PLANNING COMMUNITY OF PRACTICE WEBINAR

Hydrology and Hydraulics during FRM, WMRS, ECO Feasibility Studies

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Flood Risk Management - Planning Center of Expertise

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FRM-PCX mission

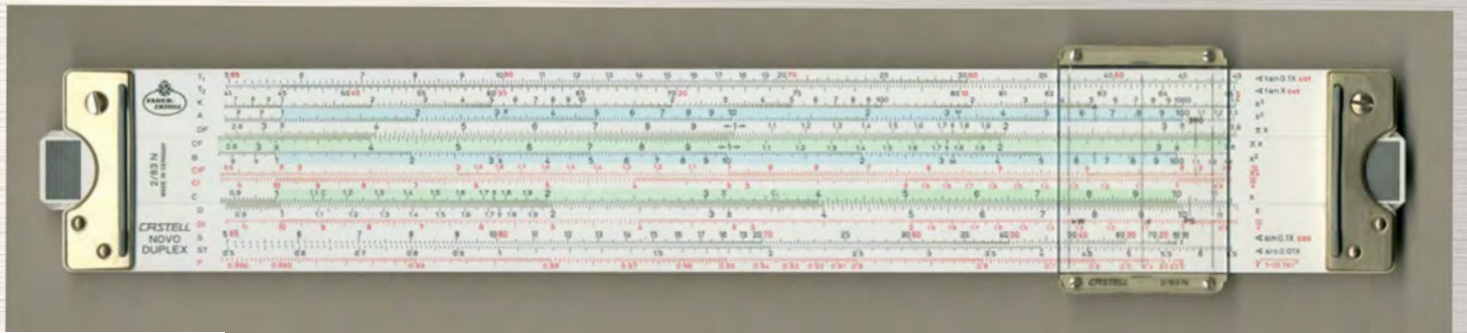
- Enhance USACE planning capability, strengthen planner competencies, and promote high quality decision documents

- **Develop**, **maintain**, and **apply** the best and most appropriate nationally available **expertise**, **science, and engineering technology for flood risk management projects**

- Promote **communication** and **sharing of lessons learned** with a specific focus on flood risk management

Overview

- Role and Responsibilities of Hydrology and Hydraulic Engineering during the feasibility study phase
  - What does the engineer do/deliver for each milestone
  - What information/data Hydrology and Hydraulic Engineers need – and Why It Matters
  - What are the policy requirements
  - Risks of not having certain types of data or pushing off to PED
- What software is used
- Addressing scoping risks
- How to manage engineering risks and uncertainty
- Tips for Successful Working Relationships between HH and Planning



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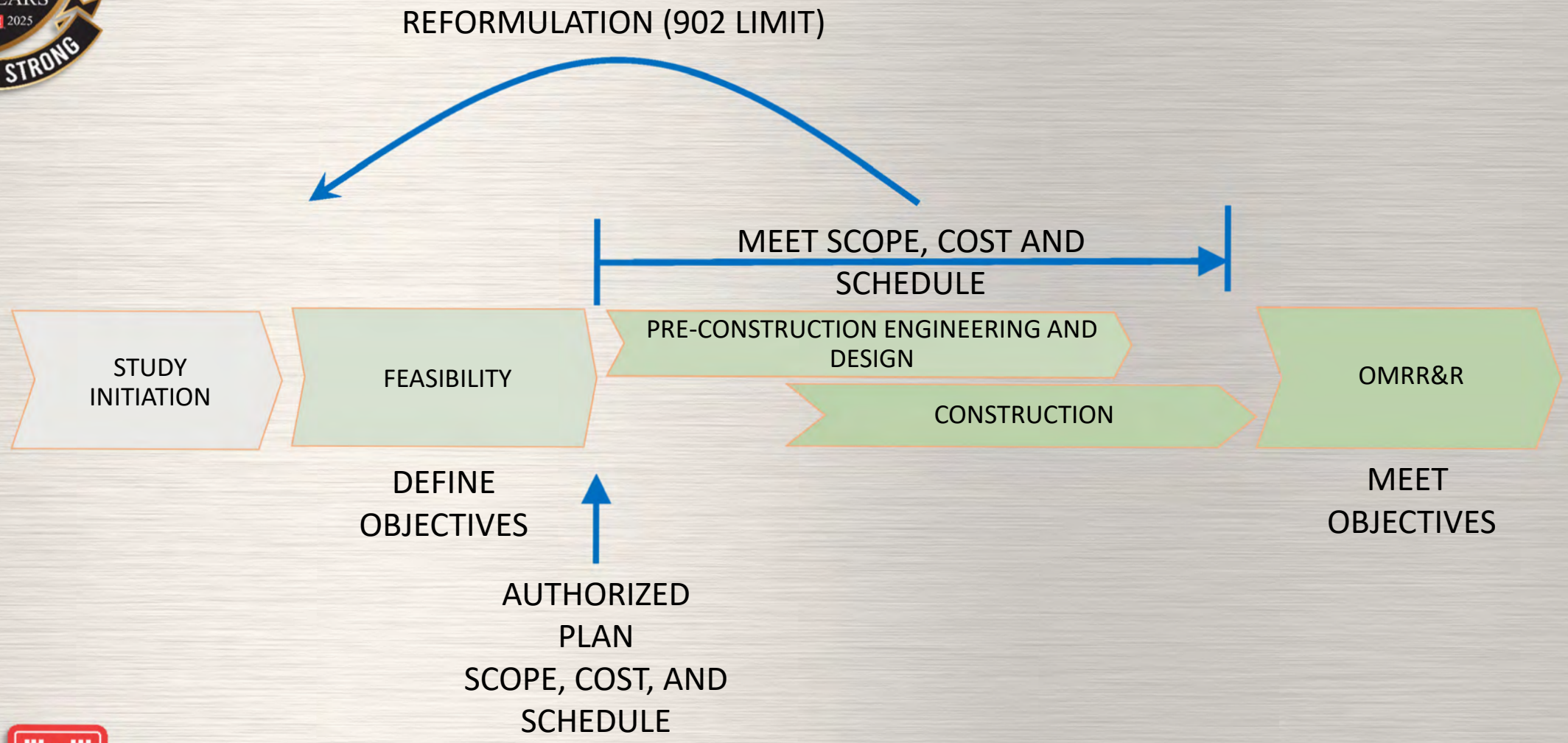
BACKGROUND

SIMPLIFIED USACE PROJECT DELIVERY PROCESS



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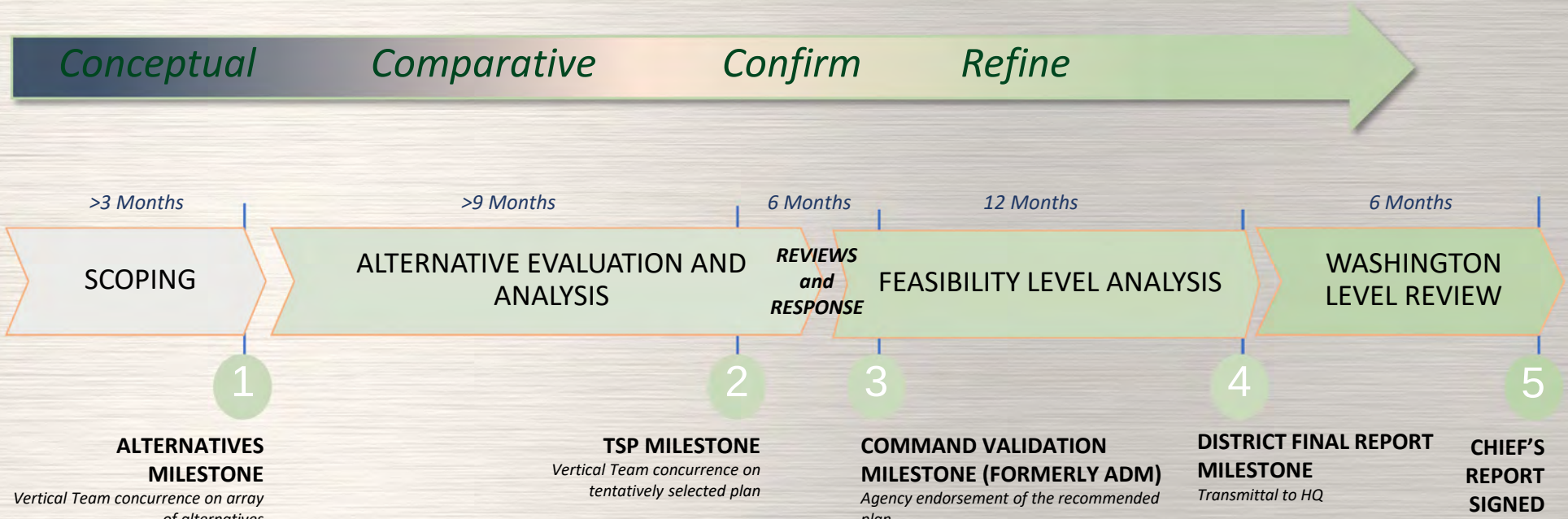
OVERVIEW OF THE FEASIBILITY PROCESS



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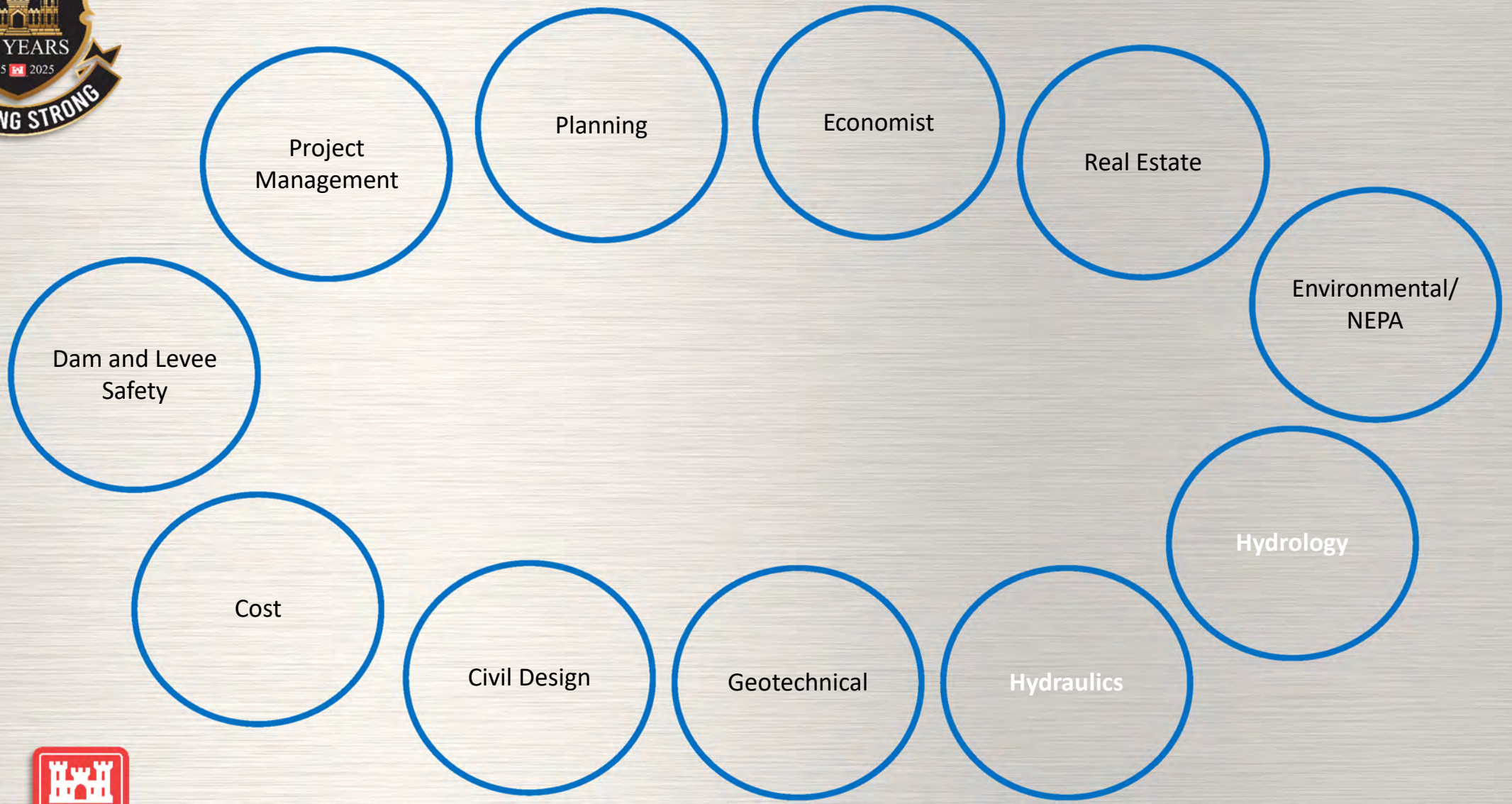
PROJECT DELIVERY IS A TEAM EFFORT



