Issues and Research Needs Related to Hydraulics for Spillways for State Regulated Dams

By

Francis E. Fiegle II, P.E.
Program Manager
Georgia Safe Dams Program
Georgia Department of Natural Resources
There are over 75,000 dams listed in the National Inventory of Dams, and state dam safety programs regulated over 90 percent of them. They range in size from small run of the river dams in the East to some very large water storage projects in the West.

Because of the number of dams regulated by the states and limited staff and budgets, historically we have looked to the major Federal Agencies that are involved in dam building for general and sometimes specific guidance on questions related to dam safety. This is the case when it comes to analyzing the hydraulics of principal and emergency spillways for our regulated dams. Most if not all our regulations reference technical guidance documents from USACOE, FERC, NRCS and BuRec as being the basis for design of the state regulated dams.

As time has passed, with training and often on the job experience, virtually every state has had issues with the hydraulic design of the spillways for some regulated dam. To that end, I prepared a brief survey and sent it to the ASDSO state representatives to gather their input. I received responses from 30 states and this is a summary of the results.

1. **Please indicate which of the following types of spillways your state regulates.**

- Corrugated Metal Pipe and Riser – 25 states
- PVC Siphon Pipe – 16 states
- Concrete Pipe and Concrete Riser – 24 states
- Earth Channel Spillway – 24 states
- Rock Spillway – 22 states
- Reinforced Concrete Chute – 22 states
- Ogee Weir – 24 states
- Labyrinth Weir – 18 states
- RCC Stepped Spillway over an Earthfill Dam – 16 states
- RCC Stepped Spillway in the Abutment – 12 states
- RCC Stepped Spillway on a RCC Dam – 14 states
- Gated Spillway – 23 states
- Fuse Plug Spillway – 16 states
- Run of the River Spillway – 19 states
- Gabion Basket Spillway – 19 states
- Rock Rip Rap Spillway – 21 states
- Concrete Block Spillway/Overtopping (cabled or individual blocks) – 14 states
- Other, Please List –
  - Bascule Gates
  - Rubber Dams
  - Plastic Honeycomb Grid filled with Concrete
  - Reinforced Concrete Siphons
  - Sheet Piles
  - Timber Crib
  - Geogrid Reinforced Earth
  - Concrete/Timber Drop Structures
  - Timber Overflow Channels
  - Fiberglass Lined Channel
  - Welded Railroad Box Cars
It is likely that every state has some unique spillway structure where there is no design guidance on which makes for some very interesting technical discussions with the regulated community.

2. **With the PVC siphon spillways in your state, are there multiple pipe installations? What is the largest pipe diameter used? If known, what is the maximum height of vertical drop from the control section to the outlet?**

Nine states responded that they had multiple pipe installations. Eighteen states had no multiple pipe installations. The largest diameter PVC pipe was 24 inches. The maximum drop was 45 feet.

In virtually every state where there are Corrugated Metal Pipe spillways, the replacement spillway of choice is the PVC siphon spillway for obvious reasons. It allows the lake to be partially drained and routine inflows to be passed with a replacement system that does not require the existing dam structure to be removed and reconstructed.

3. **Is ice/freezing of the reservoir an issue with the operation of the spillways on your regulated dams? Does it affect the hydraulics of the spillway? Do you have enough information on how ice affects the hydraulics?**

Sixteen states responded that ice/freezing of the reservoir was an issue. Ten states from the southern climes did not have an issue with ice. Ten states stated that ice affected the hydraulics of spillways and seven more states thought it might. Only two of the affected states thought they had enough information on ice. Fifteen states wanted more information on this wintertime problem.
4. **Do you have concerns about skimming flows causing hydraulic jumps in stilling basins on stepped spillways during high flow events?**

Six states had concerns about skimming flows causing hydraulic jumps in stilling basins below stepped spillways and five more states thought there may be some issues. Four states did not have concerns including one that required step spillways to be modeled. Seven states responded that they were unfamiliar with skimming flows or had no stepped spillways. With RCC overlays creating new spillway capacity oftentimes over the existing dam, what happens if there is a hydraulic jump in the stilling basin to the RCC floor that is subject to uplift during extremely high flow events?

5. **Do you have questions about how the hydraulics work with any of the spillway applications listed in number one?**

Fifteen states had questions about the hydraulics of one or more of the spillway types they regulate. Five states stated they did not. This led to the next question which I thought validated the previous response.

6. **Have you and your staff had adequate training to evaluate how your regulated spillways operate under all loading conditions?**

Thirteen states needed more training specifically related to hydraulics. Five states did not need more training. Interestingly, the same five states that had no questions about the hydraulics of their spillways did not necessarily respond that they did not need training.

7. **Is there anything about the hydraulics of these spillways that need further research?**

I have taken the state responses to this question and summarized the results by topic.

A. Siphons (6 states)
   - Hydraulics for multiple intakes/outlet pipes (turbulence)
   - Hydraulic rating curves for each pipe (spreadsheet calculations accounting for head, lift, diameter screens, etc.)
   - Maximum height installation
   - Material types, life span (PVC, HDPE, steel, etc.)
   - Joint integrity
   - Maximum diameter of pipes
B. Snow and Ice (16 states)
  - Hydraulic changes due to the ice buildup
  - Cost effective designs to minimize icing impacts and ice jams
  - Frozen fuse plugs
  - Ice/snow removal without a site visit (especially small dams)

C. Drop Structures (3 states)
  - Slugging flows in deep drop structures/pipes
  - Rational approach to air demand/minimum air pressure in outlet pipes
  - Deflector plates at pipe/drop structure interfaces (are they necessary?)

D. Stepped Spillways (RCC) (7 states)
  - Changing hydraulics of RCC spillways due to weathering or scour
  - Skimming flows especially in high flow conditions
  - Hydraulic jumps in stilling basins. Are RCC stilling basins adequately designed? Have we forgotten lessons learned with reinforced concrete chutes?
  - Cracking in RCC overlays for overtopping. Does this affect the uplift loading in the stilling basin?
E. Concrete Blocks (5 states)
   - Performance during extreme floods
   - Debris flows
   - Long term material performance

F. Irregular Spillway Shapes (4 states)
   - Geometric shape evaluation: rock and rock lined channels
   - Rapids artificially created for fish passage
   - Standing wave run up in steep curved channels

G. Hydraulic Coefficients (5 states)
   - Overstated coefficient capacities
   - Better software
   - Realistic and relevant evaluations

H. Miscellaneous
   - Corrugated metal pipe life
- Overtopping of earth dams
- Rip rap, reinforced concrete drop structure design
- Flash boards that do not fail
- Application of earthquake loading condition forces with hydraulic/other loading conditions (is that reasonable?)

While there are more issues about spillway performance or actual inspection techniques that need to be discussed, these are some of the hydraulic issues that states are struggling with. In closing, if there is research done on these issues, the results need to be relevant and reliable. The results need to be proven in the field in long term applications. Small dam owners do not have the financial capability to do the same upgrade twice.