

WHALEY BRIDGE – THE DAM FAILURE AT WHALEY BRIDGE ON 1ST AUGUST 2019 AND AN OVERVIEW OF DAM SAFETY IN THE UNITED KINGDOM

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ABSTRACT

The Canal & River Trust is the guardian of 3,200 kilometres of historic inland waterways across England and Wales. We maintain 72 large raised reservoirs, as well as embankments and cuttings, the nation’s third largest collection of listed structures, including locks, aqueducts, bridges, tunnels, docks, wharves, historic warehouses, offices and houses, as well as and many important wildlife habitats. Whilst the original purpose of these assets was industrial, today they provide important recreational and wellbeing benefits to the United Kingdom population and overseas visitors.

Toddbrook reservoir is in Whaley Bridge in Derbyshire, England. The dam is a conventional earth fill embankment with puddle clay core completed in 1840. With a maximum height of some 23.8 metres and a crest length of 201 metres, the dam was built to supply water to the Peak Forest Canal and continues to do so. The reservoir stores 1,288,000 cubic metres of water with a surface area of 158,000 square metres. An auxiliary spillway was built in 1970, over the central part of the embankment with a chute down the downstream slope to meet the main spillway at the toe. The auxiliary spillway has a length of 76.2 metres.

On the 31st July 2019 the catchment feeding Toddbrook Reservoir experienced two storms in quick succession which caused the reservoir level to rise and as a result the auxiliary spillway came into operation as well as the main spillway. The auxiliary spillway then broke up with severe damage to the slabs and removal of large amounts of fill from beneath the slabs. As a result, a full-scale emergency was declared, more than 1,500 residents in Whaley Bridge evacuated for seven days, and emergency action was taken to stabilise the situation and draw down the water level in the reservoir.

This paper tells the story of the failure, the subsequent emergency response and the two independent enquiries carried out. It references dam safety in the United Kingdom and the paper concludes with a summary of the lessons learnt for the dam industry in the United Kingdom and implications that other dam owners across the world may want to consider.

1. INTRODUCTION

The Canal & River Trust was formed in July 2012 with the aim to protect, manage and improve the nation’s canals and river navigations for the millions who enjoy them. The Canal & River Trust’s navigations are roughly two-thirds of the national network in the United Kingdom. The other key navigation organisations are Scottish Canals and the Environment Agency. Figure 1 shows the spread of inland waterways in England and Wales.

The canals are used today for pleasure and recreation. They have become very popular through several television programmes and visitors travel from all over the world to holiday and explore the iconic waterways of the United Kingdom. Pictures 1 and 2 show typical photos of the canals. The canals rely on reservoirs to feed the canals. They fill during the winter period when boating activity is less. They are then drawn down during the summer period when boating activity is high.



Figure 1 : Inland waterways in England and Wales.



Pictures 1 and 2 : Typical Photos of Canals

Toddbrook reservoir feeds the Peak Forest Canal. It has an inlet weir, a by-wash channel, a primary spillway, and an earth fill dam and an auxiliary spillway. The auxiliary spillway was built in 1970, over the central part of the dam embankment. The layout of the site is shown in picture 3.



Picture 3 – The Layout at Toddbrook Reservoir

On the 31st July 2019 two storms in quick succession caused the reservoir level to rise and as a result the auxiliary spillway came into operation as well as the main spillway. The auxiliary spillway then failed. As a result, a full-scale emergency was declared, more than 1,500 residents in Whaley Bridge were evacuated for seven days, and emergency action was taken to stabilise the situation and draw down the water level in the reservoir.

A Royal Air Force (RAF) Chinook helicopter flew for 3 days to place over 500 tonnes of aggregate bags to stabilise the dam. Such scenes had not been seen in the United Kingdom for more than a decade. The incident has resulted in many photographs of the RAF Chinook helicopter dropping aggregate bags, as shown in picture 4. The event has raised several questions. The main question is how could this have happened?



Picture 4 – The Failure at Whaley Bridge

2. INCIDENT AT WHALEY BRIDGE

There were two periods of heavy rainfall prior to the failure. The first event was on the 27th July 2019. During this first event 94mm of rain fell, and this equated to a 43-year return period. The second event was on the 31st July 2019. During this event 114mm of rain fell, and this equated to a 92-year return period. The spillway in flood on the 31st July is shown in photographs 5 and 6.



Picture 5 and 6 – Spillway in Flood on the 31 July 2019

Concerns were raised by members of the public early on 1st August 2019 when the flow of water over the spillway had reduced. Damage was seen to the concrete spillway. Picture 7 shows the initial spillway concrete slab that collapsed into a void that had opened under the spillway. The photo shows the fill material has been washed away, with signs of brown coloured water flowing down the spillway.

Once operational staff got to site early on the 1st August 2019, the two outlet valves of the reservoir were fully opened to start to reduce the reservoir water levels. Water entering the reservoir was reduced by using the bywash channel to its maximum capacity. Opening the two outlet valves and maximising the flow in the bywash channel stopped any further water flowing over the spillway. This stopped any additional erosion to the embankment structure and the concrete spillway. The scale of the damage to the spillway is shown in Picture 8. This picture was taken late in the day on 1 August 2019.



