RAIB

Rail Accident Investigation Branch

Rail Accident Report

Embankment washout under a passenger train at Haddiscoe
30 January 2022

Report 07/2023
July 2023

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC
- the Railways and Transport Safety Act 2003
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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Preface

The purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences. It is not the purpose of such an investigation to establish blame or liability. Accordingly, it is inappropriate that RAIB reports should be used to assign fault or blame, or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

RAIB's findings are based on its own evaluation of the evidence that was available at the time of the investigation and are intended to explain what happened, and why, in a fair and unbiased manner.

Where RAIB has described a factor as being linked to cause and the term is unqualified, this means that RAIB has satisfied itself that the evidence supports both the presence of the factor and its direct relevance to the causation of the accident or incident that is being investigated. However, where RAIB is less confident about the existence of a factor, or its role in the causation of the accident or incident, RAIB will qualify its findings by use of words such as 'probable' or 'possible', as appropriate. Where there is more than one potential explanation RAIB may describe one factor as being 'more' or 'less' likely than the other.

In some cases factors are described as 'underlying'. Such factors are also relevant to the causation of the accident or incident but are associated with the underlying management arrangements or organisational issues (such as working culture). Where necessary, words such as 'probable' or 'possible' can also be used to qualify 'underlying factor'.

Use of the word 'probable' means that, although it is considered highly likely that the factor applied, some small element of uncertainty remains. Use of the word 'possible' means that, although there is some evidence that supports this factor, there remains a more significant degree of uncertainty.

An 'observation' is a safety issue discovered as part of the investigation that is not considered to be causal or underlying to the accident or incident being investigated, but does deserve scrutiny because of a perceived potential for safety learning.

The above terms are intended to assist readers' interpretation of the report, and to provide suitable explanations where uncertainty remains. The report should therefore be interpreted as the view of RAIB, expressed with the sole purpose of improving railway safety.

Any information about casualties is based on figures provided to RAIB from various sources. Considerations of personal privacy may mean that not all of the actual effects of the event are recorded in the report. RAIB recognises that sudden unexpected events can have both short- and long-term consequences for the physical and/or mental health of people who were involved, both directly and indirectly, in what happened.

RAIB's investigation (including its scope, methods, conclusions and recommendations) is independent of any inquest or fatal accident inquiry, and all other investigations, including those carried out by the safety authority, police or railway industry.

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Embankment washout under a passenger train at Haddiscoe, 30 January 2022

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Summary

At about 07:45 hrs on Sunday 30 January 2022, a passenger train, which was travelling from Norwich to Lowestoft, ran on to a washed out section of track between Reedham and Haddiscoe stations. The train, which was crewed by a driver and a guard, was carrying five passengers. The driver had seen that the track was flooded ahead of the train and so brought it to a stand. Once the train had stopped, the driver noticed that the ballast was washing away under the train. While the driver was preparing to drive back towards Reedham, the situation worsened and a section of ballast washed away, leaving a large void under the track on which the train was standing. As the driver moved the train it started to lean over. The driver therefore made the decision that it was too dangerous to continue moving the train, and they and the guard evacuated the five passengers.

RAIB's investigation found that unusually high water levels existed on the day of the incident due to a combination of tidal surge and tidal locking. Localised low spots in the flood defences next to the track concerned then allowed this water to enter the railway. The train involved was not prevented from entering the flooded section of track because Network Rail was not aware that water was entering the railway at this location. RAIB also found that Network Rail's flood risk management processes were not effective at warning that the track at Haddiscoe was at serious risk of flooding.

Underlying factors were that the Environment Agency's management of flooding risk in the area did not account for, and was not required to account for, the impact of localised flooding on the railway, and that Network Rail was not effectively managing the risks to its assets and services associated with third party flood defences. A possible underlying factor was that no joint strategy was in place to protect the railway from flooding at this location due to the Environment Agency and Network Rail not effectively collaborating.

As a result of the investigation RAIB has made five recommendations. The first is made to the Environment Agency and Network Rail and aims to ensure that railway-related flood risk is managed appropriately alongside Haddiscoe Cut. The second and third recommendations are made to Network Rail and concern the integration of flood risk into their weather management strategies. The fourth recommendation is intended to improve interaction between Network Rail and those organisations responsible for tidal flood defences in England and Wales, while the final recommendation is intended to improve these interactions in Scotland.

Introduction

Definitions

1 Metric units are used in this report, except when it is normal railway practice to give speeds and locations in imperial units. Where appropriate the equivalent metric value is also given.

2 The report contains abbreviations and acronyms, which are explained in appendix A. Sources of evidence used in the investigation are listed in appendix B.

The incident

Summary of the incident

3 At approximately 07:45 hrs on Sunday 30 January 2022, the driver of train reporting number 2J66, the 07:25 hrs Greater Anglia passenger service travelling from Norwich to Lowestoft, made a call to the signaller reporting water escaping from an adjacent waterway and towards the railway. During this call, the driver also reported pooling water on the line ahead, and brought the train to a stand between Reedham and Haddiscoe stations (figure 1).

4 The train stopped on the area of flooding, where a significant amount of ballast supporting the track was washing away. This began creating a void under the track beneath the stationary train. After a short period, in which the driver attempted to reverse the train off the affected area, the train started to lean to one side.

5 The driver and guard decided it was therefore safer to leave the train where it was and to evacuate the five passengers from the train. All passengers and crew were off the train by 08:12 hrs and were picked up by a rescue train at 09:08 hrs.

6 Both lines were blocked by the washout, and services between Ipswich, Norwich and Lowestoft were suspended until 5 February 2022.

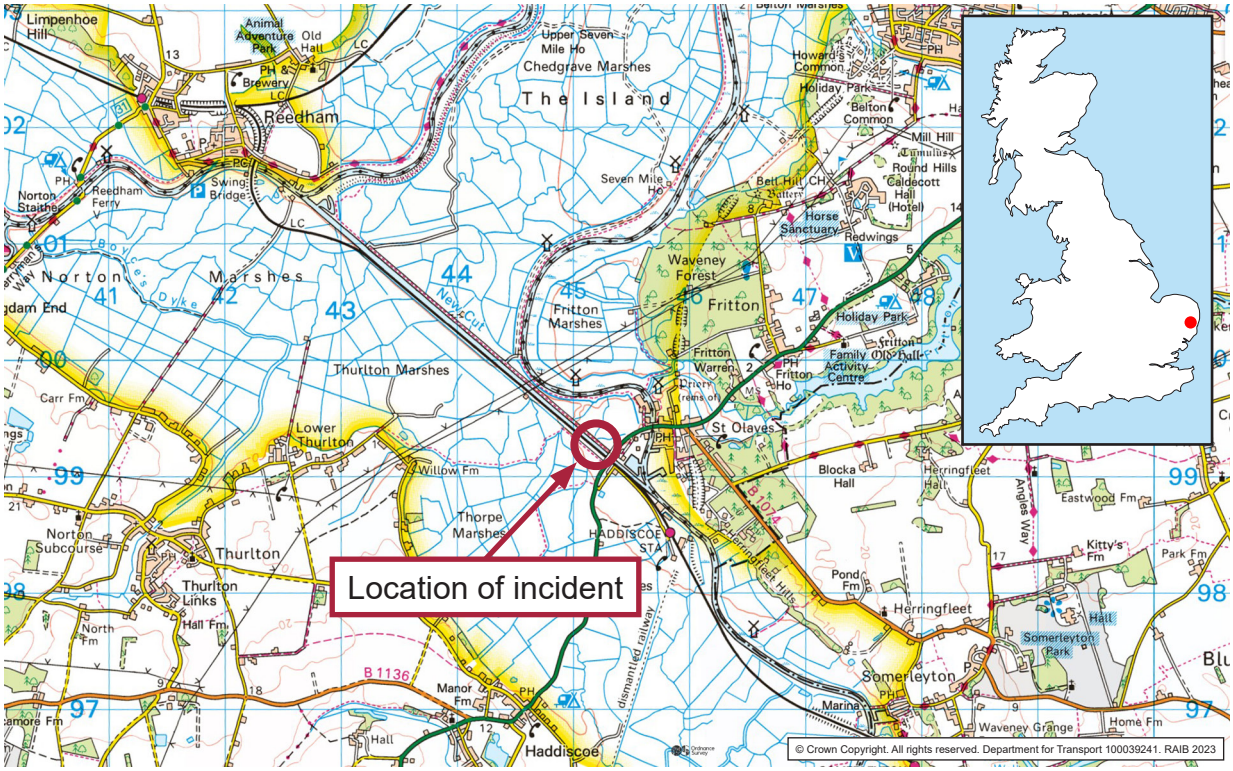


Figure 1: Extract from Ordnance Survey map showing location of incident at Haddiscoe.

Context

Location

7 The incident occurred on the lines from Norwich to Lowestoft, between the villages of Reedham and Haddiscoe, in Norfolk. At this location, the railway consists of the Up and Down Lowestoft lines with each line allowing a maximum permitted speed of 60 mph (97 km/h). Trains are signalled in accordance with track circuit block regulations using colour light signals, with the signalling controlled from Colchester signal box.

8 From Reedham, the railway continues east, then diverges; trains can continue north-east on to Great Yarmouth, or curve south towards Lowestoft. The Lowestoft lines then pass over the River Yare using Reedham swing bridge,[1] and curve left and then right. For around 1.24 miles (2 km), the railway then runs straight and parallel to a body of water known as the New Cut waterway (New Cut, figure 2). The track washout occurred on this section at 15 miles 28 chains,[2] approximately 16 miles (25.7 km) south-east of Norwich.

