



Federal Energy Regulatory Commission Division of Dam Safety and Inspections



Dam Safety Monitoring 101: Monitoring the Health of Dams Why & How We Do It



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Outline

- Why We Monitor Dams
- Potential Failure Modes
- Development of a Dam Safety Surveillance and Monitoring Program (DSSMP)
 - To monitor identified PFMs
 - General health monitoring
- Example Dam Safety Surveillance and Monitoring Plans



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Why do we need to monitor dams?

A dam can fail!



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Why do we need to monitor dams?

There can be major consequences to failure!



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The Monument to the Unknown Dead, 1892. It still stands in Johnstown's Grandview Cemetery.



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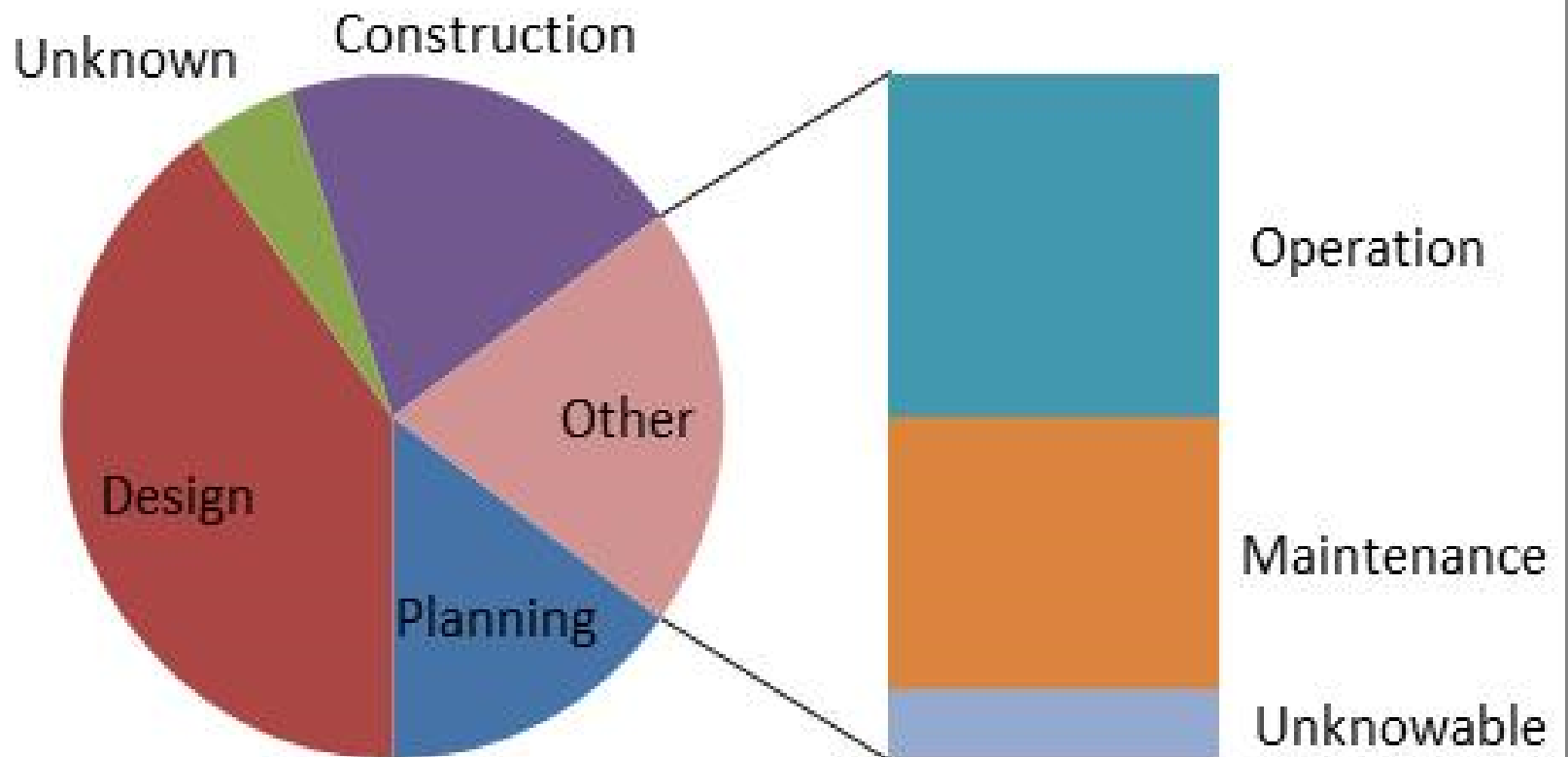
Why do dams fail?

