

Yorkshire Water Services Limited  
**Lundwood WwTW Upgrade**  
Flood Risk Assessment

247877

Issue | 17 August 2016

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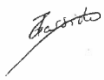
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## Executive summary

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As part of the feasibility study for proposed new development and refurbishment within Lundwood Wastewater Treatment Works (WwTW), Barnsley, South Yorkshire, Arup have been commissioned by Yorkshire Water Services to carry out a Flood Risk Assessment for the site, using the existing data available.

The planned expansion of the Lundwood WwTW site includes a pumping station, final settlement tanks, sludge thickening building, grit handling equipment, substations, sludge storage tanks, activated sludge process lanes and access roads. This comprises “less vulnerable” development, as defined in Table 2 of National Planning Practice Guidance, provided adequate measures to control pollution and manage sewage during flooding events are in place. Such development is potentially appropriate in Flood Zones 1, 2 and 3a.

It can be concluded as follows:

- the majority of the proposed development lies in Flood Zone 1 and is at very low risk of flooding. The majority of the proposals are on ground that is 2m above the 2007 flood, which is the highest flood on record by some margin;
- three Final Settlement Tanks are definitely within Flood Zone 2 or above, which means that they are at risk of inundation from a flood with an AEP of greater than 0.1%;
- hydrological and hydraulic modelling of this site undertaken by the Environment Agency is now 12 years out-of-date and should not be relied upon for design purposes;
- the available evidence suggests that the 2007 flood reached a level of approximately 36.5mAOD at this site. This flood was an order of magnitude more extreme than any previous recorded flood on the River Dearne at Lundwood since records began 61 years ago;
- when floods occur at this site, available evidence suggests that floodwater is slow-moving and the risks associated with erosion, scour or damage caused by fast-moving floating debris impact are therefore considered to be low.

It is recommended that:

- in the absence of a fully updated hydrological and hydraulic modelling study, the scheme designs should ensure that the Final Settlement Tanks, and all associated equipment and infrastructure, would be flood resilient to a level of **37mAOD** or above. This is based on the 2007 flood level with an additional precautionary allowance for climate change and uncertainty;
- the scheme designs should ensure that runoff from the 400m<sup>2</sup> of new impermeable surface proposed is attenuated to existing levels, taking account of a potential increase of 20% in peak rainfall intensities over the coming century;
- existing measures to control pollution and manage sewage during flooding events should be updated to reflect the changes proposed at the site;
- whilst provision of compensatory floodplain storage is not generally required for developments in Flood Zone 2, it is recommended that consideration be given to providing level-for-level compensatory storage, where it is reasonably practicable to do so within this site. This issue should be investigated and discussed with the Local Planning Authority and Environment Agency.

# 1 Introduction

As part of the feasibility study for proposed works at Lundwood Wastewater Treatment Works (WwTW), Barnsley, South Yorkshire, Arup has been commissioned by Yorkshire Water Services (YWS) Limited to carry out a Flood Risk Assessment for the site. The existing works is directly adjacent to the River Dearne and its floodplain and flood risk is therefore a key consideration for any proposals to develop and refurbish the site.

## 2 Scope

The scope of this study is to assess the following on the basis of the existing information available, primarily from the Environment Agency:

- the potential risks to the proposed development posed by flooding;
- the potential impact of the development on flood risks off site.

The report assesses the significance of the issues and recommends appropriate measures, where these are required to mitigate potentially adverse flood risk effects.

## 3 Site location and description

### 3.1 Location

The Lundwood WwTW site, property of YWS, is located on the north / left bank of the River Dearne, close to the residential area of Lundwood, east Barnsley (NGR SE 380 069) as shown in Figure 1 below.

