ENCLOSURE 4

RPTWR 12-020, Rev. 0
James River and Flooding at the B&W Mount Athos Facility

RPTWR 12-020

TITLE: **James River and Flooding at the B&W Mount Athos Facility.**

RP Program Area: RP- 08, Environmental Hazards and Issues

Key Words: Flood, Dam, Standard Project Flood, SPF, Project Maximum Flood, PM, Design Basis Flood, NUREG/CR-7046, Dam Breach, Inconsequential

Performed by: Kenneth Conway Date 11-1-12

Reviewed by: Ly M Sitt Date 11/1/12

Reviewed by: ____________ Date ________

ABSTRACT:

The Facility is located on an elevated bend in a shallow gradient portion of the James River. The facility is elevated with the main site being approximately 500 feet MSL at its lower (plant north) fence line, with its principle facilities at 568 MSL or above. The main facility is above the 100 year flood plain and the Standard Project Flood (SPF). Facility storage areas are secure. An area Probable Maximum Flood (PMF) event with two significant dam breaches will not affect the majority of the site, as the site active and main storage facilities are **568 feet MSL or higher and the PMF (with 2 dam breaches) crest is ~ 523 feet MSL**. Facility processes can be suspended or placed into storage mode without loss of control. An area SPF event is ½ the volume of a PMF event (Regulatory Guide 1.59 page 7) and would crest at 502 feet MSL.

Critical facilities (active Uranium storage and processing portions of the site) are located more than 60 feet above the Standard Project Flood (SPF) level of 502 feet MSL and more than 40 feet above the expected Probable Maximum Flood (PMF) of 2 X SPF flow rate or **521** feet MSL for a Probable Maximum Flood ("highly unlikely" or $< 10^{-5}$ by NUREG -1520-Rev.1 page 3-D-1 definition) event without dam breaches and well above the **</=523** feet MSL for a PMF event with dam breaches and wave action. In terms of Nuclear Power Plant Design Criteria -Standard Review Plan NUREG -0800, the facility **is dry** (see page 2.4.3-2). Please note that the hazard potential of a Fuel Cycle facility is orders of magnitude less than that of a Nuclear Power Station and therefore the use of NPP based criteria is highly conservative. The difference in depth between a dam breach event at PMF or SPF and a non-breach PMF (highly unlikely) or SPF (rare as per NUREG 1049 page 3-10) event is limited (< 2 feet) and rapidly decreases with distance from the breach.

Two encapsulated material storage building first floors (Rail yard Storage and Container Storage) are at the Standard Project Flood (SPF) level of ~ 502 feet MSL, but higher than the maximum flood levels seen in historical floods over a 240 year period. Nuclear Criticality Analysis has demonstrated criticality control of these materials is not affected by total inundation, let alone partial flooding of these stored materials.

Portions of support facilities, which are typical of standard industrial facilities, for the Fuel Cycle site at Mount Athos are located below the SPF crest line. Consistent with NUREG 1520 recommendations (page 3-D-6), flood warning times are used to prepare facilities and equipment and move materials to minimize the impact for these events (which are rare as per NUREG-1049). The relationship between Mount Athos River Levels and those at a monitoring station upstream at Holcombe Rock is well known and Holcombe Rock is used to provide substantial warning and reaction time to adjust operations top reflect local flooding conditions. The reactions, adjustments, flood warning times and relationships to Holcombe Rock values are proceduralized in EP-311,

PURPOSE:

To demonstrate that the facility critical facilities are well above the elevation attained by a PMF, the Corp of Engineers (NUREG - 1049 attachment 1) determined the SPF flow rate at the site to be 378,000 cfs and therefore the PMF level to be 756,000 cfs. NUREG - 0800 Standard Review Plan Office of Nuclear Reactor Regulation, states that for a Nuclear Power Station, (a facility at least a 1000 times more hazardous than a Uranium facility as per the International Nuclear and radiological Event Scale), demonstration that the facility is dry, i.e. the important facilities are well above the elevation obtained by a PMF represents a fully adequate design basis.

BACKGROUND:

The Mount Athos facility lies on an elevated bend in a shallow gradient portion of the James River approximately 12 miles below the Reusens dam and approximately 21 miles below the confluence of the Pedlar and James Rivers. The Lynchburg water supply reservoir, the Pedlar Dam facility, lies on the Pedlar River, a tributary to the James River, approximately 38 miles from the Mount Athos site. Several other dams lie in the span or feeding into it. However they are similar to or smaller than the selected dams or known to cause no issues (i.e. Lynchburg dam see Reusens Project attachment 2).

A history of floods dating from 1771 to present is known (~ 240 years). Four floods affecting site support facilities or the area they presently occupy (floods reaching levels >/= 488 feet MSL) have occurred, with two reaching up to 494 feet MSL as per NUREG 1049 -Environmental Impact Appraisal for Renewal of Special Nuclear Material License SNM-42 and Emergency Action Plan- Reusens Project No. 2376-Va National Inventory of Dams No. VA 00904. The 1791 flood and the 1985 flood (discussed in Reusens Project Flood and Dam break inundation maps - attachment 3) reached a level of ~494 feet MSL at the site for both floods and 535 feet MSL (1795) and 534.3 feet MSL (1985) at Lynchburg VA. These are the highest known flood levels.

The facilities on the 488 feet MSL level are support facilities including:

- Waste treatment
- Sewage disposal facility
- Holding ponds
- River pumphouse
- Tank farm

The great majority of the facility is built on an elongated elevated mound ringed by a river plain on which the aforementioned standard industrial facility support facilities are located, with the main site being ~ 500 feet MSL at its lower fenceline. The critical portions of the site including the portions handling unencapsulated radioactive materials, and chemical tank farms et al and with release potential are **568 feet MSL or higher.**

DISCUSSION

The Lynchburg Mount Athos facility has a Corp of Engineers determined Standard Probable Flood estimated flow rate of 378,000 cfs, and a SPF maximum flood stage of 502 feet MSL (see attachment 1) at Mount Athos. Lynchburg area history from 1771 to present a period of > 240 years has had no flood event equal to a SPF, which supports a maximum likelihood of an SPF flood of <4.2 E-3.

SPF flood likelihoods range from 1 E-2 to 1 E-3. According to Regulatory Guide 1.59, the Probable Maximum Flood (PMF) is twice the flow of a Standard Probable Flood (SPF). The PMF volume flow consistent with this and numerous additional guidance is there for 2* 378,000 cfs at the site or 756,000 cfs.

The Mount Athos depth at PMF was calculated by:

- Determining the width of the flooded river from the 502 feet MSL level at the new storage building at the plant north fence line to the 502 feet MSL level on the far side of the river. A conservative value of 1870 feet was determined.
- The additional water was assumed to occupy a rectangle of 1870 feet in length. Water dispersion due to the slopes on either side of the river was conservatively neglected.
- The SPF data was used to determine the flow velocity of the river at SPF. The main river bed was treated as a 500 foot wide, 32 foot high rectangle, as the Corp of engineers determined the maximum flood level to be 502 feet MSL and the normal level to be 470 MSL. The normal flow rate of 3900 cfs was neglected. The linear distance from the side of the main river bed to the 502 MSL was determined (1210 feet), the flood depth of 32 feet was used and the area of the resulting right triangle determined. Similarly the far side of the river cross sectional area was determined (160 feet in length). The cross sectional area with the known flow volume was used to determine river speed (6.8 MPH or 10 fps).
- The additional 368,000 cfs for a PMF event was assumed to flow at the same rate as the SPF event flow in a "box". The limiting effects on flood height of the slopes hillsides were neglected.
- Flow rates determined were similar to those stated in the Reusens project study.

A PMF flood rate is much less likely than the SPF flood. NUREG 1520 classifies a PMF as "highly unlikely" or < 1 E-5 probability per year. A PMF flood with multiple dam breaks is correspondingly more unlikely. Calculated river channel depth is ~ 53 feet above normal with PMF conditions and several dam breaks. The remaining possible contributor to flood crest waves were evaluated, but considered a negligible factor under these conditions. NUREG 0800 page 7.4.3.4 suggests 1% additional height for flood estimate purposes or < 1 foot additional flood level depth.

The breaches of the Reusens and Pedlar dams, which are significant facilities in the area drainage basin, were analyzed for an additional effect (results attached). However once the flooding approaches the ~SPF level, as it did in 1791 (494 feet MSL at site) and 1985

(~ 490-494 feet MSL at the site see site flood map attachment 3) floods, the breach effect is minimal, even at the Reusens dam. Specifically at " flow rates greater than those of the 1985 flood flow rate of 207,000 cfs will result in increased flood heights of less than 2 feet (page V-3 in attachment 1) at the dam (and ~ 1 foot at Mount Athos). The 1985 flow rates are less than those of a SPF event and the additional effect of a Reusens dam breach is less than 2 feet at the dam. Reusens dam is ~ 13 miles from the site and 45 foot high. The NEI publication Flooding Issues: Guidance Inquiry Process, Hazard Re-Evaluations (attachment 1) contains a graph for purposes of evaluating dam breaks based on height and distance from the site. The graph confirms the negligible effect of a Reusens dam break.

Similarly a Pedlar Dam breach is stated to have a maximum flood level increase of < 2 feet (over a non breach PMF condition) at the join to the James River (attachment 4 page 1095). The Pedlar River and James River confluence is approximately 9 miles above the Reusens dam and ~ 21 miles from Mount Athos. The increased flood potential is appropriately considered part of the > 207,000 cfs at the Reusens dam. The summed additional effect of 2 dam breaches is less than 2 feet at the Reusens dam and ~ 1 foot total at Mount Athos (see attached maps). The use of the NEI Dam break graph also demonstrates that the Pedlar dam at 38 miles away and 87 foot tall has a negligible effect at the site.

The Pedlar and the Reusens Dams are the largest facilities which outlet to the James River in the Middles James drainage basin above the site. Two large dams also exist in the Upper James River Basin. As per the graph, the effect of dam breaches of the Gathright Dam at 137 miles away and 257 foot in height or the Goshen Dam 78 miles away and 40 feet in height are inconsequential at the site.

SUMMARY

The critical facilities at Mount Athos are "dry" under Probable Maximum Flood conditions. The probability of flooding of these facilities is << than highly unlikely or << 1 E-5 as per NUREG 1520. No historical flood has reached the Standard Project Flood level (or 1/2 of a PMF). Standard industrial support facilities have a "rare" probability of flooding as per NUREG -1049. As per the recommendations of NUREG 1520 standard proceduralized actions and responses are in place to address such events should they occur. Flooding is a minor facility hazard that can cause site access of support facility issues but no major issue.

NUREG-1049

Environmental Impact Appraisal
for renewal of Special Nuclear Material License No. SNM-42

Docket No. 70-27

Babcock & Wilcox Company
Naval Nuclear Fuel Division
Lynchburg, VA

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

March 1984

3.4.3 Historic Significance

A review of the *Federal Register*[14,15] reveals that the only historic site on the National Register of Historic Places within 8 km (5 miles) of the B&W facilities is the 19th-century Mt. Athos Plantation, which is across the road to the east (Fig. 3.1). There are numerous historic places between 8 and 40 km (5 and 25 miles) from the B&W site, particularly in Bedford County and Lynchburg to the west. The best known historic site is the Appomattox Court House National Historic Park, about 24 km (15 miles) to the east.

During an earlier environmental review for licensing of the facilities at the B&W site, the State Liaison Officer for Historic Preservation indicated that the plant operation would not adversely affect historic properties in Lynchburg,[10] and there is no indication that adverse effects have been observed. Therefore, the staff does not expect that historic places in Lynchburg or further from the plant site would be affected by continued operation.

The Mt. Athos Plantation played a significant role in the community during the first half of the 19th century. However, the mansion was destroyed by fire in 1876 and was not rebuilt. The plantation lands that were subsequently subdivided are privately owned and not open to the public.[12] The staff does not expect that this historic site would attract a large concentration of visitors unless it is intensely developed. There is no current active effort for development (Wayne Swift, Central Virginia Planning District Commission, private communication to N. E. Hinkle, Oak Ridge National Laboratory, April 1, 1982). Because the B&W facilities have little impact on residents near the site boundary (Sect. 4), the staff does not expect that the Mt. Athos historic site, or visitors at the site, would be adversely affected by B&W operations.

3.4.4 Floodplains and Wetlands

A relatively large forested floodplain exists onsite along the James River (Sect. 3.7). Although most of the NNFD facilities are located above the maximum recorded flood stage, several activities could be affected by the Standard Project Flood (Sect. 3.5.1.1). Effects of such a flood are discussed in Sect. 4.3.2.4.

The B&W site contains very few wetlands. An abandoned sewage lagoon and a fire pond and its associated wetland habitats are described in the NRC Environmental Impact Appraisal for the B&W CNFP.[18] These areas are not affected by the NNFD operation. Surface drainage at the NNFD facility is into one small creek (Fig. 2.1). Minor wetland habitats are associated with this drainage system. The creek has been impounded north of the facility to hold up to 7,191,000 L (1,900,000 gal). The impoundment acts as a catchment basin to permit treatment of runoff prior to discharge in the event of a hazardous material spill (Sect. 4.3.2.2).

3.5 HYDROLOGY

3.5.1 Surface Water

3.5.1.1 James River hydrology

The James River is formed about 154 km (96 miles) upstream of the site by the confluence of the Jackson and Cowpasture rivers. The James River flows generally south-southeast from the Valley and Ridge Province to the Atlantic Ocean through the Hampton Roads and Chesapeake Bay.

On the basis of records for two U.S. Geological Survey gaging stations, one about 32 km (20 miles) upstream and the other about 34 km (21 miles) downstream of the site, the annual average flow rate of the river at the plant site is estimated to be about 110 m^3/s (3900 cfs).[17] The estimated water surface elevation at the site at the average flow rate is ~143 m (470 ft) above MSL.

Ten great floods of the James River occurred at the plant site in 1771, 1795, 1870, 1877, 1889, 1913, 1920, 1936, 1969, and 1972 (ref. 18 and W. H. Tamm, U.S. Corps of Engineers, Norfolk, Virginia, personal communication with B&W, April 4, 1974). The 1795 flood had the highest flood stage [163 m (535 ft) MSL at Lynchburg and 151 m (494 ft) MSL at the site (estimated)]. The largest recent flood occurred in 1969, with a flood stage of 161 m (527 ft) MSL at Lynchburg. Recently installed upstream flood control facilities (J. T. Ford, B&W, personal communication, including response to NRC questions at CNFP site visit, to R. G. Page, NRC, July 30, 1982), reduce the probability that the largest historic flood stages will ever be exceeded.

The Standard Project Flood (SPF) as determined by the U.S. Army Corps of Engineers for the James River would produce a discharge rate of 10,700 m^3/s (378,000 cfs) and a flood stage of 153 m (502 ft) MSL at the site.

Most NNFD facilities, at an elevation of 173 m (568 ft) MSL,[9] would not be affected by an SPF. The following facilities, however, lie at an elevation of ~149 m (488 ft) MSL and would therefore be inundated by an SPF:

1. waste treatment facility;
2. copper calciner;
3. copper and zirconium recovery facility;
4. shipping and receiving facility;
5. sewage disposal facility;
6. holding ponds;
7. equalization ponds;
8. river pumphouse; and
9. tank farm.

32

1985 to ~~not over~~ RR at WT.
as per RBS KCC

Three historical floods have reached or exceeded 149 m (488 ft) MSL, the last such flood occurring in 1870.[9] Thus, flooding of these facilities is a rare event (see Sects. 4.1.3 and 4.3.2.4).

3.5.1.2 James River water quality

The state of Virginia has established water quality standards for the protection of public and municipal water supplies as the state's part of the 1983 national goal of "water quality suitable for all types of recreation" (D. C. Prager, Virginia State Water Control Board, letter communication to N. E. Hinkle, Oak Ridge National Laboratory, April 8, 1982). Those constituents for which standards have been set are shown in Table 3.6. In addition, the following water quality standards apply for the James River at the NNFD discharge:

- dissolved oxygen: 4.0 mg/L minimum, 5.0 mg/L average,
- pH: 6.0–8.5, and
- temperature: 32°C maximum.

The water quality of the James River must, therefore, meet these goals.

EMERGENCY ACTION PLAN

REUSENS PROJECT

PROJECT NO. 2376-VA

NATIONAL INVENTORY OF DAMS NO. VA00904

Appalachian Power Company
P.O. Box 2021
Roanoke, VA 24022

800-956-4237

Compiled By:
American Electric Power
Hydro Generation Dept.

Submitted: October 31, 1991
Resubmitted: September 1, 1993
Revised: November 30, 1994
Revised: March 19, 1996
Revised: March 7, 1997
Revised: September 14, 1998
Revised: November 1, 1999

Reusens Project

State of Virginia

City of Roanoke, as:

The undersigned, being first duly sworn, states that he or she has read the above document and knows the contents of it, and that all of the statements contained in that document are true and correct, to the best of his or her knowledge or belief.

Teresa P. Rogers
Hydro Generation Department
American Electric Power

Sworn to and subscribed before me this the 5th day of November 1999. My commission expires October 31, 2002.

SEAL:

Judith W. Emery

EMERGENCY ACTION PLAN
REUSENS PROJECT

Contents of the Plan

September 1, 1993

II. General Responsibilities Under the Emergency Action Plan

This Emergency Action Plan (EAP) establishes the notification procedures for rapid implementation of the emergency actions to be taken prior to and/or following a project emergency. An emergency is defined as an impending or actual release of water caused by an accident to or failure of a dam, or by unusually large spillway releases.

A. Failure is Imminent or Has Occurred

Only minutes may be available for response. In the event that a dam failure is imminent or has occurred, the person observing the emergency condition should proceed immediately to the nearest safe location and notify the Roanoke Operations Center (ROC) in Roanoke, Virginia. Upon notification that a dam failure is imminent or has occurred, the ROC personnel will immediately notify the proper public officials according to the Failure is Imminent or Has Occurred flowchart. The urgency of the situation should be stated so they will take positive action immediately; for example, this call is to notify you that the dam has failed (or will fail). Notification will be made if the ROC personnel observe through monitoring devices or alarms the following:

1. An unexplained rapid decrease in forebay elevation

2. An unexplained rapid increase in tailwater elevation, and,

3. An unexplained reduction in load of any generating unit at the plant.

In all cases, the ROC personnel will consider the conditions of the failure and determine to what extent, if any, the generating units or spill gates should be utilized. In no case should flood stages be exceeded downstream while attempting to ameliorate the effects of a dam break. The intention of this procedure is to reduce the forebay elevation as rapidly as possible in case this would ameliorate the effects of a dam-break. There may be cases whereby bringing the units on-line or opening spillgates would not be possible or prudent.

The ROC personnel will also request others to store water in upstream reservoirs where storage room is available. In order to store water, the upstream reservoir's discharge should be reduced as much as possible allowing the reservoir to be filled to full pond elevation. Once the upstream reservoir is full, the discharge should be set equal to inflow in order to avoid increasing the downstream flows more than is necessary. There are no reservoirs located downstream of the Reusens Project which could be operated during an emergency to store flood flows.

