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CATASTROPHIC FAILURE OF AN UNDERGROUND DAM

THE SITUATION

A 730 ft. long dam was installed in an underground coal mine in Southeast Ohio. The purpose of the dam (or hydraulic bulkhead) was to eliminate the downslope groundwater seepage from abandoned workings that was constantly flowing downslope and was collecting at lower elevations where active mining operations were taking place. Consequently, this water had to be continually pumped out and treated in surface facilities before it could be released into a nearby stream. The dam would eliminate these efforts. Figure 1 illustrates the purpose of the bulkhead in eliminating the downslope seepage issues.

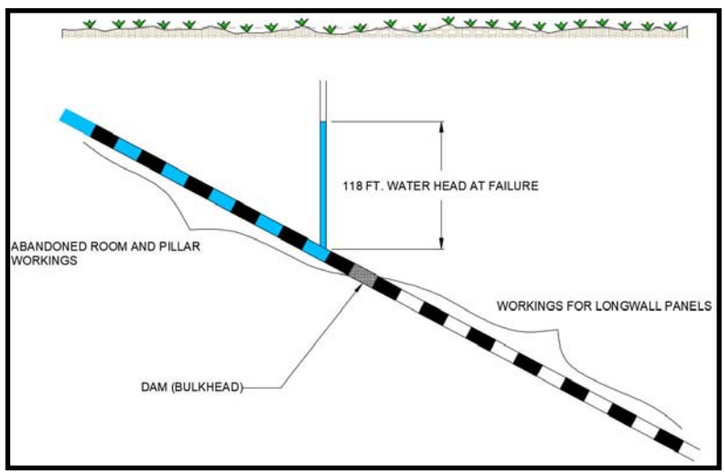

FIGURE 1 CROSS-SECTION ILLUSTRATING DAM LOCATION DOWNSTREAM FROM FLOODED ABANDONED WORKS AND UPSTREAM FROM ACTIVE LONGWALLING

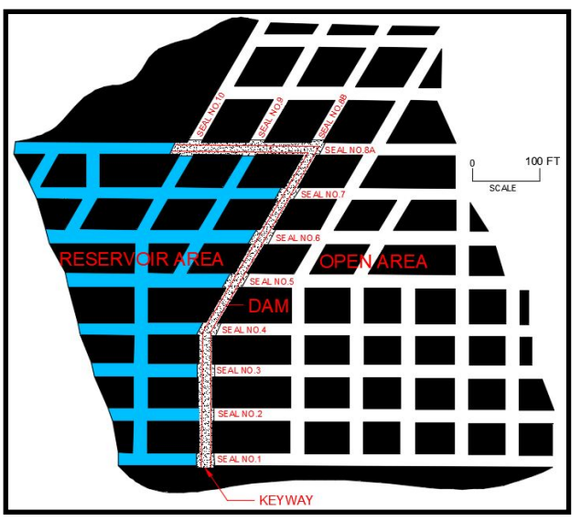

FIGURE 2 PLAN VIEW OF THE CONCRETE BULKHEAD

FIGURE 3 DOWNSTREAM SEEPAGE EFFECTS AT SEAL NO. 7. PHOTO TAKEN AFTER FAILURE

THE CONSTRUCTED CONDITIONS

The layout of the concrete hydraulic bulkhead is shown in Figure 2. As can be seen in Figure 2, what was constructed was essentially a continuous concrete (grout) wall from solid coal to solid coal. The bulkhead was made to be 20 ft. thick and filled the mine void space from coal pillar to coal pillar and from roof to floor at the height of about 6 ft. or greater where roof cave existed. The 20 ft. wide dam was seated in a soft floor. In an attempt to cut off underseepage in the soft floor, a 12 ft. wide concrete keyway up to 2 ft. deep into the floor was installed along the alignment of the wall (see Figure 2). The floor in this area was claystone which was heavily fissured, and extended well beyond the depth of the keyway.

