Vortex Valves

Flood prevention tools catching on in UK dam projects.

By Robert Y. G. Andoh

The 100,000 or so dams that operate in the U.S. serve a variety of purposes. More than 30 percent are used primarily for recreation. About a fifth of the dams were built primarily for fire protection. The third most popular use is for flood control (16 percent), followed by irrigation, water supply, hydroelectric, fish and wildlife, mining, debris control, and navigation.

Dams used for flood control are particularly important for public safety, because if they fail the runaway floodwaters cause extensive damage to local communities. Among the more destructive dam failures in the U.S. were two that took place in the 1970s—in Buffalo Creek, WV, where a 16-mile valley flooded, killing 125 people; and near Rexford, ID, where the failure of the Teton Dam caused up to $2 billion in property damage and killed 11.

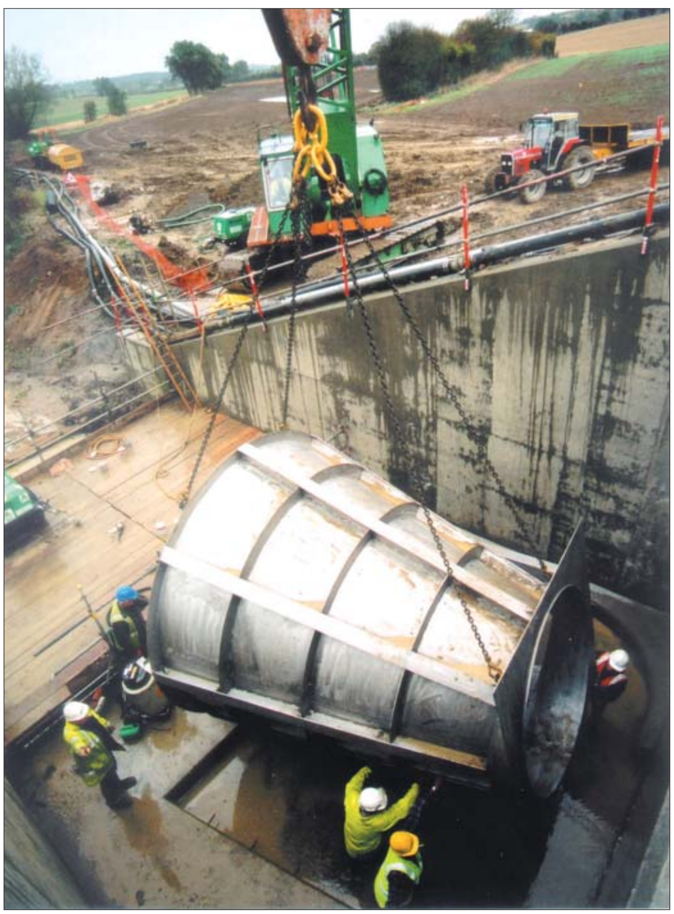
To protect against downstream flooding in heavy rains, engineers typically deploy two principal strategies. They build up the communities' flood defenses and/or they hold back the flood waters upstream.

Building up a community's defenses is an expensive and disruptive proposition. Municipalities must enlarge their existing conveyance channels or build up protective walls to ensure that heavy flows do not flood local streets. They need to create higher embankments or shored-up levees. But that can be a challenge in many older urban areas, where residential and commercial projects have been built close to the channels. To ensure adequate protection, local leaders often have to resort to land takings.

Holding back flows is usually the more efficient, cost-effective way. To allow for a regulated flow downstream of the dam, and to protect against excessive damaging flows, flood scheme designers deploy flow control devices upstream of dams. These devices contain an orifice sized to allow a calculated flow that will proceed through the dam and be slowly released during a major flood threat. But the downside of holding back flows is that the practice creates floods on the other side of the dam. This creates a problem for farmers upstream of the dam who do not want their land to flood every time it rains. And it often requires municipalities to resort to additional land takings of developments that fall within the expanded floodplain.

The challenge is to deploy a flow control scheme that balances the need to stop the damaging floods downstream of the dam and limit the protective flooding on the upstream side. In Europe, a number of dam projects have used vortex valves to help strike this balance. These valves are currently used in the U.S. for flow control purposes in urban drains and ponds, but they have not been applied to dam projects.

Vortex valves act like natural hydraulic brakes. Designed with a snail or conical shape, high flows initiate a vortex within the valve, which in turn restricts the flow of water out of the device. When head pressure builds, water circulates in a vortex pattern, allowing an air core to form within the device preventing excess amounts of water from entering conveyance systems such as channels through urbanized



Installation of a large vortex valve, whose design—a snail or conical shape—cause high flows to initiate a vortex within the valve, restricting the flow of water out of the device.

areas or combined sewers and other collection systems.

Under low-flow conditions, the valve acts as a large orifice where water and debris pass directly from the inlet to the outlet. As flow increases and reaches the flush flow point, high peripheral velocities start to throttle the flow. As pressure increases, an air core, accompanied by substantial backpressure, effectively restricts the flow through the outlet aperture.

Examples of the use of vortex valves in dam projects can be found in Weedon Bec and Glasgow in the United Kingdom. Both projects have deployed vortex flow control valves supplied by Hydro International Inc. (www.hydro-international.biz).