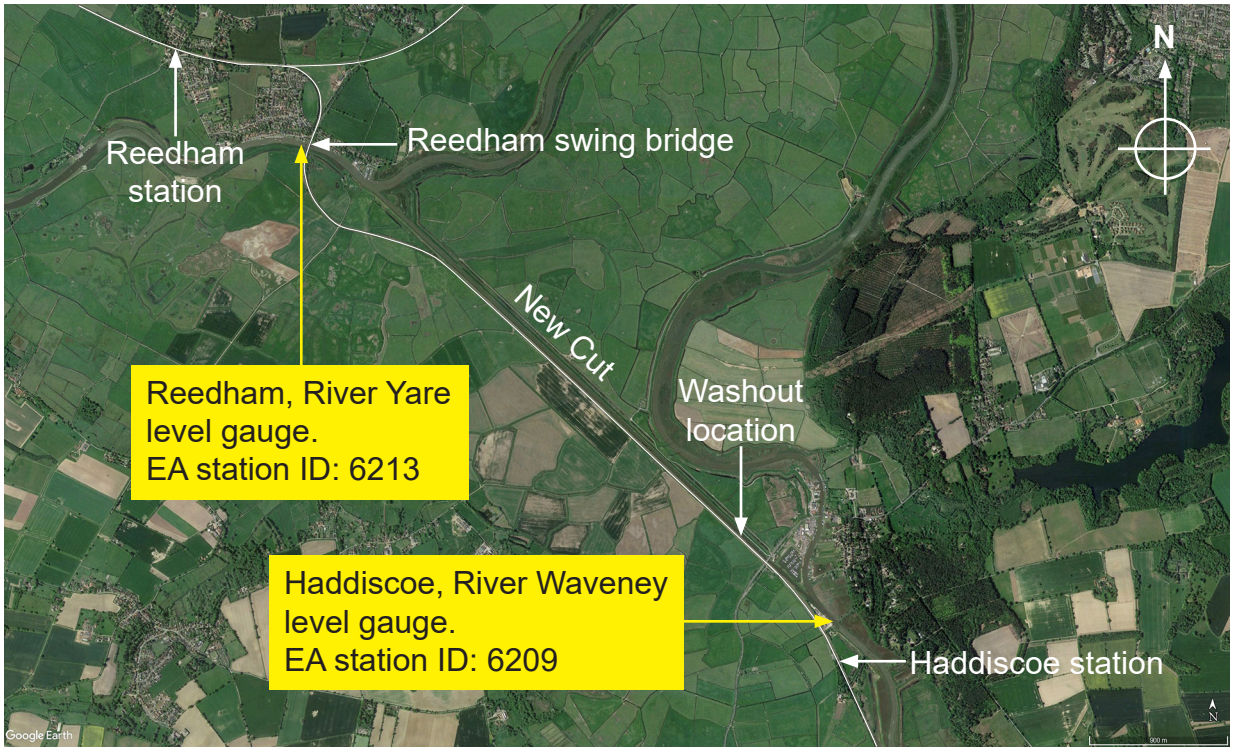


Figure 2: Map of area showing the track layout and relationship between the railway and New Cut.

9 The Norfolk and Suffolk Broadlands form a large, low-lying wetland in a flat landscape in Norfolk and on the Suffolk border, commonly known as the 'Broads'. This wetland drains a vast area of these two counties which ranges from beyond Fakenham, to the north on the River Wensum, to beyond Eye on the River Dove, to the south in Suffolk. The water drains into three main tidal rivers, the Bure, the Yare and the Waveney, which meet near Great Yarmouth, where they enter the North Sea.

[1] A swing bridge is used to allow watercraft to pass through on the river which would otherwise be partially restricted by the railway above.

[2] A chain is a unit of length equal to 66 feet, or 22 yards (around 20 metres).

10 The Environment Agency (EA – see paragraph 15) divides the Broadlands area into around 40 flood risk management compartments which operate both independently and together to protect adjacent property (figure 3). There are 149 miles (240 km) of flood bank within the Broadlands area as most of the land is below high tide level or below the level of adjacent rivers.

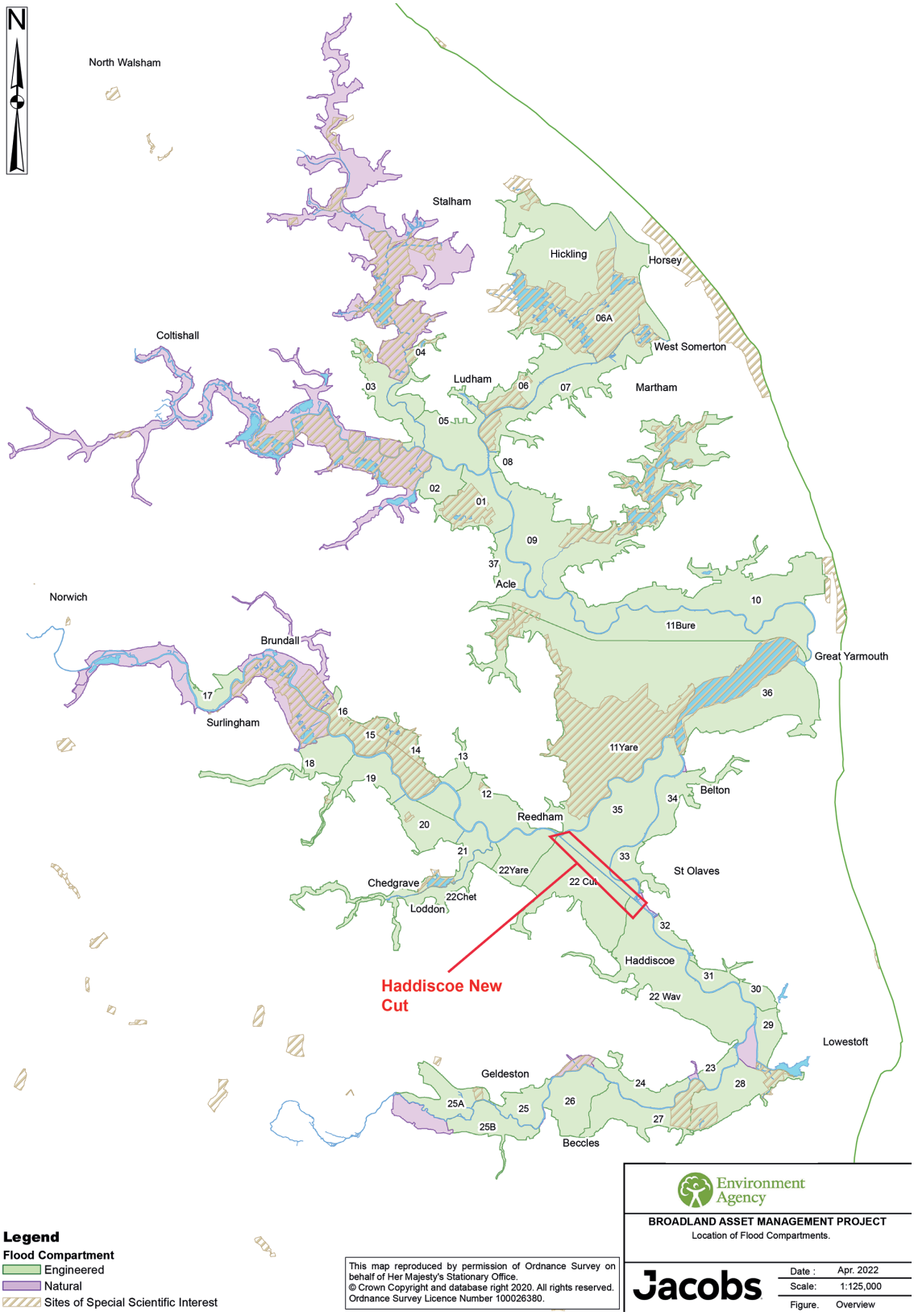


Figure 3: Environment Agency flood compartments.

11 The New Cut waterway was originally constructed in 1832, joining the rivers Waveney and Yare to provide a direct, navigable link between Lowestoft and Norwich. The west side bank of New Cut, which is adjacent to the railway, forms part of the boundary of compartment 22, one of the largest flood compartments. The east side bank of New Cut lies within compartment 35, which is an island between New Cut and the Rivers Yare and Waveney.

12 The rivers within the Broadlands area are tidal, and so rise and fall under the influence of the adjacent North Sea. In addition to the astronomical tidal cycle giving a high tide every 12 hours and 24 minutes, sea levels are affected by surges. These are increases or reductions in water levels caused by deep low-pressure weather systems in conjunction with the astronomical tidal cycles (see paragraph 51).

Organisations involved

13 Network Rail is the owner and maintainer of the railway infrastructure at this location. It also employed the staff responsible for signalling the train and managing weather-related incidents affecting the railway.

14 Greater Anglia (GA), part of Abellio Transport Holdings, is the operator of the train involved in the incident and employs the driver of the train.

15 EA owns the land that includes the bed of the Haddiscoe New Cut and a thin strip of land between it and the railway. EA owns the flood defences (crest and frontage piling – see paragraphs 19 to 21) along the bank of New Cut and manages these defences to achieve specified objectives (see paragraph 84). EA also monitors water levels at approximately 3500 locations around the UK coast and along main rivers using measuring stations. It uses this data to issue flood alerts and warnings to anyone who signs up to this service.

16 Broadlands Environmental Services Limited (BESL) was contracted by EA in 2001 to manage and maintain the flood defences as part of the Broadland Flood Alleviation Project (BFAP). BESL originally comprised a construction company, Edmund Nuttall, and a design company, Halcrow. Changes in ownership led to these becoming, respectively, part of BAM Nuttall and Jacobs before BESL completed its flood defence contract in November 2021.

17 Jeremy Benn Associates Limited (which trades as JBA Consulting) hosts the Flood Warning Database (FWD) for Network Rail which sends flood warnings to Network Rail control centres.

18 All organisations freely co-operated with the investigation.

The flood defences

19 The flood defences along Haddiscoe New Cut comprise a bank supported by frontage piles, which is topped with crest piling. The bank also supports the railway, with the railway boundary fence on the landward side of the crest piling (figure 4).

20 Frontage piles, which can be made of various materials including wood and steel, protect the riverbank from the erosion caused by river currents and provide some support to the ground behind them. Steel frontage piling was in use at the location of the incident.