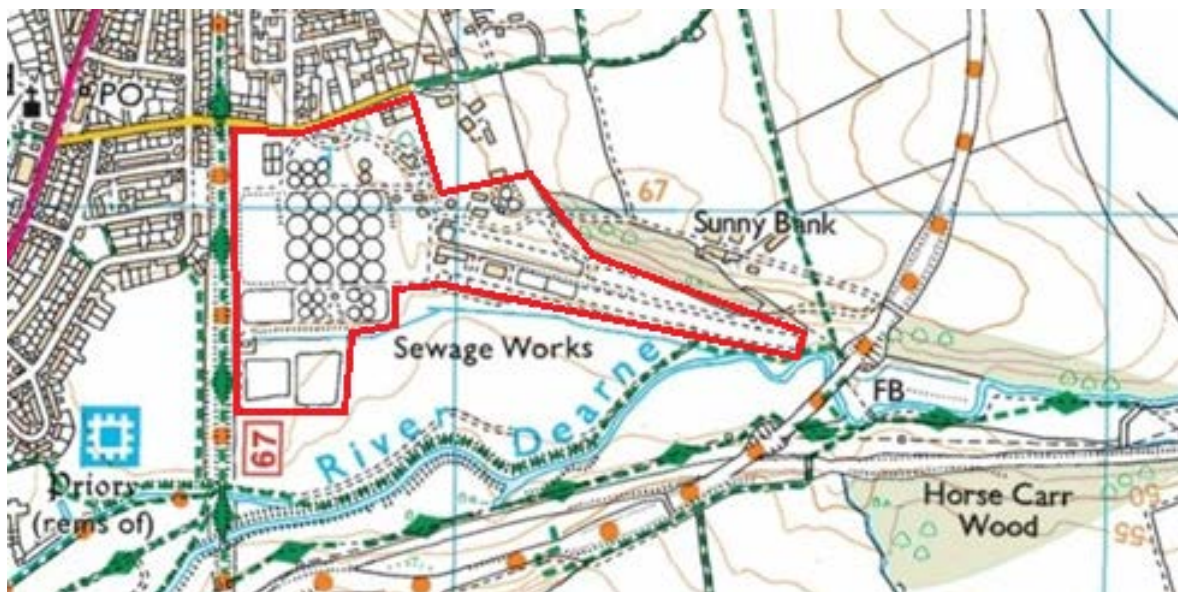


Figure 1 Lundwood WwTW as shown on Ordnance Survey Maps, Yorkshire Water site boundary indicated by red line. Yorkshire Water mapping is based upon Ordnance Survey Map data with the permission of the Controller Her Majesty's Stationary Office, © Crown Copyright. Licence No.100019559.

## 3.2 Description

The majority of the WwTW site, with the exception of the existing humus tanks, lies on high ground outside the natural floodplain boundary. Ground levels rise from south to north at an approximate gradient of 1 in 40, from approximately 35.5mAOD at the south edge of the site to 43.5mAOD in the north. The humus tanks are defended by an embankment (shown in yellow in Figure 2 below) along the site boundary. The crest level of this embankment varies between 36.5mAOD and 37.8 mAOD along the boundary of the works. A drain (shown in blue in Figure 2) runs along the southern perimeter of the works which collects water from a number of outfalls for surface water from the site. This drain discharges to the river via a large culvert at its downstream end.

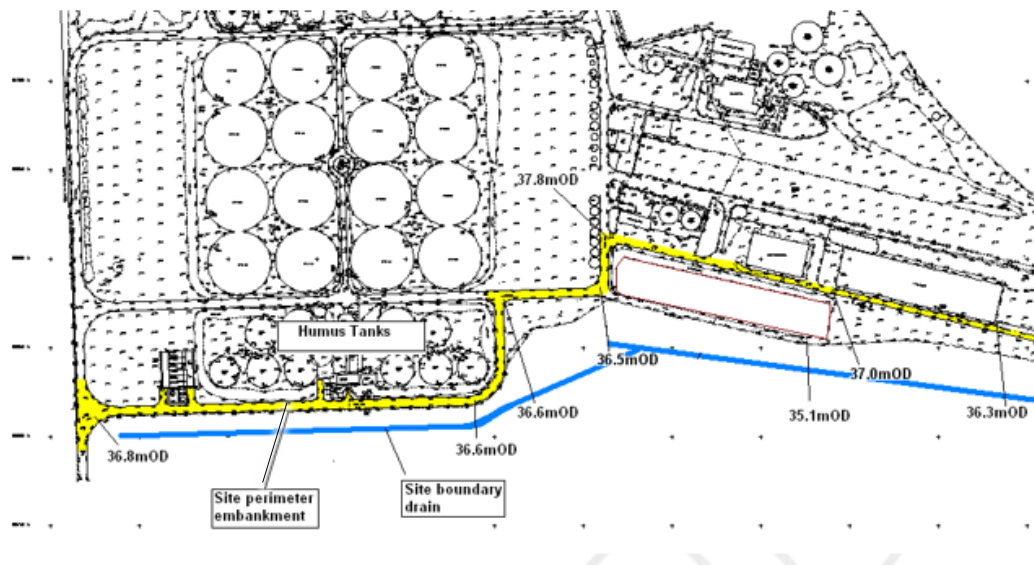


Figure 2 Site lay-out, based on detailed topographic survey of the site, showing the boundary embankment and drain.

## 4 Development proposals

The planned expansion of the Lundwood WwTW site, as shown in Figure 3, includes:

- a pumping station, final settlement tanks, sludge thickening building, grit handling equipment, substations, sludge storage tanks, activated sludge process lanes;
- access roads associated with the above.

The majority of these components will lie within the boundary of the existing site boundary embankment at ground levels above 38.5mAOD. The exceptions to this are the three Final Settlement Tanks. These will lie on land outside the protection of the boundary embankment, with an average level of 35.30mAOD (min level 35.07mAOD). These tanks, as water retaining structures, are water compatible, although strictly the proposals comprise “less vulnerable” development, as defined in Table 2 of National Planning Practice Guidance<sup>1</sup> (provided adequate measures to control pollution and manage sewage during flooding events are in place).

The locations of the individual components are to a great extent constrained by the existing layout of the WwTW, both in terms of the available space within the site, and because flows within the system are driven by gravity.