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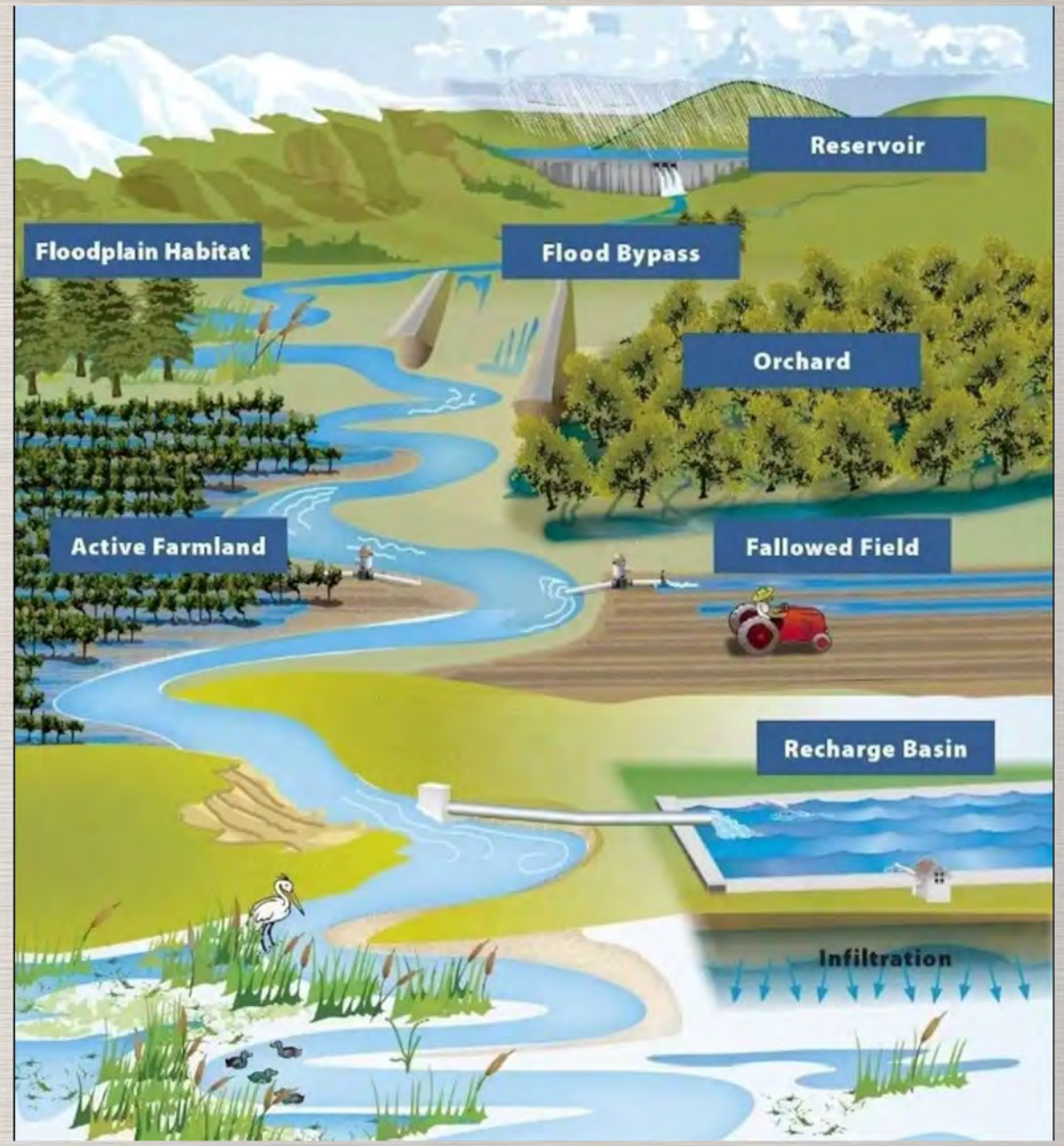
WHAT IS THE DIFFERENCE BETWEEN A “H” AND A “H” ENGINEER?

- The first H is Hydrology
- The second H is Hydraulics

- Hydrology – Study of Precipitation, snowmelt, evaporation, infiltration and runoff that influence surface water dynamics.

- Hydraulics – River Hydraulics refers to the study of water flow in rivers.



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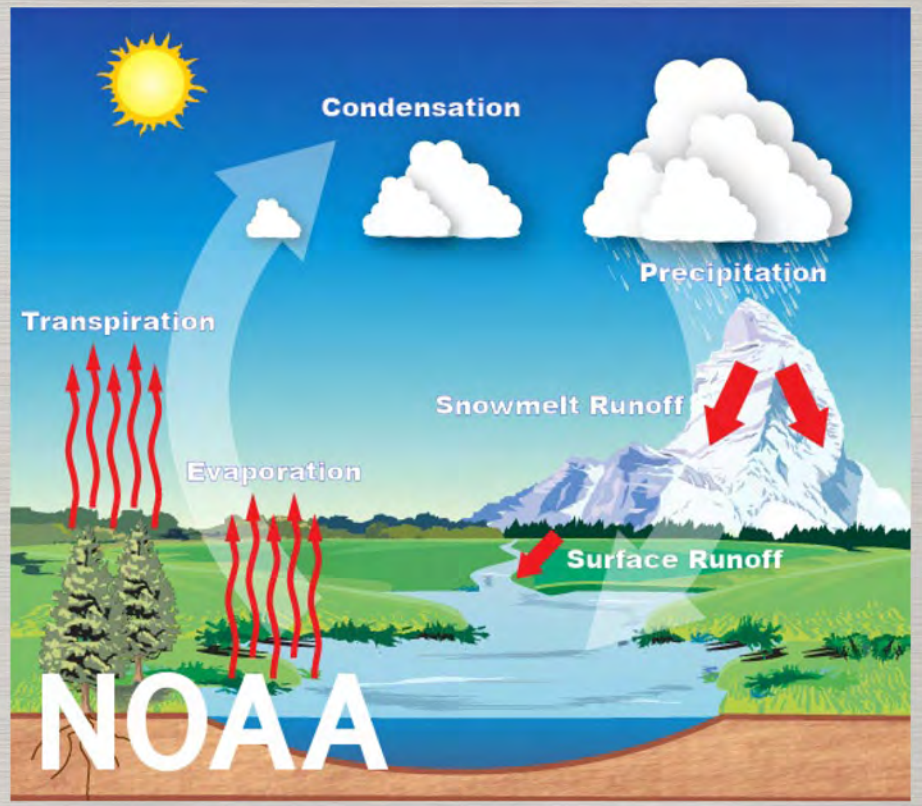
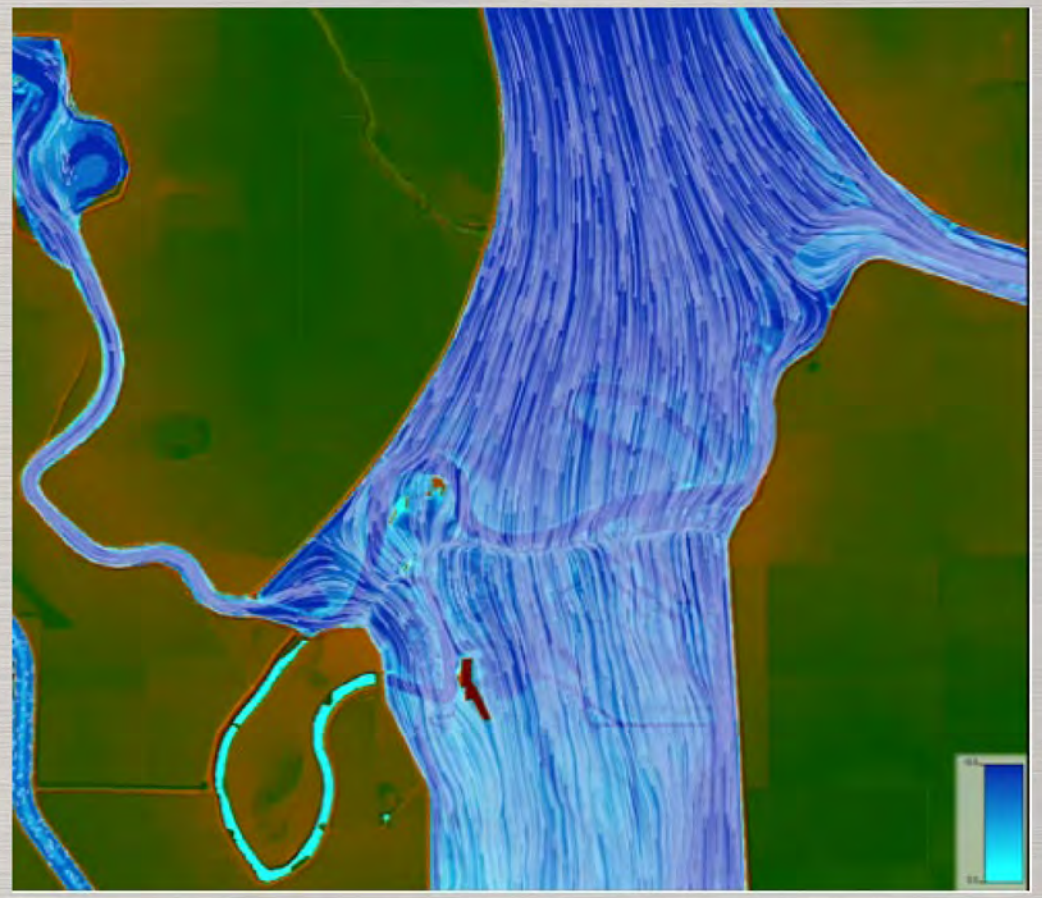
HYDROLOGY

- Estimates how much water and rate of flow.
- Uses statistical analysis, formulas, and models.
- Key inputs are topography, infiltration rates, precipitation data, streamflow data and reservoir data.



HYDRAULIC ENGINEERING

- Describes the depth and velocity of water for a given flow rate. Also estimates sedimentation and channel stability.
- Makes Inundation Mapping that shows risk from a particular flow.
- Induced Flooding mapping
- Key inputs are hydrologic data, topographic data, and design criteria and constraints.



