

Risk Analysis and Levee Certification

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Outline of Presentation

- Levee certification defined.
- CFR requirements for certification.
- USACE risk analysis Policy/key concepts.
- RA and levee certification – why?
- What is ‘Conditional Non-exceedance Probability’ (CNP) and what is it for?
- Data/analysis requirements & applications.
- Proposed USACE guidance to field.
- Closing thoughts.



Certification, Significance, General Policy

- Official determination by FEMA that levee protects against base flood, usually 1% event.
- Defines flood insurance zones/rates which impacts grants/mortgages, emergency relief, land management policies. Locals want!
- Non-Federal: 44 CFR, Ch I, Part 65, Sec. 65.1. Engineering analysis to certify levee performance per CFR. *<CFR=Code of Federal Regulations.>*
- Federal: Letter to FEMA certifying that levee protects against base flood is acceptable.



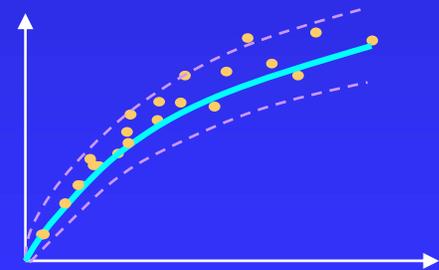
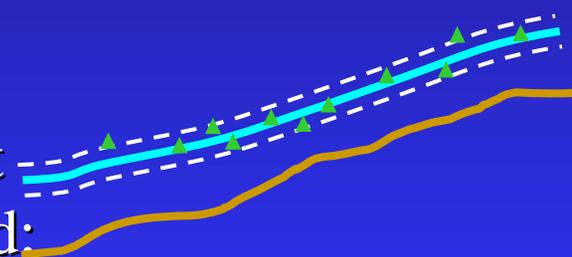
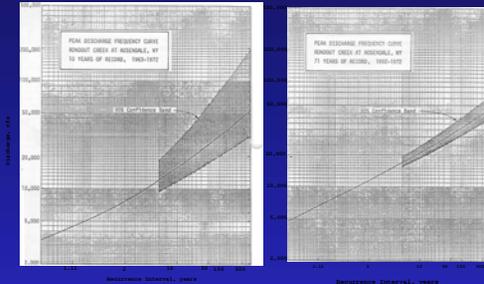
Basic CFR Requirements

- Demonstration that a high degree of assurance of protection for the base flood is provided.
- Freeboard:
 - ▼ Riverine: Minimum 3 ft., another foot by structures, up to foot less elsewhere depending on uncertainly analysis; coastal: 1 ft. above 1% wave or max run up. 2 ft. min.
- Need closures by engineered devices as part of levee system.
- Embankment protection:
 - ▼ Erosion protection and seepage integrity from erosion; seepage analysis for base flood; foundation stability; settlement not to compromise freeboard; interior drainage.
- Operation plans and criteria.
- Certified by registered professional engineer.



Some Truths

- Flood hazard is depicted by flood elevation.
 - ▼ Either estimated directly (stage-frequency).
 - ▼ Or computed from flow, then from a river model.
- Flow is estimated by statistics from a gaged record or computed with a model from a hypothetical precipitation event.
- In either case, we have long known about confidence limits but mostly have ignored: same with imperfect hydraulic models.
- **We know what we don't know!** We should use what we know we don't know.



Some Definitions

- Webster's Ninth Collegiate Dictionary:
 - ▼ Risk – “possibility of loss or harm”. <As used here, it's the probability of a flood and the associated consequence of its occurrence.>
 - ▼ Uncertainty – “the quality or state of being uncertain.” <As used here, it's the concept that flow or stage are not perfectly known for a probability and may have a range of likely values.>



USACE Risk Analysis Policy

- Policy developed over period of 3 to 4 years in mid 1990's in response to challenges to USACE flood damage reduction project development and justification findings and reporting documents.
- Policy objective: Improve decision making and confidence by quantifying and disclosing risk and uncertainty in key data and parameters.
- Documentation provided in USACE regulations (ER's), manuals (EM's), software and analytical tools (HEC-FDA et. al.), training course manuals, seminar proceedings, NRC review reports, and technical papers in the literature.

