



FLOOD RISK AND DRAINAGE ASSESSMENT

Cleator Mill,
Proposed Residential Development,
Flood Risk Assessment.

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CONFIDENTIALITY STATEMENT

This report is addressed to and may be relied upon by the following:

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DOCUMENT HISTORY

VERSION	PURPOSE/DESCRIPTION	DATE
1	Draft Issue - for client comment	04.11.2020
2	Amended following Environment Agency comments	12.07.2021

1.0 EXECUTIVE SUMMARY

This assessment has looked at the implications of the proposed Residential developments in relation to flood risk, including overtopping and breach analysis agreed with the Environment Agency during meetings in June 2019.

The proposed development site is shown as being in Flood Zone 3a on the Environment Agency flood maps. When reviewing the defended flood modelling undertaken by the Environment Agency the site is afforded protection for all events up to and including the 1:200 year return period.

The flow rates and water levels for varying events have been considered including the upper central and higher and flow rates are comparable to the 1:1000 year return period, giving a clear indication of potential water levels on the site when looking at the modelled results.

It is proposed to raise FFL's above the 1:1000 year flood levels, as these flood levels are comparable with the 1:100 year plus 70% climate change levels based upon flow rates. FFL's will be raised 600mm above the 1:1000 year flood level for each associated parcel of land. By raising the ground levels and FFL's, will afford the proposed development protection against flood waters regardless of the flood defence condition and performance.

The Environment Agency surface water flood maps have been reviewed against the topography with flows shown coming over the site in a low-risk event. When reviewing the contours and local topography we believe that surface water flows would follow the road, given the kerb phase and raised levels to the site on the boundary as opposed to run straight across the site. As such surface water overland flow can be managed with the route maintained around the perimeter of the development site.

Safe access and egress have been established via the new proposed access road onto the A5086. The overland flood flow routes do not impede the proposed access/egress for the development's new entrance.

The Environment Agency does not provide a Flood Warning Service for Cleator. It is noted that the site is covered by the River Ehen, Calder, Irt and Esk Flood Alert areas, it would therefore be recommended this be included within the homeowner's packs.

A Surface Water Management Plan (SWMP) has been identified including the levels of treatment required to ensure the River Ehen water quality remains protected.

Any potential impact of the development can be adequately addressed by good drainage design.

2.0 INTRODUCTION

RWO Associates Ltd (RWO) has been instructed by Gleeson Regeneration client to prepare a Flood Risk Assessment to support a planning application for a proposed residential development at Cleator in Cumbria.

This site is covered by a Strategic Flood Risk Assessment (by Jacobs dated 2007 and published on the local authority website [Strategic Flood Risk Assessment | Copeland Borough Council](#)) commissioned by Copeland Borough Council. This, more detailed, site-specific Flood Risk Assessment supplements the findings of the Strategic Flood Risk Assessment. It is also covered by the more recent Draft Copeland Borough Council, Level 1 SFRA. For clarity and reference purposes this report has utilised the latest Draft SFRA dated 2018 to ensure the latest SFRA maps are utilised

Envireau Water has been utilised to undertake a Breach Analysis of the existing flood defences located on the North and Eastern boundaries, with the locations agreed with the Environment Agency during a meeting in June 2019. The proposed development site has previously been granted outline planning permission for residential use, with RWO Associates Flood Risk assessment reference RO/FRA/RES/13000.3 utilised as a part of the previous planning application.

The site is currently Greenfield in nature and the client wishes to create residential development; location plans are included in Appendix A.

3.0 THE SITE

The proposed development site is located to the east of Cleator, about 300m to the south of Cleator Moor and immediately to the west of the Lake District National Park; Figure 1 below shows the site location.



Figure 1 – Site Location (Redline indicates approximate extents)

The River Ehen forms the eastern and southern boundary, with residential dwellings located to the west and north. To the immediate south of the proposed development site is the former Kangol hat factory, with the building varying in age between the early 19th Century and the 1960s. The original building was a linen mill in the 19th Century. The eastern portion of the site has a derelict factory located on it, currently owned by Gates. The A5086 is on the north-western boundary of the proposed development site.

4.0 PROPOSED DEVELOPMENT

It is proposed to consider the site for residential development, with circa 115 dwellings to be constructed. Based upon the Copeland Strategic Flood Risk Assessment the development site is located in Flood Zone 3a, an extract of the map can be seen below in Figure 2 (area identified as E8) with the full map included in Appendix B.

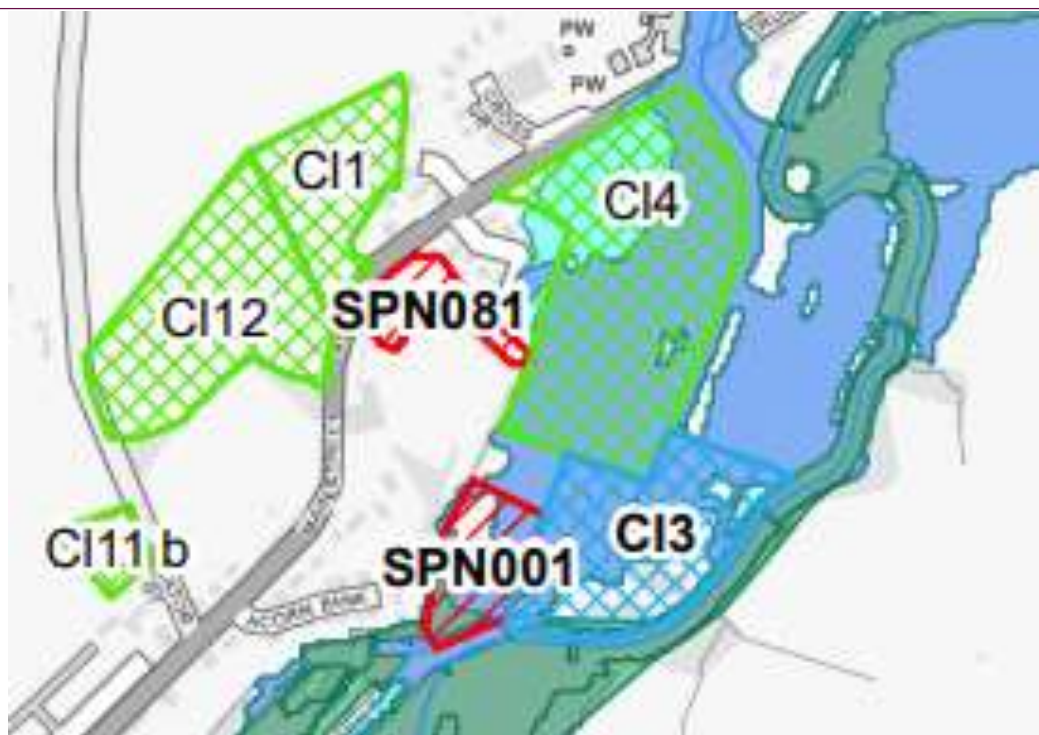


Figure 2 – Draft Copeland SFRA 2018 Extract

As the development site is shown as being located in Flood Zone 3a with an annual probability of flooding of greater than 1:100 years (>1%), it will therefore be subject to the sequential and exception test in accordance with NPPF Technical Guidance.

A site layout is included in Appendix C.

5.0 FLOOD RISK

River Ehen

The site is located adjacent to the River Ehen, to the west, within flood zone 3a as identified by the Copeland Strategic Flood Risk Assessment, map included in Appendix B. Modelled flood levels have been reviewed based upon the Environment Agency hydraulic modelling with further breach analysis undertaken by Envireau Water on behalf of the developer. Envireau Water has utilised the Environment Agency model from 2016, further details noted within the Envireau Water report included in Appendix F. The Environment Agency modelled flood levels are included below in Table 1.

Table 1 – Modelled Flood Levels (defended)

A detailed map of the Cleator Moor area, showing various landmarks such as Cleator Moor, Wath Brow, Wath Grove, Ramsgill Wood, Blackhow Wood, Bragg Wood, and Woodend. The map includes roads like A72, A77, and A84, and features like the River Ehen, Cleator Brook, and several mines (dis). Sampling locations are marked with yellow labels and connected by lines to specific points on the map. The labels include EA01104EHEN04_1726u, EA01104EHEN04_1896, EA01104EHEN04_1896d, EA01104EHEN04_1606u, EA01104EHEN04_1206d, EA01104EHEN04_1206u, EA01104EHEN04_1726d, EA01104EHEN04_1806u, EA01104EHEN04_1606d, EA01104EHEN04_1502, EA01104EHEN04_1406d, EA01104EHEN04_1406u, EA01104EHEN04_1299u, and EA01104EHEN04_1206u.

Figure 3 – Modelled Node Locations

Cleator Mill 5

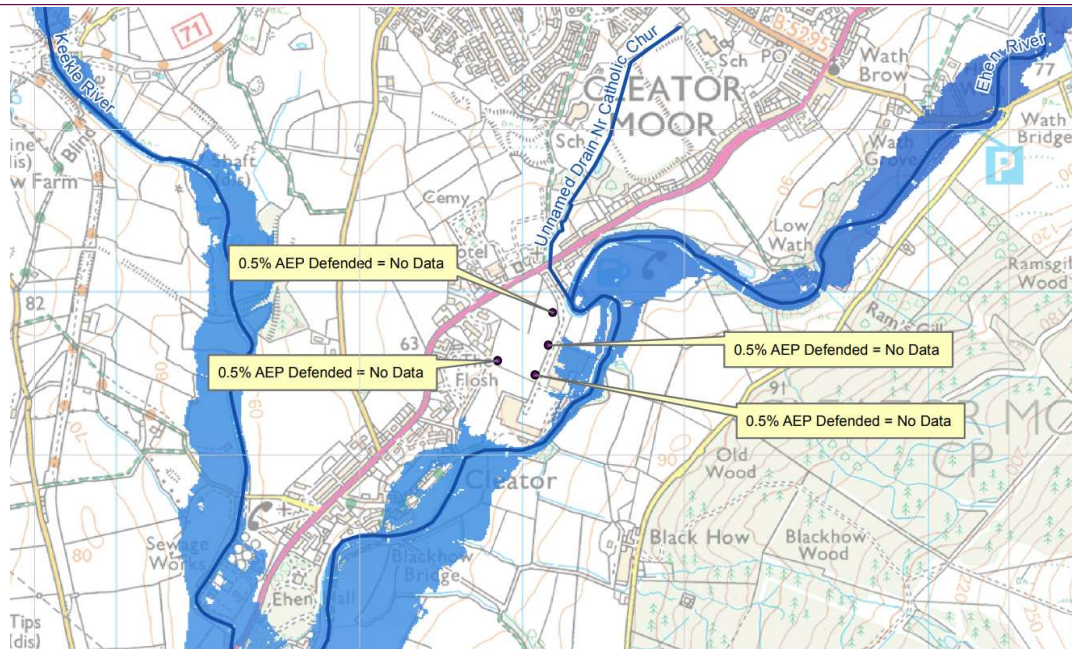


Figure 4 – Extract of Product 4 1:200 Year return period flooding. Defended Scenario

The above extract demonstrates that the site does not flood in the defended scenario when considering the 1 in 200 year turn period from the Environment Agencies modelled flood data. A full suite of Product 4 flood maps is included in Appendix H.

Flood water is shown as breaching the site on the 1 in the 1000 year return period, in the defended scenario impacting approximately 50% of the site as can be seen in the below extract;

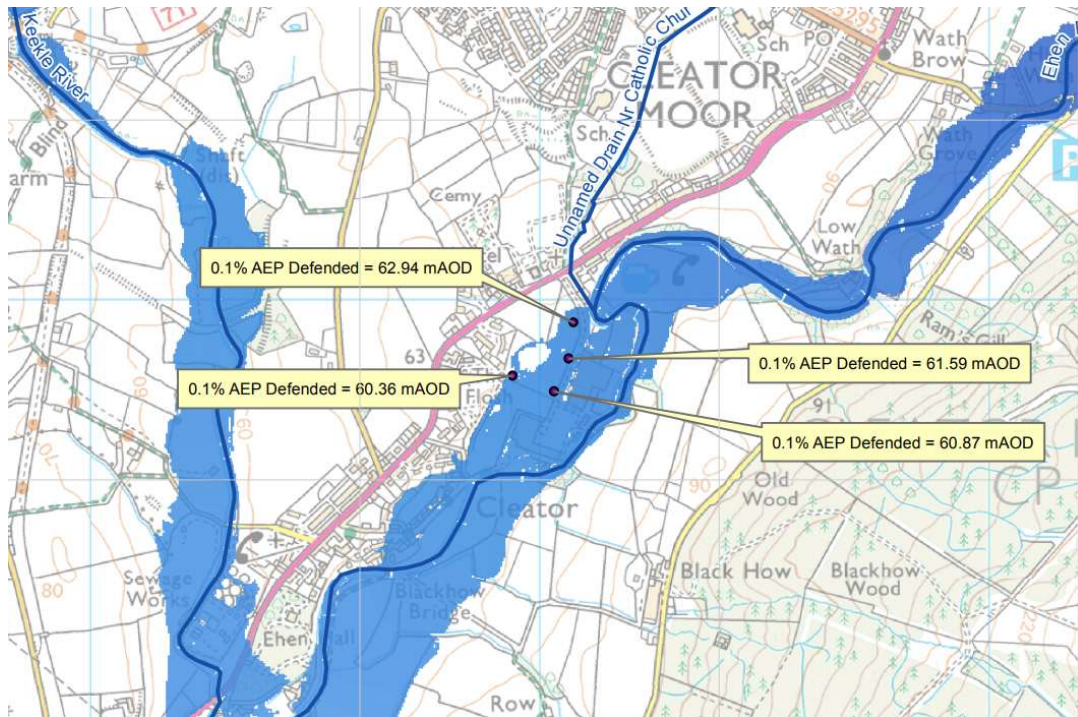


Figure 5 – Extract of Product 4 1:1000 Year return period flooding. Defended Scenario

Based upon the defended scenario the site is located in Flood Zone 2.

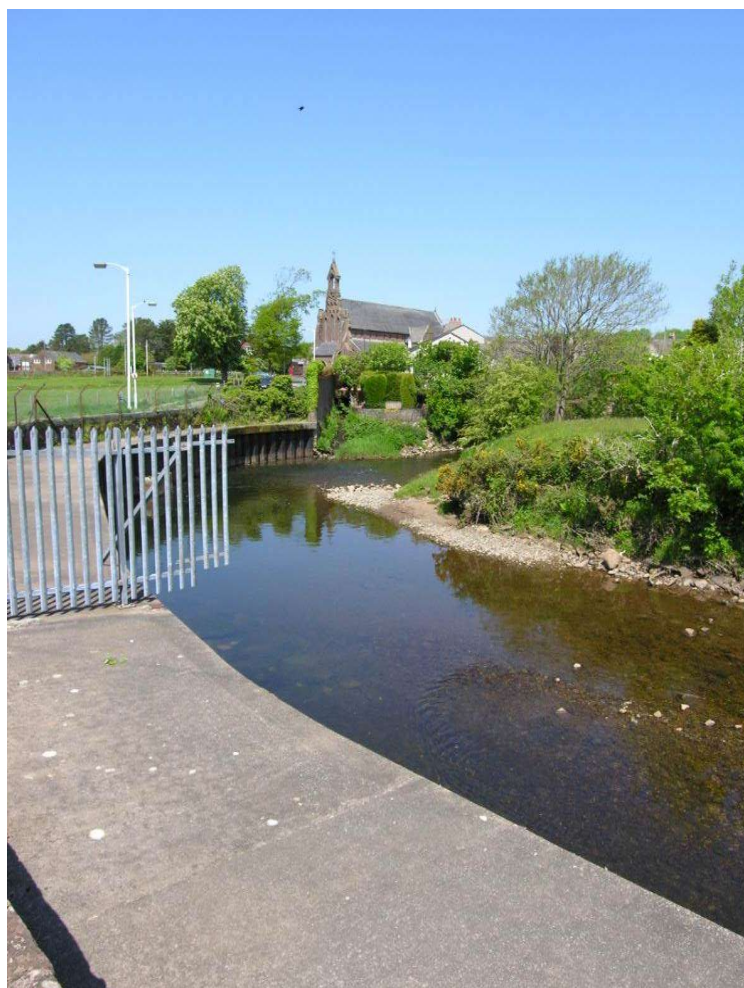


Photo 1 – Hard flood defences between 1896 & 1726

Downstream of the hard defences, soft earth defences exist continuing north to the extents of the Kangol Factory/premises. As states above these afford the site a level of protection to the 1:200 year modelled return period. The location of the modelled reference points has been cross-referenced against a topographical survey undertaken by Site; this is included in Appendix D; this includes sections showing the flood levels against the existing ground levels. The flood levels against the existing ground profiles along the site demonstrate the site is afforded protection up to and including the 1 in 200 years modelled flood level.

To assess the flood risk associated with the proposed development site climate change needs assessing under the Environment Agency guidance for higher central and upper-end allowances as per Table 1: peak river flow allowances by river basin district.

River Ehen – Climate Change Impact

As per the Environment Agency request, the higher central and upper-end allowances for the North West river basin district has been considered. As there is not an Environment Agency model for these climate change uplifts this has been calculated utilising the available data from the Environment Agency data and then compared for sensitivity based upon the peak flow rate increase against the 100 year return period event and comparing the calculated water level.

Node Reference	Water Level	Flow	Water Level	Flow	Flow	Water Level
	100yr	100yr	100yr + 20%CC	100yr + 20%CC	1% increase	1% increase
1896	63.972	96.513	64.029	101.484	0.24855	0.00285
1726	62.472	127.207	62.692	143.88	0.83365	0.011
1806	63.621	91.358	63.823	93.242	0.0942	0.0101
1606	61.427	126.737	61.666	145.965	0.9614	0.01195
1502	60.808	129.137	61.001	151.25	1.10565	0.00965
1406	60.451	128.097	60.559	149.927	1.0915	0.0054
Values taken from Environment Agency Model						

Table 2 – Climate Change increase of water level and flow for each 1% from 100yr to 100yr + 20% CC

Table 2 above shows the increase for each 1% uplift of climate change from the 100 year return period to the 100 year plus 20% climate change, the 1% uplift has been applied to the higher central and upper-end values as identified in Table 1: peak river flow allowances by river basin district.

	Higher central	15%	20%	25%
	Central	10%	15%	20%
North west	H++	25%	45%	95%
	Upper end	20%	35%	70%

Extract 1 – Table 1: peak river flow allowances by river basin district

	Water Level	Flow	Water Level	Flow	Water Level	Flow	Water Level	Flow	Flow	Water Level	Flow	Water level Increase
	100yr	100yr	100yr + 20%CC	100yr + 20%CC	100yr + 25%CC	100yr + 25%CC	100yr + 70%CC	100yr + 70%CC	100yr	100yr	1000yr vs 100 yr + 70% CC	1000yr vs 100 yr + 70% CC
1896	63.972	96.513	64.029	101.484	64.04325	102.72675	64.1715	113.9115	147.259	64.939	33.3475	-0.7675
1726	62.472	127.207	62.692	143.88	62.747	148.04825	63.242	185.5625	173.534	63.685	-12.0285	-0.443
1806	63.621	91.358	63.823	93.242	63.8735	93.713	64.328	97.952	100.247	64.135	2.295	0.193
1606	61.427	126.737	61.666	145.965	61.72575	150.772	62.2635	194.035	165.107	62.193	-28.928	0.0705
1502	60.808	129.137	61.001	151.25	61.04925	156.77825	61.4835	206.5325	198.323	61.398	-8.2095	0.0855
1406	60.451	128.097	60.559	149.927	60.586	155.3845	60.829	204.502	202.596	61.039	-1.906	-0.21
Values taken from Environment Agency Model												

Table 3 – Climate Change increase of 25% and 70% as per higher central and upper-end values in Extract 1 above.

Table 3 above gives the increased flow rate for the climate change variations requested, the calculated increase in water depth and a comparison between the modelled Environment Agency 1000-year return period and the calculated 100-year plus 70% climate change. It is worth noting that the calculated water level for the 100-year plus 70% Climate Change is a linear arrangement and assumes the channel profile remains as the water level for the 100-year modelled return period, on this basis, the approach is conservative as the channel, in reality, widens when looking at the surrounding topography.

	Water Level	Flow	Flow	Water Level	Flow	Water level Increase
	100yr + 70%CC	100yr + 70%CC	1000yr	1000yr	1000yr vs 100 yr + 70% CC	1000yr vs 100 yr + 70% CC
1896	64.1715	113.9115	147.259	64.939	33.3475	-0.7675
1726	63.242	185.5625	173.534	63.685	-12.0285	-0.443
1806	64.328	97.952	100.247	64.135	2.295	0.193
1606	62.2635	194.035	165.107	62.193	-28.928	0.0705
1502	61.4835	206.5325	198.323	61.398	-8.2095	0.0855
1406	60.829	204.502	202.596	61.039	-1.906	-0.21
Values taken from Environment Agency Model						

Extract 2 – Extract of Table 2, showing the calculated 100-year +70% CC vs the 1000-year Environment Agency modelled flood data

When reviewing extract 2 above there are two node anomalies in 1896 & 1726, these nodes relate to locations against the hard flood defences as shown in Photo 1, therefore will not have a linear increase in the rate of discharge as flows are going through an S-bend arrangement as well as being against the hard defences on the southern side of the watercourse. The other nodes show a tangible arrangement between flow rate and predicted depth of water for the 100yr + 70% climate change event for example node 1806 has a 100yr + 70% climate change flow rate of 97.952, with the 1000 year being 100.247 with the predicted 100yr + 70% climate change given an increased water depth of 0.193m over the modelled result. As previously noted this is anticipated given that extrapolating the data out to predict the flow depths for various events does not take into account the change in channel profile however, this is the most accurate way of undertaking this work without fully modelling each reach and the above comparison gives confidence in the answer when comparing flow rate and depths. As such broadly speaking the 100yr + 70% climate change events results align with the 1000 year modelled results, although in some locations the predicted gives a slight increase in water depth.

It is recommended that the 1000yr modelled flood levels be utilised given the close comparison in flow rate between the 100yr + 70% climate change flow rates and the modelled 1000yr flow rates. For summary purposes

Flood History

The fact flood defences have been formed along the boundary with the River Ehen suggest a historic flooding problem. It is understood the flood defences in their current form were constructed in 1978 by English Industrial Estates.

It is noted that the Copeland SFRA states there was some flooding from the River Ehen that caused damage to the factory in the autumn of 2000. A previously prepared FRA noted that the site warden had been interviewed and could not recall any flooding in his 15 years, this was in March 2010. As such if any flooding did occur or to what extent it is unknown. It was noted during our site walkover that outfalls to the River Ehen did not have tidal flaps/non-return valves installed and as such, it may have been possible for waters to back up the onsite drainage system causing localised flooding.

Having reviewed available data and previously prepared reports it is understood during the extensive flooding in Cumbria during 2008 & 2009 this site was not affected.

Flood Defence Overtopping

Flood defences are affording the site protection from the risk of flooding, as identified in Appendix D. The hard flood defences are substantial and appear to be in an operational condition which is supported by the Environment Agencies grade 3 'fair', on the Environment Agencies asset condition criteria. The soft defences and the riverbank do not appear to be adequately maintained to the required standard to ensure effective operation; the Environment Agency have graded these 4 'poor'.

A previous report assessing the condition of the embankment was commissioned by Hampton Investment Properties Ltd and undertaken by Dr John Chatterton, this is included in Appendix E, for reference purposes only.

It is the responsibility of the Environment Agency to ensure flood defences are maintained under their statutory powers. As highlighted by the Environment Agency the flood defences are not within the developer's control and for this reason, all proposed FFL's will be raised above the required flood level so that the quality of the flood defences does not need to be taken into consideration.

As the site is protected to the 1:200 year return period, this risk could be reduced by raising ground levels within the proposed development site. No flood storage compensation is required as there is not a loss of storage given the site is afforded protection for all events up to and including the 1:200 year return period as demonstrated by the Environment Agencies own modelling.

Flood Defence Breaching

A detailed breach analysis has been prepared by Envireau Water, with the breach locations agreed in the meeting with the Environment Agency on the 20th June 2019, in their Penrith offices. The two agreed two locations were set as per the original locations agreed with Mott MacDonald who undertook the modelling in October 2013 for the previous application which was approved. In addition to the location, the required storm event was also agreed with the Environment Agency before progressing with the site-specific breach modelling, undertaken by Envireau Water.

based upon the requirements of the Environment Agency have been undertaken. The purpose of the breach analysis was to determine flood extents, depths, velocities and hazard ratings for the site for the 1:100-year return period with climate change as required under NPPF Technical Guidance. Figure 4 below shows the two breach locations which have been utilised and previously agreed with the Environment Agency.



A breach in the gabion baskets north of the site has been considered for the 1:100 year plus climate change return period. The approximate location of the breach event is indicated in Figure 4. During the breach, floodwaters reach the site at the 1.5-hour mark, with the existing Kangol factory being flooded first and then flows head to the west reaching the proposed residential development site.

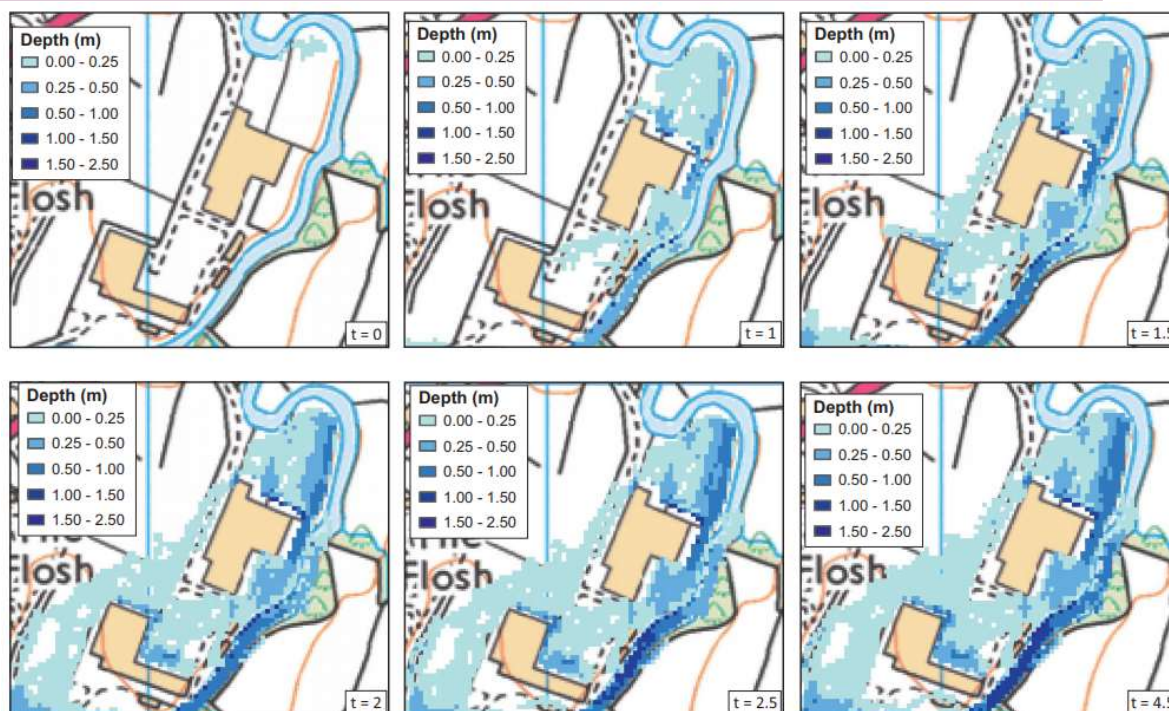


Figure 5 – Extract from Envireau Water of Breach 1

Breach 2

A breach in the earth embankment to the east of the site has been considered for the 1:100 year plus climate change return period. The approximate location of the breach event is indicated in Figure 4. During this breach event, the only building impacted upon is the Kangol Factory which does not form part of this application. As such the risk of the site flooding from a breach at this location is deemed low.

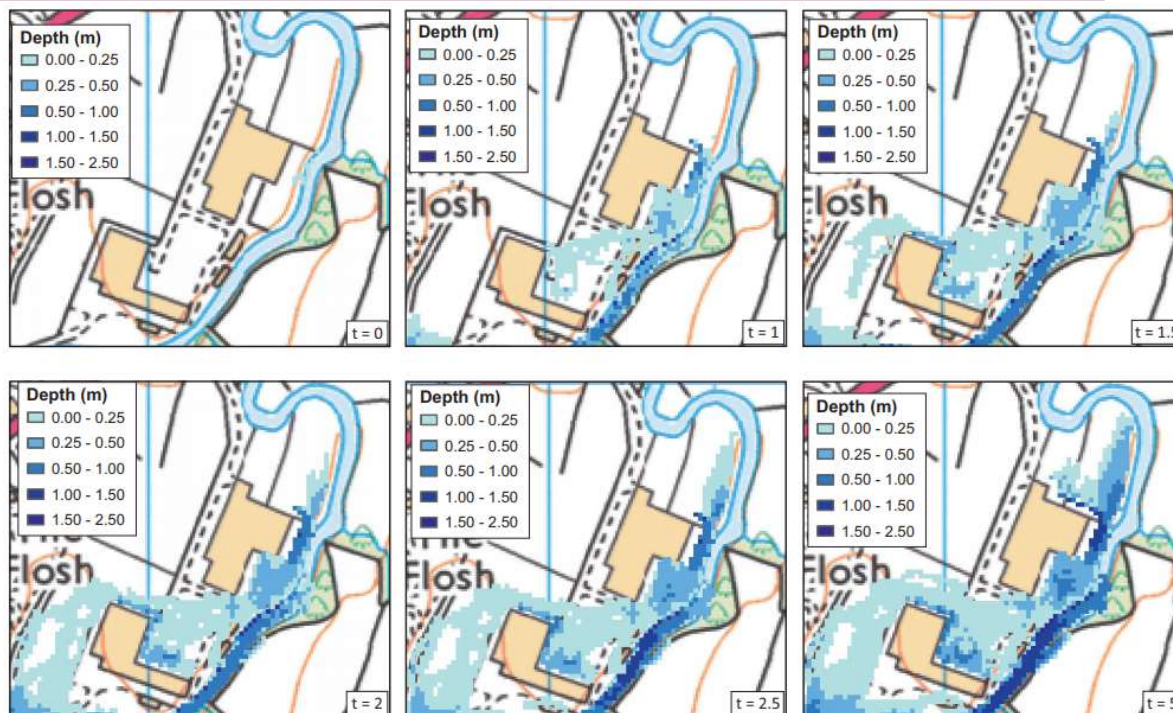


Figure 6 – Extract from Envireau Water of Breach 2

The Envireau Water report 'Updated Flood Risk Modelling – Cleator Mills Site' is included in Appendix F.

Surface Water Flooding

The surface water flood map available on the Environment Agency website [see Figure 7] indicated that part of the site is at risk of flooding due to surface water. The proposed residential development is at low risk of flows being conveyed across the site as identified by the Environment Agencies own flood maps.

Flood risk

Low risk: depth

Location

Enter a place or postcode

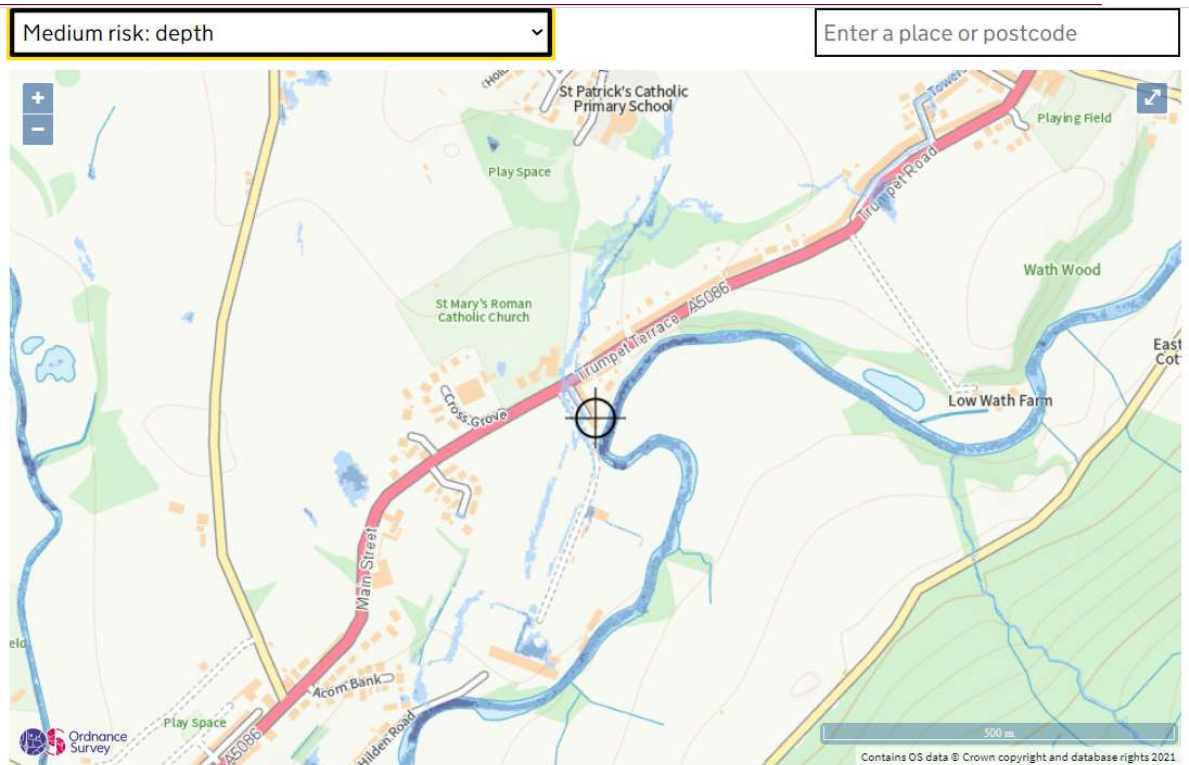


Extract 3 – Environment Agency Low-Risk Surface Water flood maps (17.07.2021)

The flow route itself is somewhat questionable given the topography given the kerb face along the road is circa 100mm and the route of flows appears to follow a raised mound as can be seen in picture 2 below;

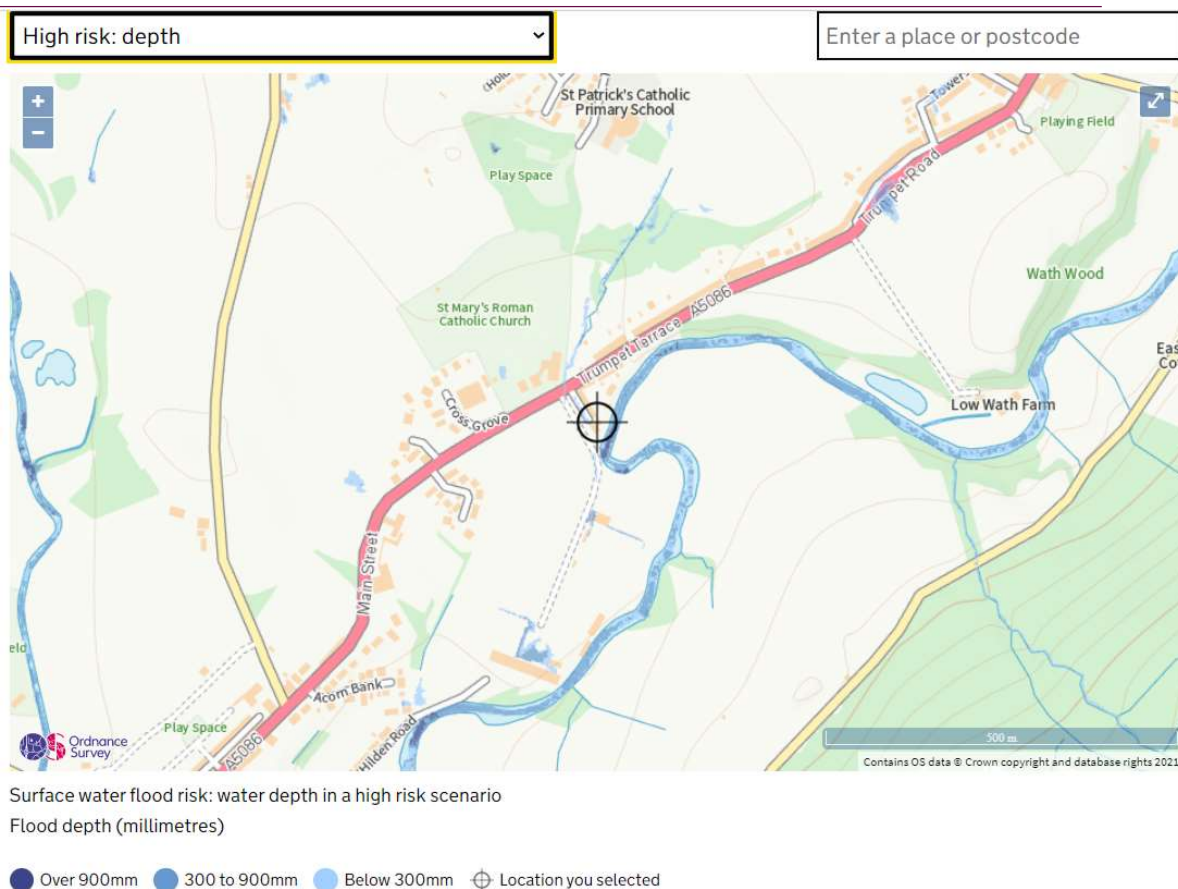


Photo 2 – Raised mound and kerbs along overland flood route



Extract 4 – Environment Agency Medium-Risk Surface Water flood maps (17.07.2021)

The Environment Agency medium flood risk maps demonstrate that no flows are being conveyed over the site and that water appears to be ponding in localised areas.



Extract 5 – Environment Agency High-Risk Surface Water flood maps (17.07.2021)

Extract 5 above highlights that the site is not at a high risk of surface water flooding.

Considering the risk of surface water flows and reviewing the local topography, a topographical survey is included in Appendix I, this demonstrates that flows would most likely follow the existing road rather than overtop the kerb and flow over the site. The data set utilised by the Environment Agency does not appear to take into account the kerbs. RWO have done a flow routing planning showing that the flows would follow the road wrapping around the site based on the existing levels and taking into account the kerbs, the drawing is included in Appendix J. As such the surface water flood route for overland, flows could be maintained and the proposed dwellings afforded protection by raising FFL's over 300mm over the road levels and grading gardens from the higher FFL's to the lower road level. By raising the FFL's would ensure any overland flows which escaped the existing road would not flood properties and afford protection whilst maintaining flow routes.