Picture 7 – Initial Failure on the 1 August 2019



Picture 8 – Extent of Failure

On 1 August 2019, on the advice of the Supervising Engineer, the population at risk was evacuated. In total 1,500 people and over 500 homes were evacuated by the emergency services. The emergency drawdown plan was initiated; requiring the delivery to site of eleven 12 inch pumps. Engineers agreed an action plan to further manage the risk of breach. Two key actions were agreed.

The first action was to continue with the emergency drawdown plan by using as many pumps as possible to reduce the water levels as quickly as possible. The emergency drawdown plan assumed it would take 5 days to reach 50%. In addition to the eleven 12inch pumps, the emergency services provided ten 6 inch pumps.

The second action was to infill the damaged embankment with one tonne aggregate bags. Engineers believed the core had not been compromised but concerned remained that the dam embankment was at risk of breach. The only way to place the one tonne aggregate bags was to use a helicopter. So, the RAF was mobilised. Flying and dropping of the bags started at first light on 2 August 2019.

During the night over 500 one tonne aggregate bags were delivery by road to Whaley Bridge. The RAF were able to bring in six one tonnes bags during each flight. Flying and dropping of bags continued for three days. Picture 9 shows

the Chinook helicopter with a full load of six one tonne aggregate bags. This picture shows how close houses were to the reservoir.

The voids in between the one tonne aggregate bags were filled with grout. Pictures 10 and 11 show the bags and grout repairs.



Pictures 9 - Chinook Helicopter with a Full Load



Pictures 10 and 11 – Final Repairs

On site assessments determined that 800 tonnes of infill material had been washed away. The pumping arrangements are shown in pictures 12 and 13.



Pictures 12 and 13 – Pumping

Residents returned to their homes on 7 August 2019 after the desired water level had been reached and a management plan had been put in place. The pumping continued with a level of -8 m being achieved on the 6th August and a level of -12m being achieved on the 8th August.

The management plan detailed measures to prevent water entering the reservoir and pumping to ensure the -12m level could be maintained.

As part of the on-going management plan, the eleven 12inch pumps are being permanently kept installed on pontoons in the reservoir. They will remain in place until the reservoir is re-built. Picture 14 shows the pumps installed on the pontoon.

The inlet arrangement is shown in Picture 15. This shows how the inlet arrangement was improved. The temporary weir was constructed of gabion baskets. They were installed to protect the inlet and ensure as much water as possible was directed down the bywash.



Picture 14 : Pumps on Pontoons



Picture 15 : Temporary Inlet Weir

3. OVERVIEW OF DAM SAFETY IN THE UNITED KINGDOM

The incident at Whaley Bridge on 1 August 2019 was the first major threat to a dam's stability in the United Kingdom since the Ulley dam suffered severe scour amid the floods of 2007. The last time anyone died due to a dam failure in the United Kingdom was in 1925, when two dams burst, killing 16 people in the north Wales village of Dolgarrog.

The disaster at Dolgarrog led the British parliament to pass the Reservoirs (Safety Provisions) Act in 1930 that introduced laws on the safety of reservoirs. This has since been updated with the Reservoirs Act 1975.

The Act covers the safety of all reservoirs that can hold at least 10,000 or 25,000 cubic metres of water, depending on location (currently the 10,000 cubic metre lower limit only applies in Wales).

The Acts set out stringent conditions for the operation of reservoirs to ensure high levels of safety. They are designed and operated in a way to ensure the likelihood of failure is incredibly low. Responsibility for ensuring the safety of reservoirs lies with their operators.

The Environment Agency (EA) is the regulator in England. Their role is to ensure operators comply with the legal safety requirements. The EA monitor compliance at 2,072 large raised reservoirs in England and employ a range of enforcement options to address non-compliance. These can include:

- Enforcement notices requiring reservoir owners and operators to complete outstanding safety works.
- Requiring operators to appoint Government-appointed supervising and inspecting engineers.
- Powers to force entry to conduct surveys, inspections and physical works.
- Direct intervention to carry out safety measures where an operator has not done so.
- Powers to force entry to land without giving notice and take any appropriate measures to reduce the risk or mitigate the effects of a failure.

Under the Act, there are Panel Engineers, who are civil engineers responsible for checking the safety of reservoirs and their dams. Every reservoir must be inspected every 10 years, or more often, when it is necessary. Panel Engineers also get involved with the construction of new reservoirs and repairs and changes to existing ones.

The Act make reservoir owners, operators and managers legally responsible for the safety of their reservoirs. They are required to employ Supervising Engineers, who are suitably qualified civil engineers. They make regular checks on safety in between the Panel Engineers' inspections. A Supervising Engineer reports every year on any potential safety issues.

