What Can Owners Do to Prepare for RIDM?

RIDM Level 1 Workshop – Spring 2012

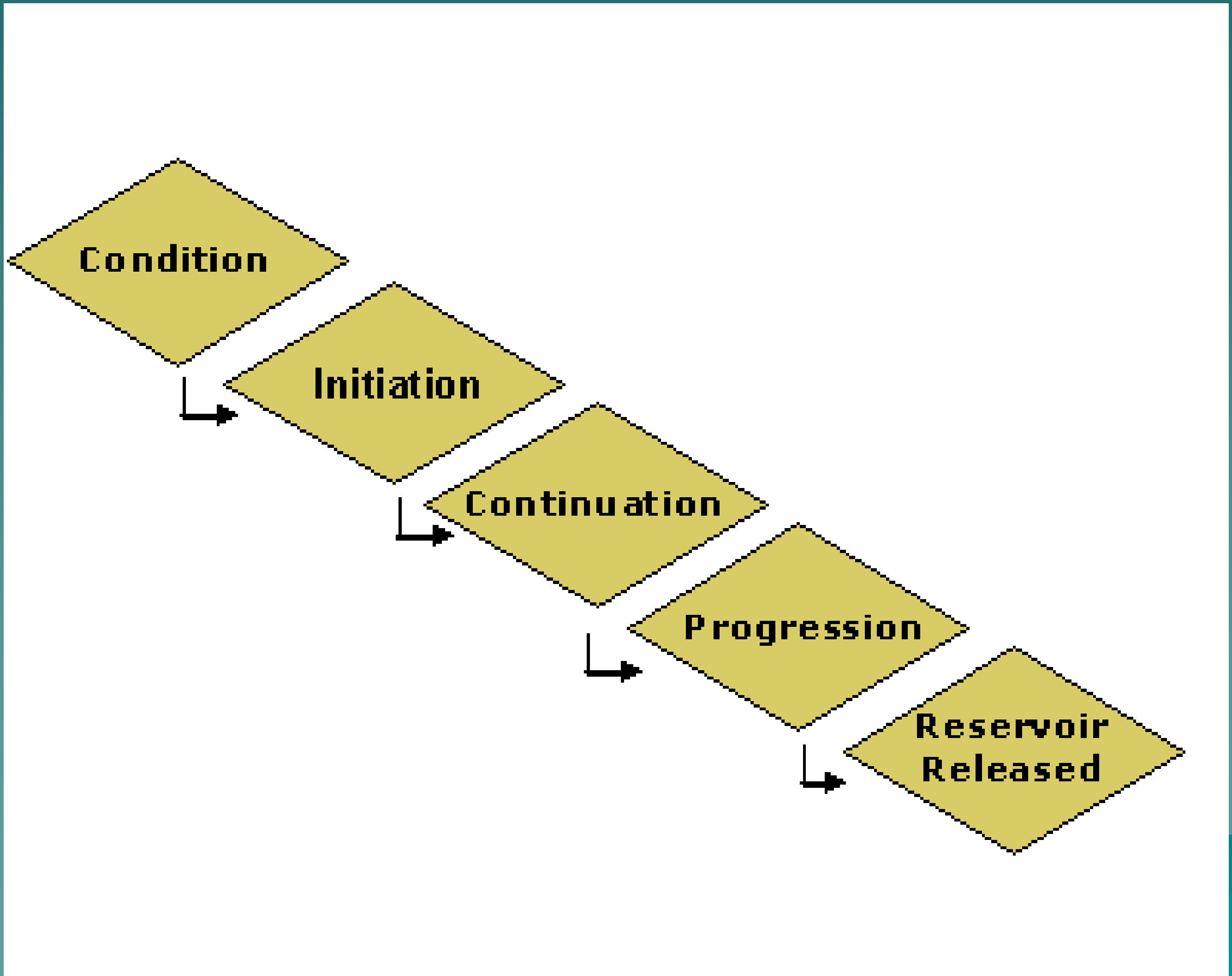
Better Potential Failure Modes (PFMs)

- Risk analysis requires PFMs be written thoroughly and as event trees
- Typically FERC PFMs are written as simplified descriptions without detail
- Some include multiple loading conditions per PFM
- Some include multiple PFMs, e.g., multiple exits for an internal erosion PFM

Better PFMs

- All PFMs need to be reevaluated and revised as needed
- One failure mode (loading, etc,) per PFM
- Critical PFMs need thorough event tree type descriptions

Event Trees


Condition
Initiation
Continuation
Progression
Reservoir
Released

Internal Erosion Event List

from BOR Best Practices

- ➥Reservoir at or above threshold level
- ➥Initiation – Erosion starts
  - ➥Continuation – Unfiltered or inadequately filtered exit exists
    - ➥Progression – Roof forms to support a pipe*
    - ➥Progression – Upstream zone fails to fill crack
    - ➥Progression – Constriction or upstream zone fails to limit flows
      - ➥Intervention fails to prevent “break-through”
- Dam breaches

- *Node eliminated for Progressive Erosion

PFM 1A

- **Unedited (insufficient detail – 3 PFMs):** Seepage or piping through the right abutment mud flow leads to an embankment failure, results in uncontrolled release of reservoir