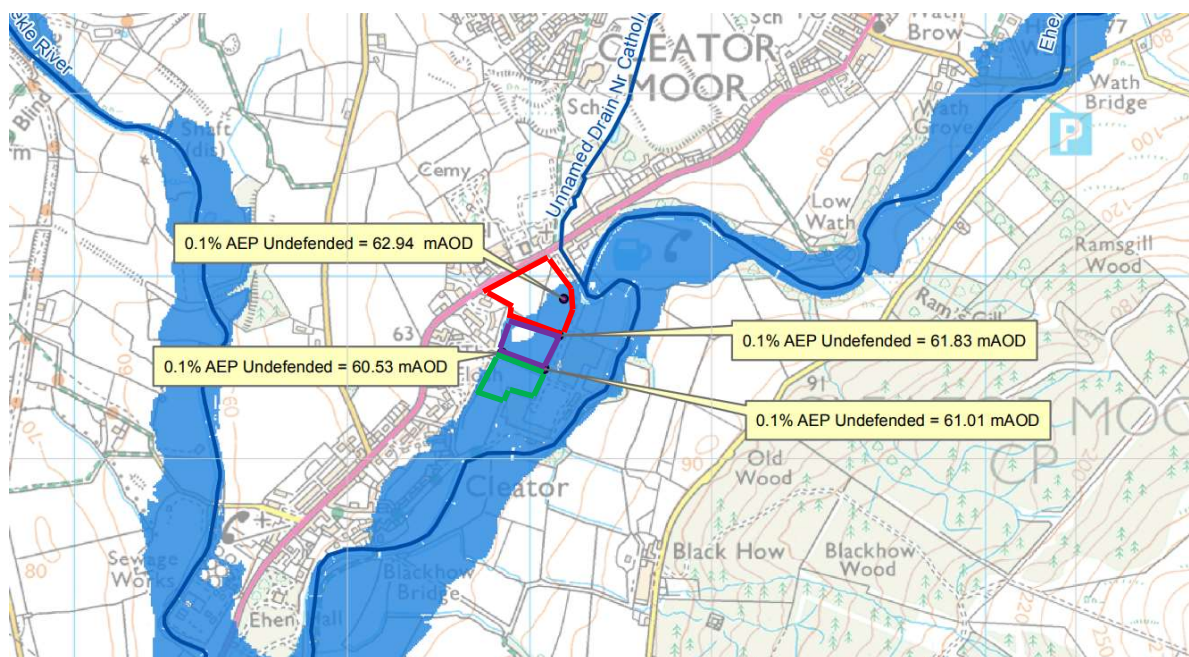
Based upon the Environment Agency surface water flood map surface water runoff enters the River Ehen to the South. South-East of the development site. Ground levels should be maintained to ensure this flood route can be utilised in the event of a surface water flooding incident.

6.0 RECOMMENDED FINISHED FLOOR LEVELS

To afford future development a level of protection against future flooding, it is our normal recommendation to increase Finished Floor Levels (FFL) by 600mm over the 1:100-year return period plus climate change. However, as requested by the Environment Agency the 25% upper central and 70% higher central climate change has been reviewed and to ensure the site is protected against these potential future events it is recommended FFL's are raised above the

1000yr modelled flood levels for the undefended scenario. This scenario then ensures should the flood defences fall into disrepair the new dwellings will be afforded protection and not at risk of flooding.

Based upon these proposals FFL's across the site will be varied subject to the Environment Agencies modelled flood level for the 1:1000 year return period (0.1%).



Extract 6 – Environment Agency undefended 1000 year flood levels

Based upon the above-modelled flood levels the site has been split into three areas with a minimum FFL established for each area. Area 1 (red outline), relates to the modelled flood level of 62.94m, Area 2 (purple outline) the modelled flood level of 61.83m and Area 3 (green outline) the modelled flood level of 61.01m. With the FFL's being set 600mm above the relevant modelled flood level.



Extract 7 – Architects layout with a redline showing Area 1

As can be seen above Area 1 covers the area in terms of topography for the 62.94m flood level on the basis it tied to the lower flood level of 61.83m ensuring these dwellings will be protected. The modelled flood node shows a water level of 62.94m, this area will require a minimum FFL of 63.54m AOD.

e



Extract 8 – Architects layout with a purple line showing Area 2 greenline & 3

As can be seen above Area 2 covers the area in terms of topography for the 61.83m flood level on the basis it tied to the lower flood level of 61.01m ensuring these dwellings will be protected. The FFL's for Area 2 need to be at a minimum of 62.43m AOD. Area 3 starts at the flood level of 61.01m and covers the remainder of the site, requiring a minimum FFL of 61.061m AOD.

The FFL's have been reviewed across the site based upon the modelled 1:1000yr flood levels, given there is a direct relationship for most node points between the flow rates of the 1000yr return period and that of the calculated 100yr + 70% climate change allowance flow rate. Through the raising of FFL's the whole of the residential estate will be afforded protection for the lifetime of the development regardless of the flood defence quality and future maintenance.

7.0 SAFE ACCESS AND EGRESS

As the proposed development site will be serviced by new access onto the A5086 located to the west of the development site, safe access and egress will always be achievable. In the event of a breach occurring in the northern flood defences, the extents of flooding do not impact upon the proposed access.

It is noted that the Environment Agency does not provide a Flood Warning service for the Cleator community. However, taking into consideration the access/egress location and the proposed FFL's, the risk of access/egress being unachievable is deemed low.

The surface water management plan associated with this development site has been considered utilising the following documentation;

- Building Regulations Part H,
- Sewers for Adoption,
- CIRIA C697

8.0 GROUND CONDITIONS

Elliot Environmental have undertaken the Site Investigation associated with the site with Geo-Environmental Engineering undertaking further soil infiltration tests following BRE365. Elliot Environmental reported ground conditions to have Sand and Gravel, which prompted the further investigation works undertaken by Geo Environment Engineering.

Geo-Environmental Engineering received instruction to undertake six soil infiltration tests across the site following BRE365. Figure 2 below shows the locations of the soil infiltration test results.



Figure 2 – Soil Infiltration Test Locations

SA01 recorded Topsoil from 0.00 – 0.40m with Sand & Gravel recorded from 0.40 – 2.00m, soil infiltration test results for this location have been calculated as $6.04665^{\circ} \text{ m/s}$.

SA02 recorded Topsoil from 0.00 – 0.30m, Sand from 0.30 – 0.70m and 0.70 – 2.00m Sand & Gravel, soil infiltration test results for this location have been calculated as $4.97347^{\circ} \text{ m/s}$.

SA03 recorded Topsoil from 0.00 – 0.20m with Sand recorded from 0.20 – 0.80m and Sand & Gravel from 0.80 – 2.00m, soil infiltration test results for this location have been calculated as $2.39464^{\circ} \text{ m/s}$.

SA04 recorded Topsoil from 0.00 – 0.30m with Sand & Gravel recorded from 0.30 – 1.50m, soil infiltration test results for this location have been calculated as $2.27591^{\circ} \text{ m/s}$.

SA05 recorded Topsoil from 0.00 – 0.35m with Sand recorded from 0.35 – 0.60m and Sand & Gravel from 0.60 – 2.00m, soil infiltration test results for this location have been calculated as $2.24551^{\circ} \text{ m/s}$.

SA06 recorded Topsoil from 0.00 – 0.50m with Sand & Gravel recorded from 0.50 – 0.90m and Sand & Gravel from 0.90 – 1.50m, soil infiltration test results for this location have been calculated as 4.22297^s m/s.

All of the recorded soil infiltration rates are well within the acceptable rates and as such the site will be suitable to utilise infiltration. Based upon this in accordance with Building Regulations and the CIRIA SuDS train, surface water should discharge into suitably designed soil infiltration drainage systems.

Geo-Environmental Engineering report is included in Appendix G.

9.0 RECEIVING WATERS

The nearest watercourse is the River Ehen, which generally flows in a south-westerly direction. The Ehen is located on the immediate eastern and southern boundaries of the proposed development site. It has been reported that the water quality within the River Ehen is Quality A in the past.

There is also a small issue located in the western boundary, which discharges into the River Ehen. A further small watercourse is shown flowing southwest before sinking or being culverted approximately 75m from the northern end of the site.

The critical issue relating to the surface water run-off from the proposed development site relates to the River Ehen which is classified as a Site of Special Scientific Interest (SSSI) and a Special Area of Conservation (SAC). It is understood that a direct discharge to the River Ehen has been deemed as unacceptable, based upon this it is proposed to utilise infiltration to dispose of surface water as stated in section 8.0 of this report.

10.0 SURFACE WATER MANAGEMENT PLAN

The surface water management plan associated with this development site has been considered utilising the following documentation;

- Building Regulations Part H,
- Sewers for Adoption,
- CIRIA C697

Soil Infiltration

Section 4.0 Ground Conditions, includes a summary of the soil infiltration test results which have been undertaken by Geo-Environmental Engineering in accordance with BRE 365. A total of six tests have been undertaken, a summary of the results is below in table 1.

Soil Infiltration Test	Results
SA01	6.04665 ^s m/s
SA02	4.97347 ^s m/s
SA03	2.39464 ^s m/s
SA04	2.27591 ^s m/s
SA05	2.24551 ^s m/s
SA06	4.22297 ^s m/s

Table 1 – Soil Infiltration Test Results

The above summary of soil infiltration test results demonstrates that soil infiltration can be utilised across the proposed development site.

Based upon the soil infiltration test results the use of soakaways to accommodate the surface water runoff is deemed as viable. It is recommended that further water monitoring be undertaken to ascertain the water level across the proposed development.

11.0 CONCLUSIONS

This assessment has looked at the implications of the proposed Residential developments in relation to flood risk, including overtopping and breach analysis agreed with the Environment Agency during meetings in June 2019.

The proposed development site is shown as being in Flood Zone 3a on the Environment Agency flood maps. When reviewing the defended flood modelling undertaken by the Environment Agency the site is afforded protection for all events up to and including the 1:200 year return period.

The flow rates and water levels for varying events have been considered including the upper central and higher and flow rates are comparable to the 1:1000 year return period, giving a clear indication of potential water levels on the site when looking at the modelled results.

It is proposed to raise FFL's above the 1:1000 year flood levels, as these flood levels are comparable with the 1:100 year plus 70% climate change levels based upon flow rates. FFL's will be raised 600mm above the 1:1000 year flood level for each associated parcel of land. By raising the ground levels and FFL's, will afford the proposed development protection against flood waters regardless of the flood defence condition and performance.

The Environment Agency surface water flood maps have been reviewed against the topography with flows shown coming over the site in a low-risk event. When reviewing the contours and local topography we believe that surface water flows would follow the road, given the kerb phase and raised levels to the site on the boundary as opposed to run straight across the site. As such surface water overland flow can be managed with the route maintained around the perimeter of the development site.

Safe access and egress have been established via the new proposed access road onto the A5086. The overland flood flow routes do not impede the proposed access/egress for the development's new entrance.

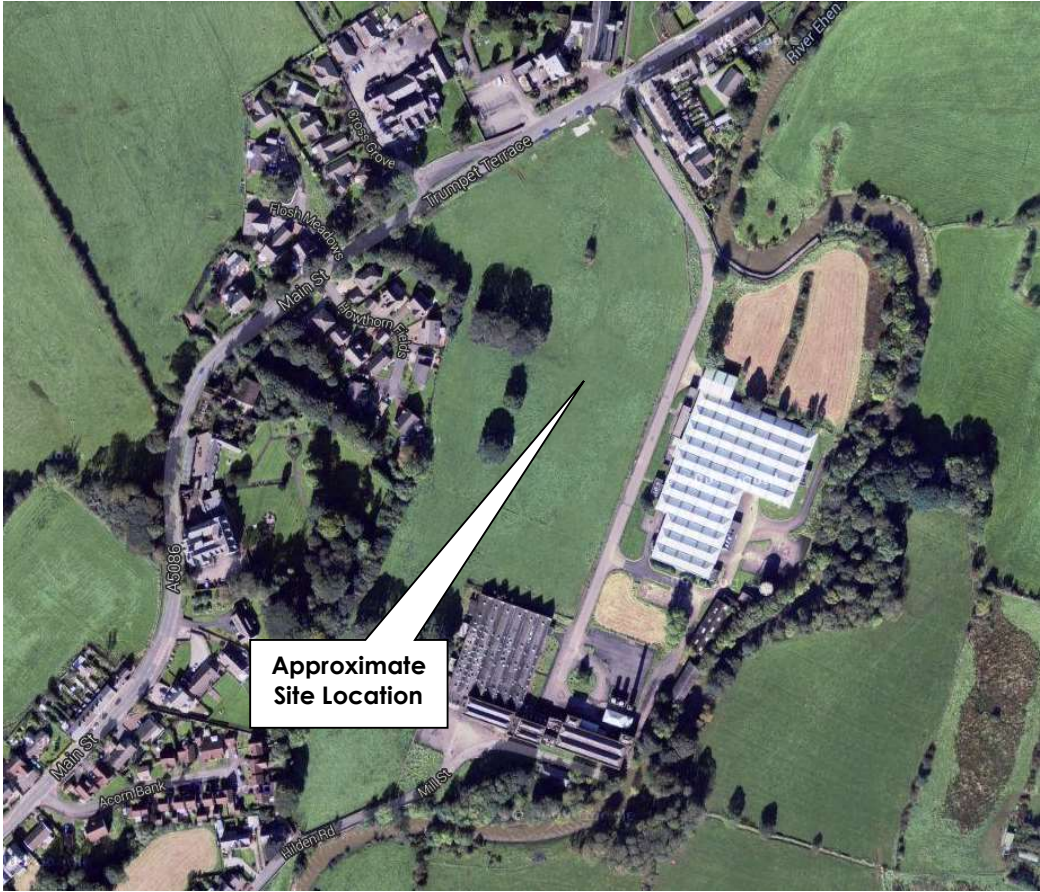
The Environment Agency does not provide a Flood Warning Service for Cleator. It is noted that the site is covered by the River Ehen, Calder, Irt and Esk Flood Alert areas, it would therefore be recommended this be included within the homeowner's packs.

A Surface Water Management Plan (SWMP) has been identified including the levels of treatment required to ensure the River Ehen water quality remains protected.

Any potential impact of the development can be adequately addressed by good drainage design.

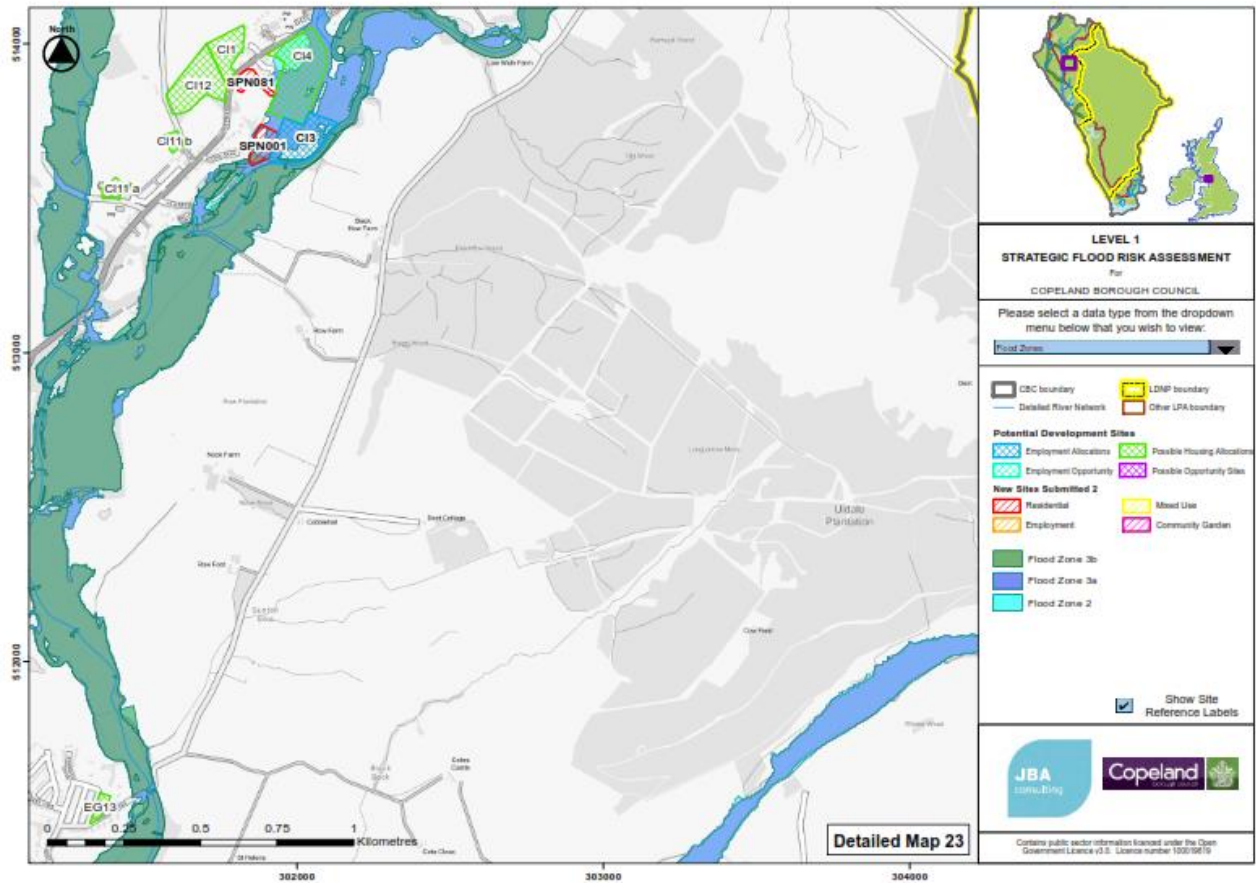
Ross Oakley
For and behalf of RWO Associates Limited
November 2020

Appendix A Site Location Plan



Location Map	
Site	Cleator Mill - Residential
Client	Gleeson Regeneration
Job Number	19002
Scale	NTS

Appendix B Flood Map



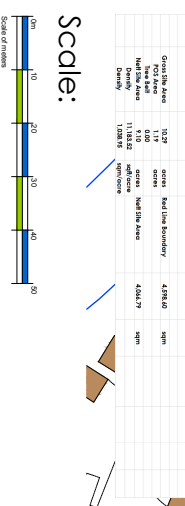
Appendix C Proposed Site Layout

Notes.

- Existing trees retained.
- Best line submission boundary.
- Existing trees removed.
- Indicative planting.
- Grass to level ground.
- Planting to be retained to protect existing trees.
- Maximum 5m length.
- Private drives first 1.5m to be retained.
- 3.2m overall.
- 1.8m high screen wall to detail.
- 1.8m high screen fence to detail.
- 1.8m high screen fence to detail.
- Adjoin high plot elevation fence to detail.
- House type codes reference on plot number.
- Plotting boxes.
- Bin collection area for private drives only.
- Sustainable 2m square with 2m street.
- Rural elevation style.
- Forterra Abbey Red multi facing brick.
- Forterra Ashwell Yellow multi facing brick.
- With full grey roof tile.

Schedule.

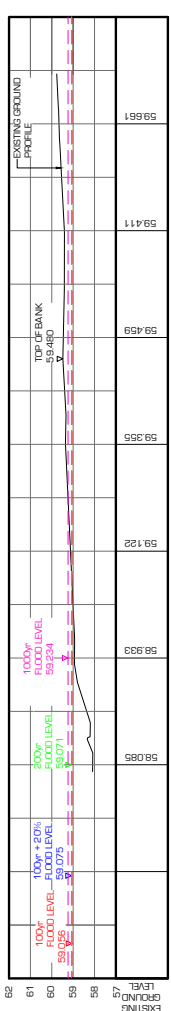
ITEM	DESCRIPTION	NO.	QUANTITY	UNIT	ESTIMATED COST	ESTIMATED VALUE
1	1.8m high screen wall	1	1.8	m	1.8	1.8
2	1.8m high screen fence	1	1.8	m	1.8	1.8
3	1.8m high screen fence	1	1.8	m	1.8	1.8
4	Adjoin high plot elevation fence	1	1.8	m	1.8	1.8
5	House type codes reference	1	1.8	m	1.8	1.8
6	Plotting boxes	1	1.8	m	1.8	1.8
7	Bin collection area for private drives only	1	1.8	m	1.8	1.8
8	Sustainable 2m square with 2m street	1	1.8	m	1.8	1.8
9	Rural elevation style	1	1.8	m	1.8	1.8
10	Forterra Abbey Red multi facing brick	1	1.8	m	1.8	1.8
11	Forterra Ashwell Yellow multi facing brick	1	1.8	m	1.8	1.8
12	With full grey roof tile	1	1.8	m	1.8	1.8



Appendix D Topographical Survey and Site Sections



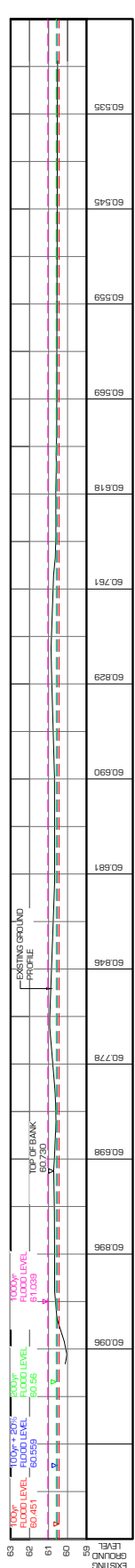
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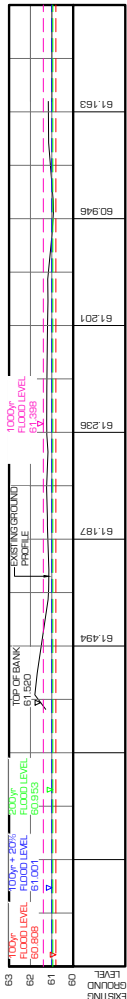
1206 NODE PROFILE



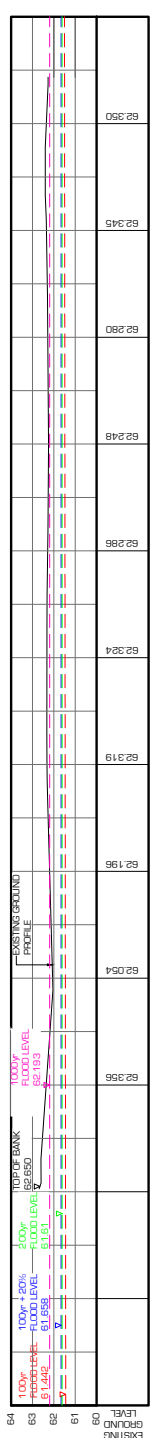
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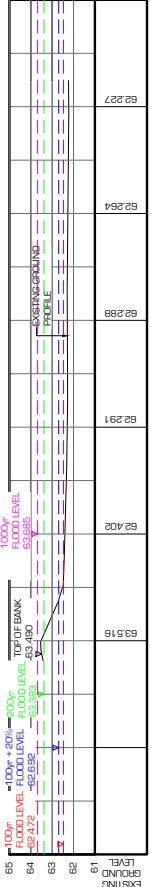
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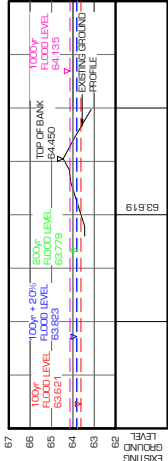
1502 NODE PROFILE



1606 NODE PROFILE



1726 NODE PROFILE



1806 NODE PROFILE

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ASSOCIATES
CONSULTING ENGINEERS

Client	GLEESON HOMES
Project	CLAYTON MILL CUMBERA

Title	SECTIONS THROUGH NOISES
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Scale	250H/500V	Drawn	RM	Checked	RM	Date	05.11.20
Sheet No.	19002	Drawing No.	951	Revision			2

Appendix E Flood Defence Survey

Appendix E – Asset condition report

Asset Condition survey: River Ehen (right bank) Flood Defence at Cleator Mills

1. Introduction

The asset survey of the flood defences on the right bank of the River Ehen, protecting the site of the Cleator Moor proposed development, was conducted on 18th November 2008 in good weather conditions. (Appendix 1 catalogues the main physical features of the defences and associated outfall structures). The crest level of the earth embankments were modestly cut back for both survey purposes and visual condition assessment. Total vegetation management and sensitive vegetation removal would be a more prolonged exercise requiring the permission and supervision of the Environment Agency's (EA's) Fisheries, Recreation and Biodiversity officers.

This report will comment on EA's allocated asset condition grades for this site, challenge their asset condition assessment where necessary (last inspection 5th June 2008) and suggest ways to improve the defences to achieve at least a grade 2 condition, along with very indicative 'ball park' costs.

2. The Condition Assessment Methodology

The process is visual and no intrusive testing is involved, other than clearing some vegetation, as necessary, to facilitate inspection of the floodbank. The inspection followed the EA's performance based visual condition survey approach, using their Condition Assessment Manual (CAM, introduced in November 2006). Broadly this breaks down the elements or components of the assets (Flood Crest, Inward or riverward face, etc) and allocates one of 5 grades between 1 (very good) and 5 (very poor) to each element. The overall condition of the asset is ascertained by weighting the importance or criticality of each element to the performance of the whole asset. Weights range from 1 to 9. Thus an asset element is given a weighting of 9 if the integrity of the asset is compromised immediately *should it fail*.; if the whole defence section will take more than a year to fail should the element fail, then a weighting of 5 or perhaps 6 is allocated. Overall condition is calculated by summing the product of each element grade and weight and dividing by the sum of the weights.

This overall grade is measured against a target grade (again 1 to 5 as before). Should the actual condition not meet the target then the defence is deemed to be inadequate or unfit for purpose and repairs or remedial work to bring the asset up to target are vital to maintain the structural integrity of the asset.

Understanding the difference between elements with a grade of 3 from those with a grade of 4 is very important as grade 3 **could affect** performance but grade 4 **would significantly affect** performance and increase the likelihood of defence failure. (Grade 2 **would not affect** performance). In January 2008, the EA's Chief Executive ruled that, except in extreme conditions, where the consequences of failure were dramatic affecting many people and their property, a target of 3 is sufficient. The right hand bank defences on the river

Ehen at Cleator Mills are allocated a target of 3 by the EA at present, as the consequences of failure are limited. Redeveloping the site may prompt a review of this target. So it is recommended that, where remedial work to the defences is required, the developer should promote improvement work to provide overall condition grade of each defence section to Grade 2

It is important to point out that remediation work, without increasing the original crest height, will be viewed more favourably by the EA as the status quo is being retained.

3. Results of visual assessment of asset condition

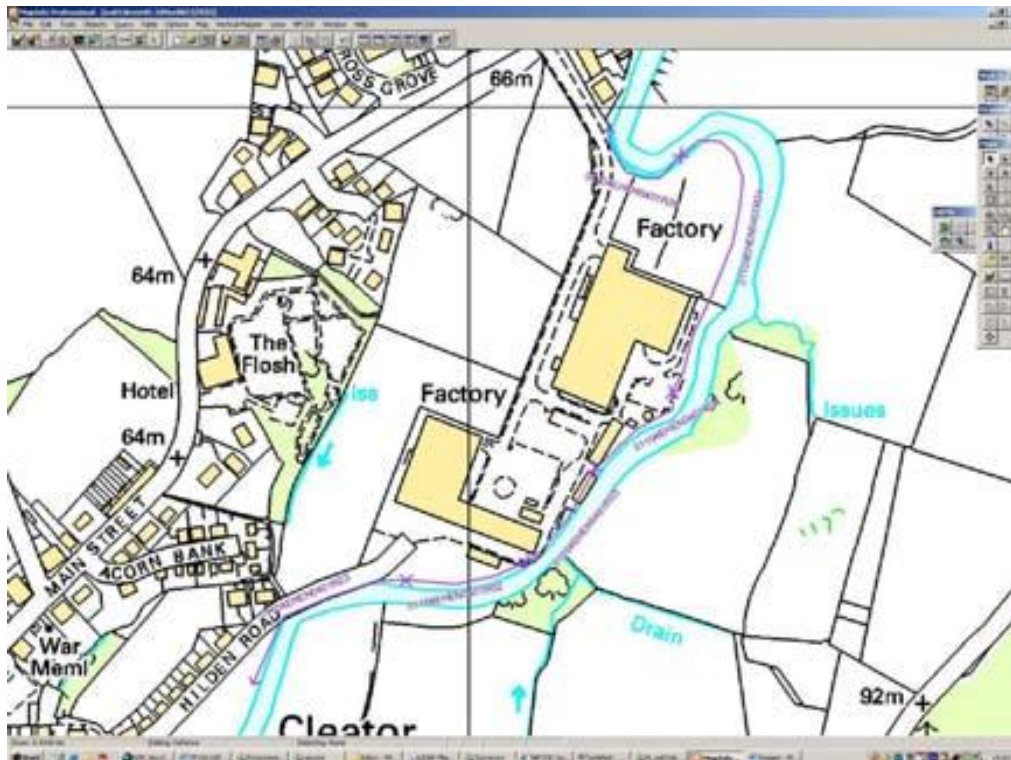


Figure 1 Environment Agency National Flood and Coastal Defence Management System map

The defences (see Figure 1) comprise:

- A 2 metre high (landward side to crest) hard defence section upstream of the site, referenced by EA as 0114EHEN0401R25, which comprises a Steel Pile retaining wall some 91.4 metres in length, a wide concrete berm (or horizontal ledge) giving protection to an approximately one metre high flood defence wall made of masonry in the upstream section and some 26 gabion baskets (each 1 metre in length, 1 metre wide and 1 metre deep) at the downstream end.
- An earth flood embankment some 253.5 metres in length, referenced by EA as 0114EHEN0401R24, which comprises an approximately 1.3 metre high earth embankment, choked with invasive, dense vegetation
- A lower earth embankment, some 92.8m in length, no higher than 0.5m referenced by EA as 01104EHEN0401R04, which is also choked with

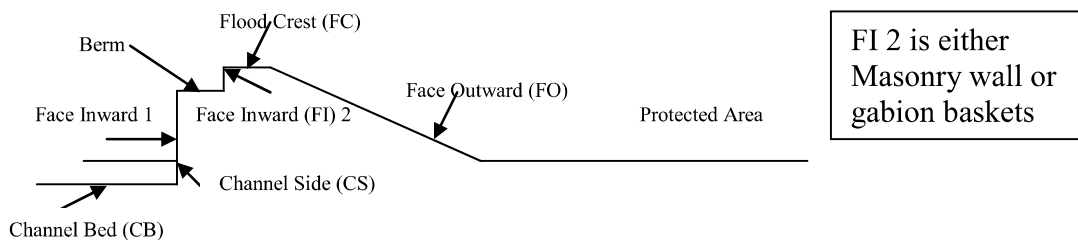
invasive, dense vegetation. The EA maps show this as no longer a formal embankment.

- Two downstream sections (adjacent to Cleator Mill) referenced by EA as 0114EHEN0401R02 and 0114EHEN0401R03, which are effectively 'high ground' adjacent to natural channel with no flood embankment at all.

3.1 Defence section 0114EHEN0401R25 (see Appendix 1.1)

NFCDD includes this defence section of 91.4 metres as one defence. This report splits the defence where the masonry Face Inward becomes a gabion basket section as the condition of the latter is far worse than the former.

3.1.1 U/S section (masonry flood wall)



Data from NFCDD

Assumed Standard of protection years (from Statutory Section 105 survey analysis)	1 in 100
Actual upstream crest level	64.52m
Actual downstream crest level	64.52m
Target standard to be achieved (from 09/11/07)	Grade 3
Overall Condition (EA) – both masonry wall and gabion elements	2.82 (rounded to 3)

Current Target achieved

Overall Condition (JCA) – masonry wall section only (see Appendix 2.1)	2.55 (rounded to 3)
--	---------------------

Current Target achieved

3.1.2 U/S section (gabion basket section)

(see above cross section)

Data from NFCDD

Assumed Standard of protection years (from Statutory Section 105 survey analysis)	1 in 100
Actual upstream crest level	64.52m
Actual downstream crest level	64.52m
Target standard to be achieved (from 09/11/07)	Grade 3
Overall Condition (EA)	2.82 (rounded to 3)

Current Target achieved

Overall Condition (JCA) – see Appendix 2.2	3.13 (rounded to 3)
--	---------------------

Current Target NOT achieved

Of the 26 baskets 7 are seriously if not totally depleted of stonework, wires cut (presumed stolen):

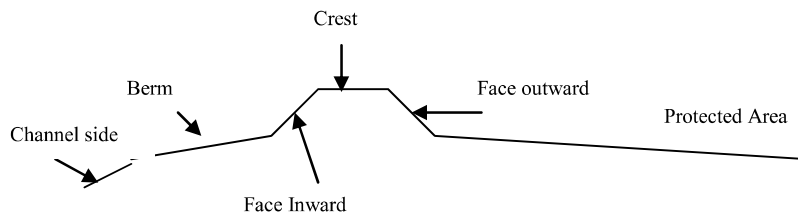
1 to 6 (upstream)	Fair to Good
7	Stonework seriously depleted
8-12	Fair to Good
13	Stonework seriously depleted
14-20	fair to Good
21-25	Majority of stonework stolen
26	Fair to Good

3.1.3 Conclusions

The CAM system works on the weakest link philosophy; in the gabion basket section of the defence, even though most of the baskets are in fair to good condition, the face inward can be assumed to have failed completely and it is likely that within a year the crest (and therefore the integrity of the whole defence) will erode away as the baskets further decay. The present target 3 has just failed. Failure of the defence is self evident and remedial work is very necessary. Along with the vegetation management and treatment of bare patches, at least 7 baskets need replacement (maybe more as the theft continues).

3.2 Defence section 0114EHEN0401R24 (see Appendix 1.2)

This section comprises some 253 .5 metre of raised embankment, with about a 1.3m protection (crest to Outward face toe) above a natural channel with an unacceptable levels of invasive vegetation covering most of the Inner and Outward faces and crest. The crest is too narrow and in parts the slopes are over-steep. The Inner or waterward face in particular is covered with mature trees and inflexible vegetation which will inhibit flood flow conveyance (increase flooding). There is little sign of vermin (moles) unlike in the adjacent defended grassland. Vegetation was cut back in parts of the bank and there were few signs of horizontal cracking or fissuring, with no evidence of seepage/piping. NFCDD identifies the standard of protection as 1 in 25 years. However the EA ISIS model results, when compared with ground levels from an earlier level survey, indicate a standard of protection much higher than this. Another map provided by the EA gives the standard of protection as 1 in 20 years.



3.2.1 Data from NFCDD

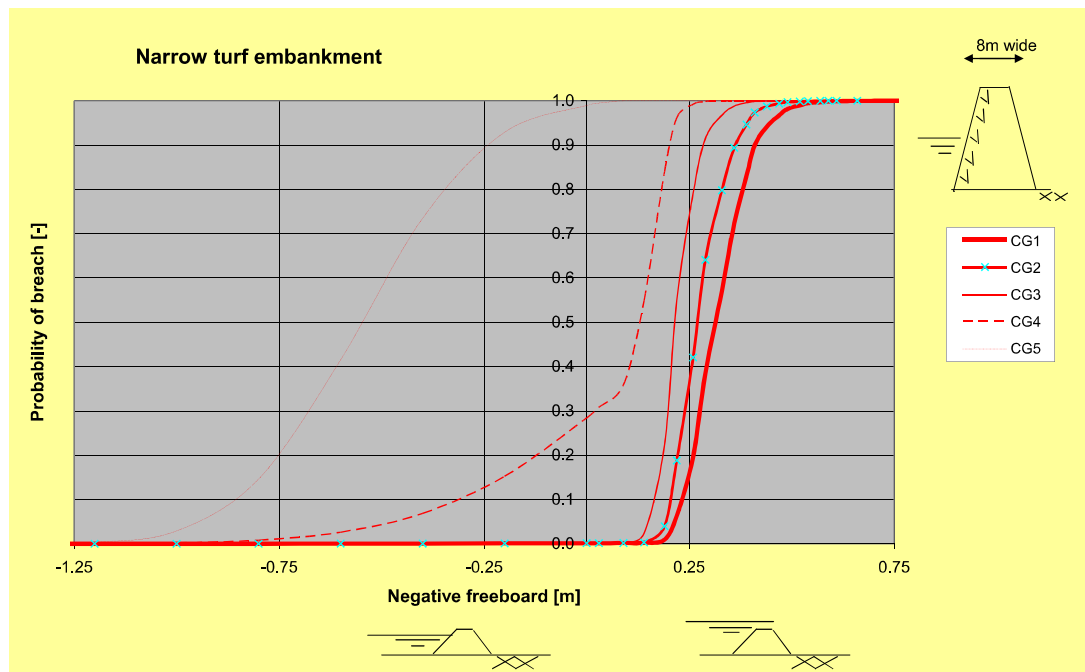
Assumed Standard of protection years (from Statutory Section 105 survey analysis)	1 in 25
Actual upstream crest level	63.40m
Actual downstream crest level	62.49m
Target standard to be achieved (from 09/11/07)	Grade 3
Overall Condition (EA)	3.58 (rounded to 4)
Current Target NOT achieved	
Overall Condition (JCA) - see Appendix 2.3	3.76 (rounded to 4)
Current Target NOT achieved	

3.2.2 Conclusion

The defence fails to meet target 3 as currently set and wholesale vegetation clearance is required along the whole length of defence, with selective vegetation management in co-operation with EA's Fisheries, Recreation and Biodiversity team on the berm and channel side. The rock revetment at the toe of the channel side is helping to prevent undercutting of the berm and strategic repair might be appropriate.

Once vegetation has been cleared the entire bank requires re-shaping to reduce its current fragility.

Research by HR Wallingford on behalf of EA indicates that a narrow earth/turf flood embankment like this in grade 4 condition would have a 70 per cent chance of failure if water levels (flood) reached 0.25 metres above crest level and about a 30 percent chance of failure should flood water should reach crest level (see diagram below). Remedial work on vegetation management and re-profiling the embankment without improving its standard of protection would reduce this fragility significantly. A Grade 2 or even 3 embankment is unlikely to fail at all until flood levels achieved are at least 0.2metres above the crest level.



3.3 Defence section 0114EHEN0401R04 (see Appendix 1.3)

EA have changed the asset type for this defence section from **Fluvial raised defence** (embankment) to **maintained channel**, though evidence suggests it is a natural channel adjacent to 'high ground'. NFCDD identifies the standard of protection as 1 in 25 years. However the EA ISIS model results, when compared with ground levels from an earlier level survey, indicate a standard of protection much higher than this. The defence length is adjacent to the Kangol factory and the accurate level of this High Ground is crucial within the context of this flood risk assessment.

The profile is however similar to the R24 section only with, at most, a 0.5m defended height.

3.3.1 Data from NFCDD

Assumed Standard of protection years (no source for this assumption)	1 in 25
Actual upstream crest level	60.64m
Actual downstream crest level	60.64m
Target standard to be achieved (from 09/11/07)	Grade 4
Overall Condition (EA)	2.0 (but recorded 3)

Current Target achieved

Overall Condition (JCA) – see Appendix 2.4	3.76 (rounded to 4)
--	---------------------

Current Target achieved

3.3.2 Conclusions

The findings of this recent survey do not agree with the EA data. However both gradings indicate that the defence is meeting the prescribed target (4). (Though one section of the asset inspection sheet suggests overall grade 3 and another overall grade 2). The target is confusing as all defences have to work

together to prevent inundation of the site. It is likely that, as this defence reach is downstream of the Kangol business units, then flooding from this section would only be local.

3.4 Defence sections 0114EHEN0401R02 and R03 (see Appendix 1.4)

Adjacent to Cleator the River Ehen is a natural channel rising directly to the road and Mill. NFCDD records that the Standard of Protection afforded by the Natural channel (R03) i.e. the channel capacity has been changed to 1 in 100 years on the basis of survey levels versus the Section 105 survey. The channel is clear with no major build up of gravel with some natural erosion and slippage to the channel side.

In summary the channel conveyance is not likely to be impeded by vegetation growth in the channel or debris/siltation.

NFCDD suggests that the downstream defence section (R02) has a 1 in 20 year standard of protection but existing topographic survey provides a discrepancy in the standard of protection between defence lengths R02 and R03 is valid.

In these two reaches there are 2 clay 18" pipes which outfall to the Ehen. It appears that they flow free and it is assumed that they emanate as drainage conduits from the Kangol factory. Some 3no. 6" iron pipes also protrude into the river taking surface water and water from down pipes to the river.

A masonry wall stands on top of the river bank but this has no flood defence function

3.4.1 Conclusions

No maintenance, other than riparian ground maintenance, is required, though a survey of the outfall pipes may be required to ascertain their purpose and source. The inspection chamber suggests the clay pipes take surface water drainage from the Kangol factory. These pipes have no flaps to prevent ingress of flood water to the lower parts of the site.