B. Potential Failure Situation is Developing

It is anticipated that this type of emergency will allow time to take remedial action. Public officials will only be notified after the situation has been analyzed and closely monitored. Initial notifications to public officials will be in the form of an advisory and updated as necessary. The ROC personnel will make notifications according to the Potential Failure Situation is Developing flowchart for any of the following indicators:

1. Significant increase in flows from known seepage points.

2. Significant increase in number of seepage points.

3. Change in appearance or development of sinkholes.

4. Change in number of sinkholes.

5. Observable subsidence of soil in abutment, tailrace, or forebay areas.

When any of the above conditions are observed or reported, the person observing the emergency condition will, as soon as possible, notify hydro supervisory personnel as shown on the notification flowchart. An engineering evaluation of the conditions will then be made and if at any time conditions deteriorate rapidly, notifications will be made according to the procedures under the Failure is Imminent or Has Occurred flowchart. The Hydro Generation Department personnel will be responsible for monitoring the emergency condition as well as directing remedial or corrective measures to arrest the condition. The operation of the project during this emergency condition will be directed by the Hydro Generation Department personnel.

C. Coordination during High Flow Events

The area between Powerhouse A and the right abutment has the potential for overtopping, eroding and acting as an emergency spillway during severe flood events. This scenario occurred during the flood of 1985 and resulted in damage to the property adjoining the right abutment (CSX Transportation rail line and county road.)

In the event of high river flows that could potentially overtop the area between Powerhouse A and the right abutment, the Roanoke Operations Center (ROC) will notify the National Weather Service, CSX railroad, City of Lynchburg, and Amherst County so that appropriate actions can be taken by these parties to minimize the potential hazards.

D. General:

As shown on the notification flowcharts, the plan delineates the close coordination between American Electric Power (AEP), the National Weather Service (NWS) and the state-operated emergency services. The plan provides the necessary notifications to alert and warn the downstream populace, industries, state and local governments, etc., of possible flood conditions. From these notifications the various state and local agencies can prepare for or implement any emergency plans, evacuations, etc. as they deem necessary.

Once notified, the state-operated emergency services provides immediate notification to each affected downstream political subdivision. The ROC personnel then also alerts the downstream political subdivisions, which in some cases is a redundant notification.

It is the responsibility of those making the notifications to make all listed contacts for anyone who cannot be reached.

The Hydro Generation Department will be responsible for the EAP-related activities in preparing revisions to the EAP, establishing training seminars, coordinating the EAP tests, etc.

Questions concerning the EAP can be directed to:

<u>Primary</u>
Stan Hagerman
American Electric Power
Hydro Generation Department
P.O. Box 2021
Roanoke, VA 24022
540-985-2662 or sahagerman@aep.com

<u>Secondary</u>
Teresa Rogers
American Electric Power
Hydro Generation Department
P.O. Box 2021
Roanoke, VA 24022
540-985-2451 or tprogers@aep.com

III. Notification Procedures

The notification flowcharts included in this EAP contain the names, titles, location, office and home telephone numbers, and radio contact where applicable for company personnel, public officials and others. Notifications are to be made according to the appropriate flowchart in the order of priority as shown on each.

Functional copies of the EAP are posted in the following locations:

- Reusens Powerhouse - Office
- Appalachian Operations Center (AOC) - Coordinator and Hydro Desks
- Roanoke Regional Dispatching Center - Emergency File

Notification flowcharts are also posted at other telephone locations within the project.

The Appalachian Operations Center (AOC) and the Regional Dispatching Centers (RDC) provide 24-hour access, directly or operator assisted, from the normal Appalachian Power Company telephone number.

A. <u>Instantaneous or Imminent Failure</u>

Under this emergency situation the notification to public officials and others is made warning them of the emergency condition that exists. The urgency of the condition must be stressed.

The Virginia Department of Emergency Services (VDES) and the National Weather Service (NWS) are to be notified first in order that they may issue their warnings in a timely fashion as described above. The political subdivisions of Lynchburg City, Amherst County, Campbell County and Appomattox County which are located downstream of the dam are next on the list to be notified. Each jurisdiction has developed evacuation plans and would initiate them as they deem necessary.

The Virginia State Police is then notified in order that they may barricade low-lying state roads when necessary and assist in evacuation.

The Virginia Department of Transportation would be alerted of the emergency in order that they can barricade low-lying state roads as necessary.

CSX Transportation, which has rail lines located along the river, would be notified allowing them to prepare for the emergency.

The Norfolk District Corps of Engineers is notified of the emergency in order that they may take appropriate action. They operate the Gathright Flood Control Project located upstream of the Reusens Project and also monitor the downstream watershed. There are no dams on the river downstream of Reusens which could be operated to store flood waters.

Other APCo personnel would then be notified of the situation in order that they can further assess the emergency and make their notifications in a timely fashion.

At this time, the FERC regional office would be informed of the emergency.

B. Potentially Hazardous Condition

Under this emergency situation notification will be made to the public officials in the form of an advisory. Updates as the condition develops are to be made to the public officials as necessary. Since more time is available than in A. above, individuals, businesses and industries will be notified by radio, television and law enforcement officials. For this emergency situation, notification of the public officials will be carried out as described in A. above.

IV. Preventive Actions

A. General Provisions for Surveillance

The Reusens Plant is normally operated by remote controls which are located in the Appalachian Operations Center (AOC) at the main office building of Appalachian Power Company in Roanoke, Virginia. The AOC is staffed full time with at least two employees, an Operation Coordinator and a Hydro Dispatcher/ Operator. Along with other duties, these employees monitor the associated river and lake elevations as well as the many plant indications pertaining to generator loading, voltage level, gate position, etc. They also operate the remote controls to start and stop the individual generators, raise or lower the output level, raise or lower the associated voltage levels, and acknowledge any plant alarm indications. Continuous strip chart recorders are provided for monitoring several important indications such as the forebay and tailwater elevations at each dam, the megawatt output of the plant, and the upstream James River elevation at Holcomb Rock, Virginia. Local and regional weather information is also available to the AOC personnel.

Weather predictions and existing lake and river elevations are factors in determining the extent of usage of the plant and are continuously reviewed. During periods of high river flows which cause or could cause flooding conditions, efficient generation is sacrificed in favor of ameliorating the effects of the high river flows.

The Reusens Dam has eight vertical lift gates and a flashboarded curvilinear spillway section, all of which can be opened to assist in regulating the discharge. The lift gates are normally operated from regular station power; however, they are provided with an alternate source of power for reliability. The Reusens Plant is not staffed full time although, an operator must be on site to operate the spill gates. To ensure the stability and integrity of the Reusens Dam, a monthly inspection of the dam, foundation, and abutment is made. If any significant changes are noted, the condition is then closely monitored. Notifications to appropriate personnel are made immediately and remedial action is begun according to type of emergency. The time factor from actual emergency to awareness will be adequate in that the above surveillance methods will give early warning.

B. Surveillance at Remotely Controlled or Unattended Dams

The remote surveillance system in the AOC monitors the headwater elevation and tailwater elevation. Each is graphically displayed on a strip chart recorder. They are continuously monitored by computer, and audible alarms sound when rates or limits are exceeded. The limits are adjustable for floods, maintenance, etc. An alarm also sounds when the monitoring system experiences a loss of power or a loss of communication. The plant will be staffed at any time the monitoring system is interrupted. Operation of the alarms are checked periodically.

If the plant operator is alerted of any emergency, the operator should visually verify the existence of the condition and determine the type of emergency. The plant operator should then make the notifications according to the appropriate notification flowchart. It is important that the plant operator frequently inspect the status of the emergency condition in order to provide updates.

In the event that AOC personnel are alerted by outside telephone of an emergency; contact cannot be established with the plant; and the remote surveillance does not show an emergency, the emergency will be considered a "Potentially Hazardous Condition" and notifications will be made accordingly. If the remote surveillance equipment indicates an emergency, the "Instantaneous or Imminent Failure" notifications will be initiated and a continuing attempt will be made to contact the plant to verify the emergency.

C. Response During Periods of Darkness

The spillway operating deck may be illuminated during periods of darkness from regular station power. The spillway gates at Reusens Project are powered by regular station power or auxiliary power as necessary. The plant personnel are familiar with the auxiliary power system and are trained to handle problems associated with it.

The procedures for contacting proper personnel and officials during periods of darkness are as noted on the notification flowcharts utilizing home phone numbers. The response time, in general, is assumed to be slightly longer; thus, additional time should be allowed for adequate warning.

Plant personnel have the ability to connect spillway deck lights to the auxiliary power source should it become necessary. The auxiliary power source is located inside "A" building.

D. Response During Periods of Adverse Weather

Due to the geographic location of this project, adverse weather does not present major problems while operating spill gates, monitoring the dam, making proper notifications or gaining access to the project. Minor delays could be experienced during periods of adverse weather and extra time should be allowed to ensure the above preventive actions can be executed.

Access to the site during adverse weather is by the same highway routes utilized for access under normal conditions.

E. Availability and Use of Alternative Systems of Communication

The Company-owned microwave telephone system is the primary means of communication between the plants and the AOC, other systems of communications immediately available are as follows:

* Appalachian Operations Center - Reusens Project

  Primary - APCO Microwave

  Alternative - Outside Telephone
"57" Power Line Carrier

* Appalachian Operations Center - Notification Agencies

The primary means of communication to the notification agencies and the National Weather Service (NWS) is through the regular telephone system (outside telephone). Should telephone communications be out, an alternative method of notification would be to send a messenger to the City of Roanoke-Police Department located at Campbell Avenue and Third Street (a distance of three city blocks). The Police Department could then notify the City's Emergency Center by radio. The Emergency Center has access to a warning service and other communications media to alert Federal, state and local authorities of an emergency.

F. Emergency Supplies and Resources

The following have been identified as potential suppliers of materials, equipment, or equipment operators in the event of an emergency. Each would make necessary materials, equipment or equipment operators available on an emergency basis if needed. Their names, and business/nonbusinesss telephone numbers have been provided below:

CONTRACTORS - LARGE GENERAL

Roanoke	Alleghany Construction Company, Inc.		
	Office:		540-345-0817
			540-345-0667
	Home:	John Douthat	540-344-0243
		Andy Douthat	540-342-2116
		Wade Douthat	540-344-3456
	Branch Highways, Inc.		
	Office:		540-982-1678
	Home:	Ralph Shivers (Pres.)	540-774-2137
		Tom Partridge (VP-Opns.)	540-362-0586
		Mike Branch (Estimator)	540-989-8859
	J. M. Turner and Company, Inc.		
	Office:		540-343-6749
	Home:	Lee Wilhelm (Pres.)	540-989-6262
		Jay Turner (Chairman)	540-344-7618
Altavista	English Construction Company		
	Office:		804-845-0301
	Home:	Gary Collie	804-369-6102
		A. Douglas Dalton, Jr.	804-369-6736
		R. B. Carpenter, Jr.	804-369-5732

CONTRACTORS - LARGE GENERAL (Cont'd.)

Shawsville	Sisson and Ryan, Inc.		
	Office:		540-268-2413
			540-268-5928
			540-268-5251
	Home:	Tom Dunkenberger (Mgr.)	540-268-2467
		Danny Sisson (Field Supt.)	540-268-2462
		David Ryan (Quarry Supt.)	540-268-2369
Charleston	Union Boiler Company		
	Office:		304-755-8171
	Home:	Randy McDavid	304-755-4474
		Tom Withrow	304-562-5646
Pt. Pleasant	Mid-Atlantic Construction		
	Office:		304-675-8810
	Home:	Robert McMillan	304-675-5285
		Kenneth McMillan	304-675-3521

HAULING AND EXCAVATING

Roanoke	Russel Short, Inc.		
	Office:		540-890-6025
			540-890-3890
	Home:	Russel Short (Owner)	540-890-0035
	Kingery Brothers Excavating		
	Office:		540-774-9463
	Home:	Randy Kingery (Pres.)	540-989-8037
	Joe Bandy and Son, Inc.		
	Office:		540-342-5187
	Home:	Don Bandy (Manager)	540-989-1515
		Dave Wilson	540-389-8558
Charleston	Charles O. Moles		
	Office:		304-965-3428
	Home:	Charles Moles (Owner)	304-965-3605
			304-965-3428
		David Moles	304-965-5912

G. Coordination of Flows

In the event of an emergency at Reusens, all available units will immediately be brought on line at maximum discharge. The intention of this procedure is to reduce the forebay elevation as rapidly as possible in case this would ameliorate the effects of a dam-break. There may be cases such as an instantaneous failure, whereby bringing the units on-line would not be possible or prudent. Therefore, in all cases the AOC Operation Coordinator will consider the conditions of the failure and determine to what extent, if any, the generating units should be utilized.

The Reusens Dam is located downstream of the Corps of Engineers' Gathright Dam and several smaller reservoirs. Upon notification that a dam failure is imminent or has occurred at Reusens, the coordinator will request the owners of the Gathright Dam and the smaller reservoirs to reduce their project discharge.

If the AOC Operation Coordinator is notified of an impending failure by an operator or attendant, the coordinator will maintain telephone contact and instruct the operator regarding spillway gate operation. The operator is to evacuate the plant after opening the spillway gates or at any time that the imminent failure becomes life-threatening.

The National Weather Service (NWS) provides current and long range weather forecasts and has the capability of making quantitative precipitation forecasts. The NWS also has the ability to forecast river flows and flood crests at various river gauging sites. The NWS issues warnings through radio and television to the general public and directly to the Virginia Department of Emergency Services (VDES). The NWS also broadcasts pertinent information over the NWS radio.

Advanced coordination of flows based on weather and runoff forecasts issued by the NWS is necessary to operate the project. Direct contact with the NWS will aid the AOC personnel in routing flood flows as well as the flood wave resulting from a dam break. Contact with the NWS is established by calling the phone numbers as shown on the notification flowchart.

There are no dams located downstream of the project which could be operated to store flood flows.

H. Alternate Sources of Power

The Reusens Plant has two permanently installed propane generators, a 65 kW unit and a 25 kW unit, located in the A-Building Powerhouse. Plant personnel are familiar with both auxiliary power units and are trained to handle problems associated with them.

V. APPENDIX

A. Description of the Project

The Reusens Hydroelectric Plant is located on the James River at river mile 260 near the northern limits of the City of Lynchburg, Virginia. Primary facilities include two powerhouses (designated as A-Station and B-Station) separated by a flashboard-topped curved auxiliary spillway and a gated main spillway. These combined facilities span the entire width of the James River at this location.

Both powerhouses have steel frame and brick superstructures supported on concrete and masonry substructures. A-Station, the powerhouse adjacent to the west bank of the James River, was constructed in 1903 and substantially modified in 1930 to house the three existing generating units. Each generating unit consists of a vertical Francis type turbine driving a vertical configuration generator which has a nameplate rating of 2,500 kW. B-Station, located east of A-Station, was constructed in 1924 and contains two generating units each consisting of a vertical Francis type turbine driving a vertical configuration generator which has a nameplate rating of 2,500 kW.

The main dam is a gravity structure of granite block and concrete construction approximately 416 feet in length and 24 feet in height from toe to crest. Initial constuction occurred about 1850 and modifications in 1924, when B-Station was constructed, and 1930 through 1931, at which time moveable floodgates were added above the dam crest. Eight steel floodgates surmount the crest of the spillway each having a top elevation of 550.75 NGVD which is approximately 16.75 feet higher than the spillway crest elevation, 534 NGVD. Each gate opening is 44 feet wide. The gates are operated by individual electric hoists supported by a steel bridge structure which extends the length of the spillway and spans the concrete piers which separate each gate opening.

Separating the powerhouses is a concrete curvilinear spillway constructed in 1924. The spillway has a total length along the arc of 125.67 feet and an internal radius of 51.33 feet. The crest elevation of the spillway is 544 NGVD. Topping the spillway are removable timber flashboards which have a crest elevation of approximately 551.25 NGVD.

The structures for the Reusens facilities are founded on granite and granite gneiss formations. The valley walls in the immediate area of the plant facilities are exposed rock.

The reservoir formed by the Reusens facilities has a surface area of 500 acres and gross storage capacity of 6,869 acre-feet at the normal maximum surface elevation of 550.75 NGVD. The drainage area to the reservoir is approximately 3,275 square miles or one-third of the drainage basin for the entire James River. Drainage to the Reusens reservoir begins at the headwaters in the Allegheny Mountains and through the Valley and Ridge, and Blue Ridge Provinces. The Reusens facilities lie just east of the Blue Ridge Province within the Piedmont Upland section. Immediately surrounding the Reusens reservoir, the drainage area has approximately 1,200 feet of relief and is indicative of the eastern portion of the Blue Ridge Province. Runoff for the most part emanates from forested and agricultural areas. Downstream of the dam and powerhouses, runoff from urban areas becomes more predominate due to the proximity of the City of Lynchburg, Virginia. Forest land accounts for approximately 70% of the land use in the drainage basin with forest cover being primarily of the oak-chestnut type. Other land uses include cropland (13%), pasture (11%), urban (4%) and other miscellaneous uses (2%).

The climatology of the area is influenced by prevailing westerly winds and the mountainous setting, the latter producing significant modifications to storm activity and general air movements. The average temperature for the region is approximately 57°F, ranging from normals of 38°F in January to 76°F in July. Annual precipitation is about 40 inches with November normally the driest (2.6 inches) and August the wettest (4.4 inches) months.

B. <u>Summary of Study Analysis to Determine Extent of Inundation</u>

Two computer models were utilized to simulate a breach-type failure of the Reusens Dam and resulting outflow: the National Weather Service DAMBRK, Dam Break Flood Forecasting Model, and the U.S. Army Corps of Engineers Model HEC-1, Flood Hydrograph Package. DAMBRK simulated the breach and resulting outflow hydrograph and routed the hydrograph downstream to a point where the flood wave has a more gradual increase in discharge. The limit of the DAMBRK model is approximately 3.8 miles below the Reusens dam at the Lynchburg dam. Below the Lynchburg dam, the flood hydrograph was routed an additional 19.2 miles utilizing the HEC-1 model. The following assumptions were made in the analysis:

a. The breach occurs when the maximum reservoir elevation (561 ft.) is reached during the 1985 flood of record (207,000 cfs).

b. The breach is formed by the failure of four of the eight spillway segments resulting in a rectangular breach approximately 176 feet wide and having a bottom elevation of 510 feet and top elevation of 534 feet.

c. The gates are fully open and the flashboards down. The flood of record passes below the bottom of the gates.

d. The full breach develops within 6 minutes (0.1 hours).

e. Manning's "n" values for downstream routing purposes are 0.04 in the main channel and 0.07 in the overbank areas.

The following justifications are given for each of the foregoing assumptions:

a. A flow rate of 207,000 cfs represents the peak discharge for the 1985 flood of record. With the gates open during the flood of record, the reservoir elevation will rise to elevation 561 feet under non-failure conditions. For floods greater than 207,000 cfs, the effects of a dam break will result in increased flood * heights of less than two feet. The assumed dam failure conditions should result in a dam failure simulation which most closely identifies the greatest area which reasonably could be inundated.

b. The breach parameters are within the upper limits of the suggested guidelines as published by FERC. The FERC guidelines indicate that the width of breach should be in excess of one monolith and usually less than one-half the crest length of the dam. Elevation 510 ft. specified for the bottom of the breach represents the lowest point of the pool behind the dam while elevation 534 ft. represents the crest elevation for the spillway. The FERC guidelines also indicate that the horizontal component of the side slope for breaches of this type of dam be zero. This results in a breach being rectangular in shape which is the case for the Reusens dam-break simulation.

c. During the 1985 flood of record scenario, it is likely that the spillway gates would be opened to their maximum and the flashboards taken down before the facility was evacuated. The gates can be raised at the Reusens Dam such that the maximum reservoir elevation during the flood of-record would be lower than the bottom elevation of the raised gates. Based on these considerations, the simulated model should reflect a reasonable worst-case scenario for determining downstream inundation.

d. FERC guidelines indicate that the time-to-failure of concrete or masonry dams should be in the range of 0.1 to 0.3 hours. The 0.1 hour failure time used in this analysis is at the lower limit of this range.

e. A review of conditions of the James River downstream of the Reusens Dam suggest that an average Manning's "n" value of 0.04 in the main channel and 0.07 for overbank areas are appropriate.

