U.S. DEPARTMENT OF AGRICULTURE
NATURAL RESOURCES CONSERVATION SERVICE
Monroe and Vernon Counties, Wisconsin
June 26, 2019

ABSTRACT OF ENGINEERING REPORT

General Description of Problem or Deficiency: Breach of dam due to extreme runoff and poor foundation materials. The breach developed by erosion of embankment and abutment soils together with seepage into jointed, soft bedrock located in the abutments. Joints in the bedrock provide flow paths from the reservoir area into the bedrock. Water pressure in the bedrock and erosion of the bedrock due to seepage flow created conditions for a rapid and complete failure of the abutment materials. Extreme runoff developed during a rainfall event that started late on August 27 and continued into the early morning hours of August 28. The runoff volume resulting from this event caused overtopping of four of the five dams. The fifth dam, WFK-1 did not overtop, but the estimated flow depth in the auxiliary spillway is four feet.

Location:
West Fork Kickapoo Watershed Protection and Flood Prevention Project, Vernon County, Wisconsin:

Site Number	Section	Township	Range	Latitude	Longitude
1	6	14N	3W	43.6891°	-90.7989°
Mlsna	13	14N	4W	43.7122°	-90.7524°

Coon Creek Watershed Protection and Flood Prevention Project, Monroe County, Wisconsin:

Site Number	Section	Township	Range	Latitude	Longitude
21	34	15N	4W	43.7314°	-90.8420°
23	27	15N	4W	43.7430°	-90.8416°
29	19	15N	4W	43.7674°	-90.8979°

Type of Facility (Purpose & Function): All five dams are flood prevention structures. WFK-1 also has Fish and Wildlife, and Recreation purposes.

	WFK-1	WFK Mlsna	CC-21	CC-23	CC-29
Job Class	VII	VII	VI	V	V
Drainage Area (mi^2)	8.06	1.48	3.16	1.42	2.88
Maximum Height (ft)	60	35	42	39	34
Total Storage (acre-feet)	2,345	257	302	133	211
Hazard Class	High	High	Low	Low	Low
Date of Installation	1969	1956	1963	1961	1961

All five dams breached during the same storm event. There was auxiliary spillway flow at all five sites and four of the five sites overtopped. WFK-1 was not overtopped but there was auxiliary spillway flow at a depth of four feet in the level section. The breach occurred in the area of the auxiliary spillway on the WFK-1 and WFK Mlsna sites. The breach occurred in the groin area opposite the auxiliary spillway on the Coon Creek sites.

The precipitation event of August 27 and 28 created conditions that exceeded the capacity of the dams to safely control the runoff. While the runoff volume exceeded design volumes on four of the five sites, rapid breach development on all five sites revealed significant problems with in-place soils and soft, fractured bedrock in the abutments.

Three problems have been consistently identified on all five sites: 1. the top soil of the natural ground that meets the embankment in the groins is a thin timber soil lacking uniform vegetative

cover. This is further exacerbated since the natural ground and embankment meet forming a 'V' channel that concentrates flow. Severe erosion of the groins developed during overtopping flow while the vegetative cover over the middle of the embankments was relatively undisturbed. This led to deep scour in the groins. 2. the auxiliary spillway on WFK-1 and WFK Mlsna were excavated into natural ground. The test holes on the plans indicate that the soils in the auxiliary spillway channels consisted of SM and GM on WKF 1, and sandy clay loam and possibly GW on WFK Mlsna; potentially highly erodible soils. Beneath these soils lay sandstone bedrock. 3. the sandstone bedrock in the abutments is soft and highly fractured. Wide vertical Valley Relief fractures run roughly perpendicular to the centerline of each dam while tighter, vertical fractures and bedding planes project into the abutments. The soft sandstone is easily eroded by both surface flow and seepage flow. Due to the extensive jointing, it is also susceptible to mass wasting under the combined forces of fast moving surface flow and hydrostatic pressures. All three conditions appear to contribute to rapid erosion of the confining surface soils and abutment bedrock creating a relatively rapid release and evacuation of the pool area upstream of the dam at each site.

The poor foundation materials and extreme runoff have been given equal weight for the cause of the breaches. The poor foundation materials have been identified as the probable cause of the speed and degree of the breaches.

<u>Recommendations:</u>

1. Conduct a Planning Study to develop and evaluate alternatives for each dam and the entire watershed. This study may include:
    a. Complete an assessment of current resource concerns, future flood control benefits and costs to aid Sponsors in evaluating what course of action best meets their needs.
    b. Decommissioning by removal of the dam, stabilizing the site and completing stream restoration.
    c. A redesign or relocation of the dam and all its components to current standards and specifications. Measures to effectively treat the foundation and abutments will be a necessary component.

2. Design considerations for dams that will be repaired or replaced:
    a. Investigation:
        i. Complete additional geologic investigation of the abutments to determine direction and extent of sandstone formations and jointing.
        ii. Coon Creek 41 had a similar breach without over-topping. Complete an inspection and assessment of Coon Creek 41. Review the failure report and repair design. Use the lessons learned from this failure and repair to guide the repair design.
    b. Seepage Control:
        i. Develop a pressure grouting plan or a slurry trench plan to cutoff upstream to downstream seepage flow and to prevent the buildup of hydrostatic pressure at the end of the dam.
        ii. Blanket valley walls up to the top of dam elevation with compacted earthfill. Geologic investigation and seepage analysis are required to determine upstream extent of blankets.
        iii. Construct the downstream groins with a clay liner to increase the head loss of abutment seepage and redirect ground water discharge downstream of the dam.
        iv. Construct drains in the downstream groins to provide a stable outlet for seepage through the abutments.

c. Auxiliary Spillways
    i. Design the dams without a vegetated auxiliary spillway.
    ii. Provide a structural auxiliary spillway to replace the vegetated auxiliary spillway.
    iii. Design the dams with a ramped spillway located away from the abutments graded all the way to the valley floor.
d. Protect the downstream groins by raising the ends of the dams to provide overtopping sheet flow across the entire width of the dam excluding the groin areas.

3. For all watershed dams located in this geologic formation:
    a. Use Geophysics technology to assess potential for failure of the abutments.
    b. Prioritize sites for the geophysics analysis by using slope mapping in ArcMap to identify sites that have significant steep hillslopes near the dam that may indicate the pool areas are shallow to bedrock or have bedrock outcrops that could increase the risk of seepage.
    c. Inspect the downstream groins for signs of erosion or material weakness and consider implementing measures listed below that protect the groins from over-topping or erosion from sidehill runoff.
        i. Review the vegetation of the groins and assure a good stand of grass exists on the embankment and the abutment side of each groin. Where timber encroaches on the abutment side of the groin, clear and/or grub trees to provide better growing conditions for grass on the abutment side of the groin.
        ii. Raise the ends of the dams to prevent concentrated overtopping flow down the groins.
        iii. Build up the groins with earthfill to keep flow off the soils that are shallow to bedrock on the wooded slopes.
    d. Review Emergency Action Plans to make sure contact information and actions planned are up to date. Review the protocols with appropriate personnel.

For final remedial treatments used or for additional information, contact:

State Conservation Engineer
USDA Natural Resources Conservation Service
8030 Excelsior Drive, Suite 200
Madison, WI 53717-2906

Problem Category:	I-B, III-D and IV-D	Site Name:	West Fork Kickapoo Watershed Sites 1 and Mlsna Coon Creek Watershed Sites 21, 23, 29
Practice Standard:	402	State:	Wisconsin