People design, build and operate them that's why.

1. There isn't adequate site investigation (drilling, foundation mapping, etc.).
2. Mistakes are made during design (blown calculations, bad assumptions, no QC, etc.)
3. Mistakes or changes made during construction
4. Improper operation and/or poor maintenance
5. Unforeseen loading condition (changes in seismic or hydrologic loading)
6. We just can't know everything...



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How do we decide what to monitor?

1. It is in a vulnerable time in its lifespan. (first filling, change in loading, end of design life)
 2. There is a specific symptom or concern (seepage, displacement, unusual instrument trends, settlement etc.)
 3. There is a underlying flaw or defect (foundation flaw, design/construction errors, misoperation, exposure to unusual loading condition, etc.).
 4. Unknowable or unidentified conditions. (possible unidentified pfms)
- Known conditions that could lead to failure (pfms)
-
- A red line with arrows at the end points from the text "Known conditions that could lead to failure (pfms)" to the first three items of the list. The line starts at the text, goes left, then down, then left again, with arrows pointing to items 1, 2, and 3. Another red arrow points from the text "(possible unidentified pfms)" to item 4.



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Determine failure modes (PFMA):

- Physical inspection
- Design
 - Plans/specifications
- Construction
 - As-builts/photos/reports
- Performance
 - Existing monitoring data



**Identify potential failure
modes so we can monitor
them**



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Potential Failure Modes

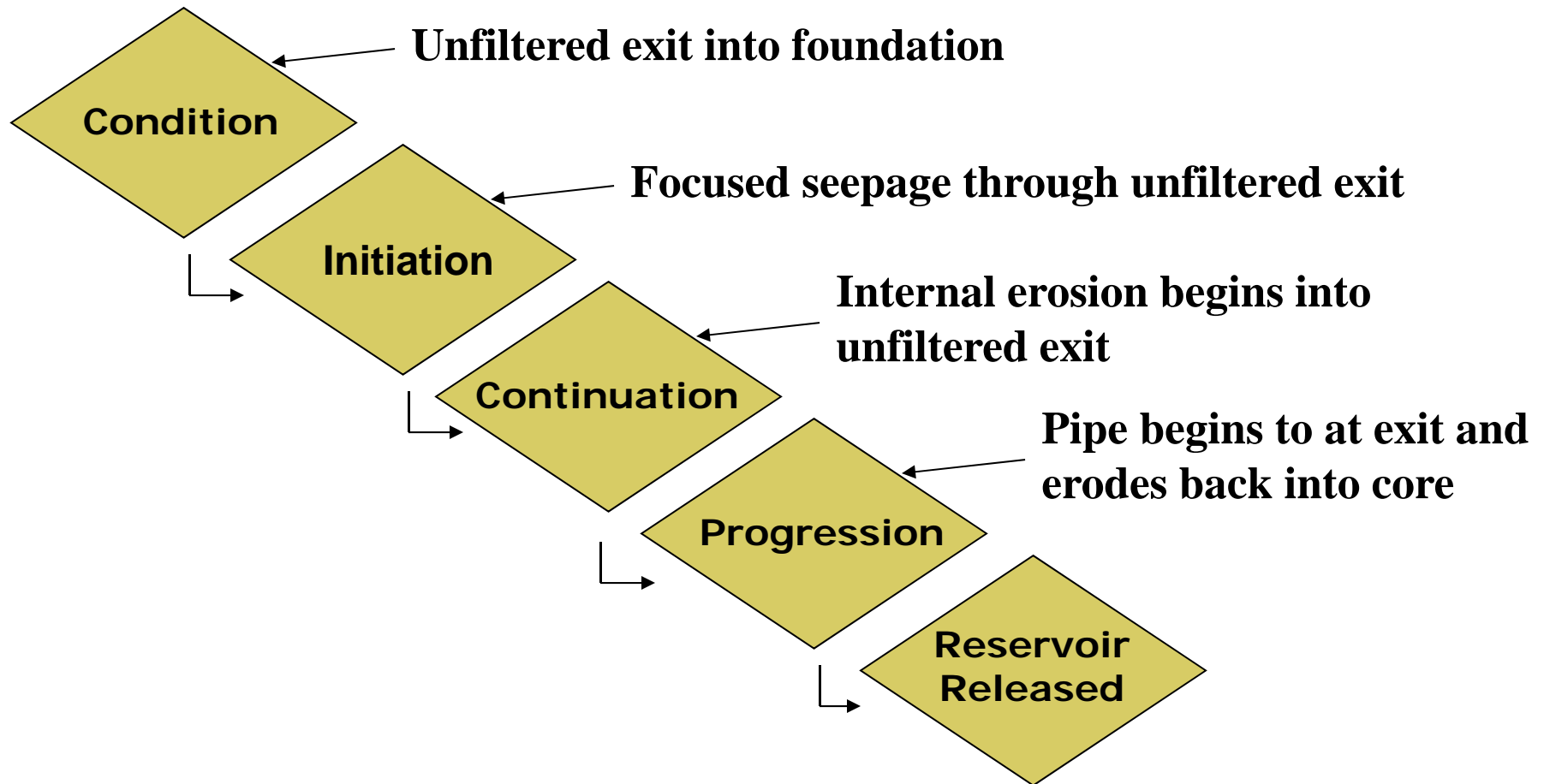
- Failure mode definition - A potential failure mode is a physically plausible process for dam failure resulting from an existing inadequacy or defect related to a natural foundation condition, the dam or appurtenant structures design, the construction, the materials incorporated, the operations and maintenance, or aging process, which can lead to an uncontrolled release of the reservoir. (from “*Federal Guidelines for Dam Safety Glossary of Terms*”, FEMA, April 2004)