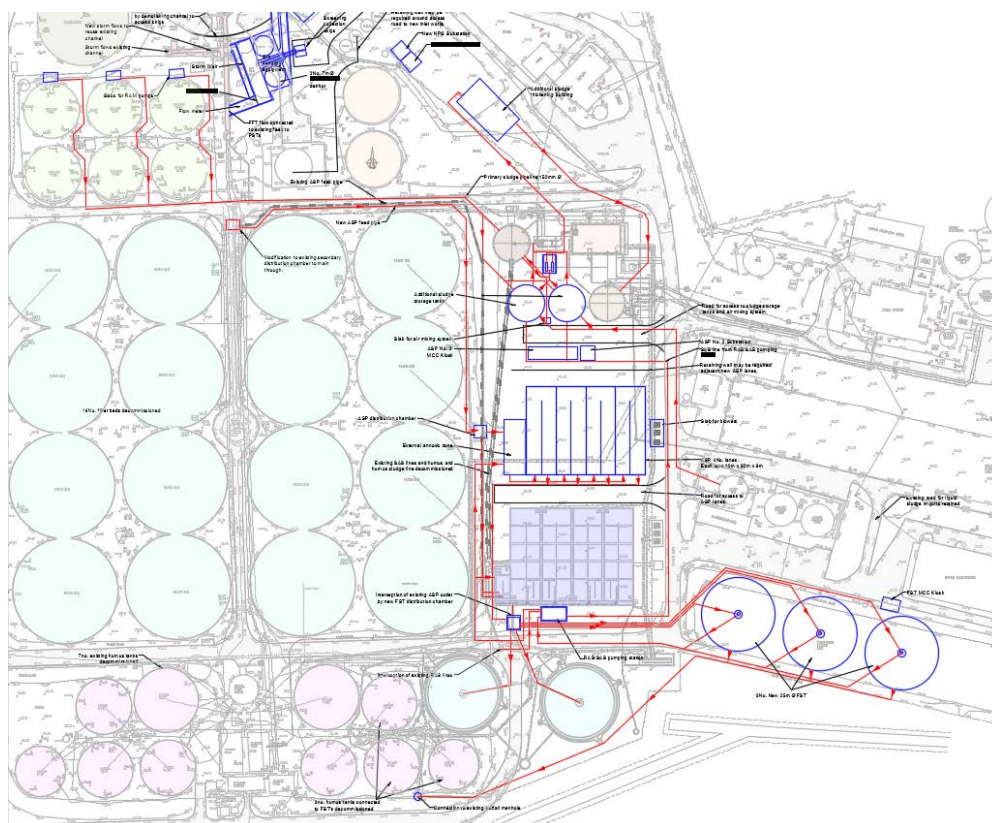


Figure 3 Site proposals (blue and red lines).

<sup>1</sup> <http://planningguidance.communities.gov.uk/blog/guidance/flood-risk-and-coastal-change/flood-zone-and-flood-risk-tables/table-2-flood-risk-vulnerability-classification/>

## 5 Flood risk assessment

## 5.1 Environment Agency Flood Maps

Reference to the Environment Agency's flood mapping information on their website indicates that surface water and reservoir inundation flood hazards are not present at this site. YWS has had no operational experience of groundwater flooding and whilst flooding has occurred in the past due to equipment failure, YWS has addressed the issues related to that risk. The key issue of potential concern is therefore flooding from the River Dearne.

The Environment Agency's Flood Map for Planning (Rivers and Sea) indicates that the Final Settlement Tanks are within Flood Zone 2, which has an annual probability of flooding of 0.1%. This is shown on Figure 4 below.