Reservoirs with the capacity to threaten human life in the event of a failure are designated Category A and subject to the most stringent inspection and supervision requirements. The Toddbrook Reservoir at Whaley Bridge is a Category A reservoir.

During a reservoir and dam inspection by the Panel Engineer, recommendations can be made to ensure its safety. These recommendations may include measures to be taken in the interests of safety (MIOS). Having a MIOS does not mean

the reservoir or dam is unsafe and does not indicate an immediate threat to life. There is no reason to assume that there is a heightened risk of a dam failure at any reservoir with an outstanding MIOS.

MIOS indicate that a robust inspection and supervision process has identified something of potential concern by the Panel Engineer, who sets an enforceable deadline for it to be addressed by the reservoir operator. MIOS can include administrative requirements such as the preparation of an on-site safety plan.

To improve the risk assessment of reservoirs, a new guide to risk assessment for reservoir safety management was published in 2103 by the EA. Although this is not a regulatory requirement, most reservoir owners have followed the guidance. It comprises a tiered approach to risk assessment. Tier 1 is a qualitative assessment, that results in a risk matrix showing the likelihood of downstream flooding versus the potential consequences of downstream flooding.

The Tier 2 is a quantitative assessment results in a detailed assessment where dams are ranked according to the number of fatalities (in the event of a failure) and the estimated probability of dam failure. All reservoirs are grouped into one of three bands; broadly acceptable (which is the lowest band in terms of risk), ALARP (as low as reasonably practicable, which is the intermediate band in terms of risk level), and unacceptable (which is the highest band in terms of risk).

All reservoirs that fall into the unacceptable band will be expected to have an intervention plan to reduce the risk to either the ALARP or broadly acceptable bands. Even for reservoirs that fall into the ALARP band, there is an expectation in the guidance that owners and operators will do whatever is reasonably practicable to reduce the risk further.

4. IMPLICATIONS FOR ASSET MANAGERS AND ASSET OWNERS

Toddbrook Reservoir was deemed to comply with the Reservoir Act 1975, in as much as the statutory (10-yearly) inspection was carried out on 14 November 2018 by an independent Panel Engineer. The Canal & River Trust received the report in April 2019 and the regulator (EA) received the final copy in May 2019. The inspection report contained actions to be completed by 31 October 2020.

There is a mature statutory process in the United Kingdom requiring very qualified Panel and Supervising Engineers to be appointed. Their role is to ensure the safety of reservoirs and dams.

This raises the key questions of why the reservoir failed, and why did the failure occur during a minor incident, when compared to the Possible Maximum Flow (PMF). To answer these questions the Canal & River Trust commissioned an independent review.

The Canal & River Trust review was carried out by Dr Andy Hughes, a Panel Engineer and a trainer of Supervising Engineers. His scope was to carry out an independent technical investigation, with a key output being to determine the root cause of the failure.

The Government body responsible for dam regulation, the Department for Environment, Food & Rural Affairs (Defra) also commissioned an independent review. They engaged Professor David Balmforth, an expert in drainage and flood risk management. He is a past President of the Institution of Civil Engineers and a former non-executive Director of CIRIA.

The Government review required an initial report covering what might have led to the damage, and if it could have been prevented or predicted. It was to identify any lessons learned. Following the initial report, the review was to be extended to consider any wider improvements needed to current reservoir safety, roles and responsibilities, and laws and regulations about reservoir safety.

5. FINDINGS AND LEARNING

At the time of writing this paper, the two independent reports had not been published. Therefore, it was not possible to include the detailed findings that will be contained within them. What can be shared are the key areas that the reviews have focused on, and areas that align with third party views, letters and posts on various websites. In addition, alignment with good practice as detailed in the ISO 55001 standard is recommended.

Design standards

For dam owners with concrete spillways, consideration should be given to whether there is a cut-off into the core at the crest of the dam spillway, and whether the concrete slabs have been reinforced sufficiently with interlocking dowels. Further consideration should be given to drainage arrangements.

Monitoring

Monitoring and surveillance is critical to pick up early warnings of movement, settlement or leakage.

Maintenance

Maintenance is critical to ensure there is no vegetation on the spillway and joints between concrete slabs are sealed.

Severe Weather Monitoring

Monitoring the approach of severe weather patterns enables dam owners to consider steps to be taken. One consideration is whether as a matter of precaution, reservoir levels are dropped to minimise the risk of an auxiliary spillway coming into operation. Even though auxiliary spillways will be designed to cope with extreme flood events, minimising the flow of water over the spillway reduces the risk of repeating what happened at Whaley Bridge.

6. CONCLUSIONS

This paper has sought to offer an insight into the dam failure at Whaley Bridge on 1st August 2019 and an overview of dam safety in the United Kingdom.

The incident happened even though there is a mature statutory process in the United Kingdom requiring Panel and Supervising Engineers to be appointed. Their role is to ensure the safety of reservoirs and dams. Given the nature of the incident, and the consequences if the dam had breached, the findings and recommendations from the two reviews carried out will be very important.

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