FCSA to AMM

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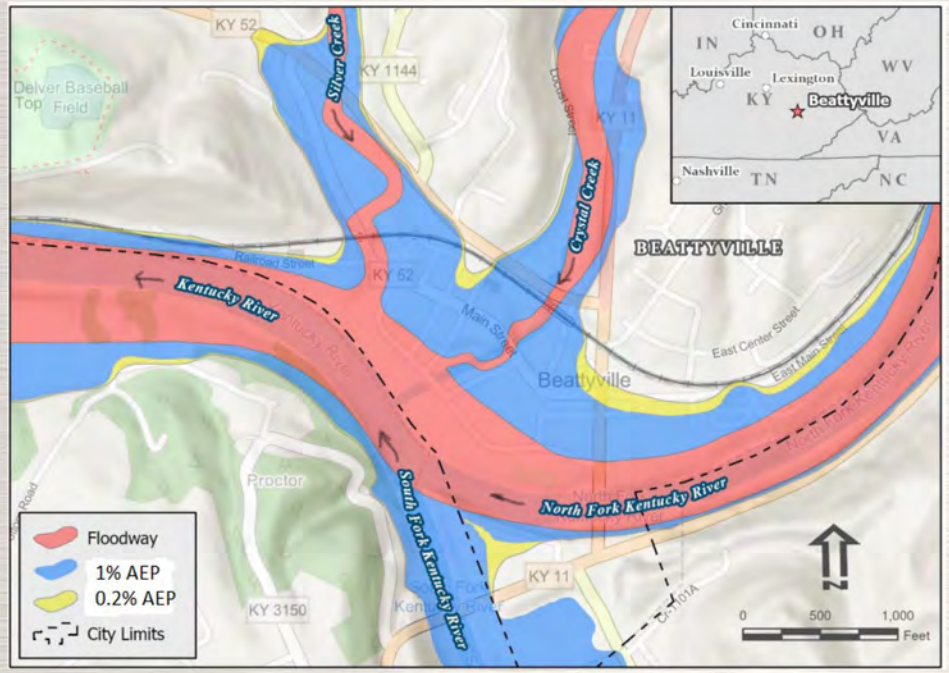
FCSA TO AMM – THE H&H ENGINEERS ROLE



- Develop a Watershed map showing topography, stream network, reservoirs, study area.
- Obtain Existing inundation maps plotted on shaded relief or satellite imagery.
- Assist with description of without project conditions
- Assist in development of Problems, Opportunities, Objectives and Constraints.
- Help Formulate Measures
- Qualitatively or Semi-Quantitatively help with initial screening of Measures

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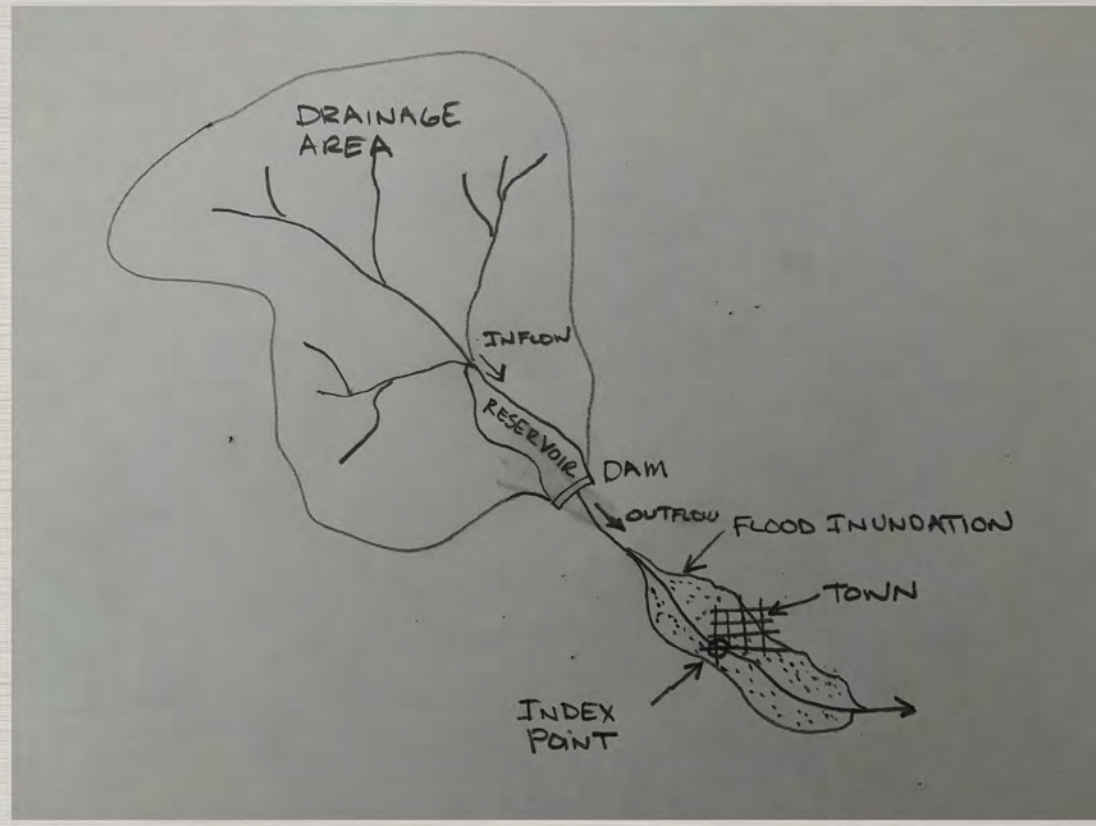
FCSA TO AMM – THE H&H ENGINEERS ROLE

FRM example – Dams

- Consider if the size of Reservoir needed is justified by damage centers downstream.
- See if impounded water is at the right time to be used for other purposes including municipal water supply, irrigation, hydropower, and recreation
- See if Geologic conditions are favorable in locations optimal for a FRM reservoir.

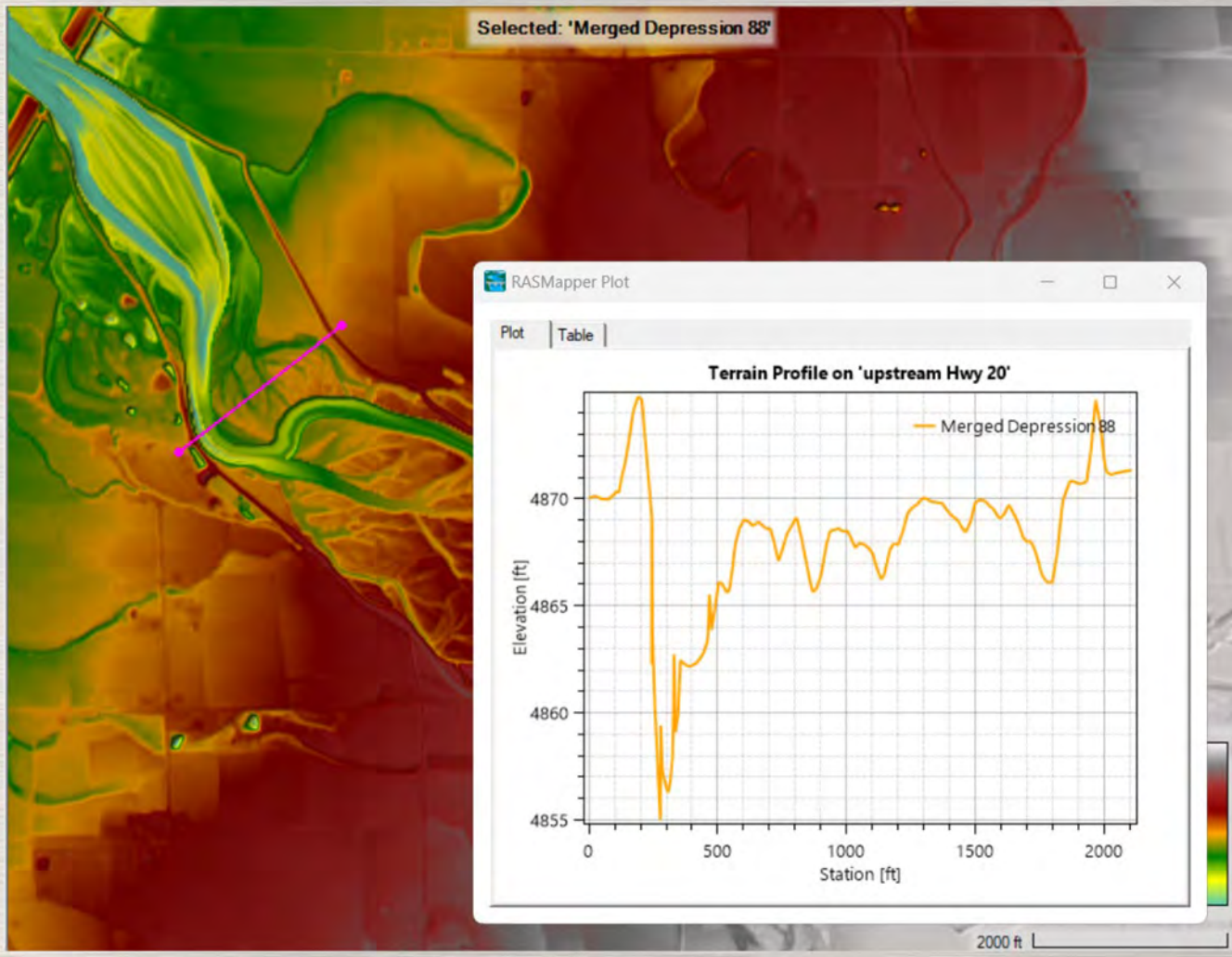


Idealized Reservoir Scenario

FCSA TO AMM – THE H&H ENGINEERS ROLE

FRM example - Levees

- Consider if the placement of the levee could have an impact on someone across from the levee – push the water laterally
- Consider if the levee could impact someone or downstream (lost attenuation) or upstream (from backwater).
- Assess if the reach could be aggregating or degrading



FCSA TO AMM – THE H&H ENGINEERS ROLE

Develop H&H scope for the remaining feasibility study

- Hydrology (typical models HEC-SSP, HEC-HMS)
- Frequencies 2%, 1%, 0.4%, 0.2% (ER 1110-2-1150, ER 1105-2-101)
- Hydraulics 1D, 1D/2D, 2D (typical model HEC-RAS)
- Terrain and field survey needs.
- Reservoir Modeling (typical model HEC-ResSim) (where applicable)
- Infrastructure and Installation Resilience [ECB 2018-14, EC 1100-1-113]
- Sea Level Change (where applicable) [ER 1100-2-8162]
- Sediment Transport (typical model HEC-RAS) [EM 1110-2-4000, ER 1110-2-8153]
- If levees or dams - Risk Assessment participation and breach modeling [ECB 2022-7]

Other Things H&H engineers consider:

- Leveraging
- Measures to be evaluated
- Number of Alternatives to be evaluated
- Model types and critical assumptions

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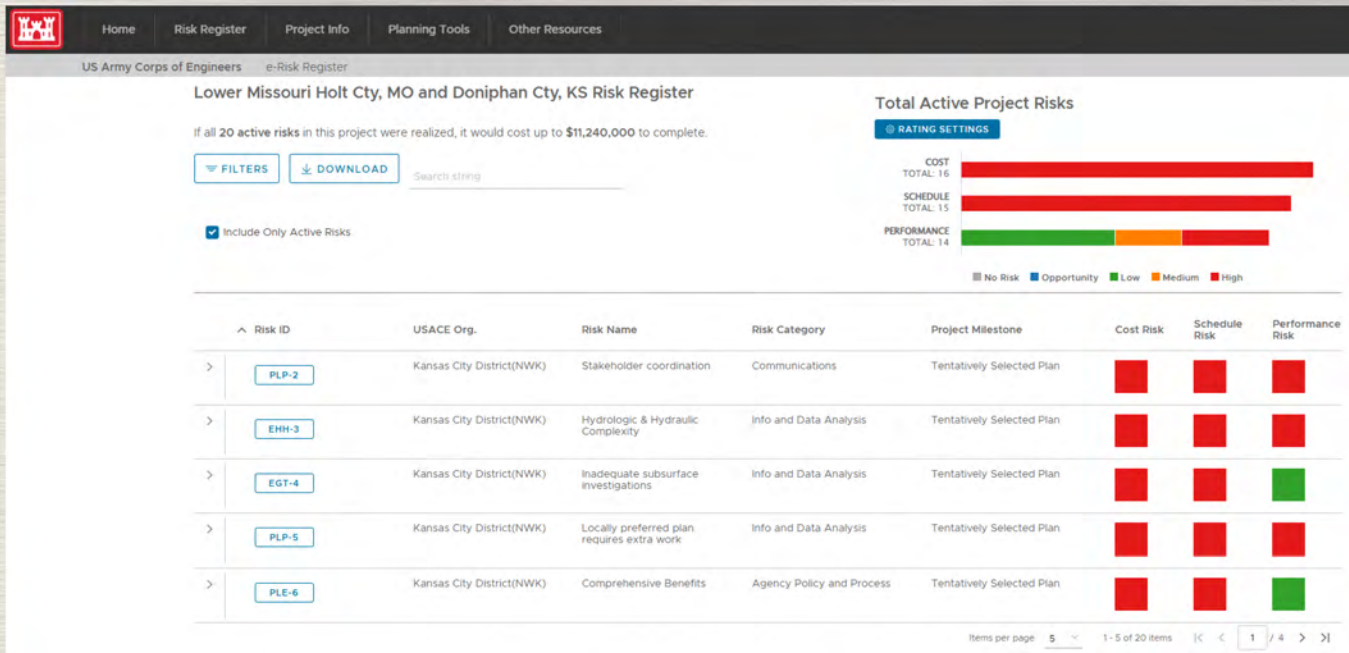
FCSA TO AMM – THE H&H ENGINEERS ROLE

Addressing Risks during Scoping H&H work

- There are a lot of risks that H&H engineers deal with during scoping.
- Types of common H&H risks included in the Risk Register:
  - Quality of available terrain data
  - Available hydrologic data
  - Leveraged models
  - More alternatives than scoped
  - Need for higher tier/stage of IIR/Sediment study

More on this later



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FCSA TO AMM – THE H&H ENGINEERS ROLE

Addressing Risks during Scoping H&H work

- Types of H&H risks that are built into the cost estimate:
  - Dealing with software error messages
  - Model development/instability
  - Learning curves of staff

March 2024

Comprehensive Study of the Sacramento River, Yolo Bypass System, CA

PROJECT MANAGEMENT PLAN

(P2-499690)

Photo Source: USFWS, Steve Martarano

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SAFCA Sacramento Area Flood Control Agency

FCSA TO AMM – THE H&H ENGINEERS ROLE

What the H&H engineer commonly misses having at the end of this milestone

- A clear scope in the PMP
- Terrain data that is current enough to show present landforms and with good enough accuracy to support defendable inundation mapping
- Knowledge of what leverageable data is available
- A plan for what will be District work, Contracted or WIK by a sponsor.