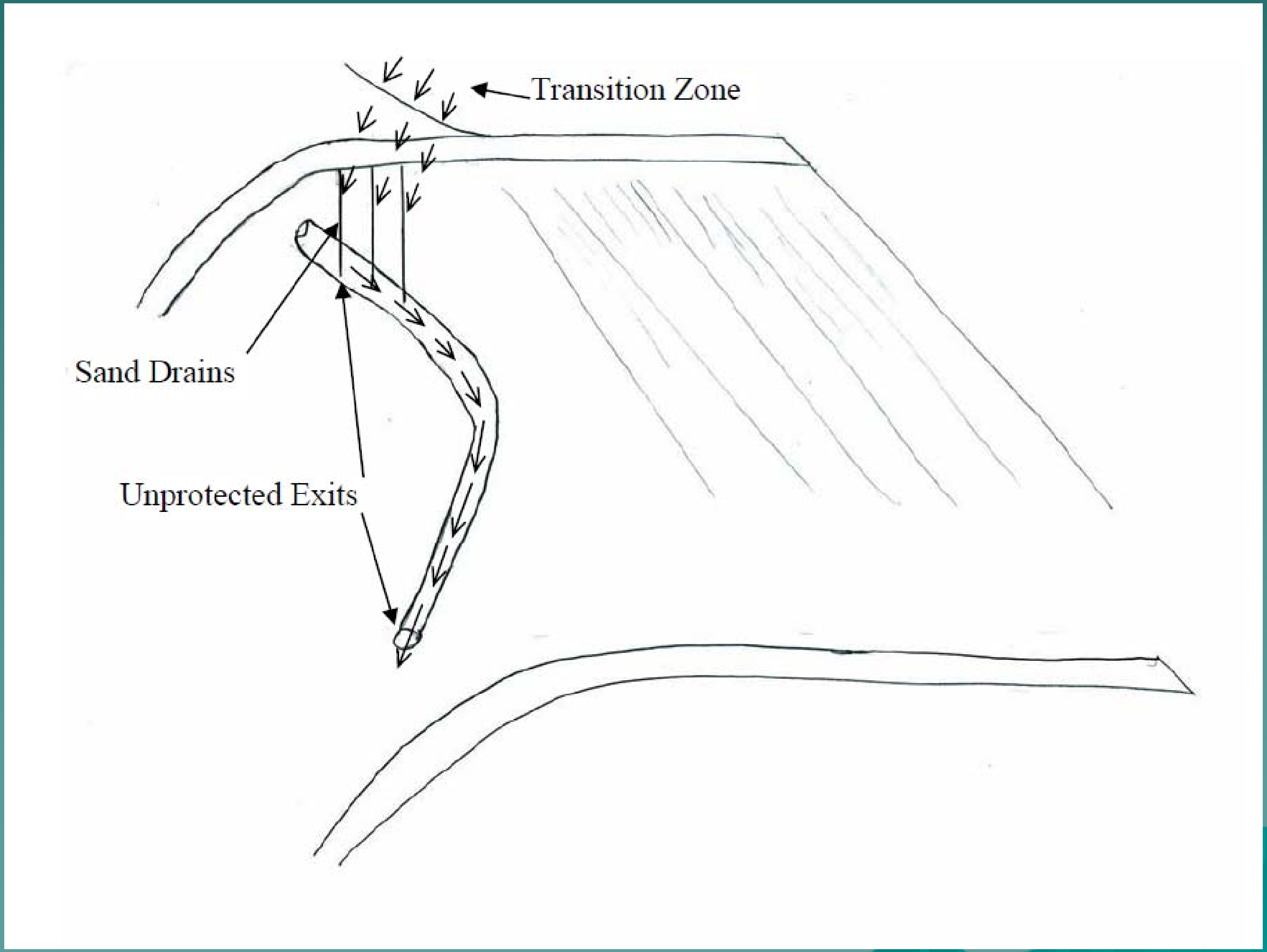
- **Edited – PMF 1A:** This PFM scenario involves seepage through the right abutment (mud flow) that is collected by one of the 8 and 12-inch CMP conduits. This section of the dam has no core and a limited transition zone.
  - **Initiation:** One of the 12-inch conduits collapses due to deterioration
  - **Continuation:** A hole is formed in the conduit that provides an unfiltered exit for seepage flows (No filter exists).
    - **Progression:** Soil material begins to pass freely into the conduit (roof exists), transported by the seepage flow.
    - **Progression:** A pipe develops upstream from the conduit through the mudflows and transition zone by backward erosion (roof develops) to the reservoir
    - **Progression:** The pipe continues to enlarge as soil is transported into the 12-inch conduit.
    - **Progression:** Collapse of the overlying soil occurs resulting in settlement of the ground/crest to below reservoir level.
  - **Breach:** Subsequent overtopping results in down cutting, leading to breach and an uncontrolled release of reservoir.

