Post-incident reporting for reservoirs

Annual report 2018

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Foreword

We take reservoir safety very seriously. Reservoirs in England have an excellent safety record overall. The last reservoir failure that led to loss of life in England being more than 100 years ago. Climate change, recent flooding and the events at Whaley Bridge demonstrate how crucial it is for all infrastructure to be fit for the future.

Reservoir structures are regulated by the Reservoirs Act 1975, which sets out stringent conditions for the operation of reservoirs to ensure high levels of safety.

The responsibility for ensuring the safety of reservoirs lies with the operators. Our job, as the regulator, is to ensure they comply with the legal safety requirements. We do this by monitoring the compliance at all 2,082 large raised reservoirs in England. We publish this report so that all those involved in reservoir safety have the opportunity to learn from past incidents. By sharing experiences we can improve safety for the future.

The information provided is also helping to identify trends as well as lessons learnt and contributing to research into reservoir safety. So, please continue to help by reporting all incidents no matter how small or insignificant they may appear.

I would like to thank everyone in the reservoir sector who has contributed to this report and who continues to support the system we have in place for post-incident reporting. By doing this we are making a very real and tangible contribution to improving reservoir safety.

Antony Deakin, Reservoir Safety Manager

Executive summary

For this report we received final information on 3 incidents that occurred during 2018. Incidents are classified by their level of severity on a scale of 1 (failure) to 3 (precautionary or unplanned works). A more detailed breakdown of the incident classification system is in the section on 'reporting arrangements'. Of the 3 incidents that occurred in 2018: one was a Level 2 incident that we formally investigated, the other 2 were classed as Level 3 incidents.

We also received final information on an incident from 2013, 2 incidents from 2016 and 3 incidents from 2017. All of these incidents were classed as Level 3.

It is not unusual for reports to include information from previous years. This is because reservoir undertakers have 12 months to provide a full and comprehensive post incident report. They provide a preliminary report immediately when the incident is under control. Every year there is also the opportunity for these reports to include information on incidents that happened before or around the time that reporting became mandatory in 2013.

All incidents are investigated by suitably qualified reservoir engineers. The incidents identified in this report have either been resolved or have plans in place to address any outstanding issues.

Key learning points are included in the incident case studies, but the main learning points are the:

- need for new large raised reservoirs to be designed and constructed to latest good industry practice
- importance of routine surveillance as a means of detecting potential issues
- importance of increased monitoring during periods of high water levels

Introduction

There are 2,082 large raised reservoirs in England that are covered by the Reservoirs Act 1975 (the act). Large raised reservoirs are those that have a volume of at least 25,000 cubic metres above ground level. This means they have to operate to strict conditions set by the act to ensure high levels of safety.

The responsibility for ensuring the safety of reservoirs lies with the operators while our job, as the regulator, is to ensure they comply with the legal safety requirements. This means monitoring the compliance at all 2,082 large raised reservoirs in England. As part of this we collect and record information from reservoir undertakers (owners and operators) on incidents that have occurred. We do this for both large and small raised reservoirs so we can use this information to improve safety by:

- investigating incidents where appropriate
- informing the reservoir industry of any trends and key lessons identified
- contributing to research into reservoir safety and incident analysis

We can also 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

Arrangements for reporting in England

Since July 2013 reservoir undertakers of large raised reservoirs in England are required to report any incidents to us. This is a requirement of Section 21B of the Reservoirs Act 1975 (the act) and regulation 14 of Statutory Instrument 2013 No. 1677.

Reporting of incidents for small raised reservoirs such as those not covered by the legislation, remains voluntary.

The reservoir operator must provide a preliminary report, as soon as an incident is under control to our Reservoir Safety team. This report must contain:

- the date and time of the incident
- the location of the reservoir
- immediately observed facts

The reservoir undertaker must send us a final report within a year from the day after the incident. This report must contain:

- information about what happened
- analysis of its circumstances
- the conclusions that can be drawn from it
- any lessons learned from the incident

We review the final report and seek further clarification if necessary. We summarise the key learning points in these annual reports. The 12 month requirement for post incident reporting can mean annual reports sometimes include information on incidents that occurred in previous years. These reports may also include information on incidents that happened before or around the time that reporting became mandatory in 2013.

Incidents are classified according to the following levels of severity.

Level 1

Failure (uncontrolled sudden large release of retained water)

Level 2

Serious incident involving any of the following:

- emergency drawdown
- emergency works
- serious operational failure in an emergency

Level 3

Any incident involving:

- a precautionary drawdown
- unplanned physical works
- human error leading to a major (adverse) change in operating procedures

An incident in any of the above incident categories is covered by the regulations.