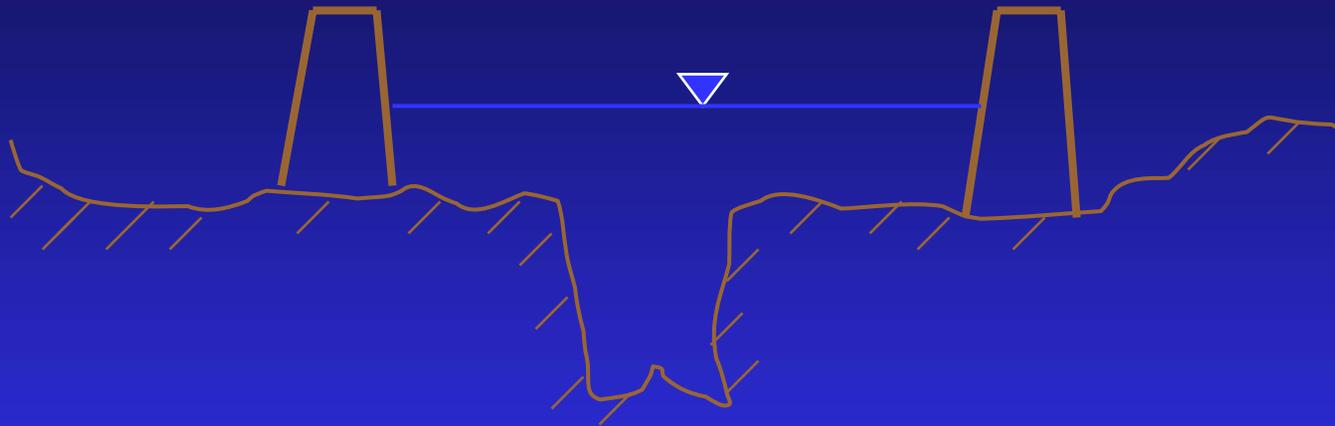


Risk Analysis - Key Concepts

- Make accurate and unbiased estimates of probability of flooding and of exposure, and communicate findings.
- Acknowledge uncertainty associated with project and performance, and quantify, expose, and communicate that information.
 - ▼ Discharge-frequency and uncertainty; stage-flow and uncertainty; geotechnical and structural performance and uncertainty; operational uncertainty; and other.
- Emphasize residual risk (probability and consequence of project capacity exceedance) - conduct specific analysis, document, and communicate findings.



Risk Analysis and Levee Certification - WHY?



Situation 1. Flat gradient, flow/stage variability low, long flow/stage record, high integrity existing levee.

Situation 2. Steep gradient, flow/stage variability high, short record, uncertain integrity existing levee .

Risk analysis explicitly quantifies difference between these situations, and ensures more equity in reflecting residual risk.

