alignment;
- Operation of the flood channel intake gates;
- Performance of the flood channel in extreme floods;
- Flood bank design; and
- Design of structures where other watercourses cross the flood channel route.

5.9 Flood channel operating criteria testing (2021)

The 1D model was used to test alternative rules for when the flood channel would operate. The modelling showed that increasing the threshold for the flood channel intake gates opening from 200 to 230m^3/s does not change flood levels or extents but reduces the frequency of operation by 50%. This would reduce the sediment load entering the flood channel, which is beneficial for the geomorphology of both the River Thames and the flood channel. The threshold of 230m^3/s was subsequently adopted in the RTS design.

5.10 Downstream compensation measures Concept Design (2016)

This was the first iteration of 1D modelling to design the downstream compensation measures at the Desborough Cut and Sunbury, Molesey and Teddington weirs. Note that when this work was undertaken the Berkshire channel was still included in the RTS design.

Based on this modelling, an option of 5 compensation gates at Teddington (through the lock island), 2 gates at Molesey (through Weir C) and 3 gates at Sunbury (through the lock island) was adopted for the Concept Design. Beyond the selected design, additional compensation gates give very little hydraulic benefit as existing gate/weir capacities are already very large.

A range of additional options, to supplement the compensation gates at weirs, were considered as a way to ensure no detriment in any flood conditions and to provide additional water level reductions. Of the options investigated, adjusted timing of abstractions to water supply reservoirs appeared the most promising. We recommended it was taken forward for further consideration and it was subsequently incorporated into the RTS Outline Design.

5.11 Desborough Cut alternative options (2016)

The 1D model was used to test alternative downstream compensation options in the vicinity of Desborough Island. The modelling showed that the hydraulic objective of this work could be achieved by:

- 3m widening of the Desborough Cut (on either bank) and deepening works under the bridges at the upstream and downstream ends of the Cut.
- Around 12,000m^3 of bed lowering in the Cut or in the Thames downstream of Desborough Island. This bed lowering is 20m wide, 0.5m deep and over a 1.1km length.
- Around 20,000m^3 of bed lowering in the Desborough Loop.

The option of bed lowering downstream of the Desborough Cut was subsequently adopted in the RTS design, following further appraisal against engineering, environmental and other criteria.

5.12 Flood risk without the Berkshire channel (2020)

The 1D model was used to assess the impact of removing the Berkshire channel from the RTS design. This showed that:

- Upstream of Bell weir, the RTS does not reduce flood levels as much without the Berkshire channel included. This is unsurprising as this is the area that would have benefited most from the Berkshire channel. However, there is no detriment (increase in flood levels) in any conditions due to the RTS. The upstream drawdown from the Runnymede channel gives a reduction in flood levels as far upstream as Windsor, although the reduction there is very small. The positive impact of the RTS flood channel reduces moving upstream.

- Downstream of Bell weir through to Teddington, the RTS is marginally more effective without the Berkshire channel. The additional water level reduction is typically 0.01-0.02m. This is because the Berkshire channel gave a small increase in peak flows passing downstream.

5.13 Optimisation of downstream compensation measures (2021)

Due to the changes to the RTS design since 2016, principally the removal of the Berkshire channel, the design of the downstream compensation measures was revisited. The 1D model was used to find the optimum design.

This work showed that:

- The downstream compensation measures achieve the objective of no detriment. There is no increase in flood levels due to the RTS at any location in any flood conditions.
- The scale of the downstream compensation measures can be reduced and still achieve the no detriment objective. The optimised combination in the modelled RTS design is:
    - 50% bed lowering depth near Desborough (compared to 100% depth for Outline Design).
    - 2 gates at Sunbury (compared to 3 gates in Outline Design).
    - 2 gates at Molesey (as in Outline Design).
    - 3 gates at Teddington (compared to 5 gates in Outline Design).
    - 100% enhanced timing of Thames Water abstractions.
- There is only a very small difference in water levels compared to the full Outline Design downstream compensation measures – up to 0.03m around Desborough Island and 0.02m or less elsewhere.

5.14 Validation of design using 1D-2D model (2021)

The 2021 1D-2D model was used to validate the effectiveness of the latest RTS design (2021 Outline Design with Berkshire channel removed). This work confirmed that the design works as intended and supported the findings derived from the 2016 Recalibrated 1D model were appropriate with respect to:

- Removal of the Berkshire channel from the RTS design.
- The optimised flood channel operation.
- The optimised downstream compensation measures.

