UNITED NUCLEAR CORPORATION

CHURCH ROCK TAILINGS IMPOUNDMENT DAM

Evaluation of Probable Cause of July 16, 1979 Failure

and

Evaluation of the Integrity of the Remaining Starter Dam and Present Divider Dike

by

JACOBS ENGINEERING GROUP INC.

and

WAHLER ASSOCIATES

August, 1979

UNITED NUCLEAR CORPORATION

CHURCH ROCK TAILINGS IMPOUNDMENT DAM

Evaluation of Probable Cause of July 16, 1979 Failure

by

JACOBS ENGINEERING GROUP INC.

and

WAHLER ASSOCIATES

August 22, 1979

INTRODUCTION

The United Nuclear Corporation dam impounding tailings and raffinate from the Church Rock mill was observed to have been breached early on July 16, 1979. This evaluation of the probable cause of failure is based on documents reporting on conditions prior to construction of the starter dam, design reports, plans and specifications approved for construction, construction testing records, post construction drill logs and results of laboratory tests of samples, post failure drill hole and trench logs, laboratory test results, site observations, photographic evidence, and personal interviews. Most of the laboratory tests have been completed and presented in final form and most of the other data has been assembled in documentary form. However, some of the long term tests are continuing but it is not anticipated that this additional test data will be significantly different from that presently available.

Available data are being assembled by Sergent, Hauskins & Beckwith and are available from them or United Nuclear Corporation and are not repeated in this evaluation. Jacobs Engineering Group and Wahler Associates were not involved with the tailings impoundment dam at the United Nuclear Corporation project at Church Rock prior to the failure. Our evaluation of the failure is based on factual data supplied by others (no drilling, sampling, testing, surveying or other field or laboratory investigations have been performed by Jacobs or Wahler).

PROBABLE CAUSE OF FAILURE

Based on factual and photographic evidence made available, personal interviews, and on-site observations of post-failure conditions, the failure is probably due to cracking with subsequent internal erosion. This cracking resulted from differential settlement which resulted from different rates of consolidation of the heterogeneous foundation. The cracking may not have extended to the downstream slope and the failure of the extreme downstream portion may have been due to other common causes of failure where a high hydraulic gradient exists.

PROBABLE CAUSE OF FAILURE - continued

Previous cracking of the embankment is well documented by observations made in December 1977 and photographs of the cracks in July 1978 when they were still visible. Cracks were observed from the area of the breach to approximately station 45+50 (Kaiser Engineers stationing) or along 1,250 feet of the starter dam.

These observed cracks were generally oriented from about a 45 degree angle to the axis of the dam to parallel to the dam and extended from the tailings deposits to and beyond the downstream edge of the dam crest. The embankment cracks probably resulted from differential settlements of the embankment caused by different rates of consolidation in the heterogeneous alluvial foundation.

The consolidation rates were variable and also accelerated as the deeper alluvial deposits gradually became saturated. The shallower alluvium did not reach saturation in the area of the breach or where cracking was observed in December 1977. The rate and pattern of saturation were probably influenced by the direct exposure of the heterogeneous alluvial strata to reservoir fluid at the deep (30± feet) excavation face created by borrowing in extremely close proximity along the southerly portion of the dam alignment.

The non-uniform and steeply inclined bedrock profile and backfilled arroyo (See Figure 1) and the configuration of the bedrock contours (see Figure 2) jutting from the near vertical rock face above the general level of the alluvial valley floor influenced the non-uniform consolidation and stress distribution in the embankment.

The embankment (especially the selected clayey zone) is dense, moderately strong, and quite stiff. Although purposely placed at moisture contents several percent wet of modified AASHO (and thus near or slightly wet also of compactive efforts actually obtainable during construction) the resulting stiffness (or brittle-like quality) would be conducive to crack formations. The low plasticity materials (silts, sands, and lean clays) are readily erodible.

PROBABLE CAUSE OF FAILURE - continued

During preconstruction geotechnical investigations in 1976 the difficult site characteristics and unfavorable soils properties were recognized. Collapsible dry desert soils, differential settlements in transition zones between rock foundations and alluvial foundations, wet-side placement to achieve less stiff embankment, clean cohesionless granular zones not susceptible to cracking, piping through transverse cracks, and drain zone elements were considered and discussed.

Pre-failure data supporting this tentative cause of failure evaluation follows:

1. Six two-dimensional consolidation tests of alluvium either from the foundation soils or nearby similar soils under overburden loading representative of the 45 feet starter embankment height indicated consolidations of 5 percent without inundation. With loadings representative of the 70 feet enlarged dam consolidations were in the order of 7 percent and increased an additional 1-1/2 to 13 percent when saturated.

2. Five consolidation tests on unsaturated foundation samples obtained after the starter dam was completed exhibited consolidations of 1-1/2 to 9-1/2 percent additional when inundated.