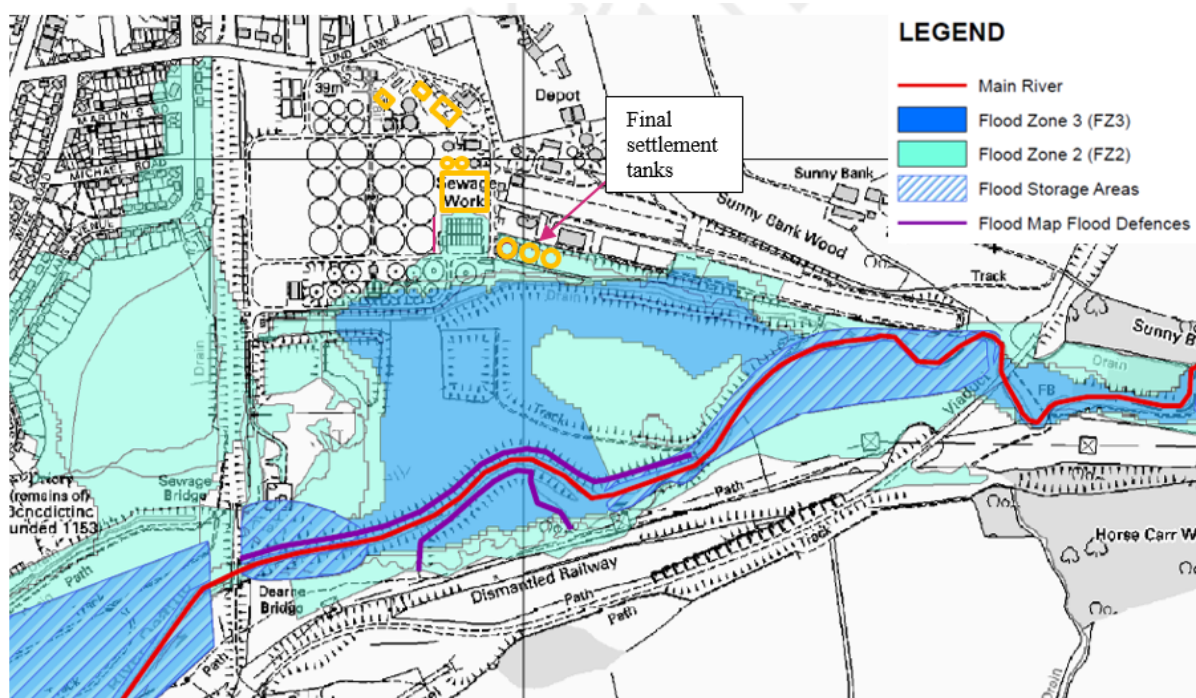


Figure 4 Site proposals superimposed (orange outlines) on mapping provided by the Environment Agency.

## 5.2 Historic flood records

Figure 5 below shows the flood extents of the following events (in order of increasing magnitude):

**March 1947:** the outline shows no significant incursion on the floodplain.

**Jan 2008:** the outline shows flooding did not enter the WwTW site.

**Autumn 2000:** the outline shows flooding generally confined by the site boundary embankment, except at the location of the proposed Final Settlement Tanks. Outline implies a level of 35.6 – 35.9mAOD.

**June 2007:** the outline shows flooding exceeding the site boundary embankment in the lower portion of the site, and at the location of the proposed Final Settlement Tanks. Comparing these mapped flood extents to detailed site topography indicates that there may be a localised error in this mapping. As this outline was drawn from aerial photography, it is possible that water in the AEP lanes, or surface water ponding in their vicinity gave a misleading impression. Ground levels at all other locations on this flood outline suggest that the peak flood level during this event was 36.3- 36.5mAOD.

With the exception of the Final Settlement Tanks, the proposals are sited on ground levels of 38.5mAOD and above – suggesting that they would be approximately **2m above the 2007 flood, which is the highest on record.**

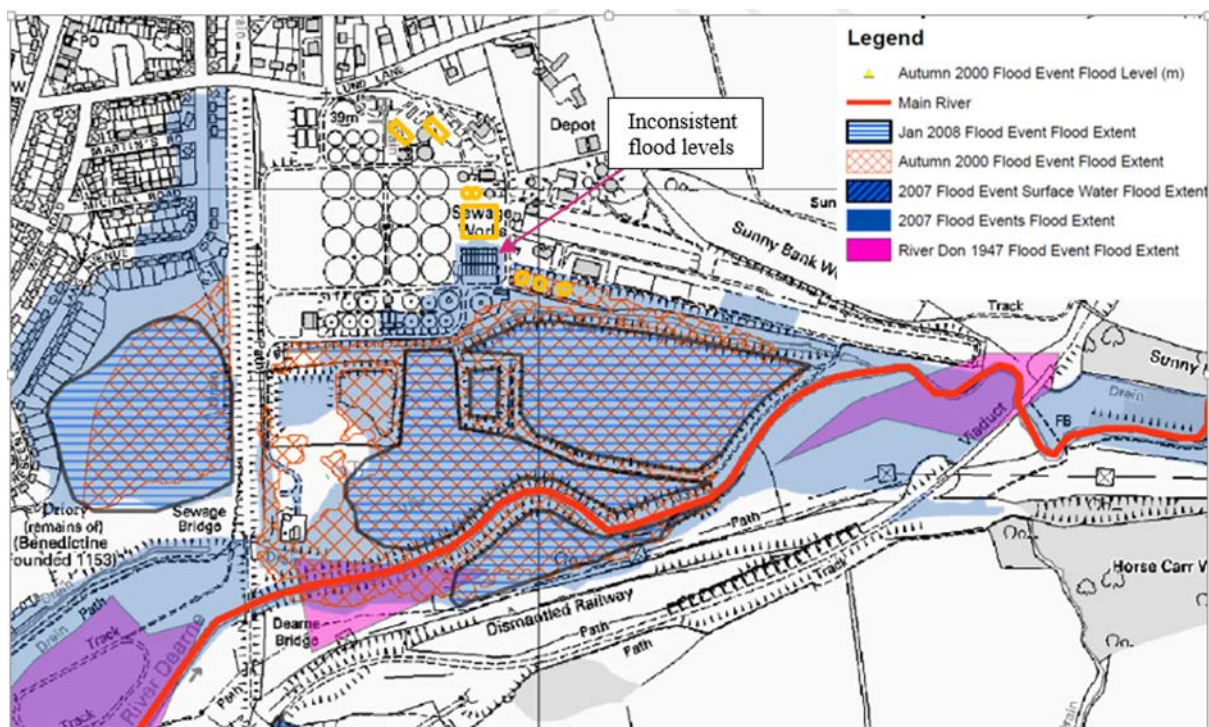


Figure 5 Historic flood mapping superimposed on the Flood Zone 2 outline (shaded blue).