PFM 1B

- **Unedited (insufficient detail – 3 PFMs):** Seepage or piping through the right abutment mud flow leads to an embankment failure, results in uncontrolled release of reservoir

- **Edited – PMF 1A:** This PFM scenario involves seepage through the right abutment (mud flow) that is collected by the 72/54-inch CMP conduit. This section of the dam has no core and a limited transition zone.
  - **Initiation:** Deterioration of the CMP leads to a large opening in the top or sides of the conduit.
  - **Continuation:** A hole is formed in the conduit that provides an unfiltered exit for seepage flows (No filter exists).
    - **Progression:** Soil material begins to pass freely into the conduit, transported by the seepage flow.
    - **Progression:** A pipe develops, potentially through the sand drains which appears to be a potential weak link since they may intercept a more pervious layer in the overlying soil which results in an increased gradient into the pipe than might otherwise exist (roof exists).
    - **Progression:** A large void develops over time through the mud-flow materials up to near the reservoir
    - **Progression:** Collapse of the overlying soil occurs, resulting in settlement of the ground/crest to below reservoir level.
  - **Breach:** Subsequent overtopping results in down cutting, leading to breach and an uncontrolled release of reservoir.

Internal Erosion PFM – Sketch



PFM 1C

- **Unedited (insufficient detail – 3 PFMs):** Seepage or piping through the right abutment mud flow leads to an embankment failure, results in uncontrolled release of reservoir

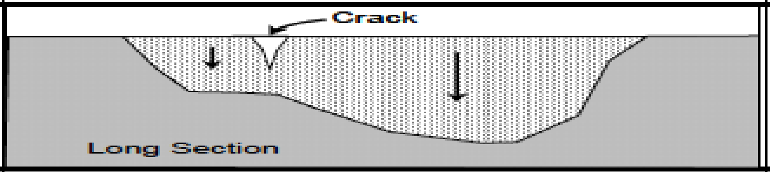
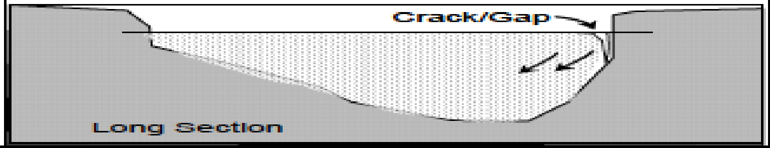
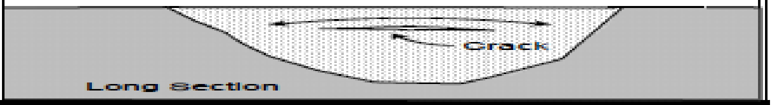
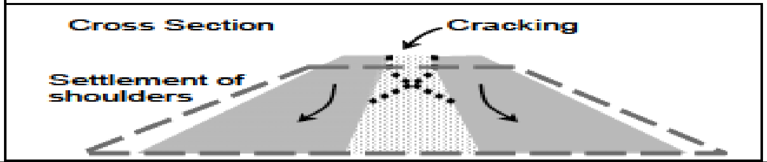
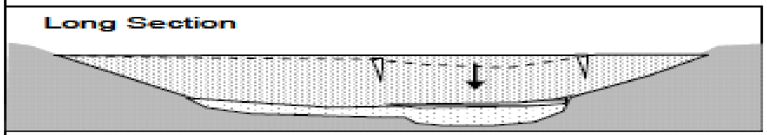
- **Edited – PMF 1A:** This PFM scenario involves seepage through the right abutment (mud flow) that is collected by the 72/54-inch CMP conduit buried and tunneled into the abutment. This section of the dam has no core and a limited transition zone.
- **Initiation:** Deterioration of the wood lagging around the tunneled 54-inch diameter portion of the CMP leads to formation of voided areas along the outside of the conduit.
  - **Continuation:** This increases the gradient along the side of the conduit, initiating soil transport at the downstream end of the conduit. (No filter exists).
    - **Progression:** Soil material begins to pass freely along the conduit, transported by the seepage flow.
    - **Progression:** A pipe develops, potentially through the sand drains (roof exists).
    - **Progression:** A large void develops over time through the mud-flow materials up to near the reservoir
    - **Progression:** Collapse of the overlying soil occurs, resulting in settlement of the ground/crest to below reservoir level.
  - **Breach:** Subsequent overtopping results in down cutting, leading to breach and an uncontrolled release of reservoir.