Weedon Bec, UK

The village of Weedon Bec, situated west of Northampton in the UK, suffered serious flooding from the River Nene during Easter 1998. The village had no formal flood defenses and there was a risk of flooding once every three years with some 95 properties at risk of flooding. The main cause of flooding was the limited capacity of culverts under a railway embankment downstream of the village and at a road bridge within the village.

As the project team considered a range of solutions, it became evident that the most viable option was the provision of upstream flood storage—improving the capacity of the channel to pass flood flows required the existing river channel to be doubled in size, producing unacceptable disruption and loss of land. The cost of enlarging the road bridge and railway culvert would also have been high.

Enlarging the channel would have had the effect of transferring the problem further downstream, producing an intolerable increase in downstream flows through several villages and the town of Northampton, which were already at risk. Containment of floodwater within the river channel would also have required construction of flood walls through 30 private gardens, which was unacceptably expensive and disruptive. This coupled with potential problems with access for future inspection and maintenance made the channel enlarging option unattractive.

A site was identified less than a mile upstream of the village where the river flows through a well-defined valley with little habitation, forming a suitable location for implementing a flood storage scheme. The scheme, which was completed in the fall 2002, comprises an earth fill dam with a maximum height of 22 ft and a crest length of just under 500 yd. The storage area occupies the valleys of the Newnham and Everdon arms of the River Nene providing a flood storage area of about 91 acres and volume of approximately 215 MG at full capacity.

The flow from the reservoir passes through a 7.8-ft wide by 6.9-ft high box culvert constructed on the line of the original river channel. A conical-type (C-type) vortex flow control with outlet aperture of 5.7 ft and overall length and height in excess of 16 ft was installed to attenuate the peak flow through Weedon Bec from 7,000 gal per second (605 mgd or 935.8 cfs) to the in-bank capacity of the river channel through the village of 2,600 gal per second (225 mgd or 347.6 cfs) during a 50-year event.

A C-type vortex valve was chosen on the basis of its simplicity, low maintenance requirements, and relatively lower cost for this site. Other alternative options for controlling flows through the culvert such as a fixed orifice, an electrical or hydraulically actuated penstock, or a float operated radial gate were considered but discounted for the following reasons:

- There is no power supply near the site for automatic gate operation. Provision of power would have been expensive and there would also be a risk of equipment failure during a flood.
- Arrangements to allow manual operation of penstocks during a flood event were not considered practical because it would be unrealistic to expect maintenance staff to operate them safely during a flood. The penstock would therefore, in effect, act as a fixed orifice.
- A fixed orifice would cause unnecessary, frequent, and significant flooding upstream of the dam, which would limit use of the land for agriculture. This was unacceptable to the

The Hydrobrake® Flow Control is a self-activating vortex flow control device that harnesses the energy inherent in the flow field. They have no moving parts and no external energy requirements. With clear openings up to 600 percent, the risk of blockage is minimized. In addition, the head/discharge characteristics with high flush and kick-back flow points, reduce storage volume requirements, lowering project costs.

affected landowners.

- A float operated radial gate across the culvert exit controlled by downstream water level was rejected because it would have pressurized the culvert and required maintenance.
- There was also the risk of failure of equipment with moving parts that only operated intermittently, imposing significant maintenance requirement that the responsible agency wished to avoid.

An essential requirement of the scheme was environmental sensitivity, adaptability, and the ability to allow the passage of both fish and small aquatic mammals through the culvert and control structure under normal operating conditions. The unique two-stage head-flow characteristics for the vortex valve, which in effect means it operates like a large orifice with unimpeded flows under normal flow conditions, made it well suited to this application. The unit installed at Weedon Dam can adjust the controlled outflow between just over 2,000 (172.8 mgd or 267.4 cfs) to 3,000 gallons per second (259.2 mgd or 401 cfs) via the use of removable stop logs on its intake. This provides flexibility and the ability to adapt flows in response to major changes in the hydrological characteristics of the catchment, such as impacts of climate change.

Glasgow, Scotland

Another example of the use of vortex valves in an urban drainage context to address space constraint issues is Glasgow's White Cart Water Flood Prevention Scheme. The project, currently under construction, is Scotland's largest flood prevention scheme, designed to protect 1,750 homes and businesses from flooding.

For nearly a century the White Cart Water has inflicted serious flooding on homes and other properties on the south side of Glasgow. This shallow, fast flowing river is prone to flash flooding—12 hours of rain can cause water levels to rise by more than 19 ft. Over 20 significant floods have taken place since 1908 and in 1984 more than 500 homes were inundated.

The solution involved the formation of three flood storage areas upstream of the city to temporarily hold back the bulk of floodwater generated by extreme rainfall and control the release of water passing downstream through the city to an acceptable level. The general criterion adopted for design was that each pond would fill to its top water level during the 1-in-200-year flood event.

By using vortex valves as opposed to traditional flow controls such as orifice plates, this allowed the project team to significantly reduce the extent of the water retention areas on sites with little available land.

Vortex valves help provide a high degree of flexibility in the design of stormwater management systems. Rather than send flows downstream to be dealt with later, vortex valves regulate flows and allow drainage systems to distribute them in a more natural manner. To solve future water issues in the most economical, efficient manner possible, society will have to adopt integrated water management plans that prevent problems before they occur. Vortex valves illustrate how those plans can work. GE

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