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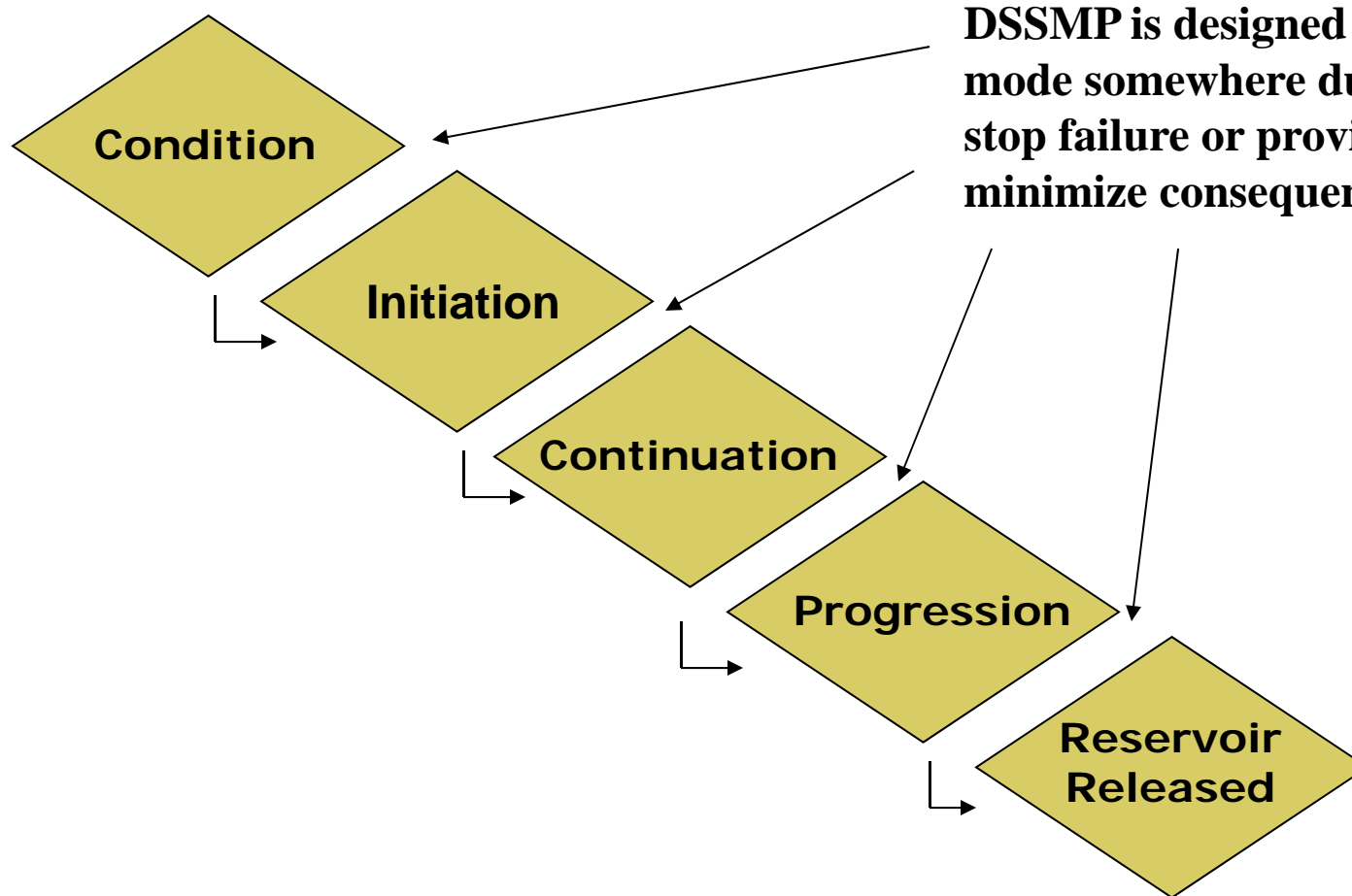