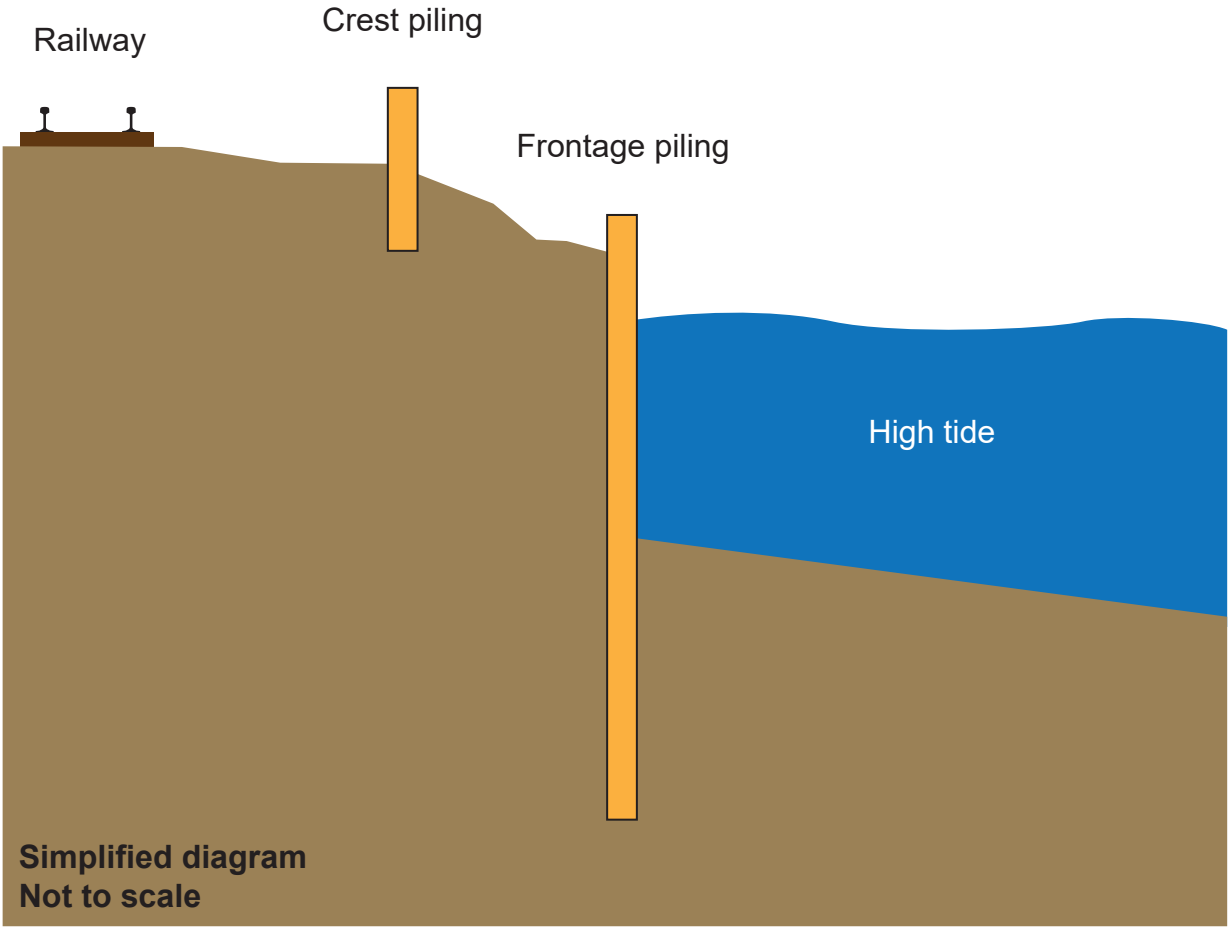


Figure 4: Flood defences and cross section of bank.

21 The crest piling was installed in 2006 to provide a consistent flood defence level in an area where the bank was no longer considered to be at a sufficient height (see paragraph 38). The crest piling was made of plastic.

Train involved

22 The train involved in the incident, reporting number 2J66, was the 07:25 hrs passenger service from Norwich to Lowestoft. It was a class 755/3 bi-mode multiple unit train, formed of four vehicles. The train was fitted with an on-train data recorder (OTDR) and with forward-facing, rear-facing, and body side mounted closed-circuit television (CCTV) systems.

Staff involved

23 The driver of the train was based at Norwich depot and had worked as a driver with GA for two years at the time of the incident. During the previous 18 years, they had worked on the railway in various other roles. All the relevant competence assessments for the driver were up to date.

External circumstances

24 At the time of the incident, there was no wind or rain in the local area and the sun was just breaking over the horizon. However, storms in the days before the incident resulted in higher than usual water levels in the Broadland river system (see paragraph 25).

The sequence of events

Events preceding the incident

25 On 29 and 30 January 2022, two storms affected much of the UK. Storm Malik and Storm Corrie were deep low-pressure systems which moved over the north of the UK, with associated strong winds from a northerly to north-westerly direction. These weather conditions caused a tidal surge, with unusually high tides on the east coast of England. This resulted in higher than usual water levels in the Broadland river system, including New Cut.

26 On Saturday 29 January 2022 at 16:28 hrs, EA issued a flood warning for riverside properties along the tidal River Yare (see paragraph 80). At 16:36 hrs it also issued a flood warning for isolated low-lying properties along the tidal River Waveney. Network Rail Anglia route control received these by email but was not required by its procedures to act based on these warnings. This is because its procedures state that route control only takes action based on alerts from the separate FWD system used for this purpose (see paragraph 81).

27 The last train to use the railway adjacent to New Cut before the incident train was 2J96. This was a scheduled passenger service and departed from Norwich at 22:40 hrs on the day before the incident and arrived at Lowestoft at 23:21 hrs. Therefore, it would have passed the incident area on the Down Lowestoft line at approximately 23:05 hrs on the night before the incident. The driver of this train did not report any issues at the incident location during this journey.

28 At 07:25 hrs on 30 January, train 2J66 departed Norwich. It was the first train scheduled to go through the incident site that day. The train called at Reedham station, departing at 07:39 hrs, and then continued its journey towards Lowestoft. The driver accelerated the train towards 60 mph (97 km/h), the maximum permitted speed on this section of line, and proceeded along the railway adjacent to the New Cut.

Events during the incident

29 At 07:45 hrs, the driver of train 2J66 made a call to the signaller using the GSM-R[3] radio system to report that there was a “tiny bit of water escaping the banks of the river” at a location approximately 0.6 miles (1 km) before the incident location. The train was travelling at around 55 mph (89 km/h) at this point. While still on the radio call, the driver started braking as they could see pooling water on the track ahead. The driver told the signaller they would need to stop the train as water was clearly visible on both lines (figure 5). The railway Rule Book requires the driver to tell the signaller if the flood water is up to the bottom of the railhead, is up to or above the top of the railhead, is moving and likely to dislodge the ballast, or has already dislodged the ballast. The train stopped on the section of pooling water while the driver was still on the call to the signaller.

[3] Global system for mobile communications – railway.

Figure 5: View from FFCCTV just before the driver stopped the train.

30 The train's guard joined the driver and together they assessed the situation. The driver called the signaller back at 07:49 hrs stating that there was some dislodged ballast under the train, but the train was safe, and the void was not big enough to pose danger. However, five minutes later, the driver called the signaller again and explained that the situation was worsening, and the void was now under the leading vehicle. The driver requested permission from the signaller to go to the rear train cab and drive the train back one carriage length towards Reedham to move it from being directly over the void.

31 At 07:58 hrs, the driver called the signaller again to say that they had changed ends and was preparing to move the train. The driver attempted to move train 2J66 but the rearmost carriage of the train (which had been at the front of the train) had by now started to lean over, so the driver stopped the movement after just a few metres. At 08:01 hrs, the driver called the signaller again and requested a line blockage (to stop any trains passing on the adjacent line) and permission to evacuate the passengers.

Events following the incident

32 By 08:12 hrs, the line blockage had been arranged, permission to evacuate the train had been given and all train crew and passengers had been safely evacuated from the train.

33 At 08:23 hrs, the driver of train 2C01 (the 08:17 hrs Great Yarmouth to Norwich service) was sent a request to detrain all passengers at Reedham and head towards Lowestoft to collect the passengers from train 2J66. All passengers were confirmed to be safely on train 2C01 by 09:08 hrs. This train then took them back to Reedham.

34 At 09:50 hrs, an empty train was dispatched from Norwich to pull train 2J66 from the affected area. After work was carried out to stabilise the track, the empty train and train 2J66 were coupled together and left site to travel back towards Reedham at 01:49 hrs on 1 February.

35 Repairs to the track and temporary repairs to the flood defence were completed by 4 February, and the line reopened to railway traffic on 5 February 2022 with an emergency procedure in place. This stated that, on receiving an FWD email notification or call from EA, the line between Reedham and Somerleyton would be blocked to traffic in both directions.

Background information

Flood Defence management

36 In 2001, EA embarked on a 20-year programme of work to maintain and improve the network of flood defences in the Broadlands. This was called the Broadland Flood Alleviation Project. The BFAP programme sought to strengthen the flood defences in the whole of the Broadlands to improve their resistance to breaches, and to restore the height of the defences to counter ground settlement.

37 EA contracted the planning, design and construction work for the project to a consortium named Broadland Environmental Services Ltd formed by the companies now known as BAM Nuttall (as civil engineering contractor) and Jacobs (as planning and design contractor). BESL was also responsible for the ongoing surveying and maintenance of the flood defences throughout the contract.

38 Due to the undulating nature of clay banks in the area, crest piling was used to provide a more consistent flood defence height. The maintenance strategy meant that the service level (nominal flood defence height) varied within the Broadlands so that water would flow into compartments that do not contain settlements or property before those that do (see paragraph 85). The service level alongside the railway at New Cut was determined by EA as 1.7 m above ordnance datum (AOD), higher than the adjacent railway track level which is about 1.25 m AOD. An allowance for ongoing ground settlement (see paragraph 57) meant that BESL installed the crest piles along New Cut to a minimum crest height of 1.9 m AOD.

39 Management of water flows meant that some short stretches of crest piling in compartment 22 were designed to have a crest height of 1.4 m AOD, but these were not adjacent to the railway where the service level of 1.7 m AOD applied.

40 In May 2021, EA took back direct responsibility for the assets and associated maintenance. BESL (BAM and Jacobs) continued to deliver certain services such as grass cutting, clearing work and specific maintenance tasks as an extension to their contract until November 2021.

Flood Warnings

41 EA continually monitors rainfall, sea conditions and river levels to give warning of possible flooding. This information is updated every 15 minutes on the websites of EA and the Met Office (the UK's national weather service). 'Flood Alert' and 'Flood Warning' thresholds are determined by the EA Flood Resilience Team Technical Advisor in discussions with local EA asset management teams and other colleagues. There are three levels of flood alerts and warnings defined by EA:

a. Flood Alert: flooding is possible. This is the lowest level of warning. Some people may need to take action to protect property or businesses such as shutting flood gates or moving equipment. Lower lying land and roads may be affected.

b. Flood Warning: flooding is expected. This is the call to action for recipients to take action to protect themselves as flooding is expected in that flood warning area.

c. Severe Flood Warning: danger risk to life. Highest level of warning issued when widespread flooding is expected, or deep fast flowing water is expected to pose a risk to life or structural damage to buildings.