The possibility of a failure of the Reusens Dam resulting in a domino effect, in which there would be a sequential failure of downstream dams, was dismissed based on consideration of conditions at the Lyunchburg Dam located approximately 3.8 miles downstream. Failure of the Lynchburg Dam would have minimal impact on the routing of the 1985 flood-of-record and resulting failure of the Reusens Dam and is not considered in the flood routing analysis.

An elevation view of the Reusens Dam is provided on the following page. The assumed breach is indicated thereon.

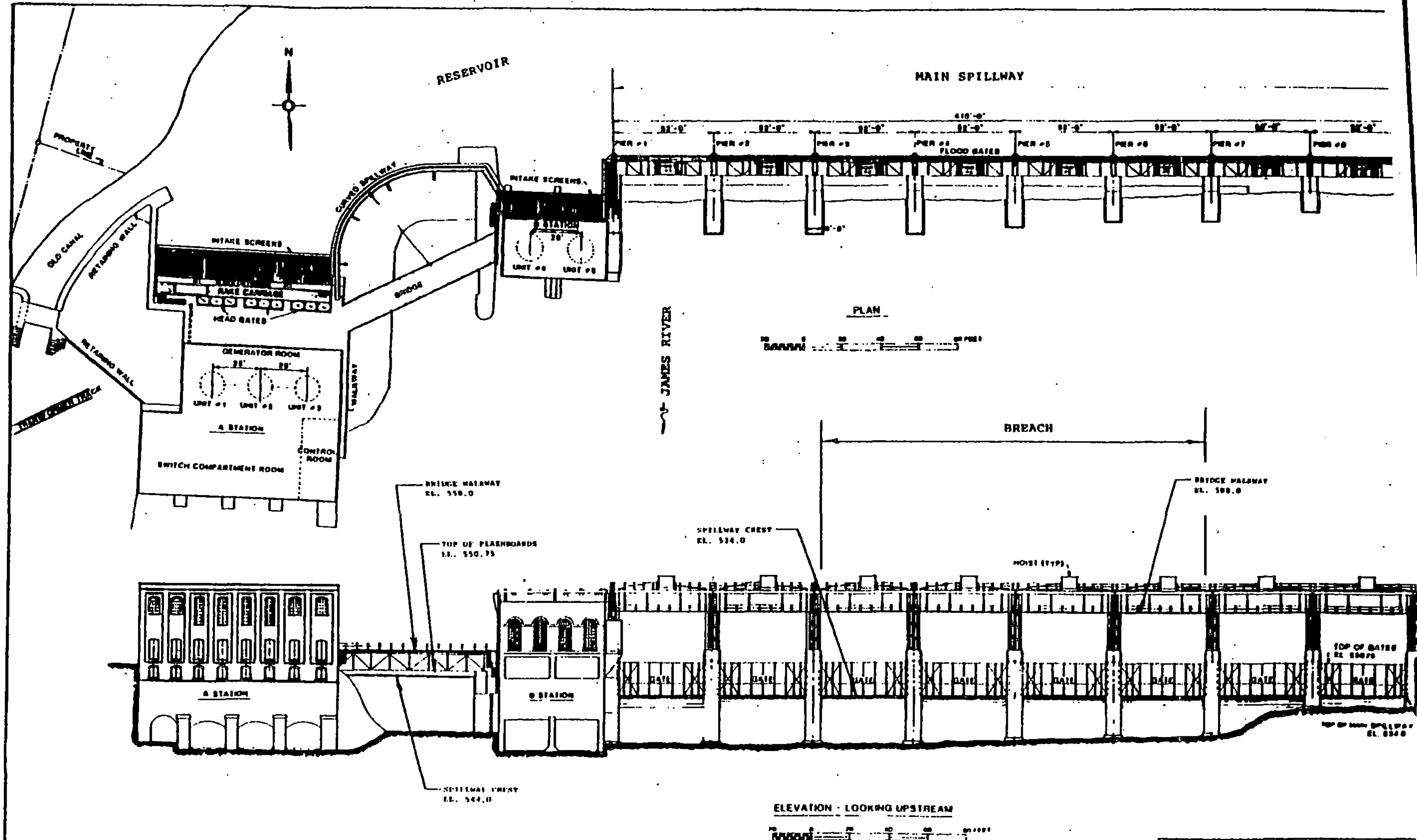
The results of the 1985 flood-of-record with dam break and clear-day dam-break analyses, including peak elevations, flood depths, and flood arrival and peak times, are contained on the flood inundation maps which follow page V-10 of this appendix. Table V-1 on page V-7 summarizes the computer analyses made for the 1985 flood-of-record flow condition with and without consideration of a failure of the Reusens Dam. Also summarized is the clear-day condition with a dam break. For the three conditions presented in Table V-1, the peak elevation flood depth and flood arrival and peak times for various reaches are presented. The flood arrival time is defined as the elasped time from the beginning of the dam failure to the time a significant increase in flow at the respective down stream location would occur. The flood peak time is the elapsed time from the beginning of the dam failure to the time of the maximum flood elevation. Following Table V-1 is a computer summary printout for the flood-of-record with a dam-break condition. This summary information is the basis for the flood inundation maps.

For all conditions considered, the flood wave from the Reusens Dam is modeled downstream approximately 19.2 miles below the Lynchburg Dam at which point the effect of the flood wave dissipates.

C. Inundation Maps

Plotted inundation maps follow page V-10 of this emergency action plan. They are based upon a simulated failure of the Reusens Dam during the 1985 flood-of-record and clear-day situations.

For the clear-day dam break situation, the starting elevation was set at the normal pool elevation of 550.75 NGVD. A constant inflow rate equal to the average flow was utilized, and no lateral inflow below Reusens Dam was considered. A constant turbine discharge of 5000 cfs was used in the clear-day dam break analysis since the DAMBRK model has a mathematical constraint which prohibits zero flow



APPALACHIAN POWER COMPANY
REUSENS
HYDROELECTRIC PROJECT NO. 2376
VIRGINIA

PLAN & ELEVATION

1985 FLOOD OF RECORD
DAM-BREAK SUMMARY

PROFILE OF CRESTS AND TIMES FOR REUSENS
BELOW REUSENS

RVR MILE FROM DAM ********	MAX ELEV (FT) ********	MAX FLOW (CFS) ********	TIME MAX ELEV(HR) ********	MAX VEL (FT/SEC) ********	FLOOD ELEV (FT) **********	TIME FLOOD ELEV(HR) **********
0.020	549.53	233877	0.525	11.00	0.0	0.0
0.540	547.43	231733	0.595	10.06	-0.0	0.0
1.060	545.67	230057	0.640	9.22	0.0	0.0
1.580	544.15	228283	0.670	8.49	0.0	0.0
2.100	542.83	226531	0.695	7.82	0.0	0.0
2.667	541.02	225076	0.725	8.22	0.0	0.0
3.233	538.75	224685	0.745	8.48	0.0	0.0
3.800	535.99	224535	0.750	8.66	0.0	0.0

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

	OPERATION	STATION		PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
	HYDROGRAPH	MILE	IN	224000.	1.00	155587.	116187.	116187.	0.0		
	ROUTED TO	4.7	RCH1	223832.	1.00	158305.	118164.	118164.	0.0	520.11	1.00
	ROUTED TO	6.8	RCH3	223590.	1.25	168679.	125712.	125712.	0.0	514.74	1.25
	ROUTED TO	9.5	RCH5	223327.	1.58	180526.	134590.	134590.	0.0	506.87	1.58
	ROUTED TO	11.1	RCH6	223190.	1.75	187512.	140262.	140262.	0.0	503.36	1.75
Bjw	ROUTED TO	14.8	RCH7	221954.	2.33	202286.	156400.	156400.	0.0	489.57	2.33
	ROUTED TO	17.8	RCH8	221205.	2.83	208730.	167391.	167391.	0.0	474.25	2.83
	ROUTED TO	23	RCH9	218378.	3.50	211255.	182637.	182637.	0.0	461.01	3.50

*** NORMAL END OF HEC-1 ***

REUSENS HYDROELECTRIC PROJECT NO. 2376
INDEX TO FLOOD INUNDATION MAPS

Sheet Number	Approximate Number of Miles Along Main Channel Downstream From Reusens Dam	
	From	To
1	0	3.4
2	3.4	13.6
3	13.6	17.5
4	17.5	23.0

D. Plans for Training, Testing and Annual Review

1. Posting the Emergency Action Plan (EAP)

An up-to-date copy of the emergency action plan with the notification flowchart is posted in a prominent location accessible to the company's operating and supervisory personnel who are responsible for controlling water flows and for notifying public health and safety agencies and affected persons.

The emergency action plan is designed to function on weekends and during hours of darkness as well as during normal working hours. Those responsible for making notifications receive at least two copies of the up-to-date plan and are instructed to post one copy at home and one at their office to maintain a working plan 24 hours a day.

The following list shows the locations of all functional copies of the notification flowchart and the EAP.

-Reusens Powerhouse - Office
-Appalachian Operations Center (AOC) - Coordinator and Hydro Desks
-Roanoke Regional Dispatching Center - Emergency File.

Notification flowcharts are also posted at other telephone locations within the project.

2. Annual Training of Project Operators and Other Responsible Personnel

The plant personnel are trained and the plan is reviewed annually to insure that they can identify potential failure conditions and that they are able to make proper notification as denoted in the emergency action plan.

The AOC personnel responsible for controlling water flows and for notifying public agencies and affected persons are trained and the plan is reviewed annually with them. This insures that they are able to instruct the plant personnel in order to control water flows and that they are able to make proper notification as indicated in the emergency action plan.

3. Annual Review

A comprehensive review of all aspects of the EAP is conducted at least once a year and the plan is updated accordingly. During the review, a determination of any new developments or other changes downstream or elsewhere will be made to determine whether any revisions to the current EAP including inundation maps are necessary. Immediately upon becoming aware of necessary changes to keep the EAP workable, updates will be furnished to the Regional Director of the FERC and all other holders of the EAP. This includes revisions when phone numbers or names change for the FERC contacts.

Annually a statement that the EAP has been thoroughly reviewed and the date it was last tested will be furnished to the Regional Director of the FERC. Any needed revisions and updates or a statement that no revisions and updates are needed will be included at that time. All pages of the EAP that are revised will be marked "Revised month, day and year" and the revised material highlighted with a vertical line beside the revision.

4. Test of the State of Readiness

The Company annually tests the state of training and readiness of key personnel by conducting a mock emergency for the most probable type of emergency. The test is initiated by notifying plant personnel that a mock emergency condition exists, specifying its location and details of severity. From this information the plant personnel proceed in following the instructions as given in the emergency action plan, thus determining the type of emergency (i.e., potentially hazardous condition or instantaneous failure) and notifying personnel listed according to the failure type. The AOC personnel notified of the mock test makes notifications as specified in the emergency action plan. In making the notifications, the AOC personnel reads the "Mock Test Notification" to each agency and individual listed in the notification flowchart under the respective type of emergency.

It is necessary that the individual making the notifications record the name of the person contacted, log the time the contact was made and state any pertinent remarks. This information is to be listed on the "Mock Test Notification" sheet.

Hydro Generation Department will review the mock test and determine if the test was successful.

Within thirty days of the date of the test, a statement that the EAP has been tested will be furnished to the FERC Regional Director and should include a critique of the test and any revisions or updates to the plan or a statement that no revisions or updates are needed as a result of the test.

E. Documentation

Coordination meetings are held on a continuing basis as the EAP is updated. Each agency is contacted to identify new developments or changes downstream to determine whether any revisions to the EAP are necessary. During the annual update, discussions are held with the agencies to ensure their support and understanding.

The following list of Federal, state and local agencies have documented that they understand their responsibility for alerting or evacuating the public in those areas within their jurisdiction. They also maintain an up-to-date copy of the EAP and receive updates annually. Acknowledgement from each agency documenting the above is kept on file and copies of such are also forwarded to the FERC Regional Director.

Mr. James W. Dixon — 2 copies
Department of Emergency Services
7700 Midlothian Turnpike
Richmond, VA 23235
Phone: 804-674-2400

Mr. Terry Benthall — 1 copy
National Weather Service
2001 Airport Road
Lynchburg, VA 24502
Phone: 804-239-5811

Mr. Mike Emlaw — 1 copy
National Weather Service
1750 Forecast Dr.
Blacksburg, VA 24060
Phone: 540-552-1613

Lt. M. B. Forrest — 1 copy
Virginia State Police, Division 3
Box 577
Appomattox, VA 24552
Phone: 804-352-7128

Mr. Stan Ballard or John Baxter — 1 copy
U. S. Army Corps of Engineers
Attn. CENAO-CO-ER
Fort Norfolk, 803 Front Street
Norfolk, VA 23510-1096
Phone: 804-441-7254

Chief Charles Bennett City of Lynchburg Police Department 905 Court Street Lynchburg, VA 24505 Phone: 804-847-1430	1 copy
Mr. Barry Martin Lynchburg Deputy Dir. of Emergency Preparedness 800 Madison Street Lynchburg, VA 24505 Phone: 804-847-1600	1 copy
Sheriff Michael W. Cox Amherst County Sheriff's Department P. O. Box 531 Amherst, VA 24521 Phone: 804-946-9300	1 copy
Mr. Stewart E. Shaner Amherst County Administrator P. O. Box 390 Amherst, VA 24521 Phone: 804-946-9400	1 copy
Sheriff R. E. Maxey, Jr. Campbell County Sheriff's Department P. O. Box 280 Rustburg, VA 24588 Phone: 804-332-5178	2 copies
Mr. David Laurell Campbell County Administrator P. O. Box 100 Rustburg, VA 24588 Phone: 804-332-5161 (one copy for Campbell County Civil Defense Coor.)	3 copies
Sheriff J. E. Richardson Appomattox County Sheriff's Department P. O. Box 366 Appomattox, VA 24522 Phone: 804-352-8241	1 copy
Mr. Freddy Godsey Appomattox County Emergency Ser. Coord. P. O. Box 909 Appomattox, VA 24522 Phone: 804-352-8241	1 copy
Mr. W. P. Ramey, District Administrator Virginia Department of Transportation P. O. Box 11649 Lynchburg, VA 24506 Phone: 804-947-2677	3 copies

CRUSHED ROCK AND STONE

Roanoke	Rockydale Quarries		
	Office:		540-774-1696
			540-989-6107
	Home:	Dan Phlegar	540-389-1783
		David Willis	540-864-5306
	Mobile		540-520-1689
	Blue Ridge Stone		
	Office:		540-947-2211
			540-985-0538
	Home:	Tim Mauze (Supt.)	540-977-6337
		Reva Orange (Office Mgr.)	540-947-2757
Shawsville	Sisson and Ryan Quarries		
	Office:		540-268-2413
			540-268-5928
			540-268-5251
	Home:	Tom Dunkenberger (Mgr.)	540-268-2467
		Danny Sisson (Field Supt.)	540-268-2462
		David Ryan (Quarry Supt.)	540-268-2369
Newbern	Holston River Quarries		
	Office:		540-674-1120
	Home:	Hugh Hill	540-980-1972
Wytheville	Wythe Stone Company		
	Office:		540-228-3631
	Home:	Ernest Williams	540-228-3829
	Charlie Morris		540-674-4850
Charleston	Shamblin Stone, Inc.		
	Office:		304-766-7316
	Home:	Doc Haynes	304-342-1059
		Monte Caruthers	304-755-5840
	Marzella Quarries		
	Office:		304-744-3682
	Home:	Joe Marzella	304-744-2714
	Dravo Basic Materials		
	Office:		304-485-7341
	Home:	Tony Pacifico	304-925-5767
		Mike Deviese	304-372-8358

DIVING SERVICES

Norfolk	Crofton Diving Co.	
	Office:	804-397-1131
	Home: J. F. (Jay) Crofton, Jr.	804-721-3693
	Robert (Bobby) Crofton	804-481-5144
	Kenneth (Kenny) Crofton	804-925-0866
Scott's Depot	Underwater Services, LTD	
	Office:	304-757-9439
	Home: Carroll Hutton (Owner)	304-757-9439
	NOTE: Also certified oil spill and HAZMAT	

MECHANICAL ASSISTANCE

Roanoke	Apex Industrial Equipment	
	Office:	540-387-3880
		540-387-3887
	Home: W. L. (Bud) Plymale, Sr.	540-389-3164
	L. Leigh Plymale, Jr.	540-389-6232
	Pager	540-224-1299
Charleston	Union Boiler Company	
	Office:	304-755-8171
	Home: Randy McDavid	304-755-4474
	Tom Withrow	304-562-5646
Aurora, IN	Legge Associates, Inc.	
	Office:	812-926-2938
	Home: Jerry Ticknor	812-926-4783
Bakersville, N.C.	High Valley Const. and Maint. Corp.	
	Office:	704-765-4004
	Home: Bob Buchanan (Pres.)	704-765-5232
	Mike Street	704-688-3599

FABRICATORS

Roanoke	Apex Industrial Equipment		
	Office:		540-387-3880
			540-387-3887
	Home:	W. L. (Bud) Plymale, Sr.	540-389-3164
		W. Leigh Plymale, Jr.	540-389-6232
		Pager	540-224-1299
	Fabricated Metal Industries		
	Office:		540-774-4423
	Home:	Frank Guynn	540-929-4341
		Chuck Ashcraft	540-389-7410
	American Machine		
	Office:		540-343-3637
	Home:	Clearence DeHaven	540-343-4289
		Jack Eberhardt	540-986-1366
Lynchburg	IMF Crane and Rigging		
	Office:		1-800-223-2594
			540-345-3712
	Home:	Gene Kidd	804-384-5994
		Andy Anderson	804-384-2308
		Alfred Giles	540-977-4187
Charleston	Central Machine Shop		
	Office:	Audinet	8-260-1100
		Audinet	8-260-1102
	Home:	Andrew Zagakyo	304-757-9659
		Fred Stotts (Asst. Mgr.)	304-722-4019
		Lewis Wood (Production)	304-722-3998

CRANE SERVICE / RIGGING / HEAVY HAULING

Roanoke	American Constructors, Inc.		
	Office:		540-344-7800
	Home:	Dan Critzer	540-342-8418
	Jason Enterprises, Inc.		
	Office:		540-890-5245
	Home:	Clinton Saunders	540-343-4775
	Cellular:	Clinton Saunders	540-520-7422

CRANE SERVICE / RIGGING / HEAVY HAULING (Cont'd.)