A number of photographs of historic flooding were provided by YWS and are included in Appendix A. These photographs clearly show the area to be occupied by the Final Settlement Tanks is on lower ground that has flooded in the past. They also indicate that high velocity flood flows are not likely to be an issue at this site. It is likely that the water backs up from a point downstream on the River Dearne system. There are also very unlikely to be any issues associated with scour and fast-moving floating debris impact loading.

## 5.3 Modelled flood levels

Results of existing ISIS modelling of flood levels and flows at the site are presented in Table 1 (JBA, 2004). The corresponding locations of modelled cross sections are shown in Figure 6. The Final Settlement Tanks are north of cross section 4.

**Table 1:** Design water levels for varying annual exceedance probability (AEP) floods from the JBA 2004 ISIS model of the River Dearne, at cross sections 1-9 (numbering system provided by Arup for clarity in this report), plus undocumented “1 in 200yr” water levels provided by the Environment Agency

| Cross section ref (see) | Chainage | Grid Reference | Water Level (mAOD) at AEP (%) |              |               |              |              |              |
|-------------------------|----------|----------------|-------------------------------|--------------|---------------|--------------|--------------|--------------|
|                         |          |                | 0.5 (200yr)                   | 0.67 (150yr) | 1.00 (100 yr) | 1.33 (75 yr) | 2.00 (50 yr) | 4.00 (25 yr) |
| 1                       | 20067    | SE 37543 06382 | 35.59                         | 35.523       | 35.325        | 35.270       | 35.189       | 34.962       |
| 2                       | 19923 U  | SE 37637 06490 | 35.39                         | 35.322       | 35.125        | 35.069       | 34.989       | 34.761       |
| 3*                      | 19923 D  | SE 37654 06492 | 35.38                         | 35.316       | 35.120        | 35.064       | 34.984       | 34.758       |
| 4*                      | 19562    | SE 37967 06613 | 35.25                         | 35.180       | 34.978        | 34.921       | 34.840       | 34.607       |
| 5*                      | 19318    | SE 38194 06610 | 35.28                         | 35.179       | 34.972        | 34.913       | 34.828       | 34.586       |
| 6*                      | 19067    | SE 38378 06766 | 34.61                         | 34.548       | 34.351        | 34.296       | 34.217       | 33.996       |
| 7*                      | 18804 U  | SE 38582 06738 |                               | 34.128       | 33.923        | 33.866       | 33.784       | 33.553       |
| 8                       | 18709 U  | SE 38631 06691 |                               | 33.263       | 33.102        | 33.056       | 32.990       | 32.805       |
| 9                       | 18562    | SE 38774 06691 |                               | 32.667       | 32.501        | 32.453       | 32.384       | 32.189       |

\*cross sections bordering WwTW.

The flows at each model node are shown in Table 2 below. This indicates a 1% AEP flow of c. 60 m<sup>3</sup>/s.

**Table 2:** Design flows for varying return periods at cross sections 1-9

| Modelled reach | Chainage | Grid Reference | Flow (m <sup>3</sup> s <sup>-1</sup> ) at AEP (%) |      |      |      |      |
|----------------|----------|----------------|---------------------------------------------------|------|------|------|------|
|                |          |                | 0.67                                              | 1.00 | 1.33 | 2.00 | 4.00 |
| 1              | 20067    | SE 37543 06382 | 66.4                                              | 60.1 | 58.6 | 55.8 | 49.1 |
| 2              | 19923U   | SE 37637 06490 | 66.4                                              | 60.0 | 58.6 | 55.8 | 49.1 |
| 3*             | 19923D   | SE 37654 06492 | 66.4                                              | 60.0 | 58.6 | 55.8 | 49.1 |
| 4*             | 19562    | SE 37967 06613 | 34.4                                              | 32.9 | 32.1 | 31.1 | 29.8 |
| 5*             | 19318    | SE 38194 06610 | 36.5                                              | 36.4 | 36.4 | 36.3 | 36.2 |
| 6*             | 19067    | SE 38378 06766 | 66.1                                              | 59.6 | 57.8 | 55.4 | 48.7 |
| 7*             | 18804U   | SE 38582 06738 | 66.1                                              | 59.6 | 57.8 | 55.4 | 48.7 |
| 8              | 18709U   | SE 38631 06691 | 66.1                                              | 59.6 | 57.8 | 55.4 | 48.7 |
| 9              | 18562    | SE 38774 06691 | 66.1                                              | 59.6 | 57.8 | 55.4 | 48.7 |

\*cross sections bordering WwTW.