42 EA provides a Flood Warning Service (FWS) which anyone can subscribe to. This free service provides emails, phone calls, or text messages alerting subscribers to possible flooding in their area. The FWS areas in the Broadlands are very large and cover whole tidal rivers (figure 6). This is because the area is very flat, and the potential sources of flooding are complex, so it is not possible to reliably produce smaller targeted flood alert areas.

Figure 6: Flood warning areas in the Broadlands.

43 Network Rail uses the FWD system, which is hosted by JBA consulting (paragraph 17, for this reason it is often referred to as the 'JBA system' in control centres). This system was originally developed in the 1990s to manage the risk of bridges being eroded by flowing water (scour). The system in its current form was developed in 2009 and was commissioned by Network Rail's Western Territory (now Western route). The FWD takes information from EA, and Natural Resources Wales, then matches it to assets and areas on Network Rail databases to issue notifications to Network Rail control centres, specifically the route control managers (figure 7). The system runs checks against the EA flood alerting information every 15 minutes to see if there has been an update and notifies accordingly via adding a new file to the shared File Transfer Protocol (FTP) server.[4]

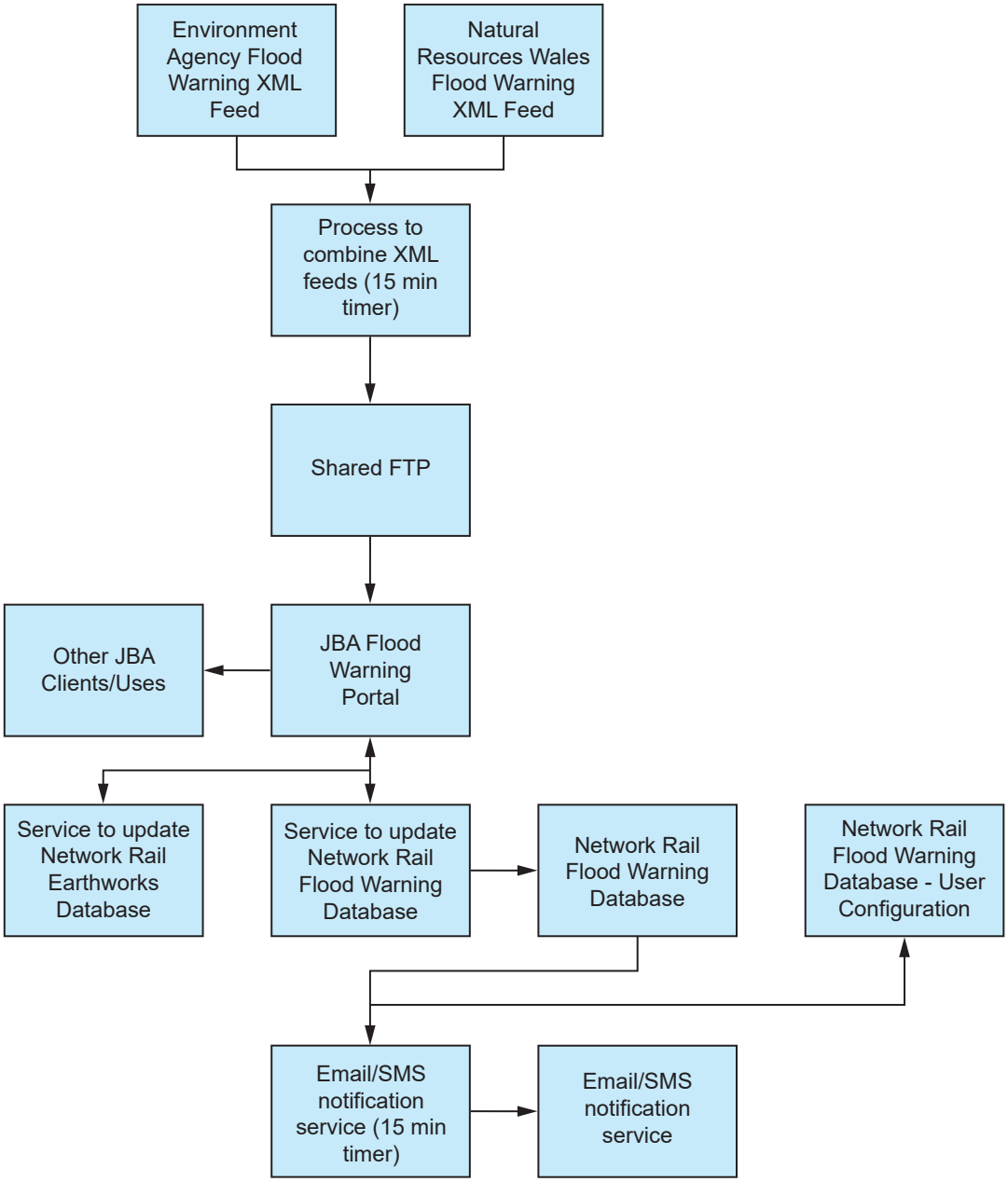


Figure 7: Network Rail Flood Warning Database architecture.

[4] FTP is a protocol for sending and receiving large files over a network or internet. These files are then saved in a shared FTP server .

44 The asset list that is cross-referenced by the FWD has been developed by asset management teams within Network Rail. This list draws together potentially at-risk assets and areas from several other databases and categorises them by risk level from 'A' to 'D', with A being split into A1 and A2 assets. These risk levels are determined in accordance with Network Rail standard NR/L3/CIV/190 'Developing extreme weather plans' issue 1, dated March 2019, with category A1 and A2 assets being those at the highest risk from flooding (figure 8). The FWD is configured to send email alerts to Network Rail's route control managers concerning only Category A assets. If the asset has a lower risk category, emails are not sent out automatically, whether or not there is an EA flood warning or severe flood warning in place in the area.

A1/A2	Assets that have been assessed as being at 'high risk' during flood events. This may be based on damage or failure caused by: • Scour risk • Hydraulic action (e.g. hydrostatic uplift) • Structure/track overtopping • Reduced freeboard (risk of trapped debris or debris impact). The category is further divided as follows: Category A1 assets which can be considered as a representative 'trigger' for action to be taken at all assets on a single identifiable route following the issue of a flood warning for a particular watercourse. Category A2 assets - an appropriate initial rapid response action can be inferred from the response to a Category A1 asset or it is known no initial rapid response action is required. If the risk to the asset is unknown, it is recommended the asset will be Category A2, taking a conservative, high risk worst case scenario until such flood risk information becomes available.
B	Assets considered to be at lower risk of failure due to scour or hydraulic action but at a 'medium/high risk' of damage during flooding. Category B assets would not normally require a rapid response during flooding but may require regular inspection, depending upon the severity of flooding being experienced at Category A assets.
C	Category C assets are considered to be at medium risk of damage and do not require a rapid response during flooding but may require inspection, depending upon the severity of flooding being experienced at Category A and B Assets.
D	Assets at least risk of damage during flooding and require no rapid response action, such as underbridges, structures with integrated inverts and retaining walls adjacent to canals or reservoirs. Includes assets where scour protection has been installed and is maintained.
U	Assets where Network Rail has no responsibility, and that have no direct risk to the operational railway or are permanently filled.

Figure 8: Risk categorisations.

Analysis

Identification of the immediate cause

45 Train 2J66 entered a section of track that was flooded.

46 The train was travelling under clear signals, without any restrictions imposed, and the driver was not aware that the track ahead was flooded. Forward-facing CCTV taken from train 2J66 shows that there was water on the railway at Haddiscoe where the train stopped (paragraph 29).

Identification of causal factors

47 The incident occurred due to a combination of the following causal factors:

a. Water overspilled flood defences and flooded the track (paragraph 48).

b. Train 2J66 was not prevented from entering the flooded section of track (paragraph 70).

Each of these factors is now considered in turn.

Flood Defences

48 Water overspilled flood defences and flooded the track.

49 The driver was in radio contact with the signaller to report water escaping the banks of the river adjacent to the railway (paragraph 29) when they saw standing water ahead of the train. The train subsequently stopped over flooded track where water from New Cut had overspilled the flood defences. This causal factor arose due to a combination of the following:

a. High water levels existed due to a combination of tidal surge and tidal locking (paragraph 50).

b. There were localised low spots of the flood defences which allowed overtopping on the day of the incident (paragraph 55).

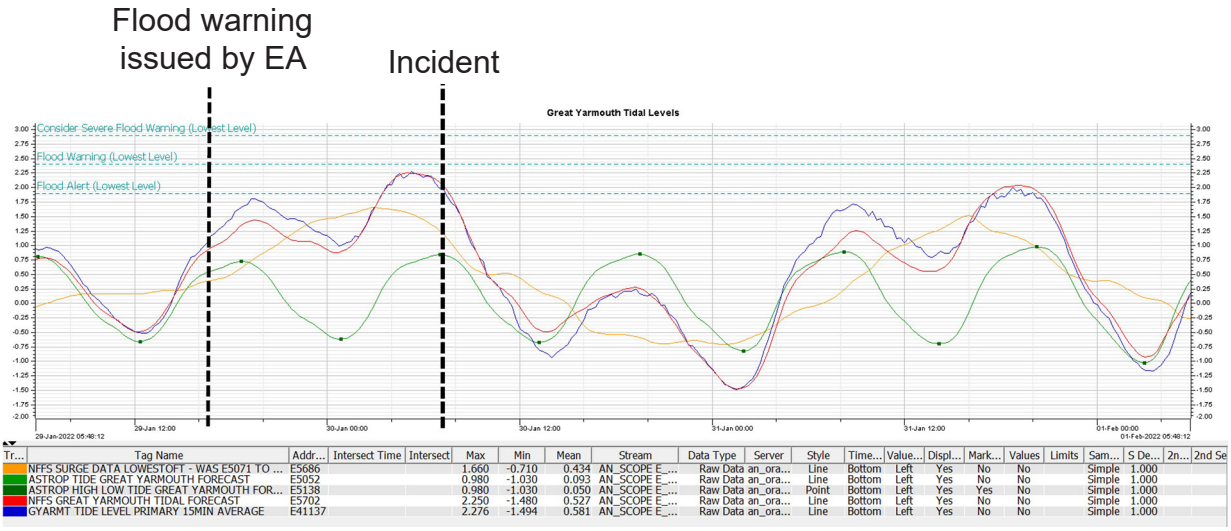
Each of these factors is now considered in turn.