THE PERFORMANCE AND FAILURE

After construction, groundwater began collecting behind the bulkhead. Reports of roof, seal, rib, and floor leakage as well as muddy floor conditions were reported throughout the entire time of impoundment. After about 100 days, seepage through Seal No. 7 (see Figure 2) accelerated with seepage rates reaching over 75 gpm with the water only about 20 ft. high (or 8.7 psi water pressure against the wall). Figure 3 shows photographic evidence of the seepage through the roof above Seal No. 7. Remedial grouting in the roof reduced seepage to

pre-accelerated levels of about 10 gpm. As the water pressure continued to build, the Seal No. 7 roof had to be grouted again because of seepage rates similar to before. At this point, the water behind the bulkhead had reached about 95 ft. (41 psi) in 600 days. After reducing the seepage to about 4 gpm, flow immediately began to increase again. Also, it was reported that 4 in. deep water was flowing from Seal No. 10. After the impounded water reached a height of 118 ft., the mine floor blew out at Seal No. 10.

As a result, 1 billion gallons of contaminated underground reservoir water rapidly flowed down through the floor of Seal No. 10 and inundated the active portion of the mine. The area of blowout resulted because of a designed and constructed weak spot in the dam. The failure conditions at Seal No. 10 are illustrated in Figure 4. As can be seen in this figure, the failure was through a fireclay (claystone) floor. This claystone was erodible and was significantly permeable due to the presence of abundant fissures. This combined with a seepage path which could avoid the constructed keyway, and where a coal corner exists, which commonly contains significant fracturing, ultimately caused failure.

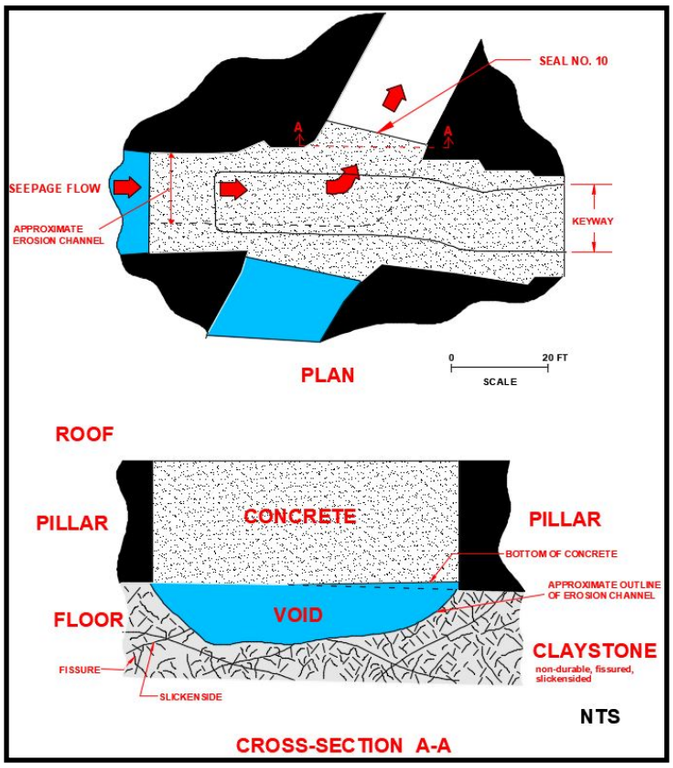

FIGURE 4 DAM BREACH CONDITIONS AT SEAL NO. 10

LESSONS LEARNED

This is a case where the in-house designer was unaware, and they did not recognize the importance of employing a qualified geotechnical consultant when considering the potential impact of failure, even though the up-front costs would be greater. Here was a case where the risk (i.e. likelihood and severity of failure) was misjudged. This was manifested in the constructed conditions, which demonstrated a fundamental lack of understanding of seepage phenomena and effects. Moreover, continued seepage which could not be abated by grouting as the water impoundment height increased should have been recognized as a clear sign of incipient failure.

Other MEA Publications that may be of Interest:

UPDATE #35: Hydrologic Impacts of an Underground Abandoned Coal Mine

ABOUT MEA: Marino Engineering Associates, Inc. focuses on engineering research, practice and expert evaluations and is licensed in 25 states in the U.S. Our projects primarily have an emphasis on Geotechnical Engineering, however, we also have significant experience in projects involving transportation, subsidence engineering, laboratory testing, training, and geophysical exploration. Gennaro G. Marino, Ph.D., P.E., D.GE is president and principal engineer of Marino Engineering Associates, Inc., and has been a licensed professional engineer since 1984. To obtain additional information on MEA, one can also visit our website at www.meacorporation.com.

FOR MORE INFORMATION: There is a significant amount of additional information that is available on the above subject. For more information, please contact Dr. Marino at the address listed below.

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