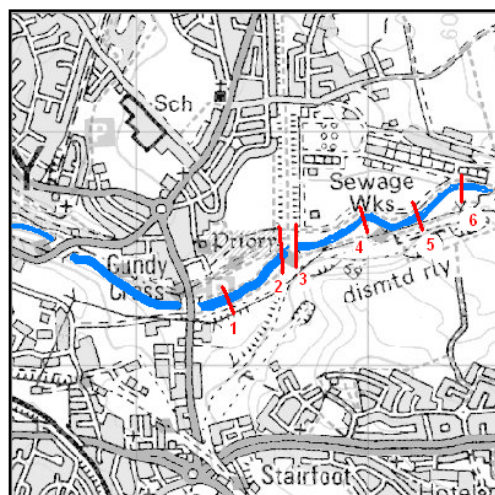


Figure 6 Indicative locations of modelled sections from JBA, 2004

The area of flooding indicated by this modelling falls slightly inside the boundary indicated by the EA Flood Zone Map. This modelling data indicates a 1% annual probability flood level of 35 mAOD. From extrapolation of the modelling outputs, the 1,000-year flood levels would be expected to be about 35.75mOD at the location of the Final Settlement Tanks. This information reinforces the fact that the tanks are in Flood Zone 2.

## 5.4 Climate change impacts on river flows

The Environment Agency's 2016 climate change guidance recommends that, for "less vulnerable" development in Flood Zone 2, the central allowance can be used. The allowance up to the 2070-2115 epoch in the Humber Basin is 20%. Application of this allowance to the modelled 1% AEP flood would increase the design water level by 0.39m to 35.369 mAOD, say **35.4mAOD**. This again only has implications for the Final Settlement Tanks.

## 5.5 Reality check

The modelling work above was undertaken in 2004 and would need to be updated if it was critical to derive an accurate estimate of the 1% AEP flood level. Information from a river flow gauge, on the Dearne @ Barnsley (27023), has therefore been considered as a check on the information provided by the Environment Agency. This gauge lies some 2km upstream of the WwTW. It has 61 years of record. The rating of this gauge is identified as being of high quality to a stage of 1.3m. Above that level the rating is based on extrapolation only, with extrapolation of the flow curve beyond that point and it is understood that some out of bank flows occur above a level of 2.15mAOD. It cannot therefore be considered fully reliable at high flows, but provides a useful overview of relative historic flood magnitudes.

The four largest events in the gauged record are:

|                              | Peak flow             | Stage (m)   |
|------------------------------|-----------------------|-------------|
| 25 <sup>th</sup> June 2007:  | 383m <sup>3</sup> /s  | 2.75m stage |
| 15 <sup>th</sup> June 2007:  | 205m <sup>3</sup> /s  | 2.33m stage |
| 13 <sup>th</sup> April 1970: | 64.2m <sup>3</sup> /s | 1.65m stage |
| 7 <sup>th</sup> July 2012:   | 62.3m <sup>3</sup> /s | 1.63m stage |

Note -15<sup>th</sup> June 2007 event was not an annual maxima (AMAX) event because of 25<sup>th</sup> June 2007.

The 2008 and 2000 floods were the 5<sup>th</sup> and 6<sup>th</sup> ranked annual maxima events in the gauge's history respectively. The 2007 flood was of significantly higher magnitude than any other event in the historic record. There are no data quality warnings noted in the gauged record against the estimated flow value for this flood, although whether it is to be fully believed is less certain. It is for instance noted that a flow of 383m<sup>3</sup>/s would be expected, based on JBA's analysis, to result in a far higher water level at the site, and there may therefore be scope for improvements to the river gauge rating. It is also likely that an updated hydrological study might provide a different flow-frequency curve to that derived by JBA.

However, it can however be concluded with some confidence, without additional modelling work, that all of the development proposals would be sufficiently safe from flooding should the 2007 flood re-occur, with the exception of the three Final Settlement Tanks. These tanks are almost certainly within Flood Zone 2 and, if not already, will likely be at risk from a 1% AEP flood at some point in the near future as a result of climate change.

## 6 Flood risk mitigation measures

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### 6.1 Design flood levels

Given the considerable uncertainty in the 2004 analysis, it is recommended that the 2007 flood level be used as the basis for the design of resilience measures, unless a fully updated hydrological and hydraulic modelling study were to be undertaken. The data available suggests that the 2007 flood reached a level of 36.5mAOD at this site. An allowance of 500mm is recommended for the potential impacts of climate change and uncertainty. Thus, the new infrastructure associated with the Final Settlement Tanks would need to be flood resilient to a level of 37mAOD on that basis.

### 6.2 Conveyance and storage

The Final Settlement Tanks are at the very edge of the floodplain. They are very unlikely to affect river conveyance such that upstream flood levels would be in any way affected on the River Dearne.

Given the modelling uncertainties outlined above, it is possible that the tanks could lie within the 1% AEP floodplain. If that were to prove the case, then they would displace floodwater, potentially increasing the peak flows downstream associated with such a flood. This impact would be mitigated by level-for-level re-profiling of adjacent ground levels, to provide an equivalent volume to that displaced by the tanks.

### 6.3 Site drainage

Flood risk is a significant issue downstream on the River Dearne. The proposed tanks and aeration lanes will not increase loading on the existing surface water drainage systems as they are open to the elements. Any rain falling on them will therefore be routed through, and attenuated by, the sewerage network.

There are some small areas of additional impermeable surface due to further components; these comprise a maximum additional impermeable surface of 400m<sup>2</sup>. These are distributed around the site. The proposed works will need to ensure that runoff from these areas is attenuated to existing levels, taking account of a potential increase of 20% in peak rainfall intensities over the coming century.