Tidal patterns

50 High water levels existed due to a combination of tidal surge and tidal locking.

51 The unusually high water levels seen on 30 January 2022 in the Broadland rivers system, including New Cut, were a consequence of unusually high sea levels in the river estuary at Great Yarmouth. These high sea levels were due to a combination of astronomical tidal effects and a tidal surge in which weather conditions increased water levels. The weather conditions comprised deep low-pressure systems including northerly to north-westerly winds pushing water towards the coast (paragraph 25).

52 The astronomical high tide prediction for Great Yarmouth on the afternoon of 29 January 2022, the day before the washout at Haddiscoe, was 0.75 m AOD. However, the surge effect meant that the actual level was more than a metre higher than this, at 1.8 m AOD. Surge effects continued so the following low tide, at around 00.50 hrs on 30 January 2022, was about 1.6 m higher than the astronomical prediction. It was also higher than the astronomical prediction for the preceding and following high tides. The next high water occurred at about 07:15 hrs on the morning of the incident, when the water levels reached 2.25 m AOD, around 1.4 m above the astronomical prediction (see figure 9).



Green – Astronomical tide (the tide that happens regardless of weather effects)

Orange – The weather-generated surge (generated by low pressure and strong winds)

Red – The tidal forecast

Blue – The level recorded at the Great Yarmouth tidal gauge

Figure 9: The tide levels at Great Yarmouth.

53 The sustained high sea levels at Great Yarmouth meant that in the early hours of the day of the incident the Broadland rivers were prevented from draining into the North Sea, as would normally happen at low tide. This tide locking increased the amount of water and the water levels in the river system during the following high tide.

54 The time taken for tidal effects to travel upriver from the coast, and the presence of water in the Broads, meant that the maximum water level at Haddiscoe was both higher, and later, than at Great Yarmouth. Water levels at the incident site would have been very similar to those at the EA river monitoring gauge at EA's Haddiscoe depot, about 700 m from the washout. On the morning of 30 January 2022, this recorded a water level of about 1.58 m AOD as the train approached the washout at 07:45 hrs, and a maximum level of about 1.59 m AOD at around 08:00 hrs (figure 10).

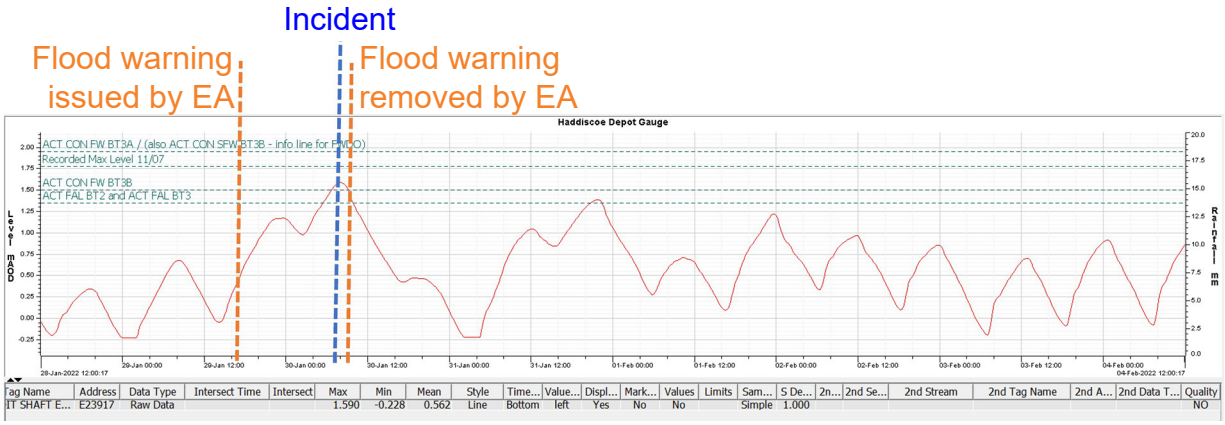


Figure 10: The levels recorded by the gauge at the measuring station at Haddiscoe.

Flood defence height

55 There were localised low spots of the flood defences which allowed overtopping on the day of the incident.

56 Witness and FFCCTV evidence shows that overtopping of the piles had started as the train approached the washout at 07:45 hrs, when the water level was about 1.58 m AOD (paragraph 54). This shows, that in at least some locations, the top of the crest piles was lower than the service level of 1.7 m AOD. RAIB considers that the crest piles would probably only need to be a few centimetres lower than the service level for overtopping to provide the amount of water seen in front of the train in CCTV images recorded as the train approached.

57 Ongoing ground settlement due to compression of natural soils is a feature of the Broadlands and affects both embankments and crest piles (see paragraph 61). This is demonstrated by the crest pile settlement that was found to have occurred between November 2006 and March 2010 (see paragraph 64). There is insufficient data to accurately quantify the amount of pile top settlement which occurred between March 2010 and 2022. However, ongoing settlement during this period may be an explanation for the tops of the crest piles being below 1.58 m AOD.

58 Surveys undertaken on the days following the incident showed that the frontage piles had by then moved towards New Cut. This movement of the frontage piles would have caused movement of the ground behind them, which would also have produced some settlement and movement of the plastic crest piles (figure 11). Jacobs reported that the frontage piles had been in place for several decades and had continued to give satisfactory performance. However, they did not accord with modern design standards particularly in respect of their length which, being shorter, would have made them more susceptible to such movement.

59 An especially low tide would have been needed to initiate frontage pile movement and this probably would have needed to follow an event, such as a particularly high tide, which allowed an unusually large amount of water to seep into the soils behind the frontage piles and push them towards New Cut. This situation occurred in the early hours of the day following the washout (figure 10), making it possible that the significant frontage pile movement found had occurred after the incident (figure 12). If the frontage pile movement had only occurred post incident, then this means that the flooding of the railway was caused only by ongoing settlement of the embankment and crest piles (paragraph 57).

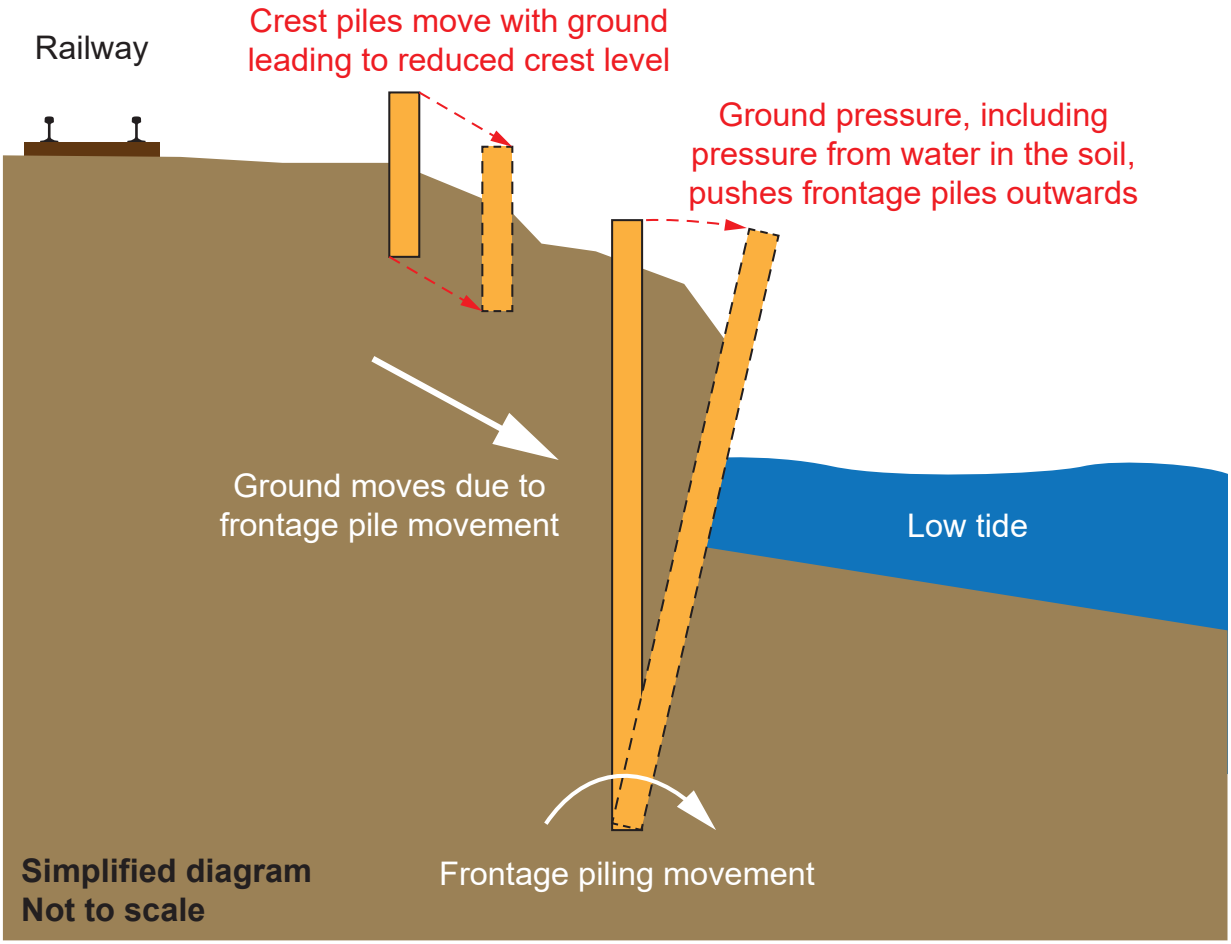


Figure 11: Crest pile movement due to failure of frontage piles.

60 It is also possible that frontage pile movement and an associated crest pile settlement was initiated by an especially low tide some time (possibly months) before the incident. This would not have resulted in flooding until a particularly high tide occurred, such as that seen on the day of the incident. RAIB found no evidence of an environmental change triggering earlier movement of the frontage piles and the available monitoring data does not prove or disprove this scenario.