The incident reporting process is separate to any incident response. If you have concerns about the operation of a reservoir you should report it to the emergency services immediately or to us on our incident hotline 0800 80 70 60.

Reported incidents

Severity and number of final reports for incidents in 2018

There are 2,082 reservoirs classed as statutory large raised reservoirs in England.

We received final reports on 3 incidents that occurred during 2018. Of these, one was a serious incident (Level 2) that we formally investigated. The other 2 were classed as Level 3 incidents. The incident level is determined by an independent reservoir panel engineer.
We also received final information on an incident from 2013, two incidents from 2016, and 3 incidents from 2017. All of these incidents were classed as Level 3.

The incidents occurred at both impounding and non-impounding reservoirs. Impounding reservoirs are created by building a dam across a valley and the river water is retained behind this dam. In non-impounding reservoirs, water is retained by embankments on all sides and they are normally filled by pumping.

The incidents within this report have either been resolved, or have plans in place to address outstanding issues. The statistics for all reported incidents since 2004 are presented on a 5 year cycle, which began with the Post-incident reporting for reservoirs annual report 2015.

2018 incidents

Incident 441

Dam type: embankment dam

Reservoir legal status: statutory

Dam height: 6 metres (m)

Incident type: instability during construction period

Incident severity: 2

Description

The incident occurred at a non-impounding farm reservoir. The reservoir had initially been built without the involvement of a construction engineer.

Following an inspection by a construction engineer under section 8 of the act, works were completed to increase the freeboard and reduce the slope of the embankments. Section 8 of the act applies in situations where it appears that a large raised reservoir has been built without the supervision of a qualified civil engineer.

Shortly after the reservoir had been filled to top water level the supervising engineer noticed slope instability on the downstream face of the dam. The supervising engineer consulted the former construction engineer. They agreed that the water level should be lowered to preserve reservoir safety. The reservoir undertaker failed to act on this advice. We were then informed, and we appointed the former construction engineer to act on our behalf under section 16 of the act to advise us on how to respond to the incident.

Three slip failures within the outer shoulder of the reservoir had happened without any release of water. However, flood mapping showed several properties would be at risk from a breach in the reservoir. Residents were made aware of the situation, but were not evacuated. The water levels in the reservoir were lowered to a safe level. A slope failure occurred in the upstream shoulder during this process.

Photo 1: One of 3 slip failures in the outer shoulder of the embankment

Photo 2: Reservoir being emptied by pumping

Lessons learned

This was a major incident which we have investigated. The original planning process did not identify the building of the reservoir as being covered by the act. Improvements were made to the reservoir embankments under section 8 of the act. However, these proved insufficient to ensure its stability. Since the incident, a notch has been cut in the embankment to prevent the reservoir from filling.

Improvements have been identified in how our national reservoir team and the local area team respond to incidents. This improvement has concentrated on the effectiveness of communications and logistical issues concerning the deployment of pumps. The incident also highlighted that having a flood plan for the reservoir would have helped in the management of the incident.

Photo 3: Slip failure in the inner shoulder of the embankment due to rapid emptying of the reservoir

Incident 442

Dam type: embankment dam

Reservoir legal status: statutory

Dam height: 7m

Incident type: internal erosion

Incident severity: 3

Description

A sink hole and leakage were observed adjacent to a headwall structure on the dam embankment. The reservoir's water level was lowered using the scour valve and the undertaker appointed an inspecting engineer. An investigation of the headwall was not conclusive. However, it appears there may have been a defect in the headwall, which contributed to internal erosion. The defective fill material was replaced and the repair was successful.

Lessons learned

It's relatively common for internal erosion to occur adjacent to hard structures and conduits through dam embankments. It is important that undertakers carry out regular inspections for sink holes in such areas and to watch for leakage on the line of conduits.

Photo 4: Excavation of fill adjacent to conduit headwall

Incident 445

Dam type: embankment dam

Reservoir legal status: statutory

Dam height: 1.6m

Incident type: animal activity

Incident severity: 3

Description

This incident is about the deterioration of a river bank adjoining an off-line flood storage reservoir. A period of sustained high river flows and tidal conditions generated leakage through the upper part of the embankment through rabbit and mole hills. This led to some overtopping of the embankment at low spots.

The reservoir undertaker reduced the risk of further deterioration by placing geotextile membrane on the outer face of the embankment and covering it with sandbags. The area was fenced off to prevent cattle getting to the reservoir. The supervising and inspecting engineers were informed and consulted on the temporary works.

Then further seepage was found in the areas adjacent to the remediated section of embankment. This was due to moles burrowing into the embankment. This led to more temporary works being done. A permanent solution to repair and raise the bank has been planned.

