Factors Influencing the Likelihood of Dam Breach				Date: July 2012
Factor	**Influence on Likelihood (see notes)**			**Comments**
	Less Likely	**Neutral**	**More Likely**	
Gross enlargement of pipe or erosion pathway				
Internal erosion mechanism	Internal migration or suffusion/suffosion.		Scour or backward erosion piping.	
Embankment Zoning			Much more likely for homogeneous embankment. Zoned embankment dam with compacted sand and gravel downstream shell that can hold a roof. Thin downstream zone of granular materials not capable of resisting significant flows.	If a large rockfill zone exists downstream that could resist significant amounts of flow, the more likely breach mechanism is sloughing.
Reservoir size and Freeboard	Very small reservoir that drains out before a full dam breach can develop. Very large freeboard (many tens of feet).		Large reservoir with sufficient volume to maintain high head, high gradients and plenty of flow during the internal erosion process. “Normal” or “average” amount of freeboard.	A large amount of freeboard could possibly prevent the dam from overtopping when the crest collapses, but must consider if crest collapse would only delay the breach.
Sloughing / Unraveling				
Internal erosion mechanism	Internal migration.	Suffusion or suffusion.	Scour or backward erosion piping.	
Embankment Zoning	A large, tightly knitted rockfill zone containing large rocks exists downstream that could resist significant amounts of flow.		Zoned embankment dams with compacted sand and gravel downstream. not able to resist significant flows. Homogeneous embankment consisting of soils that are not capable of sustaining a roof and that will not resist significant flows.	
Reservoir size and Freeboard	Very small reservoir that drains out before a full dam breach can develop. Large freeboard (tens of feet).		Large reservoir with sufficient volume to maintain high head, high gradients and plenty of flow during the internal erosion process. “Normal” or “average” amount of freeboard.	Large freeboard could possibly allow formation of a “berm” at the downstream slope from the slumped material that ultimately arrests breach development.
Sinkhole Development				
Internal erosion mechanism	Scour or backward erosion piping.		Internal migration or suffosion.	Sinkholes could possibly lead to other internal erosion processes and/or breach mechanisms.

Factors Influencing the Likelihood of Dam Breach				**Date: July 2012**
Factor	**Influence on Likelihood (see notes)**			**Comments**
	Less Likely	**Neutral**	**More Likely**	
Likely location of sinkhole	Sinkhole on downstream or upstream slope and not likely to impact crest		On crest	Upstream sinkholes are generally considered to be more serious than downstream sinkholes and potentially indicate a serious condition. This table considers the likelihood that the sinkhole results in overtopping.
Freeboard	A large amount of freeboard exists (tens of feet).		Typical freeboard (~6-10 ft). Much more likely if there is little freeboard (< 6 ft).	
Crest width	Wide crest	Average crest	Narrow crest	
Flow limiter	A core wall or upstream concrete face remains in place			
Slope Instability				
Embankment Zoning	Large, free-draining rockfill or gravel downstream zone Drainage zone with high capacity that will prevent buildup of pore pressures in downstream zones		Sands, silty sands, and other materials in downstream zones susceptible to shear strength reduction with increased pore pressures	
Static slope stability	Analysis and evidence indicates significant margin of safety against instability.		Analysis or evidence indicates marginal stability; observations of sloughs or slides	
Freeboard	A large amount of freeboard exists		Typical freeboard Much more likely if there is little freeboard	
Crest width	Wide crest	Average crest	Narrow crest	
Downstream slope	Earthfill: 3:1 or flatter Rockfill: 1.75:1 or flatter	Earthfill: 2.5:1 Rockfill: 1.5:1	Earthfill: 2:1 or steeper Rockfill: 1.4:1 or steeper	

<u>Notes on use of Table 5:</u>

1. Table is intended to provide guidance on the probability of dam breach for internal erosion.

2. Unlike the "initiation" tables, there are no historical average base rates to compare relative probabilities. The more likely and less likely factors can be considered qualitatively, and can be considered along with verbal descriptors for a quantitative estimate. The neutral factors listed in the table are factors that have a small influence on the likelihood, or factors that could equally increase or decrease the likelihood of unsuccessful intervention. Neutral factors do not automatically imply a 50% probability.

References:

Draft Risk Analysis Methodology Appendix E (2000), Estimating Risk of Internal Erosion and Material Transport Failure Modes for Embankment Dams, version 2.4, Bureau of Reclamation, Technical Service Center, Denver, CO. August 18, 2000. (This document was never finalized; it was superseded in 2008 by Dam Safety Risk Analysis Best Practices Training Manual, Chapter 24.)

Fell, R., C.F. Wan, and M. Foster (2004), "Progress Report on Methods for Estimating the Probability of Failure of Embankment Dams by Internal Erosion and Piping," University of New South Wales, Sydney, Australia. UNICIV Report 428. 2004.

Bureau of Reclamation (2011), Dam Safety Risk Analysis Best Practices Training Manual.