6. Discussion

6.1 Impact of the RTS

(a) Flood levels

The histogram in Figure 6.1 shows the impact of the RTS on flood levels compared to existing conditions. The horizontal axis shows locations along the River Thames – moving downstream from Romney Lock near Windsor on the left-hand-side to Teddington Lock on the right. The green bars show the range between the minimum and maximum reduction, for a range of design flood magnitudes (1 in 5, 10, 20, 50, 75 and 100 annual chance). This illustrates that:

- The greatest reduction in water levels is around Penton Hook at the upstream end of the Runnymede channel (0.4m to 0.9m).
- The reduction parallel to the Spelthorne channel is also considerable (0.1m to 0.8m).
- There is a reduction in water levels of up to 0.5m through Staines. This is due to the drawdown effect of the Runnymede channel taking flow out of the Thames further downstream. This drawdown effect of the flood channels gives some benefit as far upstream as Datchet and Windsor (Romney Lock), although the reduction is very small there (less than 0.1m).
- The impact downstream of Shepperton is relatively modest (up to 0.2m). The reduction in this area is due to the bed lowering downstream of the Desborough Cut; capacity improvements at Sunbury, Molesey and Teddington; and modified water supply abstraction timings.

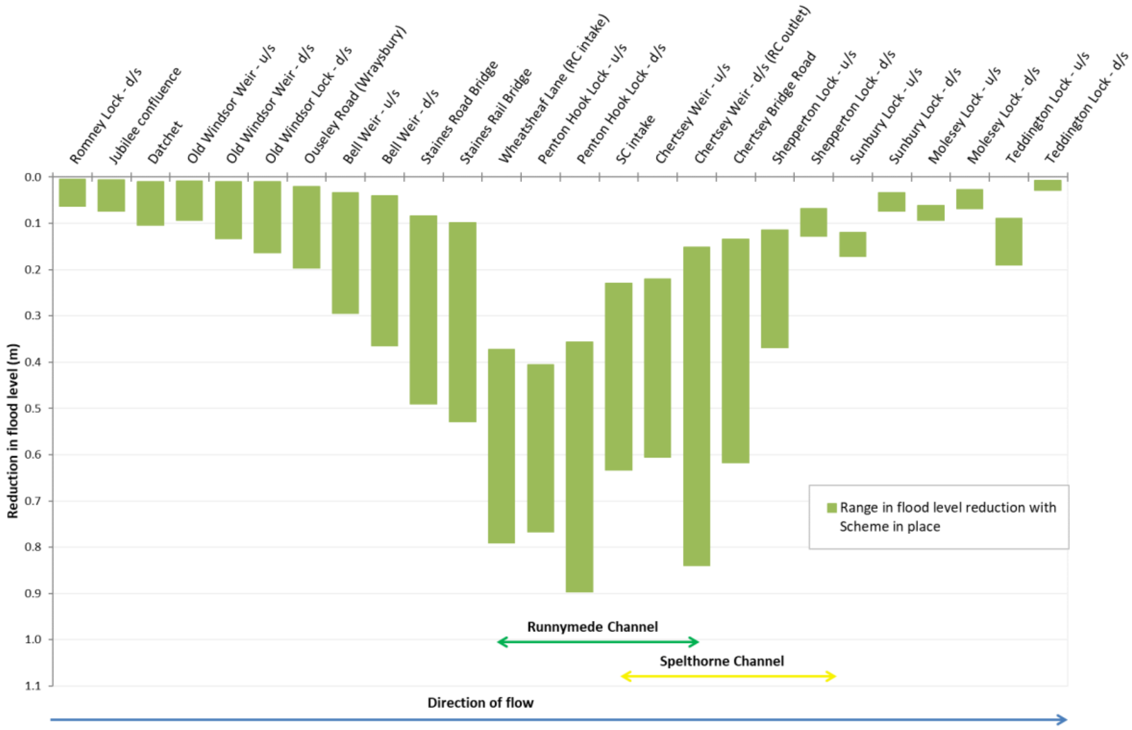


Figure 6.1 Reduction in flood levels due to RTS

(b) Peak flows

As discussed in Section 3.1(b), the flood channel leads to a small increase in peak flows passing downstream in some conditions (up to 5-10m^3/s, which is 1-2% of the total flow):

- The small increase in peak flows due to the flood channel is fully compensated for by the flood level reductions achieved by the bed lowering downstream of the Desborough Cut and additional weir gates at Sunbury, Molesey and Teddington.
- If the modified timing of water supply abstractions is implemented, in total the RTS slightly reduces peak flows. The reduction in peak flows from implementing modified abstractions exceeds the increase in peak flows from the flood channel, giving a small overall reduction. As such, modified abstraction timings increases the flood level reductions achieved by the RTS.