Internal Erosion PFMs Examples

from Piping Toolbox

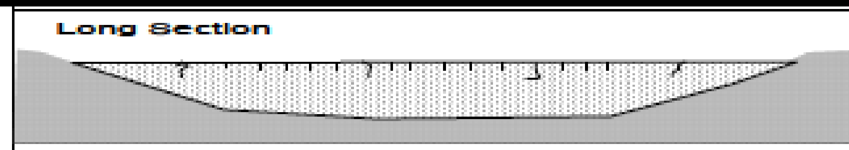
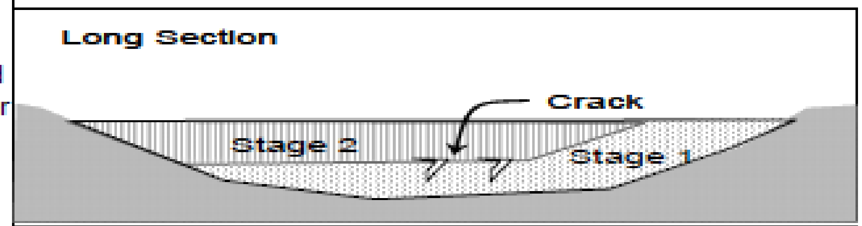
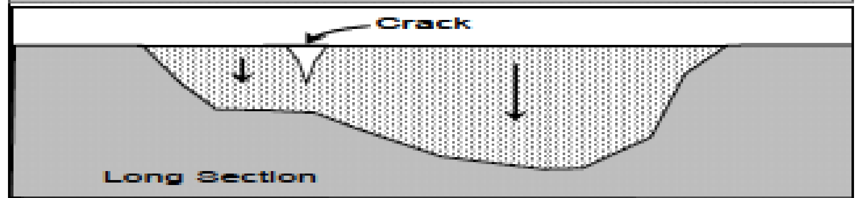
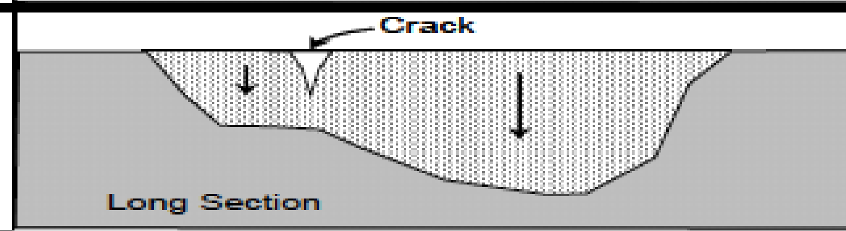
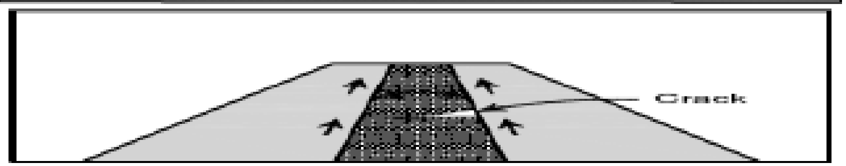
Failure Mode: Internal Erosion through the Embankment

Consider cracking of the upper part of the embankment as appropriate

	Failure Path/Location	Sketch
FM 1	Transverse cracking due to cross valley differential settlement	
FM 2	Transverse cracking due to differential settlement adjacent a vertical cliff at the top of the embankment	
FM 3	Transverse cracking due to cross valley arching	
FM 4	Transverse cracking resultant on cross section settlement	
FM 5	Transverse cracking due to differential settlements in the foundation beneath the core	
FM	Transverse cracking due to differential settlements due to embankment staging	

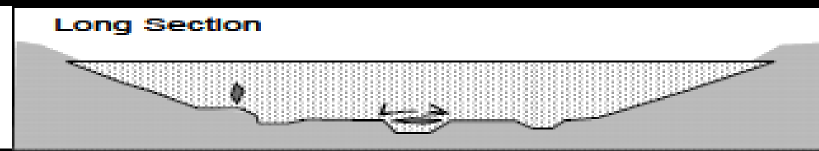
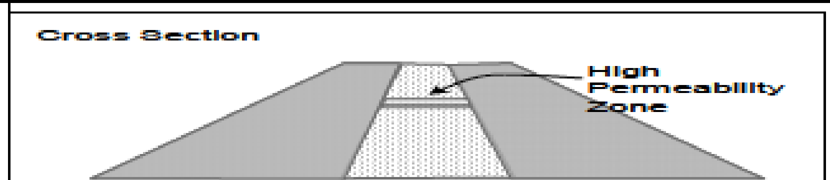
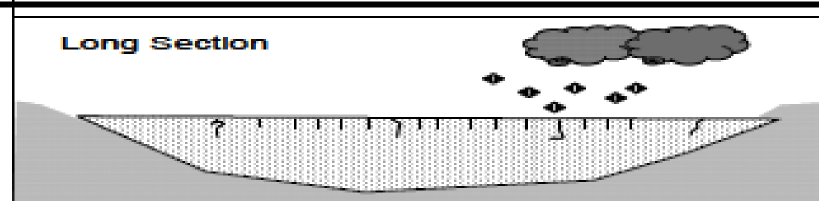
Internal Erosion PFMs Examples

from Piping Toolbox

FM 6	Cracking in the crest due to desiccation by drying	
FM 7	Cracking on seasonal shutdown layers during construction and staged construction due to desiccation by drying - also consider for the middle and lower parts of the dam	
FM9	Transverse cracking due to differential settlements due to embankment staging	
FM9	Transverse cracking due to cross valley differential settlement	
FM 10	Transverse cracking due to differential settlement causing arching of the core onto the shoulders of the embankment	
	Failure Path/Location	
FM 11	Transverse cracking or hydraulic fracture in the lower part of the embankment due to differential settlement in the foundation under the core	See FM 5

