TECHNICAL MEMO

Prepared By: Water Resources Management Division (WRMD)
Date: October 2023
Re: Controlled Breach of Earthen Dams

Background

This memo is part of a series of documents on dam emergency interventions. The focus of this memo is to provide guidance on the controlled breaching of earthen or partially earthen dams. This method would be implemented in a situation where the water level in the reservoir threatens the integrity of the dam by risk of the dam overtopping and sustaining erosional damage. The idea behind employing this method is that the drawdown of the reservoir would prevent the total failure of the dam or, at very least, facilitate the gradual release of water in order to minimize damage to the dam and minimize damage caused by flooding downstream.

Figure 1: Earthen embankment dam at Double Creek Watershed, Washington County

Breaching the crest of an earthen dam is a last resort emergency measure. Only use this approach in a situation where the dam is almost surely going to fail should the reservoir level not be drawn down. If conditions are not favourable, an intervention should not be made in order to avoid unnecessarily endangering people and possibly compromising the integrity of the dam further.

Mode of Failure

The method of creating a controlled breach in the dam's crest should be used in a situation where the dam is at risk of failure due to overtopping. Overtopping occurs when the water level in the reservoir surpasses the crest height and begins to spill over the top of the dam and onto the downstream face [1]. This can be caused in still water by continuous overtopping, where the reservoir is above maximum capacity and water is constantly flowing over the crest, or by over wash resulting from wind action, where the wind is creating waves on the waterbody and these waves are being driven over the top of the dam [1]. In some instances, overtopping can be caused by a combination of both high water level and wind action. High water levels in a reservoir can be caused by large amounts of water run off from a storm or heavy snow melt, a reservoir breach

upstream, blocked/damaged stop logs or flood gates, blocked/damaged reservoir outlet, or a combination of these. Figure 2 demonstrates the stages of failure of an earthen dam from overtopping.

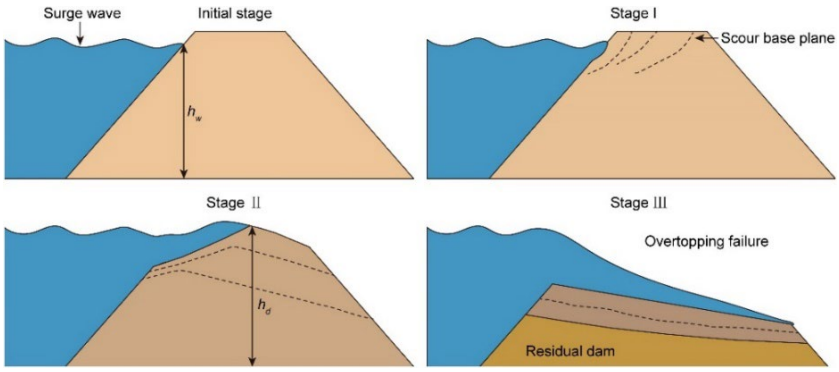

Figure 2: Stages of failure by overtopping

Unlike concrete dams, which can usually withstand some overtopping, earthen dams are much more vulnerable to the erosional damage caused by overtopping. Compared to an erosion resistant and ridged structure like a concrete dam, earthen dams are especially vulnerable to erosional effects on their downstream faces. The upstream face of the embankment typically has erosion protection in the form of riprap or erosion resisting fabric, however, the downstream face will have little to no erosion protection [1]. If water begins to flow over the crest, the unprotected downstream face can suffer severe erosional damage [2]. Depending on the depth and speed of the water flowing over the crest the damage can lead to partial embankment failure or, in extreme situations, total failure. A few inches of depth does not prompt immediate action, however, a foot or more of depth should be very concerning, especially when moving at high speeds [3]. Another factor that can affect the level of erosional damage is the cohesiveness of the fill used to build the earthen dam. The more cohesive the soil is the more resistant it will be to erosion [2]. Light vegetation growth, such as grass, can also help to protect against erosion and stabilize the embankment (see Figure 3). Anything more significant like trees or bushes can negatively impact the integrity of the dam.

Figure 3: Earthen embankment dam at Glade Run Lake, Pennsylvania

Breaching Procedure

The first step of the process is to determine the location of the breach. Ideally, the breach would be made at the most erosion resistant area on the embankment. This would be a rugged or rock covered area or wherever there is a bedrock foundation. Typically, this location is on or around the abutments of the dam, where the earthen fill meets the original more compacted foundation terrain. In some situations, where the water level is rising too quickly and there isn't enough time to set up a breach at the abutments, the breach may have to be made at a low point on the dam's crest (see Figure 4). Earthen dams are supposed to be completely uniform, however over time, things like consolidation, settlement and seepage can cause sloughing and elevation changes to the crest [1]. The reservoir would begin overtopping at this low point so it may make more sense to work at this area rather than a higher point on the dam. This may be the case in some situations, however, the preferred location is still where the most erosion resistant material exists.