Roanoke	IMF Crane and Rigging		
	Office:		1-800-223-2594
			540-345-3712
	Home:	Gene Kidd	804-384-5994
		Andy Anderson	804-384-2308
		Alfred Giles	540-977-4187
Charleston	Henson Brothers, Inc.		
	Office:		304-768-7315
	Home:	Joe Henson	304-369-5961
		Michael Linville	304-776-0233
		Henry Henson	304-757-7367
	All Crane and Equipment Corp.		
	Office:		304-766-0300
	Home:	Bill Blankenship	304-766-0300
	Union Boiler Company		
	Office:		304-755-8171
	Home:	Randy McDavid	304-755-4474
		Tom Withrow	304-562-5646

CONCRETE PATCHING MATERIALS

Roanoke	Saunders Oil Company, Inc.		
	Office:		1-800-868-1107
			or 1-800-868-3804
	Home:	Larry Finn (Sales Mgr.)	804-739-1658
Salem	Virginia Construction Supply		
	Office:		540-389-0040
	Home:	Gerald (Jerry) McPeak	540-774-3838
		Jeff Sain	540-989-8113
Christiansburg	Marshall Concrete Products		
	Office:		540-389-7116
			or 540-382-1734
	Home:	Steve Marshall (Pres.)	540-951-2033
		David Stallings	540-382-4047
		Nick Thomas (Roanoke Sales)	540-989-3216

REUSENS HYDROELECTRIC PROJECT NO. 2376

APPALACHIAN POWER COMPANY

DAM-BREAK FLOOD INUNDATION MAP

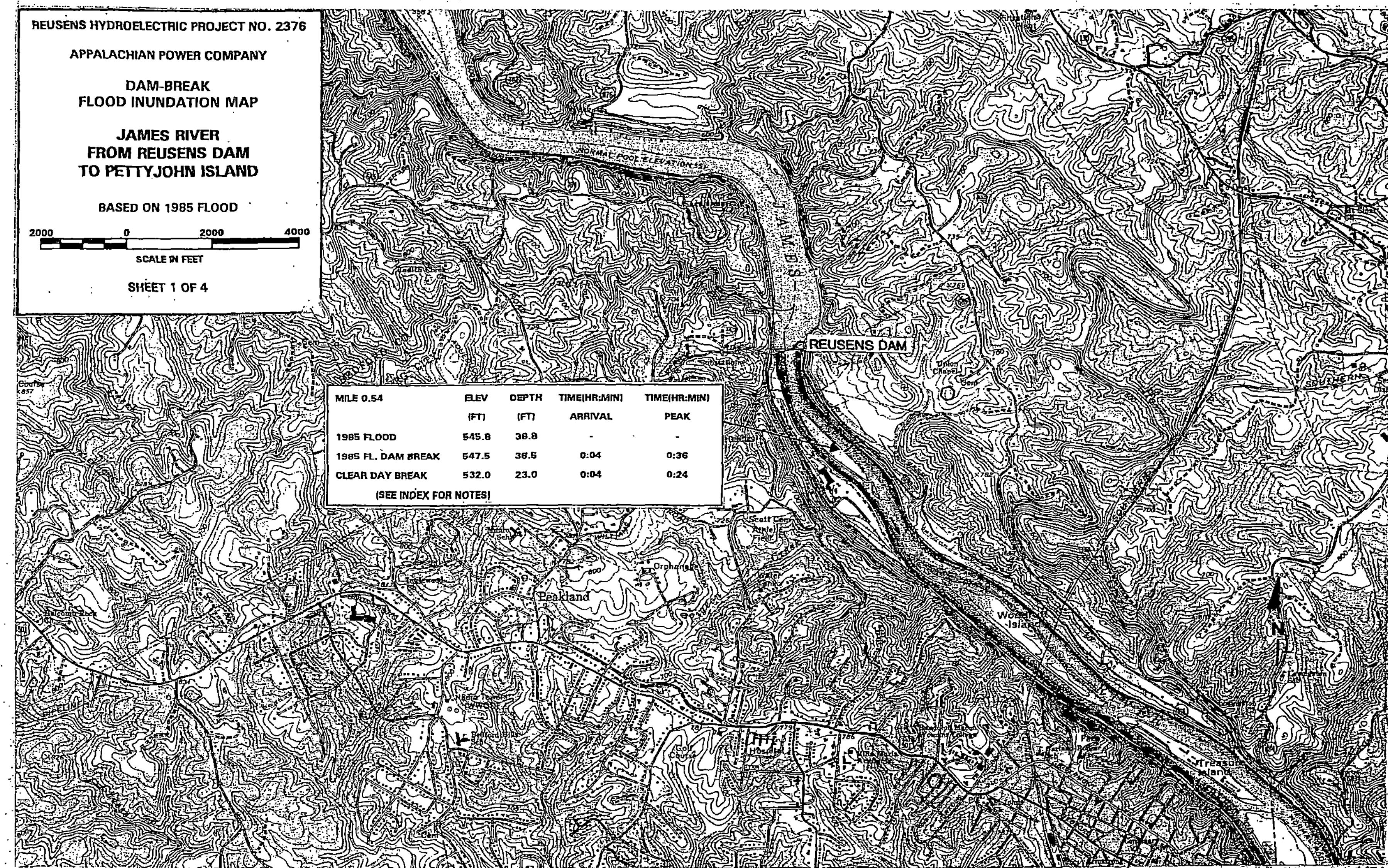
JAMES RIVER FROM REUSENS DAM TO PETTYJOHN ISLAND

BASED ON 1985 FLOOD

2000 0 2000 4000

SCALE IN FEET

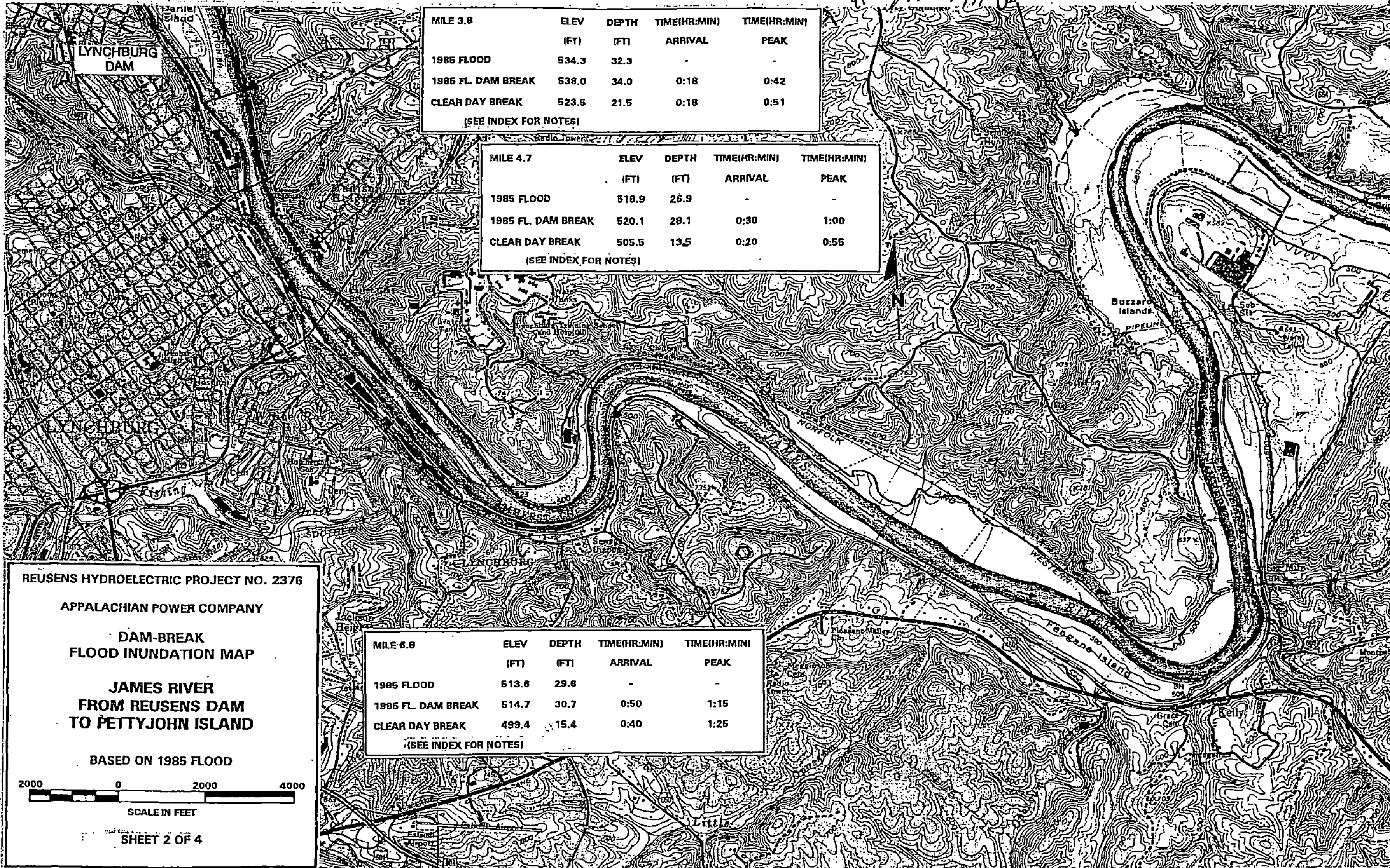
SHEET 1 OF 4



MILE 0.54	ELEV (FT)	DEPTH (FT)	TIME(HR:MIN) ARRIVAL	TIME(HR:MIN) PEAK
1985 FLOOD	545.8	38.8	-	-
1985 FL. DAM BREAK	547.5	38.5	0:04	0:36
CLEAR DAY BREAK	532.0	23.0	0:04	0:24

(SEE INDEX FOR NOTES)

SHEET 1 9/91



MILE 3.8	ELEV (FT)	DEPTH (FT)	TIME(HR:MIN) ARRIVAL	TIME(HR:MIN) PEAK
1985 FLOOD	534.3	32.3	-	-
1985 FL. DAM BREAK	538.0	34.0	0:18	0:42
CLEAR DAY BREAK	523.5	21.5	0:18	0:51

(SEE INDEX FOR NOTES)

MILE 4.7	ELEV (FT)	DEPTH (FT)	TIME(HR:MIN) ARRIVAL	TIME(HR:MIN) PEAK
1985 FLOOD	518.9	26.9	-	-
1985 FL. DAM BREAK	520.1	28.1	0:30	1:00
CLEAR DAY BREAK	505.5	13.5	0:20	0:55

(SEE INDEX FOR NOTES)

MILE 6.8	ELEV (FT)	DEPTH (FT)	TIME(HR:MIN) ARRIVAL	TIME(HR:MIN) PEAK
1985 FLOOD	513.6	29.6	-	-
1985 FL. DAM BREAK	514.7	30.7	0:50	1:15
CLEAR DAY BREAK	499.4	15.4	0:40	1:25

(SEE INDEX FOR NOTES)

REUSENS HYDROELECTRIC PROJECT NO. 2376

APPALACHIAN POWER COMPANY

DAM-BREAK
FLOOD INUNDATION MAP

JAMES RIVER
FROM REUSENS DAM
TO PETTYJOHN ISLAND

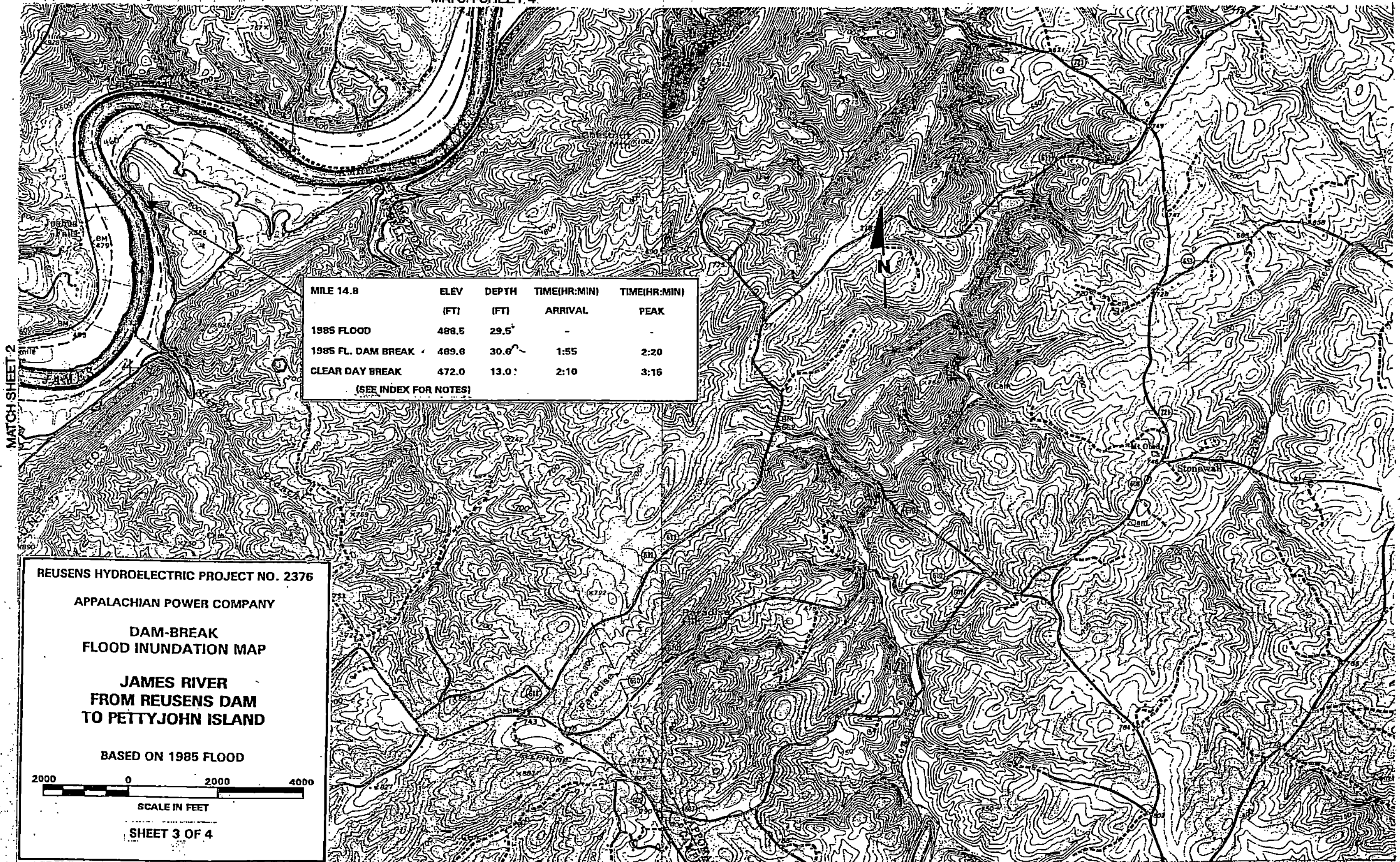
BASED ON 1985 FLOOD

2000 0 2000 4000
SCALE IN FEET

SHEET 2 OF 4

Clear Day Break

MATCH SHEET 4



MILE 14.8	ELEV (FT)	DEPTH (FT)	TIME(HR:MIN) ARRIVAL	TIME(HR:MIN) PEAK
1985 FLOOD	488.5	29.5	-	-
1985 FL. DAM BREAK	489.6	30.6	1:55	2:20
CLEAR DAY BREAK	472.0	13.0	2:10	3:16

(SEE INDEX FOR NOTES)

REUSENS HYDROELECTRIC PROJECT NO. 2376

APPALACHIAN POWER COMPANY

DAM-BREAK
FLOOD INUNDATION MAP

**JAMES RIVER
FROM REUSENS DAM
TO PETTYJOHN ISLAND**

BASED ON 1985 FLOOD

2000 0 2000 4000
SCALE IN FEET

SHEET 3 OF 4

REUSENS HYDROELECTRIC PROJECT NO. 2376

APPALACHIAN POWER COMPANY

DAM-BREAK FLOOD INUNDATION MAP

JAMES RIVER FROM REUSENS DAM TO PETTYJOHN ISLAND

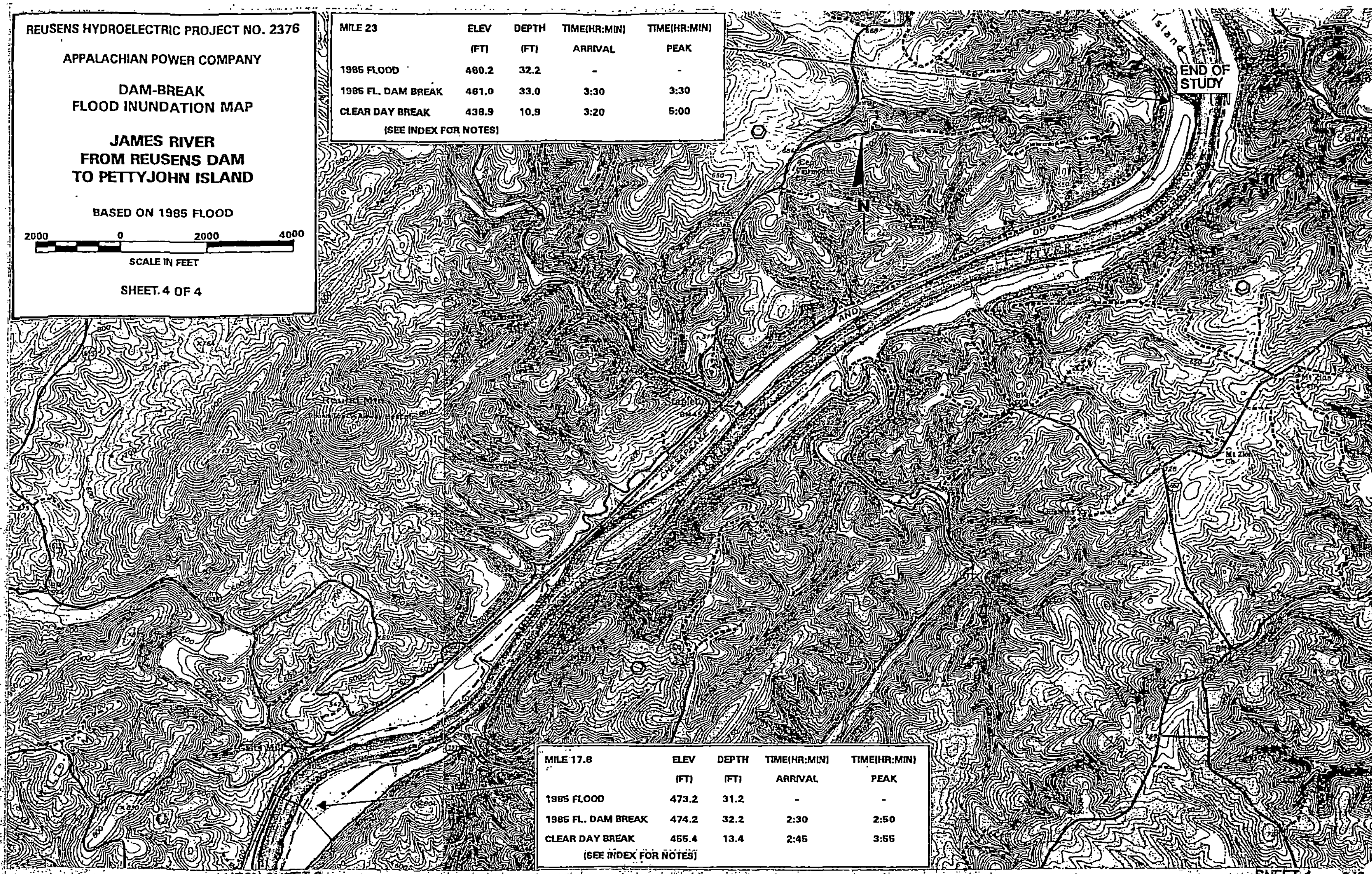
BASED ON 1985 FLOOD

2000 0 2000 4000
SCALE IN FEET

SHEET 4 OF 4

MILE 23	ELEV (FT)	DEPTH (FT)	TIME(HR:MIN) ARRIVAL	TIME(HR:MIN) PEAK
1985 FLOOD	460.2	32.2	-	-
1985 FL. DAM BREAK	461.0	33.0	3:30	3:30
CLEAR DAY BREAK	438.9	10.9	3:20	5:00

(SEE INDEX FOR NOTES)



MILE 17.8	ELEV (FT)	DEPTH (FT)	TIME(HR:MIN) ARRIVAL	TIME(HR:MIN) PEAK
1985 FLOOD	473.2	31.2	-	-
1985 FL. DAM BREAK	474.2	32.2	2:30	2:50
CLEAR DAY BREAK	455.4	13.4	2:45	3:56

(SEE INDEX FOR NOTES)

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On the Cover

Artist's rendition of San Vicente Dam after completion of the dam raise project to increase local storage and provide a more flexible conveyance system for use during emergencies such as earthquakes that could curtail the region's imported water supplies. The existing 220-foot-high dam, owned by the City of San Diego, will be raised by 117 feet to increase reservoir storage capacity by 152,000 acre-feet. The project will be the tallest dam raise in the United States and tallest roller compacted concrete dam raise in the world.