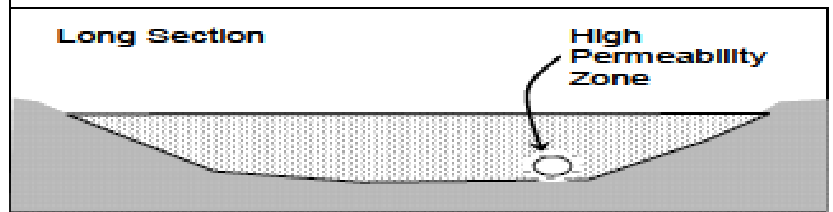
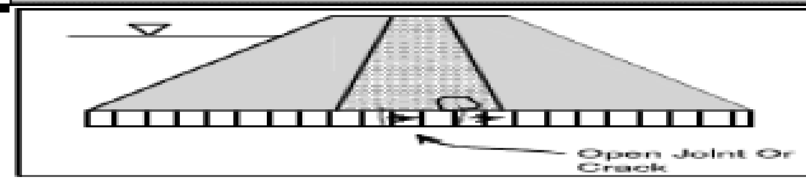
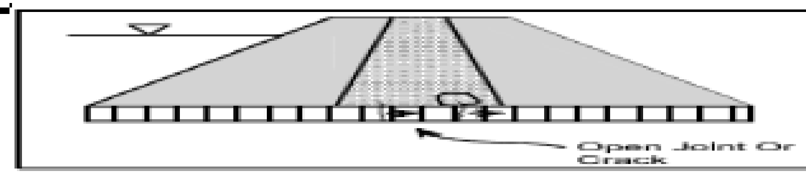
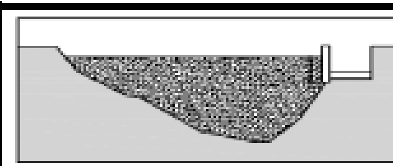
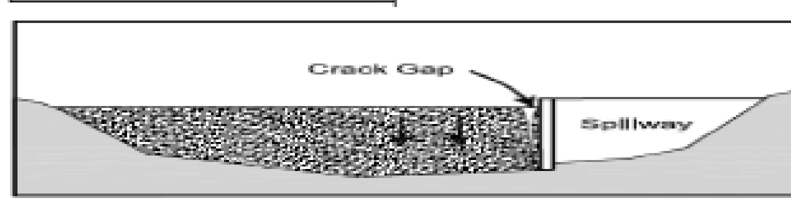
Internal Erosion PFMs Examples

from Piping Toolbox

FM 12	Transverse cracking at the foundation contact due to small scale irregularities in the foundation profile under the core	
FM 13	Transverse cracking due to desiccation on construction lifts, seasonal shutdown surfaces during construction and staging construction surfaces.	See FM 7
	Consider high permeability zones in the embankment as appropriate	
	Failure Path/Location	
FM 14	Poorly compacted or high permeability layer in the embankment	
FM 15	Poorly compacted or high permeability layer on the core-foundation contact	
FM 16	Poorly compacted or high permeability layers in the crest due to freezing	
FM 17	Seasonal shutdown layers during construction and staged construction surfaces due to freezing	

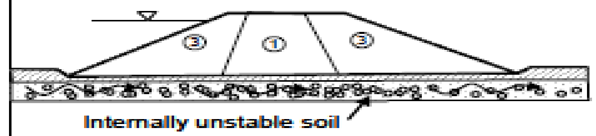
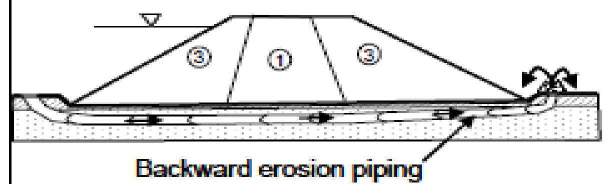
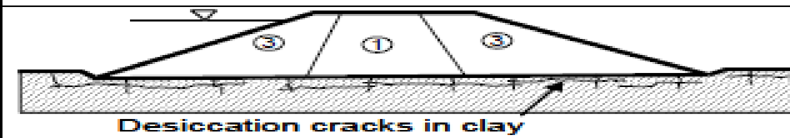
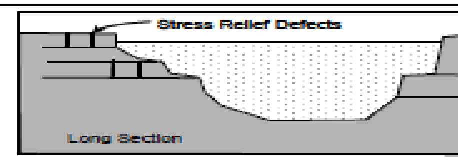
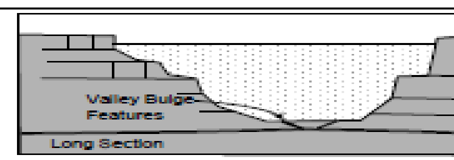
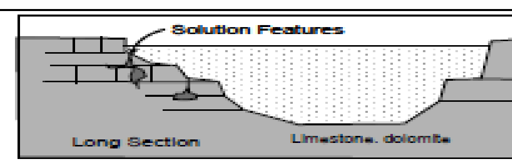
Internal Erosion PFMs Examples

from Piping Toolbox

FM 18	Poorly compacted or high permeability zone around a conduit through the embankment	
FM 19A	Erosion into a (non-pressurized) conduit	
FM 19B	Erosion into a (non-pressurized) conduit leading to erosion along the conduit.	
FM 20	Poorly compacted zone associated with a spillway or abutment wall	
FM 21	Crack/gap adjacent to a spillway or abutment wall	
FM 23	Wrap around details for connection of embankment dam to concrete gravity dam	

