REMR TECHNICAL NOTE HY-FC-1.1

CAUSES OF EXCESSIVE SCOUR DOWNSTREAM FROM HIGH-LEVEL EMERGENCY SPILLWAYS

PURPOSE: To describe causes of excessive scour downstream from high-level emergency spillways and thereby alert project personnel of potential problems at these locations.

DEFINITION: The term "excessive scour" refers to scour that may threaten the safety of a spillway.

CAUSES OF EXCESSIVE SCOUR: Excessive scour at these locations can be caused by the following conditions:

a. Flow concentration in the exit channel:

   1. Exit channel geometry may confine flows.

   2. Composition of exit channel material may permit localized scouring.

   3. A depressed roadway in the exit channel may be susceptible to scour by concentrated flow.

   4. Flow passing through a culvert may concentrate flow.

   5. A laterally sloping spillway apron tends to concentrate flow in the center of an exit channel.

   6. Scour material may deposit in the exit channel, forming a debris dam that can concentrate flow.

b. Excessive velocities and turbulence at the downstream end of a spillway chute.

c. Inadequate energy dissipation at the downstream end of a spillway chute.

d. Headcutting in the exit channel:

   1. Composition of exit channel material may permit localized scouring and thereby initiate headcutting.

   2. Change in exit channel grade may permit flow to change from sub-critical to super-critical and thereby promote headcutting.

3. Excessive velocities and turbulence in the exit channel may initiate headcutting.

e. Standing waves caused by flow at critical depths.

f. Inadequate downstream protection.

g. Flow duration greater than 30 days.

FIELD EXPERIENCE:

a. Grapevine Spillway. Grapevine Spillway is about 20 miles northwest of Dallas on Denton Creek. The dam is an earthfill embankment with an uncontrolled 500-ft-wide spillway with an ogee crest (el 560) and a 200-ft-long concrete discharge chute. The concrete is at elevation 550 at the upstream end and has a 5 percent grade for the center 100-ft-wide portion and a 2.5 percent grade along the training walls. The chute floor has a linear slope from the training walls to the 100-ft-wide central strip.

A review of the early design studies for the spillway indicated that erosion of the spillway channel downstream from the paved chute was expected, but the hard shales underneath the overburden material were thought to be resistant to erosion.

The spillway has overflowed twice since its construction. The first instance was in 1957, when the lake pool reached elevation 560.8, with a peak discharge of 520 cfs passing over the spillway. Damage downstream from the spillway was minor.

The second time the spillway overtopped, the lake pool reached elevation 563.5, which is equivalent to the 100-year pool. The peak discharge over the spillway was 9100 cfs. Duration of flow was 21 days. Severe damage from erosion occurred to the discharge channel. The exit channel at the downstream end of the concrete apron was scoured to a depth of about 8 ft and 700 ft downstream from the concrete apron to a depth of 40 ft.

The spillway design flood would produce a flow of 191,000 cfs. Review of the damage from the second overtopping convinced responsible officials that the spillway could not pass the design flow without extreme hazard to the structure.

b. Lewisville Spillway. Lewisville Spillway is located about 30 miles north of Dallas on the Elm Fork of Trinity River. The crest of the spillway is located at elevation 532.0 and has a length of 560 ft. The design discharge is 216,800 cfs. The downstream end of the 200-ft-long chute is at elevation 508.0 for 100 ft, then slopes uniformly to elevation 510.0 at each training wall (230 ft each way).

The spillway was overtopped in 1957, 1981, and 1982. In 1957, flow passed over the spillway for 25 days with a peak discharge of 10,200 cfs. Scour damage downstream from the spillway was minor.

In 1981, flow passed over the spillway for 36 days with a peak discharge of 15,350 cfs. At the downstream end of the concrete chute, the scour depth below the surface of the chute ranged from 2.1 to 8.3 ft.

During the floods in 1957 and 1981, the tailwater level was generally above the the floor of the spillway chute. In 1982, flow passed over the spillway for 48 days with a peak discharge of 8120 cfs. During the 1982 flood, the tailwater was below the floor of the chute, and there was a free overfall jet from the apron to tailwater. Maximum scoured depths of 8 ft were measured at the downstream end of the concrete chute. The apron cutoff wall has a depth of 10 ft. Above 40 ft downstream from the cutoff wall, the channel bottom scoured about 3 ft below the downstream end of the chute. About 500 ft below the cutoff wall, the discharge channel has narrowed and deepened. At a distance 1000 ft downstream from the cutoff wall, the thalweg is about 12 ft below the initial channel bottom.

An unnumbered Waterways Experiment Station report, "Erosion Tests on Rock from Spillway Channel at Lewisville Dam," dated January 1982 and prepared by Dr. Edward B. Perry, concludes: "A physical hydraulic laboratory model is recommended to develop an appropriate energy dissipator immediately downstream of the concrete apron to reduce the erosion to an acceptable value."