Failure Mode Process (piping failure)





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DSSMP should also include General Health Monitoring:

- Instrumentation that does not monitor an PFM is considered general health monitoring.
- PFMs are based on conditions at the time of the PFMA session and rely on knowns and known unknowns. Unknown/Unknowable conditions could be present and result in unidentified PFMs.
- General health monitoring instrumentation can be used to detect changes in those conditions, which could result in reevaluation of PFM.
- The need for general health monitoring instrumentation should be dealt with on a case by case basis depending on project condition.



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Questions that should be asked when developing DSSMP:

- How quickly the failure mode will develop?
- At what point in the failure mode process can it be detected?
- Is the failure mode something that can be detected with instrumentation?
- Can the failure mode be detected visually?
- Is there someone there who can detect the failure mode?
- What action will be taken if failure mode is detected?
- Will there be time to take action if the failure mode is detected?
- What general health monitoring is appropriate in addition to PFM monitoring?



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What parameters need to be monitored?

- Headwater/tailwater levels
- Pore pressure
- Uplift pressure
- Seepage / leakage
- Movement
- Stress / strain
- Temperature



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Select the right instrument for the parameter:

- Select the right instrument based on:
 - The parameter being measured
 - The speed at which the failure could develop
 - The challenges of the site (exposure, weather, etc.)
 - Recourses available to monitor

- Consider more than just cost:
 - Simplicity
 - Reliability
 - Durability
 - Longevity
 - Precision
 - Accuracy
 - Satisfactory performance history.
 - Remember human eye may be the best instrument (if connected to a well trained brain)





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Select location of instruments/visual monitoring:

- Where can the required parameter be monitored.
- Provide a sufficient number to provide a complete picture.
- Focus visual inspections in the correct locations.
- If you are trying to monitor a specific area make sure the instruments sensor is actually in that area.
- Provide redundancy, if cost effective



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Establish frequency of monitoring and method of data collection:

- Frequency of dam safety inspections or special inspections (tunnel, gate, etc.)
- Frequency of instrument readings
- Method of data collection and evaluation
 - Automated or manual readings?
 - Set appropriate threshold/action levels
 - Who collects data and how is it reported
 - Who evaluates data and how often is this done
- What are the reporting procedures if unusual readings/conditions are noted?
 - How does person taking readings decide something is a concern?
 - Who gets notified and what actions are taken?



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Monitoring program documentation (DSSMP):

- Description of visual monitoring
- Description of all instruments (type, photos, manuals, etc)
- Purpose of each instrument
- Drawings showing instrument locations
- Threshold/action limits
- Detailed monitoring procedures
- Evaluation/reporting procedures
- How staff is trained
- Calibration/maintenance instructions





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Evaluate visual monitoring/instrumentation data and report findings (DSSMR):