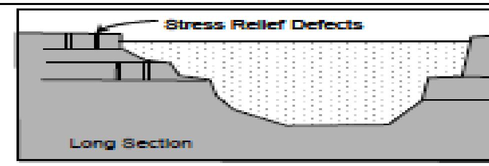
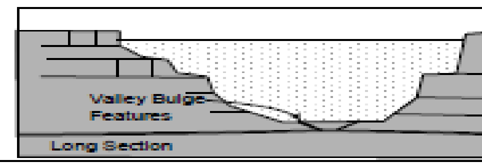
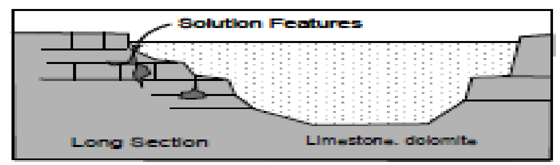
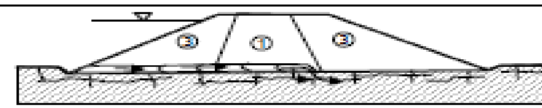
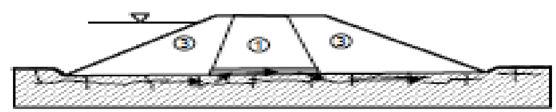
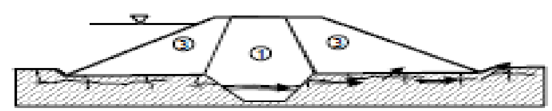
Internal Erosion PFMs Examples

from Piping Toolbox

Internal Erosion through the Foundation		
FM 24	All modes of internal erosion of the foundation (backward erosion, suffusion, erosion in a crack) (Soil foundation)	
FM 25	Backward erosion in a cohesionless soil foundation Suffusion in a cohesion less soil in the foundation (Soil foundation)	
FM 26	Erosion in a crack in cohesive soil in the foundation	
		
FM 27	Erosion in defects in a rock foundation	
		

Internal Erosion PFMs Examples

from Piping Toolbox

	Internal Erosion of the Embankment into or at the Foundation	
	Table 3.5	Transverse cracks in the middle and lower parts of embankment dams
FM 28	Internal erosion of the embankment into or at a rock foundation	  
FM 29	Internal erosion of the embankment into or at a soil foundation	 Backward erosion piping  Erosion of core by water flowing in open rock defects  Hydraulic fracture in cut-off trench

Calculate Population at Risk (PAR)

- A basic tenet of owning a dam is that each owner should know the risk associated with each dam.
- The first step in knowing the risk is knowing the PAR
- Several methods can be used to develop this information
- However, it starts with calculating the inundation zones from dam failures associated with specific PFMs.

Aerial Photo of Priest Rapids Dam

Priest Rapids Project, P-2114

(Courtesy of Grant County PUD)