4. Recommendations

The EA have a target grade for the defences of Grade 3 as the defences 'protect' only the Kangol site and rough grazing. The asset survey has concluded that the current condition of the flood defence is at best grade 3 but at worst grade 4. Therefore, priority remedial work is strongly recommended on the three NFCDD defence lengths, as follows (see site map above):

4.1 0114EHEN0401R25

Vegetation management of Face Outward and Flood Crest, some pointing to masonry wall; reseeded bare patches and fencing with an approximate cost of circ £3,000. Maintenance to retain target condition requires superficial vegetation management and regular inspection to monitor any deterioration.

- Vegetation management and re-profiling of Outward face
£3,000
- Replacement of 7 gabion baskets
£10,000

4.2 0114EHEN0401R24

- Total but sensitive vegetation management over the whole length
£10,000
- Re-profiling the earth embankment to existing levels
£125,000

4.3 0114EHEN0401R04

- Total but sensitive vegetation management over the whole length
£2,000
- Re-profiling the earth embankment to existing levels
£10,000

4.4 0114EHEN0401R02 and 0114EHEN0401R03

- Following construction of the development the clay pipes or their replacements should be fitted with flaps to prevent ingress of flood water.

4.5 Summary

The total cost of bringing the flood defence up to an appropriate standard would therefore be in the order of £150,000.

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Birmingham

20th November 2008

Appendix 1: Defence photographs

1. 01104EHEN0401R25 (Hard Raised embankment)



Flood crest Upstream (rutting)



Outward face and Flood crest (heavy poaching)



Steel pile retaining wall with concrete berm



Heavily overgrown Flood crest



Heavily overgrown flood crest



Inward face (masonry) and flood crest



Gabions in Good condition (Grade 2)



Gabions in Very Poor condition (Grade 5)



Heavily eroded outward face



D/S gabion baskets in failed condition



*Sheet pile FI showing minor distortion
But flood wall well protected by concrete berm*



Minor grass growth in masonry wall joints

2. 01104EHEN0401R24 (Raised earth embankment)



Crest heavily vegetated with rutting



Outward Face with vegetation cleared



Invasive vegetation on whole bank



Mature Trees on Inward face



Invasive vegetation on outward face



Outward Face and protected area

3. 01104EHEN0401R04 (Raised earth embankment)



Trees on „crest“ of defence



Invasive vegetation on whole embankment



Trees on Channel Side



“Embankment at rear of Kangol



Stone revetment on channel side

4. 01104EHEN0401R02/R03 (Natural Channel)



U/S broken 18" clay pipe



D/S 16" iron pipe flowing clear #1



D/S 16" iron pipe #2



6" iron pipe #1



6" iron pipe #2



Channel side showing wrack from flooding

Appendix 2 Condition Grading - Element Charts

1. Defence section 0114EHEN0401R25 (concrete wall)

Type	Sub type	EA		JCA		JCA Comments
		condition	weighting	condition	weighting	
CB	Natural	2	1	2	2	Limited shoaling not affecting conveyance
CS	Pile	3	3	2	4	Some minor displacement
FI1	Pile	did not grade		2	4	Some minor displacement
Berm	Concrete	2	3	2	4	3m wide protecting flood wall
FI2	Wall	3	5	2	6	Minor defects with slight lateral displacement
Crest	Embank	3	5	4	6	Concrete front protection; heavily rutted and overgrown
FO	Embank	3	5	3	5	Heavily overgrown with extensive bare patches and churning by machinery

2. Defence section 0114EHEN0401R25 (Gabion wall)

Type	Sub type	EA (masonry and gabions)		JCA		JCA Comments
		condition	weighting	condition	weighting	
CB	Natural	2	1	2	2	Limited shoaling not affecting conveyance
CS	Pile	3	3	2	4	Some minor displacement
FI1	Pile	did not grade		2	4	Some minor displacement
Berm	Concrete	2	3	2	4	3m wide protecting flood wall
FI2	Gabion	3	5	5	6	Stonework stolen from 7 metre cubed baskets
Crest	Embank	3	5	4	6	Concrete front protection; heavily rutted and overgrown
FO	Embank	3	5	3	5	Heavily overgrown with extensive bare patches and churning by machinery

3. Defence section 0114EHEN0401R24

Type	Sub type	EA		JCA		JCA Comments
		condition	weighting	condition	weighting	
CB	Natural	2	1	2	2	Limited shoaling not affecting conveyance
CS	Natural	2	1	3	2	Overgrown; signs of undercutting of berm; Partial rock revetment
Berm	Natural	2	2	4	3	1m to 6m wide covered with mature trees and inflexible vegetation
FI	Embank	4	5	4	6	Over steep and infested with vegetation
FC	Embank	4	5	4	6	Invasive vegetation, uneven and significant rutting
FO	Embank	4	5	4	6	Infested with vegetation, cannot see embankment

4. Defence section 0114EHEN0401R04

Type	Sub type	EA		JCA		JCA Comments
		condition	weighting	condition	weighting	
CB	Natural	2	1	2	2	No build up of debris
CS	Natural	2	1	3	2	Signs of slippage and undercutting
Berm	Natural	Did Not Grade		4	3	1m to 6m wide covered with mature trees and inflexible vegetation
FI	Embank	Did Not Grade		4	6	Totally unmanaged
FC	Embank	Did Not Grade		4	6	Narrow 'crest' and wholly uneven crest line
FO	Embank	Did Not Grade		4	6	Serious vegetation management required

Appendix F Envireau Water Breach Analysis

UPDATED FLOOD RISK MODELLING REPORT

CLEATOR MILLS



For

RWO Associates
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Blezard Business Park
Seaton Burn
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WATER

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APPENDICES

Appendix A	Previous Model Report
Appendix B	RWO Associates Topographical Survey
Appendix C	Breach 1 Flood Maps – Figures 6a, 6b, 6c and 6d
Appendix D	Breach 2 Flood Maps - Figures 7a, 7b, 7c and 7d

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Revision	Details	Completed by	Date	Checked by	Date
REV01	Final	RH	27/02/2020	LC	02/03/2020
REV02					
REV03					
REV04					

UPDATED FLOOD RISK MODELLING REPORT

CLEATOR MILLS

1 INTRODUCTION

1.1 Background

Envireau Water has been commissioned to provide an updated flood defence breach analysis at Cleator Mills, Cleator, Cumbria, CA23 3DU. This work follows on from a previous flood defence breach analysis undertaken by Mott MacDonald based on the Environment Agency hydraulic model produced in 2010. The previous modelling report is provided in Appendix A.

This report describes the methodology and results of the two-dimensional modelling and mapping of the flood defence breach scenarios.

1.2 Location and Setting

Cleator Mills (the "Site") is located to the south-east of Cleator Moor Village (Figure 1). The Site is centred on National Grid Reference NY 02067 13818. The River Ehen located adjacent to the north and eastern boundaries of the Site. The Site is split into three areas, the existing Kangol factory, a disused Kangol factory and a car park area. The flood defences are located between the river and Site.

1.3 Scope of Breach Analysis

The scope of the flood defence breach analysis is summarised below:

- Build a 2D model of the Site to replace the previous model developed by Mott MacDonald in 2013 which is not available.
- Obtain and apply new topographic survey information provided by RWO Associates (Appendix B) and LiDAR 1m Digital Terrain Model (DTM) from the Environment Agency dated 2013 (Ref. 1).
- Develop breach hydrographs using the updated 2016 Environment Agency hydraulic model for the River Ehen. The model was built and run using linked Flood modeller TUFLOW simulations.
- Prediction of flood extent, depth, velocities and hazard ratings for the 1 in 100 year plus climate change flood defence breach at two locations.

2 BREACH ANALYSIS

2.1 Breach Scenarios

Two breach scenarios are analysed in the updated assessment. The locations for the flood defence breaches were agreed with the Environment Agency in March 2010 and remain unchanged. Details of the two scenarios are provided in Table 1 below and shown on Figure 2.

Table 1 Breach Location and Details

Breach Scenario	Location	Defence Type	Breach Width (m)	Point X	Point Y	Elevation (mAOD)	Bank
Breach 1	North of Site	Combination of gabion lined baskets and earth embankment	40	302196	513947	64.52	Right Bank
Breach 2	East of Site	Earth Embankment	40	302202	513840	62.49	Right Bank

The following criteria was agreed with the Environment Agency for the previous assessment and maintained for this update:

- One design event to be assessed – 1 in 100 year plus climate change.
- As both breach locations are on a fluvial river, the following breach width and time apply:
 - Combination of hard defence and earth bank: 40m width, 36 hours to closure.
 - Earth banks: 40m width, 36 hours to closure.
- The start of the breach is the bank-full condition or at the peak water level if lower.

2.2 Breach Methodology

The method used to assess the flood defence breach has been maintained from the previous assessment to ensure consistency between the two results. The method applied is summarised below.

- Review the updated Environment Agency hydraulic model which covers the entire River Ehen, including the two breach locations.
- Spill units representing the breach locations within the Environment Agency model were identified. Where necessary an interpolated channel cross section was added 40m downstream of the breach to ensure a breach width of 40m was achieved. Spill units that represent the breaches floodplains within the Environment Agency model are represented by 1D reservoir units with water exchanged between the river and floodplain via spill units.
- Where an interpolation was required a spill unit to connect it to the 1D reservoir unit was added to ensure all flood water from the main channel was captured.

- The breach was assumed to develop within a single one second timestep in the model run across the full 40m width. This represents a worst case scenario for the breach assessment.
- The breach was assumed to occur through the full embankment height to the surrounding ground level. This was represented within the Environment Agency model by lowering the elevation of the right bank spill at the breach location from the embankment level to the level of the surrounding floodplain.
- The level of the surrounding flood plain was obtained from the topographical survey provided by RWO Associates and 2013 Environment Agency LiDAR data. Table 2 identifies the embankment and floodplain elevation used within the model for each Breach. The floodplain elevations are above those used in the previous model due to the updated topographical survey and Environment Agency LiDAR data differing from that used in the previous model.

Table 2 Flood Defence and Floodplain Elevations

Breach Number	Flood Defence Elevation (mAOD)	Floodplain Elevation (mAOD)
Breach 1	64.52	62.6
Breach 2	62.49	61.5

- The hydrographs for the spill units representing the breach locations were used as an input to a 2D model of the Site to establish the flood depth, extent, velocity and hazard rating from each breach event.

3 2D HYDRODYNAMIC MODELLING

3.1 Approach

The 2D modelling approach is outlined below for assessing the two flood defence breaches for the 1 in 100 year plus climate change event:

1. Construct a 2D hydraulic model incorporating topographic data provided by RWO Associates and Environment Agency 1m LiDAR data dated 2013;
2. Insert the breach hydrographs for each scenario extracted from the updated Environment Agency River Ehen model;
3. Predict flood extents at the site for the specified return period of 1 in 100 year plus climate change;
4. Produce flood extent, depth, velocity and hazard maps.

The model was built and run within Flood Modeller v4.6.

3.2 Model Build

The model extent has been iteratively adjusted to cover a sufficient length of the River Ehen and the maximum flood plain extent which is flooded during the breach assessments. The same model extent was used for both breach scenario.

3.2.1 Digital Terrain Model

The DTM for the Site was produced using 1m resolution LiDAR dated 2013. To make sure flood water from the breach was not underestimated the DTM was edited to raise the channel elevation to the bank elevation. This ensured the watercourse channel was not available for storage or conveyance of the 'breached flows'. This is in accordance with the breach occurring at the same time as bank full conditions with the River Ehen.

Details of the grid used within the model is summarised in Table 3, each cell within the grid is assigned a z value, which is the elevation in mAOD. The previous assessment used a grid size of 7m, for this assessment a grid size of 5m was determined to provide sufficient detail for flood mapping, whilst not creating onerous model run times.

Table 3 2D Model Grid Details

Grid Information	
Grid Size (spacing)	5 m
Origin	301,135N 512,883E (British National Grid)
Orientation	0 degrees
Width of grid (in the east direction)	1260 m
Height of grid (in the north direction)	1051 m

3.2.2 Boundary Conditions

The inflow (upstream) boundary is a flow-time boundary assigned to the breach location via a polyline shapefile. The breach hydrograph extracted from the updated Environment Agency model was assigned to the polyline to simulate the flood defence breach. The breach hydrographs are shown in Figure 3.

The peak flow for Breach 2 is greater than the peak flow for Breach 1. We have assumed this is different from the previous model due to the inclusion of flow re-entering the River Ehen from the floodplain between Breach 1 and Breach 2 in the updated Environment Agency model. However, we would naturally expect to see a higher flow at Breach 2 than at Breach 1.

3.2.3 Manning's n

A roughness grid was applied to the 2D grid based on land classification. The roughness values (Table 4) allows the model to calculate the resistance provided by the land to the flood water.

Table 4 Manning's n Values for Land Use Classification.

Land Classification	Manning's n (Roughness)
Water	0.035
Grassed floodplain	0.055
Buildings	0.300
Woodland	0.120
Roads and railways	0.020

3.3 Flood Hazard Classification

The hazard rating has been defined using the method outlined in Defra's Flood Risks to People report (FD2321/TRA) (Ref 2). The hazard rating is calculated from depth, velocity and debris factor at each time step in the model. The equations governing this calculation are provided below:

$$HR = d (v + 0.5) + DF$$

Where, HR = (flood) hazard rating;
 D = depth of flooding (m);
 V = velocity of floodwaters (m/s); and
 DF = debris factor

The debris factor varies with depth and velocity for each land use classification as shown in Table 5. The debris factor used within the flood mapping is Urban as the Site is occupied as a factory and used for car parking with no extensive woodland coverage.

Table 5 Debris Factor for Land Use and Flood Depths (Table 4.1, FD2321/TRA)

Depths	Debris Factor		
	Pasture/Arable	Woodland	Urban
0 to 0.25 m	0	0	0
0.25 to 0.75 m	0	0.5	1
d>0.75m and/or v>2	0.5	1	1

Hazard rating (HR) has been classified into four categories as defined within FD2321/TRA, the categories are listed in Table 6.

Table 6 Hazard to People as a Function of Depth and Velocity (Table 4.2, FD2321/TRA)

Hazard Rating	Degree of Flood Hazard	Description
<0.75	Low	Caution <i>"Flood zone with shallow flowing water or deep standing water"</i>
0.75 – 1.25	Moderate	Dangerous for some (e.g. children) <i>"Danger: Flood zone with deep or fast flowing water"</i>
1.25 – 2.0	Significant	Dangerous for most people <i>"Danger: flood zone with deep fast flowing water"</i>
> 2.5	Extreme	Dangerous to all <i>"Extreme danger: flood zone with deep fast flowing water"</i>

4 RESULTS

4.1 Breach 1

During a 1 in 100 year plus climate change event flood defence breach at location 1 flood water flows onto the floodplain progressing south flooding the existing factory. Water then flows each side of the existing factory flooding the car park area and the disused factory downstream. Flood water re-enters the River Ehen near the existing factory site. Figure 4 shows the progression of the flood wave across the Site from the initial time at which the flood breaches fail ($t = 0$ hour) to the maximum flood extent ($t = 4.5$ hour).

Flood depths in the vicinity of the existing factory building are significant reaching up to 1.46m near the existing factory building. In the wider area surrounding the existing factory and land around the disused factory water depths reach up to 0.6m. Water depths in the car parking area reach 0.45m. The remainder of the floodplain flood depth typically reaching 0.26m.

The velocity reaches a maximum of $3.2\text{m}^3/\text{s}$ at the Site. The highest velocities are located close to the breach location and along the eastern edge of the Site adjacent to the River Ehen.

The hazard rating for the Site is typically Low (<0.75), however the hazard increased in areas with deeper flooding or higher velocities. These areas are located adjacent to the eastern edge of the existing factory and along the banks of the River Ehen. The hazard level of these areas are moderate to significant indicating that it would be dangerous to people during a flood defence breach.

Compared to the previous assessment the maximum flood depth has increased from 0.9m to 1.46m in the vicinity of the existing factory, this in turn has increased the hazard rating in these areas of the Site. However the maximum flood extent at the Site remains the same. The velocities experienced on site are slightly increased from those predicted in the previous breach due to the higher peak in the breach hydrograph.

4.2 Breach 2

During a 1 in 100 year plus climate change event flood defence breach at location 2, flood water flow onto the floodplain encountering the existing factory where it is deflected south through the car park towards the disused factory. As the breach progresses water flows towards the disused factory with some water re-entering the River Ehen downstream of the breach location. Water builds around the existing factory and begins to flow north adjacent to the River Ehen, while water flows around the disused building to the west before flowing south and back into the River Ehen south of the Site. Figure 5 shows the progression of the flood wave across the Site from the initial time at which the flood defence fails ($t = 0$ hour) to the maximum flood extent ($t = 5$ hour).

Flood depths in the vicinity of the existing factory are significant reaching up to 1.21m in depth along the eastern wall of the factory. Flood depths at the car park reach 0.55m. Flood depths at the disused factory reach 0.64m with the remainder of the floodplain typically reaching 0.27m.

The velocity reaches a maximum of 3.2m/s at the Site, high velocities are experienced on the eastern edge of the existing factory and to the south of the disused factory.

The hazard rating for the Site during Breach 2 is typically Low (<0.75), however like Breach 1 there are areas of higher hazards associated with deeper flooding or higher velocities. These areas are located adjacent to the eastern edge of the existing factory and along the bank of the River Ehen. The hazard level of these areas are moderate to significant indicating that it would be dangerous to people during a flood defence breach.

In comparison to the previous assessment the maximum flood extent has increased due to the updated Environment Agency hydraulic model incorporating flow back into the River Ehen from the floodplain upstream. This has resulted in a higher peak in Breach 2's hydrograph compared to Breach 1's.

The flood depth has also increased under Breach 2 scenario from 0.5m to 1.21m in the vicinity of the existing factory. This has increased velocities and hazard ratings at the site as a result of the increased volume and peak in the flood defence breach hydrograph. Therefore, although the hazard rating for the Site is typically Low, the area small areas with a hazard rating rising to moderate or significant..

5 FLOOD MAPPING

Flood maps have been produced from the outputs of the 2D model. The maps show the maximum depth, velocity, water level and hazard rating for each Breach individually. Flood maps figures for Breach 1 (Figure 6a – 6d) are provided in Appendix C and flood maps figures for Breach 2 (Figure 7a – 7d) are provided in Appendix D. Table 7 summarise the flood maps.

Table 7 Summary of Flood Maps

Figure Number	Parameter Shown	Breach Location	Return Perion
6a	Depth	Breach 1	100 year + Climate Change
6b	Velocity	Breach 1	100 year + Climate Change
6c	Water Level	Breach 1	100 year + Climate Change
6d	Hazard Rating	Breach 1	100 year + Climate Change
7a	Depth	Breach 2	100 year + Climate Change
7b	Velocity	Breach 2	100 year + Climate Change
7c	Water Level	Breach 2	100 year + Climate Change
7d	Hazard Rating	Breach 2	100 year + Climate Change

6 ASSUMPTIONS AND LIMITATIONS

The following assumptions were made within the model:

- The River Ehen is at bank-full levels downstream of the breach.
- Flood defence and embankment levels within the updated Environment Agency model are correctly representing the modelled area.
- The updated Environment Agency model accounts for surface runoff within the modelled area.
- The Site is an urban environment with no extensive woodland or pastureland.

The following limitations apply to the hydraulic model:

- LiDAR data has a verified vertical accuracy of +/- 15cm.
- Models are not calibrated or verified for flood extent due to breaches due to the lack of observed historic data.
- The updated Environment Agency model was only run to peak producing results for 25 hours. To run the dam breaches for 36 hours to closure, the rising limb has been used as a proxy for the falling limb.

7 CONCLUSIONS

An updated flood defence breach analysis has been undertaken for two breach locations adjacent to Cleator Mills. The breach assessment methodology has been maintained from previous assessment to ensure consistency between assessments. The breach hydrographs have been updated applying the updated Environment Agency 2016 River Ehen hydraulic model results.

A new 2D hydraulic model was constructed using a grid assigned levels from a DTM and flow-time boundary conditions representing the inflow from the flood defence breach. The 2D model grid covered an area representing the potential for flooding from the breach with a grid size of 5m.

A flood defence breach at location 1 would result in extensive flooding of the Site. The main areas affected are the existing factory and car park area and the disused factory downstream of the Site. The hazard rating for the majority of the Site was Low, however there were areas that had a Moderate to Significant hazard rating where the flood depth was greater. In these areas the breach poses a significant risk to people.

A flood defence breach at location 2 would result in less extensive flooding with flood water covering the eastern edge of the existing factory, car parking area and disused factory area. Similar to Breach, 1 the hazard rating for the majority of the Site was Low, with areas experiencing greater flood depths having a Moderate to Significant hazard rating. These areas pose a significant risk to people during a flood defence breach at location 2.

The extent of flooding experienced in Breach 1 remains similar to that experienced in the previous assessment however the flood extent in Breach 2 is increased from that identified in the previous assessment. The flood depths for both assessments are increased by 0.56m and 0.71m for Breach 1 and Breach 2 respectively. The increased depths on Site have resulted in an increase in hazard ratings in these areas, however the majority of the Site remains within the Low hazard category.

Envireau Water
02/03/2020

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- Ref.1 Environment Agency (2013). LIDAR Tiles DTM: 2013 DTM 1M.
<https://environment.data.gov.uk/DefraDataDownload/?Mode=survey>
- Ref.2 DEFRA (2006). Flood Risks to People – Phaser 2, FD2321/TR2 Guidance Document.

FIGURES

KEY

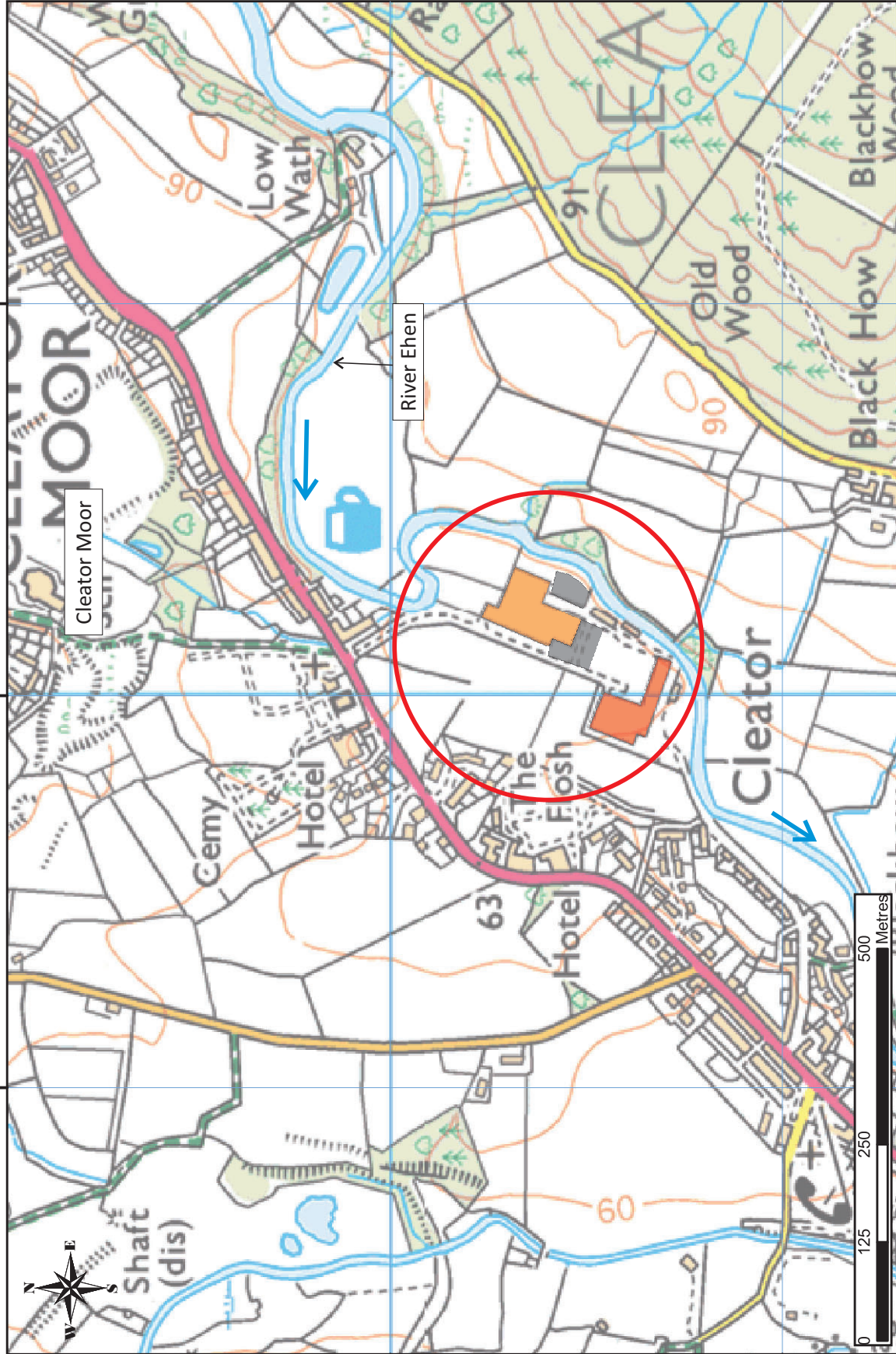
Approximate Site Area

Existing Factory

Disused Factory

Car Parking Area

Flow Direction



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Ref: P19-310 Cleator Mills Breach Assessment\FIG 1
Site Setting
Date: 27/02/2020

RWO Associates -Cleator Mills

Figure 1

Site Setting



302000

302250

514000

513750



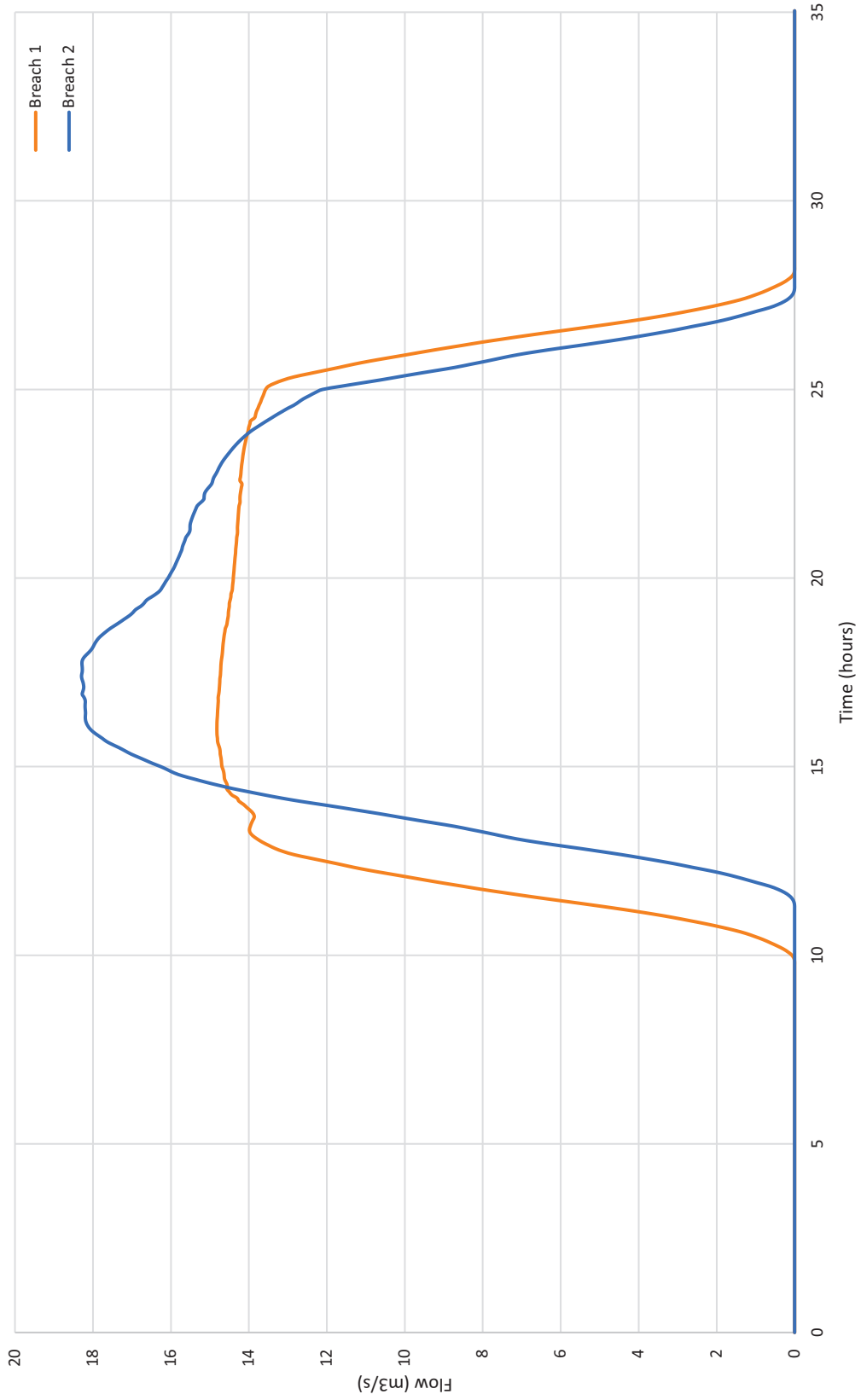
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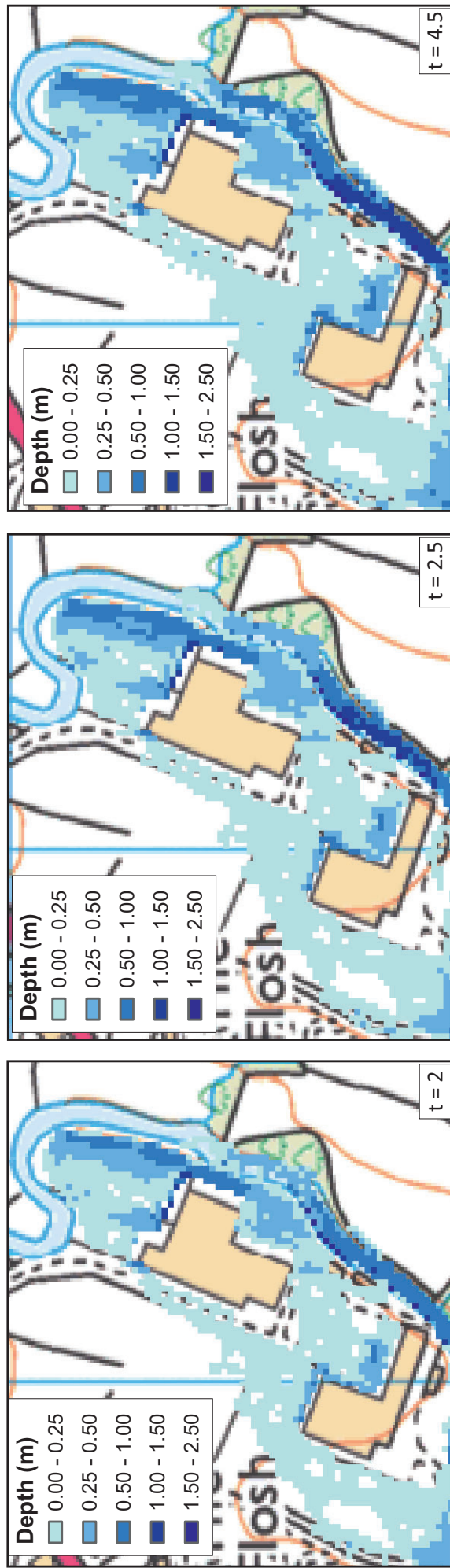
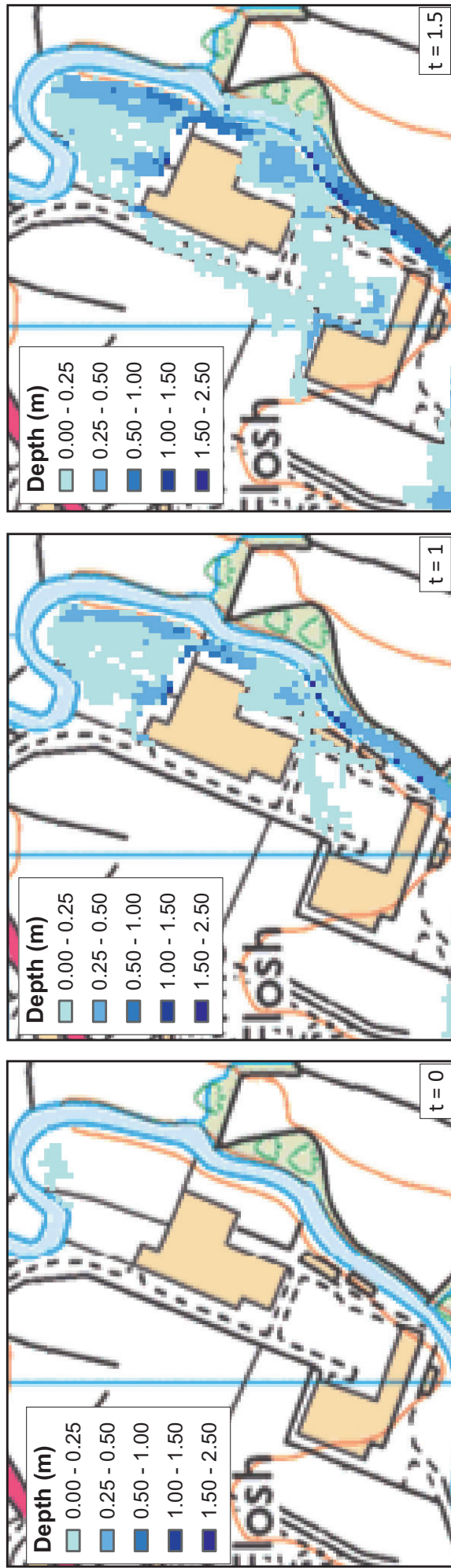
KEY

 Breach 1 Location

 Breach 2 Location

Flood Defence Breach Hydrographs



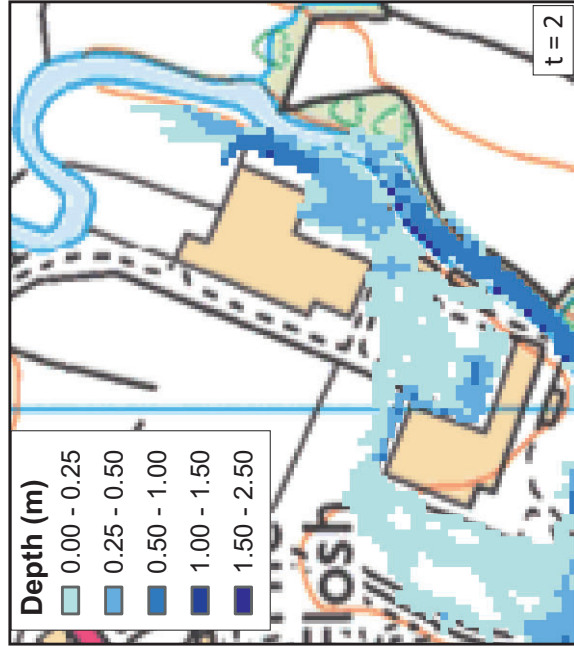
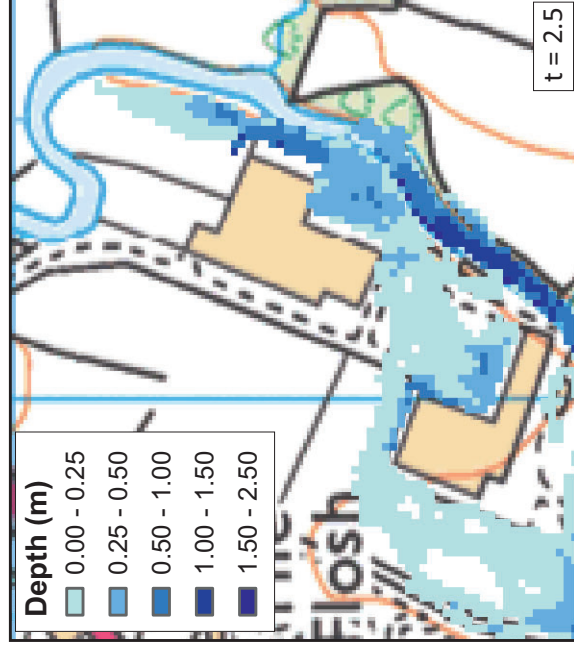
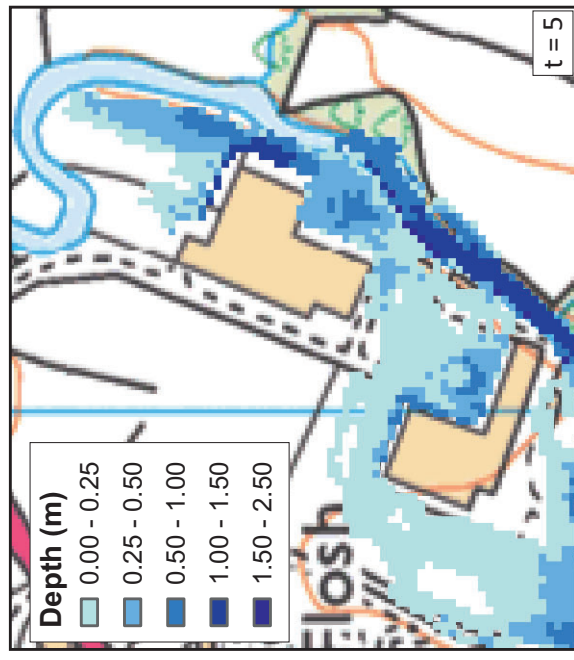
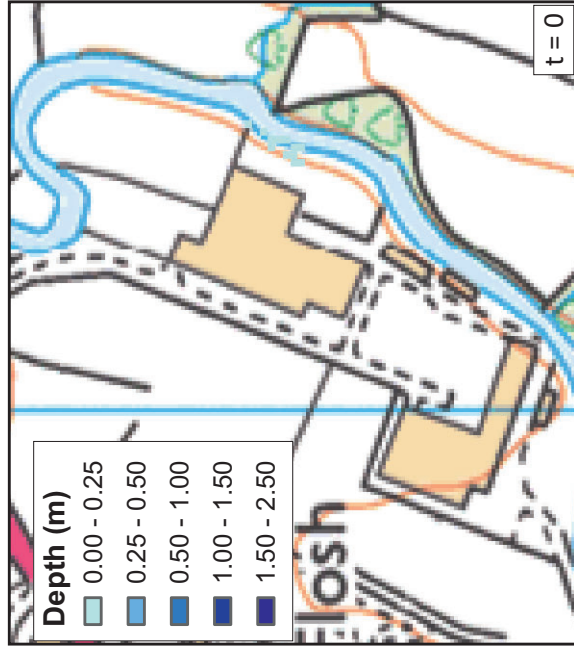
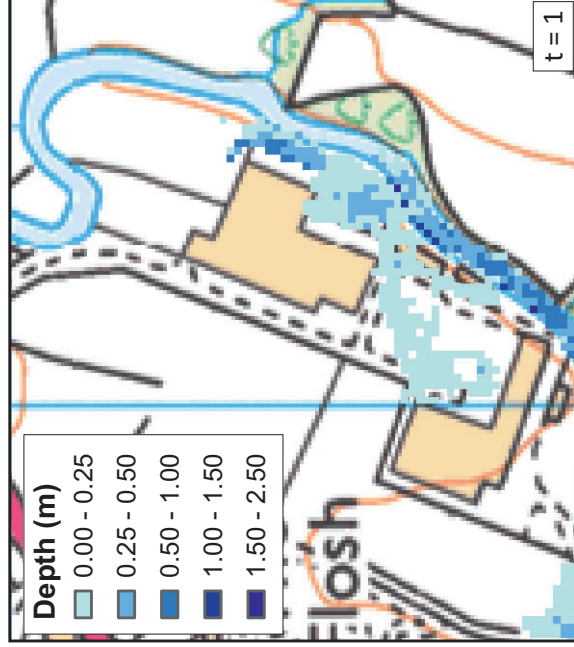
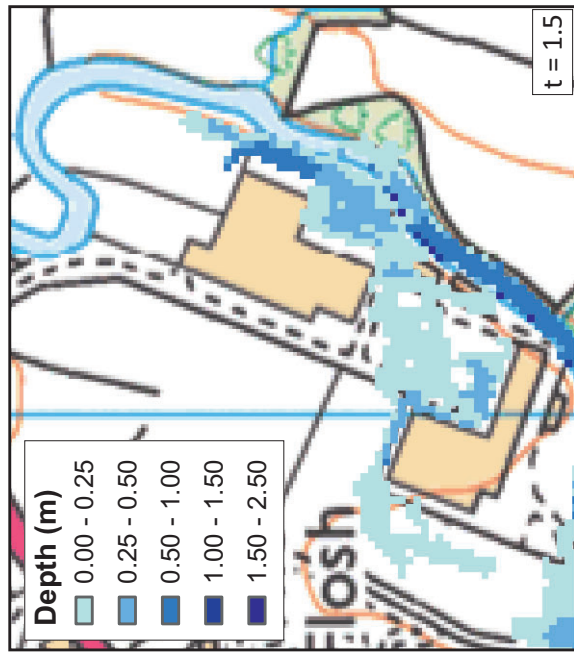


Ref: 19-310 Cleator Mills Breach Assessment\FIG 4
 B1 Flood Wave
 Date: 28/02/2020

RWO Associates - Cleator Mills

Breach 1 Flood Wave Progression

Figure 4



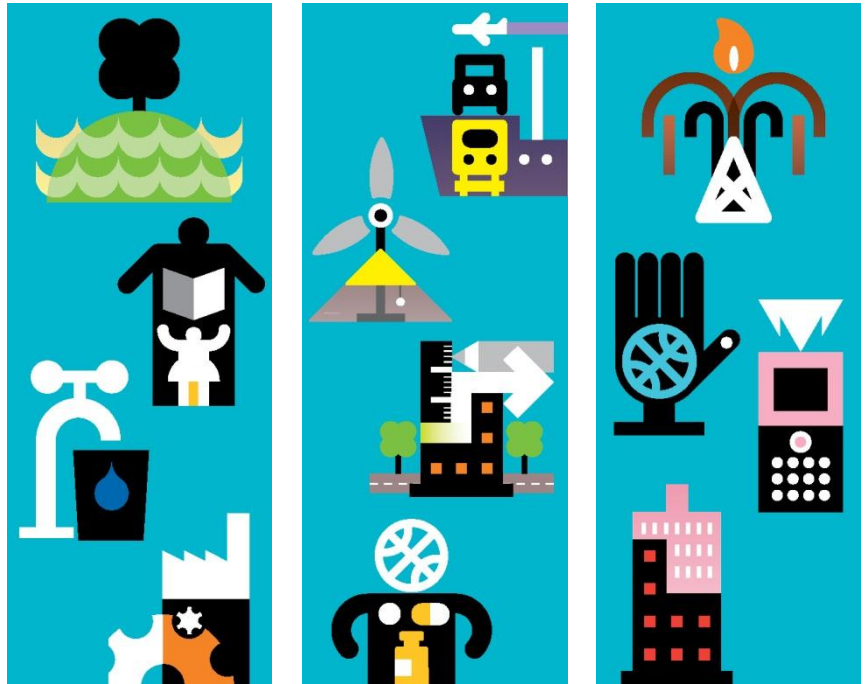
Ref: 19-310 Cleator Mills Breach Assessment\FIG 5
B2 Flood Wave
Date: 28/02/2020

RWO Associates - Cleator Mills

Breach 2 Flood Wave Progression

Figure 5

**APPENDIX A
PREVIOUS MODEL REPORT**



Updated Flood Risk Modelling - Cleator Mills Site

Modelling Report

October 2013

RWO Associates



Updated Flood Risk Modelling - Cleator Mills Site

Modelling Report

October 2013

RWO Associates

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Issue and revision record

Revision	Date	Originator	Checker	Approver	Description	Standard
A	23/10/2013	Istvan Galambos	Richard Gamble	Richard Gamble	First Issue	

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1 Introduction

1.1 Background and Objectives

Mott MacDonald has been commissioned by RWO Associates to undertake a flood defence breach analysis in the River Ehen catchment, near the Cleator Mills site at Cleator in Cumbria. This work follows on from the previous breach analysis work, which Mott MacDonald carried out for a proposed redevelopment of land on the Cleator Mills site in 2010.