3. The steep left abutment bedrock profile and associated rapidly increasing depth of alluvium is revealed by the pre-construction and pre-failure drill hole logs.

4. Bedrock configuration and contours are generally discernible from pre-construction photos and maps indicating steep and irregular bedrock profiles and contours.

Post failure exploration supporting the tentative evaluation follows:

1. Two vertical and one horizontal cracks have been found in the embankment at the side of the breach. The vertical cracks are filled with

tailings sand and are in positions such that they are probably not due to stress relief resulting from the breach. The horizontal crack may be filled with sand.

2. Vertical cracks located near the center of the breach in the upstream bench and near the sides of the breach run subparallel to the breach and are filled with bentonite -- evidencing previous cracking in the area and the remedial action taken.

3. Steep abutment bedrock profile and saturation of alluvium at depth under the crest and downstream toe and saturation of all alluvium upstream of the crest as evidenced by post-failure drilling, sampling, and laboratory tests.

Other modes of failure considered and rejected:

1. Sabotage -- No evidence and it is not plausible that the type of failure could have been perpetrated without detection.

2. Overtopping -- High water mark well below the crest of the dam.

3. Failure of structure -- No structure in the vicinity of the breach.

4. Erosion by tailings line failure -- All evidence indicates that tailings lines were not in a position to cause the breach should they have failed.

5. Piping (without substantial cracking) -- All evidence indicates that the embankment and upper alluvium downstream of the dam are not saturated (possible exception in cracked areas) and upward flow of fluids that could have caused piping are not likely to have occurred.

PROBABLE CAUSE OF FAILURE - continued

6. Slope instability -- The low dam and wide crest would require a deep failure to extend from the downstream to the reservoir. The narrowness of the breach would not accommodate this type of slope failure. The upstream slope was buttressed with tailings sands and a failure in this direction is not plausible. Drill holes and trenches in the dam, breached area, and downstream of the breach indicated no disturbance of the layered materials. Preliminary post-failure strength tests indicate that strength values used in design analyses were conservative and moisture content determinations indicate that the phreatic surface developed was not higher than that assumed during analyses. Therefore stability analyses appear to be conservative and indicate that a slope failure would not occur.

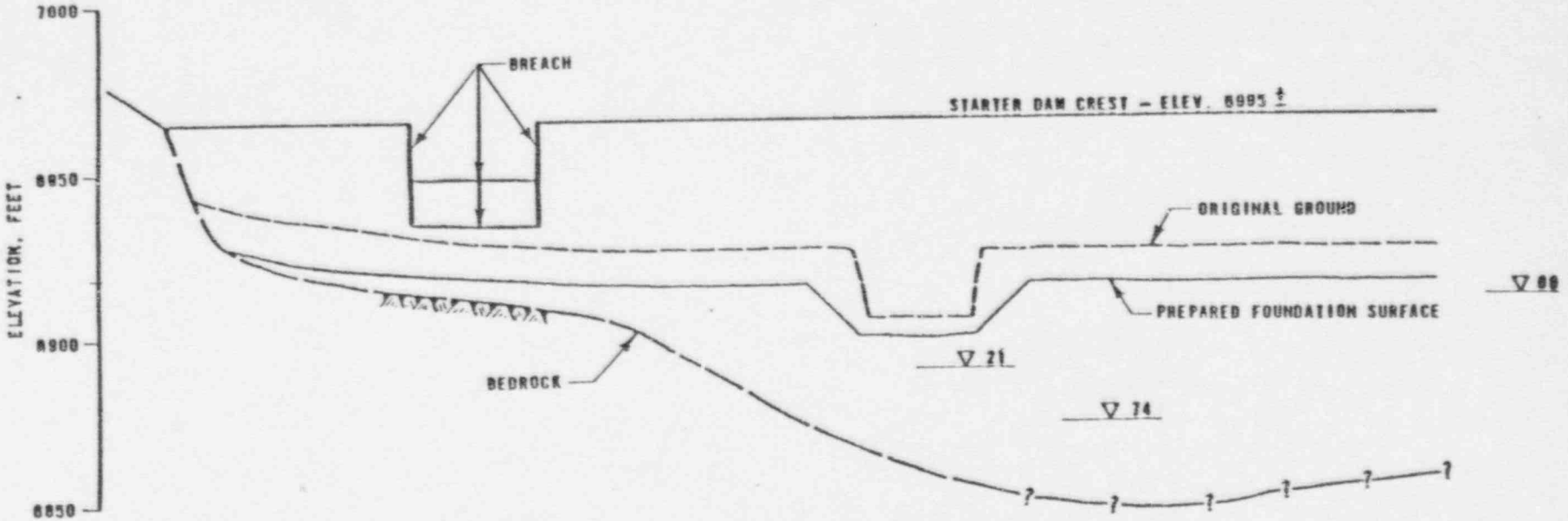
7. Raffinate - soil reaction -- The embankment and foundation was not saturated with raffinate to the extent that this would be considered a plausible prime reason for failure.