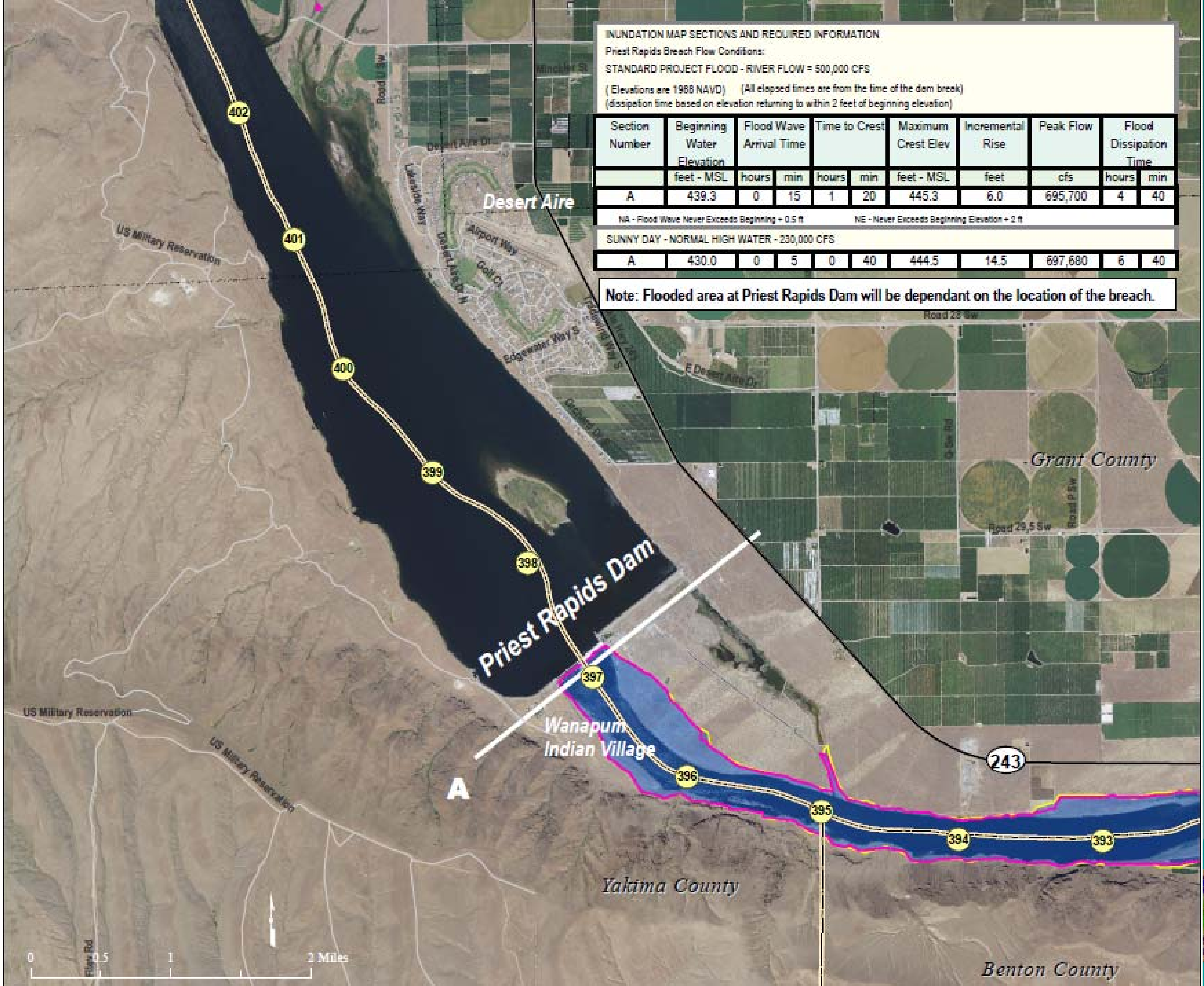
Aerial Photo of Priest Rapids Dam

Google Earth

Looking Downstream at Priest Rapids Right Embankment

Looking Downstream at Priest Rapids Right Abutment

Village



INUNDATION MAP SECTIONS AND REQUIRED INFORMATION

Priest Rapids Breach Flow Conditions:

STANDARD PROJECT FLOOD - RIVER FLOW = 500,000 CFS

(Elevations are 1988 NAVD) (All elapsed times are from the time of the dam break)

(dissipation time based on elevation returning to within 2 feet of beginning elevation)

Section Number	Beginning Water Elevation	Flood Wave Arrival Time		Time to Crest		Maximum Crest Elev	Incremental Rise	Peak Flow	Flood Dissipation Time	
	feet - MSL	hours	min	hours	min	feet - MSL	feet	cfs	hours	min
A	439.3	0	15	1	20	445.3	6.0	695,700	4	40

NA - Flood Wave Never Exceeds Beginning + 0.5 ft NE - Never Exceeds Beginning Elevation + 2 ft

SUNNY DAY - NORMAL HIGH WATER - 230,000 CFS

A	430.0	0	5	0	40	444.5	14.5	697,680	6	40

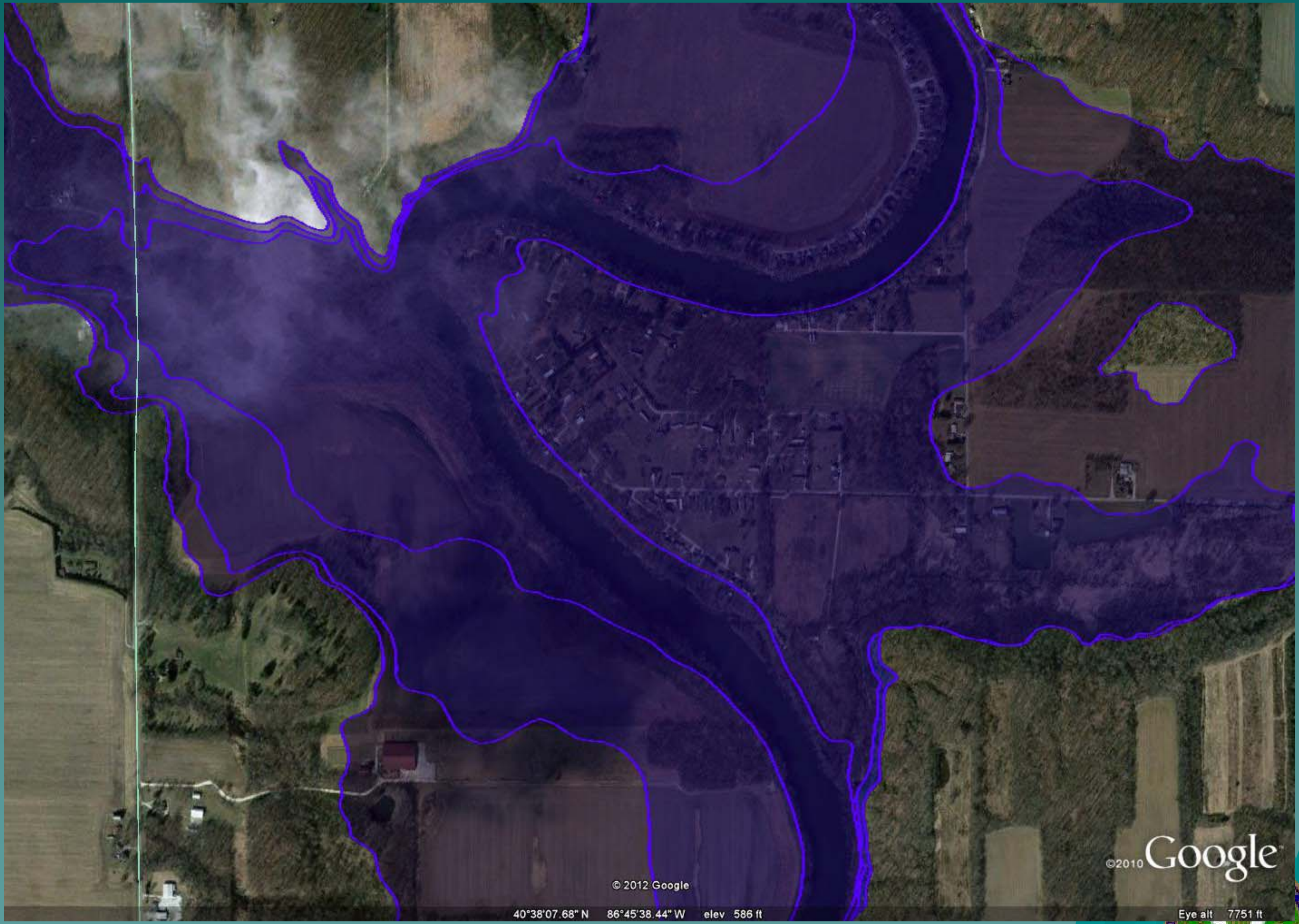
Note: Flooded area at Priest Rapids Dam will be dependant on the location of the breach.