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FCSA TO AMM – TYPICAL HH DATA NEEDS

The time to identify HH data available or needed is during PMP scoping or earlier.

Data	Why It is Important
Stream gage data (flow)	Need for flow frequency/duration analysis. Used to calibrate models.
Precipitation Frequency Data	Needed whenever there is no or little stream flow gage data and in other situations where floods of different frequency or shape are needed that are not available in the current stream gage data.
Current Terrain Data (typically LiDAR)	Without it river hydraulic modeling cannot progress. Using low quality or outdated data can lead to cost busts after feasibility. Can alter results if gathering this data postponed to PED.
Structure/Bathymetry Field Survey	This data is typically critical to good hydraulic model development. Shows landforms under water, and structures that shape water movement.
Existing Models	If they meet the engineers need, they could be used in whole, or if not, they could be modified or used as a source of leverageable data. This saves the study money.

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FCSA TO AMM – TYPICAL HH DATA NEEDS

The time to identify HH data available or needed is during PMP scoping or earlier.

Data	Why It is Important
Existing Sediment or Infrastructure Resilience studies	This saves the study money.
Existing Levee Risk Assessments SQRA/Screening	These can include breach analysis of existing levees that can be leveraged or have data to reduce study costs.
Reservoir operations data (where applicable)	Needed to form a starting point for existing conditions reservoir operations.

FCSA TO AMM - FEMA A GOOD SOURCE FOR DATA

- FEMA has a large amount of H&H data.

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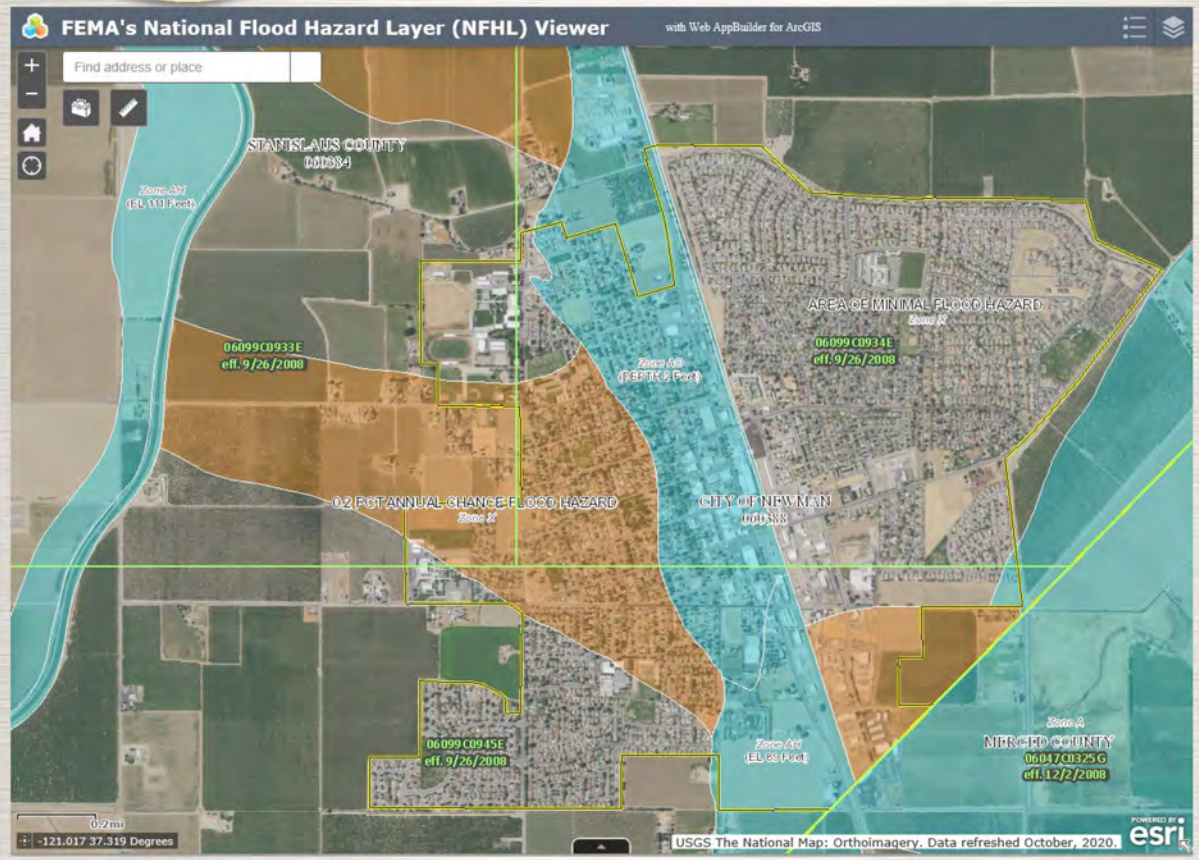
FCSA TO AMM – FEMA NFIP MAPS



- Digital FEMA Flood Insurance Rate Map (DFIRM)
- 1% AEP Base Flood Elevations (BFE)
- 1% AEP Inundation limits
- 0.2% AEP Inundation limits
- Floodway Boundaries
- Flood Hazard Zones
- Levees

Maps are available to download as GIS layers. Models and detailed technical information can be obtained from FEMA by special request.

Check FIS Report first – it might not be worth it.

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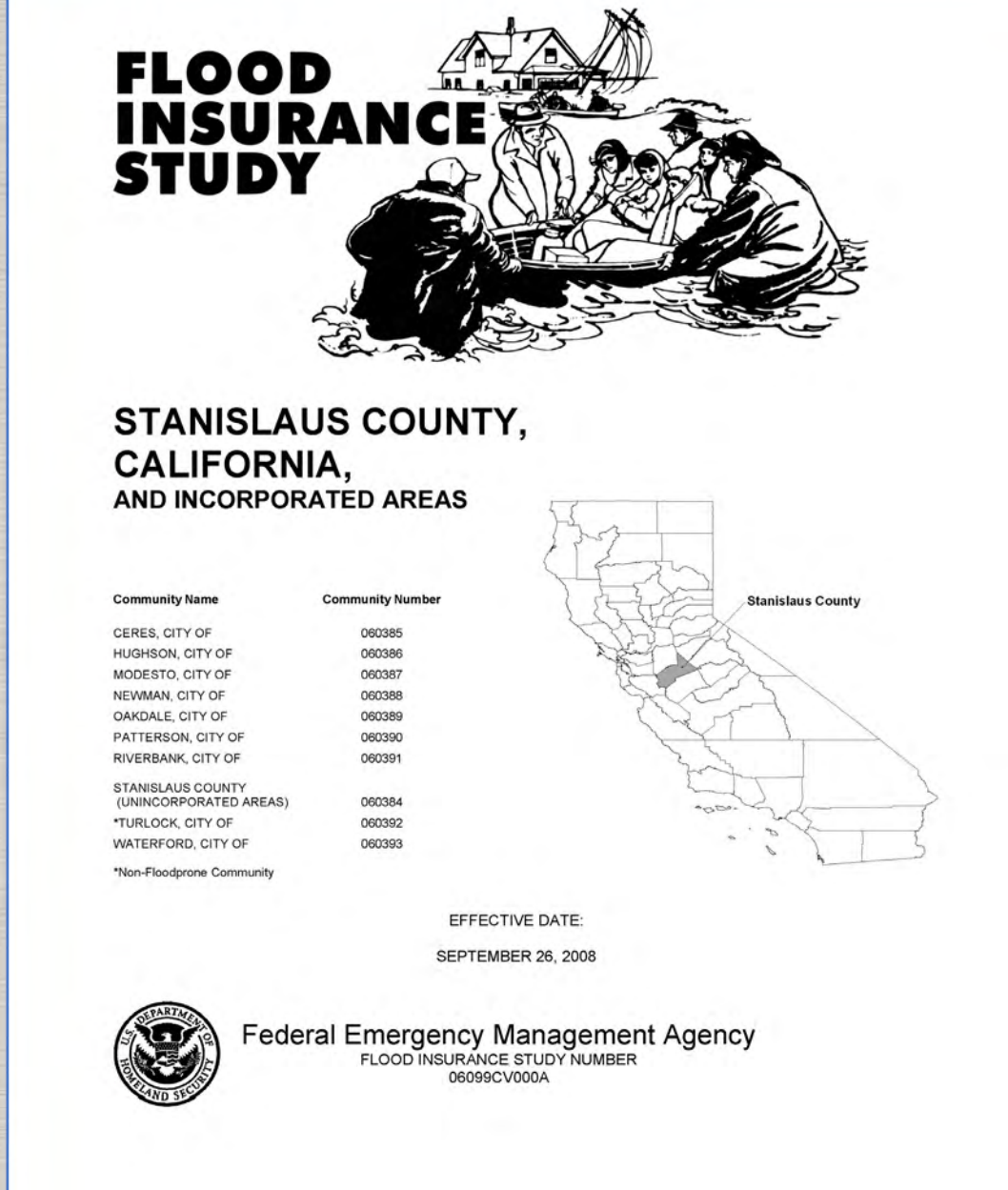
FCSA TO AMM - FEMA NFIP REPORTS

- FEMA Flood Insurance Study (FIS)
- Study Area Description
- Technical Assumptions
- Principle flooding problems
- Hydrologic summary
- Table of Discharge Frequency
- Profiles for 10% AEP, 1% AEP, 0.2% AEP Events



FLOOD INSURANCE STUDY

STANISLAUS COUNTY, CALIFORNIA, AND INCORPORATED AREAS

Community Name	Community Number
CERES, CITY OF	060385
HUGHSON, CITY OF	060386
MODESTO, CITY OF	060387
NEWMAN, CITY OF	060388
OAKDALE, CITY OF	060389
PATTERSON, CITY OF	060390
RIVERBANK, CITY OF	060391
STANISLAUS COUNTY (UNINCORPORATED AREAS)	060384
*TURLOCK, CITY OF	060392
WATERFORD, CITY OF	060393

*Non-Floodprone Community

Stanislaus County

EFFECTIVE DATE:

SEPTEMBER 26, 2008

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER

06099CV000A

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AMM TO TSP

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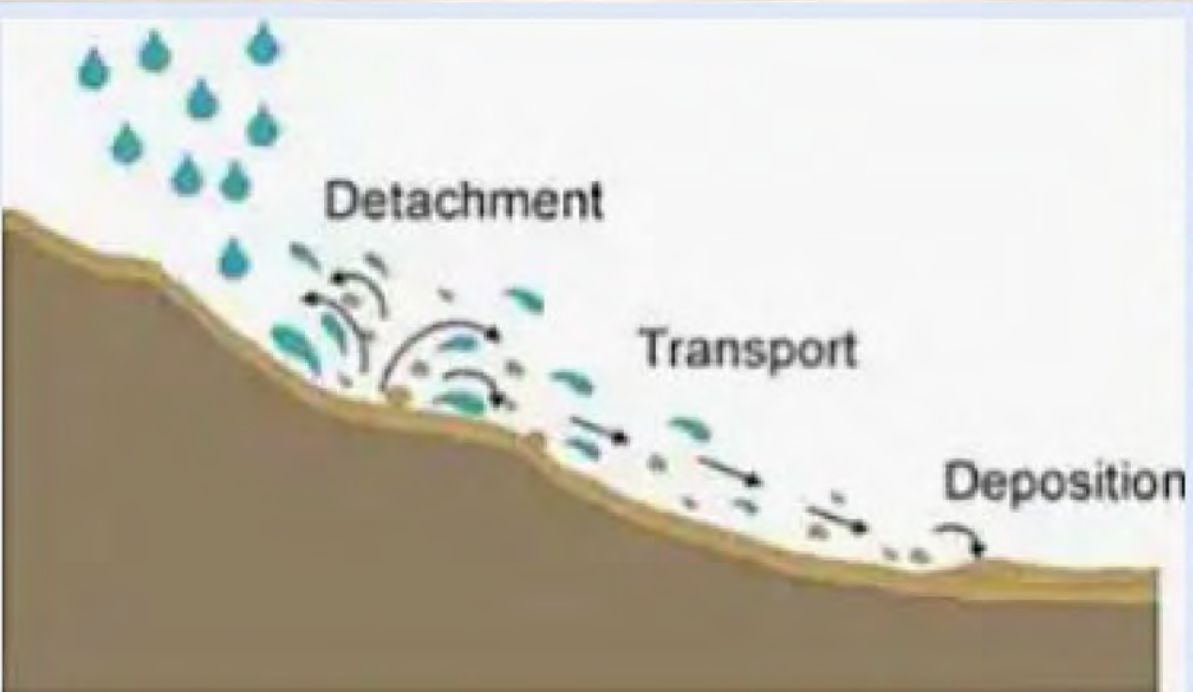
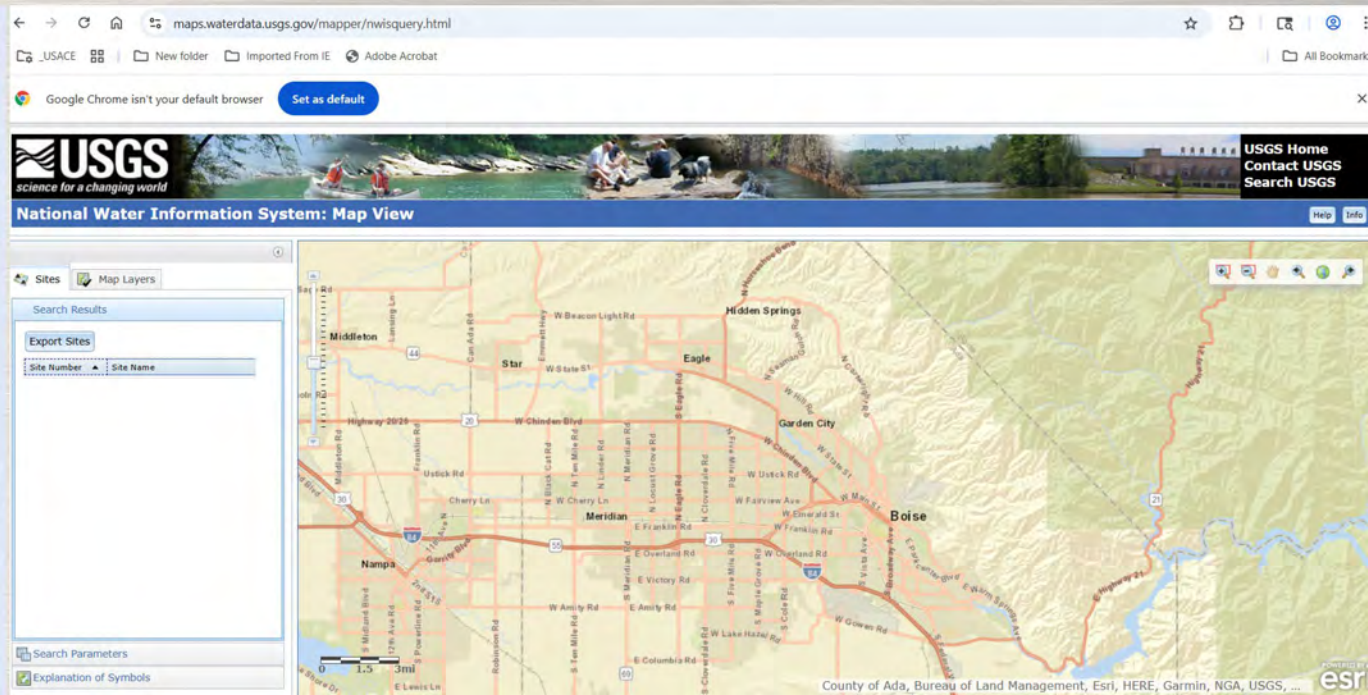
AMM TO TSP – THE H&H ENGINEERS ROLE

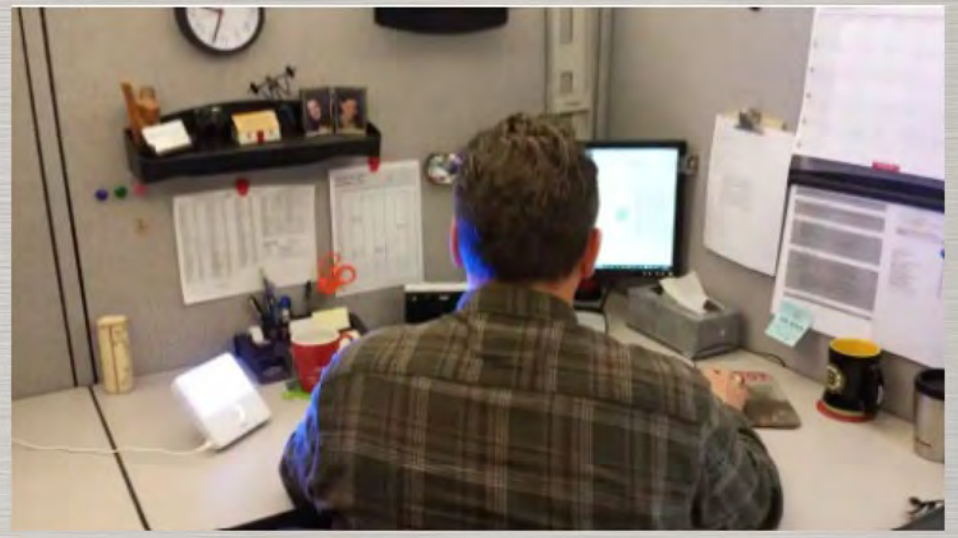
Getting Started

- Gather available data and models
- Obtain all data required for the study
- Begin Infrastructure and Installation Resilience assessments
- Begin Sediment study. Some push it to post TSP or even PED (risk).





AMM TO TSP – THE H&H ENGINEERS ROLE



Existing Conditions and FWOP

- Sea Level Change assessment (if applicable)
- Assessing if coincident probability is needed
- Develop Modeling
  - Hydrology
  - Reservoir (as needed)
  - Hydraulics
- Balance need for detail verses what is adequate
- Develop Documentation
- Address all guidance requirements at a reasonable level of detail.
- Conduct focused DQC/ATR on FWOP modeling (recommended)
- Pass data to Economist (if applicable)

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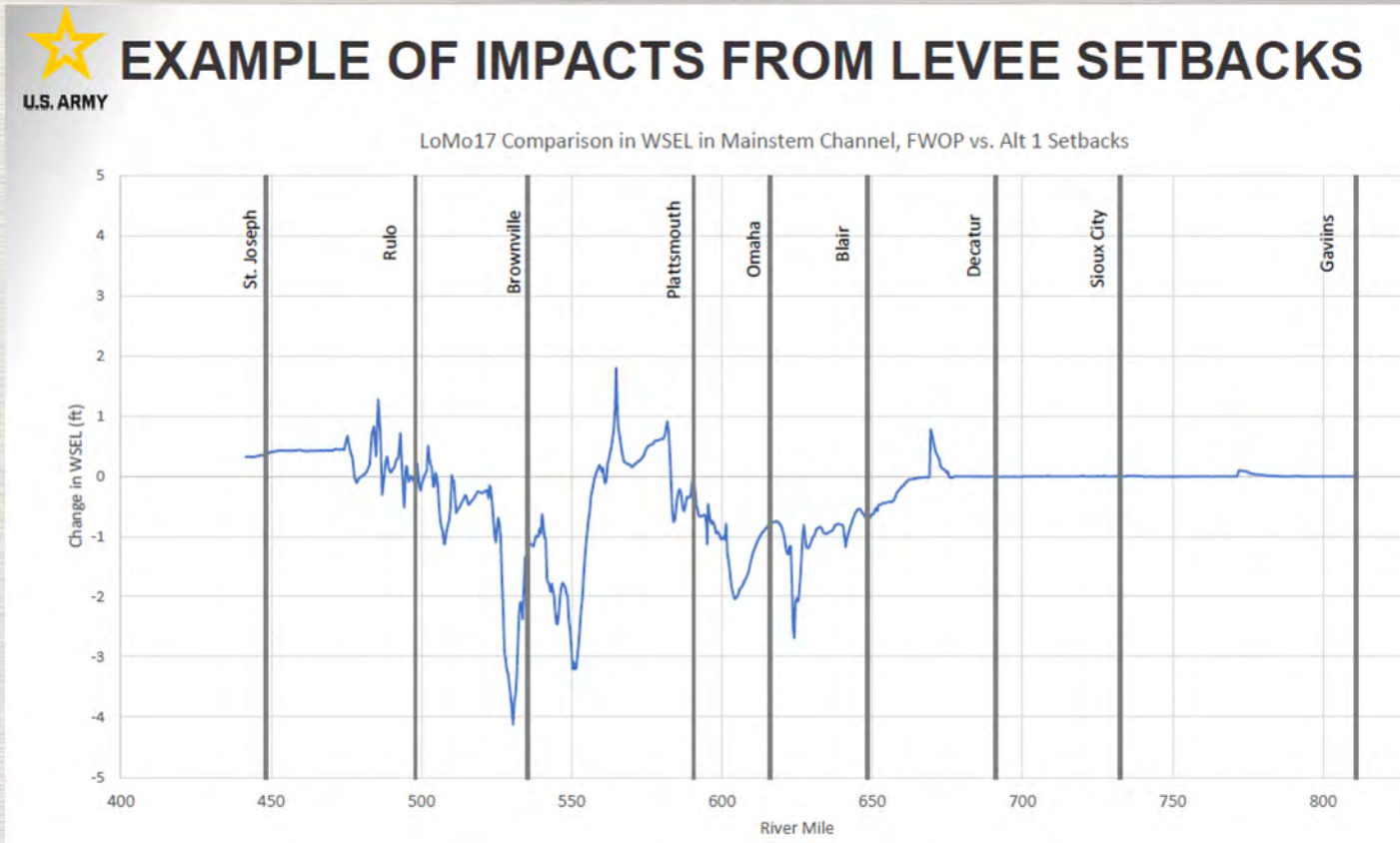
AMM TO TSP – THE H&H ENGINEERS ROLE

FWP

- Participate in Formulation and Development of Alternatives
- Refine Alternatives to make sense Hydrologically and Hydraulically
- Develop Modeling
  - Reservoir Scenarios (as needed)
  - Terrain Adjustments
  - Hydraulics
- Continue documentation
- Balance need for detail verses what is adequate
- Pass data to Economist (if applicable)