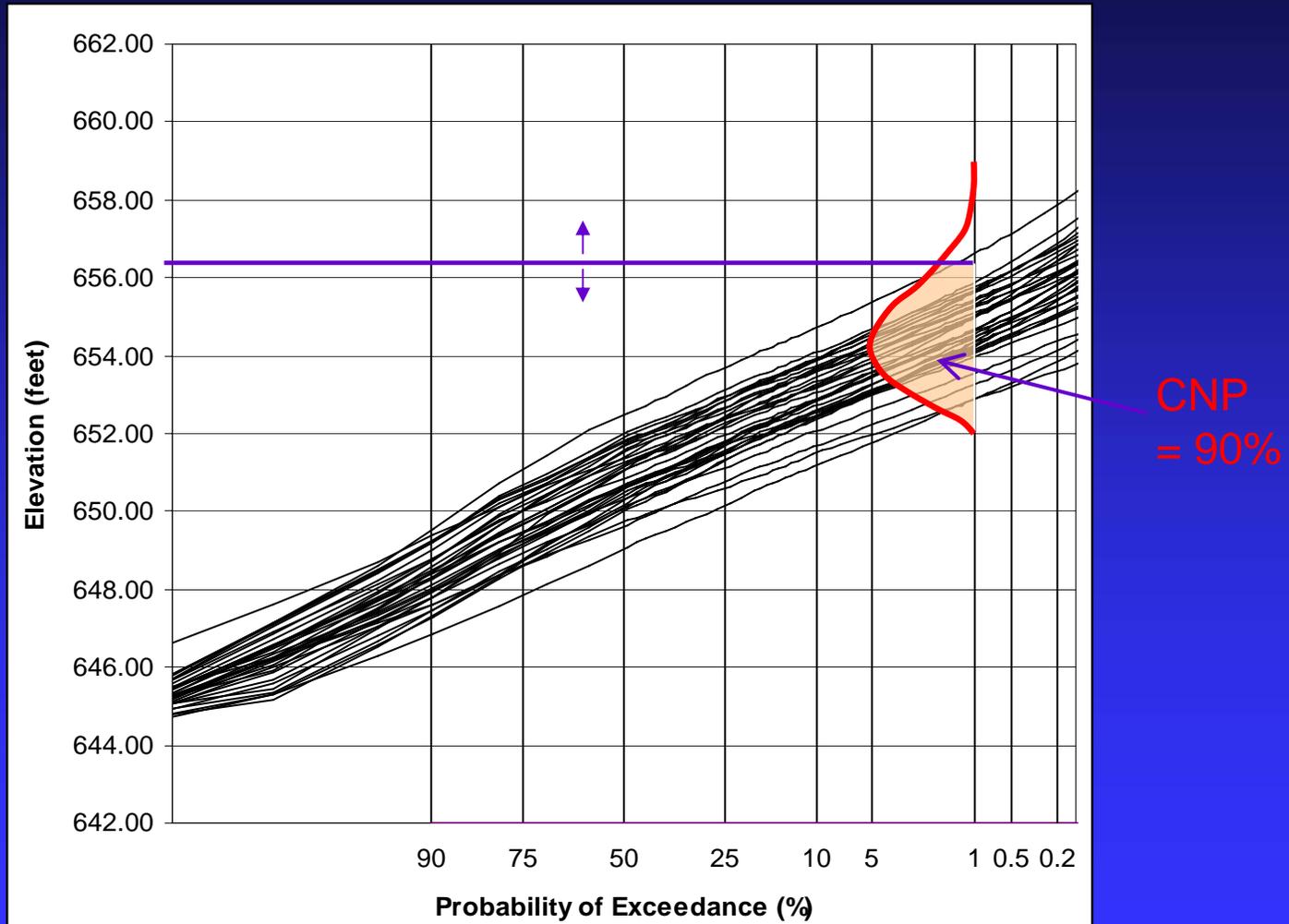


Conditional Non-exceedance Probability (CNP) – What?

- CNP (Assurance): The probability that a project will provide protection from a specified event. For levees, this probability includes both the chance of capacity exceedance as well as the chance of failure at lesser stages.
- Computed by determining the expected exceedances/failures at top of levee (levee will not fail before overtopping); or application of levee elevation-failure probability curve (chance of failure prior to overtopping)..
- Monte Carlo sampling of Q-f, S-Q with associated uncertainties; and geo-technical failure curve yields CNP (assurance).



CNP (Assurance) Concept



Certification Policy per 25 March 1997 (edited Jan 2006) Guidance

- Respect CFR principles and guidance (demonstrate high degree of assurance of protection for the base flood).
- Certify if have protection 1) to at least 90% assurance/CNP stage (may be higher than CFR would require); 2) but protection need not be greater than flood stage corresponding to 95% assurance (may be lower than CFR would require).
- 1) Can govern for steep, highly variable streams with uncertain levee integrity.
- 2) Can govern for mild slope, moderate/low variability streams, high levee integrity.
- Typical circumstance is often between 1) and 2).



Technical Data for Certification founded on Risk Analysis

- Basically same as CFR – levee physical dimensions and geotechnical properties, flow-frequency, rating/profiles, closures, operations.
- Added RA data: 1) uncertainty in flow or stage-frequency (equivalent record length); alt. - uncertainty in rating/profiles (standard deviation); uncertainty in geotechnical performance (failure probability curve); other.