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- Fostering dam technology for socially, environmentally and financially sustainable water resources systems;
- Providing public awareness of the role of dams in the management of the nation's water resources;
- Enhancing practices to meet current and future challenges on dams; and
- Representing the United States as an active member of the International Commission on Large Dams (ICOLD).

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PROACTIVE OWNERSHIP OF THE PEDLAR DAM LEADS TO TIMELY AND COST-EFFICIENT SOLUTIONS WITH CHANGING REGULATIONS

Dennis Hogan, P.E.[1]
Greg Zamensky, P.E.[2]

ABSTRACT

Significant amendments to the Virginia dam safety regulations, enacted September 2008, include safety standards similar to the federal standards and the standards of many other states. Changes to the dam safety regulations include, but are not limited to:

- reclassifying dams as high, significant or low hazard potential, instead of I through IV
- increased spillway design flood (SDF) criteria
- more rigorous certification renewal requirements
- dam break inundation zone mapping
- incorporation of the inundation zone maps into local zoning and land use plans
- stronger Emergency Action Plans and annual drills with local emergency responders
- more rigorous construction/alterations permit process
- additional administrative fees

The Pedlar Dam is owned by the City of Lynchburg, with a regular Operations and Maintenance certificate from the Virginia Department of Conservation and Recreation (DCR), Dam Safety Group, as a Class II (or significant hazard), medium size dam. In preparation for certificate renewal, engineering analyses were performed to determine the proper hazard classification, ability of the dam to withstand the associated SDF, and dam alterations that would be needed to meet the new requirements.

The City's Utilities Department is proposing dam alterations in the City's Capital Improvement Plan. These alterations would include general concrete repair, dredging and removal of sediment and debris from inside and outside the intake tower, repair of gates, addition of trash racks, and the above improvements required to meet the amended dam safety regulations. It is anticipated that the City will apply for an Alterations Permit by submitting a design report in accordance with the regulations.

INTRODUCTION

The City of Lynchburg (City) owns, operates, and maintains the Pedlar Dam and Reservoir. The reservoir is the primary water source for the residents of Lynchburg. The dam is regulated by the Virginia Department of Conservation and Recreation, Dam Safety Group (DCR) as a Class II (or significant hazard), medium size dam. The City holds a regular Operation and Maintenance Certificate for the dam. According to the certificate, the dam is capable of passing approximately 23% of the probable maximum

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flood (PMF) without overtopping. At present, this flood event is the accepted spillway design flood (SDF).

Significant revisions to the Virginia dam safety regulations were enacted in September 2008. The purpose of this study is to provide inundation mapping and determination of the proper hazard classification and SDF in accordance with the revised regulations, and to identify corrective action, if necessary.

The 119-acre reservoir is impounded by an 87-foot high, 462-foot long concrete dam with a 150-foot wide spillway. The dam was initially constructed in 1904. The spillway was raised in 1926 and the entire dam was raised in 1931 and again in 1964. Flow over the spillway discharges to the Pedlar River. The various stages of dam raising are shown below in Figure 1, taken from the 1964 design drawings.

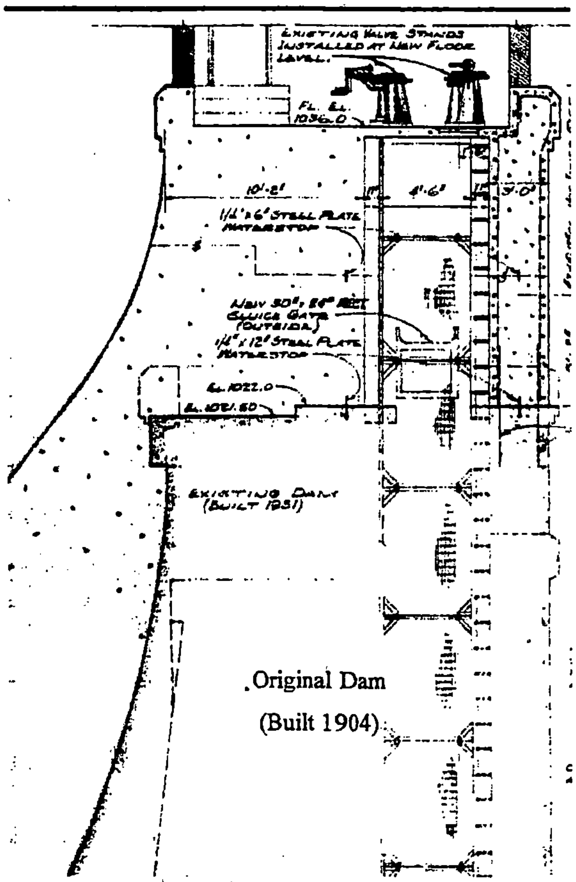

Figure 1. Various Dam Raising Stages

The US Army Corps of Engineers (USACE) performed a Phase I inspection as part of the national dam safety program in June 1980. Since that time, the dam has been inspected regularly, and analyzed for stability and other general reservoir considerations. Table 1 summarizes pertinent data about the dam and reservoir.

Table 1. Pertinent Data

Dam	
Type	Concrete Gravity
Length, feet	462.25
Height, feet	87
Spillway Crest Elevation, feet	1026.7 MSL (NAVD 1988)
Top of Parapet Elevation, feet	1035.4 MSL (NAVD 1988)
Toe of Dam, feet	948.4 MSL (NAVD 1988)
Reservoir	
Normal Operating Level	El. 1026.8 (NAVD 1988)
Storage (at normal level),ac-ft	3170
Surface Area (at normal level), acres	119
Drainage Area, square miles	32.2
Length, miles	1.55
Spillway	
Type	Ungated overflow, ogee crest
Total Spillway Length, ft	150
Maximum Spillway Capacity, cfs	15,069 (23% of the PMF)

Several historical sources were referenced in the updated modeling and characterization of the dam, including: 1904 Original Design Drawings (reproduced), 1930 Dam Raising Drawings, 1964 Dam Raising Drawings, Stability Analysis (1991), Safe Yield Study (2003), Bathymetric Survey (2003), Upstream dam inspection by divers (2006), Annual Inspection Reports (various dates), and an Emergency Action Plan (2003).

Different vertical elevation datums were used during the original 1904 construction, 1926, 1931, and 1964 modifications, as well as the 2003 Safe Yield Report. The dam crest was surveyed in August 2008 to establish the reference elevations for this project using the most current survey datum. The Vertical Datum is NAVD 88, and the horizontal datum in NAD 83 Virginia State Plane coordinates.

HYDROLOGY

The watershed upstream of Pedlar Dam is approximately 32 square miles. This sub-basin draining into the reservoir is located within the George Washington National Forest; development of the area contributing to the water supply reservoir is strictly controlled. The watershed below the dam is sparsely populated. The community of Pedlar Mills is located on the Pedlar River approximately 11 river miles downstream from the dam.

Probable Maximum Precipitation (PMP)

The National Oceanographic and Atmospheric Administration (NOAA) has published Hydrometeorological Report (HMR) Numbers 36, 43, 49, 51, 52, and 55 to provide logic and methodology for predicting the PMP for a given area between 10 and 20,000 square miles within the United States. HMR Nos. 51 and 52 are used to determine PMP east of the 105th Meridian, including the Pedlar River Watershed. HMR 52 recommends a procedure for estimating PMP to an area for which both temporal and spatial distributions of precipitation are required. According to the generally accepted standard of practice, the center of the PMP storm pattern is coincident with the centroid of the sub-basin upstream of the dam. The resulting rainfall was defined in 1-hour time steps. With regard to the temporal rainfall distribution, the model assumes that the maximum precipitation occurs in the seventh six-hour time period.

After the storm pattern distribution and basin-averaged rainfall hyetographs were defined, a hydrologic model was developed using HEC-HMS version 3.2, the standard of practice software package developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers. The purpose of this model is to simulate hydrologic losses associated with rainfall-runoff processes. Application of the PMS onto the watershed using HEC-HMS results in calculation of the Probable Maximum Flood (PMF).

The dam is 462.25 feet long and 87 feet high as measured from the downstream toe of the dam. The spillway crest is set at 1026.7 ft MSL according to the project survey data, with a length of 150 feet. The spillway is represented as an ogee spillway with HEC-HMS spillway parameters defined from design and construction details. The dam top is set at 1035.4 ft MSL according to the project survey data. The dam length is set at 312 feet (total dam length minus the spillway length). The level overflow method is prescribed for flow over the dam crest.

The initial elevation set in the reservoir at the start of the simulation was 1026.7, simulating a reservoir full to the spillway elevation at the start of the precipitation event. Therefore modeled inflow into the reservoir is only slightly attenuated by reservoir storage prior to spilling over the dam abutment into the downstream receiving channel.

The results of the HEC-HMS model provide an estimate of the PMF that would drain to the reservoir and the lower sub-basins in the event of PMP event occurring in the watershed as previously described. The maximum flow rate into the reservoir is 67,236 cfs (by comparison, the 1980 calculated value is 65,667 cfs). The maximum water surface elevation in the reservoir is 1043.8 ft MSL (by comparison, the datum-adjusted 1980 value is 1043.5 ft MSL). The maximum storage behind the dam at peak water surface elevation is 5,510 acre-feet.

The model was also run at one half the calculated PMF runoff into the reservoir from the Upper Pedlar sub-basin. The peak outflow is 33,200 cfs, and the corresponding maximum water surface elevation in the reservoir is 1039.0 ft MSL. By comparison, the 1980 corresponding values were 32,833 cfs and 1038.8 ft MSL, respectively.

To confirm that the 72-hour PMP in fact generates the highest water surface elevation, the HMR52 program was run to generate basin-averaged rainfall hyetographs for the 6-hour, 12-hour, and 24-hour events. These rainfall events were simulated into the HEC-

HMS model. The results indicate that the 72-hour event results in the maximum discharge from the reservoir, and therefore is considered the critical storm duration.

BREACH ANALYSIS METHODOLOGY

Simulation of the dam breach was performed using HEC-HMS. Breach parameters were developed that conform to the Federal Energy and Regulatory Commission (FERC) guidelines. To be conservative, the breach height was assumed to equivalent to the height of the dam from the reservoir bottom to the dam crest. Breach simulations were represented during sunny day conditions with the reservoir full to the spillway crest, and at the peak of the PMF. The sunny day breach and PMF breach simulations resulted in maximum flows of 189,726 cfs and 271,453 cfs, respectively.

Table 2. Pedlar Dam Breach Analysis Parameters

Parameter	Symbol	FERC Recommended Range	Selected Value
Height of Breach (ft)	hb	Height of dam above zero storage	87
Breach Width (ft)	Bw	One or more monoliths	150
Side Slope	Z	0≤Z≤Valley Wall Slope	0
Time to Failure (hrs)	TFH	0.1≤TFH≤0.3	0.2

Results of this analysis in terms of reservoir inflow and maximum water surface elevation are comparable and slightly higher than results reported from a similar analysis by the Norfolk District Corps of Engineers in a published 1980 report.

HYDRAULICS

Hydraulic Model

An unsteady flow hydraulic model was developed using the U.S. Army Corps of Engineers' HEC-RAS computer program to evaluate the breach wave propagation resulting from a breach of Pedlar Dam. The initial hydraulic model was limited to the main branch of the Pedlar River between Pedlar Dam and its confluence with the James River. PMF tributary inflow calculated using HEC-HMS was input into the hydraulic model as lateral inflow hydrographs at appropriate locations along the model.

Model Results

The maximum water surface elevation (WSEL) at each cross section location in each model was used to define inundated areas for the sunny day breach and the PMF breach conditions.

The Pedlar River model was run in steady-state mode to determine the dam tailwater conditions for the PMF flow and 50% of PMF with no breach simulated. The tailwater elevation for PMF conditions is 976.73 ft; the 50% PMF tailwater elevation is 968.78 feet

MSL. (The values documented in the 1980 Phase I Inspection Report were 979.7 feet and 971.8 feet MSL, respectively.)

The Pedlar River unsteady hydraulic model was run to simulate a dam breach under three conditions: the PMF dam breach flood, PMF without dam breach, and sunny day breach. Maximum WSELs were calculated at each of the 147 cross sections to generate an area of inundation under both sunny day and PMF conditions. The peak WSELs associated with the three scenarios along with the ground surface were plotted versus river station. Figure 2 presents a profile of the maximum WSEL profile calculated by HEC-RAS for the PMF dam breach flood (red line), PMF without dam breach (green line), and sunny day breach (blue line).

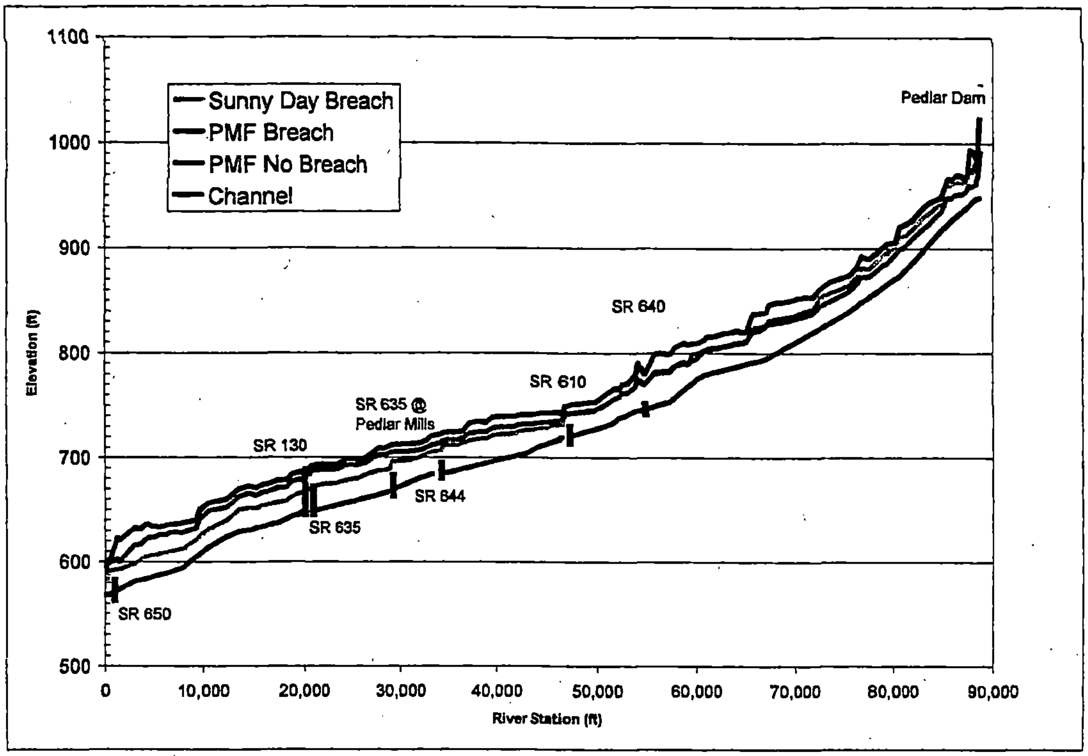

Figure 2. Pedlar Dam Hydraulic Analysis Maximum WSELs

The PMF breach simulation indicates that the Pedlar River breach flow attenuates from the peak flow of 232,315 at Cross Section A (0.4 miles downstream of the dam) to 147,928 cfs at the Pedlar River confluence during the course of the dam breach wave propagation. (Some minor numerical instability is apparent in some of the downstream reaches during the PMF breach simulation, resulting in slightly elevated WSELs at these locations.) The peak of the breach wave takes approximately one hour forty-eight minutes (1:48) to reach the Pedlar River confluence. The maximum WSEL at the confluence is 594.05 feet MSL.

The PMF non-breach simulation does not represent a breach wave. Consequently, flow increases in a downstream direction as tributary inflow enters the main channel. Model results indicate that flow increases from a maximum of about 66,730 cfs at Cross Section A to 126,213 cfs as it enters the James River under this scenario. The maximum WSEL at the confluence under this condition is 592.13 feet. Thus, the difference in maximum WSEL between the PMF breach and non-breach simulations is 1.92 feet.

The sunny day breach simulation indicates that the Pedlar River breach flow attenuates from the peak outflow of 171,277 cfs at Cross Section A to 38,642 cfs at the James River confluence. The breach wave peak takes approximately two hours fifteen minutes (2:15) to reach the James River confluence.

STRUCTURAL ANALYSIS

The material properties used for the structural and stability analysis of the dam were based on the assumption that the dam can be considered as a cohesive and homogenous concrete unit. Material properties were based on previously published concrete data. ACI and FERC publications were used in determining the material values for the analyses. No laboratory testing was performed as part of these assessments. The concrete material properties used for these studies are summarized in Table 3.

Table 3. Dam Material Properties

Properties	Values	
Dam Concrete		
Unconfined Compressive Strength	3,000	lb/in²
Tensile Strength	150	lb/in²
Shear Strength	600	lb/in²
Modulus of Elasticity		
Sustained	2,081,333	lb/in²
Instantaneous	3,122,000	lb/in²
Unit Weight	150	lb/ft³
Poisson's Ratio	0.18	

Foundation Material Properties

The foundation rock properties at Pedlar Dam were based on visual observations and published documentation for similar types of rock in the vicinity. Pedlar Dam is founded on the metasedimentary rocks of the Harpers Formation of the Chilhowee Group. The results of the geologic mapping performed indicate that the rock beneath the dam consists primarily of fine to medium grained, light greenish grey to grayish green, foliated, micaceous schist. The data collected from the geological mapping suggests that reasonably conservative values for compressive strength and angle of friction for the foundation rock are 15,000 pounds per square inch (psi) and 25 degrees, respectively.

Structural Evaluation Criteria

The structural adequacy and stability of Pedlar Dam has been evaluated for the following potential failure modes:

- Dam Overstressing. The results from the structural analysis are compared with the allowable strength of the concrete to determine if the material will crack or crush.

- Dam Stability. Force and moment equilibrium shall be maintained without exceeding the limits of concrete, foundation, or concrete-foundation interface strength. This requires that the allowable unit stresses established for the concrete and foundation materials not be exceeded.