Right Embankment Failure

- Right embankment has liquefaction concerns
- Currently part of a seismic risk analysis (pilot study)
- Current EAP inundation maps do not flood village
- For risk, either a new PFM specific dambreak will be needed
- Or, assume all residents of village are in Population at Risk (PAR)
- But, how deep is the flow?

Refine Dam Break Modeling

- If new dambreak studies are needed, update old models to HEC-RAS, preferably GeoRAS
- Create GIS based inundation areas
- Use potential failure modes to guide dam break model runs, not 'worst case scenario'
- For IDF/PMF get incremental inundation information.



© 2012 Google
©2010 Google
40°38'07.68" N 86°45'38.44" W elev 586 ft
Eye alt 7751 ft

Estimate Consequences

- Download Census data for inundation areas (or simply estimate from Google Earth).
- Perform a quick PAR estimate.
- Locate any critical infrastructure downstream (HAZUS).

HAZUS Infrastructure Data Sets

TRN
- eqAirportFlty
- eqBusFlty
- eqFerryFlty
- eqHighwayBridge
- eqHighwaySegment
- eqHighwayTunnel
- eqLightRailBridge
- eqLightRailFlty
- eqLightRailSegment
- eqLightRailTunnel
- eqPortFlty
- eqRailFlty
- eqRailwayBridge
- eqRailwaySegment
- eqRailwayTunnel
- eqRunway
- flExposureTransport
- flHighwayBridge
- flLightRailBridge
- flRailwayBridge
- hzAirportFlty
- hzBusFlty
- hzFerryFlty
- hzHighwayBridge
- hzHighwaySegment
- hzHighwayTunnel
- hzLightRailBridge
- hzLightRailFlty
- hzLightRailSegment
- hzLightRailTunnel
- hzPortFlty
- hzRailFlty
- hzRailwayBridge
- hzRailwaySegment
- hzRailwayTunnel
- hzRunway

UTIL
- eqCommunicationFlty
- eqElectricPowerFlty
- eqNaturalGasDL
- eqNaturalGasFlty
- eqNaturalGasPl
- eqOilFlty
- eqOilPl
- eqPotableWaterDL
- eqPotableWaterFlty
- eqPotableWaterPl
- eqWasteWaterDL
- eqWasteWaterFlty
- eqWasteWaterPl
- flElectricPowerFlty
- flExposureUtil
- flNaturalGasFlty
- flNaturalGasPl
- flOilFlty
- flOilPl
- flPotableWaterFlty
- flPotableWaterPl
- flWasteWaterFlty
- flWasteWaterPl
- hzCommunicationFlty
- hzElectricPowerFlty
- hzNaturalGasFlty
- hzNaturalGasPl
- hzOilFlty
- hzOilPl
- hzPotableWaterFlty
- hzPotableWaterPl
- hzWasteWaterFlty
- hzWasteWaterPl

EF
- eqCareFlty
- eqEmergencyCtr
- eqFireStation
- eqPoliceStation
- eqSchool
- flCareFlty
- flEmergencyCtr
- flFireStation
- flPoliceStation
- flSchool
- hzCareFlty
- hzEmergencyCtr
- hzFireStation
- hzPoliceStation
- hzSchool

HPLF
- eqDams
- eqHazmat
- eqLevees
- eqMilitary
- eqNuclearFlty
- hzDams
- hzHazmat
- hzLevees
- hzMilitary
- hzNuclearFlty

Probabilistic Analyses

- If there are questions about the potential for a large flood to overtop and fail the dam, for instance from failure of a gate to operate or debris blockage of gates, consider performing an FFA.
- If a new seismicity analysis is needed, consider performing a probabilistic seismic hazard assessment.

Reevaluate Priorities

- Dam safety issues were prioritized in 2007 in the FERC's Chicago Regional Office
- The 10 highest dam safety issues were selected
- During the recent SLPRA work, those risks were reevaluated.
- Of the top 10, only 1 remained a higher risk after the reevaluation.
- The other 9 were found to be much smaller risks than previously assumed because of small consequences or low likelihood, i.e., failure from a very unlikely event like an extreme flood.
- Note that only a QRA could fully evaluate the likelihood and consequence at these dams, so these conclusions are not definitive, but they do show a need for recalibrating our priorities.

FINE