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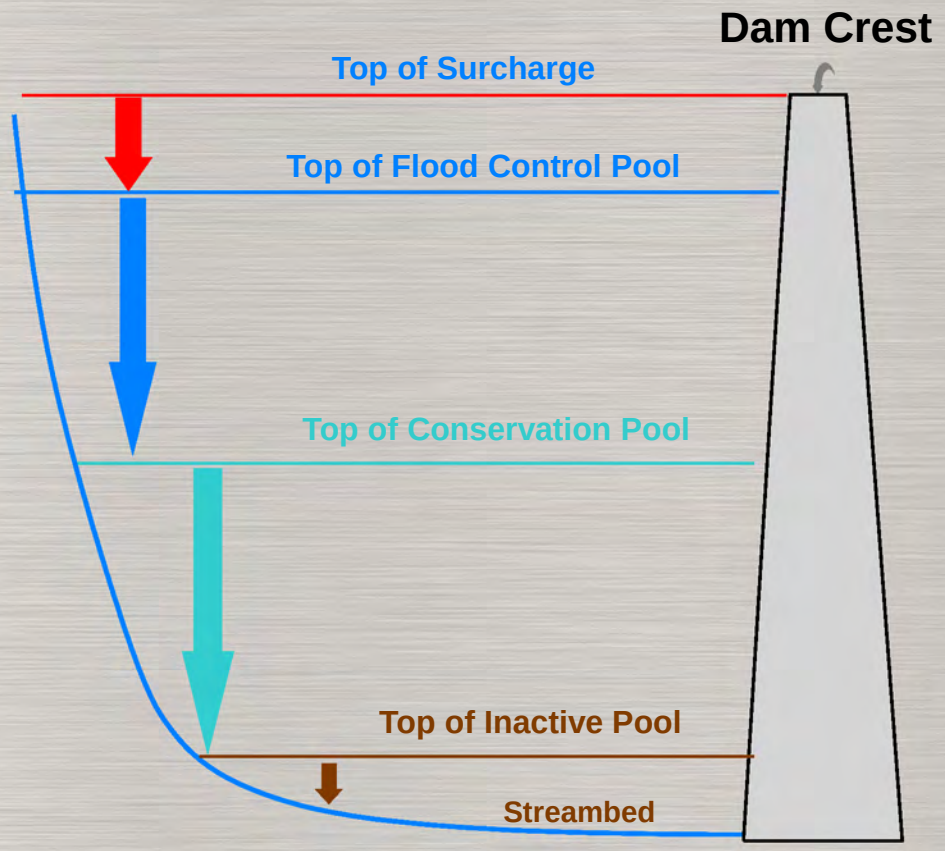
AMM TO TSP - Dams

- If a project has an existing dam there may be interest in modifying the operations of the dam. Or there may be interest in building a new dam
- These are the things that H&H will be considering for each of 3 types of dams.

Multipurpose dam - Rainfall dominated basin

- **Surcharge** –Accommodates water above the emergency spillway.
- **Flood Control Pool** – Water is stored in this zone when it cannot be safely passed through the downstream channel system.
- **Conservation Pool** –Water is reserved for various water demands, agricultural, environmental, municipal, etc.
- **Inactive Pool** – May be zero or a minimum pool level.



Reservoir Storage Zones

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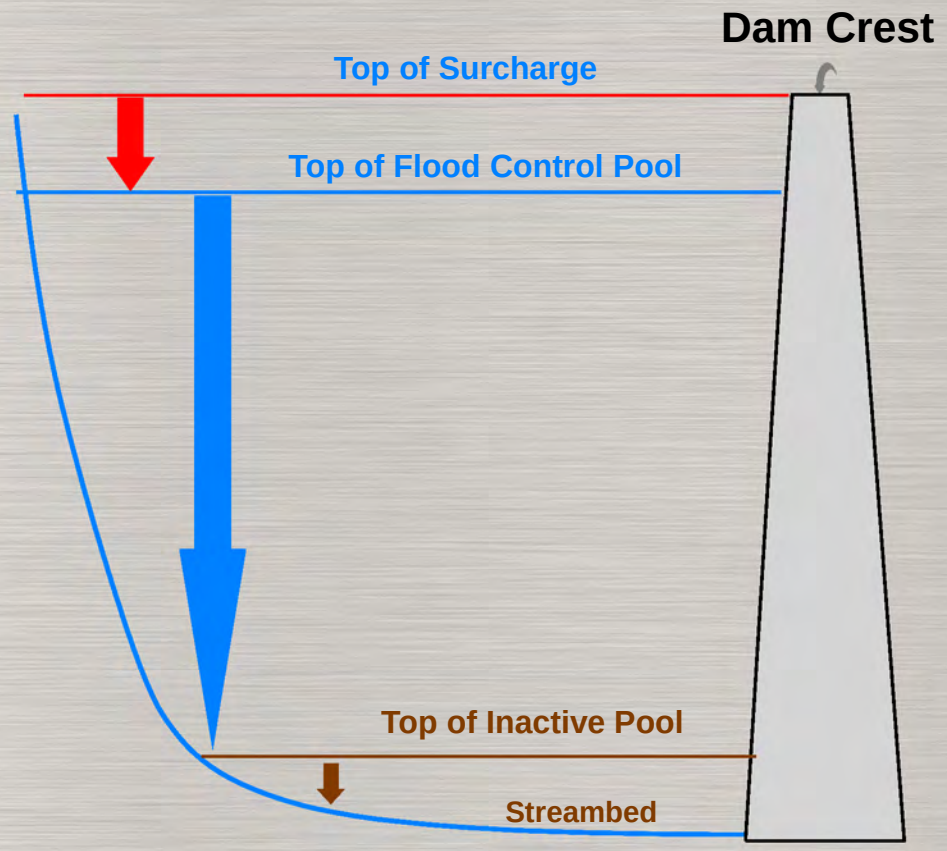
Single purpose dam

- **Surcharge** –Accommodates water above the emergency spillway.
- **Flood Control Pool** –
  - Fill and Spill – No operational decisions. Fixed outlet limits outflow, storing water until the reservoir fills and spills.
  - Controlled outlet - Water is stored in this zone and can be retained during certain times of the year.
- **Inactive Pool** – May be zero or a minimum pool level.



Reservoir Storage Zones

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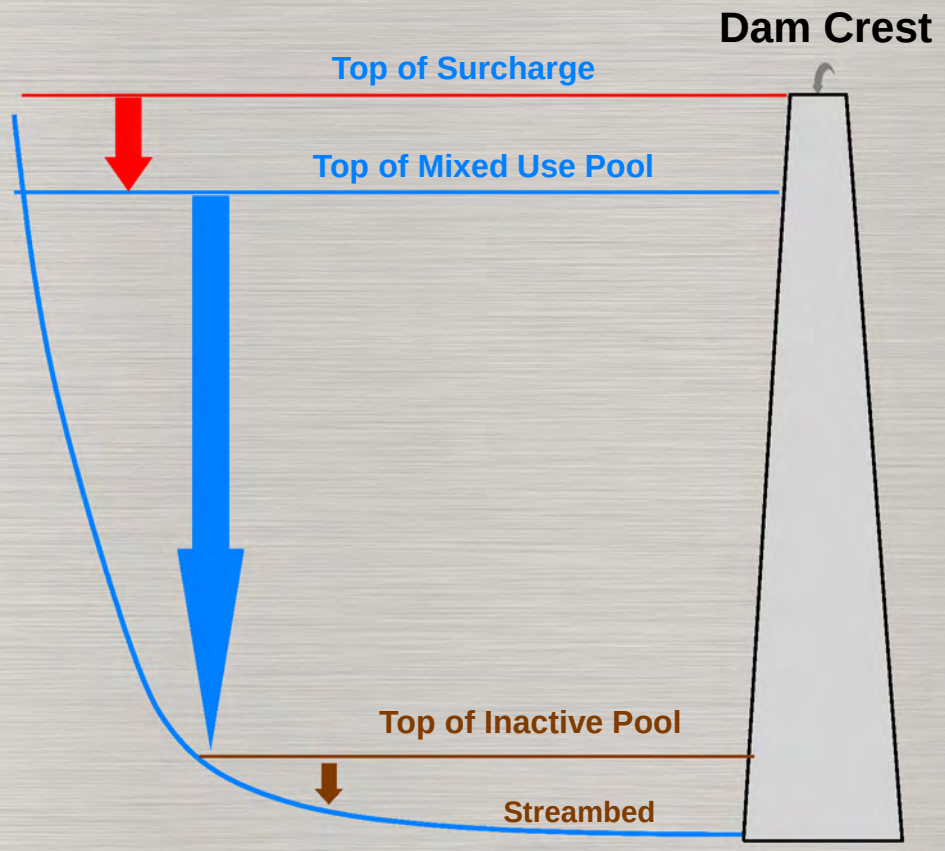
Multipurpose dam - snowmelt basin

- **Surcharge** –Accommodates water above the emergency spillway.
- **Mixed Use Pool** – Water and space is balanced for competing purposes of Flood Control (ideal pool is empty) and Water Demands (agricultural, environmental, municipal, ect.) (ideal pool is full)
- **Inactive Pool** – May be zero or a minimum pool level.



Reservoir Storage Zones

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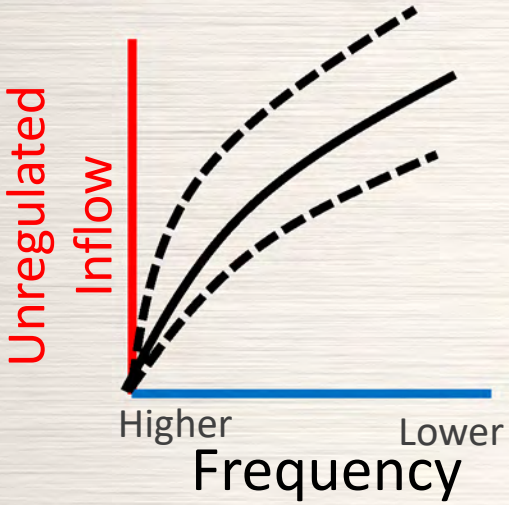
AMM TO TSP - RISK ASSESSMENT

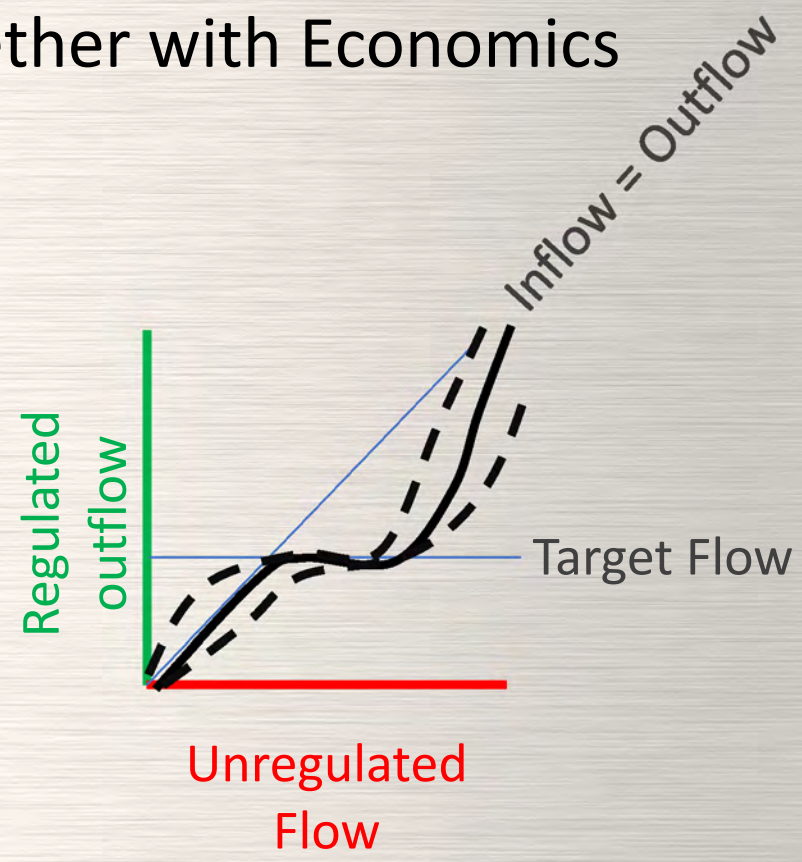
- If a project has an existing dam or levee, a risk assessment is needed unless one is available. In addition, a risk assessment is needed for the TSP if it includes a dam or levee. (PB 2019-04, ECB 2019-15, ECB 2022-7)
- H&H will support a risk assessment for either a dam or a levee
- Typical H&H tasks beyond other feasibility work:
  - Probable Failure Mode Analysis
  - Dam/Levee Breach modeling