With or without modified abstraction timings implemented, there is no increase in flood levels at any location in any flood conditions.

(c) Flood extent and depth

The figures below show:

- The areas where flooding is prevented by the RTS (pink shaded areas).
- The areas where flooding is reduced by the RTS (yellow to green shaded depth reduction contours).
- The areas where there is no change in flood levels with the RTS (darker blue shaded areas).
- The watercourses and lakes through the study area (light blue shaded areas).
- The RTS flood channel (orange outline), Desborough bed lowering (grey dashed outline) and additional weir gates (grey diamonds).
- The 1 in 20 annual chance flood in Figure 6.2.
- The 1 in 100 annual chance flood in Figure 6.3.

These flood maps show that:

- Upstream of Staines / the M25 crossing, there is only a small change in flood extent for these flood magnitudes. Water level reductions are less than 0.2m here, with the reductions diminishing with flood magnitude.
- The biggest reduction in flood extent due to the RTS is in the Egham Hythe area, near the upstream end of the Runnymede channel.
- There are also large reductions in flood extent through Laleham and Chertsey.
- Downstream of the flood channel (Walton onwards), the reduction in flood extent due to the RTS is small. Generally, the flood extent remains the same through this area and water level reductions are less than 0.2m.

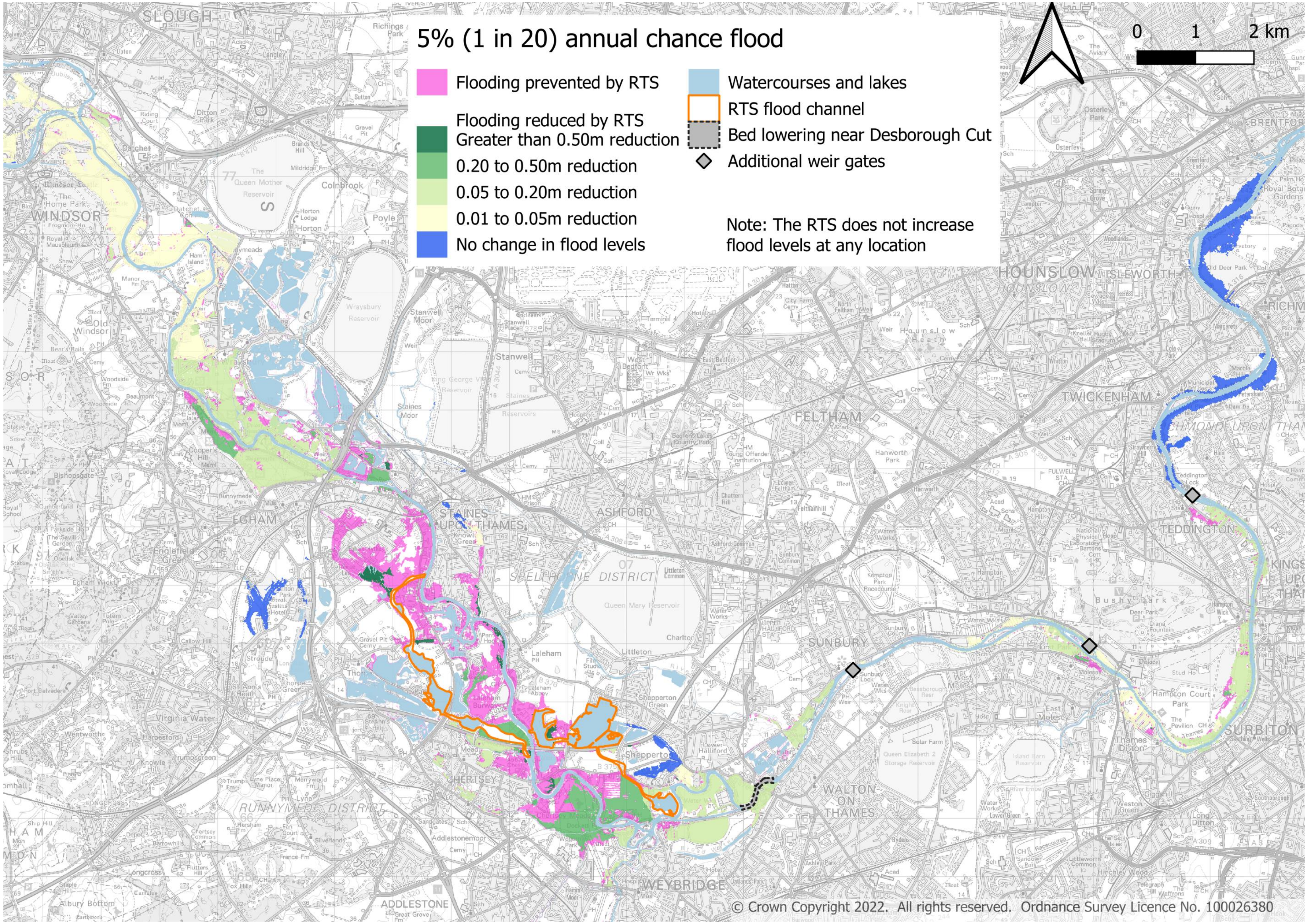


Figure 6.2 Flood extent in 1 in 20 annual chance flood

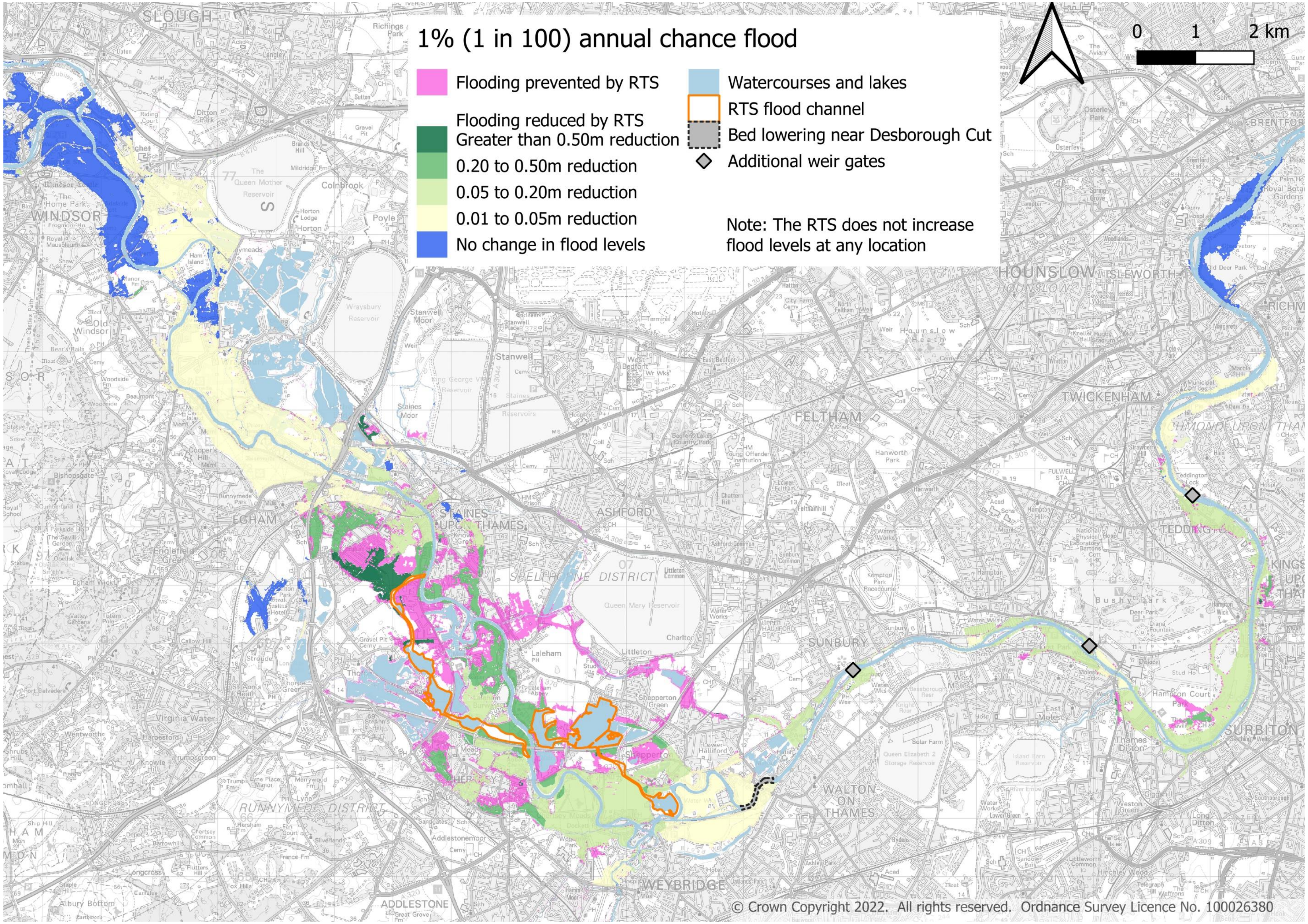


Figure 6.3 Flood extent in 1 in 100 annual chance flood

6.2 Other sources of flooding

This report focusses on fluvial flooding originating from high flows in the lower River Thames and its tributaries. Tidal influence is accounted for within the modelling, although purely tidal flooding is not considered since the Thames Barrier provides protection through the study area.