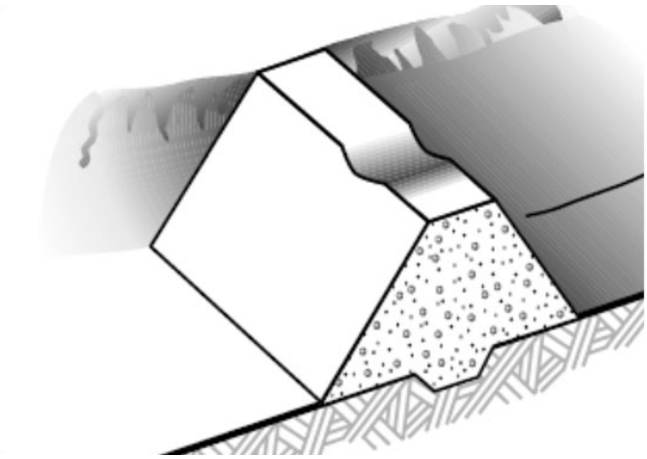

Figure 4: Low point on dam crest

Once the breaching point has been determined, the flow path that the discharging water will follow must be reinforced against erosion. This path can be visually identified by the low points between the breach and the downstream flow path since the water will follow across the lowest path until it reaches the tail waters downstream. The downstream face of earthen dams typically don't have much erosion protection, which leaves these areas susceptible to the erosional forces of the discharging water. Therefore, the path along which the water will flow needs to be reinforced. With the lowest elevation path identified, reinforcement to protect against erosion can be implemented by laying riprap, erosion resistant blanket, geotextile fabric, or plastic sheets along the flow path [3]. See Figures 5 and 6 showing the use of geotextile and riprap for erosion protection. Sandbags can also be used to line the sides of the flow path and the area around the breach. This can help to further protect against erosion, provide additional depth for the flow channel, and direct the path of the flowing water to prevent it from spreading out and causing further erosional damage.

Figure 5: Geotextile lined spillway in Gridley, California

Figure 6: Riprap lined spillway in Truckee River, Nevada

When all the necessary and available measures have been put in place, the breaching of the dam's crest can begin. This process should start on the downstream face of the dam, digging towards the reservoir. Cuts to the earthen fill should be very incremental and made in a controlled manner, slowly carving away at the embankment so that the release of water can be as gradual as possible. This will help to control the breach, preventing it from becoming too large and eroding too much material away. The breach will enlarge on its own in terms of both width and depth, especially in erodible areas, so it is crucial that the initial breach is minute. Figure 7 demonstrates the phases of a controlled dam breach on an earthen dam.

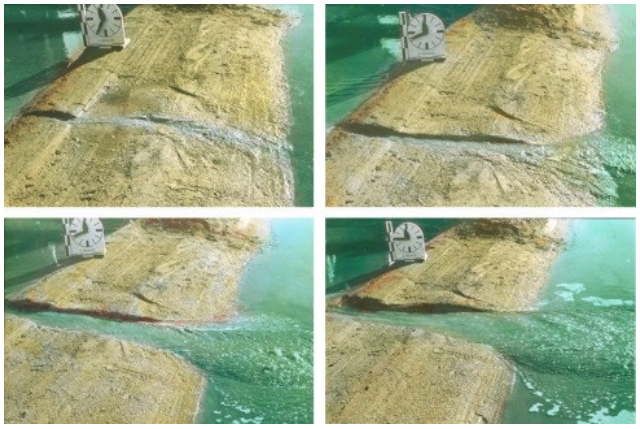

Figure 7: Earthen dam breach in Obernach Hydraulics Laboratory, Germany

Recommendations

In conclusion, there are many considerations to be made when preparing for an emergency breach on an earthen dam, these include:

- Is this the best course of action based on the situation?

- This is an emergency procedure used in drastic situations
- If conditions are not ideal the breach does not need to be performed
- Proceed if conditions are favourable and there is time to implement protective measures

- Determining the location of the breach
  - Erosion resistant area (rock covered/bedrock foundation)
  - Near the abutments
  - Low point on crest of the dam
- Identifying the flow path of the water exiting the breach
  - Low points along the path between the breach and the downstream flow path
- Reinforce the flow path using some form of erosion resisting material
  - Lay riprap, erosion resistant blanket, geotextile fabric, or plastic sheets along the flow path.
  - Lay sandbags at breach and along flow path to protect against erosion, provide additional depth, and direct the flow
- Slowly breach the crest
  - Work from the downstream face towards the upstream face
  - Dig a very small trench starting off
  - Try to control the flow and erosion of the discharging water

References

[1] "Causes of Failures of Earthen Dams", National Institute of Technology Jamshedpur, Available: http://www.nitjsr.ac.in/course_assignment/CE10CE-%204234Failure%20of%20earthen%20dams.pdf

[2] W. Wu, M. Altinakar, M Al-Riffai, N Bergman, "Earthen Embankment Dam Breaching", Journal of Hydraulic Engineering, 2011, Available: https://www.researchgate.net/publication/237512978_Earthen_Embankment_Breaching

[3] C. Cooper, R. Dewey, B. Fielder, K. Frizell, T. Helper, T. Wahl, "Technical Manual: Overtopping Protection for Dams", Federal Emergency Management Agency (FEMA), 2014, Available: https://damfailures.org/wp-content/uploads/2015/06/Technical-Manual_Overtopping-Protection-for-Dams.pdf