The main objectives of the new study are:

- Set up and run a two-dimensional TUFLOW model with new ground survey now available;
- To map the spatial variation of depth, velocity and hazard rating across the floodplain resulting from failure of defences in two alternative locations for a fluvial flood with a return period of 100 year plus climate change.

This report describes the methodology and results of two-dimensional modelling and mapping of the River Ehen breach scenarios.

1.2 Study Area and Model Extent

The breach analyses cover an area situated to the south-east of Cleator Village, adjacent to the River Ehen. The location is shown on the map included in Appendix A. The River Ehen is located to the north and east of the Cleator Mills site. The site is divided into three sections, including the existing Kangol premises, a disused Kangol factory and a car park area.

1.3 Scope of Work

The scope of work for this study is summarised below:

- Use of the existing 2D model of the Cleator Mills site which was developed by Mott MacDonald in 2010;
- Update the model with new topographic survey information provided by RWO Associates;
- Use breach hydrographs as developed for the 2010 modelling and apply these at the same locations as for the 2010 modelling;
- Prediction of the flooding extent, flood depth, velocities and hazard ratings for the 1 in 100 year plus climate change fluvial event;
- Reporting.

2 Breach Analysis

The initial locations of defence breaches to be assessed were agreed with the Environment Agency in March 2010. Output from the existing ISIS model, developed by JBA in 2004, was used by Mott MacDonald in the 2010 study to generate breach scenario hydrographs. Hydrology and boundary inputs that form the basis of this assessment are based on the 2010 study.

2.1 Breach Constraints and Inputs

The following breach locations were used in the 2010 study:

Table 2.1: Breach Locations and Details

Breach	Location	Defence Type	Breach Width (m)	Point X	Point Y	Elevation (mAOD)	Bank
Breach 1	North of the site	Combination of gabion lined baskets and earth embankment	40	302196	513947	64.52	Right bank
Breach 2	East of the site	Earth embankment	40	302202	513840	62.49	Right bank

The following additional requirements were also agreed with the Environment Agency at the time:

- One design event to be considered: 1 in 100 year plus climate change return period;
- All of the breach locations are on a fluvial river, and therefore the following breach width and time to closure details were to be used:

Earth bank: 40m width; 36 hours to closure.

Combination of hard defence and earth bank: 40m width; 36 hours to closure.

- The start of the breach is the bank-full condition or at the peak water level if lower.

2.2 Breach Methodology

The following gives details of the method used in 2010 to model the breach hydrographs in the 1D ISIS model.

- The existing hydraulic model covers the entire reach of River Ehen, including the breaches identified in Table 2.1. The objective of the assessment was to determine a flow hydrograph through each of the breach locations. These hydrographs identified the flows leaving the main channel at these points and was then used as an input to a 2D model of the surrounding area to establish a flood extent and rate of inundation from the breach event.
- In the existing ISIS model of River Ehen, floodplains were represented by ISIS RESERVOIR units which model the rate of water accumulation in a storage pond/lake and made the assumption of a water level surface in the storage. Exchange of flow between river channel and flood cells was characterised by SPILL units representing side weir flow over the river banks.

- The breach locations were identified on the model network. Where necessary an interpolated channel cross-section was added 40m downstream to ensure the breach width of 40m was maintained. The interpolated channel cross-sections were also connected to the RESERVOIR units to ensure any excess water was spilled from the main channel onto the flood cells. This prevented any downstream water level increase, any backwater effect through the breach and also stabilised free flow conditions.
- The breaches were assumed to be formed over a single one second time step in the model runs. The breaches were assumed to form to the full extent of 40m width, thereby providing a 'worst-case' assessment for the development of the breach. The breach was taken as occurring through the full height of the embankment to the level of the surrounding land. This was represented by lowering the elevation of the right bank spill from embankment level to the elevation of the surrounding floodplain. This lower level was obtained from the LiDAR data available for the catchment (See Table 2.2).

Table 2.2: Embankment and Floodplain Levels

Breach Nr.	Embankment Elevation (mAOD)	Floodplain Elevation (mAOD)
Breach 1	64.52	62.5
Breach 2	62.49	61.0

3 2D Hydrodynamic Modelling

3.1 Introduction

The main purpose of this study was to assess the flood extent in the event of flood defence breach for the 100 year plus climate change fluvial event.

The approach to hydraulic modelling has comprised the following stages:

Step 1: constructing a two-dimensional hydraulic model incorporating the new topographic data made available by RWO Associates;

Step 2: breach analysis using the breach hydrographs generated in 2010 study;

Step 3: predicting flood extent for the specified fluvial return period (1 in 100 year plus climate change);

Step 4: producing flood extent, depth, velocity and hazard maps.

3.2 Model Build

The proposed development site is located to the south-east of the village of Cleator adjacent to the River Ehen. The extent of the model was estimated so that the model would include a sufficient length of the River Ehen within the model, whilst also including the Cleator Mills site that has a theoretical chance of flooding. Two breach locations are identified in the study area, as described in Table 2.1.

3.2.1 Digital Terrain Model

The Digital Terrain Model (DTM) for the Cleator Mills area was produced using 1m resolution LiDAR and ground based topographic survey data. In order to ensure that channel volume was not available to flood waters (since during a breach scenario channels are assumed to be full to bank-top) the DTM along channel lengths was raised to bank-top levels.

The topographic survey (North Associates - Kangol Factory, Cleator_topo.dwg) was provided by RWO Associates. The survey data was recorded in local coordinate system, therefore the first step was to transform it to the national coordinate system. After the transformation the 2d_zsh feature of TUFLOW was used to incorporate the survey into the DTM.

The TUFLOW model comprises of a grid of the Cleator Mills area, with grid points (z points) assigned elevations from the above mentioned sources. Details of the grid used for modelling the River Ehen at Cleator Mills are summarised in Table 3.1 below.

Table 3.1: Cleator Mills TUFLOW Model Grid Details

Grid Information	
Grid size (spacing)	7m
Origin	301,135N, 512,883E (British National Grid)
Orientation	0 degrees
Width of grid (in the east direction)	2.16km
Height of grid (in the north direction)	2.15km

A grid size of 7m was used as this is of sufficient detail for flood mapping, whilst not being so small as to result in unacceptably long model run times.

3.2.2 Boundary Conditions

The upstream boundary of the model is a flow-time boundary condition. Breach hydrographs were extracted at SPILL units connected to the model river cross-sections at each breach location for the 100 year plus climate change fluvial event. The breach hydrographs were developed in the 2010 modelling study and have been used in this updated study without modification. The breach hydrographs are shown on Figure 3.1

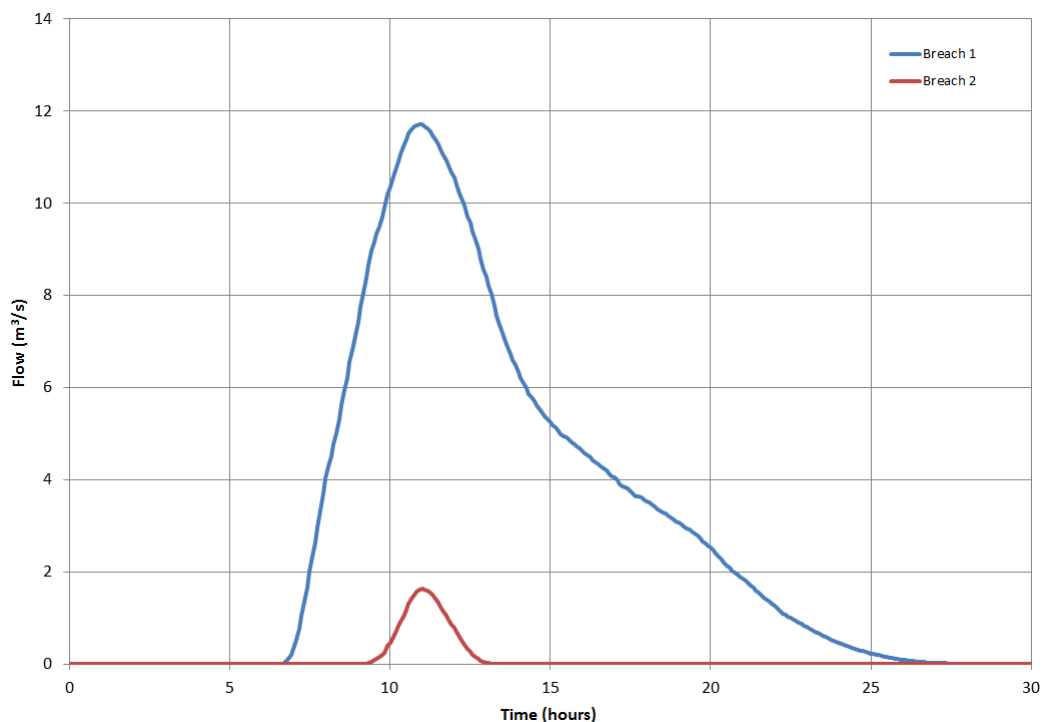


Figure 3.1 – Breach hydrographs

3.2.3 Manning's n

Land classification within the TUFLOW model determines the roughness values (Manning's n) of each land type, and therefore the resistance that is provided by the land to the flood water. For this study, a detailed land classification was used, as outlined in Table 3.2.

Table 3.2: Summary of Manning's n Values Used in the Model

Terrain Type	Roughness
Water	0.035
Grassed floodplain	0.055
Buildings	0.300
Woodland	0.120
Roads and railways	0.020

3.3 Flood Hazard Classification

Hazard rating has been defined in the *Supplementary Note on Flood Hazard ratings and Thresholds for Development Planning and Control Purpose – Classification of the Table 13.1 of FD2320/TR2 and Figure 3.2 of FD2321/TR1* (Defra 2008). Hazard rating is calculated from depth, velocity and a debris factor at each time step in the model using the following equation:

$$HR = d (v + 0.5) + DF$$

where, HR = (flood) hazard rating;

d = depth of flooding (m);

v = velocity of floodwaters (m/s); and

DF = debris factor (0, 0.5, 1 depending on probability that debris will lead to a hazard).

The debris factor was based on the conservative land use classification. It varies with depth and velocity of flooding as shown in Table 3.3.

Table 3.3: Guidance on debris factors for different flood depths, velocities and dominant land use (from Table 4.2 in Flood Risks to People)

Depth (d)/Velocity (v)	Debris Factor based on Conservative Land Use
d = 0 to 0.25m	0.5
d = 0.25 to 0.75m	1.0
d > 0.75 and/or v > 2m/s	1.0

Hazard rating has been classified into four categories in the *Supplementary Note on Flood Hazard ratings and Thresholds for Development Planning and Control Purpose – Clarification of the Table 13.1 of FD2320/TR2 and Figure 3.2 of FD2321/TR1* (Defra, 2008) for emergency planning purposes.

Table 3.4 summarises the four categories. This classification has been used in the description of the results.

Table 3.4: Hazard to People as a Function of Velocity and Depth

Hazard Rating	Degree of Flood Hazard	Elevation (m AOD) Bank
<0.75	Low	Caution "Flood zone with shallow flowing water or deep standing water"
0.75 – 1.25	Moderate	Dangerous for some (e.g. children) "Danger: Flood zone with deep or fast flowing water"
1.25 – 2.0	Significant	Dangerous for most people "Danger: flood zone with deep fast flowing water"
>2.0	Extreme	Dangerous for all "Extreme danger: flood zone with deep fast flowing water"

3.4 Scenarios Modelled

Two scenarios using the above methodology have been modelled for the 1 in 100 year plus climate change event. These scenarios are listed in Table 3.5 below:

Table 3.5: Scenarios Modelled

Breach Nr.	Design Event
Breach 1	100 year plus climate change
Breach 2	100 year plus climate change

Appendix A shows the location of breaches.

4 Results

4.1 Breach 1

A breach in the gabion lined baskets north of the site has been considered for the 1 in 100 year plus climate change event. The approximate location of the breached defence is indicated on the Appendix A. A breach of the flood defence was assumed to occur when the river was at bank-full downstream. During a breach for the 100 year plus climate change event, floodwaters flow onto the floodplain (see Figure 4.1), flooding the existing premises, car park area and the disused factory building downstream of the site. Some of the floodwaters flow back into the River Ehen near the downstream end of the existing Kangol premises. Flood depths in the vicinity of the breach are fairly significant reaching up to 0.90 m near this building.

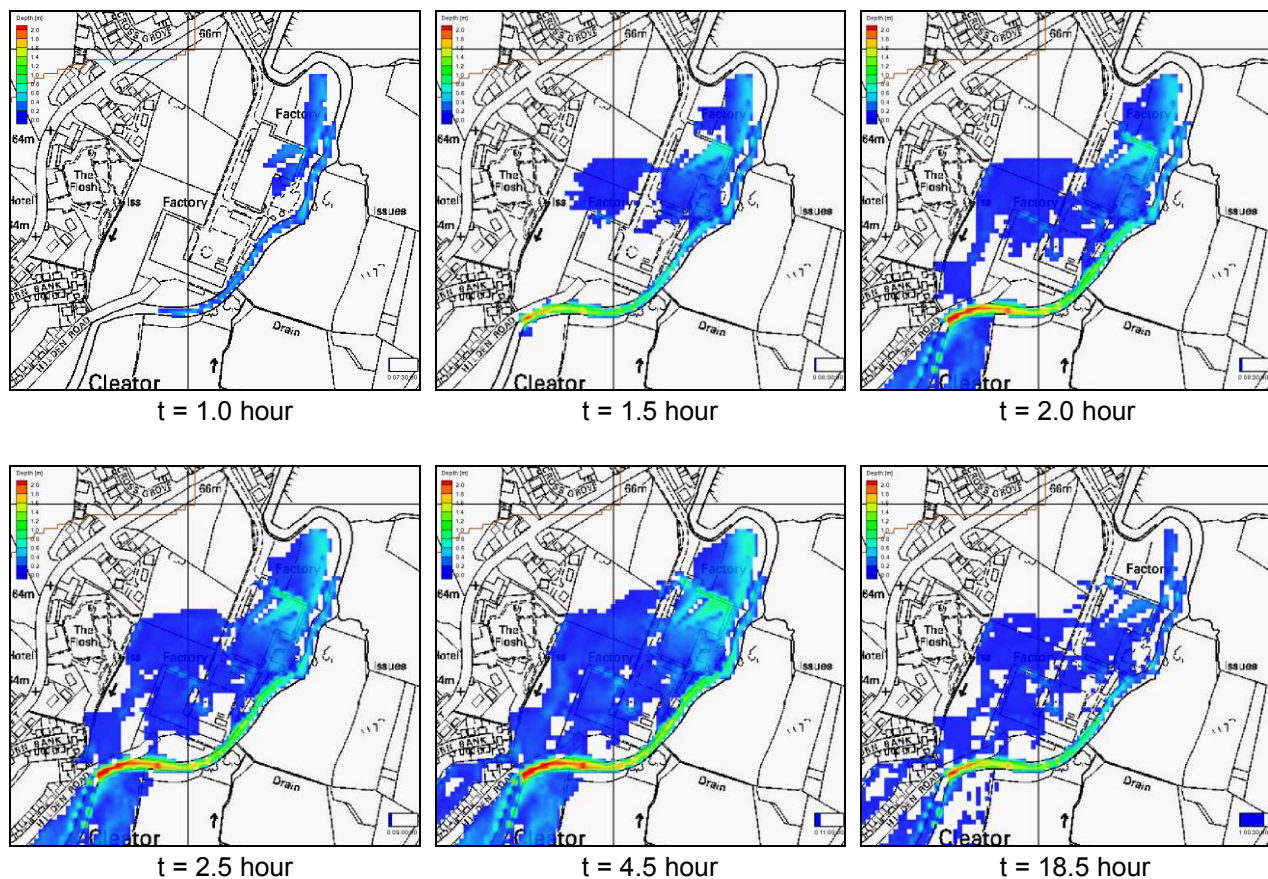


Figure 4.1 – Progress of flood wave from Breach 1

The hazard rating was generally low (0 to 0.75) throughout the site, although this was observed to be greater in the areas of deeper waters. There are areas, in the vicinity of the Kangol Building where the hazard rating is significant (1.25 to 2) implying that it is dangerous for most people.

4.2 Breach 2

A breach in the earth flood embankment east of the site was considered for the 100 year plus climate change event. The approximate location of the breached flood embankment is shown on Appendix A. For this analysis it has been assumed that the River Ehen was bank-full downstream of the breached

embankment. During a breach, floodwaters spread onto the floodplain (see Figure 4.2), inundating the Kangol premises, and then flow through parts of the car park area and the disused factory building. Flood depths generally remain low (0 to 0.25m) through the site, although there are small areas in the vicinity of the Kangol building where there is deeper flooding of up to 0.5m. The flood hazard rating of the breach floodwaters is low (0 to 0.75) as the depth of flooding is shallow (less than 0.25m) and the velocities are low (less than 0.3m/s) with the exception of a few areas in the vicinity of the existing building (0.8m/s).

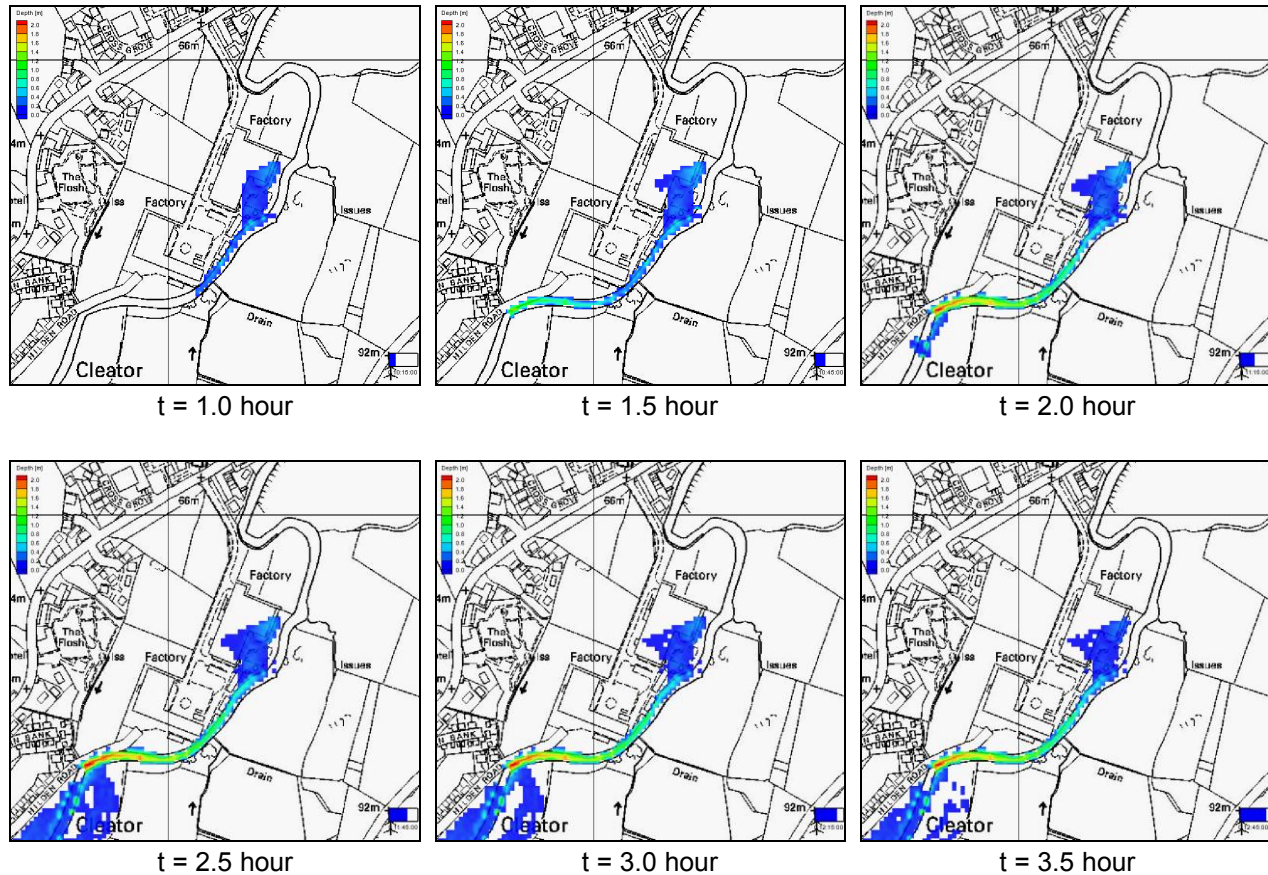


Figure 4.2 – Progress of flood wave from Breach 2

5 Flood Mapping

Flood maps have been produced from the outputs of the 2D modelling. The maps show maximum water level, flood depth, velocities and hazard rating for all of the scenarios which have been modelled. Table 5.1 summarises the flood maps located in Appendix B and discussed in Section 4.

Table 5.1: Summary of Flood Maps

Drawing No.	Parameter Shown	Breach Location	Return Period
1.01	Depth	Breach 1	100 year + 20%
2.01	Velocity	Breach 1	100 year + 20%
3.01	Water Level	Breach 1	100 year + 20%
4.01	Hazard Rating	Breach 1	100 year + 20%
1.03	Depth	Breach 2	100 year + 20%
2.03	Velocity	Breach 2	100 year + 20%
3.03	Water Level	Breach 2	100 year + 20%
4.03	Hazard Rating	Breach 2	100 year + 20%

6 Assumptions and Limitations

The model and input data are based on the following assumptions:

- River channel is bank-full downstream of breach locations.
- Flood defences and embankment levels used in the existing ISIS model are correctly representing the study area.
- The ISIS model accounts for surface runoff in the study area.

The model has several limitations which should be understood before applying the findings of this report:

- Models are not calibrated or verified, owing to lack of observed historic data.
- LiDAR data has verified accuracy of +/- 150mm.

7 Conclusions

The outputs from the updated Cleator Mills FRA Breach Analysis facilitate the assessment of extent and severity of flooding in the event of breaches in the fluvial defences. The breach hydrographs used were those produced in the previous breach analysis (2010) and are for the 100 year plus climate change event, based on best available data at the time.

Breach hydrographs were input as flow-time boundary conditions into the 2D TUFLOW model. The 2D model covered areas adequate to model the full extent of flood waters, using a grid size of 7m.

It was observed that the extent of flooding south of the breached gabion lined baskets (Breach 1) was significant. Areas affected were mainly near the existing Kangol premises, car park area and the disused factory building downstream of the site. Hazard rating was generally low through the site, with the exception of a few areas in the vicinity of the existing building. Flood waters were observed to be deeper in these areas (up to 0.9 m), and the hazard rating was identified to be significant (1.25 to 2) implying that it is dangerous for most people.

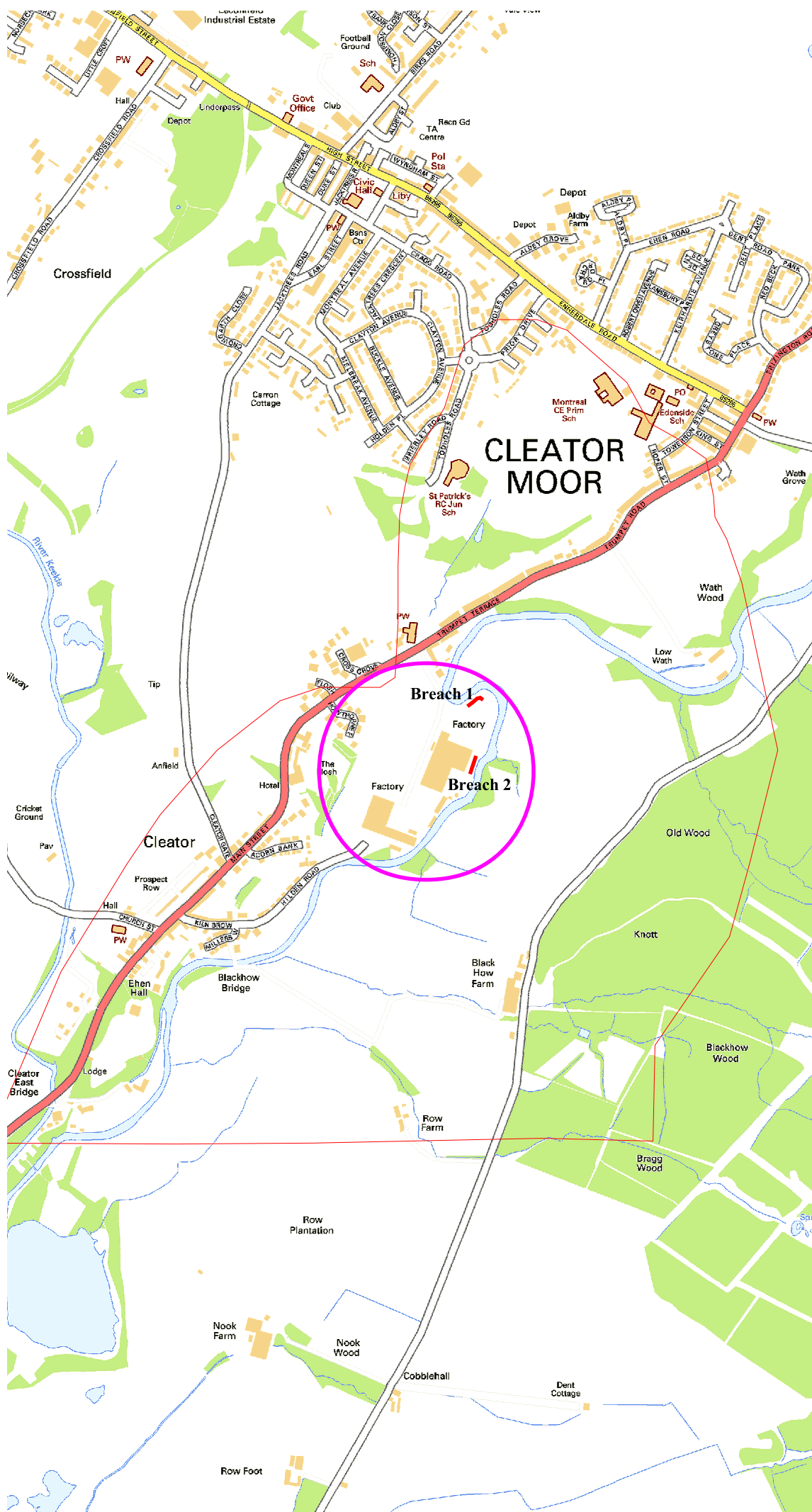
During a breach in the earth embankment east of the site (Breach 2), floodwaters covered the existing building and parts of the car park area. Flood depths generally remained low (0 to 0.25m) through the site, although there were small areas in the vicinity of the factory building where there was deeper flooding of up to 0.5m. The flood hazard rating of the breach floodwaters was low (0 to 0.75) as the depth of flooding was shallow (less than 0.25m) and the velocities were low (less than 0.3m/s) with the exception of a few areas in the vicinity of the existing building (0.8m/s).

The extent and severity of flooding predicted for both breaches is very similar to that predicted in the 2010 study. The additional ground based topographic data now available indicates that the area to north-west of the existing factory are lower than given by LiDAR data used in 2010. This results in greater flood extent in this area. However maximum values of flood depth, velocity and hazard around the site has not significantly changed.

Appendices

Appendix A. Study Area	15
Appendix B. Flood Maps	16

Appendix A. Study Area



KEY PLAN



LEGEND

Extent of 2D Domain

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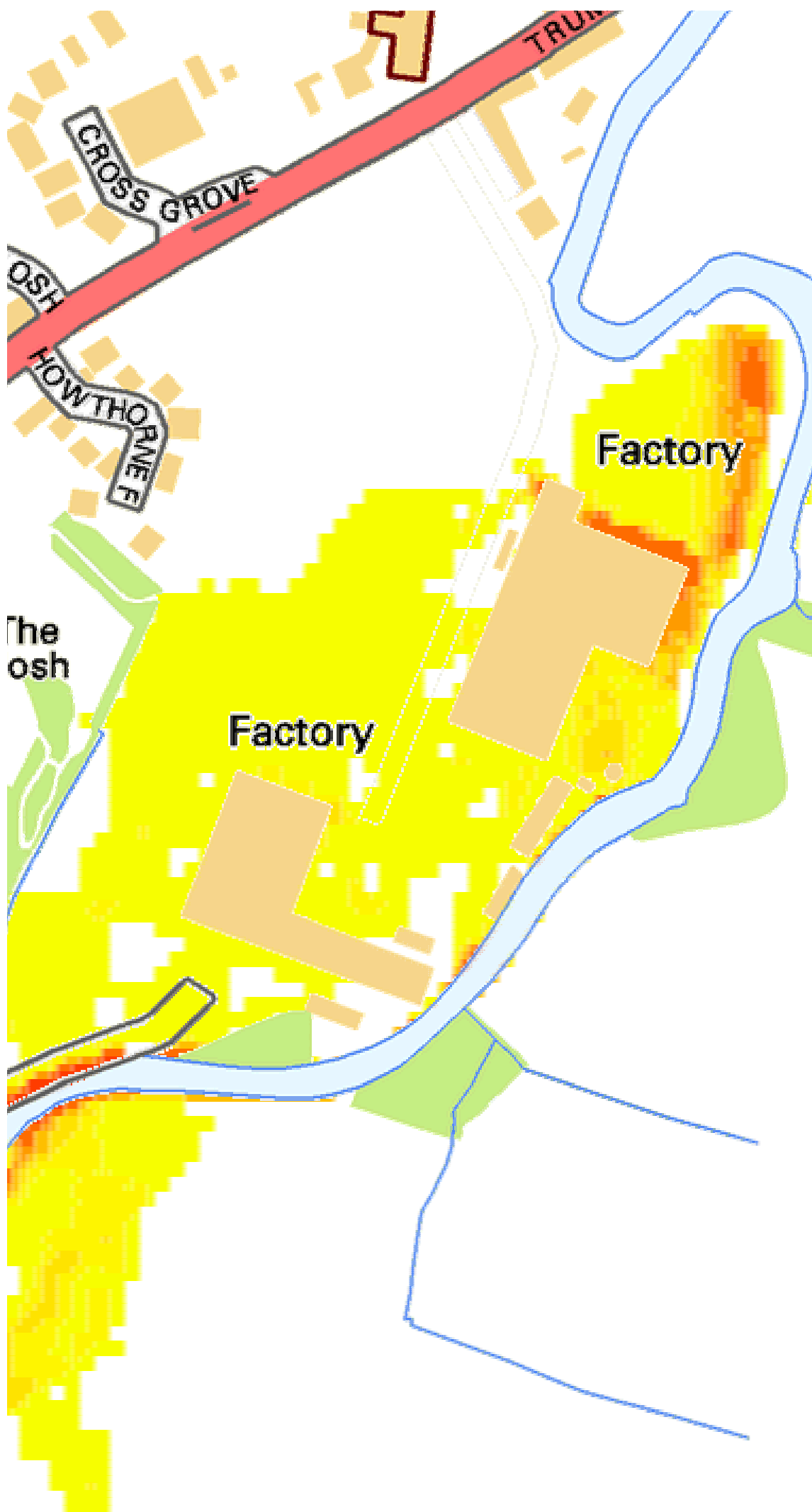
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Project Title
Flood Risk Modelling - Cleator Mill Site

Map Title
2D Model Extent

Date / Revision	14/10/2013
Modelled	IG
Checked	RJG
Approved	RJG
Drawing No.	0.01
Drawing Scale at A3	1:5000

Appendix B. Flood Maps



KEY PLAN

LEGEND

Depth [m]

< 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 1.0
1.0 - 2.0
2.0 - 3.0
> 3.0

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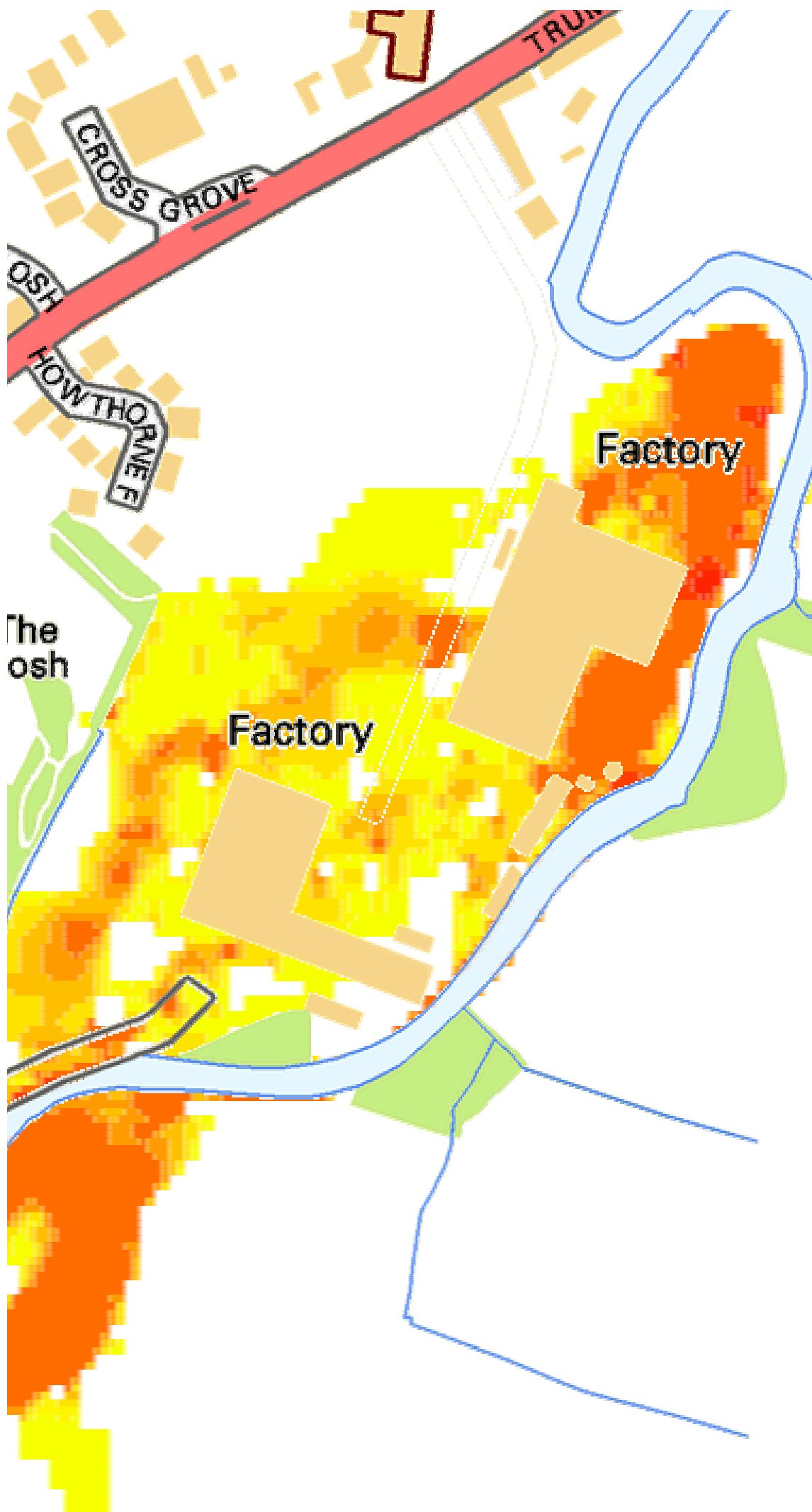
Project Title

