DESIGN OF SPILLWAYS AND OUTLET WORKS FOR DAMS

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The main purpose of a spillway is to pass moderate floods and to prevent a dam from failing during very major floods. It is therefore essential that the spillway designer provides a structure that complies with all safety requirements at the least combined cost of the spillway and the dam.

Design guidelines distinguish between normal service spillways, and auxiliary (emergency) spillways. Service spillways can be either uncontrolled or gated. Uncontrolled spillways are most commonly used at small dams because of their reliability, simplicity and ability to pass debris. Gated spillways are generally more complex and more costly to build and maintain than uncontrolled spillways, but they enable storage to be maximised by controlling water levels. They should be backed-up by auxiliary spillways as the gates may be subject to automatic operation malfunction, human error and debris blockage. Auxiliary spillways are uncontrolled spillways used in combination with service spillways and might take the form of either a fuse plug or fuse gate.

The choice of spillway type depends on a number of factors including the dam type, topography, geology, flood discharge and frequency and duration of overflows. The relationship between discharge and head above the spillway crest is determined by the control structure. The following types of uncontrolled control structures are available:

- open channel spillways (unlined rock/earth channels and grassed channels)
- free overfall spillways (ogee)
- side channel spillways
- shaft spillways (morning glory)
- labyrinth spillways
- syphon spillways

A variety of gated spillway designs are currently available, including the following:

- vertical lift gates
- radial type crest gates
- drum and flap type crest gates

- inflatable dams
- bottom outlet gates
- fuse gates

Outlet works enable stored water to be released from the reservoir to users, and also to empty the dam within a reasonable period for safety reasons. Multilevel draw-offs are frequently provided to draw well-oxygenated water from just below the surface of the reservoir.

1. Introduction

The main purpose of a spillway is to safely pass moderate floods and to prevent a dam from failing during very major floods. It is therefore essential that the spillway designer provides a structure that complies with all safety requirements at the least combined lifetime cost of the spillway and dam *(see Large Dams)*.

The spillway system has to safely pass the Recommended Design Flood (RDF) with adequate freeboard. However, when the system passes the Safety Evaluation Flood (SEF), it might not cause the dam to fail catastrophically, but could cause substantial damage to the structure and its surroundings.

2. Spillway Types

Design guidelines clearly distinguish between normal service spillways, and auxiliary (emergency) spillways.

2.1 Service spillways can be either uncontrolled or gated spillways - both are able to cope with frequent flood releases without significant erosion or other related damage.

2.2 Uncontrolled spillways are most commonly used at small dams because of their reliability, simplicity and ability to pass debris and to reduce the magnitude of incoming flood peaks, as well as being cheaper to build and maintain. Free overspill crest spillways, shaft spillways and syphon spillways also fall into this category.

2.3 Gated spillways should be backed-up by auxiliary spillways as the gates may be subject to automatic operation malfunction, human error and debris blockage. These spillways enable storage to be maximised by controlling water levels. They also allow pre-releases, but if incorrectly operated, can aggravate downstream flooding. Gated spillways are generally more complex and more costly to build and maintain than uncontrolled spillways.

2.4 Auxiliary spillways are uncontrolled spillways used in combination with service spillways and sometimes also with flood outlets, specifically at dams without a service spillway. The auxiliary spillway might take the form of either a fuse plug or fuse gate, which must be designed to function automatically when required without aggravating downstream floods.

The choice of a spillway type depends on a number of factors including the dam type, topography, geology, flood discharge and the frequency and duration of overflows. The main components of spillways influenced by these factors and which have to be combined in the most economically effective manner are the following as shown in Figure 1:

- the entrance tunnel
- the control structure
- the discharge carrier
- the energy dissipater
- the outlet channel

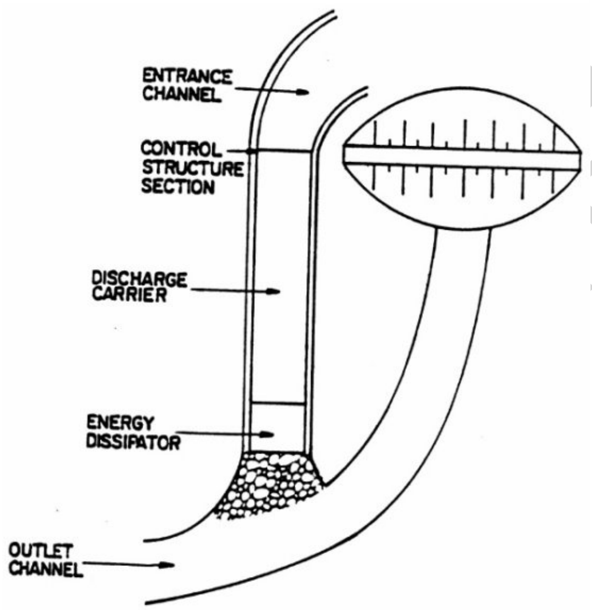

Figure 1: Spillway Components

Equations in subsequent sections are in metric units.

3. Service Spillway Design

The design of spillways is conveniently also divided into the above mentioned components shown in Figure 1 as follows:

3.1 Entrance Channel

This channel conveys water from the reservoir to the control structure. Entrance velocities should be limited and channel transitions gradual to minimize head loss. This will increase the spillway discharge for a given reservoir level and also provide uniformity of flow over the crest. To ensure such conditions, the approach flow must be subcritical with a Froude Number (F) of less than 0.7 *(see Fluid Mechanics).*

$$F = v / \sqrt{gy} < 0.7 \qquad (1)$$

where v = approach velocity (m s^{-1})
y = approach depth (m)
g = 9.81 m s^{-2}

Depending on the velocities and the materials, entrance channels may require protection such as riprap, gabion mattresses, grass blocks, grassing or concrete lining.

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Biographical Sketch

Mike Shand qualified as a civil engineer from the University of Cape Town and received his Masters and Doctorate degrees from the University of California at Berkley. His thesis was based on a research project for the United States Bureau of Reclamation concerning automatic downstream control of irrigation canal gates.

In 1969 he joined Ninham Shand, a South African civil engineering consulting firm. He initially served as resident engineer on Xonxa Dam near Queenstown, then worked in Port Elizabeth and managed offices in Maseru Lesotho, Port Elizabeth, Durban and Cape Town. He has headed the firm's Hydro Department since 1977 covering the full spectrum of water projects ranging from hydrology to water resources management, hydraulics, dam spillways and outlet works, pipelines and water hammer and also river and stormwater management.

He was responsible for planning the spillways of a number of major dams including Xonxa Dam near Queenstown, Garden Route Dam near George, Stettynskloof Dam near Worcester, Impofu Dam near Port Elizabeth, Bridle Drift Dam at East London, Fika Patso Dam in Qwaqwa and a number of smaller dams. He was also involved with the planning of the spillways for the 180 m high Katse Dam of the Lesotho Highlands Water Project and for the 115 m high Maguga Dam in Swaziland and with the feasibility study for Skuifraam Dam to augment the supply to Cape Town

He served as project leader of the Department of Water Affairs and Forestry's water resources studies to plan the augmentation and the annual management of water supplies for the cities of East London, Port Elizabeth and Cape Town and also for the towns of Oudtshoorn and Plettenberg Bay. He was joint study leader of the Orange River Replanning Study and of the Mzimvubu component of the Vaal Augmentation Planning Study. He has also been closely involved with urban catchment management in the Western Cape.

He is actively involved in the activities of the South African Institution of Civil Engineering and has served as Chairman of the Western Cape Branch and the Water Division. He has organized a number of congresses and symposia and is the author or co-author of sixteen professional papers.