Compare RA and CFR Certification Results for Selected Levees

Levee Projects	CFR Cert. Elev.	NED Plan Elev.	NED Elev. Exceedance	% CNP CFR Elev.	% CNP NED Elev.	Elev. - 90% CNP for 1%	Elev. - 95% CNP for 1%
Pearl R., Jackson, MS	44.6	47.0	1/770	97.6	99.8	43.4	44.0
American R, Sacramento, CA	49.1	52.0	1/230	91.9	94.4	48.5	52.3
Portage, WS	798.3	797.0	1/10000	99.9	99.6	796.6	797.3
Hamburg, IA	912.2	911.5	1/910	99.9	99.2	910.7	910.8
Pender, NE	1329.3	1330.0	1/380	76.3	83.6	1330.9	1331.5
Muscatine, IA	560.8	561.5	1/330	90.1	94.4	560.8	561.7
E Peoria, IL	458.1	462.6	1/10000	45.3	99.5	460.7	461.2
Cedar Falls, IA	864.7	866.0	1/360	90.0	94.0	865.0	866.3
Guadalupe, TX	57.9	56.8	1/110	87.2	76.9	58.4	59.5
White River, IN	715.0	713.2	1/250	98.0	86.0	713.5	713.9



USACE, MapMod, Risk Analysis, and Proposed Guidance to Field

- Levee certification policies and guidance in place founded on risk analysis; comprehensive, rigorous, well documented, accepted by FEMA. OK for now.
- Letter to field w/attachements January 2006.
 - ▼ Encourages collaboration with FEMA MapMod at regional/local level; reminds of existing guidance; attaches CFR, FEMA memo 34, Risk Analysis ER (Jan 2006 update), 1997 certification letter (edited Jan 2006).
 - ▼ Provides guidance in responding to MapMod certification requests. USACE levees: 1) Recently certified – reissue; 2) under study & data available – full analysis; 3) older levee – full analysis and require reimbursement. Non-USACE levees: Commander decision – full analysis and require reimbursement.



Some Closing Thought on Risk Analysis, Levee Certification, MapMod and the Future

- RA emerged in USACE in response to need to advance technology for FDR project development.
- RA for levee certification for MapMod leverages advanced technology and positions certification scope to be extended to better reflect public safety.
 - ▼ Residual risk information from RA could be another component of certification, e.g. managing consequence base flood exceedance: Examine project features for control of how exceedance will occur; and require response plans to manage consequences of exceedance.
 - ▼ RA directly yields AEP in protected floodplain, providing accurate data for residual risk actuarial insurance calculations.



Basic References

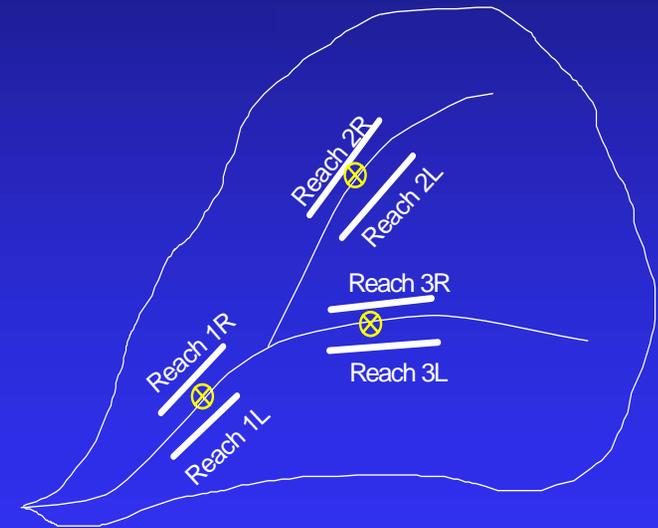
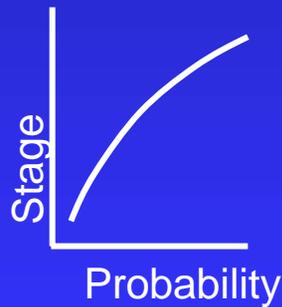
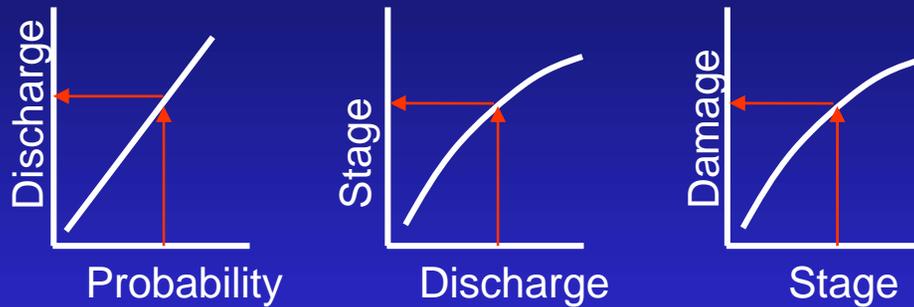
- 44 Code of Federal Regulations (CFR), Ch I, Part 65, Sec. 65.1.
- “Guidance for Levee Certification for the National Flood Insurance Program,” CECW-P/CECW-E letter 25 March 1997, edited January 2006.
- “Risk Analysis and Uncertainty in Flood Damage Reduction Studies,” National Research Council, National Academy Press, 2000.
- “Risk Analysis for Flood Damage Reduction Studies,” USACE ER 1105-2-101, March 1996, updated January 2006.