Flood Risk Modelling - Cleator Mill Site

Map Title

Maximum flood depth for breach 1 (DTM 2013)

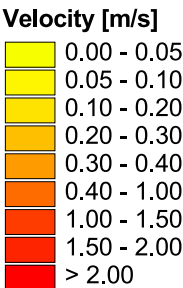
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Checked	RJG
Approved	RJG
Drawing No.	1.01
Drawing Scale at A3	1:1100



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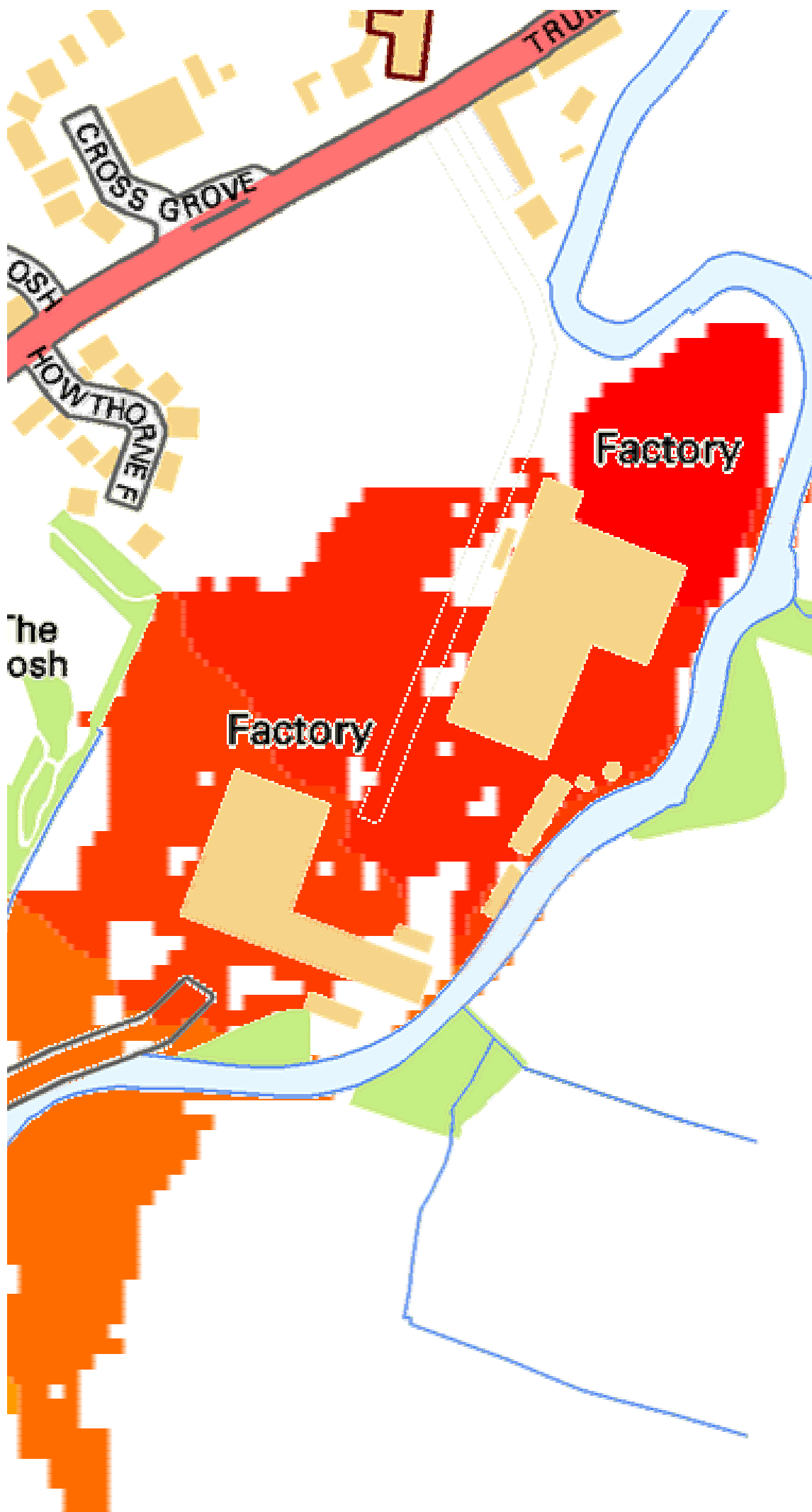


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Project Title
Flood Risk Modelling - Cleator Mill Site

Map Title
Maximum flow velocity for breach 1
(DTM 2013)

Date / Revision	14/10/2013
Modelled	IG
Checked	RJG
Approved	RJG
Drawing No.	2.01
Drawing Scale at A3	1:1100

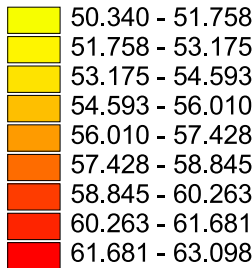


KEY PLAN



LEGEND

Water Level [mAD]



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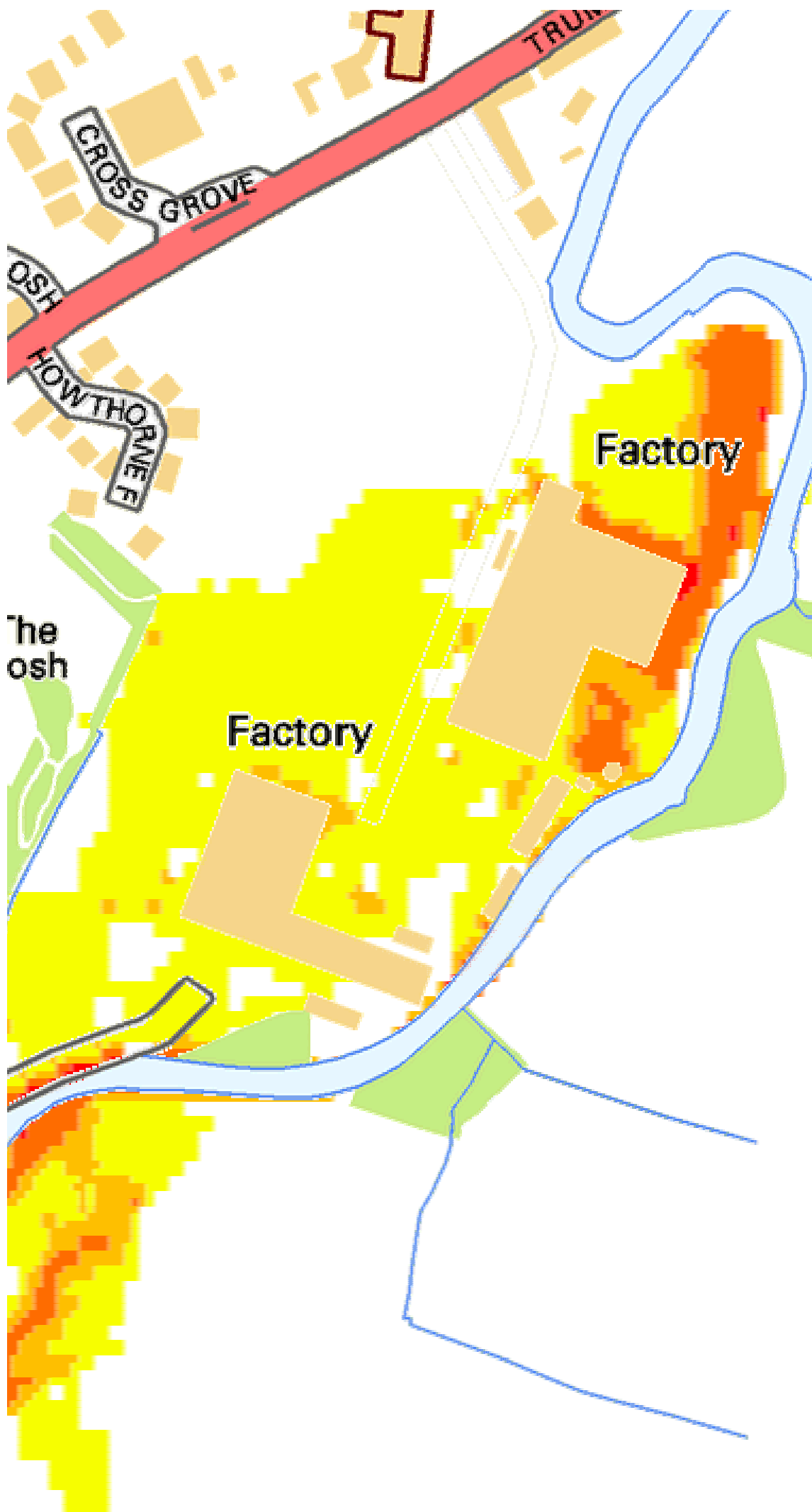


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Project Title
Flood Risk Modelling - Cleator Mill Site

Map Title
Maximum water level for breach 1
(DTM 2013)

Date / Revision	14/10/2013
Modelled	IG
Checked	RJG
Approved	RJG
Drawing No.	3.01
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KEY PLAN



LEGEND

Flood Hazard Category

- Low
- Moderate
- Significant
- Extreme

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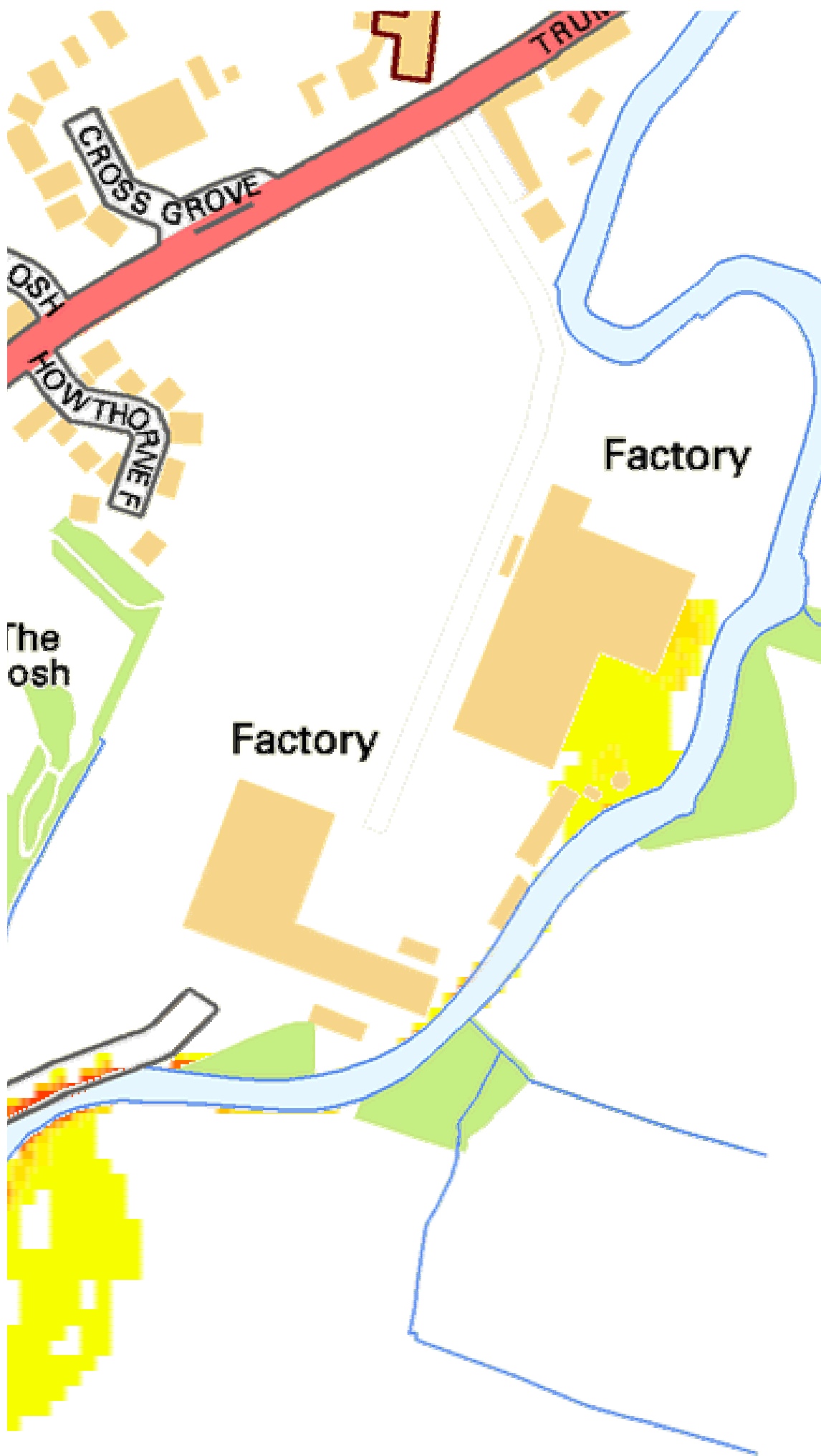


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Project Title
Flood Risk Modelling - Cleator Mill Site

Map Title
Hazard categories for breach 1
(DTM 2013)

Date / Revision	14/10/2013
Modelled	IG
Checked	RJG
Approved	RJG
Drawing No.	4.01
Drawing Scale at A3	1:1100

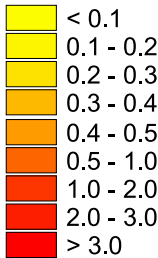


KEY PLAN



LEGEND

Depth [m]



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CB1 2RS
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Fax: 01223 461007
www.mottmac.com

Project Title

Flood Risk Modelling - Cleator Mill Site

Map Title

Maximum flood depth for breach 2
(DTM 2013)

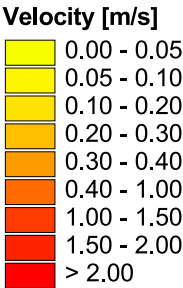
Date / Revision	14/10/2013
Modelled	IG
Checked	RJG
Approved	RJG
Drawing No.	1.03
Drawing Scale at A3	1:1100



KEY PLAN



LEGEND



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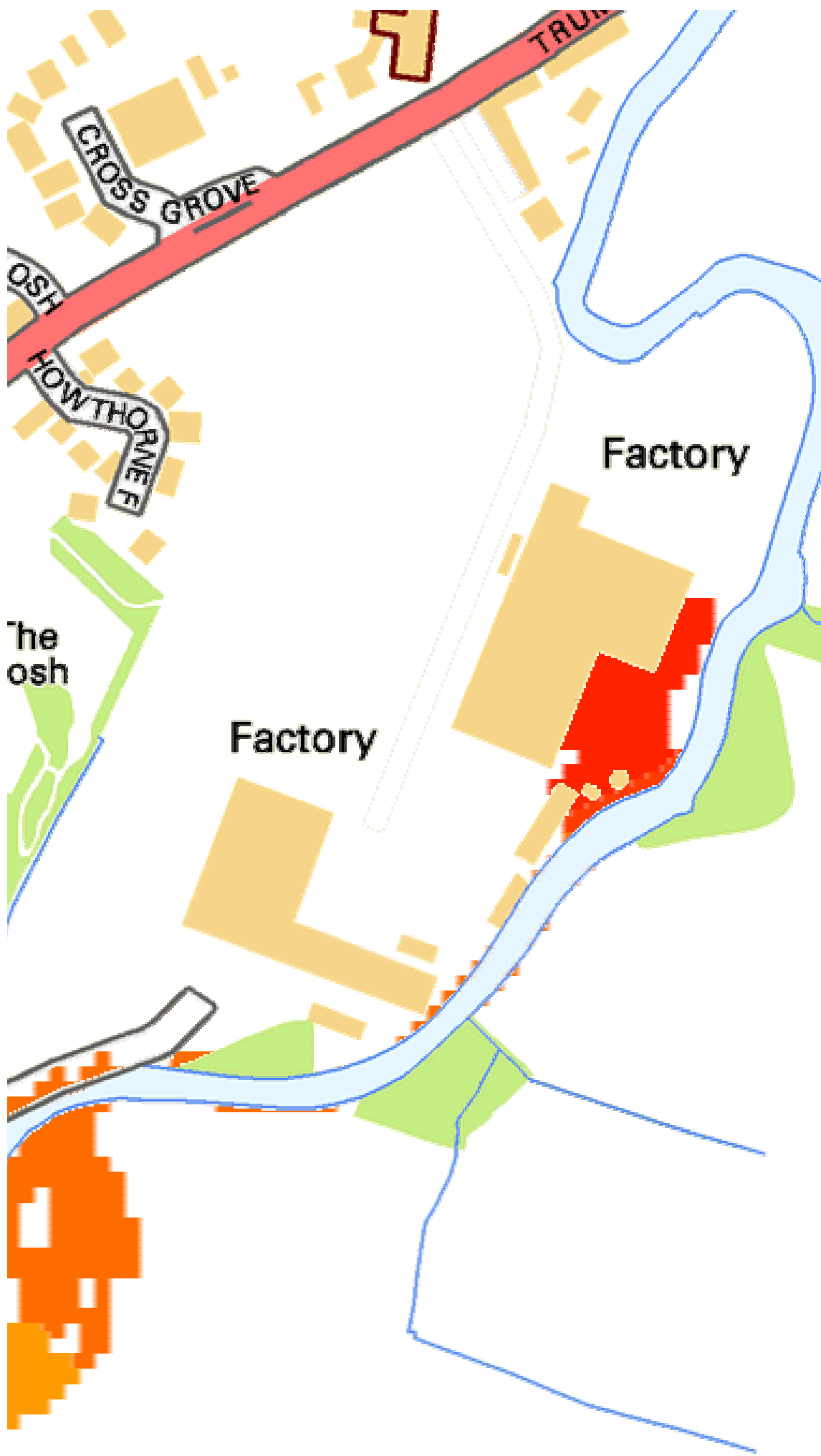


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Project Title
Flood Risk Modelling - Cleator Mill Site

Map Title
Maximum flow velocity for breach 2 (DTM 2013)

Date / Revision	14/10/2013
Modelled	IG
Checked	RJG
Approved	RJG
Drawing No.	2.03
Drawing Scale at A3	1:1100

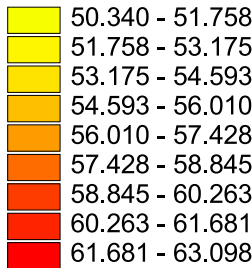


KEY PLAN



LEGEND

Water Level [mAD]



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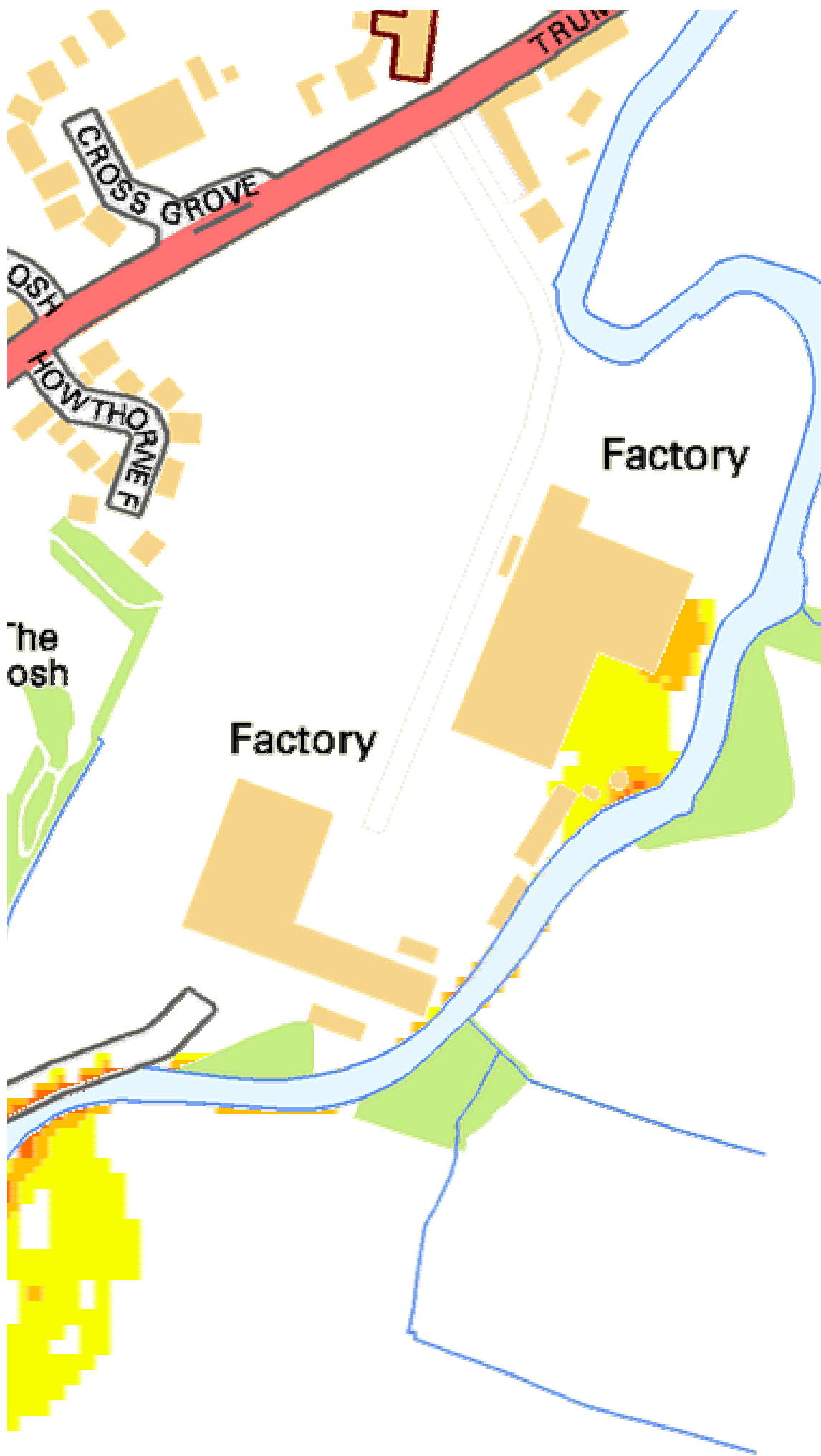
Project Title

Flood Risk Modelling - Cleator Mill Site

Map Title

Maximum water level for breach 2
(DTM 2013)

Date / Revision	14/10/2013
Modelled	IG
Checked	RJG
Approved	RJG
Drawing No.	3.03
Drawing Scale at A3	1:1100



LEGEND

Flood Hazard Category

- Low
- Moderate
- Significant
- Extreme

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Project Title

Flood Risk Modelling - Cleator Mill Site

Map Title

Hazard categories for breach 2 (DTM 2013)

Date / Revision	14/10/2013
Modelled	IG
Checked	RJG
Approved	RJG
Drawing No.	4,03
Drawing Scale at A3	1:1100

APPENDIX B
RWO ASSOCIATES TOPOGRAPHICAL SURVEY

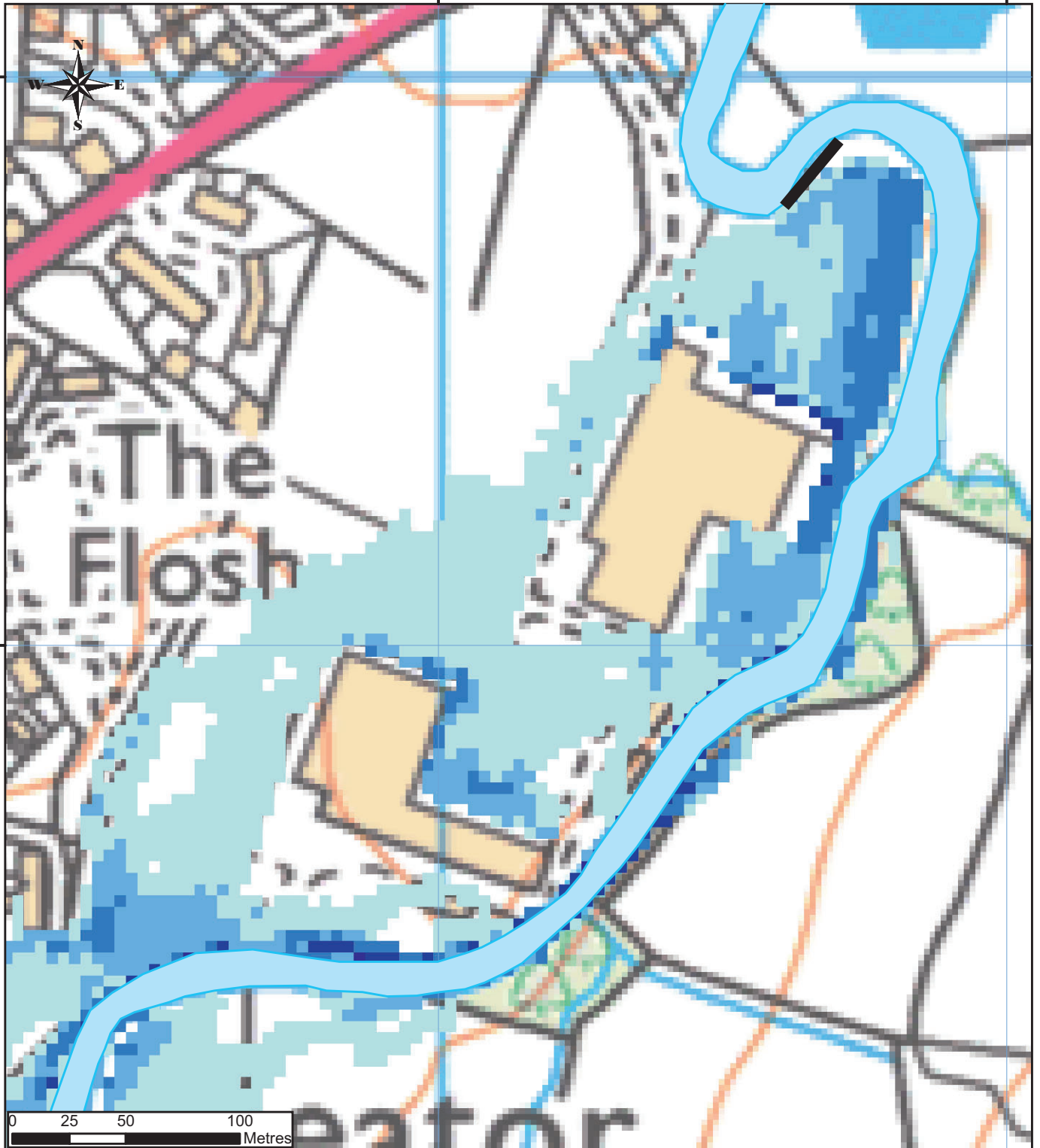
APPENDIX C
BREACH 1 FLOOD MAPS – FIGURES 6A, 6B, 6C AND 6D

302000

302250

514000

513750



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Flood Depth (m)

	0.01 - 0.25
	0.25 - 0.50
	0.50 - 1.00
	1.00 - 1.50
	1.50 - 2.50

KEY

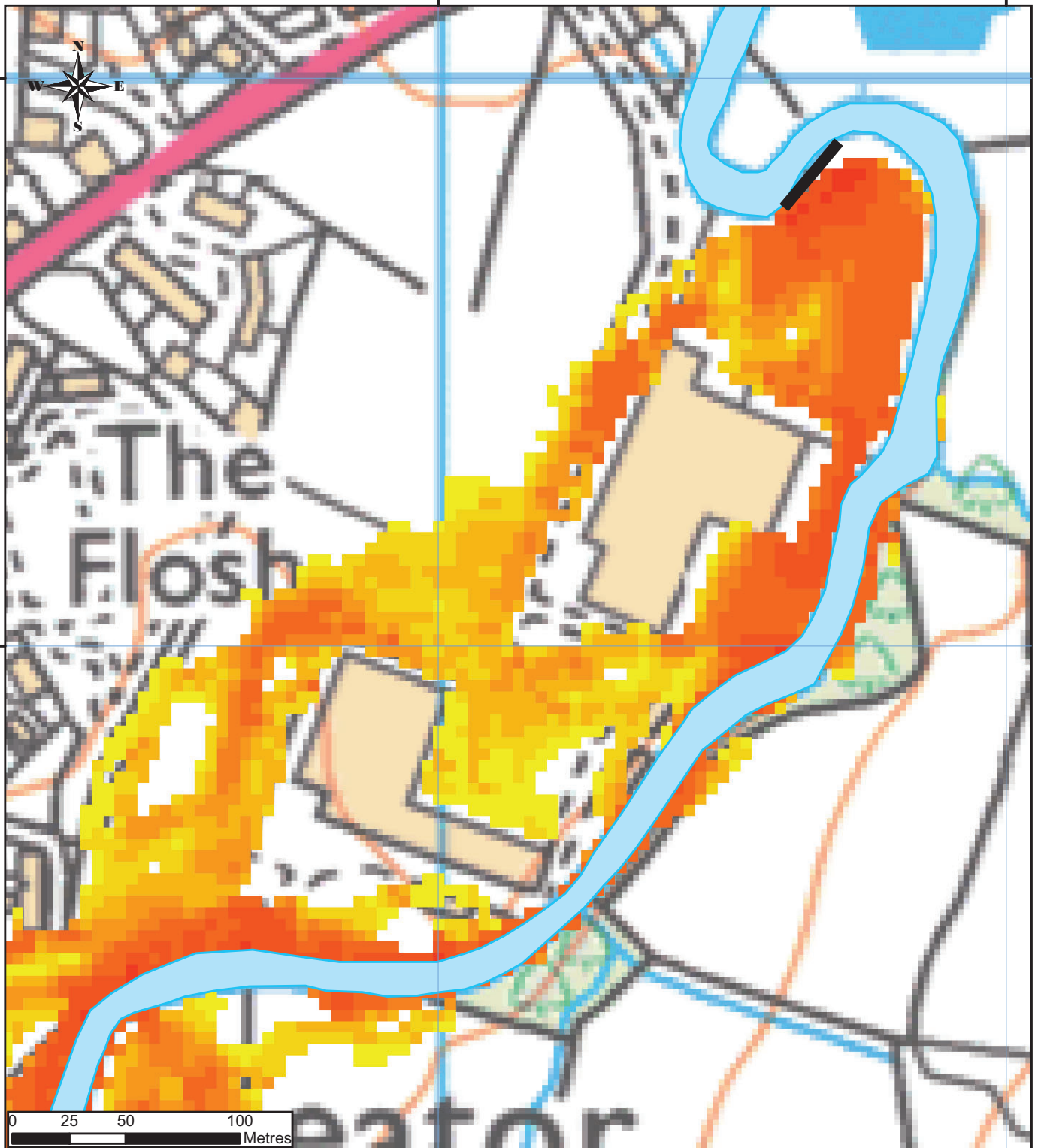
	Breach 1 Location
	River Ehen

302000

302250

514000

513750



KEY

Velocity (m/s)

	< 0.1		0.5 - 1.0
	0.1 - 0.2		1.0 - 2.0
	0.2 - 0.3		2.0 - 3.0
	0.3 - 0.4		> 3
	0.4 - 0.5		

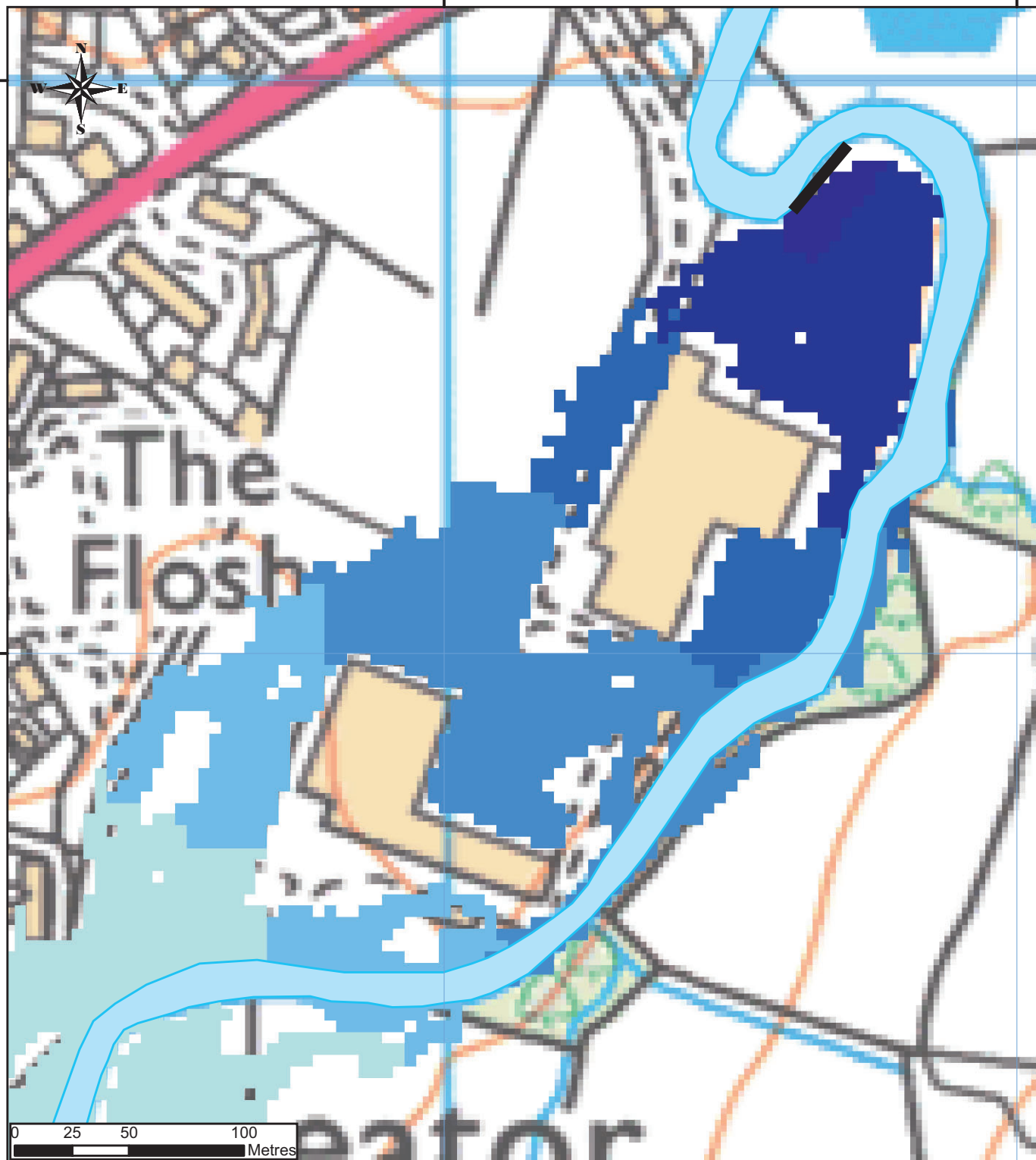
- Breach 1 Location
- River Ehen

302000

302250

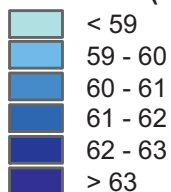
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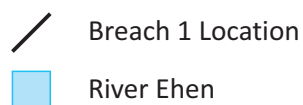


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WaterLevel (mAOD)



KEY

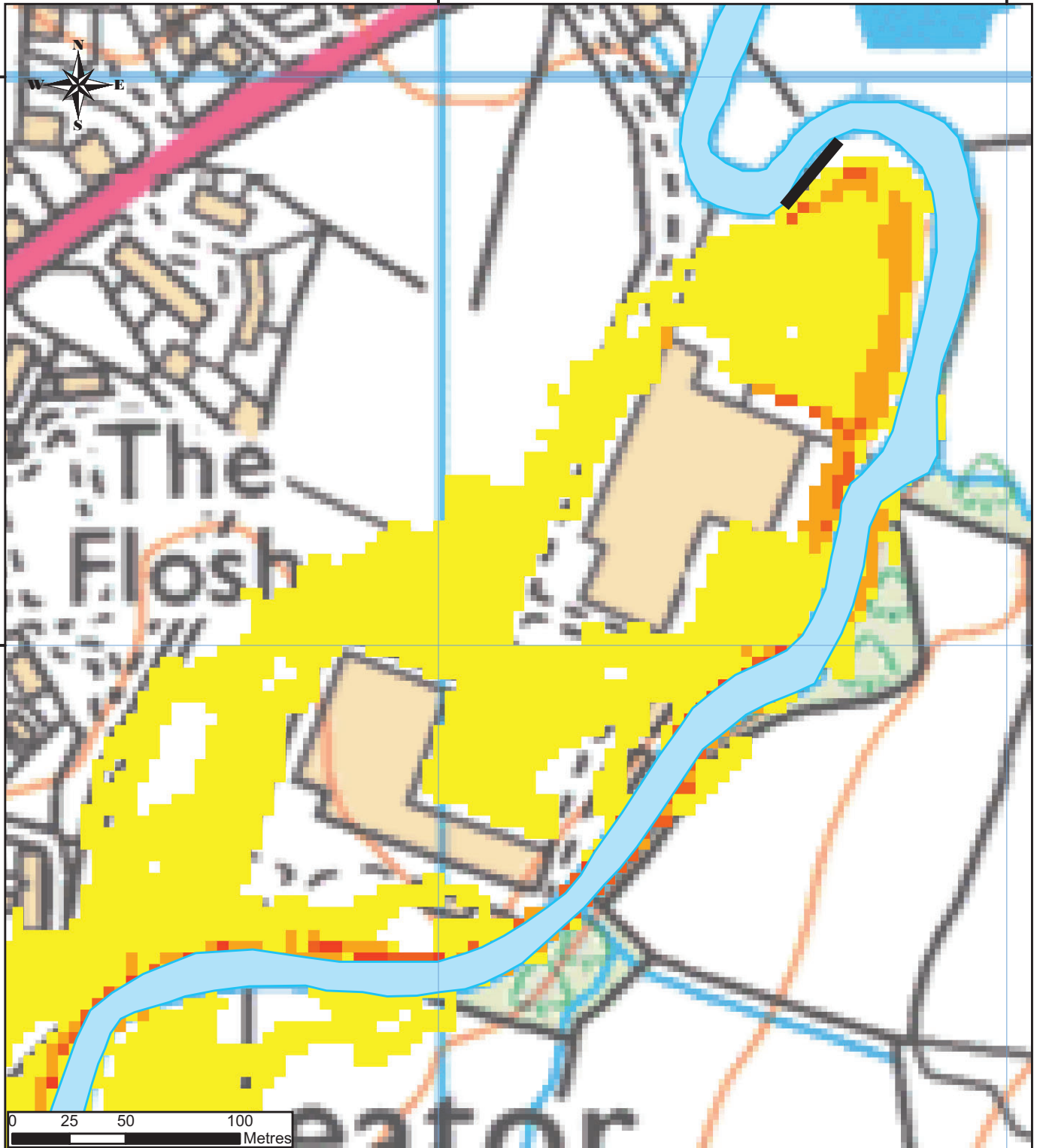


302000

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Flood Hazard Category

- Low
- Moderate
- Significant
- Extreme

KEY

- Breach 1 Location
- River Ehen

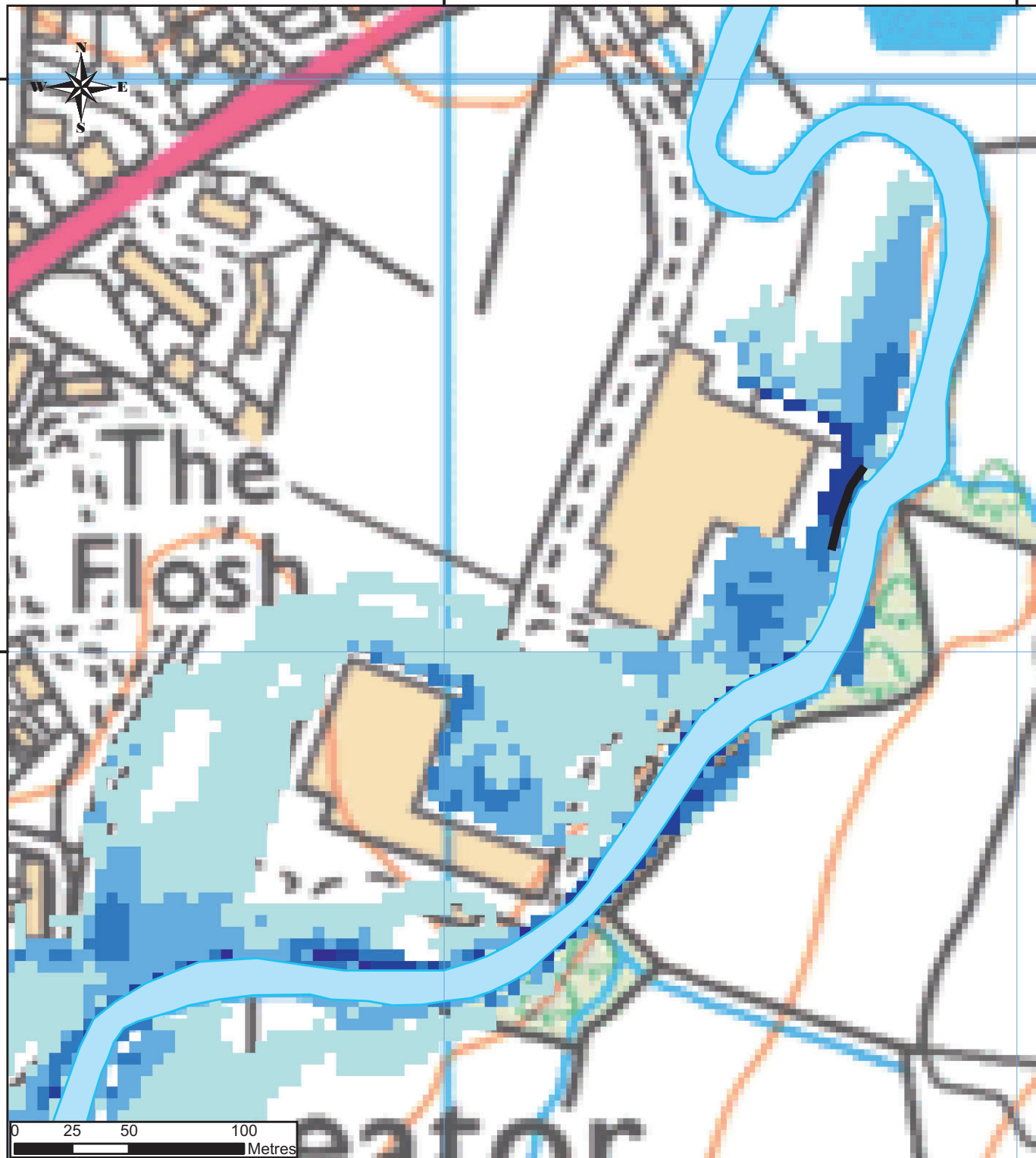
APPENDIX C
BREACH 2 FLOOD MAPS – FIGURES 7A, 7B, 7C AND 7D

302000

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514000

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Flood Depth (m)