61 The embankment supporting the railway overlies natural soils typical of the Broadlands. In 1934 an exploratory hole was sunk into the ground alongside the railway embankment, about 30 m from the 2022 incident site. The findings from this exploratory hole have been interpreted by RAIB, taking account of information from a hole sunk 470 m from the site in 1995, using modern soil sampling and modern soil descriptors. This interpretation shows that the 1934 hole encountered soft or very soft soils, including a peat band 1.8 m thick, to a depth of 20.7 m below field level. Beneath this, sand, gravel and very stiff clay were encountered.

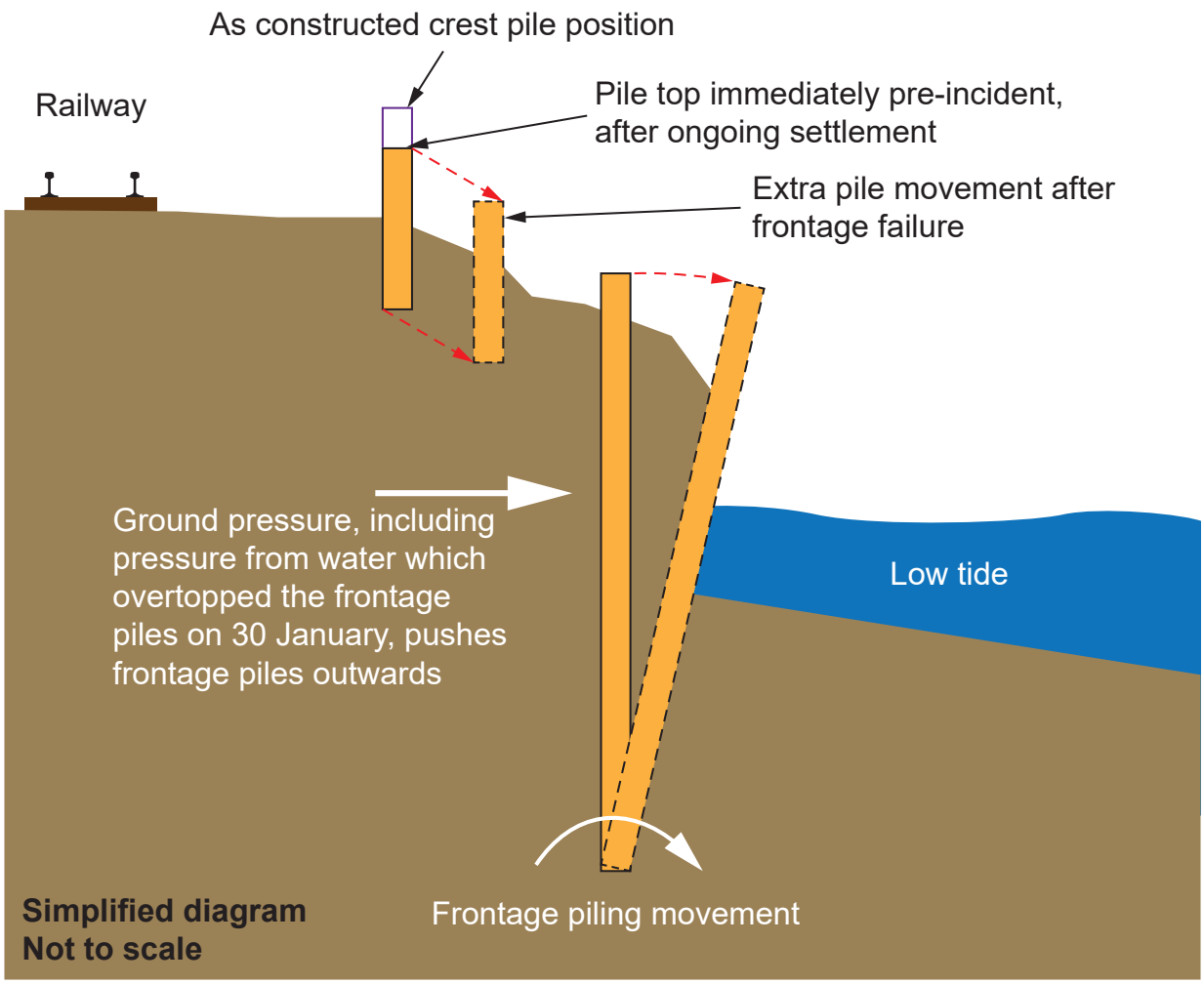


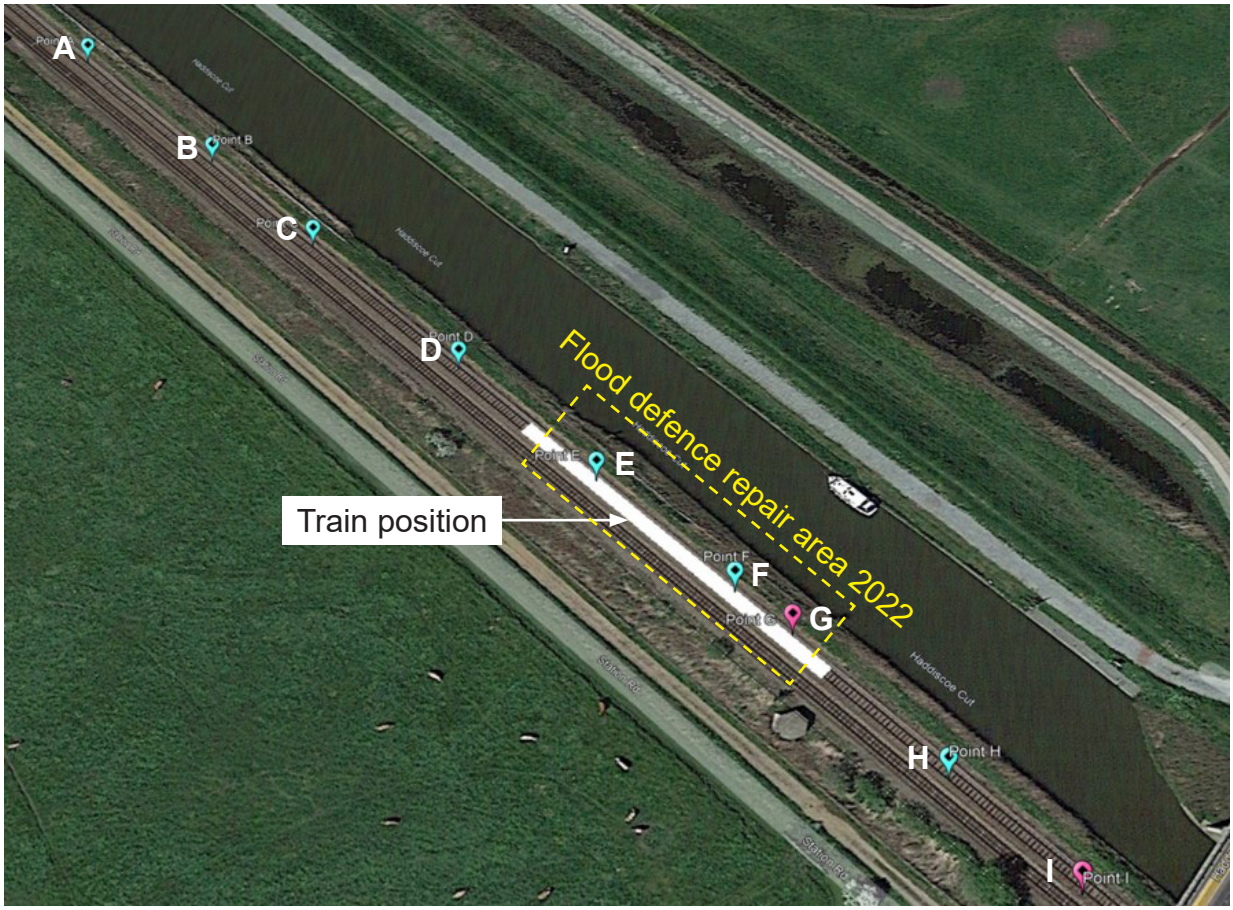
Figure 12: Flooding due only to settlement with subsequent failure of frontage piles.

62 The way in which the soft, very soft and peat soils were deposited means that the proportion of each is likely to vary rapidly over short distances and that less compressible zones of silt and sand will sometimes be encountered within this layer of ground. Long-term processes mean that, throughout much of the Broadlands, gradual compression of this layer is causing settlement of the ground surface. The variable soil composition means that the amount of settlement can vary significantly over relatively short distances.

63 To provide the flood defence service level of approximately 1.7 m AOD (paragraph 38) with an allowance for ongoing compression of the natural soils, BESL installed plastic crest piles in 2006 with a specified top level of 1.9 m AOD.

64 Post-construction spot checks in August 2006 at two locations found pile tops slightly above this height at 1.94 metres AOD. One of these points was very close to the washout location (figure 13, point G). A survey in March 2010 found that the pile top here had sunk to 1.75 metres AOD, a settlement of almost 200 mm in four years. Other measurements shown on figure 13 demonstrate that the settlement at point G was typical of other nearby points.

65 No subsequent survey data of the pile tops is available after this date. However, as there is no evidence to suggest a sudden change in ground behaviour, it is probable that compression of the underlying natural soils continued between March 2010 and the day of the incident.



Chainage	Point	August 06 (MAOD)	August 10 (MAOD)
12400	A		1.76
12410	B		1.58
12419	C		1.60
12422	D		1.72
12450	E		1.88
12475	F		1.83
12500	G	1.94	1.76
12523	H		1.87
12537	I	1.94	1.85

Figure 13: Survey measurement points.

Surveys

66 BESL was contracted to carry out two types of surveys on the flood defences, across the whole of the Broadlands. These were:

a. Topographic surveys, requiring a surveyor to measure heights of the bank and flood defences (crest levels) at the edge of the waterway. The survey also includes recording the profile and cross section of the bank and riverbed at 200-metre intervals. BESL was contracted to carry out three topographic surveys during the life of the contract, in years 6, 12, and 19.

b. Visual surveys, requiring an examiner to take photographs and assess the general condition of the flood defences by boat. The main purpose of a visual survey is to identify any visible defects or damage to the flood defences, which could indicate maintenance is required.