Photo 5: Leakage from animal burrow

Lessons learned

Burrowing animals can cause damage to earth embankments. In this case they became noticeable when sustained high water levels caused leakage, due to internal erosion between burrows, weakening the embankment and making it more prone to overtopping and erosion.

This incident shows that steps need to be taken to prevent burrowing animals damaging embankments. Care is needed in the design and planning of permanent remediation works for the whole site.

Leakage through dam embankments due to animal activity is unusual. However, design changes to the existing bank may be appropriate, where river banks are used to form part of a flood storage reservoir, to reduce the risk posed by animals.

2017 incidents

Incident 439

Dam type: embankment dam

Reservoir legal status: statutory

Dam height: 9m

Incident type: internal erosion

Incident severity: 3

Description

Seepage was found at several locations on the downstream face of a non-impounding reservoir. This was along the embankment approximately one-third of the dam height down from the crest of the dam. Two months earlier, a sink hole had been detected on the

dam's downstream face. The water level in the reservoir level had been kept high for some time to allow the seepage to be investigated.

The inspection frequency was increased and an inspecting engineer was called to the site. The seepage points were mapped and the reservoir water level reduced to 1m below the overflow level. Trial pits were excavated on the crest to uncover the top of the core wall. These were inspected as part of a statutory inspection. The inspecting engineer also asked for piezometers to be installed as part of a stability assessment of the embankment.

Further seepage studies were done using several geophysical survey techniques. The seepage and stability studies will inform any works to raise the core wall or to improve its performance.

Lessons learned

It is sometimes necessary to maintain a high reservoir water levels to complete certain types of seepage investigation. Where this takes place for an unusually long period, inspection and monitoring should be increased. This is because of the higher risk of internal erosion causing damage at such times.

Photo 6: Sink hole near the dam crest

Photo 7: Line of seepage on the downstream face

Incident 440

Dam type: embankment dam

Reservoir legal status: statutory

Dam height: 5m

Incident type: internal erosion

Incident severity: 3

Description

Leakage was found at the downstream toe of an earth fill embankment dam during a weekly inspection. There had been low-level seepage at this location for some time. However, this increased after a period of sustained high water levels due to rainfall. The rate of leakage was estimated as 0.5 litres per second.

The water level in the reservoir was lowered to a safe level and maintained at this level. An inspection under section 10 of the act and a site investigation were undertaken to inform the work needed to seal the embankment. The investigations found a higher amount of gravel and cobbles within the clay matrix in one location. Five minutes after dye was introduced into the borehole it emerged from the point of leakage at the downstream toe of the dam. This confirmed the area of leakage. The embankment was repaired by injecting cement-bentonite grout using the tube-à-manchette method.

Lessons learned

Leakage paths can develop over a long period of time and may worsen during periods of high water levels. Therefore, it's important to increase surveillance and monitoring at such times, as was done in this case.

A number of trees are present on the dam crest. However, it's unclear if the impact of the trees caused the leakage. The site investigation identified geotechnical differences in the fill material in the leakage zone. This suggests that a more permeable zone had been in the dam body during construction over 250 years ago.

Photo 8: Leakage from the embankment right mitre

Photo 9: Grouting works to remediate and improve the embankment using the tube-à-manchette method.

Incident 443

Dam type: embankment dam

Reservoir legal status: statutory

Dam height: 1.6m

Incident type: human error

Incident severity: 3

Description

A landowner damaged an offline flood storage reservoir embankment. The reservoir is formed by a low earthfill embankment. It has a crest width of approximately 10m where the embankment separates the reservoir from an A road. The embankment is a historical flood defence, which has only recently been recognised as a reservoir structure under the act.

The embankment features several properties either on the crest or built within the downstream shoulder. The reservoir undertaker noticed that one of the home owners had made an unconsented excavation into the embankment crest. This was on the downstream shoulder and reduced the crest width to approximately 4.5m. The excavation depth was up to 550 millimetres (mm) to make a flat area suitable for building some sheds.

There was no immediate flood risk due to the embankment's geometry and because the reservoir could be controlled. However, the excavation had removed some of the support to the dam crest. Therefore a retaining wall was built to ensure the appropriate support was in place to make the embankment safe. A flood warning system was instigated and maintained until the remedial works had been completed.

Lessons learned

Undertakers need to communicate the importance of reservoir structures to people living close to them. Siting properties close to reservoirs can also reduce access to the site making it more difficult for undertakers to carry our effective monitoring and surveillance and maintenance, which could impact the operation, safety or effectiveness of the structures.

In this incident the damage was caused by a new landowner who had not been told about the importance of the embankment. Explaining the importance of reservoir structures can be more difficult in the case of flood storage reservoirs where the function of the embankment is more difficult to understand, as it is empty for much of the time.