The impact of the RTS on groundwater has been modelled and considered in detail as part of the RTS Outline Design and is reported separately. That report found that:

> *"Under flood conditions in a wet year, groundwater levels along the River Thames are likely to be lower relative to the baseline (reflecting a reduction in peak river levels)."*

The RTS is not expected to have a significant impact on surface water flooding. The RTS has been designed to prevent any increase in fluvial flood risk. If flood levels in rivers are lower or unchanged with the RTS in place, it follows that there will be no negative impact on surface water flooding due to the RTS. The lower fluvial flood levels may give some reductions in surface water flooding, due to improved drainage into watercourses. Any such improvements are likely to be modest. The principal benefit of the RTS is to reduce fluvial flood risk.

There is ongoing work looking at groundwater and surface water flood risk, which will be reported separately.

6.3 Confidence in model outputs

When considering the accuracy of model outputs it is important to distinguish between:

- **Absolute accuracy** of the model. This is the accuracy of the model predictions compared to real life. For example, comparing model predictions of water levels at a particular location in an observed flood to actual water level recordings.
- **Relative accuracy** of the model. This is the model accuracy in predicting differences between two modelled scenarios. For example, predicting the relative impact of the RTS compared to existing conditions such as how much water levels are lowered with the scheme.

The target absolute accuracy for water levels used by JBA when calibrating the model (and GB when recalibrating the 1D-only model) was ±0.15m. This remains the best measure of the absolute accuracy of the model. However, it should be remembered that the accuracy of the calibration results varied by location and event. In some cases, the calibration accuracy was exceeded, whereas in others it was not met.

It is normally acknowledged that the confidence that can be placed in the relative accuracy of a hydraulic model is higher than the absolute accuracy of the model. This is because inaccuracies in the prediction for the base model will be shared and reproduced when testing alternative options. For example, a base model could over-predict water levels at a particular location by 0.1m (perhaps mainly because the inflows were too high). The modelled alternative option scenario will have a similar over-prediction (as it will have the same inflows) but the relative difference of 0.2m between scenarios would be much more accurate. It is difficult to give a numerical measure of this relative accuracy as there is no real-life data with which to calibrate against for proposed alternative options until they are constructed. However, the model convergence tolerance (±0.01m) provides a useful guide for the model accuracy when evaluating relative changes between scenarios.

There are several reasons to have high confidence in the absolute accuracy of the Lower Thames model outputs:

- The design flood inflows are primarily based on the record of gauged flows at Kingston / Teddington. Beginning in 1883, this is the longest continuous flow series in the UK so gives an unusually long period of record. This gives additional confidence in the flood estimates, particularly for more extreme floods, than is usually available. This is supplemented with the flow records at Royal Windsor Park, Staines and Walton. Having four flow gauges in the study area gives a good cross-check on the gauging accuracy.