The structural capacity of the material in the dam was evaluated by comparing the calculated stresses from the finite element analysis to the allowable tensile and compressive strength of the assumed homogenous concrete material.

The unconfined compressive strength of the concrete (dam material) is conservatively assumed as approximately 3000 psi. The tensile strength can be estimated using the modulus of rupture ($7.5{*}f'_c{}^{1/2}$). However, a more conservative assumption of $0.2f'_c$ will be used. Given the area of the concrete, shear strength was estimated using FERC 11-3.7.3. The instantaneous modulus of elasticity of the concrete was estimated using ACI 318 (8.5.1). The sustained modulus can be estimated as approximately 2/3 of the instantaneous value.

FERC guidelines recommend that the allowable compressive stress be computed by dividing the actual strength by an appropriate factor of safety (i.e., 2.0 and 1.5 for the usual and unusual loads, respectively). The allowable tensile and shear strengths of the concrete are determined in a manner similar to the allowable compressive strength. Tensile stresses across lift joints may only be a portion of the tensile strength of the intact concrete. Therefore, it is not appropriate to evaluate the indicated tensile stresses of a finite element model solely in terms of an allowable tensile stress for the intact concrete alone.

Loads and Loading Conditions

The behavior of the dam was analyzed for the static loads associated with the usual (normal operating), and unusual (0.5PMF and PMF flood conditions) loading conditions. The static load includes the normal gravity, reservoir level, backfill, and appropriate tailwater. Figure 3 below illustrates a typical summation of each loading condition.

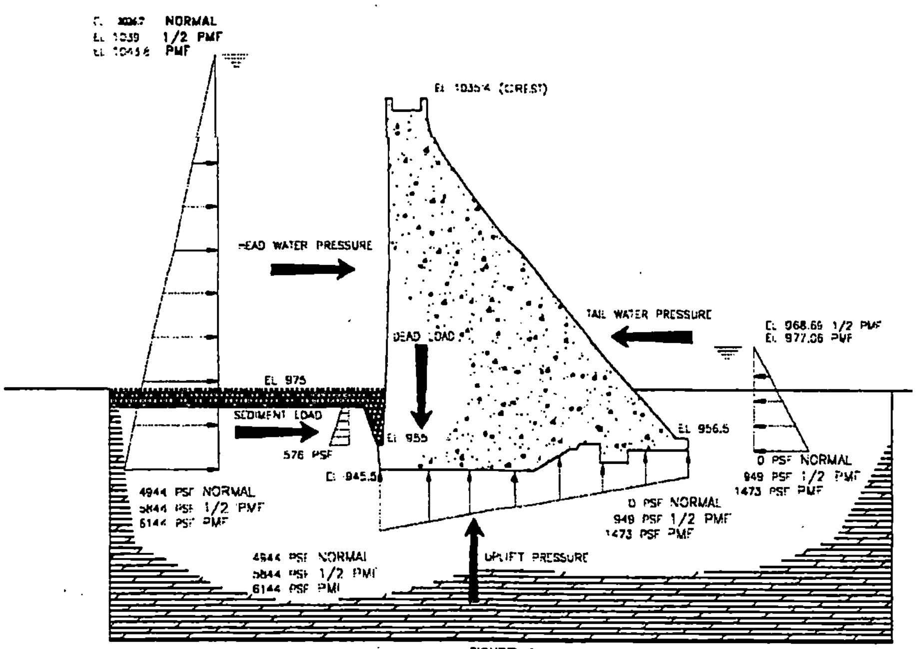

FIGURE 1
LOADING DIAGRAM
(NON-OVERFLOW SECTION)

Figure 3. Loading Diagram

Finite Element Model

The finite element computer program ANSYS was used to perform a linear elastic analysis of Pedlar Dam. The purpose of the analysis was to evaluate the safety of the dam against the identified failure mode for the usual, and unusual loading conditions. The finite element model (FEM) included both the dam and a significant portion of the foundation. The dam portion of the FEM consists of 2 non-overflow sections and 1 spillway section.

The body of a concrete structure is typically assumed to be bonded to the foundation rock. This, however, is not the case for concrete dams. The state-of-the-art practice in concrete dam design and evaluation assumes that the actual dam-foundation interface is not capable of developing tensile stress (no tension condition). Cracking along the dam-foundation interface will result in a redistribution of stresses. Within ANSYS, crack formation (debonding) can be simulated using gap-friction elements or rough-frictional contact. Rough-frictional contact elements are ideal when shear stresses are low and there is no sliding. In the case of Pedlar Dam, the presence of a large key and undulating foundation rock surface suggest shear stress will be small under all loading conditions.

As a result, we initially assumed low shear stress allowing the use of rough-frictional contact. If the model indicated development of shear stresses, the foundation contact assumptions would be re-evaluated and revised accordingly.

The usual (Normal Operating) load combination analyzed the dam for normal static load due to gravity, reservoir at EL 1026.7 feet, silt loads, uplift pressure, and hydrostatic pressure on the dam. The results from the analysis indicate that the entire base of the dam is in compression along with a great majority of the body of the dam itself. All compressive stresses are significantly less than the allowable compressive strength of the dam concrete material. There are places of tension indicated, especially near the top of the dam. However, these values are significantly below the allowable tensile value.

Isolated tensile stresses, above allowable values, are also indicated. These values are anomalies based on singularities from model construction and meshing. They dissipate quickly and are not a concern. Shear stresses throughout the model are also well below allowable values. Based on these stress results, the dam is considered to have adequate safety for the usual load combination.

For the unusual (PMF Flood Condition) loading, the results indicate that the entire base of the dam is in compression along with a great majority of the body of the dam itself. All compressive stresses are less than the allowable compressive strength of the dam material.

There are places of tension indicated, especially near the top of the dam. This is mainly a bending stress due to the PMF loading on the upstream side of the dam. These results are conservative. The dam in this case is overtopped, and there will actually be water on the downstream side of the parapet walls which will reduce these vertical bending stresses. Still, these values are significantly below the allowable tensile value.

Shear stresses are also below allowable values. Isolated higher tensile and shear stresses are also indicated. These values are anomalies based on singularities from model construction (i.e. re-entrant corners) and meshing. They dissipate quickly and are not a concern.

Based on the stress results, the dam is considered to have adequate safety for the unusual load (Flood Condition) combinations for the full and half PMF.

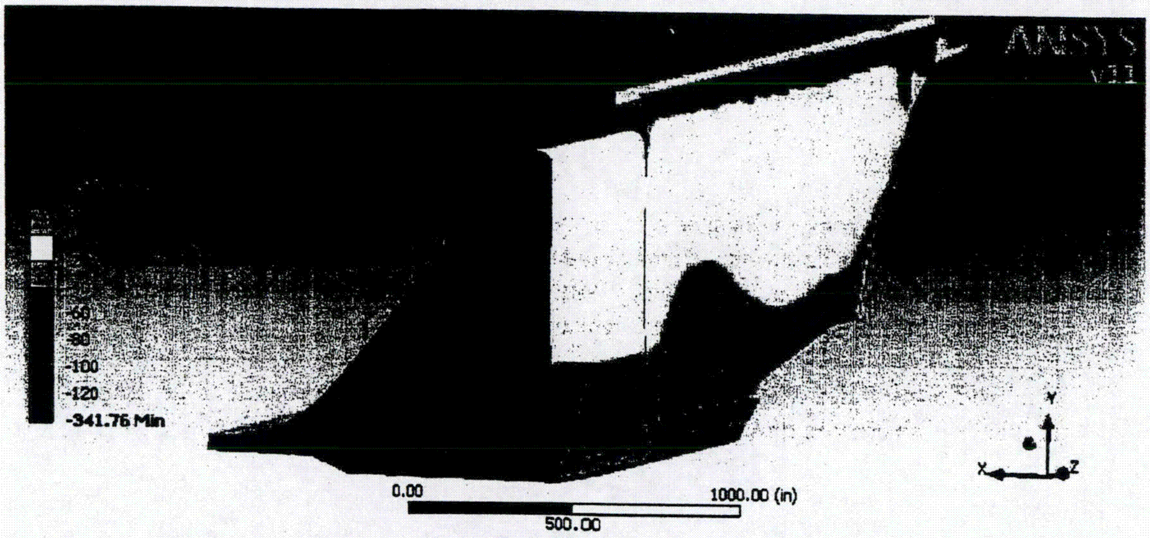

Figure 4. Vertical Stress Plot for Pedlar Dam; PMF Load Case

Displacements for all load cases are minimal and well below any reasonable action level. Modeling results indicate that the entire base of the dam is in compression for all three load cases. Sliding is not a concern especially based on the actual geometry of the base of the dam (two-tier foundation with key). Shear stresses for all load cases are below allowable values. Therefore, based on the results, there was no need to modify the uplift loading or the coefficient of friction along the dam-foundation interface.

Dam stability criteria, along with FERC Chapter 3 – Gravity Dams, state that the basic requirement for stability requires that the allowable unit stresses established for the concrete and foundation materials should not be exceeded. As indicated above, all stresses are within the allowable limits. Modern dam analysis assumes zero tensile strength in the dam-foundation interface. Results show that the base of the dam is entirely in compression for all loading conditions. Therefore, the results of these analyses indicate that Pedlar Dam is stable under the assumed loading conditions and all stability requirements are satisfied.

ROCK SCOUR PROCESS

Rock scour occurs when the erosive capacity of water exceeds the ability of rock to resist scour. The erosive capacity of the water is characterized by the mean and fluctuating dynamic pressures. Pressure fluctuation is the most important hydraulic force leading to scour of rock, and these fluctuations are ever-present in turbulent flow. The magnitude of pressure fluctuation is a function of the turbulence intensity and kinetic energy of the flowing water.

The mean and fluctuating dynamic pressure magnitudes can be estimated by either a direct or indirect approach. The direct approach requires site-specific measurements of pressure fluctuations, which cannot be obtained at Pedlar Dam without an overtopping event. The indirect approach estimates stream power based on the flow and water surface elevations from the hydrologic evaluation of the spillway design flood. The indirect approach is based on the case studies and research of George Annandale (1995), which is accepted by FERC and the design community as the state of the practice.

Rock Erodibility

The ability of the rock to resist scour is quantified by the Erodibility Index. The Erodibility Index is based on several characteristics of the rock mass that are discussed in further detail below. Data collected by Annandale has correlated stream power and the Erodibility Index, and established a threshold for erosion.

The Erodibility Index Method developed by Annandale (1995) is based on an erosion threshold. The erosion threshold relates the relative ability of rock and other earth materials to resist scour to the relative magnitude of the erosive capacity of the water. The relative magnitude of the erosive capacity of flowing water is expressed in terms of its rate of energy dissipation, also known as stream power.

Using the Erodibility Index Method to estimate the scour potential of rock entails calculation of the Erodibility Index of the rock, estimating the magnitude of the erosive power of water, and comparing their magnitudes to determine whether scour will likely occur. If the stream power is greater than the Erodibility Index, then it is concluded that rock scour will develop. If the stream power is less than the erodibility threshold, then it is concluded that rock scour is not likely to occur. The joint sets, Rock Quality Designation (RQD), and compressive strength are important factors in characterizing the rock for erodibility.

Erodibility Index

Water jets from dam overtopping will usually produce erosion in the areas downstream of the dam, unless the rock is extremely hard and quite sound. The Erodibility Index is used to determine the likelihood of erosion based on the rate of energy dissipation due to the overtopping. The Erodibility Index is computed using the following equation:

$$K = M_S \times K_b \times K_d \times J_S \tag{1}$$

where: K = Erodibility Index;

M_S = Mass Strength Number;

K_b = Block Size Number;

K_d = Inter-block Bond Shear Strength Number; and

J_S = Ground Structure Number.

Based on the estimated values for mass strength number (M_s), block size number (K_b), inter-block bond shear strength number (K_d), and the ground structure number (J_s), the estimated Erodibility Index for the schist at the Pedlar Dam is approximately 1,995. This indicates that the rate of energy dissipation due to overtopping (stream power), must be greater than 300 kW/m in order to initiate erosion in the rock mass.

For Pedlar Dam, the rock in the foundation and abutments of the dam is relatively massive, and en-mass removal of rock is unlikely to occur prior to a fracturing of the rock. The field observations of the foundation at Pedlar Dam noted only two prominent joint sets. The joints observed in the rock were typically tight, with joint openings generally characterized as closed. Joint surfaces were generally described as smooth and planar with some staining noted. The likely mode of failure, should this ever occur, would be primarily due to fracture.

Stream Power Calculation

The estimated stream power, which is computed using Equation 2, must be greater than the Erodibility Index in order to initiate erosion in the rock mass. As summarized above, the stream power value necessary to initiate foundation rock scour is 300 kW/m. The erosive stream power of the overtopping jet is computed using the equation below:

$$E = \frac{q \times \Delta E \times \gamma}{A} \tag{2}$$

where: E = Rate of energy dissipation due to overtopping

q = unit discharge

ΔE = Elevation difference (i.e., Reservoir and foundation)

γ = Unit weight of water

A = Area of jet at impact

For these studies, the erodibility of the rock was performed for the probable maximum flood (PMF). The maximum reservoir surface due to the PMF event is estimated to be about El. 1043.8 feet, which results in about 8.4 feet of over-topping of the non-overflow sections of the dam. The overtopping of the Pedlar Dam non-overflow sections occurs for over 8 hours.

The stream power estimating process first computes the jet profile for the overtopping discharge. The stream power is dependent on the total velocity head (i.e., ΔE), computed as the difference between the reservoir and the contact location of the stream jet on the foundation bedrock. In some cases, the stream jet impacts the downstream face of the concrete dam. In these instances, if the concrete is considered in good condition, it is assumed the concrete will not erode. The elevation of the foundation rock was selected based on topographic contours and field observations.

The area of the overtopping jet at the foundation rock can then be estimated from the jet profile. The elevation difference and jet area are then used in Equation 2 to compute the stream power of the overtopping jet. Figure 5 illustrates the stream jet (top and bottom) relative to the downstream slope of the dam for the maximum and minimum jet height conditions, respectively.

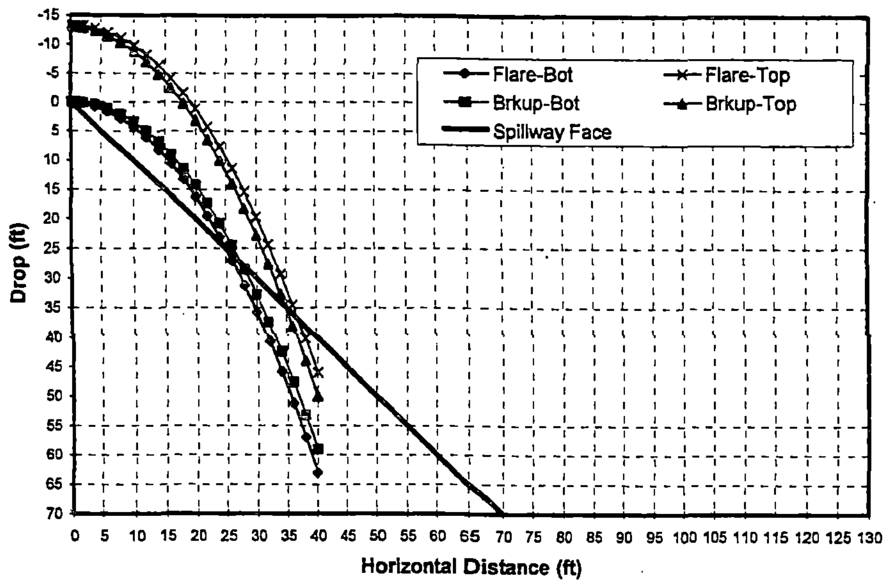

Figure 5. Maximum Stream Jet Projection

As illustrated by Figure 5, the overtopping jet impacts the downstream concrete face and spillway of the dam over much of the dam as shown in red on Figure 6. The maximum stream jet (spillway section) impacts only the downstream face of the spillway. However, the minimum stream jet (non-overflow sections) will impact a relatively small portion of the downstream toe along both abutments as illustrated in blue on Figure 6. The right downstream abutment is exposed to erosive overtopping for approximately 30 feet, and the left abutment for approximately 20 feet. The elevation of the foundation rock in these two areas is approximately El. 1010 feet. The resulting stream power imparted in these areas is estimated to be about 977 kW/m.

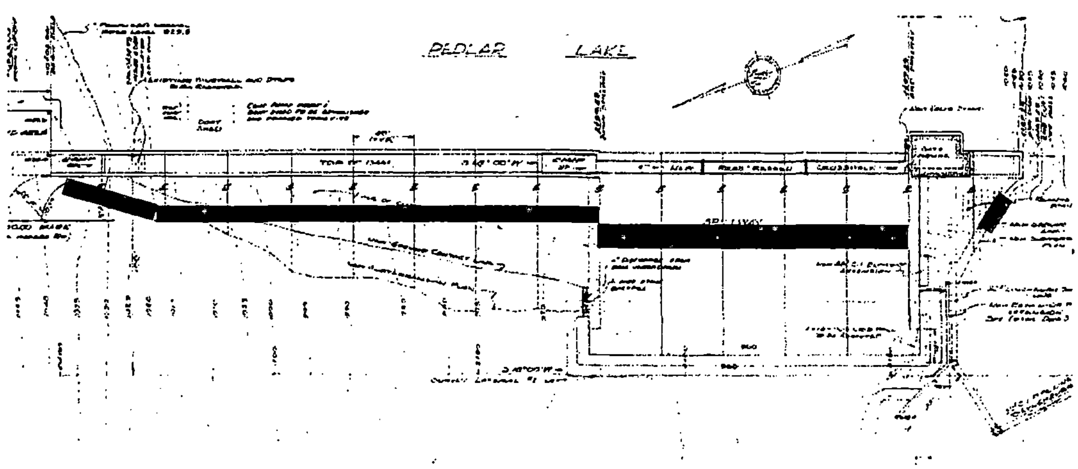

Figure 6. Stream Jet Projection Impact Zones

The Pedlar Dam non-overflow sections will be overtopped during the PMF by about 8.4 feet. This overtopping flow results in a water jet that impacts either the dam (or spillway) or foundation materials. The mass concrete of Pedlar Dam is not considered erodible by the stream power of the overtopping jet. The erodibility results do, however, indicate that the stream power of the overtopping jet is greater than the rock Erodibility Index factor along the exposed abutment areas. Because the estimated stream power (977 kW/m) is in excess of the allowable Erodibility threshold (300 kW/m), scour of the foundation rock for these limited distances from the abutments may occur during overtopping flows associated with the PMF storm event.

CONCLUSIONS

Hazard Classification

Pedlar Dam is a high hazard potential structure based on review of the sunny day inundation limits. As a result of the high hazard designation, according to the dam safety regulations, the assigned SDF is the probable maximum flood (PMF). The spillway configuration at Pedlar Dam is an approximately 150 feet wide ogee crested weir and capable of passing approximately 23% of the PMF without overtopping the rest of the dam.

Armoring Alternatives

In order to protect the dam and abutments from the affects of overtopping, multiple approaches were developed for consideration. For the left abutment, which has a steep rock wall face, shotcrete protection of the rock surface was considered a viable approach. Alternatively for the left abutment, construction of a diversion wall between the abutment face and the intake tower structure would route flows through the primary spillway rather than impacting the abutment.

On the flatter right abutment, more conventional surface protections schemes were analyzed, including precast concrete elements, cast in place concrete, and riprap. A diversion wall also considered for the right abutment, positioned such that it would route overtopping flows around the right abutment or onto the main dam face, but prevented impact with the overburden and foundation at the dam toe.