67 Crest level topographic surveys were originally planned to be carried out in 2007, 2013 and 2020, in years 6, 12 and 19 of the BESL contract. These surveys included walking the bank to check for pile damage and bank instability. Crest height measurements were taken approximately every 200 m. These surveys were undertaken at later dates than those given in the original contract. BESL stated that these later dates were agreed due to delays in the early stages of the project initially following the foot and mouth outbreak in 2007, and then later due to bird flu, and also the coronavirus pandemic. Although no crest level topographic surveys were carried out in the incident area between 2010 and the day of the washout, surveys were undertaken in some other areas in 2014 and 2018.

68 Visual inspections were carried out by boat and were supposed to be performed annually. BESL has stated that visual inspections can be challenging due to vegetation obscuring visibility, and minor deflections in the frontage piling being difficult to see (see figure 14). Before the incident, the last visual inspections in the area of the washout were carried out in December 2019. No deficiencies were identified, and the frontage piles and crest piles were deemed to be in good condition. Inspections were not carried out in 2020/21 for reasons recorded by EA as *'flooding elsewhere on the broads causing "*complications and difficulties*" and the coronavirus pandemic'.*

Figure 14: View from visual inspection boat (courtesy of BESL).

69 It is probable that crest level topographic surveys undertaken in the incident area between 2010 and 2022 would have provided an indication that localised flooding could occur with water levels below service level. The relatively small movements needed for this to happen mean that visual inspection would not be a reliable way of detecting these. For reasons explained in paragraphs 76 to 81, it is unlikely that topographic surveys after March 2010 would have led to EA or BESL contacting Network Rail so that appropriate action could be taken to ensure the safety of the railway.

Entry of train onto flooded section

70 Train 2J66 was not prevented from entering the flooded section of track.

71 Train 2J66 was signalled normally between Reedham and Haddiscoe even though the track was flooding near Haddiscoe. This causal factor arose due to a combination of the following:

a. Network Rail was not aware that water was entering the railway in the Haddiscoe area on the day of the incident (paragraph 72).

b. Network Rail's flood risk management processes were not effective at warning that the track at Haddiscoe was at serious risk of flooding (paragraph 76).

Each of these factors is now considered in turn.

Water level monitoring

72 Network Rail was not aware that water was entering the railway in the Haddiscoe area on the day of the incident.

73 Overtopping on the day would only have started as water levels approached their highest point (paragraph 54). Because the exact level of the crest piles before the incident are not known (paragraphs 57, 64 and 65), it is not possible to determine exactly when overtopping occurred. It is also not known whether any overtopping had occurred during previous high tides.

74 As train 2J66 was the first train of the day to pass through the incident site, there was no opportunity for a preceding train driver to identify any problems apparent earlier in the day. There were no earlier reports of problems in the area from train drivers the day before the incident.

75 The operator of Reedham swing bridge, while a member of Network Rail staff, was not required to monitor water levels in New Cut or alert signalling staff to high water levels. There were no other Network Rail staff in the area carrying out any patrols or maintenance activities who may have seen water flowing though the flood defences and raised the alarm.

Flood Risk Management

76 Network Rail's flood risk management processes were not effective at warning that the track at Haddiscoe was at serious risk of flooding.

77 The FWD system is the main mechanism Network Rail uses to be alerted to flood warnings (paragraph 43). The FWD was offline at the time of the incident and this was communicated to two members of operational Network Rail staff by email at 18:41 hrs on 29 January 2022. The operational staff that the emails were sent to were not on shift at the time and therefore did not see this email.

78 The buildings and civils team of Network Rail's Anglia route reviewed the list of sites in the FWD, matching them to alerts and warnings from EA, in November 2015 and August 2018. The outcome of the 2015 review was that notifications for Flood Alerts (which indicate that flooding is possible, paragraph 41) were switched off for the Haddiscoe area and that only notifications at Flood Warning level (which indicate that flooding is expected) or above generated automatic emails (or text messages, if the system is configured to do this) to Network Rail control. Following the 2018 review, and repair work undertaken reducing the risk to a level that was deemed acceptable (see paragraph 93), Network Rail recategorized the section of flood defence adjacent to the railway from category A1 to B (paragraph 44, figure 8).

79 RAIB has concluded that the FWD being offline did not contribute to this incident because of the way the email alerts are configured in the system. Email alerts are sent only for those assets that are categorised as A in the system (paragraph 44) and the area at Haddiscoe was in category B, meaning that no alert would have been sent anyway, despite the system being online. Even with the email alert system offline, it is possible for Network Rail route control to log into the FWD to view all categories of at-risk asset if needed. However, no attempt to seek flooding risk information in the days leading up to the incident was made by Network Rail route control staff as there was no requirement for them to do so.

80 Network Rail Anglia route control was also sent alerts and warnings via the FWS (paragraph 42). On 29 January, Anglia route control was sent three emails from this system. These were at 16:07 hrs (a Flood Alert for the tidal River Waveney), 16:29 hrs (a Flood Warning for riverside properties along the tidal River Yare), and 16:37 hrs (a Flood Warning for isolated low-lying properties along the tidal River Waveney). The flood alert referred to large areas and, while the flood warnings referred to a flooding risk of the railway between Reedham and Brundall, the stretch of railway along New Cut where the incident occurred was not specifically mentioned.

81 Network Rail route controllers are not required to act on the FWS alerts and warnings as the FWD is their formal alerting mechanism. However, Network Rail control stated that they would sometimes advise the relevant maintenance delivery unit (the depot where maintenance staff are located) when receiving FWS notifications. They did not do so on 29 January as there were no Network Rail weather warnings in place.

Identification of underlying factors

Impact of localised flooding

82 EA management of flooding risk in the area did not account for, and was not required to account for, the impact of localised flooding on the railway.

83 The crest level measurements carried out by BESL from March 2010 show that some areas were below the service level of 1.7 m AOD (paragraph 64 and figure 13). These measurements were considered acceptable as the location of the measurements would not, until water levels exceeded the service level, lead to amounts of overtopping with adverse effects on settlements or property. RAIB has found no evidence that, when accepting this overtopping risk, BESL considered risk to the railway or that EA expected it to do so.

84 EA has legal powers under the Water Resources Act 1991[5] (as amended by the Flood and Water Management Act 2010[6]) to carry out flood risk management works. These include the maintenance and improvement of existing works (such as watercourses, flood defences, and other associated structures) as well as the construction of new works. There are two conditions for the exercise of these powers. The first of these is that EA considers the work desirable with regard to the national flood and coastal erosion risk management strategy and the second, that the purpose of the work is to manage a flood risk from the sea or a designated 'main river' (which are generally the larger arterial watercourses).

85 These legal powers are discretionary or 'permissive'. This means that there is generally no obligation on EA to exercise these powers to a particular standard, in a particular way, or even at all. National funding allocations require EA to adopt a prioritised approach in determining which flood risk management works to undertake. BESL's remit as part of BFAP involved mitigating the effects of flooding on settlements and property, but did not specifically require it to consider flooding of the railway.

Management of third party assets

86 Network Rail was not effectively managing the risks to its assets and services associated with the reliance upon third party flood defences.

87 Network Rail does not have a register of locations at risk from coastal, tidal and fluvial flooding and no formalised process exists to manage flood risk at these types of locations. The flood defences at Haddiscoe also do not appear on any asset risk databases, so are not subject to regular inspections or risk assessments.

88 Network Rail standards do not clearly define who is accountable for identifying and mitigating flood risk. It is currently the responsibility of the route engineers for structures, geotechnical, and drainage to develop a register of assets vulnerable to flooding, and for each to work individually with the maintenance team to develop plans to mitigate the risk. Each route engineer should then work with the seasonal delivery specialist to ensure the route integrated weather management plan (which provides location specific plans to manage risk to the railway due to adverse weather, including flooding, across different seasons) is populated with the correct sites. They should also ensure that the roles of operations, maintenance and the route engineering teams are clearly defined during circumstances of extreme and adverse weather. This includes the triggers to be used to initiate a response, who is responsible for actions associated with the response, and what operational restrictions may be required.

89 There is no definitive guidance to support route engineers in determining the level of risk acceptable to the railway and no guidance is provided on what sites should be included in the integrated weather management plan register. Standards are also not briefed across asset owners and with no formal structure of communication or co-ordination by senior staff with multi-asset responsibility it is likely that any plan produced on an individual asset basis will be inconsistent, contain overlapping risk sites, and potentially leave gaps.

[5] https://www.legislation.gov.uk/ukpga/1991/57/contents.

[6] https://www.legislation.gov.uk/ukpga/2010/29/contents.

90 Although the Haddiscoe area is captured on the FWD system (paragraph 43), the flood defence itself did not appear on any Network Rail asset register at the time of the incident. This is because it is not a structure (such as a bridge), a track asset, a geotechnical asset (as it is not more than 3 metres high or having a history of instability) or a coastal asset (such as a sea wall). The flood defence is also not captured on any Network Rail list for third-party assets. This means that the risk associated with the flood defence was not fully understood and mitigated.

Learning from previous incidents

91 EA and Network Rail Anglia were not effectively collaborating in their management of the flooding risk at Haddiscoe. This means that no joint strategy was in place to protect the railway from flooding at this location. This is a possible underlying factor.

92 There have been at least two previous significant washout incidents which affected railway infrastructure in this area:

- On 1 November 2006, a washout incident at Haddiscoe between 15 miles 49 chains and 15 miles 51 chains led to 160 tonnes of ballast being washed away after the flood defences were overtopped.
- In 2013, a washout occurred near Haddiscoe between 14 miles and 14 miles 57 chains. Network Rail was not able to provide any further information about this incident.

These incidents had a substantial impact on the railway and in both cases closed the line for several days.

93 Repairs were made following these incidents, including crest raising works in 2015. Although this led to relationships being formed between the two organisations at a local operational level, these links eventually ceased as time passed and the respective staff left their posts. Despite these previous incidents and the ongoing risk of flooding at Haddiscoe, EA and Network Rail did not have a strategy to jointly manage this risk or a formal liaison framework (such as the Wales and Western region who have a jointly funded liaison officer) to enable effective communication and co-operation.