2016 incidents

Incident 437

Dam type: embankment dam

Reservoir legal status: statutory

Dam height: 7m

Incident type: mining subsidence

Incident severity: 3

Description

This dam embankment has a long history of seepage. This may have been caused by mining subsidence. Increased leakage from a point just below the crest of the dam was identified by the undertaker who told the supervising engineer. Following discussions with an inspecting engineer the reservoir's water level was reduced in 0.2m increments to 1m below top water level. The impact of each reduction was assessed against the leakage flow rate. This successfully reduced the flow rate which showed that the leakage was at a high level. A site investigation confirmed that repairs to the upper part of the dam core were needed. A plan is now in place to resolve the problem.

Lessons learned

The leakage was detected through routine surveillance site visits. It's believed that repairs made over 50 years ago to address mining subsidence had only left a small margin between the top water level and the top of the core in some areas. Further settlement and tree root damage are thought to have contributed to the issue.

Incident 438

Dam type: embankment dam

Reservoir legal status: statutory

Dam height: 14m

Incident type: deterioration of toe support

Incident severity: 3

Description

This incident happened at a canal reservoir where the canal runs parallel with the downstream toe of the dam. It's separated by a tow path and masonry canal wall which forms the sides of a lock. Routine inspections showed that the section of wall between the two lock gates was failing. It was thought that this damage was due to the condition of the masonry and boat impact damage.

Failure of the wall into the lock could have affected the stability of the downstream shoulder of the embankment. The undertaker decided to carry out a precautionary draw down of the reservoir to 1m below top water level. The damaged section of wall was next

to the spillway outfall and directly above a reservoir outlet pipe. There was concern that operation of the spillway could reduce the stability of the wall and the dam.

The canal was emptied and investigations identified that the section of canal wall between the locks was damaged. There had also been several structural repairs and the foundations had been replaced or improved. The failed section of wall was of a different construction to the adjacent wall sections.

There was no active seepage or erosion from the spillway structure. The reservoir outlet pipe below the wall was surveyed by CCTV and was found to be in good condition. The investigation concluded that the action of boat traffic had destabilised the wall. It also showed that the damaged section of wall had not had the same improvements as the adjacent wall sections. This is possibly due to the pipe passing beneath it. The damaged section of wall was reconstructed with the lock emptied.

Photo 10: Damaged section of wall

Photo 11 Repaired wall

Lessons learned

The stability of reservoirs can rely on other structures beyond the downstream toe of the dam. The damage to the canal wall was identified through routine inspection. The initial concern was the canal wall had been undermined due to leakage from the high-level outlet pipe that passes beneath the canal wall to the left of the spillway. Another possibility was that the water spilling into the canal had undermined the wall foundations to the side of the spillway. If the wall had collapsed it could have affected the stability of the downstream

shoulder of the dam embankment. Fortunately, the reservoir inflow could be controlled to manage this risk. Action was taken to reduce:

- the risk of the reservoir spilling
- the hydraulic load on the embankment
- the volume of reservoir water
- the risk of any spill flows affecting the damaged area

The incident shows how erosion below the waterline of canals or other watercourses can go unnoticed until bank structures fail. Therefore, it's important that they are monitored for erosion where these structures are relied upon for dam stability.

2013 incidents

Incident 444

Dam type**:** embankment dam

Reservoir legal status**:** statutory

Dam height**:** 8m

Incident type: instability

Incident severity**:** 3

Description

This happened at a non-impounding farm reservoir formed by homogeneous clay embankments. The embankments of the reservoir had shown signs of instability on the inner face. This was believed to have been caused by wave erosion and had been fixed.

Nearly 10 years after the reservoir was built shallow surface slips occurred on the outer face of the embankment. High winter rainfall was thought to have been a reason for these slips. A detailed inspection of the embankment by an inspecting engineer identified more areas of instability. The reservoir water level was drawn down to a safe level and the affected slopes were fixed by making the outer slopes less steep (in technical terms this changed it from 1V:3H to 1V:4H). To keep within the site boundary and maintain the crest width, this meant that the height of the reservoir walls were also reduced. A new overflow was also constructed to maintain the new, lower water level in the reservoir.

Lessons learned

The construction engineer appointed to manage the repair works and alteration of the reservoir volume put the instability down to:

- the material used for construction (London Clay)
- reservoir age (relatively new)
- the construction methods
- the slope angle employed (1V:3H)
- heavy rainfall

The engineer also noted that the original construction had been hampered by wet weather. However, this seems unlikely to have affected the reservoir's stability so long after construction. This incident highlights the importance of proper design and construction

supervision in the building of new reservoirs and the need to install proper protection against wave erosion.

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