0.01 - 0.25
0.25 - 0.50
0.50 - 1.00
1.00 - 1.50
1.50 - 2.50

KEY

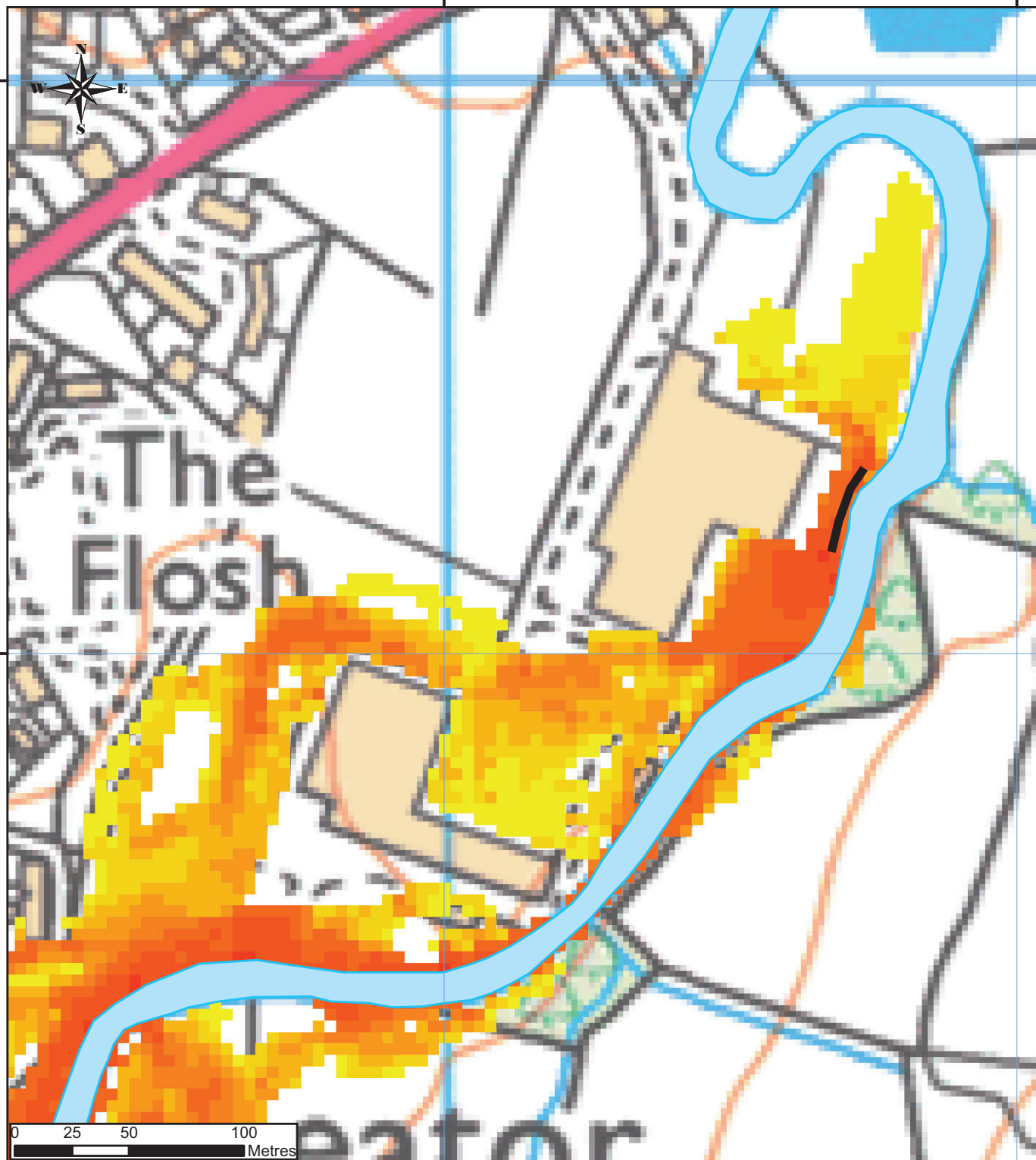
	Breach 2 Location
	River Ehen

302000

302250

514000

513750



KEY

Velocity (m/s)

	< 0.1		0.5 - 1.0
	0.1 - 0.2		1.0 - 2.0
	0.2 - 0.3		2.0 - 3.0
	0.3 - 0.4		> 3
	0.4 - 0.5		

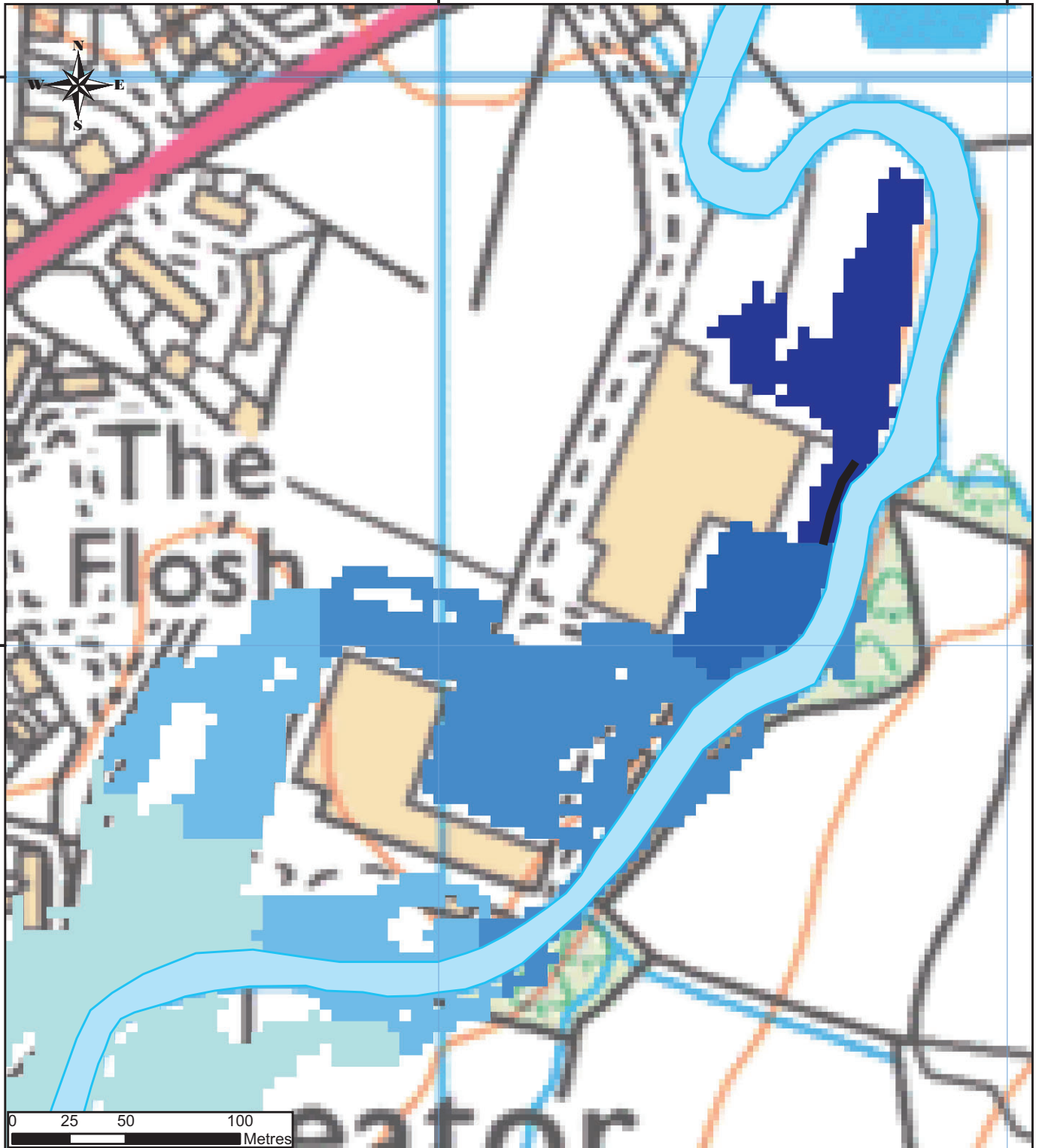
- Breach 2 Location
- River Ehen

302000

302250

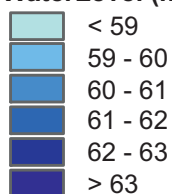
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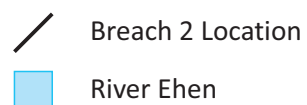


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WaterLevel (mAOD)



KEY

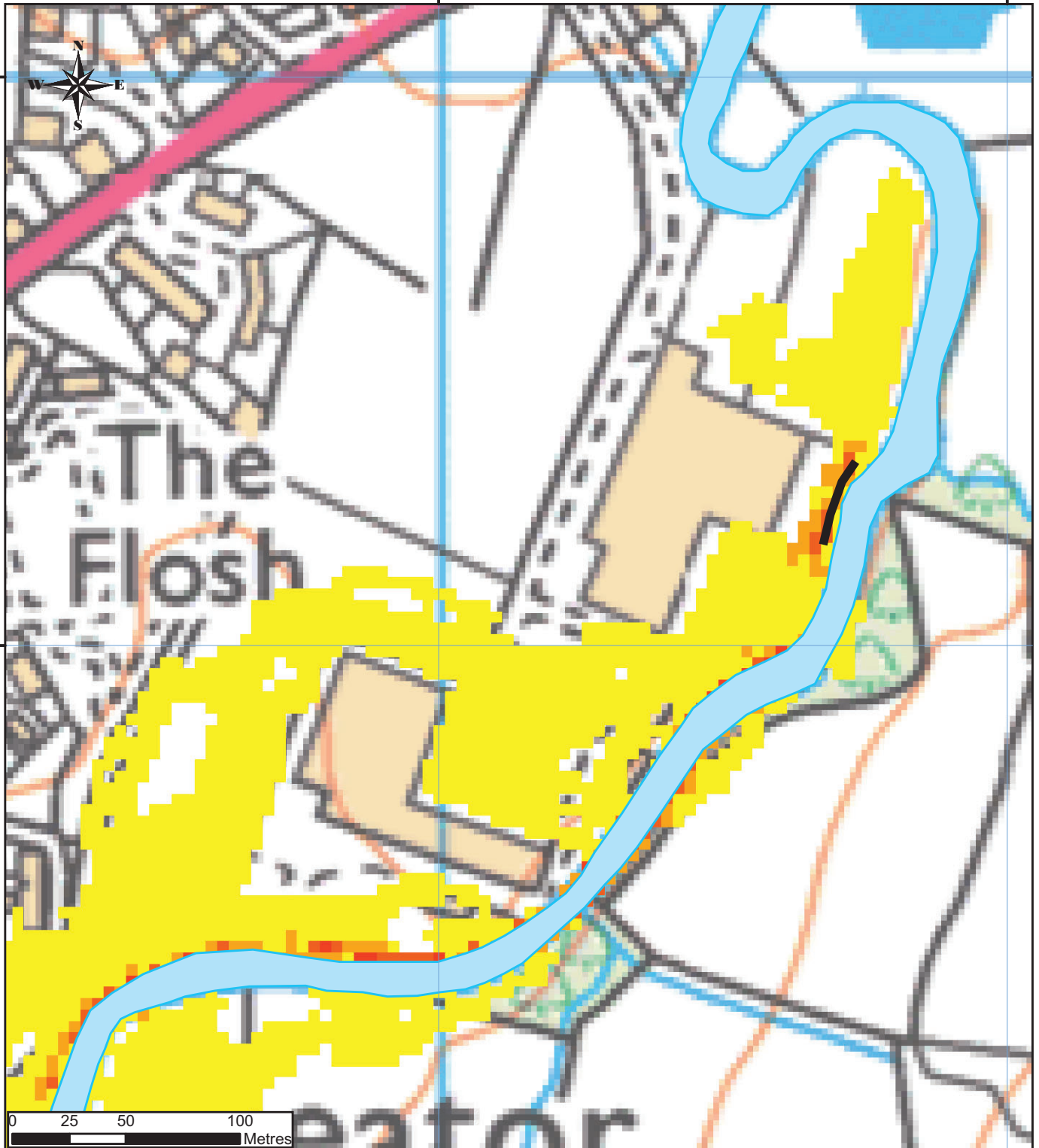


302000

302250

514000

513750



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Flood Hazard Category

- Low
- Moderate
- Significant
- Extreme

KEY

- Breach 2 Location
- River Ehen

Appendix G Soil Infiltration Test Results



GEO

Environmental Engineering

FAO Ross Oakley
RWO Associates Ltd
6A
Union Quay
North Shields
NE30 1HJ

****Sent by Email****

21st October 2013

Dear Ross,

Re: Land at Cleator Mills – Soakaway Test Letter Report

Please find attached to this letter the following information:

- Exploratory Hole Location Plan (TP01 to TP06)
- Trial Pit Logs
- Soakaway Test Workbook Extracts (SA01 to SA06 inclusive)

From the trial pit logs it can be seen that the ground conditions typically comprised grass and topsoil over sand and gravel with many cobbles and boulders to the terminal depths of the trial pits between c.1.50m and c.2.00m below current ground levels. No water ingress was noted within the trial pits, although the sand and gravel materials were generally unstable with the materials posing a risk of sidewall collapse.

As requested in-situ soakaway tests were undertaken at the six trial pit locations at depths varying between c.0.50m and c.2.00m below ground levels. All the trial pits successfully drained completely within 2 hours of commencing the tests.

I trust the above and attached is to your satisfaction and if you have any questions or then please call or email.

Yours Faithfully

.....
Curtis R. Evans *B.Sc (Hons) FGS*

Director

For and On Behalf Of Geo Environmental Engineering Ltd

Visit our *NEW* Website: www.geoenvironmentalengineering.com Email: info@geoenvironmentalengineering.com

Tel: 08456 768 895, Mob: 07883 440 186

“Without Site Investigation Ground is a Hazard”

Site Investigation Steering Group (SISG), 1993

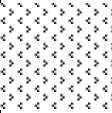
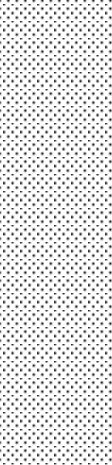
GEO Environmental Engineering Ltd
North West (Registered Office):
4 Culgarth Avenue, Cockermouth, Cumbria CA13 9PL
North East:
6A Union Quay, North Shields, Tyne & Wear NE30 1HJ

Telephone: 08456 768 895
Email: info@geoenvironmentalengineering.com
Website: www.geoenvironmentalengineering.com
Company No.: 07180338
VAT No.: GB 986617072

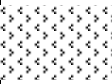
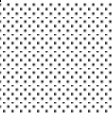
GEO2013-776: Exploratory Hole Location Plan (Approximate Locations – Not to Scale)



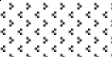
GEO2013-776: TP01

Depth From (m)	Depth To (m)	Strata Description	Legend	Testing / Samples
0.00	0.40	TURF over TOPSOIL: Grass over dark brown sandy gravelly clayey topsoil with some rootlets.		
0.40	2.00	Medium dense appearing reddish brown SAND and GRAVEL. Many cobbles and boulders noted throughout.		0.50m Soakaway Test (results on SA01)
		End of trial pit Trial pit remained dry on completion Trial pit noted as unstable below c.1.50m Soakaway test completed from c.0.50m to c.1.50m		
Site: Land at Cleator Mills Client Reference: N/A Engineer: CE Plant: JCB3CX		Log Notes: Spt = Standard Penetration test (blows per 300mm n300) HSV = Hand Shear Vane (result in kN/m ²) CBR = California Bearing Ratio by Mexe Cone Penetrometer (result as percentage) LP = Limited Penetration (HSV/CBR) NP = No penetration (HSV/CBR) B = Bulk Bag, J = Amber Glass Jar, T = Plastic Tub		

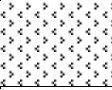
GEO2013-776: TP02

Depth From (m)	Depth To (m)	Strata Description	Legend	Testing / Samples
0.00	0.30	TURF over TOPSOIL: Grass over dark brown sandy gravelly clayey topsoil with some rootlets.		
0.30	0.70	Red brown slightly gravelly SAND.		
0.70	2.00	Medium dense appearing reddish brown SAND and GRAVEL. Many cobbles and boulders noted throughout.		1.00m Soakaway Test (results on SA02)
		End of trial pit Trial pit remained dry on completion Trial pit noted as unstable below c.1.50m Soakaway test completed from c.1.00m to c.2.00m		
Site: Land at Cleator Mills Client Reference: N/A Engineer: CE Plant: JCB3CX		Log Notes: Spt = Standard Penetration test (blows per 300mm n300) HSV = Hand Shear Vane (result in kN/m ²) CBR = California Bearing Ratio by Mexe Cone Penetrometer (result as percentage) LP = Limited Penetration (HSV/CBR) NP = No penetration (HSV/CBR) B = Bulk Bag, J = Amber Glass Jar, T = Plastic Tub		

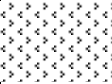
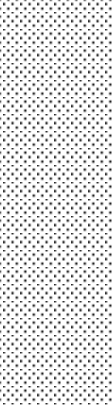
GEO2013-776: TP03

Depth From (m)	Depth To (m)	Strata Description	Legend	Testing / Samples
0.00	0.20	TURF over TOPSOIL: Grass over dark brown sandy gravelly clayey topsoil with some rootlets.		
0.20	0.80	Red brown slightly gravelly SAND.		
0.80	2.00	Medium dense appearing reddish brown SAND and GRAVEL. Many cobbles and boulders noted throughout.		1.00m Soakaway Test (results on SA03)
		End of trial pit Trial pit remained dry on completion Trial pit noted as unstable below c.0.80m Soakaway test completed from c.1.00m to c.2.00m		
Site: Land at Cleator Mills Client Reference: N/A Engineer: CE Plant: JCB3CX		Log Notes: Spt = Standard Penetration test (blows per 300mm n300) HSV = Hand Shear Vane (result in kN/m ²) CBR = California Bearing Ratio by Mexe Cone Penetrometer (result as percentage) LP = Limited Penetration (HSV/CBR) NP = No penetration (HSV/CBR) B = Bulk Bag, J = Amber Glass Jar, T = Plastic Tub		

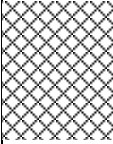
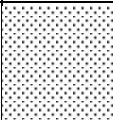
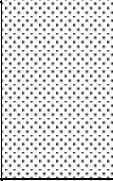
GEO2013-776: TP04

Depth From (m)	Depth To (m)	Strata Description	Legend	Testing / Samples
0.00	0.30	TURF over TOPSOIL: Grass over dark brown sandy gravelly clayey topsoil with some rootlets.		
0.30	1.50	Medium dense appearing reddish brown SAND and GRAVEL. Many cobbles and boulders noted throughout.		0.50m Soakaway Test (results on SA04)
		End of trial pit Trial pit remained dry on completion Trial pit noted as unstable below c.1.00m Soakaway test completed from c.0.50m to c.1.50m		
Site: Land at Cleator Mills Client Reference: N/A Engineer: CE Plant: JCB3CX		Log Notes: Spt = Standard Penetration test (blows per 300mm n300) HSV = Hand Shear Vane (result in kN/m ²) CBR = California Bearing Ratio by Mexe Cone Penetrometer (result as percentage) LP = Limited Penetration (HSV/CBR) NP = No penetration (HSV/CBR) B = Bulk Bag, J = Amber Glass Jar, T = Plastic Tub		

GEO2013-776: TP05

Depth From (m)	Depth To (m)	Strata Description	Legend	Testing / Samples
0.00	0.35	TURF over TOPSOIL: Grass over dark brown sandy gravelly clayey topsoil with some rootlets.		
0.35	0.60	Red brown slightly gravelly SAND.		
0.60	2.00	Medium dense appearing reddish brown SAND and GRAVEL. Many cobbles and boulders noted throughout.		1.00m Soakaway Test (results on SA05)
		End of trial pit Trial pit remained dry on completion Trial pit noted as unstable below c.1.50m Soakaway test completed from c.1.00m to c.2.00m		
Site: Land at Cleator Mills Client Reference: N/A Engineer: CE Plant: JCB3CX		Log Notes: Spt = Standard Penetration test (blows per 300mm n300) HSV = Hand Shear Vane (result in kN/m ²) CBR = California Bearing Ratio by Mexe Cone Penetrometer (result as percentage) LP = Limited Penetration (HSV/CBR) NP = No penetration (HSV/CBR) B = Bulk Bag, J = Amber Glass Jar, T = Plastic Tub		

GEO2013-776: TP06

Depth From (m)	Depth To (m)	Strata Description	Legend	Testing / Samples
0.00	0.50	MADE GROUND: TURF over TOPSOIL: Grass over dark brown sandy gravelly clayey topsoil with some rootlets and rare brick pieces.		
0.50	0.90	Red brown slightly gravelly SAND.		0.50m Soakaway Test (results on SA06)
0.90	1.50	Medium dense appearing reddish brown SAND and GRAVEL. Many cobbles and boulders noted throughout.		
		End of trial pit Trial pit remained dry on completion Trial pit noted as unstable below c.1.00m Soakaway test completed from c.0.50m to c.1.50m		
Site: Land at Cleator Mills Client Reference: N/A Engineer: CE Plant: JCB3CX		Log Notes: Spt = Standard Penetration test (blows per 300mm n300) HSV = Hand Shear Vane (result in kN/m ²) CBR = California Bearing Ratio by Mexe Cone Penetrometer (result as percentage) LP = Limited Penetration (HSV/CBR) NP = No penetration (HSV/CBR) B = Bulk Bag, J = Amber Glass Jar, T = Plastic Tub		

CALCULATIONS/SKETCHES

PROJECT GEO2013-776 Land at Cleator Mills			
JOB No	2013-776	PREPARED BY	CRE
DATE	21-Oct-13	CHECKED BY	CRE/GE
		REV	P1

REF										OUTPUT										
Calculation of soil infiltration rate in accordance with BRE Digest 365																				
Length of trial pit				=	L_{TP}		=	3.000 m												
Width of trial pit				=	W_{TP}		=	0.450 m												
Effective Depth				=	D_{TP}		=	1.500 m		(measured below incoming invert)										
75% Effective Depth of trial pit				=	D_{75}		=	(D_{TP} x 0.75)		=	1.125 m									
50% Effective Depth of trial pit				=	D_{50}		=	(D_{TP} x 0.50)		=	0.750 m									
25% Effective Depth of trial pit				=	D_{25}		=	(D_{TP} x 0.25)		=	0.375 m									
Pit Voids				=	PV		=	100 %		(For open pits, PV = 100%. For stone filled pits, PV = 30%)										
Carry out 3 tests, each measuring the time taken for water levels to fall from 75% effective depth to 25% effective depth																				
Test No 1		time to fall from 75% to 25% eff depth				=	T_1		=	40.0 mins										
Test No 2		time to fall from 75% to 25% eff depth				=	T_2		=	mins										
Test No 3		time to fall from 75% to 25% eff depth				=	T_3		=	mins										
TAKE THE LONGEST OF THE 3 TESTS ABOVE						=	T_L		=	40.0 mins										
Volume of water escaping during this test between D_{75} and D_{25}																				
				=	V_{TP75_25}		=	(L_{TP} x W_{TP} x (D_{75} - D_{25}) x PV)		=	1.013 cu m.									
The mean surface area through which the above volume escapes, is the <i>wetted area</i> . Only 50% of the effective depth is allowed in the calculation.																				
ie		A_{P50}		=	(Wet Base Area + 50% of Wet Sides Area)															
		A_{P50}		=	(L_{TP} x W_{TP})		+	($2L_{TP}$ + $2W_{TP}$) x D_{50}												
		A_{P50}		=	1.350		+	5.175												
					A_{P50}		=	6.525 sq m												
Soil Infiltration Rate				=	f		=	$\frac{V_{TP75_25}}{A_{P50} \times 60 \times T_L}$		m/s										
Soil Infiltration Rate = f = 6.46552E-05 m/s																				
Notes: Pit drained completely within 40 minutes.																				

CALCULATIONS/SKETCHES

PROJECT GEO2013-776 Land at Cleator Mills			
JOB No	2013-776	PREPARED BY	CRE
DATE	21-Oct-13	CHECKED BY	CRE/GE
		REV	P1

REF										OUTPUT										
Calculation of soil infiltration rate in accordance with BRE Digest 365																				
Length of trial pit				=	L_{TP}				=	2.000 m										
Width of trial pit				=	W_{TP}				=	0.450 m										
Effective Depth				=	D_{TP}				=	2.000 m (measured below incoming invert)										
75% Effective Depth of trial pit				=	D_{75}				=	($D_{TP} \times 0.75$)				=	1.500 m					
50% Effective Depth of trial pit				=	D_{50}				=	($D_{TP} \times 0.50$)				=	1.000 m					
25% Effective Depth of trial pit				=	D_{25}				=	($D_{TP} \times 0.25$)				=	0.500 m					
Pit Voids				=	PV				=	100 %				(For open pits, PV = 100%. For stone filled pits, PV = 30%)						
Carry out 3 tests, each measuring the time taken for water levels to fall from 75% effective depth to 25% effective depth																				
Test No 1		time to fall from 75% to 25% eff depth						=	T_1		=	52.0 mins								
Test No 2		time to fall from 75% to 25% eff depth						=	T_2		=	mins								
Test No 3		time to fall from 75% to 25% eff depth						=	T_3		=	mins								
TAKE THE LONGEST OF THE 3 TESTS ABOVE								=	T_L		=	52.0 mins								
Volume of water escaping during this test between D_{75} and D_{25}																				
				=	V_{TP75_25}				=	($L_{TP} \times W_{TP} \times (D_{75} - D_{25}) \times PV$)				=	0.900 cu m.					
The mean surface area through which the above volume escapes, is the <i>wetted area</i> . Only 50% of the effective depth is allowed in the calculation.																				
ie		A_{P50}		=	(Wet Base Area + 50% of Wet Sides Area)															
		A_{P50}		=	($L_{TP} \times W_{TP}$)		+	($2L_{TP} + 2W_{TP}$) x D_{50}												
		A_{P50}		=	0.900		+	4.900												
				A_{P50}		=	5.800		sq m											
Soil Infiltration Rate				=	f				=	$\frac{V_{TP75_25}}{A_{P50} \times 60 \times T_L}$				m/s						
Soil Infiltration Rate = f = 4.97347E-05 m/s																				
Notes: Pit drained completely within 52 minutes.																				

CALCULATIONS/SKETCHES

PROJECT GEO2013-776 Land at Cleator Mills			
JOB No	2013-776	PREPARED BY	CRE
SHEET No	SA 03	CHECKED BY	CRE/GE
DATE	21-Oct-13	REV	P1

REF											OUTPUT																									
Calculation of soil infiltration rate in accordance with BRE Digest 365																																				
Length of trial pit											=	L_{TP}			=	2.500 m																				
Width of trial pit											=	W_{TP}			=	0.500 m																				
Effective Depth											=	D_{TP}			=	2.000 m (measured below incoming invert)																				
75% Effective Depth of trial pit											=	D_{75}			=	(D_{TP} x 0.75)			=	1.500 m																
50% Effective Depth of trial pit											=	D_{50}			=	(D_{TP} x 0.50)			=	1.000 m																
25% Effective Depth of trial pit											=	D_{25}			=	(D_{TP} x 0.25)			=	0.500 m																
Pit Voids											=	PV			=	100 %			(For open pits, PV = 100%. For stone filled pits, PV = 30%)																	
Carry out 3 tests, each measuring the time taken for water levels to fall from 75% effective depth to 25% effective depth																																				
Test No 1											time to fall from 75% to 25% eff depth											=	T_1			=	120.0 mins									
Test No 2											time to fall from 75% to 25% eff depth											=	T_2			=	mins									
Test No 3											time to fall from 75% to 25% eff depth											=	T_3			=	mins									
TAKE THE LONGEST OF THE 3 TESTS ABOVE											=	T_L			=	120.0 mins																				
Volume of water escaping during this test between D_{75} and D_{25}																																				
											=	V_{TP75_25}			=	(L_{TP} x W_{TP} x (D_{75} - D_{25}) x PV)			=	1.250 cu m.																
The mean surface area through which the above volume escapes, is the <i>wetted area</i> . Only 50% of the effective depth is allowed in the calculation.																																				
ie											A_{P50}											=	(Wet Base Area + 50% of Wet Sides Area)													
											A_{P50}											=	(L_{TP} x W_{TP})			+	($2L_{TP}$ + $2W_{TP}$) x D_{50}									
											A_{P50}											=	1.250			+	6.000									
																						A_{P50}			=	7.250			sq m							
Soil Infiltration Rate											=	f			=	$\frac{V_{TP75_25}}{A_{P50} \times 60 \times T_L}$			m/s																	
Soil Infiltration Rate = f = 2.39464E-05 m/s																																				
Notes: Pit drained completely within 120 minutes.																																				

CALCULATIONS/SKETCHES

PROJECT GEO2013-776 Land at Cleator Mills			
JOB No	2013-776	PREPARED BY	CRE
DATE	21-Oct-13	CHECKED BY	CRE/GE
		REV	P1

REF										OUTPUT																					
Calculation of soil infiltration rate in accordance with BRE Digest 365																															
Length of trial pit										=	L_{TP}					=	2.600 m														
Width of trial pit										=	W_{TP}					=	0.500 m														
Effective Depth										=	D_{TP}					=	1.500 m (measured below incoming invert)														
75% Effective Depth of trial pit										=	D_{75}					=	$(D_{TP} \times 0.75)$					=	1.125 m								
50% Effective Depth of trial pit										=	D_{50}					=	$(D_{TP} \times 0.50)$					=	0.750 m								
25% Effective Depth of trial pit										=	D_{25}					=	$(D_{TP} \times 0.25)$					=	0.375 m								
Pit Voids										=	PV					=	100 %					(For open pits, PV = 100%. For stone filled pits, PV = 30%)									
Carry out 3 tests, each measuring the time taken for water levels to fall from 75% effective depth to 25% effective depth																															
Test No 1										time to fall from 75% to 25% eff depth										=	T_1					=	120.0 mins				
Test No 2										time to fall from 75% to 25% eff depth										=	T_2					=	mins				
Test No 3										time to fall from 75% to 25% eff depth										=	T_3					=	mins				
TAKE THE LONGEST OF THE 3 TESTS ABOVE										=	T_L					=	120.0 mins														
Volume of water escaping during this test between D_{75} and D_{25}																															
										=	V_{TP75_25}					=	$(L_{TP} \times W_{TP} \times (D_{75} - D_{25}) \times PV)$					=	0.975 cu m.								
The mean surface area through which the above volume escapes, is the <i>wetted area</i> . Only 50% of the effective depth is allowed in the calculation.																															
ie										A_{P50}										=	(Wet Base Area + 50% of Wet Sides Area)										
										A_{P50}										=	$(L_{TP} \times W_{TP}) + (2L_{TP} + 2W_{TP}) \times D_{50}$										
										A_{P50}										=	1.300 + 4.650										
																				$A_{P50} = 5.950 \text{ sq m}$											
Soil Infiltration Rate										=	f					=	$\frac{V_{TP75_25}}{A_{P50} \times 60 \times T_L}$					m/s									
Soil Infiltration Rate = f = 2.27591E-05 m/s																															
Notes: Pit drained completely within 120 minutes.																															

CALCULATIONS/SKETCHES

PROJECT GEO2013-776 Land at Cleator Mills			
JOB No	2013-776	PREPARED BY	CRE
SHEET No	SA 05	CHECKED BY	CRE/GE
DATE	21-Oct-13	REV	P1

REF										OUTPUT										
Calculation of soil infiltration rate in accordance with BRE Digest 365																				
Length of trial pit				=	L_{TP}		=	2.700 m												
Width of trial pit				=	W_{TP}		=	0.450 m												
Effective Depth				=	D_{TP}		=	2.000 m		(measured below incoming invert)										
75% Effective Depth of trial pit				=	D_{75}		=	(D_{TP} x 0.75)		=	1.500 m									
50% Effective Depth of trial pit				=	D_{50}		=	(D_{TP} x 0.50)		=	1.000 m									
25% Effective Depth of trial pit				=	D_{25}		=	(D_{TP} x 0.25)		=	0.500 m									
Pit Voids				=	PV		=	100 %		(For open pits, PV = 100%. For stone filled pits, PV = 30%)										
Carry out 3 tests, each measuring the time taken for water levels to fall from 75% effective depth to 25% effective depth																				
Test No 1		time to fall from 75% to 25% eff depth				=	T_1		=	120.0 mins										
Test No 2		time to fall from 75% to 25% eff depth				=	T_2		=	mins										
Test No 3		time to fall from 75% to 25% eff depth				=	T_3		=	mins										
TAKE THE LONGEST OF THE 3 TESTS ABOVE						=	T_L		=	120.0 mins										
Volume of water escaping during this test between D_{75} and D_{25}																				
				=	V_{TP75_25}		=	(L_{TP} x W_{TP} x (D_{75} - D_{25}) x PV)		=	1.215 cu m.									
The mean surface area through which the above volume escapes, is the <i>wetted area</i> . Only 50% of the effective depth is allowed in the calculation.																				
ie		A_{P50}		=	(Wet Base Area + 50% of Wet Sides Area)															
		A_{P50}		=	(L_{TP} x W_{TP})		+	($2L_{TP}$ + $2W_{TP}$) x D_{50}												
		A_{P50}		=	1.215		+	6.300												
				A_{P50}		=	7.515 sq m													
Soil Infiltration Rate				=	f		=	$\frac{V_{TP75_25}}{A_{P50} \times 60 \times T_L}$		m/s										
Soil Infiltration Rate = f = 2.24551E-05 m/s																				
Notes: Pit drained completely within 120 minutes.																				