- An unusually large number of gauges were available and used for the model calibration – 20 water level gauges and four flow gauges within the main RTS study area. Often a hydraulic model can be calibrated to only one or two level-flow gauges. The large number of calibration points gives additional confidence that the model is achieving a high level of accuracy throughout its domain.

- Using six calibration events, including three relatively large recent floods (2003 and Jan/Feb 2014) for which observed flood outlines were available for comparison. A cross-check with the major 1947 flood was also made.

- The calibration exercise was extensive with many iterations to refine and improve the model accuracy. This work involved expert modellers from three different consultants, all of whom are specialists in this type of work:

    - JBA for the model build and calibration;

    - GB initially reviewing the calibration outputs and then undertaking recalibration of the 1D-only model; and

    - CH2M (now Jacobs) acting as peer reviewers, utilising experience developing the Lower Thames models since the 1990s.

- The calibration of 1D-only and 1D-2D models show good consistency, which gives confidence in the floodplain representation in both models.

6.4 Considerations for future model updates

Note that this section refers to potential future updates to the baseline flood model to understand existing flood risk, rather than identifying further testing required for the RTS design.

There are aspects of every flood model that could be refined and enhanced. The EA review of the baseline 2021 1D-2D model noted three areas for improvement or further investigation, based on their knowledge of observed flooding mechanisms. This related to a pipe connection in Datchet, groundwater flooding at Old Windsor and groundwater flooding through the Thames gravels more generally. These should be considered in any future updates to the Lower Thames model. However, they are not critical for this study as the model still provides a fair basis for assessing the RTS and, in any case, the impact of the RTS is relatively small in these locations. These are refinements that could give increased understanding of flood risk, rather than errors in the model setup.

7. Conclusions

The River Thames Scheme will reduce fluvial (river) flood risk from Windsor to Teddington. The impact of the scheme varies by location and flood magnitude. As an overview:

- The greatest reduction in flood levels is in the Egham Hythe and Penton Hook area, near the upstream end of the Runnymede channel (up to 0.9m).
- The reduction parallel to the Spelthorne channel is also considerable (up to 0.8m).
- There is a reduction in flood levels upstream of the flood channel through Staines and beyond. This is due to the drawdown effect of the Runnymede channel diverting flow out of the Thames further downstream. In Staines, the reduction in flood levels can be significant (up to 0.5m) but this impact diminishes moving upstream so that by Datchet and Windsor the benefit provided by the RTS is very small (0.1m or less).
- The impact downstream of Shepperton is relatively modest (up to 0.2m). The reduction in this area is due to the bed lowering downstream of the Desborough Cut; additional gates at Sunbury, Molesey and Teddington weirs; and modified abstractions.
- Downstream of Teddington the impact is even smaller (0.03m or less) so effectively there is no change in flood risk.
- There is no increase in flood risk predicted at any location in any flood conditions. The RTS will not make flooding worse for anyone.

This Non-Technical Summary of the Flood Modelling Report records the flood modelling undertaken by GB in developing the River Thames Scheme design between 2014 and 2022. This includes:

- The development and improvements made to the baseline model used to represent the River Thames and tributary system as they are now (existing conditions). This includes both 1D-only and 1D-2D flood models. The 1D-only model has been used primarily for option testing and refinement, whereas the 1D-2D model provides the definitive assessment of scheme performance.
- Model testing with the RTS included to examine its impact. This led to changes in the design such as:
    - Refinement of the structures along the two flood channel sections.
    - Improving the connecting structures to allow Chertsey Bourne floods to be diverted into the Runnymede channel and reduce flood risk through Chertsey.
    - Revising the route of the Spelthorne channel to deliver greater flood level reductions.
    - Increasing the flow threshold in the Thames that triggers operation of the flood channel.
    - Optimising the configuration of the downstream compensation measures near the Desborough Cut and at Sunbury, Molesey and Teddington weirs.

There is ongoing work to further refine the RTS design, such as changes to the landscaping. This design development is supported by additional flood model testing. Once complete, reporting of the additional flood modelling will be included in future updates to the Flood Modelling Report and this Non-Technical Summary.

The River Thames Scheme, delivered in a partnership le
by the Environment Agency and Surrey County Counci
will reduce flood risk for residents and businesses an
improve the surrounding area.