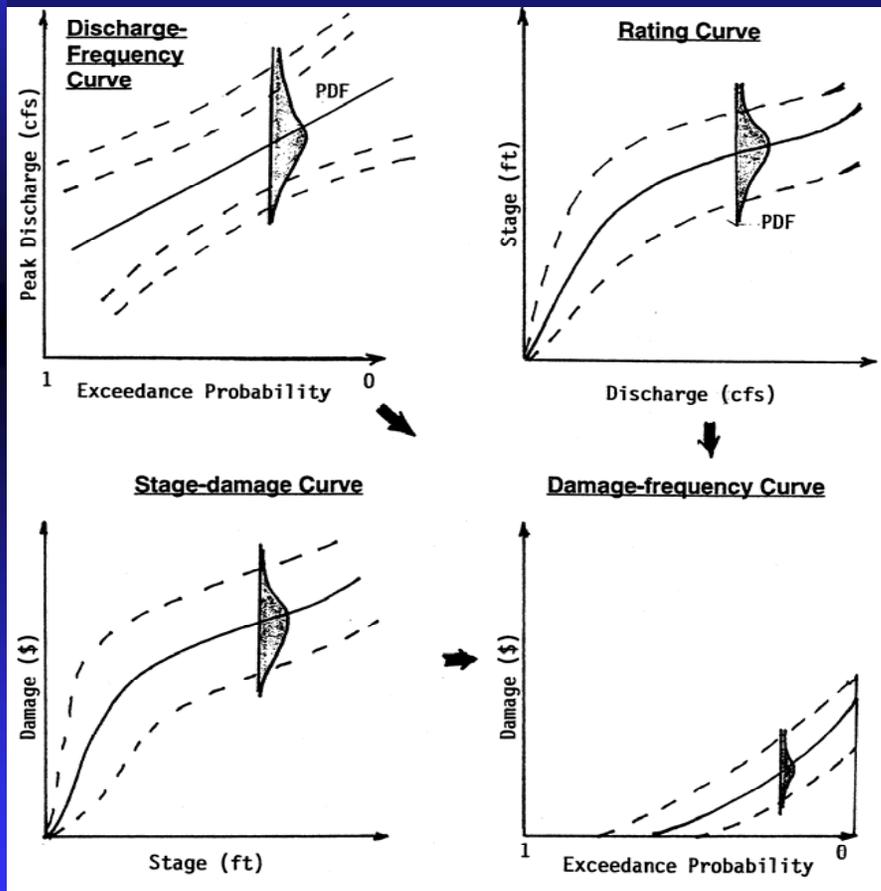
Following slides are supplemental to presentation and may (or not) be used and discussed.