Summary of conclusions

Immediate cause

94 Train 2J66 entered a section of track that was flooded (paragraph 45).

Causal factors

95 The causal factors were:

a. Water overspilled flood defences and flooded the track (paragraph 48). This causal factor arose due to a combination of the following:

i. High water levels existed due to a combination of tidal surge and tidal locking (paragraph 50, **Recommendation 2**).

ii. There were localised low spots of the flood defences which allowed overtopping on the day of the incident (paragraph 55, **Recommendation 1**).

b. Train 2J66 was not prevented from entering the flooded section of track (paragraph 70). This causal factor arose due to a combination of the following:

i. Network Rail was not aware that water was entering the railway in the Haddiscoe area on the day of the incident (paragraph 72, **Recommendation 3**).

ii. Network Rail's flood risk management processes were not effective at warning that the track at Haddiscoe was at serious risk of flooding (paragraph 76, **Recommendation 2**).

Underlying factors

96 The underlying factors were:

a. EA management of flooding risk in the area did not account for, and was not required to account for, the impact of localised flooding on the railway (paragraph 82, **Recommendation 1**).

b. Network Rail was not effectively managing the risks to its assets and services associated with the reliance upon third party flood defences (paragraph 86, **Recommendation 2**).

c. EA and Network Rail Anglia were not effectively collaborating in their management of the flooding risk at Haddiscoe. This means that no joint strategy was in place to protect the railway from flooding at this location. This is a possible underlying factor (paragraph 91, **Recommendations 4 and 5**).

Previous RAIB recommendations relevant to this investigation

97 The following recommendations, which were made by RAIB as a result of its previous investigations, have relevance to this investigation.

Failure of Bridge RDG1 48 (River Crane) between Whitton and Feltham 14 November 2009, RAIB report 17/2010, Recommendation 5

98 This recommendation reads as follows:

Recommendation 5

The purpose of recommendation 5 is to give infrastructure managers the opportunity to respond to scour risk where identified by an EA inspection.

The Environment Agency should, in conjunction with railway infrastructure owners, introduce processes to allow the immediate reporting of obstructions in watercourses where these occur adjacent to railway structures such as bridge piers or abutments, and regardless of whether there is an associated flooding risk.

99 The relevance of this recommendation to the current investigation is that there has been a need identified for EA and Network Rail to mutually understand what the acceptable levels of risk are for each organisation and to communicate that risk effectively.

100 On 29 August 2014, EA informed RAIB that it had entered into a Memorandum of Understanding (MoU) with Network Rail. This was intended to commit local management teams in EA and Network Rail to share intelligence of risk resulting from asset inspections, surveys and assessments. The most up-to-date MoU, dated 26 April 2021, concentrates on three areas:

a. environmental protection

b. flood and coastal resilience

c. communication, engagement, and knowledge sharing.

Section 3.4 of the MoU covers flood and coastal resilience and refers to asset management. Section 3.5 focuses on communication, engagement and knowledge sharing, including '*identifying and highlighting any increased environmental risks from impacts of extreme weather or climate change*.'

Actions reported as already taken or in progress relevant to this report

101 Following the flooding incident on 30 January 2022, the crest piling was re-instated along a 50 m length at Haddiscoe. The levels were checked in June 2022 and the crest height was found to be around 1.8 m AOD in the repair area.

102 Network Rail's weather taskforce is considering the implications of tidal flood risk in line with other weather threats. Network Rail has stated that this work is ongoing.

103 Immediately after the incident, Network Rail reassessed the Haddiscoe flood defence and changed its status from category B to A in the FWD system. The distribution lists have been updated by Network Rail to ensure notifications are sent to the correct staff. A replacement for the FWD, the Targeted Flood Warning Service, had been identified by Network Rail. This became fully operational on 31 March 2023 and is delivered by EA.

104 Network Rail installed a tidal gauge at Reedham in October 2022. This allows Anglia route control to log into a system to view the water levels in real time. This process is carried out when an FWD alert is received. The route control manager will then chair a conference and deploy a watchperson to site if necessary.

Background to RAIB's recommendations

105 In England the management of tidal flood defences falls to EA within a discretionary or 'permissive' legislative framework (paragraph 84). Natural Resources Wales performs a comparable role in Wales.

106 In Scotland these responsibilities are more complex, and Transport Scotland has stated to RAIB that the responsibility for tidal flood defences will depend upon the source of the flooding. Those responsible may include the roads authority (for non-trunk roads), the water and sewerage authority (usually Scottish Water), the Scottish Government (for trunk roads), the 32 Local (Unitary) Authorities and private landowners/occupiers and homeowners. The Scottish Government additionally sets national policy on flood risk management and flood warning, while the Scottish Environment Protection Agency provides a flood warning service for Scotland, provides advice to local authorities on flood risk and planning and co-ordinated flood risk management policy and activities.

Recommendations

107 The following recommendations are made:[7]

1 *The intent of this recommendation is to ensure that railway-related flood risk is managed alongside Haddiscoe New Cut, taking account of issues such as the potential for flooding to be caused by relatively small amounts of overtopping.*

The Environment Agency and Network Rail should agree a shared understanding of how railway-related flooding risk alongside the New Cut at Haddiscoe is managed. Their considerations should include:

- ensuring that the Haddiscoe flood defence is included in appropriate Network Rail infrastructure management systems
- the circumstances in which overtopping and/or failure of the Environmental Agency flood defence infrastructure could occur, and the potential impacts of this on the railway
- learning from previous overtopping/failures of the flood defences
- the flood warning arrangements required and provided
- the types and frequency of inspections, monitoring and assessment required to manage railway-related flood risk, how the associated access will be provided and how the results of these activities will be communicated between the Environment Agency and Network Rail, including any understanding of consequent risk
- if any changes are required to existing flood defences to mitigate the risks identified, both in the long term and the interim period before any longer-term measures are implemented.

(Paragraphs 95a and 96a)

[7] Those identified in the recommendations have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, recommendation 1 is addressed to the Environment Agency and the Office of Rail and Road, recommendations 2, 3 and 5 are addressed to the Office of Rail and Road and recommendation 4 is addressed to the Office of Rail and Road, the Environment Agency and Natural Resources Wales. This is to enable them to carry out their duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 200 to 203) can be found on RAIB's website www.gov.uk/raib.

2 *The intent of this recommendation is to ensure Network Rail weather management processes are consistent for all types of weather events, including tidal flooding.*

Network Rail should develop processes for the effective identification, recording, and management of sites at risk from coastal/tidal and fluvial flooding (for example, via the integrated weather management plan). These should include:

- criteria for identifying specific areas at risk, the level of acceptable risk and the threshold at which mitigations are required
- standard guidance for carrying out flood risk assessments and developing mitigations
- identifying the staff in Network Rail who will be responsible for carrying this out.

(Paragraphs 95a, 95b, and 96b)

3 *The intent of this recommendation is to ensure controls and processes are adequate to manage the operational response to all types of weather events that can cause the railway to flood, and that tidal flooding is integrated into existing weather management standards.*

Network Rail should ensure that flood warnings from external organisations are managed and disseminated in a timely manner to operational and maintenance staff, and that any required response is clearly defined in the integrated weather management plan (paragraph 95b).

4 *The intent of this recommendation is to improve interaction between Network Rail and organisations responsible for tidal flood defences where the operation of these defences affects railway safety. This includes consideration of railway-specific risk such as localised flooding leading to washout of material supporting the track resulting in a serious accident.*

Network Rail, the Environment Agency and Natural Resources Wales should work together to identify any railway-related risks arising from the overtopping and/or failure of tidal flood defences where this could adversely affect the safety of Network Rail infrastructure.

Where such locations are identified, Network Rail, the Environment Agency and Natural Resources Wales should undertake the following:

- agree a shared understanding of roles and responsibilities in the management of flood defences, including where railway infrastructure (such as embankments) forms an integral part of the flood defence

- ensure processes are provided to identify, and assign to the appropriate organisation, the actions required at each flood defence location to maintain railway safety. This should include:
  - identifying the nature of the risks arising from the overtopping and/or failure of the flood defence
  - developing the requirements for inspection, monitoring and maintenance for each organisation
  - specifying how information is communicated so that each organisation can manage its own risks appropriately
  - determining how lessons will be learned across all of these organisations where overtopping and failures of tidal flood defences occur.

As part of this work, Network Rail and the Environment Agency and Natural Resources Wales should review and, where necessary, improve any relevant existing agreements such as Memorandums of Understanding.

(Paragraph 96c)

5 *The intent of this recommendation is to improve interaction between Network Rail and local authorities responsible for tidal flood defences in Scotland where the operation of these defences affects railway safety. This includes consideration of railway-specific risk such as localised flooding leading to washout of material supporting the track resulting in a serious accident.*

Network Rail should liaise with local authorities in Scotland who are responsible for tidal flood defences to identify any risks arising from their overtopping and/or failure that could adversely affect the safety of Network Rail infrastructure.

Where such locations are identified, Network Rail should undertake the following:

- agree a shared understanding of roles and responsibilities in the management of flood defences, including where railway infrastructure (such as embankments) forms an integral part of the flood defence
- ensure processes are provided to identify, and assign to the appropriate organisation, the actions required at each flood defence location to maintain railway safety. This should include:
  - identifying the nature of the risks arising from the overtopping and/or failure of the flood defence
  - developing the requirements for inspection, monitoring and maintenance for each organisation
  - specifying how information is communicated so that each organisation can manage its own risks appropriately

- determining how lessons will be learned across all of these organisations where overtopping and failures of tidal flood defences occur.

As part of this work, Network Rail and local authorities responsible for tidal flood defences in Scotland, should review and where necessary, improve any relevant existing agreements such as Memorandums of Understanding.

(Paragraph 96c)

Appendices

Appendix A - Glossary of abbreviations and acronyms

AOD	Above ordnance datum
BESL	Broadlands Environmental Services Ltd
BFAP	Broadlands Flood Alleviation Project
CCTV	Closed-circuit television
EA	Environment Agency
FFCCTV	Forward-facing closed-circuit television
FTP	File Transfer Protocol
FWD	Flood Warning Database
FWS	Flood Warning Service
GA	Greater Anglia
GSM-R	Global System for Mobile Communications – Railway
JBA	Jeremy Benn Associates Limited
MoU	Memorandum of Understanding
OTDR	On-train data recorder

Appendix B - Investigation details

RAIB used the following sources of evidence in this investigation:

- information provided by witnesses
- information taken from the train's OTDR
- CCTV recordings taken from train 2J66
- GSM-R recordings
- site photographs and measurements provided by Network Rail and EA

weather reports and observations at the site

- a review of previous reported incidents
- a review of previous RAIB investigations that had relevance to this accident.

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