AMM TO TSP – THE H&H ENGINEERS ROLE

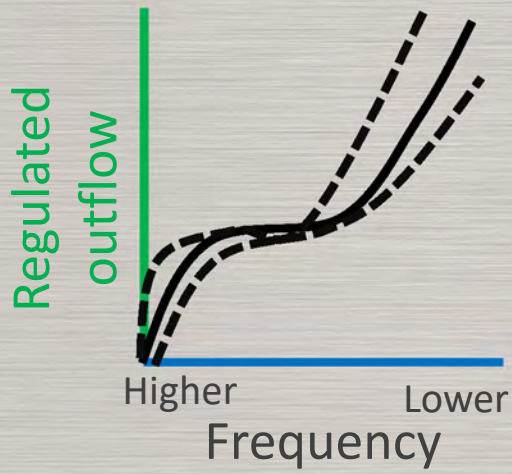
Pulling it all together with Economics



Use this for the FWOP
May also be used for FWP
if there is no reservoir



Developed by routing floods of different magnitudes and shapes through a reservoir

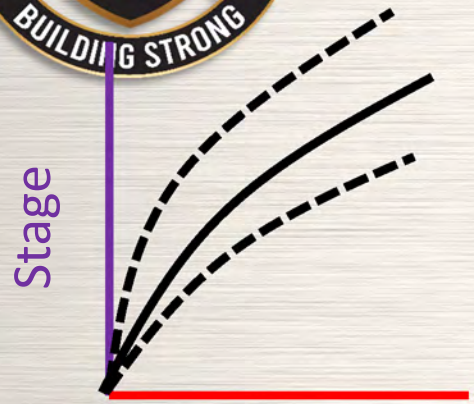


Developed by combining the two relationships

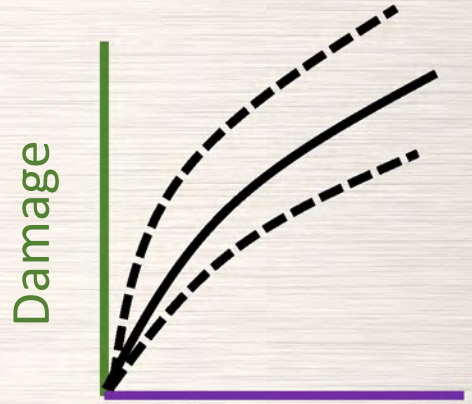
Use this for FWP if there is a reservoir

AMM TO TSP – THE H&H ENGINEERS ROLE

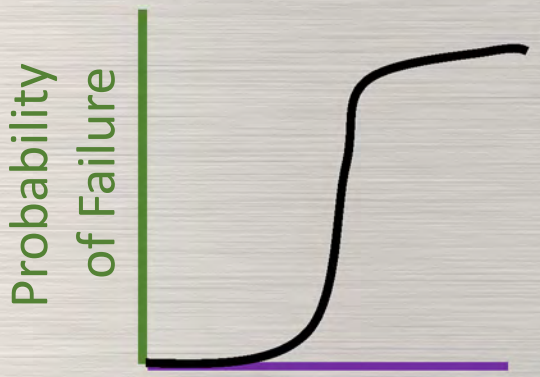
Pulling it all together with Economics



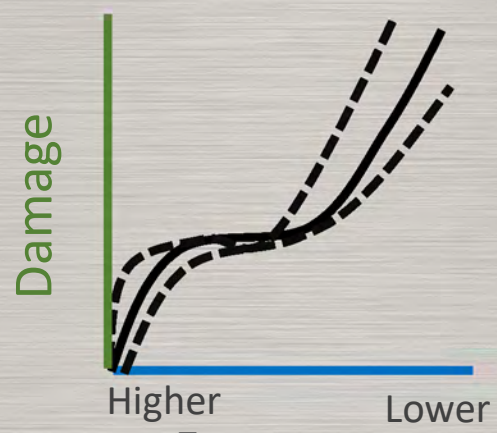
Developed with Hydraulic Analysis
A reservoir does not change this function



Developed with Economic Analysis
A reservoir does not change this function



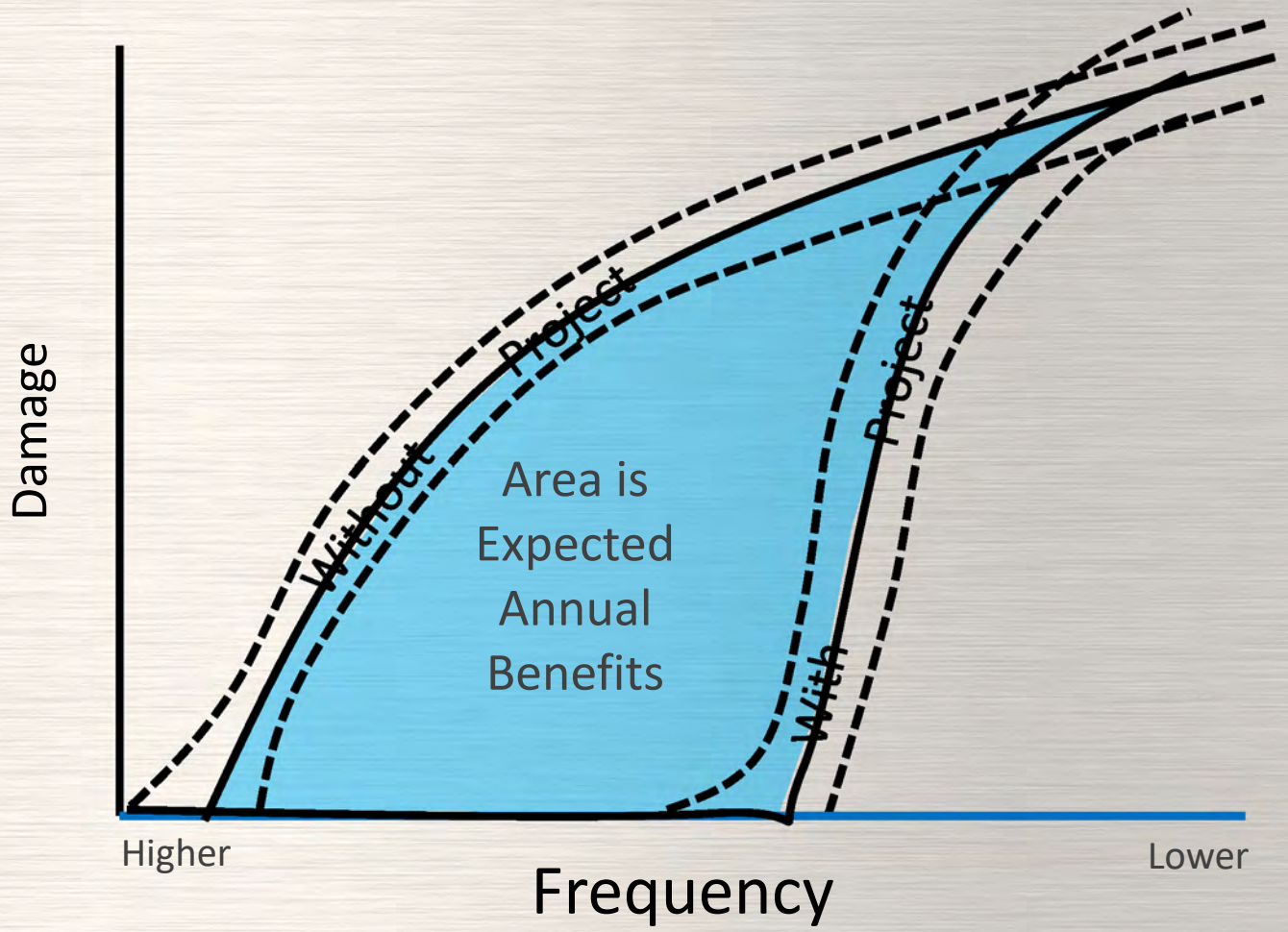
Fragility Curve for Levees
A reservoir does not change this function



Developed by combining relationships in HEC-FDA

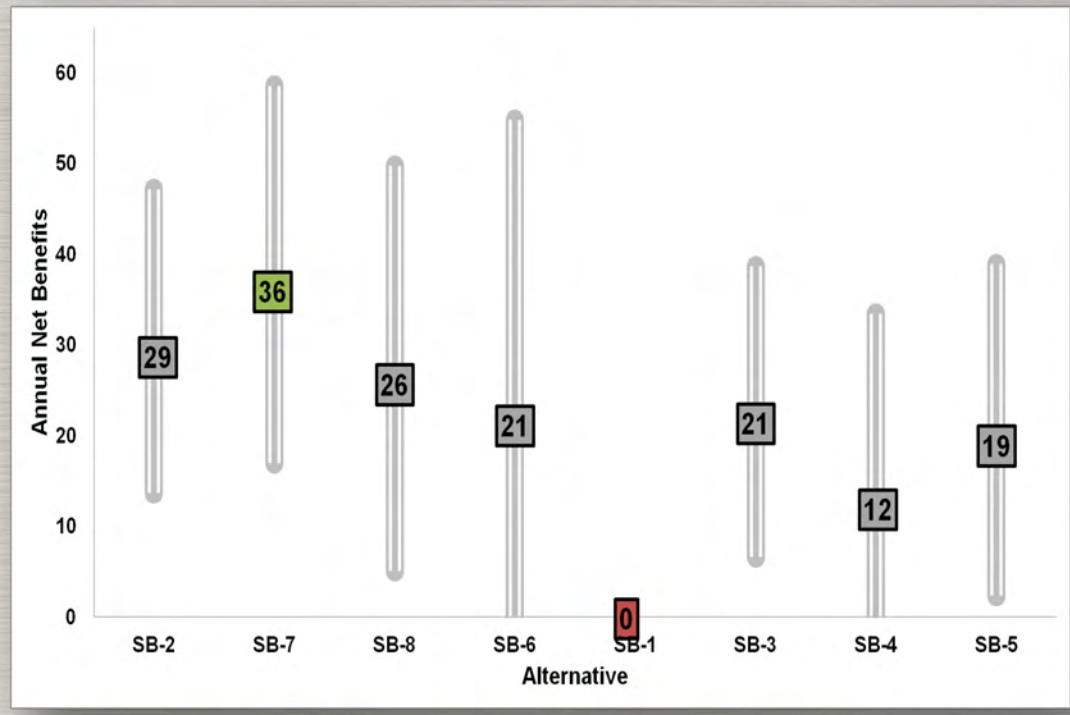
Above image is for FWP with a reservoir
Will have a differently shaped image for FWOP

AMM TO TSP – THE H&H ENGINEERS ROLE



AMM TO TSP – THE H&H ENGINEERS ROLE

- H&H will compare plans with the PDT
- Selecting the Plan (TSP Milestone)
  - The TSP milestone is a relative comparison between plans
  - H&H will Identify H&H uncertainties that impact all plans in a similar direction.
  - Identify uncertainties that impact some plans more than others.



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AMM TO TSP – THE H&H ENGINEERS ROLE

- Quality control process (recommended)
  - Conduct focused DQC and ATR of future without project conditions.
  - Conduct early DQC review of IIR analysis.
  - Conduct DQC of alternative plans prior to TSP.
  - Document all DQC efforts to support ATR (ER 1165-2-217)

AMM TO TSP – H&H ENGINEER PRODUCTS

Not every study will include all these products

- Flow Frequency Curve (probability of a given flow)
- Hydrographs for specific flow frequency (time delineated flows leading to the peak and falling off from it)
- Volume Frequency curves
- Flow Duration information
- Inundation Mapping for each Flow Frequency, for FWOP and all FWP alternatives
- Induced Flooding Mapping
- Levee Breach Mapping
- Dam Break Mapping
- Reservoir Operations plan
- Sediment Study
- Infrastructure and Installation Resilience Assessment
- Documentation

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AMM TO TSP – THE H&H ENGINEERS ROLE

- H&H will help improve documentation
  - Describe plans in final array at equivalent level of detail.
  - Defer to main report to describe selection of TSP to avoid conflicts.
  - Try to address all guidance requirements at reasonable level of detail. This avoids unnecessary review questions on potential missing items.
  - Describe plan performance per ER 1105-2-101.
  - Avoid phrases like “level of protection” or “return period”

AMM TO TSP – IMPROVING COORDINATION BETWEEN PLANNING AND H&H

- Areas for targeting improved team coordination with H&H

  (A ETL can help drive this improvement)

  - Improve H&H involvement in formulation and design of alternatives.
  - Improve H&H coordination for economic and life risk inputs.
  - Have H&H share preliminary information with the economist for parallel economic model development.