CALCULATIONS/SKETCHES

PROJECT GEO2013-776 Land at Cleator Mills			
JOB No	2013-776	PREPARED BY	CRE
SHEET No	SA 06	CHECKED BY	CRE/GE
DATE	21-Oct-13	REV	P1

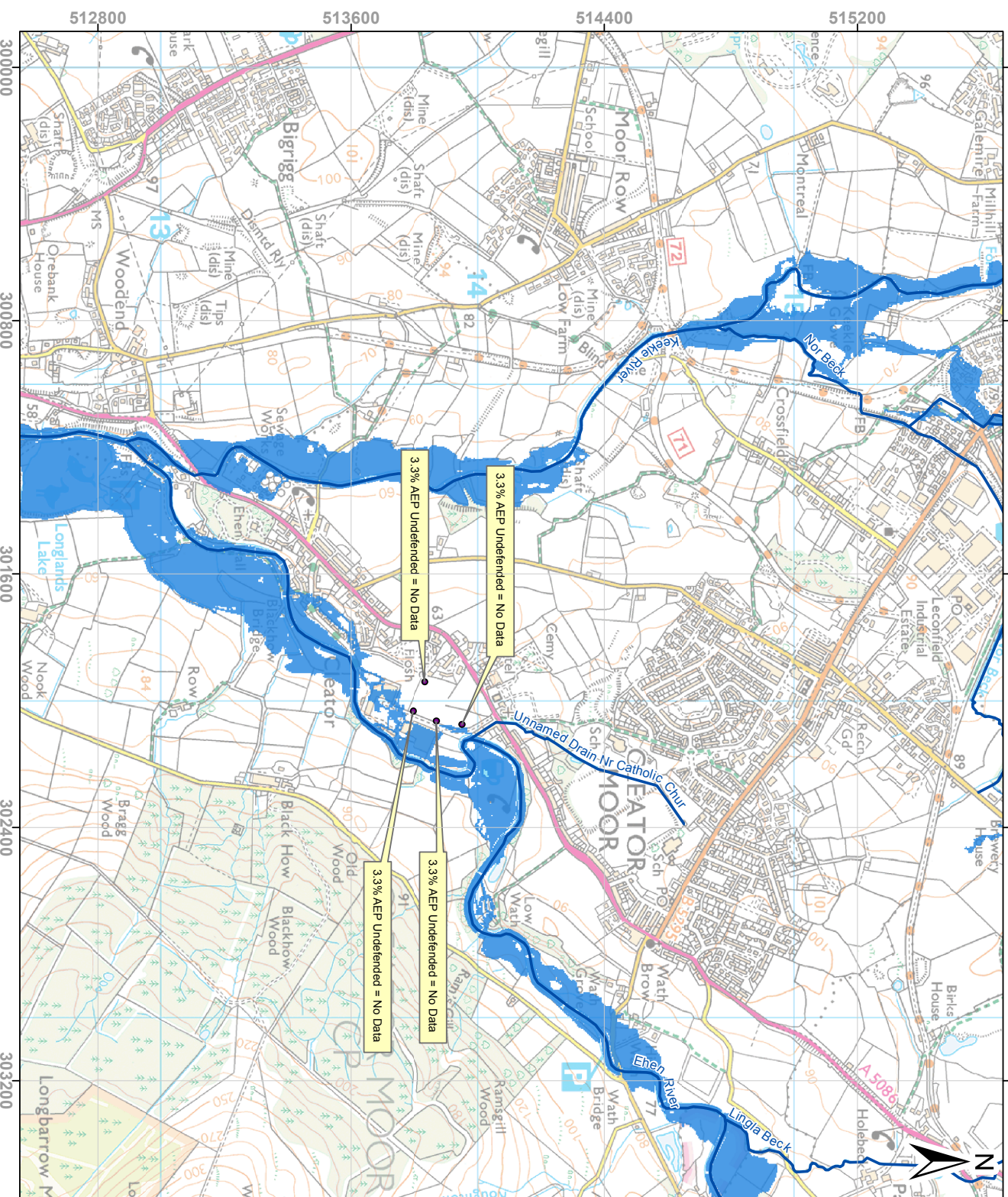
REF										OUTPUT										
Calculation of soil infiltration rate in accordance with BRE Digest 365																				
Length of trial pit				=	L_{TP}		=	2.500 m												
Width of trial pit				=	W_{TP}		=	0.450 m												
Effective Depth				=	D_{TP}		=	1.500 m		(measured below incoming invert)										
75% Effective Depth of trial pit				=	D_{75}		=	(D_{TP} x 0.75)		=	1.125 m									
50% Effective Depth of trial pit				=	D_{50}		=	(D_{TP} x 0.50)		=	0.750 m									
25% Effective Depth of trial pit				=	D_{25}		=	(D_{TP} x 0.25)		=	0.375 m									
Pit Voids				=	PV		=	100 %		(For open pits, PV = 100%. For stone filled pits, PV = 30%)										
Carry out 3 tests, each measuring the time taken for water levels to fall from 75% effective depth to 25% effective depth																				
Test No 1		time to fall from 75% to 25% eff depth				=	T_1		=	60.0 mins										
Test No 2		time to fall from 75% to 25% eff depth				=	T_2		=	mins										
Test No 3		time to fall from 75% to 25% eff depth				=	T_3		=	mins										
TAKE THE LONGEST OF THE 3 TESTS ABOVE						=	T_L		=	60.0 mins										
Volume of water escaping during this test between D_{75} and D_{25}																				
				=	V_{TP75_25}		=	(L_{TP} x W_{TP} x (D_{75} - D_{25}) x PV)		=	0.844 cu m.									
The mean surface area through which the above volume escapes, is the <i>wetted area</i> . Only 50% of the effective depth is allowed in the calculation.																				
ie		A_{P50}		=	(Wet Base Area + 50% of Wet Sides Area)															
		A_{P50}		=	(L_{TP} x W_{TP})		+	($2L_{TP}$ + $2W_{TP}$) x D_{50}												
		A_{P50}		=	1.125		+	4.425												
					A_{P50}		=	5.550 sq m												
Soil Infiltration Rate				=	f		=	$\frac{V_{TP75_25}}{A_{P50} \times 60 \times T_L}$		m/s										
Soil Infiltration Rate = f = 4.22297E-05 m/s																				
Notes: Pit drained completely within 60 minutes.																				



Geotechnical
&
Environmental
Drilling Experts
&
Consultants

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Appendix H Environment Agency Flood Data



Fluvial Model Level Map:

Cleator Mills,

Cleator, CA23 3DU

Produced: 10 July 2019

Our Ref: CL132929

NGR: 301,733 514,107

Key

Main River

1 in 30 Undefended Scenario

MAOD

High - 113.229



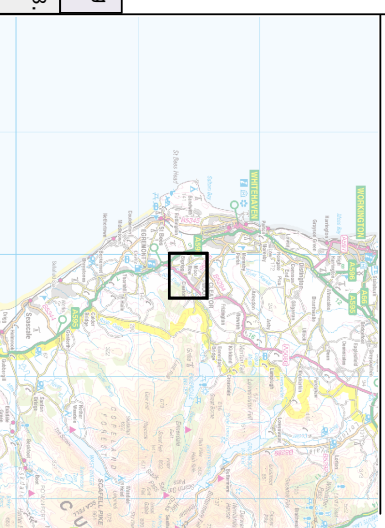
Low: 0

Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

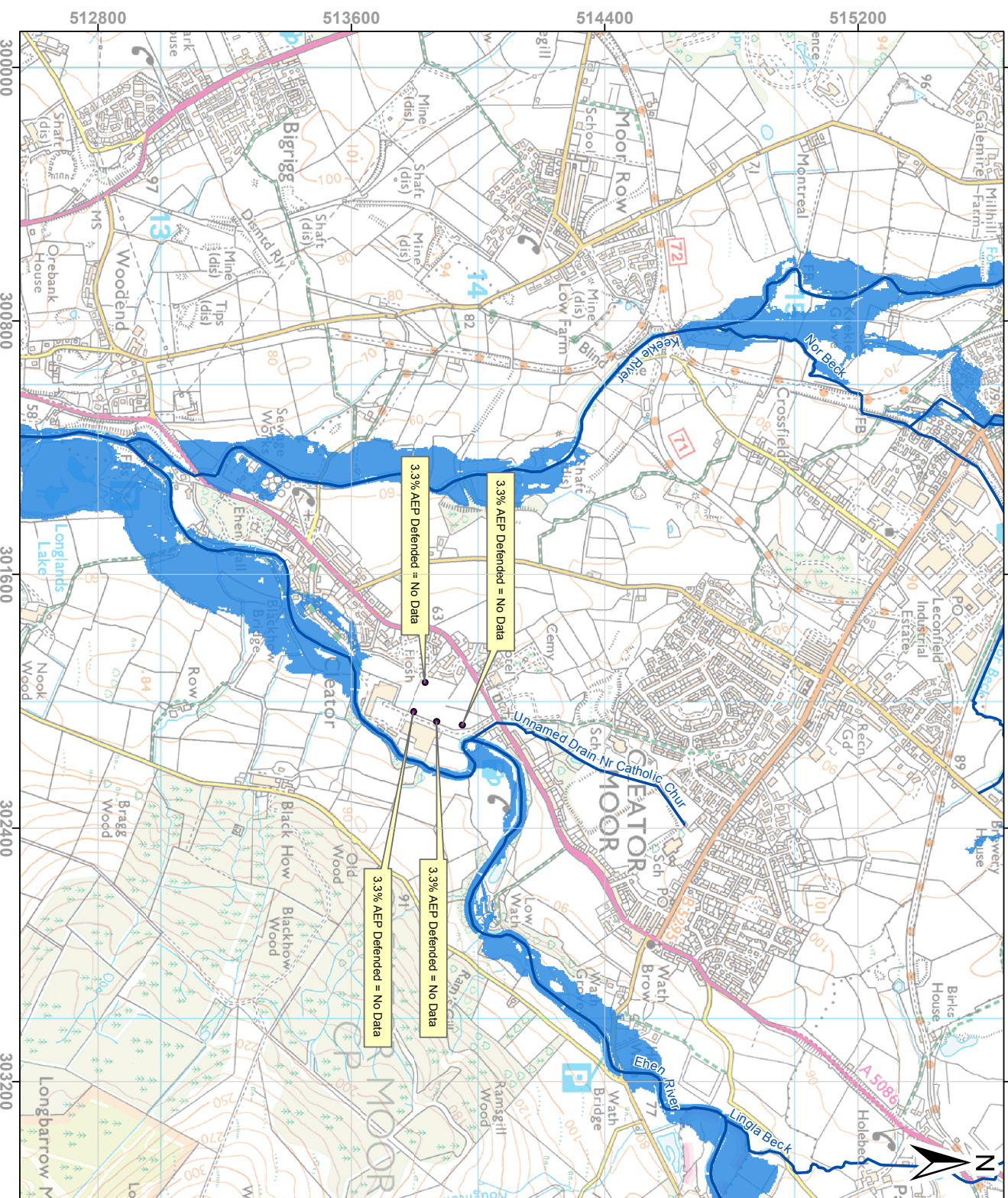
Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Fluvial Model Level Map:

Cleator Mills,
Cleator, CA23 3DU

Produced: 10 July 2019
Our Ref: CL132929

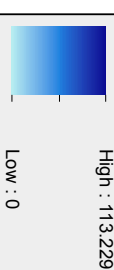
NGR: 301,733 514,107

Key

Main River

1 in 30 Defended Scenario

MAOD

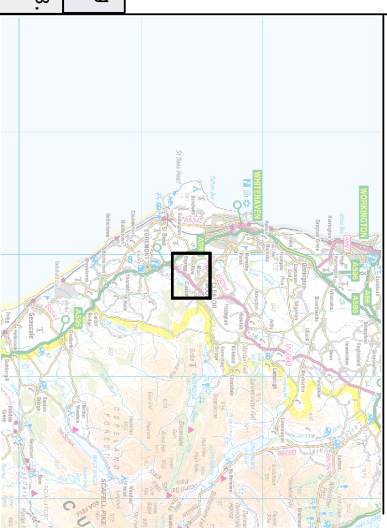


Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

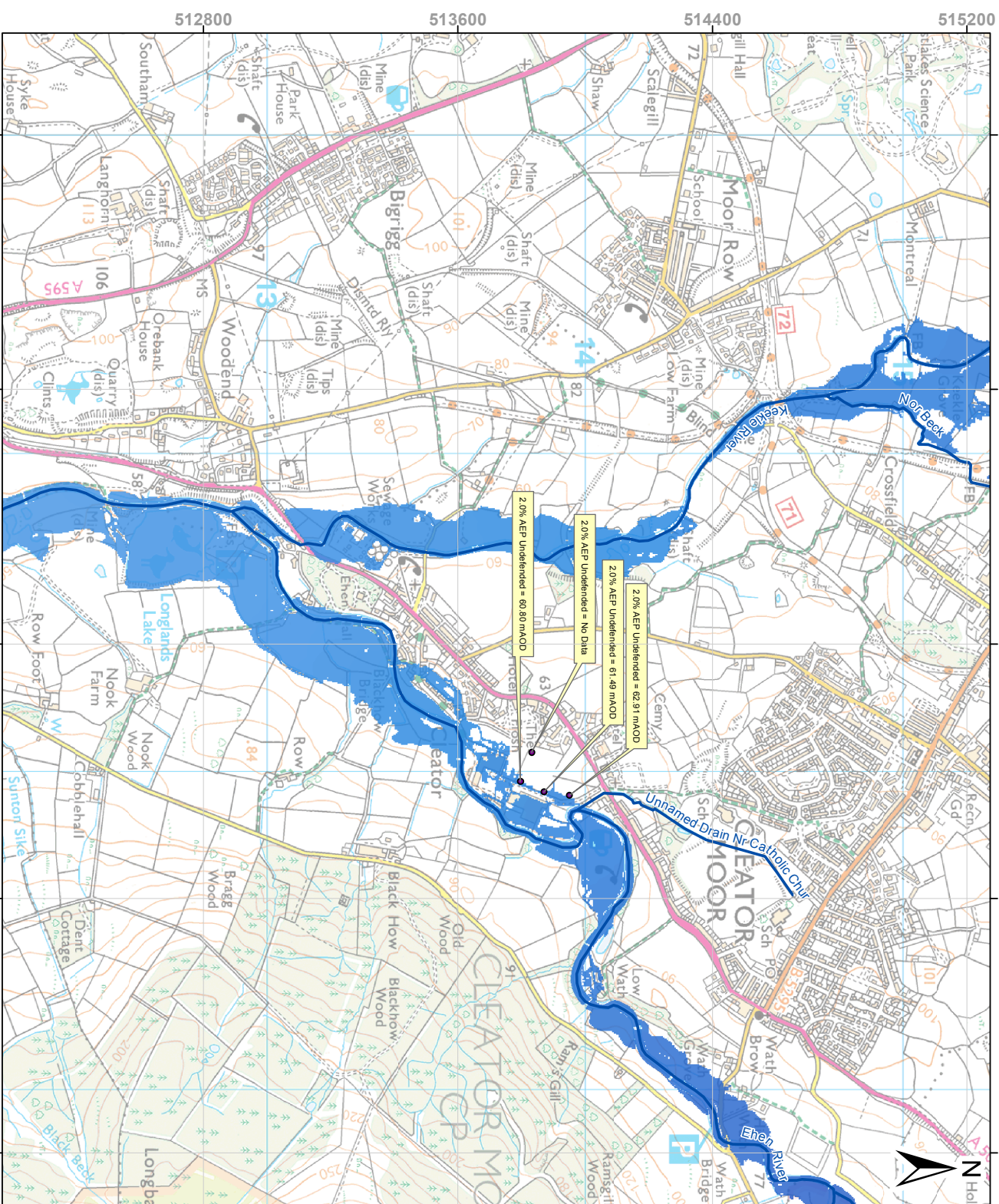
Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Fluvial Model Level Map: Cleator Mills, Cleator, CA23 3DU

*Produced: 09 July 2019
Our Ref: CL132929
NGR: 301,526 513,720*

Key

Main River

1 in 50 Underflooded Scenario

mAAD

High : 113.229



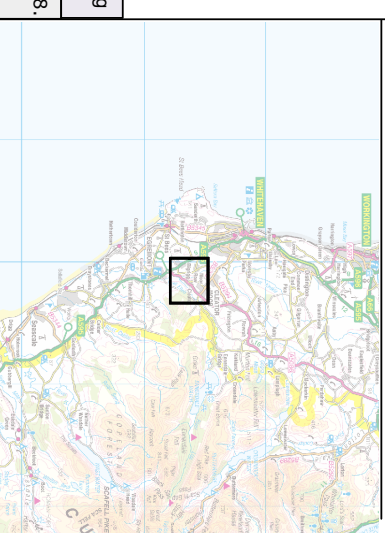
Low : 0

Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

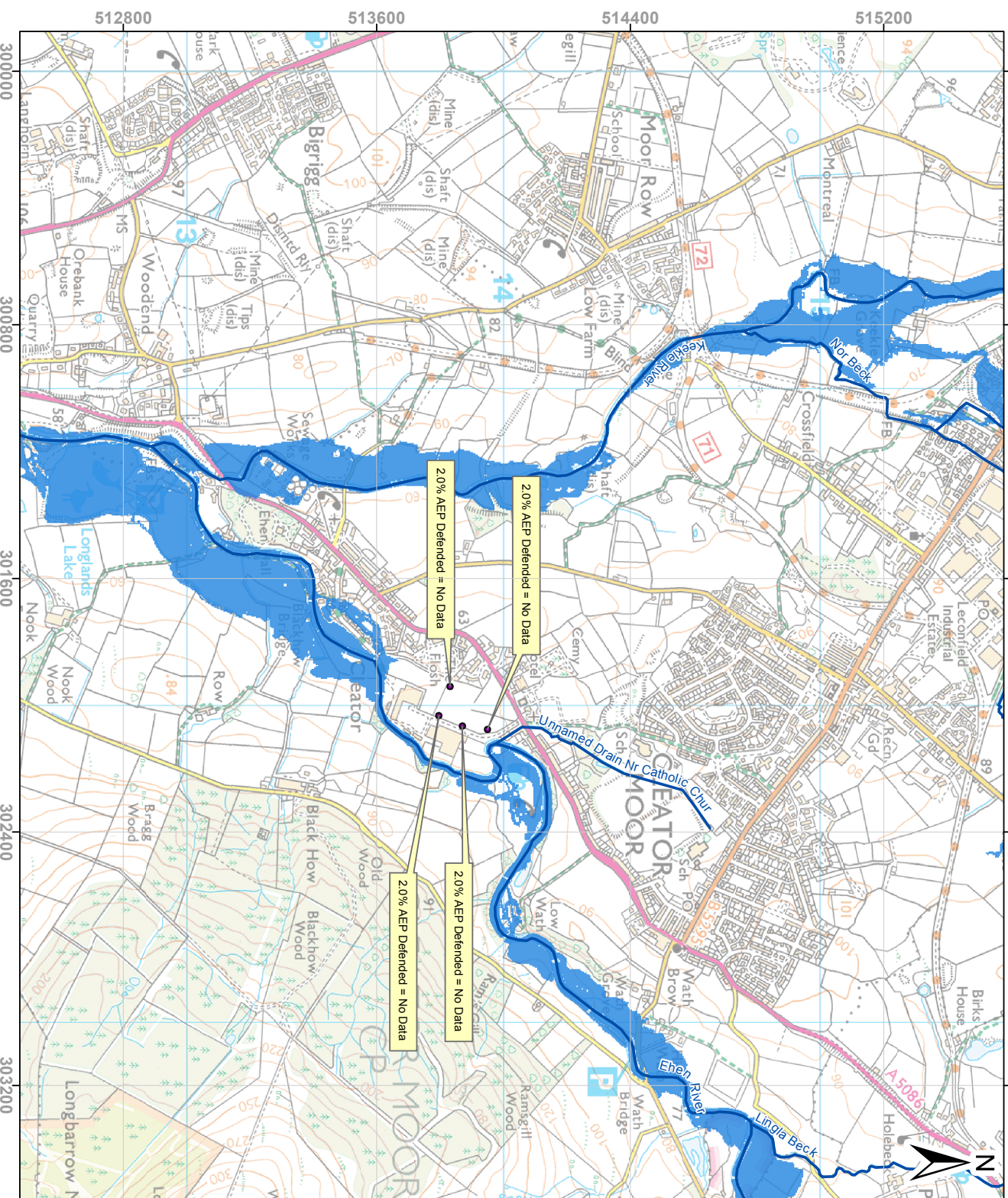
Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Fluvial Model Level Map:

**Cleator Mills,
Cleator, CA23 3DU**

Produced: 10 July 2019

Our Ref: CL132929

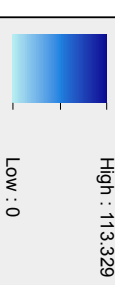
NGR: 301,720 514,026

Key

Main River

1 in 50 Defended Scenario

MAOD

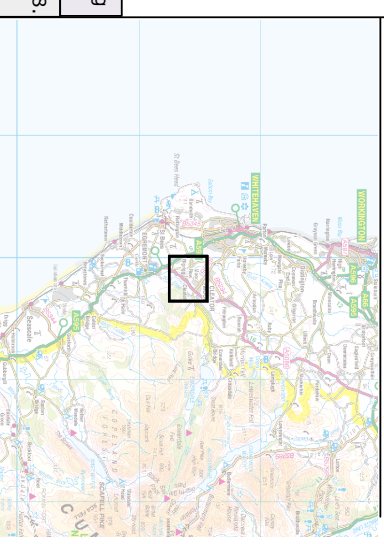


Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

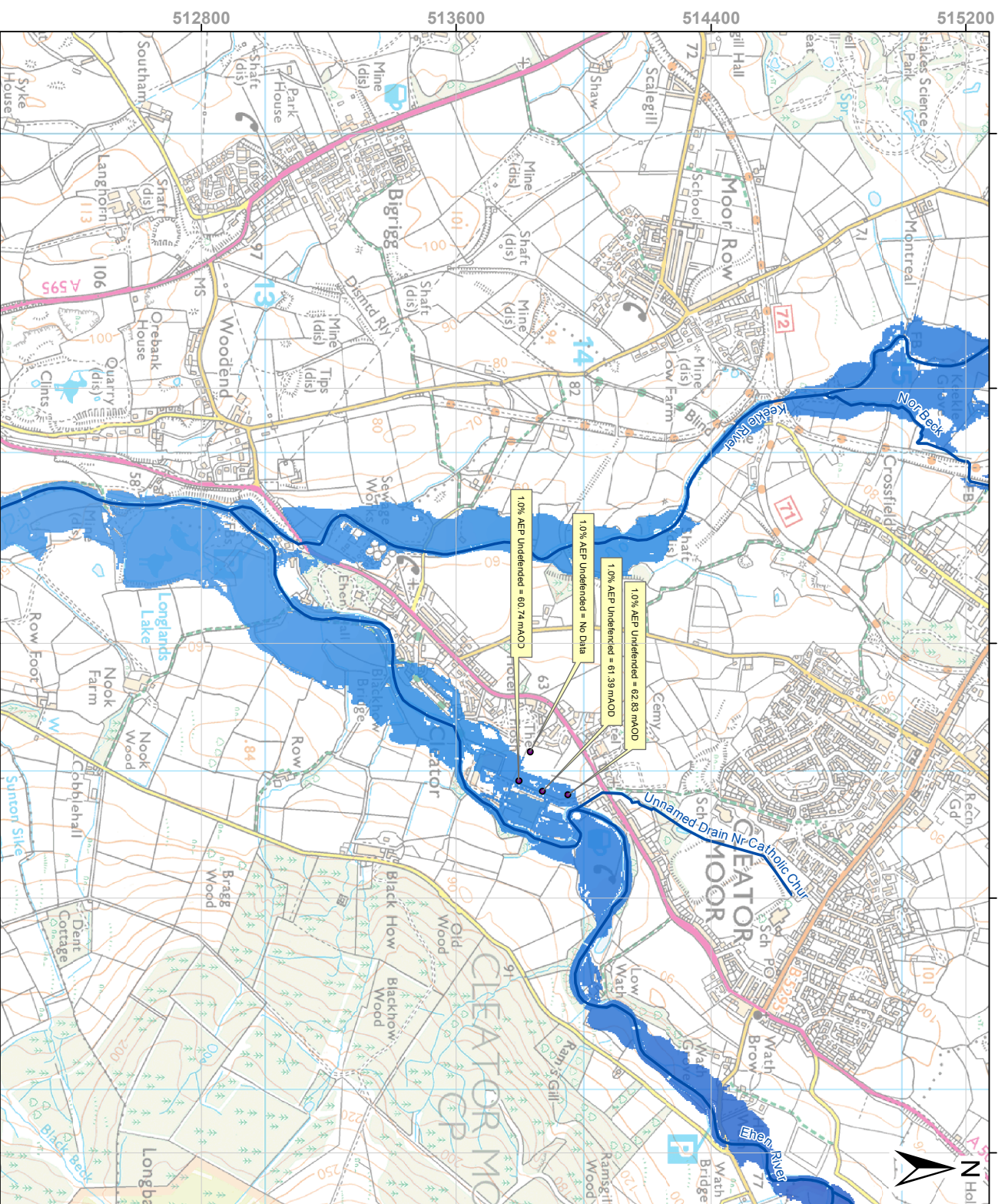
Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Fluvial Model Level Map: Cleator Mills, Cleator, CA23 3DU

*Produced: 09 July 2019
Our Ref: CL132929
NGR: 301,526 513,720*

Key

Main River

1 in 100 Und防ended Scenario

mAOD

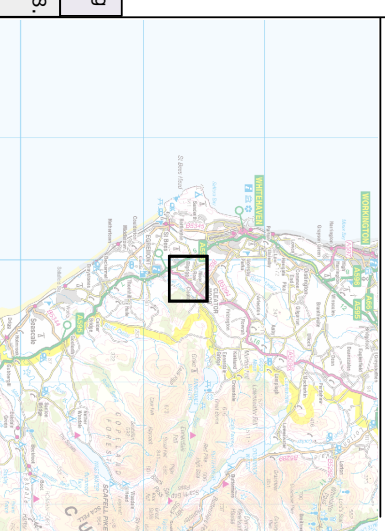
High : 113.343

Low : 0

Flood Zone 3 shows the area that could be affected by flooding:
- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

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

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Fluvial Model Level Map:

Cleator Mills,

Cleator, CA23 3DU

Produced: 10 July 2019

Our Ref: CL132929

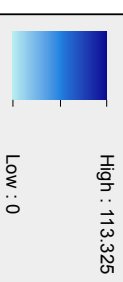
NGR: 301,720 514,026

Key

 Main River

1 in 100 Defended Scenario

MAOD

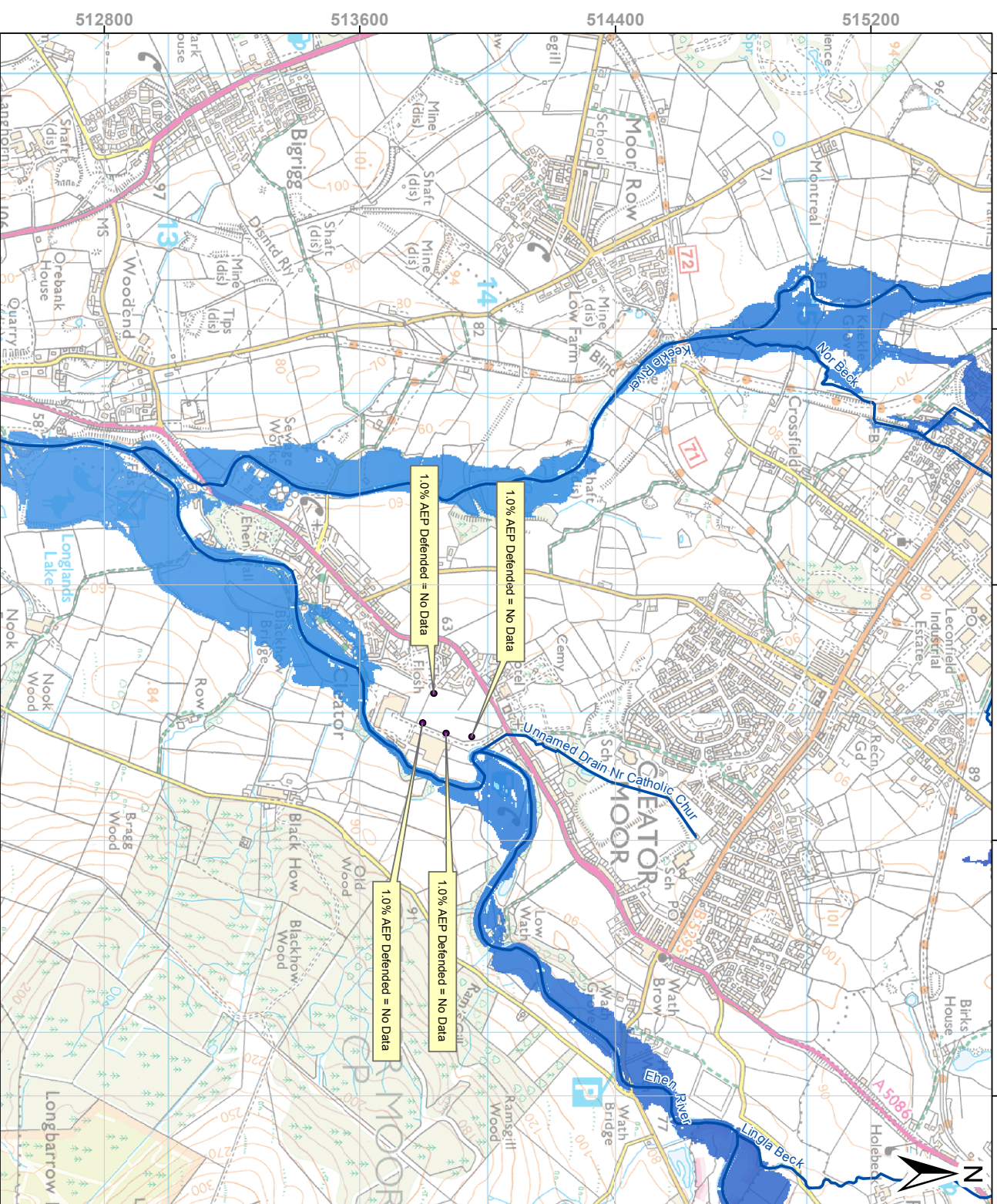


Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

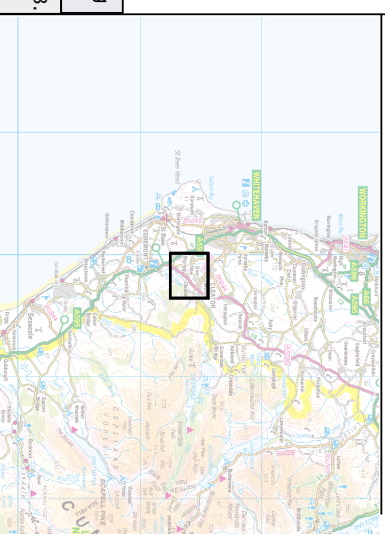
Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

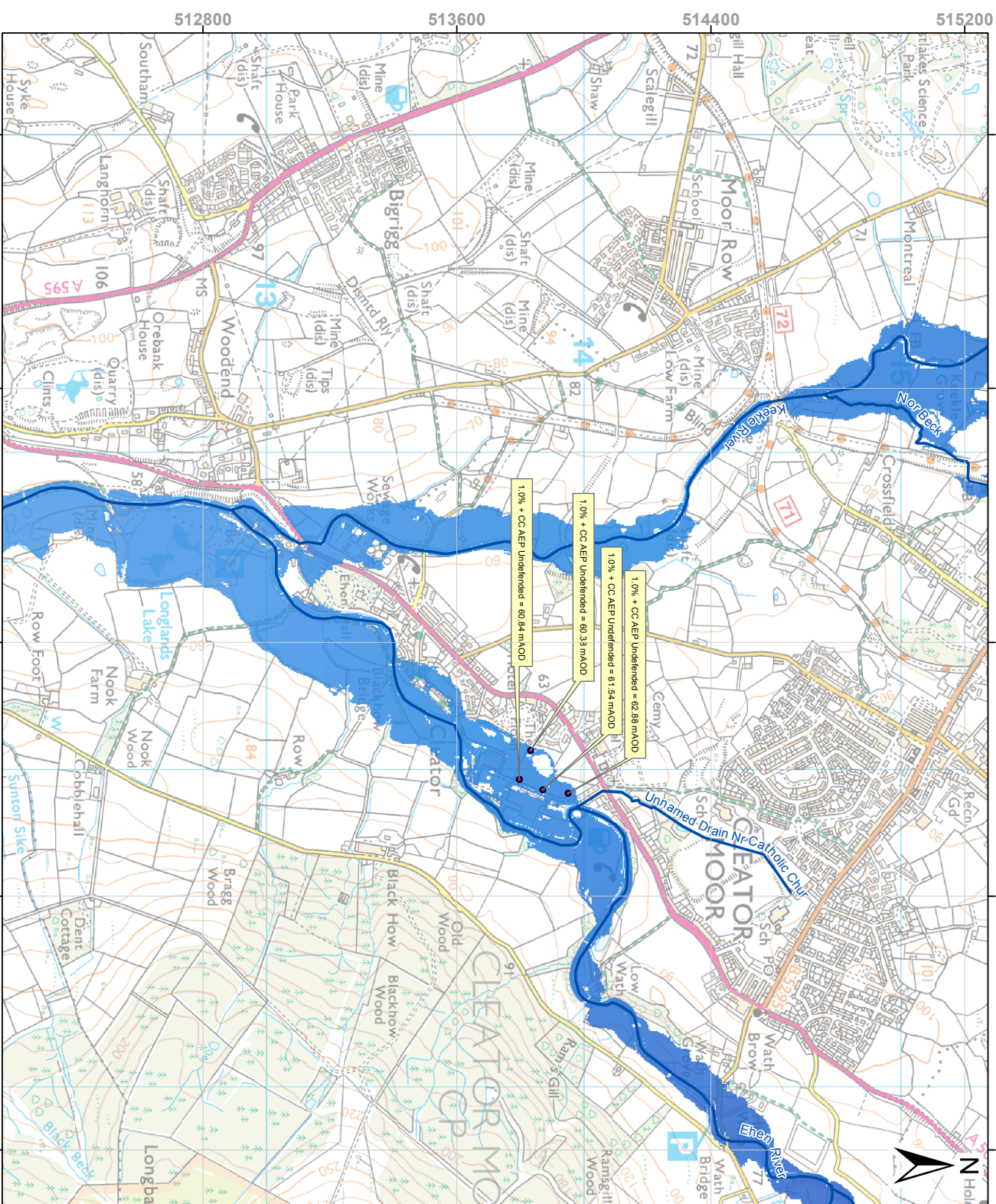
ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Fluvial Model Level Map:

**Cleator Mills,
Cleator, CA23 3DU**

Produced: 09 July 2019

Our Ref: CL132929

NGR: 301,526 513,720

Key

Main River

1 in 100 + CC Undeclared

MAOD

High : 113.547



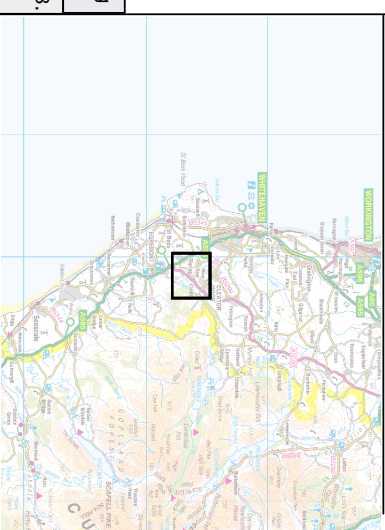
Low : 0

Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

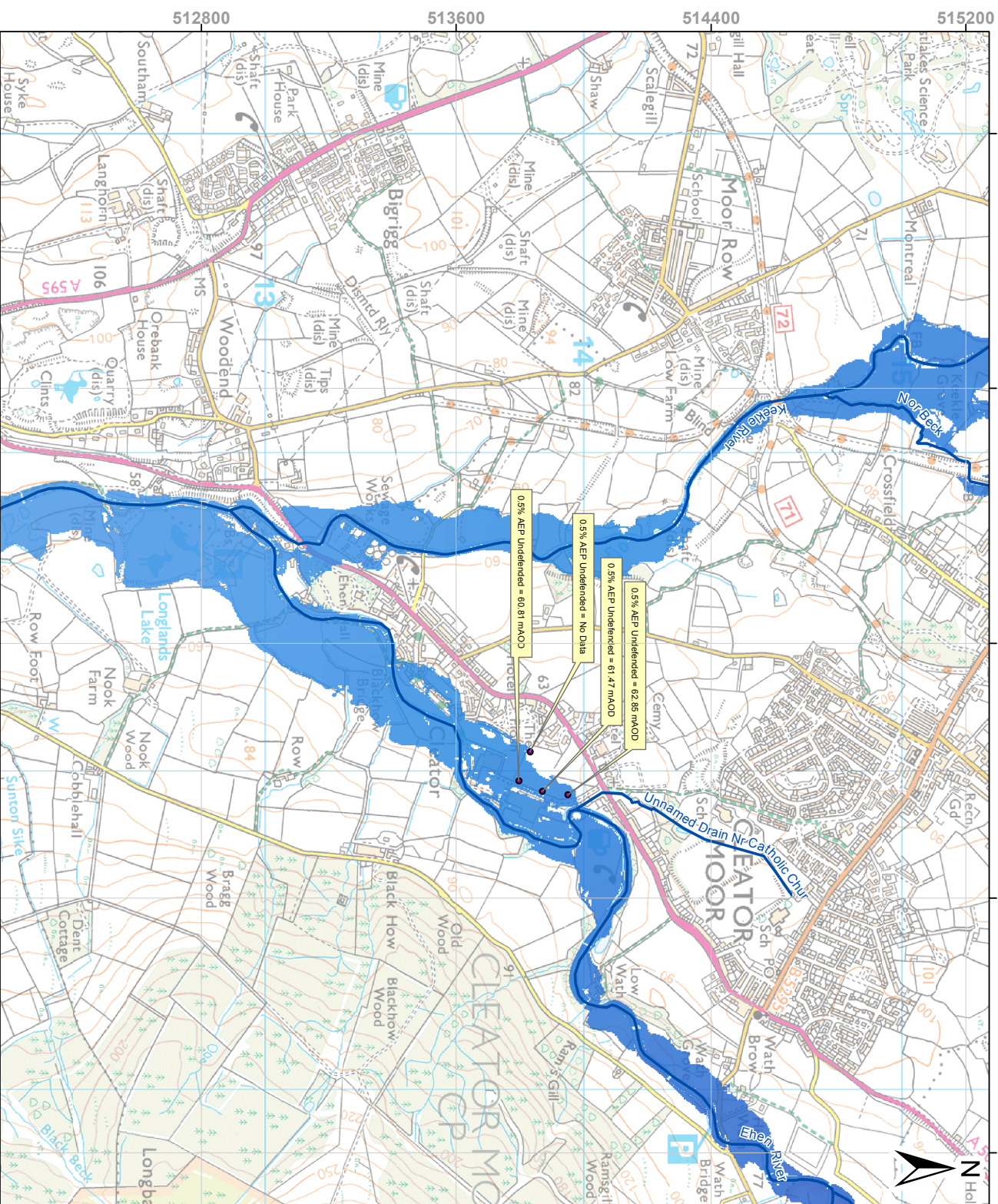
Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Fluvial Model Level Map: Cleator Mills, Cleator, CA23 3DU

Produced: 09 July 2019
Our Ref: CL132929
NGR: 301,526 513,720

Key

Main River

1 in 200 Und防ended Scenario

mAOD

High : 113.464



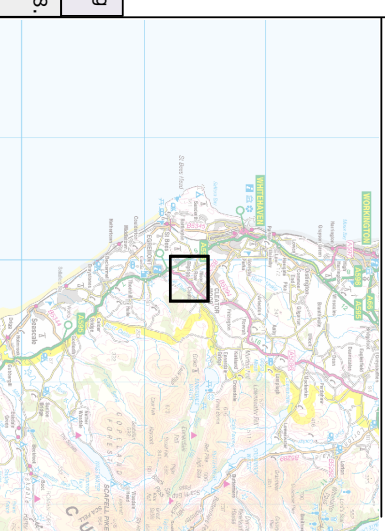
Low : 0

Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

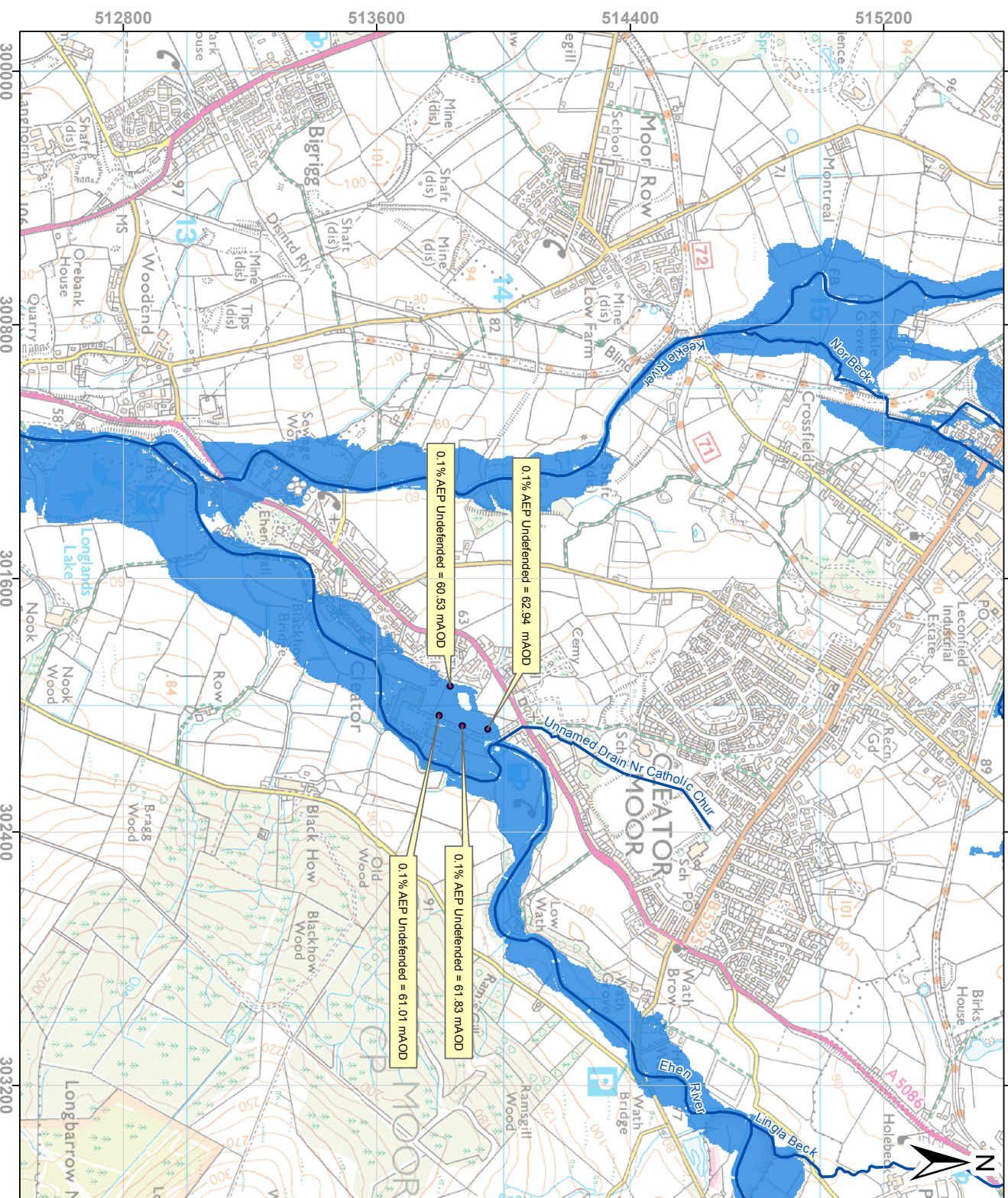
Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 03708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk



Fluvial Model Level Map:

Cleator Mills,
Cleator, CA23 3DU

Produced: 10 July 2019

Our Ref: CL132929

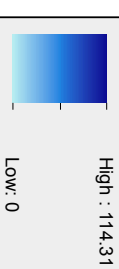
NGR: 301,720 514,026

Key

Main River

1 in 1000 Undefended Scenario

MAOD

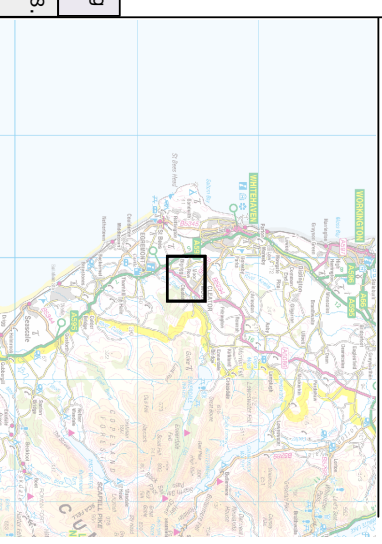


Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

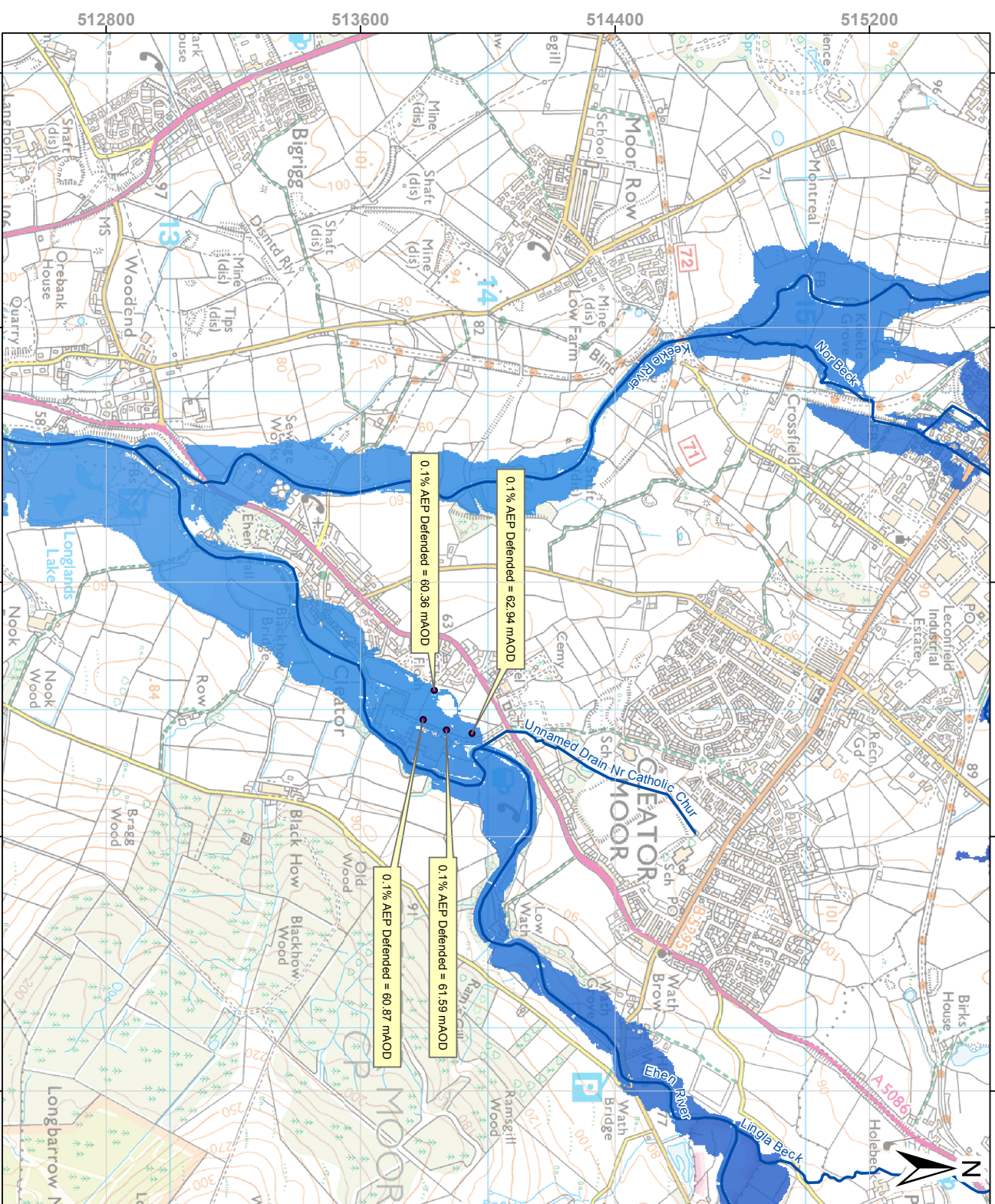
Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Fluvial Model Level Map:

Cleator Mills,

Cleator, CA23 3DU

Produced: 10 July 2019

Our Ref: CL132929

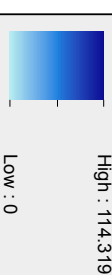
NGR: 301,720 514,026

Key

Main River

1 in 1000 Defended Scenario

MAOD

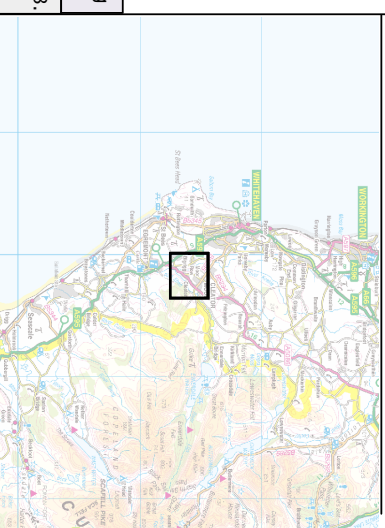


Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

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

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Node Point Location Map:

Cleator Mills,

Cleator, CA23 3DU

Produced: 10 July 2019

Our Ref: CL132929

NGR: 301,720 514,026

Key

- Modelled Node Point

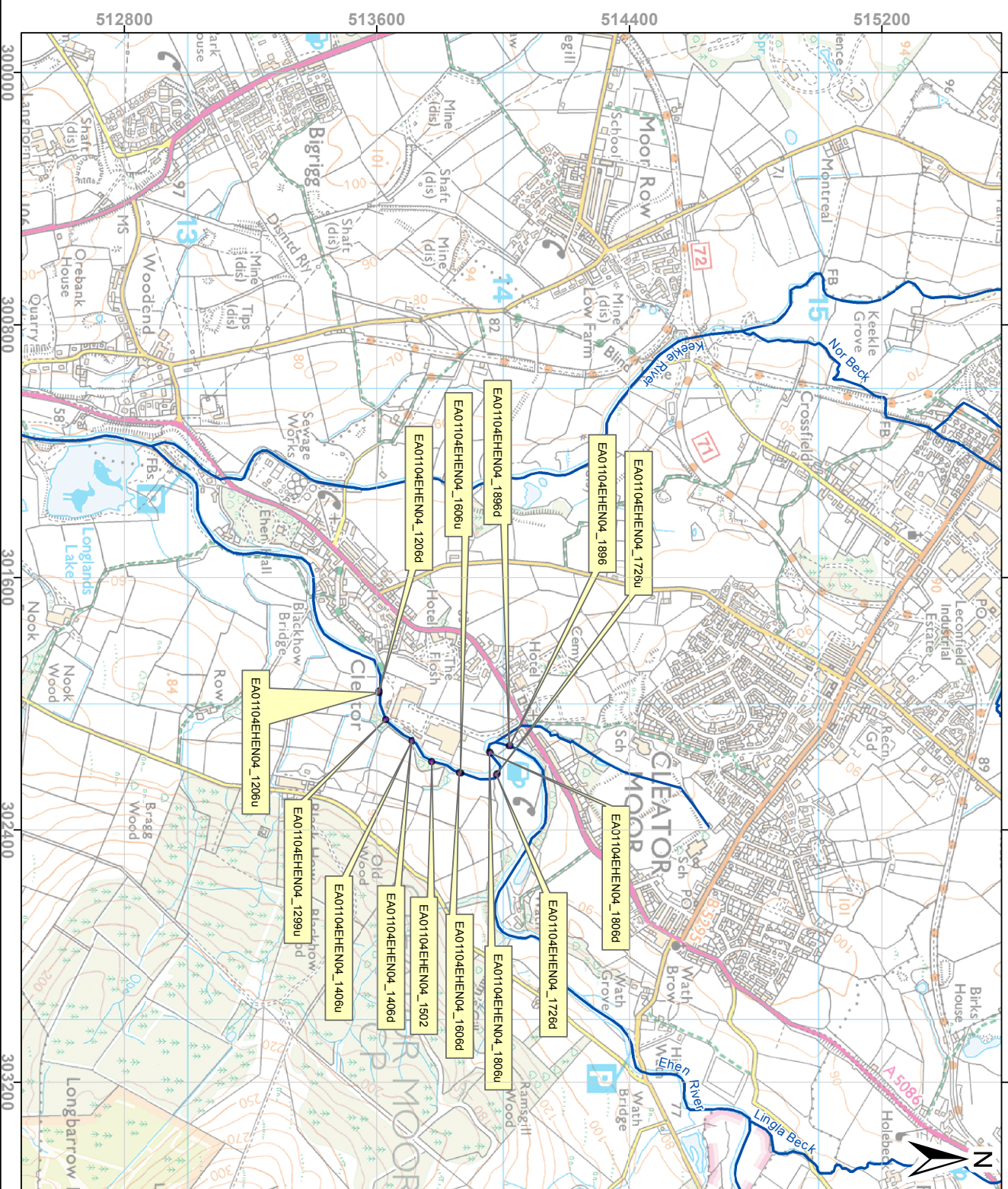
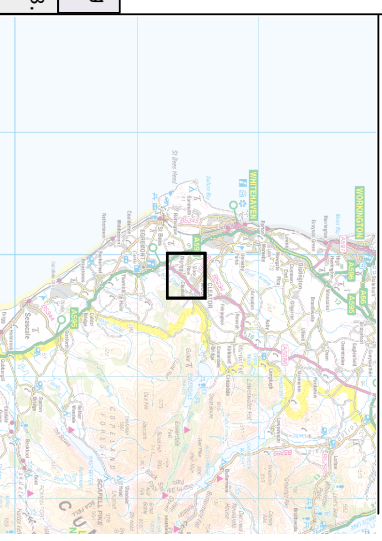
Main River

Flood Zone 3 shows the area that could be affected by flooding:

- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

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

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



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Defended		Return Period(Yrs) Water Level (maod Flow (cumecs)		
Node Point ID	Model Flood group			
EA01104EHEN4_1726d	EA1104FRMEHEN2015_def	10	62.013	85.003
EA01104EHEN4_1726d	EA1104FRMEHEN2015_def	25	62.223	101.675
EA01104EHEN4_1726d	EA1104FRMEHEN2015_def	50	62.32	111.803
EA01104EHEN4_1726d	EA1104FRMEHEN2015_def	75	62.42	122.091
EA01104EHEN4_1726d	EA1104FRMEHEN2015_def	100	62.472	127.207
EA01104EHEN4_1726d	EA1104FRMEHEN2015_def	100+CC	62.692	143.88
EA01104EHEN4_1726d	EA1104FRMEHEN2015_def	200	63.383	140.216
EA01104EHEN4_1726d	EA1104FRMEHEN2015_def	1000	63.685	173.534
EA01104EHEN4_1726u	EA1104FRMEHEN2015_def	10	62.772	67.006
EA01104EHEN4_1726u	EA1104FRMEHEN2015_def	25	62.972	101.675
EA01104EHEN4_1726u	EA1104FRMEHEN2015_def	50	63.086	111.803
EA01104EHEN4_1726u	EA1104FRMEHEN2015_def	75	63.198	122.091
EA01104EHEN4_1726u	EA1104FRMEHEN2015_def	100	63.251	127.207
EA01104EHEN4_1726u	EA1104FRMEHEN2015_def	100+CC	63.419	143.88
EA01104EHEN4_1726u	EA1104FRMEHEN2015_def	200	63.779	92.749
EA01104EHEN4_1726u	EA1104FRMEHEN2015_def	1000	64.135	100.247
EA01104EHEN4_1806d	EA1104FRMEHEN2015_def	10	63.052	77.551
EA01104EHEN4_1806d	EA1104FRMEHEN2015_def	25	63.284	86.275
EA01104EHEN4_1806d	EA1104FRMEHEN2015_def	50	63.418	89.701
EA01104EHEN4_1806d	EA1104FRMEHEN2015_def	75	63.553	91.197
EA01104EHEN4_1806d	EA1104FRMEHEN2015_def	100	63.621	91.358
EA01104EHEN4_1806d	EA1104FRMEHEN2015_def	100+CC	63.823	93.242
EA01104EHEN4_1806d	EA1104FRMEHEN2015_def	200	63.779	92.749
EA01104EHEN4_1806d	EA1104FRMEHEN2015_def	1000	64.135	100.247
EA01104EHEN4_1896	EA1104FRMEHEN2015_def	10	63.948	76.434
EA01104EHEN4_1896	EA1104FRMEHEN2015_def	25	64.086	85.916
EA01104EHEN4_1896	EA1104FRMEHEN2015_def	50	64.146	90.072

EA01104EHEN4_1896	EA1104FRMEHEN2015_def	75	64.194	92.974
EA01104EHEN4_1896	EA1104FRMEHEN2015_def	100	64.223	94.056
EA01104EHEN4_1896	EA1104FRMEHEN2015_def	100+CC	64.291	98.815
EA01104EHEN4_1896	EA1104FRMEHEN2015_def	200	64.015	100.488
EA01104EHEN4_1896	EA1104FRMEHEN2015_def	1000	64.152	116.027

EA01104EHEN4_1896d	EA1104FRMEHEN2015_def	10	63.74	77.543
EA01104EHEN4_1896d	EA1104FRMEHEN2015_def	25	63.852	87.567
EA01104EHEN4_1896d	EA1104FRMEHEN2015_def	50	63.898	92.126
EA01104EHEN4_1896d	EA1104FRMEHEN2015_def	75	63.941	95.293
EA01104EHEN4_1896d	EA1104FRMEHEN2015_def	100	63.972	96.513
EA01104EHEN4_1896d	EA1104FRMEHEN2015_def	100+CC	64.029	101.484
EA01104EHEN4_1896d	EA1104FRMEHEN2015_def	200	64.7	120.715
EA01104EHEN4_1896d	EA1104FRMEHEN2015_def	1000	64.939	147.259

EA01104EHEN4_1806u	EA1104FRMEHEN2015_def	10	63.052	77.551
EA01104EHEN4_1806u	EA1104FRMEHEN2015_def	25	63.284	86.275
EA01104EHEN4_1806u	EA1104FRMEHEN2015_def	50	63.418	89.701
EA01104EHEN4_1806u	EA1104FRMEHEN2015_def	75	63.553	91.197
EA01104EHEN4_1806u	EA1104FRMEHEN2015_def	100	63.621	91.358
EA01104EHEN4_1806u	EA1104FRMEHEN2015_def	100+CC	63.823	93.242
EA01104EHEN4_1806u	EA1104FRMEHEN2015_def	200	64.276	97.704
EA01104EHEN4_1806u	EA1104FRMEHEN2015_def	1000	63.754	86.424

EA01104EHEN4_1606u	EA1104FRMEHEN2015_def	10	61.545	85.032
EA01104EHEN4_1606u	EA1104FRMEHEN2015_def	25	61.765	101.24
EA01104EHEN4_1606u	EA1104FRMEHEN2015_def	50	61.882	111.013
EA01104EHEN4_1606u	EA1104FRMEHEN2015_def	75	61.994	121.169
EA01104EHEN4_1606u	EA1104FRMEHEN2015_def	100	62.052	126.737
EA01104EHEN4_1606u	EA1104FRMEHEN2015_def	100+CC	62.231	145.965
EA01104EHEN4_1606u	EA1104FRMEHEN2015_def	200	62.192	141.565

EA01104EHEN4_1606u	EA1104FRMEHEN2015_def	1000	62.545	185.438
EA01104EHEN4_1606d	EA1104FRMEHEN2015_def	10	60.834	85.032
EA01104EHEN4_1606d	EA1104FRMEHEN2015_def	25	61.064	101.24
EA01104EHEN4_1606d	EA1104FRMEHEN2015_def	50	61.208	111.013
EA01104EHEN4_1606d	EA1104FRMEHEN2015_def	75	61.354	121.169
EA01104EHEN4_1606d	EA1104FRMEHEN2015_def	100	61.427	126.737
EA01104EHEN4_1606d	EA1104FRMEHEN2015_def	100+CC	61.666	145.965
EA01104EHEN4_1606d	EA1104FRMEHEN2015_def	200	61.61	129.311
EA01104EHEN4_1606d	EA1104FRMEHEN2015_def	1000	62.193	165.107
EA01104EHEN4_1502	EA1104FRMEHEN2015_def	10	60.275	85.057
EA01104EHEN4_1502	EA1104FRMEHEN2015_def	25	60.504	101.728
EA01104EHEN4_1502	EA1104FRMEHEN2015_def	50	60.626	111.889
EA01104EHEN4_1502	EA1104FRMEHEN2015_def	75	60.744	122.965
EA01104EHEN4_1502	EA1104FRMEHEN2015_def	100	60.808	129.137
EA01104EHEN4_1502	EA1104FRMEHEN2015_def	100+CC	61.001	151.25
EA01104EHEN4_1502	EA1104FRMEHEN2015_def	200	60.953	146.021
EA01104EHEN4_1502	EA1104FRMEHEN2015_def	1000	61.398	198.323
EA01104EHEN4_1406d	EA1104FRMEHEN2015_def	10	59.892	85.08
EA01104EHEN4_1406d	EA1104FRMEHEN2015_def	25	60.118	101.697
EA01104EHEN4_1406d	EA1104FRMEHEN2015_def	50	60.224	111.657
EA01104EHEN4_1406d	EA1104FRMEHEN2015_def	75	60.379	122.255
EA01104EHEN4_1406d	EA1104FRMEHEN2015_def	100	60.451	128.097
EA01104EHEN4_1406d	EA1104FRMEHEN2015_def	100+CC	60.559	149.927
EA01104EHEN4_1406d	EA1104FRMEHEN2015_def	200	60.56	144.657
EA01104EHEN4_1406d	EA1104FRMEHEN2015_def	1000	61.039	202.596
EA01104EHEN4_1406u	EA1104FRMEHEN2015_def	10	59.892	85.08
EA01104EHEN4_1406u	EA1104FRMEHEN2015_def	25	60.118	101.697
EA01104EHEN4_1406u	EA1104FRMEHEN2015_def	50	60.244	111.657

EA01104EHEN4_1406u	EA1104FRMEHEN2015_def	75	60.379	122.255
EA01104EHEN4_1406u	EA1104FRMEHEN2015_def	100	60.451	128.097
EA01104EHEN4_1406u	EA1104FRMEHEN2015_def	100+CC	60.599	149.927
EA01104EHEN4_1406u	EA1104FRMEHEN2015_def	200	60.953	146.021
EA01104EHEN4_1406u	EA1104FRMEHEN2015_def	1000	61.398	198.323
EA01104EHEN4_1299u	EA1104FRMEHEN2015_def	10	59.379	85.106
EA01104EHEN4_1299u	EA1104FRMEHEN2015_def	25	59.549	101.801
EA01104EHEN4_1299u	EA1104FRMEHEN2015_def	50	59.64	111.974
EA01104EHEN4_1299u	EA1104FRMEHEN2015_def	75	59.733	123.071
EA01104EHEN4_1299u	EA1104FRMEHEN2015_def	100	59.775	129.253
EA01104EHEN4_1299u	EA1104FRMEHEN2015_def	100+CC	59.912	152.206
EA01104EHEN4_1299u	EA1104FRMEHEN2015_def	200	60.56	144.657
EA01104EHEN4_1299u	EA1104FRMEHEN2015_def	1000	61.039	202.596
EA01104EHEN4_1206u	EA1104FRMEHEN2015_def	10	58.826	85.128
EA01104EHEN4_1206u	EA1104FRMEHEN2015_def	25	58.938	101.546
EA01104EHEN4_1206u	EA1104FRMEHEN2015_def	50	58.992	111.299
EA01104EHEN4_1206u	EA1104FRMEHEN2015_def	75	59.044	121.701
EA01104EHEN4_1206u	EA1104FRMEHEN2015_def	100	59.056	127.645
EA01104EHEN4_1206u	EA1104FRMEHEN2015_def	100+CC	59.075	150.014
EA01104EHEN4_1206u	EA1104FRMEHEN2015_def	200	59.88	146.482
EA01104EHEN4_1206u	EA1104FRMEHEN2015_def	1000	60.205	210.945
EA01104EHEN4_1206d	EA1104FRMEHEN2015_def	10	58.826	85.128
EA01104EHEN4_1206d	EA1104FRMEHEN2015_def	25	58.938	101.546
EA01104EHEN4_1206d	EA1104FRMEHEN2015_def	50	58.992	111.299
EA01104EHEN4_1206d	EA1104FRMEHEN2015_def	75	59.044	121.701
EA01104EHEN4_1206d	EA1104FRMEHEN2015_def	100	59.056	127.645
EA01104EHEN4_1206d	EA1104FRMEHEN2015_def	100+CC	59.075	150.014
EA01104EHEN4_1206d	EA1104FRMEHEN2015_def	200	59.071	144.439
EA01104EHEN4_1206d	EA1104FRMEHEN2015_def	1000	59.234	203.897

Undefended			Return Period(Yrs)	Water Level (maod)	Flow (cumecs)
Node Point ID	Model Flood group				
EA01104EHEN4_1726d	EA1104FRMEHEN2015		10	62.024	85.635
EA01104EHEN4_1726d	EA1104FRMEHEN2015		25	62.203	98.295
EA01104EHEN4_1726d	EA1104FRMEHEN2015		50	62.29	104.334
EA01104EHEN4_1726d	EA1104FRMEHEN2015		75	62.392	109.629
EA01104EHEN4_1726d	EA1104FRMEHEN2015		100	62.443	112.064
EA01104EHEN4_1726d	EA1104FRMEHEN2015		100+CC	62.208	119.508
EA01104EHEN4_1726d	EA1104FRMEHEN2015		200	62.241	140.216
EA01104EHEN4_1726d	EA1104FRMEHEN2015		1000	63.035	135.814
EA01104EHEN4_1726u	EA1104FRMEHEN2015		10	62.78	85.635
EA01104EHEN4_1726u	EA1104FRMEHEN2015		25	62.933	98.295
EA01104EHEN4_1726u	EA1104FRMEHEN2015		50	63.003	104.334
EA01104EHEN4_1726u	EA1104FRMEHEN2015		75	63.062	109.629
EA01104EHEN4_1726u	EA1104FRMEHEN2015		100	63.089	112.064
EA01104EHEN4_1726u	EA1104FRMEHEN2015		100+CC	63.17	119.508
EA01104EHEN4_1726u	EA1104FRMEHEN2015		200	63.383	118.004
EA01104EHEN4_1726u	EA1104FRMEHEN2015		1000	63.339	135.814
EA01104EHEN4_1806d	EA1104FRMEHEN2015		10	63.097	67.006
EA01104EHEN4_1806d	EA1104FRMEHEN2015		25	63.284	69.381
EA01104EHEN4_1806d	EA1104FRMEHEN2015		50	63.367	71.016
EA01104EHEN4_1806d	EA1104FRMEHEN2015		75	63.438	72.753
EA01104EHEN4_1806d	EA1104FRMEHEN2015		100	63.469	73.652
EA01104EHEN4_1806d	EA1104FRMEHEN2015		100+CC	63.563	76.122
EA01104EHEN4_1806d	EA1104FRMEHEN2015		200	63.544	75.778
EA01104EHEN4_1806d	EA1104FRMEHEN2015		1000	63.754	86.424
EA01104EHEN4_1896	EA1104FRMEHEN2015		10	63.778	64.737
EA01104EHEN4_1896	EA1104FRMEHEN2015		25	63.844	66.953
EA01104EHEN4_1896	EA1104FRMEHEN2015		50	63.887	68.838

EA01104EHEN4_1896	EA1104FRMEHEN2015	75	63.929	71.243
EA01104EHEN4_1896	EA1104FRMEHEN2015	100	63.949	72.743
EA01104EHEN4_1896	EA1104FRMEHEN2015	100+CC	64.016	78.371
EA01104EHEN4_1896	EA1104FRMEHEN2015	200	64.002	77.1
EA01104EHEN4_1896	EA1104FRMEHEN2015	1000	64.458	112.23

EA01104EHEN4_1896d	EA1104FRMEHEN2015	10	63.601	65.878
EA01104EHEN4_1896d	EA1104FRMEHEN2015	25	63.667	68.625
EA01104EHEN4_1896d	EA1104FRMEHEN2015	50	63.707	70.898
EA01104EHEN4_1896d	EA1104FRMEHEN2015	75	63.743	73.527
EA01104EHEN4_1896d	EA1104FRMEHEN2015	100	63.758	75.168
EA01104EHEN4_1896d	EA1104FRMEHEN2015	100+CC	63.805	81.063
EA01104EHEN4_1896d	EA1104FRMEHEN2015	200	63.794	79.925
EA01104EHEN4_1896d	EA1104FRMEHEN2015	1000	63.925	97.461

EA01104EHEN4_1806u	EA1104FRMEHEN2015	10	63.097	67.006
EA01104EHEN4_1806u	EA1104FRMEHEN2015	25	63.284	69.381
EA01104EHEN4_1806u	EA1104FRMEHEN2015	50	63.367	71.016
EA01104EHEN4_1806u	EA1104FRMEHEN2015	75	63.438	72.753
EA01104EHEN4_1806u	EA1104FRMEHEN2015	100	63.469	73.652
EA01104EHEN4_1806u	EA1104FRMEHEN2015	100+CC	63.563	76.122
EA01104EHEN4_1806u	EA1104FRMEHEN2015	200	63.544	75.778
EA01104EHEN4_1806u	EA1104FRMEHEN2015	1000	63.754	86.424

EA01104EHEN4_1606u	EA1104FRMEHEN2015	10	61.556	85.791
EA01104EHEN4_1606u	EA1104FRMEHEN2015	25	61.738	99.175
EA01104EHEN4_1606u	EA1104FRMEHEN2015	50	61.834	106.938
EA01104EHEN4_1606u	EA1104FRMEHEN2015	75	61.928	115.064
EA01104EHEN4_1606u	EA1104FRMEHEN2015	100	61.974	119.209
EA01104EHEN4_1606u	EA1104FRMEHEN2015	100+CC	62.107	132.378
EA01104EHEN4_1606u	EA1104FRMEHEN2015	200	62.077	129.311

EA01104EHEN4_1606u	EA1104FRMEHEN2015	1000	62.468	165.107
EA01104EHEN4_1606d	EA1104FRMEHEN2015	10	60.846	85.791
EA01104EHEN4_1606d	EA1104FRMEHEN2015	25	61.066	99.175
EA01104EHEN4_1606d	EA1104FRMEHEN2015	50	61.219	106.938
EA01104EHEN4_1606d	EA1104FRMEHEN2015	75	61.368	115.064
EA01104EHEN4_1606d	EA1104FRMEHEN2015	100	61.442	119.209
EA01104EHEN4_1606d	EA1104FRMEHEN2015	100+CC	61.658	132.378
EA01104EHEN4_1606d	EA1104FRMEHEN2015	200	61.61	141.565
EA01104EHEN4_1606d	EA1104FRMEHEN2015	1000	62.193	165.107
EA01104EHEN4_1502	EA1104FRMEHEN2015	10	60.291	85.849
EA01104EHEN4_1502	EA1104FRMEHEN2015	25	60.51	100.509
EA01104EHEN4_1502	EA1104FRMEHEN2015	50	60.632	109.947
EA01104EHEN4_1502	EA1104FRMEHEN2015	75	60.75	120.011
EA01104EHEN4_1502	EA1104FRMEHEN2015	100	60.814	125.364
EA01104EHEN4_1502	EA1104FRMEHEN2015	100+CC	60.984	143.259
EA01104EHEN4_1502	EA1104FRMEHEN2015	200	60.947	139.137
EA01104EHEN4_1502	EA1104FRMEHEN2015	1000	61.321	193.319
EA01104EHEN4_1406d	EA1104FRMEHEN2015	10	59.906	86.039
EA01104EHEN4_1406d	EA1104FRMEHEN2015	25	60.115	101.387
EA01104EHEN4_1406d	EA1104FRMEHEN2015	50	60.238	110.983
EA01104EHEN4_1406d	EA1104FRMEHEN2015	75	60.397	121.057
EA01104EHEN4_1406d	EA1104FRMEHEN2015	100	60.435	126.415
EA01104EHEN4_1406d	EA1104FRMEHEN2015	100+CC	60.562	144.742
EA01104EHEN4_1406d	EA1104FRMEHEN2015	200	60.549	140.363
EA01104EHEN4_1406d	EA1104FRMEHEN2015	1000	61.039	194.063
EA01104EHEN4_1406u	EA1104FRMEHEN2015	10	59.09	86.039
EA01104EHEN4_1406u	EA1104FRMEHEN2015	25	60.115	101.387
EA01104EHEN4_1406u	EA1104FRMEHEN2015	50	60.238	110.983

EA01104EHEN4_1406u	EA1104FRMEHEN2015	75	60.367	121.057
EA01104EHEN4_1406u	EA1104FRMEHEN2015	100	60.435	126.415
EA01104EHEN4_1406u	EA1104FRMEHEN2015	100+CC	60.562	144.742
EA01104EHEN4_1406u	EA1104FRMEHEN2015	200	60.549	140.363
EA01104EHEN4_1406u	EA1104FRMEHEN2015	1000	60.998	194.063
EA01104EHEN4_1299u	EA1104FRMEHEN2015	10	59.39	86.067
EA01104EHEN4_1299u	EA1104FRMEHEN2015	25	59.547	101.558
EA01104EHEN4_1299u	EA1104FRMEHEN2015	50	59.634	111.404
EA01104EHEN4_1299u	EA1104FRMEHEN2015	75	59.725	121.991
EA01104EHEN4_1299u	EA1104FRMEHEN2015	100	59.767	127.705
EA01104EHEN4_1299u	EA1104FRMEHEN2015	100+CC	59.881	1146.854
EA01104EHEN4_1299u	EA1104FRMEHEN2015	200	59.854	142.423
EA01104EHEN4_1299u	EA1104FRMEHEN2015	1000	60.162	201.548
EA01104EHEN4_1206u	EA1104FRMEHEN2015	10	58.833	86.088
EA01104EHEN4_1206u	EA1104FRMEHEN2015	25	58.937	101.308
EA01104EHEN4_1206u	EA1104FRMEHEN2015	50	58.989	110.761
EA01104EHEN4_1206u	EA1104FRMEHEN2015	75	59.039	120.695
EA01104EHEN4_1206u	EA1104FRMEHEN2015	100	59.059	126.069
EA01104EHEN4_1206u	EA1104FRMEHEN2015	100+CC	59.088	144.551
EA01104EHEN4_1206u	EA1104FRMEHEN2015	200	59.08	140.338
EA01104EHEN4_1206u	EA1104FRMEHEN2015	1000	59.218	195.285
EA01104EHEN4_1206d	EA1104FRMEHEN2015	10	58.833	86.088
EA01104EHEN4_1206d	EA1104FRMEHEN2015	25	58.937	101.308
EA01104EHEN4_1206d	EA1104FRMEHEN2015	50	58.989	110.761
EA01104EHEN4_1206d	EA1104FRMEHEN2015	75	59.039	120.695
EA01104EHEN4_1206d	EA1104FRMEHEN2015	100	59.059	126.069
EA01104EHEN4_1206d	EA1104FRMEHEN2015	100+CC	59.088	144.551
EA01104EHEN4_1206d	EA1104FRMEHEN2015	200	59.08	140.338
EA01104EHEN4_1206d	EA1104FRMEHEN2015	1000	59.218	195.285



Historic Flood Map: **Cleator Mills,** **Cleator, CA23 3DU**

Produced: 09 July 2019
Our Ref: CL132929
NGR: 301,526 513,720

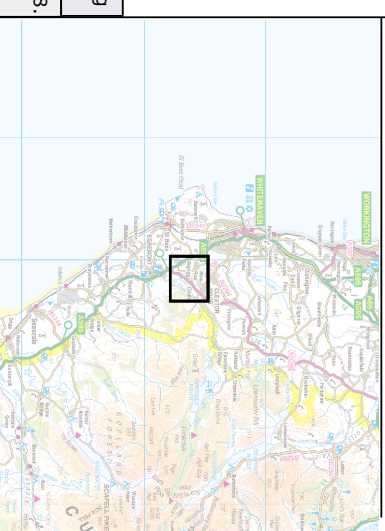
Key

 November 2009 Recorded Flood
Outline

Flood Zone 3 shows the area that could be affected by flooding:
- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

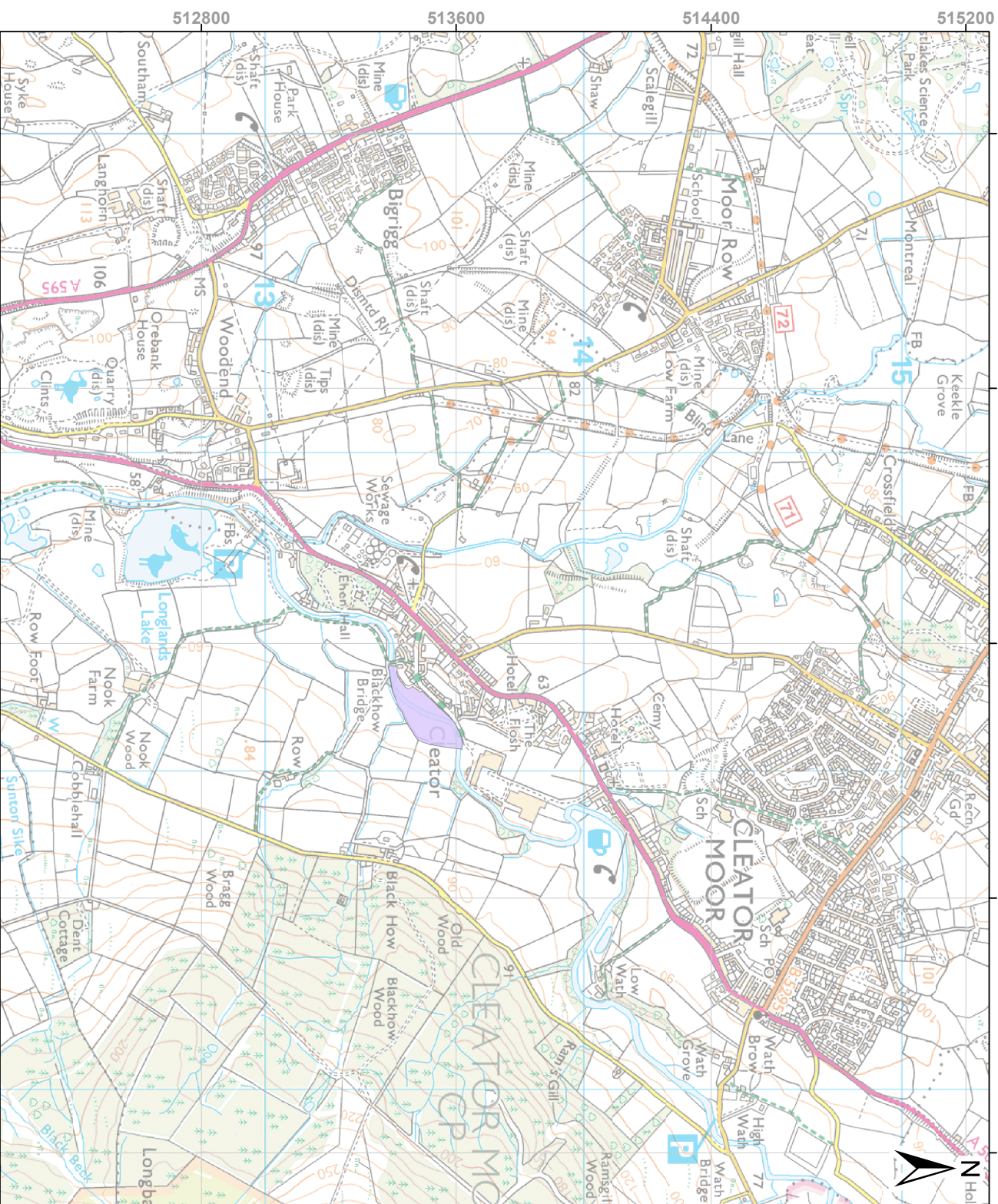
Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to 0.1% chance of occurring each year.

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



Modelled water levels with climate change using +20% flow allowances are not suitable for the majority of planning purposes. New climate change allowances can be checked on the following website: www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

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Historic Flood Map: **Cleator Mills,** **Cleator, CA23 3DU**

Produced: 09 July 2019
Our Ref: CL132929
NGR: 301,526 513,720

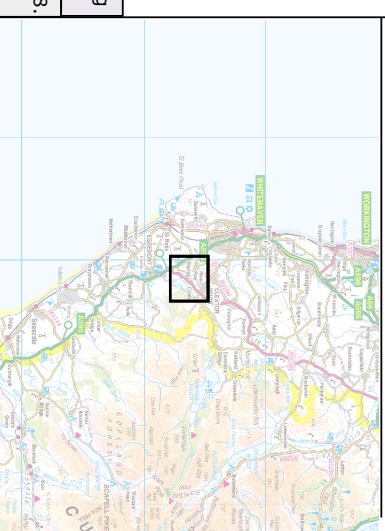
Key

 October 2017 Recorded Flood
 Flood Zone 3

Flood Zone 3 shows the area that could be affected by flooding:
- from the sea with a 0.5% or greater chance of happening each year
- or from a river with a 1.0% or greater chance of happening each year.

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

ABDs (Areas Benefiting from Defences) show the area benefiting from defences during a 0.5% tidal, or 1.0% fluvial flood event.



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Appendix I Topographical Survey

Appendix J Overland Flow Route

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