## 7 Conclusions and recommendations

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It can be concluded as follows:

- the majority of the proposed development lies in Flood Zone 1 and is at very low risk of flooding. The majority of the proposals are on ground that is 2m above the 2007 flood, which is the highest flood on record by some margin;
- three Final Settlement Tanks are definitely within Flood Zone 2 or above, which means that they are at risk of inundation from a flood with an AEP of greater than 0.1%;
- hydrological and hydraulic modelling of this site undertaken by the Environment Agency is now 12 years out-of-date and should not be relied upon for design purposes;
- the available evidence suggests that the 2007 flood reached a level of approximately 36.5mAOD at this site. This flood was an order of magnitude more extreme than any previous recorded flood on the River Dearne at Lundwood since records began 61 years ago;
- when floods occur at this site, available evidence suggests that floodwater is slow-moving and the risks associated with erosion, scour or damage caused by fast-moving floating debris impact are therefore considered to be low.

It is recommended that:

- in the absence of a fully updated hydrological and hydraulic modelling study, the scheme designs should ensure that the Final Settlement Tanks, and all associated equipment and infrastructure, would be flood resilient to a level of **37mAOD** or above. This is based on the 2007 flood level with an additional precautionary allowance for climate change and uncertainty;
- the scheme designs should ensure that runoff from the 400m<sup>2</sup> of new impermeable surface proposed is attenuated to existing levels, taking account of a potential increase of 20% in peak rainfall intensities over the coming century;
- existing measures to control pollution and manage sewage during flooding events should be updated to reflect the changes proposed at the site;
- whilst provision of compensatory floodplain storage is not generally required for developments in Flood Zone 2, it is recommended that consideration be given to providing level-for-level compensatory storage, where it is reasonably practicable to do so within this site. This issue should be investigated and discussed with the Local Planning Authority and Environment Agency.

## Appendix A

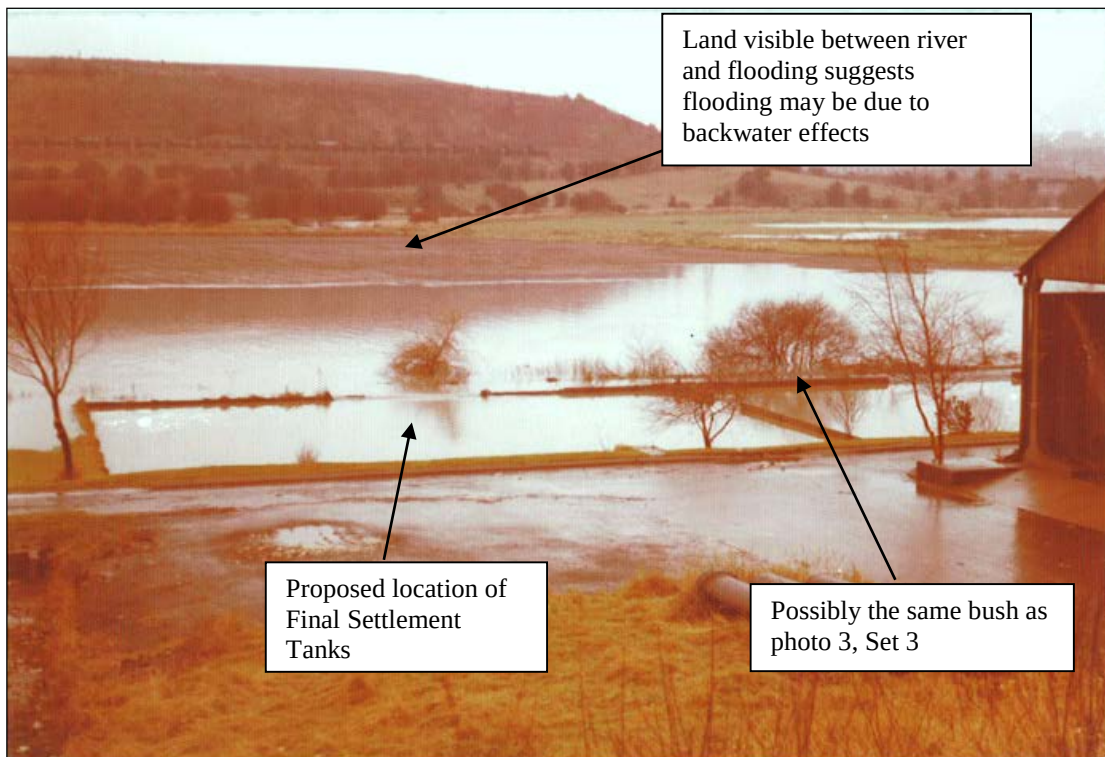
### Historic flooding photographs

A number of photographs were obtained from Yorkshire Water relating to the site. There are three notable sets of photographs.