8. Dispersive soils -- Pinhole dispersion tests indicate that the materials are not dispersive when the pH of the raffinate was above 2 and the materials were dispersive when the pH is below 2 (normal pond liquid). Since such a small portion of the dam or foundation in areas near the breach are saturated this reaction is not believed to be the cause of failure. However, dispersion could have accelerated the loosening of material along sides of a crack and contributed to extension of the crack and internal erosion.

9. Dessication cracks -- Moisture contents of the embankment at significant depths below the surface are near placement moisture contents and cracks from drying are not considered a viable cause of failure.

SYMBOLS

▽ 21 SATURATION LEVEL DETERMINED AT HOLE NUMBER.

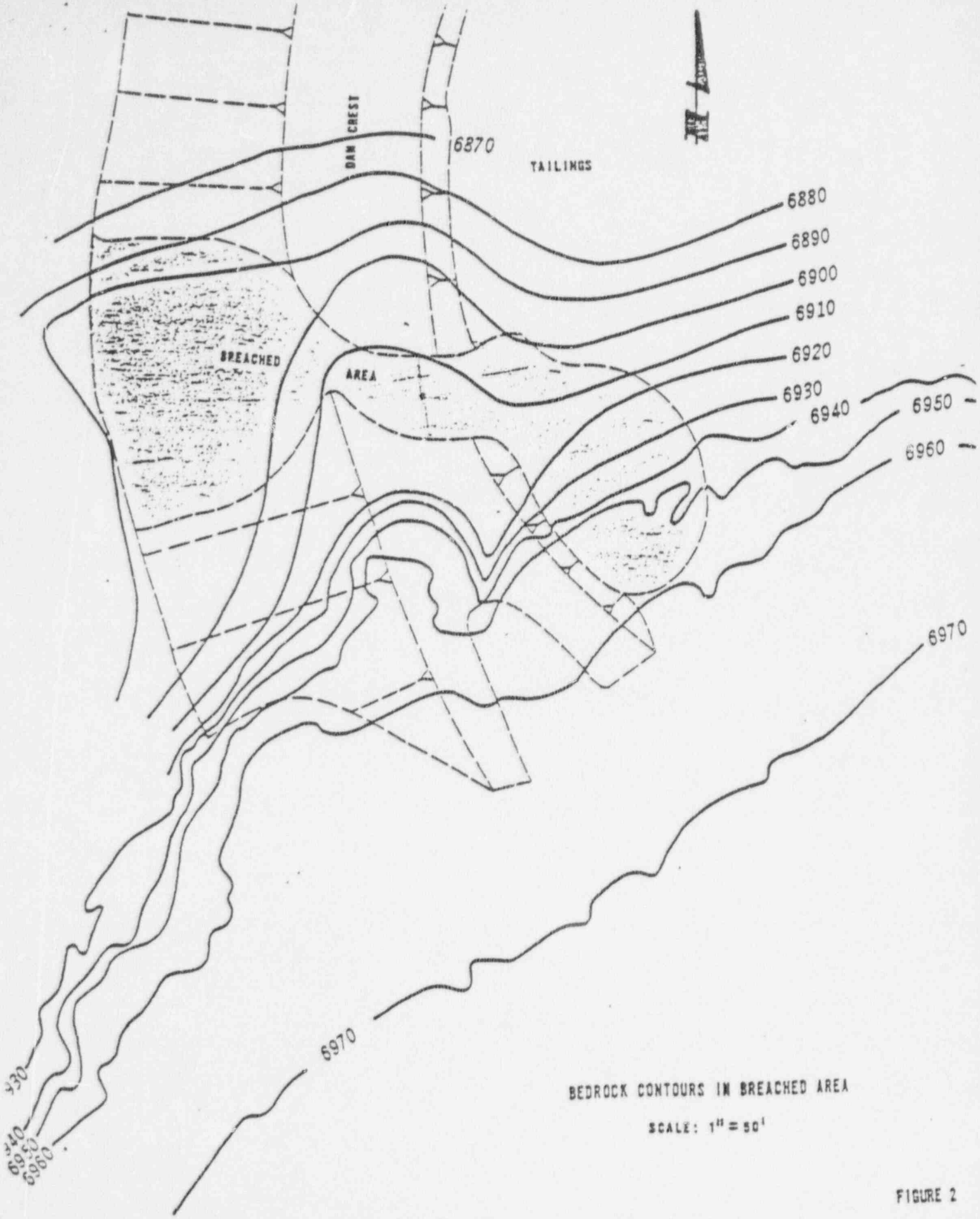


PROFILE ALONG STARTER DAM CENTERLINE

(LOOKING DOWNSTREAM)

SCALE: 1" = 50'

FIGURE 1



BEDROCK CONTOURS IN BREACHED AREA

SCALE: 1" = 50'

FIGURE 2