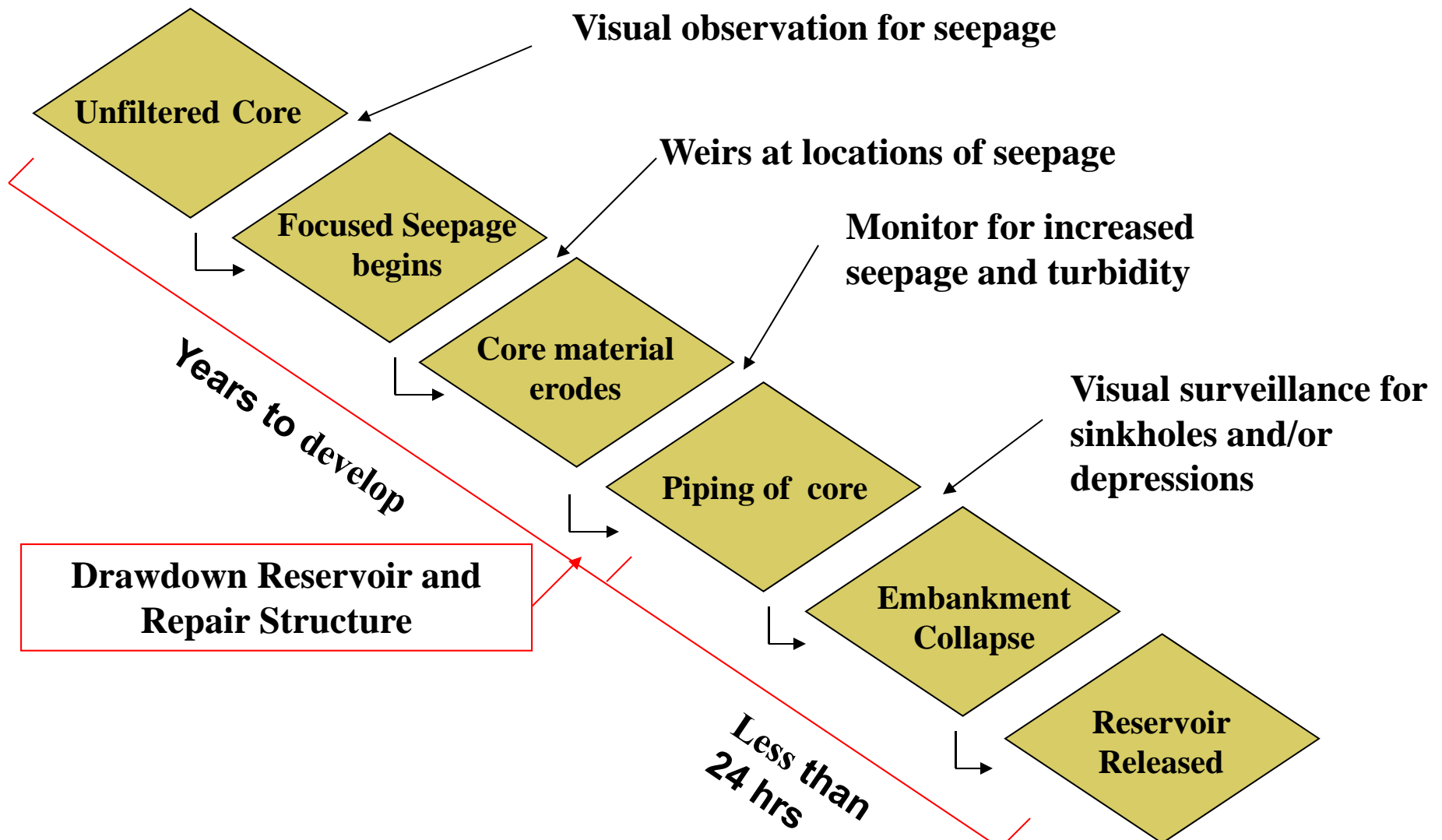
- DSSMP is useless if information is not being evaluated
 - Do timely evaluations, not just once a year when doing DSSMR
 - Evaluations should be at multiple levels (in the field while reading instruments/doing inspections, each time new data is received, at the end of each reporting period)
- Don't focus solely on threshold/action levels when evaluating instruments. Look for trends over time.
- Compare groups of instruments in similar locations to visual observations
 - Are there trends in more than one set of instrument?
 - Are there visual indications that back up what is seen in instrumentation?
- Prepare quality DSSMR to report findings.
 - Clear presentation of findings and how they relate to pfms.
 - Clear presentation of instrument data.



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Piping Failure Example DSSMP





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QUESTIONS??