These solutions were developed in concert with Virginia Dam Safety regulators and construction of the improvements is scheduled for 2011.

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(1) Lines 1 to 5 establish the index rainfall and the magnitude and time arrangement of 24-hour rainfall amounts that would be obtained for the entire basin without reduction for the fact that the storm isohyets do not conform to the shape of the basin.

(2) Lines 6 to 12 incorporate the adjustment required for basin shape and the subdivision of rainfall among sub-basins. These lines can be eliminated where these refinements are not required. Values given in lines 6 to 8 were obtained by planimetering isohyets on Plate 13. Values of line 9 are those of line 5 divided by the total-storm rainfall (15.7 inches). Values of lines 10 to 12 are obtained by multiplying values of line 5 by those of lines 6 to 8 respectively.

(3) Lines 13 to 21 establish the hyetographs for each area. Six-hour percentage of maximum 24-hour rainfall obtained from Plate 10, are applied to each successive 24-hour period of rainfall. These are multiplied by respective values in lines 10-12 to obtain 6-hour rainfall amounts in lines 14 to 16. The tabulation on Plate 13 indicates that t_R is 3 hours in this case (see Plate 11). Appropriate percentages of maximum 6-hour rainfall in 3-hour intervals shown on Plate 11 are entered in line 18, Plate 14. These are multiplied by the respective values of the 66-hour column, lines 14 to 16, to obtain 3-hour amounts on lines 19 to 21.

(4) Lines 22 to 29 establish rainfall excess amounts. Infiltration losses (lines 22 and 23) are subtracted from rainfall amounts for the sub-areas A and B to obtain rainfall excess amounts for those sub-areas (lines 24 and 25). These are converted to volumes (lines 26 and 27, and are added to obtain rainfall-excess volumes for the total area (line 28). These volumes divided by the total area yield average rainfall-excess depths for the total area (line 29). Values of line 24 and 25 would be used in conjunction with unit hydrographs for the subareas in this case because of the existence of a flood-control reservoir at the lower end of area A. In cases where subdivision of the area is made only to account for areal differences in loss rates, values of line 29 can be used in conjunction with a unit hydrograph for the entire area.

2-04. APPROXIMATION OF SPF AS PERCENTAGE OF MAXIMUM PROBABLE FLOOD. As stated in sub-paragraph 1-06 d (2), estimates completed to date indicate that SPF discharges based on detailed studies usually equal 40 to 60 percent of the maximum probable (or "maximum possible") flood for the same basin; a ratio of 50 percent is considered representative of average conditions. Inasmuch as computation of maximum probable flood estimates are normally required as the basis of design of spillways for high dams, it is convenient to estimate the SPF for reservoir projects as equal to 50 percent of the maximum probable flood hydrograph to avoid the preparation of a separate SPF estimate (see paragraph 1-05 and 3-02 d regarding SPF series). Accordingly, this convention is acceptable for reservoir projects in general. The rule may also be applied in estimating SPF hydrographs for basins outside of the region and range of areas covered by generalized charts presented herein where maximum probable flood estimates based on detailed hydrometeorological investigations have been completed. Where snow melt or extreme

Flood Forecasting Data Sheet

River Stage Level (feet) Lynchburg Lower Basin	Date / Reference
35	11/85 Flood
34	100 yr. Flood
33	1877 Flood
30	WT floor level
28	8/69 Flood, Rt. 726 Bridge
26	6/72 Flood, Rt. 726 Bridge
18	Flood Stage

River Level Data

USGS River Data Internet page – http://waterwatch.usgs.gov

Weather / Flood Information

General Weather Info - www.erh.noaa.gov/rnk
www.weather.com/

Godwin Pumps

Virginia: (434) 798-6600
Maryland: (301) 390-3806
North Carolina (919) 661-6061

Estimating Flood Magnitude

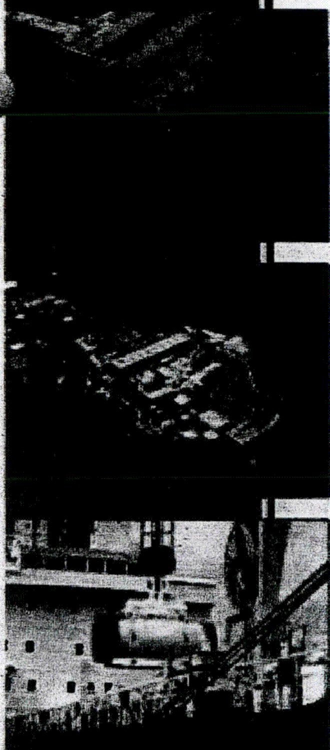
NOTE: The following guidelines are meant to provide general information for predicting the impact of flooding at NOG-L based on easily accessible data. The estimates that are provided are based on historical data that may have changed depending on development within the upstream portion of the James River watershed. Analysis of gauge data should not be taken as a substitute for direct observation of river levels adjacent to the Waste Treatment Complex.

Flood Magnitude	*Holcomb Rock Gauge Station*	*Lynchburg Lower Basin*
MINIMAL	22-27 ft.	18-22 ft.
MODERATE	27-31.5 ft.	22-25 ft.
MAJOR	> 31.5 ft.	> 25 ft.

Minimal – Flood waters will be confined to the area immediately surrounding the river, and will only extend a short distance south onto NOG-L property.

Moderate – Flood waters will inundate the roadway immediately surrounding the ponds, and will begin to threaten to flood the final mixing chamber and Rt. 726.

Major – Flood waters will threaten to inundate the ponds and Waste Treatment, and Rt. 726 will be flooded.



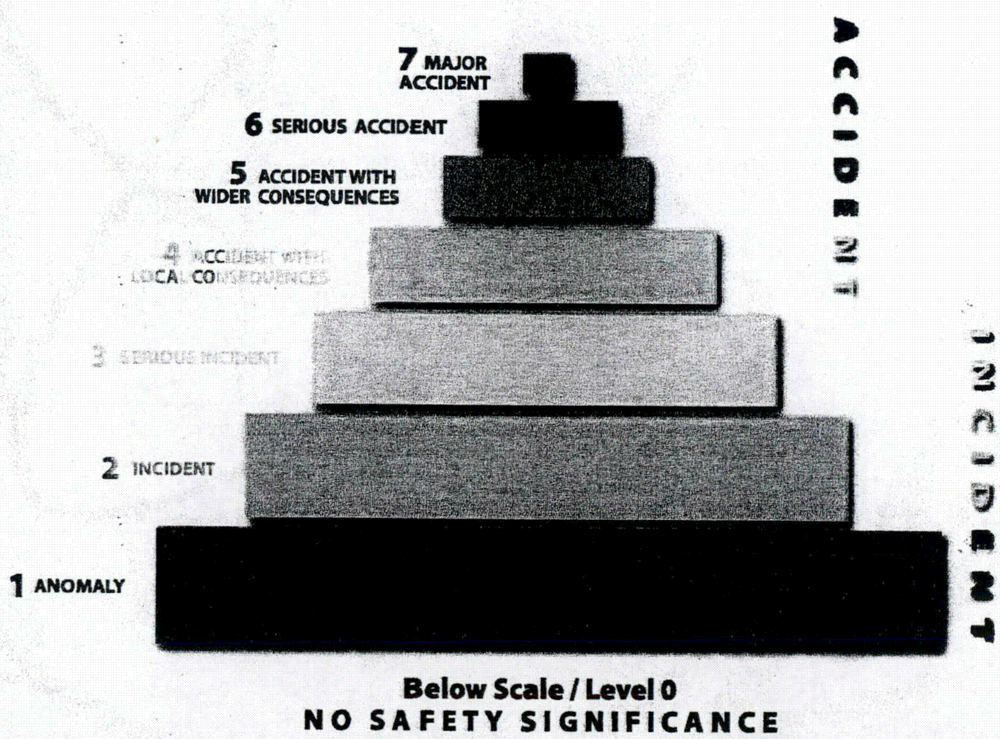
INES

THE INTERNATIONAL NUCLEAR AND RADIOLOGICAL EVENT SCALE

The INES Scale is a worldwide tool for communicating to the public in a consistent way the safety significance of nuclear and radiological events.

Just like information on earthquakes or temperature would be difficult to understand without the Richter or Celsius scales, the INES Scale explains the significance of events from a range of activities, including industrial and medical use of radiation sources, operations at nuclear facilities and transport of radioactive material.

Events are classified on the scale at seven levels: Levels 1–3 are called "incidents" and Levels 4–7 "accidents". The scale is designed so that the severity of an event is about ten times greater for each increase in level on the scale. Events without safety significance are called "deviations" and are classified Below Scale / Level 0.



IAEA
International Atomic Energy Agency

OECD

For more information: *www-news.iaea.org*

Accident with Local Consequences Level 4

Serious Incident Level 3

Incident Level 2

NO SAFETY SIGNIFICANCE (Below Scale Level 0)

INES classifies nuclear and radiological accidents and incidents by considering three areas of impact:

People and the Environment considers the radiation doses to people close to the location of the event and the widespread, unplanned release of radioactive material from an installation.

Radiological Barriers and Control covers events without any direct impact on people or the environment and only applies inside major facilities. It covers unplanned high radiation levels and spread of significant quantities of radioactive materials confined within the installation.

Defence-in-Depth also covers events without any direct impact on people or the environment, but for which the range of measures put in place to prevent accidents did not function as intended.

Communicating Events

Nuclear and radiological events are promptly communicated by the INES Member States, otherwise a confused understanding of the event may occur from media or from public speculation. In some situations, where not all the details of the event are known early on, a provisional rating may be issued. Later, a final rating is determined and any differences explained.

To facilitate international communications for events attracting wider interest, the IAEA maintains a web-based communications network that allows details of the event to immediately be made publicly available.

The two tables that follow show selected examples of historic events rated using the INES scale, ranging from a Level 1 anomaly to a Level 7 major accident; a much wider range of examples showing the rating methodology is provided in the INES Manual.

Scope of the Scale

INES applies to any event associated with the transport, storage and use of radioactive material and radiation sources, whether or not the event occurs at a facility. It covers a wide spectrum of practices, including industrial use

EXAMPLES OF EVENTS AT NUCLEAR FACILITIES

	People and Environment	Radiological Barriers and Control	Defence-in-Depth
7			
6			
5			
4	*Tokaimura, Japan, 1999* — Fatal overexposures of workers following a criticality event at a nuclear facility.	*Saint Laurent des Eaux, France, 1980* — Melting of one channel of fuel in the reactor with no release outside the site.	
3	*No example available*	*Sellafield, UK, 2005* — Release of large quantity of radioactive material, contained within the installation.	*Vandellos, Spain, 1989* — Near accident caused by fire resulting in loss of safety systems at the nuclear power station.
2	*Atucha, Argentina, 2005* — Overexposure of a worker at a power reactor exceeding the annual limit.	*Cadarache, France, 1993* — Spread of contamination to an area not expected by design.	*Forsmark, Sweden, 2006* — Degraded safety functions for common cause failure in the emergency power supply system at nuclear power plant.
1			

EXAMPLES OF EVENTS INVOLVING RADIATION SOURCES AND TRANSPORT

	People and Environment	Defence-in-Depth
7		
6		
5		
4	*Fleurus, Belgium, 2006* — Severe health effects for a worker at a commercial irradiation facility as a result of high doses of radiation.	
3	*Yanango, Peru, 1999* — Incident with radiography source resulting in severe radiation burns.	*Ikitelli, Turkey, 1999* — Loss of a highly radioactive Co-60 source.
2	*USA, 2005* — Overexposure of a radiographer exceeding the annual limit for radiation workers.	*France, 1995* — Failure of access control systems at accelerator facility.
1		

such as radiography, use of radiation sources in hospitals, activity at nuclear facilities, and transport of radioactive material.

It also includes the loss or theft of radioactive sources or packages and the discovery of orphan sources, such as sources inadvertently transferred into the scrap metal trade.

When a device is used for medical purposes (e.g., radiodiagnosis or radiotherapy), INES is used for the rating of events resulting in actual exposure of workers and the public, or involving degradation of the device or deficiencies in the safety provisions. Currently, the scale does not cover the actual or potential consequences for patients exposed as part of a medical procedure.

The scale is only intended for use in civil (non-military) applications and only relates to the safety aspects of an event. INES is not intended for use in rating security-related events or malicious acts to deliberately expose people to radiation.

What the Scale is Not For

It is not appropriate to use INES to compare safety performance between facilities, organizations or countries. The statistically small numbers of events at Level 2 and above and the differences between countries for reporting more minor events to the public make it inappropriate to draw international comparisons.

History

Since 1990 the scale has been applied to classify events at nuclear power plants, then extended to enable it to be applied to all installations associated with the civil nuclear industry. By 2006, it had been adapted to meet the growing need for communication of the significance of all events associated with the transport, storage and use of radioactive material and radiation sources.

The IAEA has coordinated its development in cooperation with the OECD/NEA and with the support of more than 60 Member States through their officially designated INES National Officers.

The current version of the INES manual was adopted 1 July 2008. With this new edition, it is anticipated that INES will be widely used by the Member States and become the worldwide scale for putting into the proper perspective the safety significance of nuclear and radiation events.

INES

THE INTERNATIONAL NUCLEAR AND RADIOLOGICAL EVENT SCALE

GENERAL DESCRIPTION OF INES LEVELS

INES Level	People and Environment	Radiological Barriers and Control	Defence-in-Depth
[redacted]	[redacted]		
[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	
Accident with Local Consequences Level 4	• Minor release of radioactive material unlikely to result in implementation of planned countermeasures other than local food controls. • At least one death from radiation.	• Fuel melt or damage to fuel resulting in more than 0.1% release of core inventory. • Release of significant quantities of radioactive material within an installation with a high probability of significant public exposure.	
Serious Incident Level 3	• Exposure in excess of ten times the statutory annual limit for workers. • Non-lethal deterministic health effect (e.g., burns) from radiation.	• Exposure rates of more than 1 Sv/h in an operating area. • Severe contamination in an area not expected by design, with a low probability of significant public exposure.	• Near accident at a nuclear power plant with no safety provisions remaining. • Lost or stolen highly radioactive sealed source. • Misdelivered highly radioactive sealed source without adequate procedures in place to handle it.
Incident Level 2	• Exposure of a member of the public in excess of 10 mSv. • Exposure of a worker in excess of the statutory annual limits.	• Radiation levels in an operating area of more than 50 mSv/h. • Significant contamination within the facility into an area not expected by design.	• Significant failures in safety provisions but with no actual consequences. • Found highly radioactive sealed orphan source, device or transport package with safety provisions intact. • Inadequate packaging of a highly radioactive sealed source.
[redacted]			[redacted]

NO SAFETY SIGNIFICANCE *(Below Scale/Level 0)*

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International Atomic Energy Agency
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08-26941 / E

Flooding Issues: Guidance Inquiry Process, Hazard Re-evaluations

July 11, 2012

NEI

Discussion Points

- NRC TI and Audit Process
- Loss of UHS
- Dam Failures
- Hazard Screening
- Other FAQs

NEI

NRC TI

- Industry comments
  - Contents of walkdown package
  - Implication of expected licensee actions upon observation of a small APM with significant consequences
    - Should be normal practices
  - Scope of significant consequences
    - Challenge to risk significant vs loss of safety function

NEI

Loss of UHS

- On June 26th NRC informed the FFTF that evaluations of loss of UHS was expected if the UHS was impounded by a down stream dam
  - Determine affect of calculated flood conditions on the downstream dam (flood only)
- This is a change in the industry's understanding of the staff's position on this issue

NEI

Loss of UHS

- Industry NRC steering committee meetings in December 2011 decided that loss of UHS water source would be addressed later (tier 2 or 3)
- FFTF NRC meetings in January addressed the question of evaluating loss of UHS during a flood
- FFTF understood that flood evaluations would only address loss of the equipment that was needed to move the water from the UHS to the plant (pumps, valves, and possible piping)

NEI

Loss of UHS

- March 2012 50.54(f) letter contains the following statement in the context of integrated assessment (emphasis added)

  "The scope also includes those features of the ultimate heat sinks (UHS) that could be adversely affected by the flood conditions <u>and lead to degradation of the flood protection</u> (the loss of UHS from non-flood associated causes are not included)."

  - Loss of UHS impounded by an upstream dam should be addressed because it affects flood protection
  - Loss of a downstream dam cannot possibly lead to degradation of flood protection
- The 50.54(f) letter is not consistent with the Staff's request

NEI

Loss of UHS

- Industry concerns
  - Utilities have not accounted for the effort needed to address downstream dam failures. This will affect completion of flooding analyses.
    - A number of sites are affected (12 known so far)
  - The steering committee agreed that addressing loss of UHS water source is a tier 2 or 3 issue
    - The integrated assessment will move a tier 2 or 3 issue into tier 1

NEI

Dam Failures - June 13th meeting

- Three levels of agreement
  - Can dam failure possibility be evaluated as opposed to assumed? - YES
  - What factors must be addressed to assess the credibility of a dam failure? – White Paper
  - What guidance is acceptable to consistently evaluate dam failure? - White Paper
- Security threats need not be considered

NEI

Dam Failure - June 13th meeting

- Seeking acceptance of methods/approaches for defining breach parameters for dam failure evaluations - OK
  - Breach geometry
  - Failure time
  - Type of breach
- Examples of breach development methods - OK
  - Army Corps of Engineers 2007
  - Bureau of Reclamation 1998 (Wahl)
  - Dept of Interior 2009 paper (Xu, Zhang)
- Techniques (such as HEC-RAS, HEC-HMS, various proprietary models) determine failure results - OK

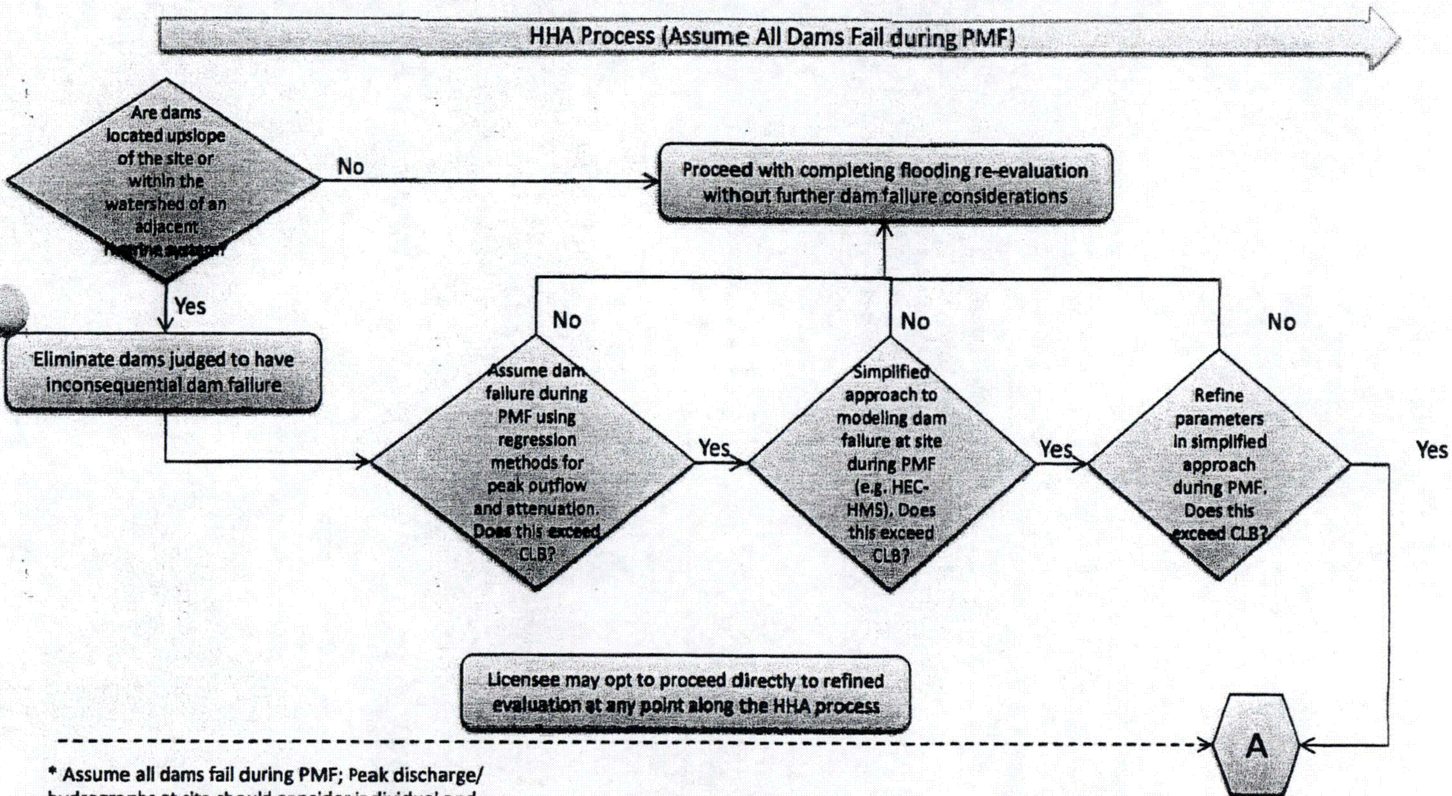
NEI

Dam Failure

- Based on June 13th meeting
  - Dam failures need not automatically be assumed for all failure modes when supported by engineering justification
  - Failure mode analysis should be physics based and realistic but conservative
  - Industry is developing a dam failure white paper for guidance and will seek NRC endorsement

NEI

Dam Failure Evaluation Decision/Process Flow Chart



* Assume all dams fail during PMF; Peak discharge/ hydrographs at site should consider individual and cascading failures as applicable. Use conservative dam breach parameters.