**Set 1)** Relates to flooding caused by a failure of the site's equipment and has not been reproduced here.

**Set 2)** Shows a flooding event on the 29<sup>th</sup> December 1978, as indicated by writing on the back of the photograph. This event shows the proposed site of the Final Settlement Tanks to be flooded after water levels rose higher than the river side track. The implied level appears to be 35.25-35.4mOD, compared with survey of the local ground levels. Land is visible between the flooded area and the river, suggesting that flooding was probably due to backwater effects rather than flow direct from the river reach running parallel to the site.

Referring to the Peaks over Threshold (POT) Record at the Barnsley Weir gauge upstream, there was no event on this date. There was an event on 29<sup>th</sup> December 1979, but this event ranks 225 out of 283 POT events, so in theory it should not have been significant.



**Set 3)** shows flooding from the November 1970 event.

**Photo 1:** Has “Flood at its height” written on back (interpreted as meaning flood peak). Shows a gauge board level of 117.5ft at the old “Low Level Pumping Station” (since dismantled). Unfortunately, no drawings are available to relate this level back to the current survey. By a crude estimate from a drawing of levels at the pumping station, the floor level of the pumping station appears to have been 121.0ft. If this is roughly equivalent to road level at this location (36.72mAOD), the peak flooding level would have been 35.65mAOD.

Another photo from this sequence shows water levels 1.5 ft lower on the board.

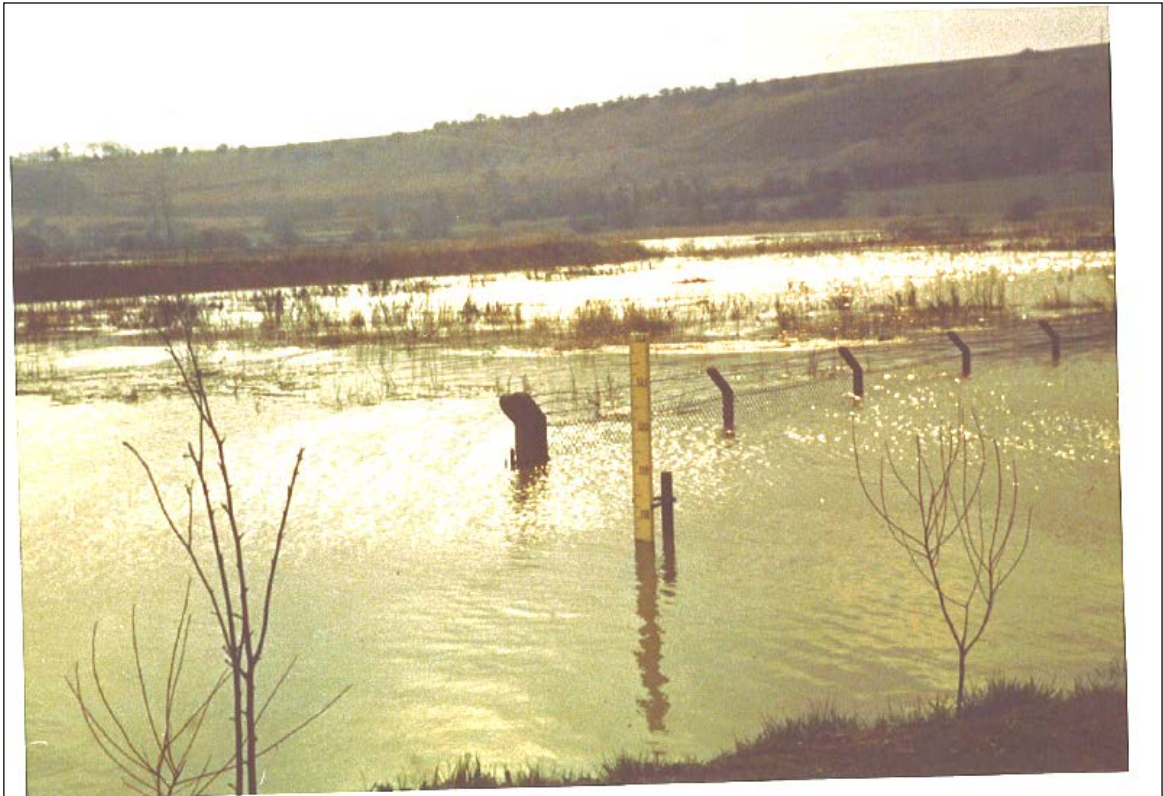


**Photo 2:** This shows flooding along the road downstream of the proposed Final Settlement Tank site. While this may not have been taken at the peak of the flood (and it is apparent from other photos in this sequence that levels may have varied by 1.5ft), it can be seen from the water levels in the beds that water did not overtop the road. The water level at this point in time is estimated at 36.10mAOD in this location.



**Photo 3:** Shows roughly the same view as the photograph in Set 2. Note however that the sludge beds are lost to view and the river side track is completely covered. Only the top of the bush shown in Set 2 can be seen. Note however that Set 2 was taken 8 years later, so the bush may have grown somewhat in the meantime. This photograph seems to suggest a level of approximately 36.5mOD, but it is hard to be certain without a defined point to compare to. Whereas the land between the river and the plant was visible in the Set 2 photograph, now only the tops of lagoon boundaries can be seen.