Reaches, Index Locations, Functions, Conjoining



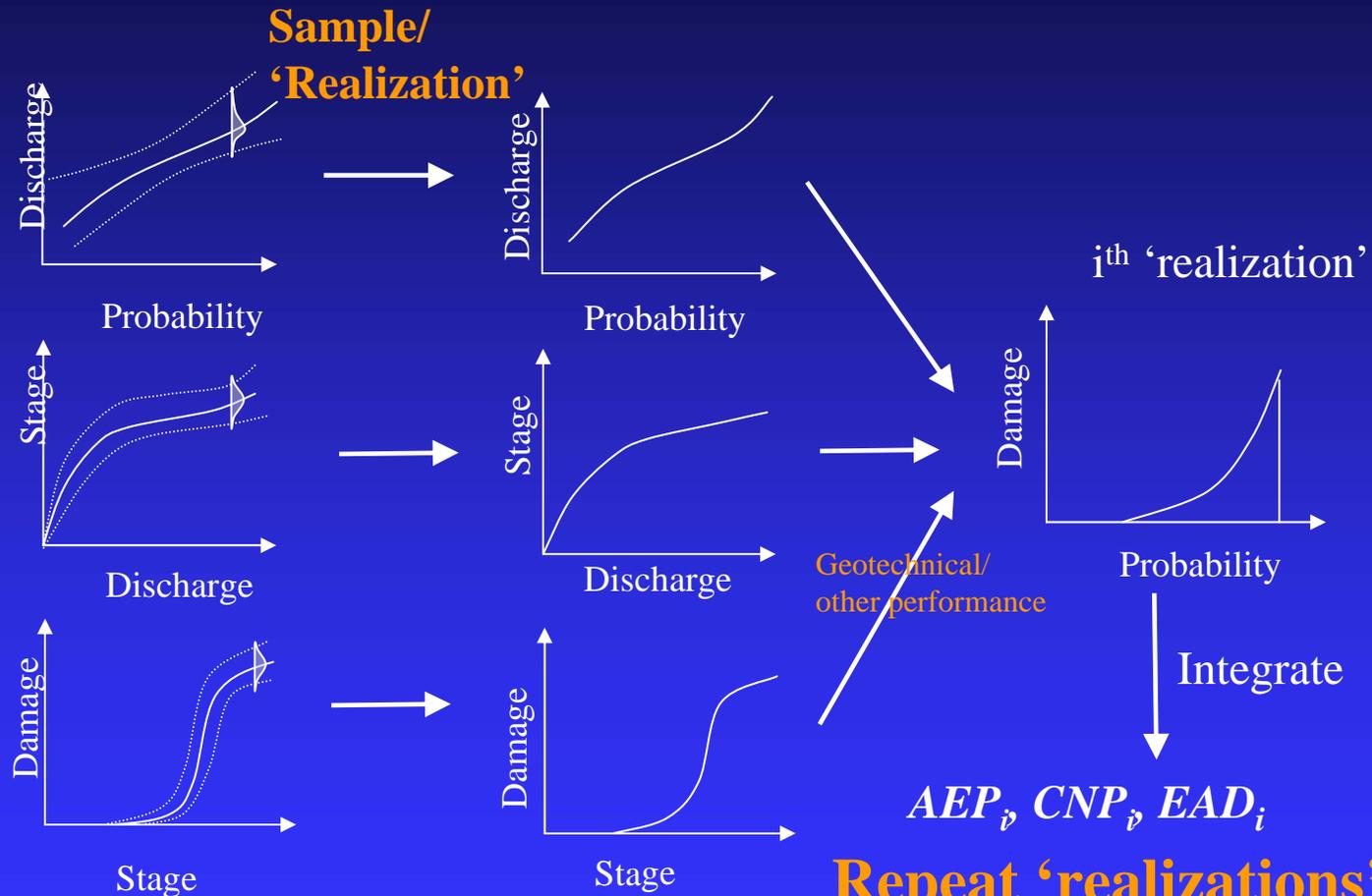
Introducing Uncertainty



- Imperfect/short record lengths; incomplete knowledge; imperfect analysis methods, nature.
- Corps 'required' uncertainty analysis: flow-frequency, hydraulics, damage, geotechnical, operational.
- Monte Carlo to solve.



Calculating AEP, CNP, and EAD using Monte Carlo



Repeat 'realizations' until accurate statistics.



Risk Analysis Results/Output

- Basically same as past with statistics added.
- Mean/statistics of major variables.
 - ▼ PDFs flows and stages.
 - ▼ EAD/EAD reduced (benefits), uncertainty.
 - ▼ Expected annual exceedance; AEP.
- Performance for levee certification.
 - ▼ Conditional non-exceedance probability (CNP).
- Quantify and emphasize residual risk, and better appreciation of risk performance and (un)certainty of results.