Assessing Dams w/ Inconsequential Failure

- Dam inventories and classification systems can be used to identify dams that can be eliminated from further consideration (e.g. small, low-hazard dams)
- When in question, a relationship can be developed between the size of dam (e.g. height) and distance to site to further screen out dams from further consideration. For example, use the USBR (1982) equations for attenuation and peak outflow estimates, respectively, as follows:

$$Q_r = 10^{\log(Q_p) - 0.01X} \; (Q_p \; in \; cfs; X \; in \; miles)$$

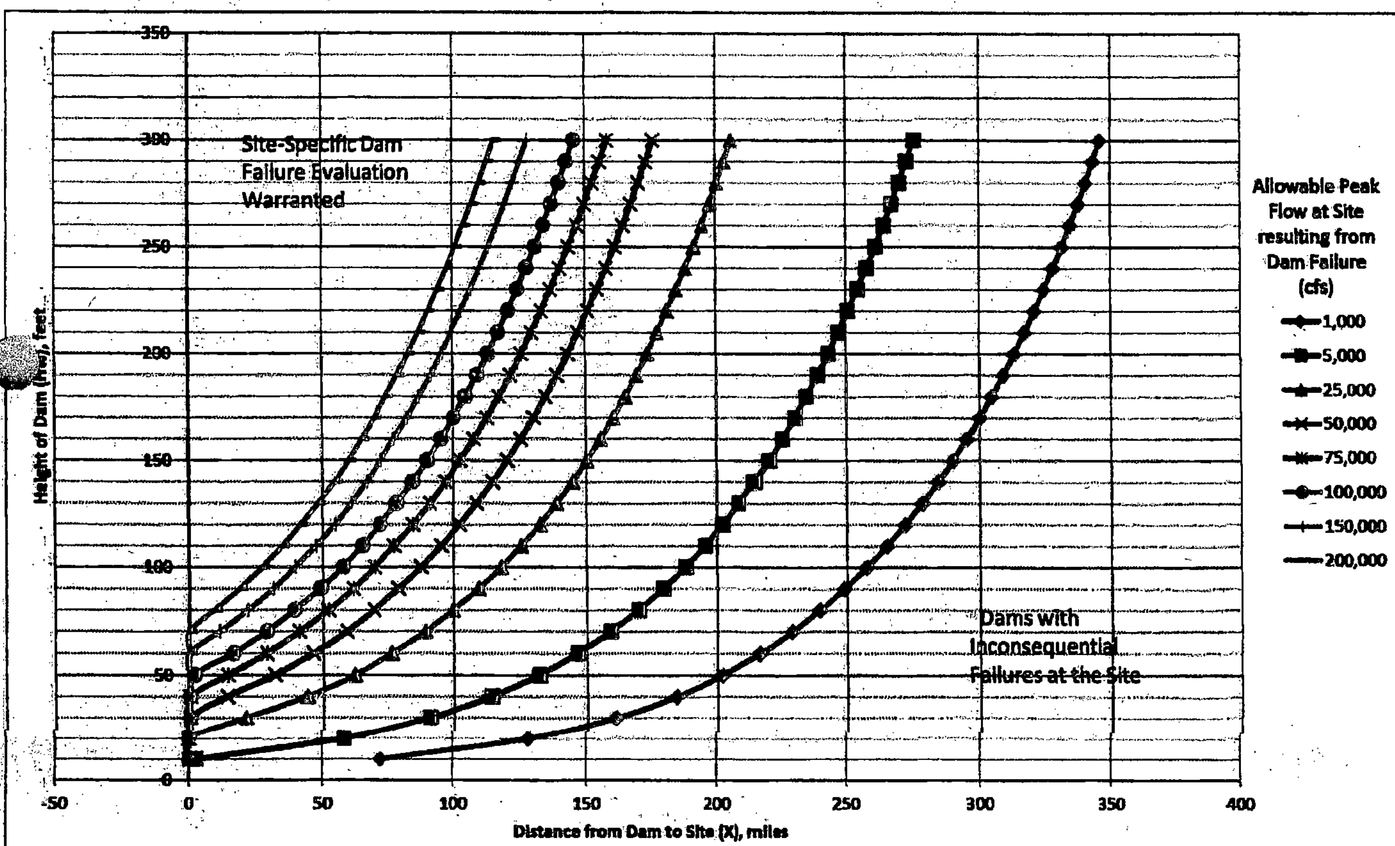
$$Q_p = 19.1 H_w^{1.85} \; (Q_p \; in \; cms; H_w \; in \; meters)$$

- Converting to English units, combining and simplifying,

$$X = 100(log(74.980 H_w^{1.85}) - log Q_r) \; (Q_r \; in \; cfs; H_w \; in \; feet; X \; in \; miles)$$

- Math needs to be checked.
- See chart on next slide.

Assessing Dams with Inconsequential Failure



Regression Methods for Peak Outflow and Attenuation Estimates

- USBR (1982) Peak Outflow (Case Study for 21 dam failures)
- Froehlich (1995b) Peak Outflow (Case Study for 22 dam failures)
- National Weather Service (NWS) Simplified Dam Break Model (for dam heights between 12 and 285 feet)
- Natural Resources Conservation Service (NRCS); formerly the Soil Conservation Service (SCS)

Simplified Dam Failure Modeling (e.g. HEC-HMS)

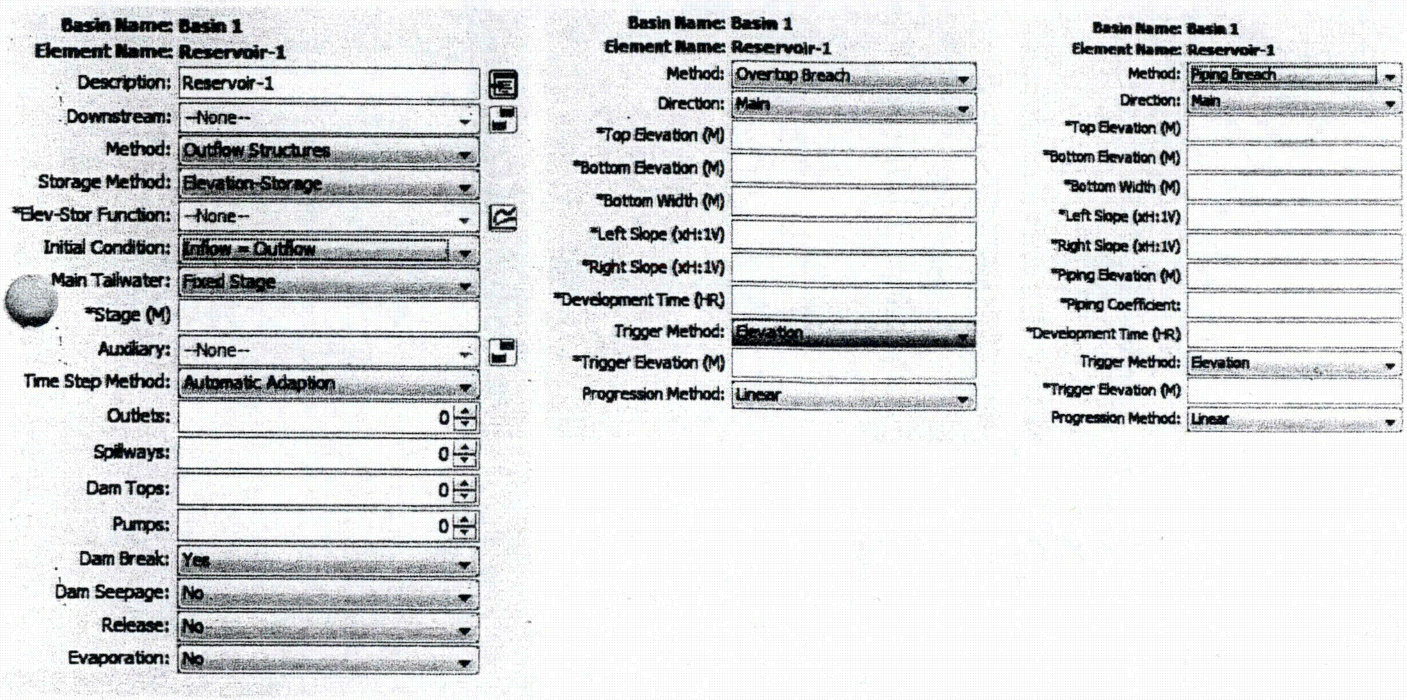
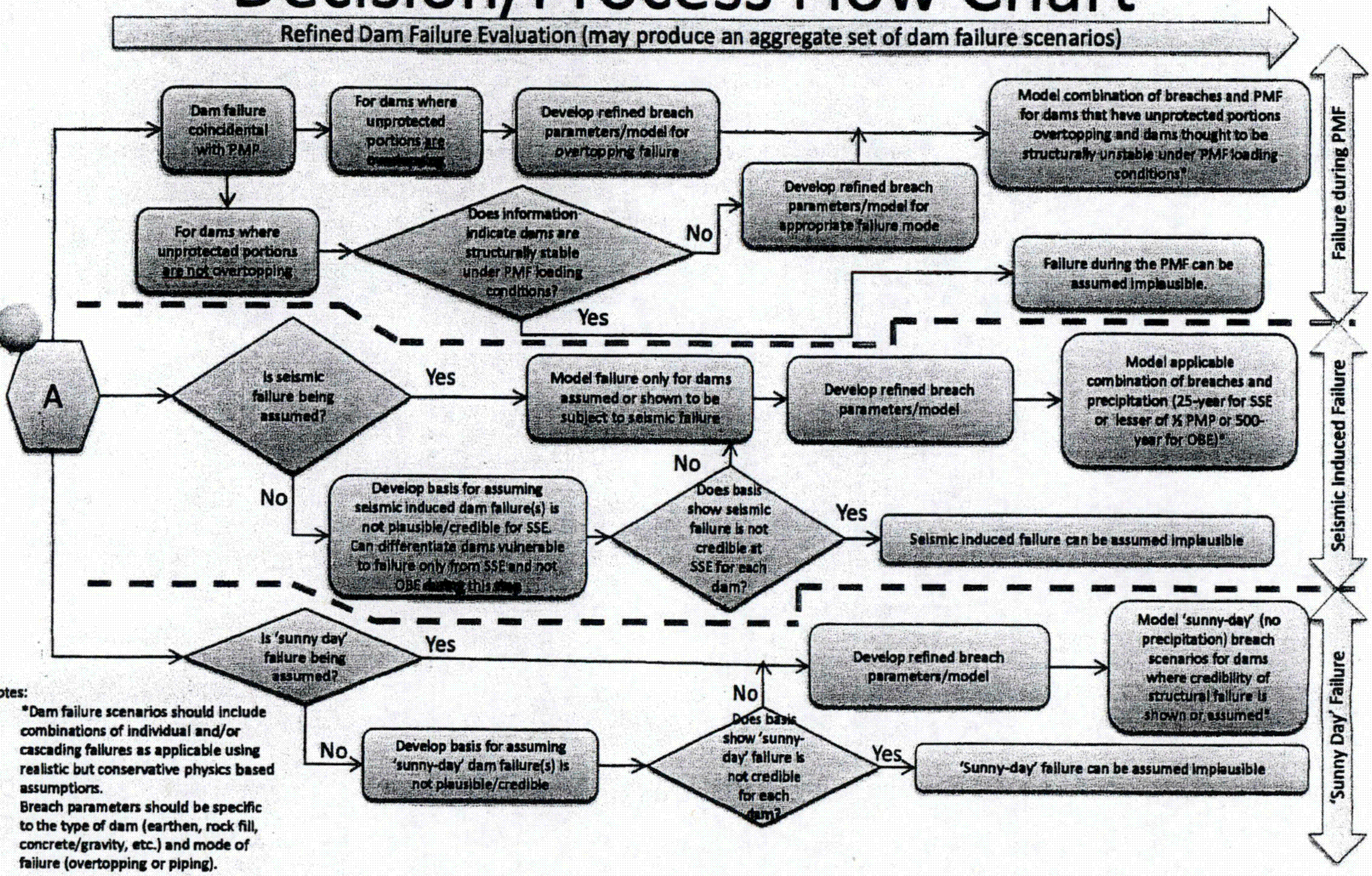


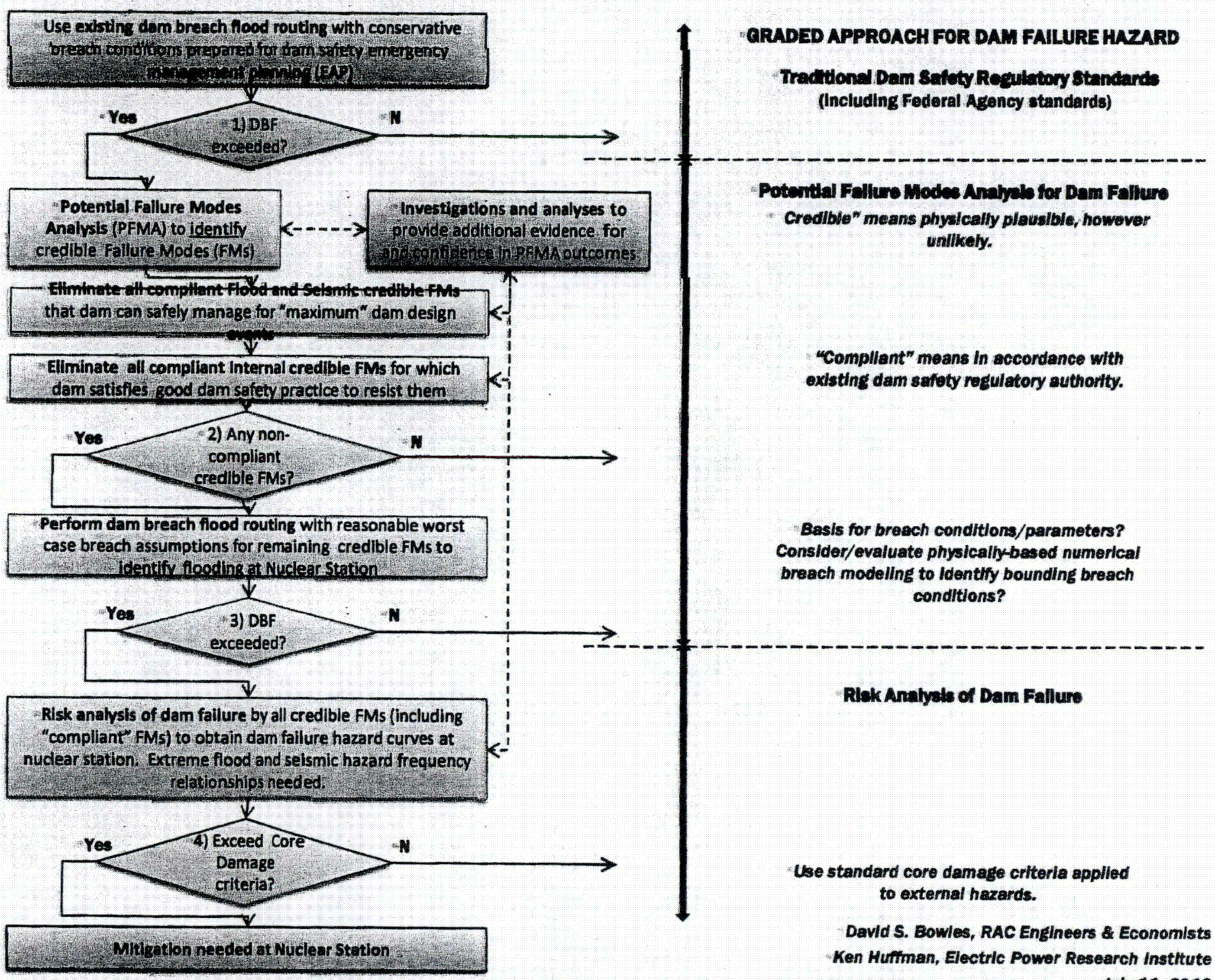
Figure 3- Dam Breach Menu Options in HEC-HMS

Dam Failure Evaluation Decision/Process Flow Chart



Notes:

1. *Dam failure scenarios should include combinations of individual and/or cascading failures as applicable using realistic but conservative physics based assumptions.
2. Breach parameters should be specific to the type of dam (earthen, rock fill, concrete/gravity, etc.) and mode of failure (overtopping or piping).



David S. Bowles, RAC Engineers & Economists
Ken Huffman, Electric Power Research Institute
July 11, 2012

Hazard Screening

- Screening (as opposed to analysis) is acceptable for some hazards
- Justification required
  - Based on facts and data
  - Addresses causal mechanisms – absent or insignificant
  - Demonstrates incapability of producing a flood
  - No historical record of causal mechanism
  - Geographical area in vicinity of site is considered

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Potential FAQs

- Sea level rise

NEI

CECW Engineer Manual 1110-2-1411	Department of the Army U.S. Army Corps of Engineers Washington, DC 20314-1000	EM 1110-2-1411 1 March 1965
	STANDARD PROJECT FLOOD DETERMINATION	
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