TSP TO COMMAND VALIDATION MILESTONE (CVM)

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TSP TO CVM – THE H&H ENGINEERS ROLE

Respond to review comments

- Address comments that could change TSP selection.
- Defer feasibility design comments until after CVM.

Confirm plan selection with PDT

CVM TO DISTRICT FINAL REPORT

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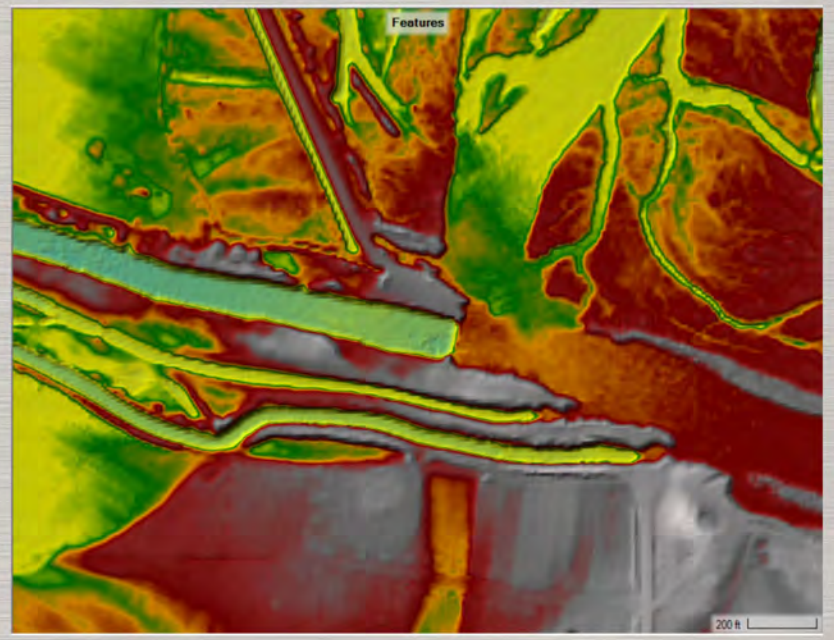
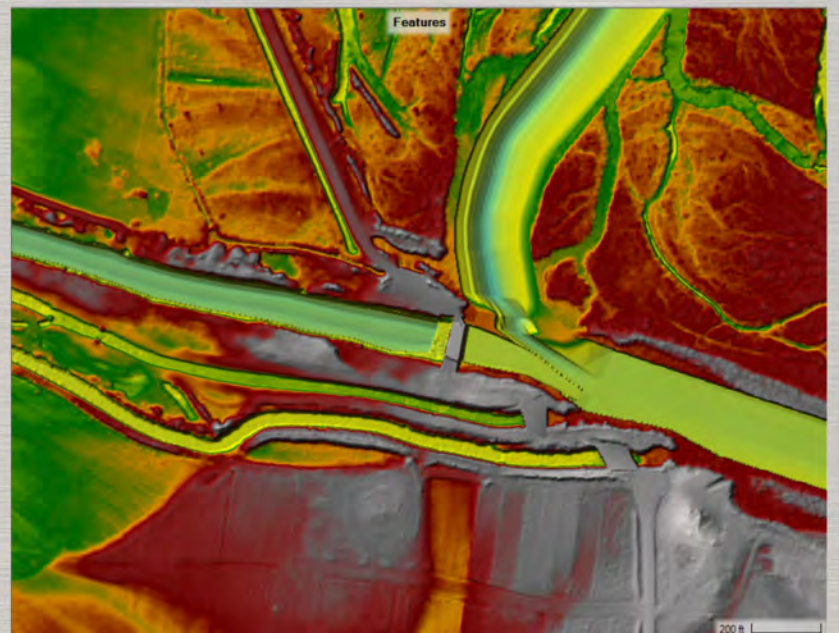
CVM TO FINAL REPORT – THE H&H ENGINEERS ROLE

- Confirm the Plan
- Conduct Sediment Analysis on TSP if not already completed. Identify if it may change the TSP.
- Conduct Model or Analysis Refinements identified prior to TSP or from review comments
- The HH engineer will focus on reducing uncertainties that had the most influence at the TSP milestone.
- These may include:
  - Better terrain data
  - Adding structures that were surveyed
  - Adding detail to the model
  - Refining model calibration





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CVM TO FINAL REPORT – THE H&H ENGINEERS ROLE

H&H engineer will:

- Increase level of design maturity, if needed, to support Class III cost estimate.
- Address feasibility design comments from ATR/IEPR
- Update engineering appendices to address any review comments.
- If applicable, evaluate range of plan sizes and select the final plan.
- Append sections to appendices to describe feasibility level design of recommended plan.

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WHAT SOFTWARE DOES A H&H ENGINEER USE

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WHAT KIND OF SOFTWARE DOES A H&H ENGINEER USE?

	Flood Risk Management Study **Typical HH Models**	**Ecosystem Study** **Typical HH Models**	**Water Management and Reallocation Studies** **Typical HH Models**
Hydrology Statistical Model (where applicable)	HEC-SSP (Statistical Software Package)	HEC-SSP	HEC-SSP
Hydrology Model (where applicable)	HEC-HMS (Hydrometeorological Modeling System)	HEC-HMS	HEC-HMS
Hydraulics Model	HEC-RAS (River Analysis System)	HEC-RAS	HEC-RAS
Reservoir Model (where applicable)	HEC-ResSim (Reservoir Simulation)	HEC-ResSim	HEC-ResSim
Levee Risk and Uncertainty/Levee Sizing (where applicable)	HEC-FDA (Flood Damage Analysis)		
Ecosystem Function modeling (where applicable)		HEC-EFM (Ecosystem Function Model)	
Systems modeling (where applicable)	HEC-WAT (Watershed Analysis Tool)	HEC-WAT (Watershed Analysis Tool)	HEC-WAT (Watershed Analysis Tool)

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WHAT KIND OF SOFTWARE DOES A H&H ENGINEER USE?

Navigation Models **Typical HH models**	**Coastal Models** **Typical HH models**
ADH (Adaptive Hydraulic Modeling System)	ADH
ADCIRC (Advanced Circulation Model)	ADCIRC
CEQUAL-ICM	CMS (HH Model)
CADET (Channel Design and Evaluation Tool)	RAS (HH Model)
Delft 3D	STWAVE (Wave Model)
ERDC Ship/Tow Simulator	WAVEWATCH III (Wave Model)
CMS-Wave	CMS Wave (Wave Model)
CMS-Flow	FUNWAVE (Wave Model)
MDFATE/MPFATE (Multiple Placement Fate of Dredged Material)	CSTORM (Combined condition model)
STFATE (Short Term Fate of Dredged Material)	CMS (Sediment Transport)
STWAVE (Steady State Spectral WAVE)	ADH (Sediment Transport)
LOCSIM	SBEACH (Cross shore/storm event beach)
	CSHORE (Cross shore/storm event beach)

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H&H RISK AND UNCERTAINTY

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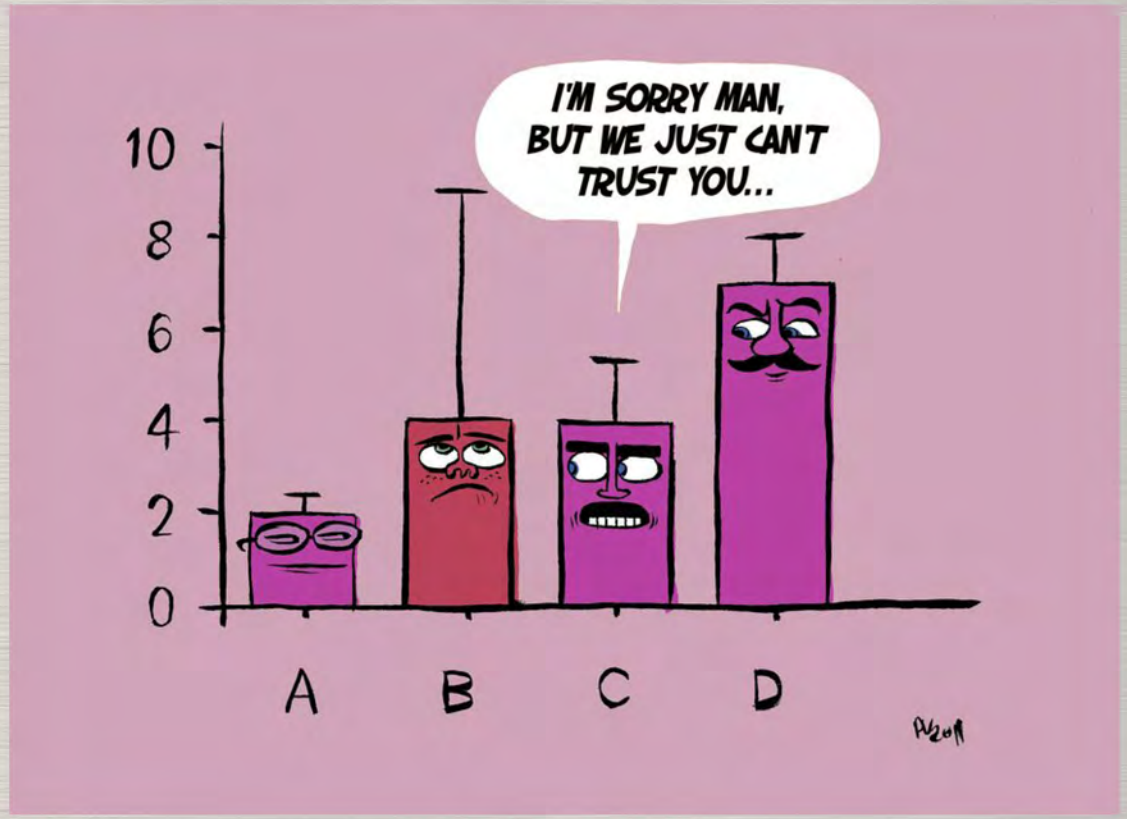
HOW TO MANAGE ENGINEERING RISKS

- Risk and Uncertainty terms are often used interchangeably.
- Risk is the likelihood of occurrence and the magnitude of consequences of an adverse event.
- Uncertainty is the indefiniteness of some aspect of the values used in the risk quantification process.



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USE THE STUDY RISK REGISTER TO MANAGE RISKS

- The HH engineering will list risks in the risk register. These may include:
  - Risks of needing better terrain
  - Risks of not being able to obtain structure information and needing field surveys.
  - Risks related to using leveraged hydrologic data
  - Risks of needing a stage 2 Sediment Assessment (EM 1110-2-4000)
  - Risks of needing a Tier 2 IIR assessment (ECB 2018-14)
  - Risks that a leveraged model may not be usable or require notable rework.
  - Risk of a request of more alternatives than scoped
- Revisit the study risk register throughout the study.

Uncertainty *Range of potential results.*	**Consequence**	**Likelihood**	**Uncertainty**	**Risk (uncertainty)**	**Recommendation for reducing or "buy down" the risk (optional column)**	**Consequence**	**Likelihood**	**Uncertainty**	**Risk (uncertainty)**	**Levels of rating buy down from mitigation recommendation**
Low	M	H	L	H(L)	Use existing data and studies to reduce risk. Identify areas where spot data (limited additional data) or desk top analysis may be useful. Capture any remaining uncertainties in the contingencies.	M	M	L	M(L)	1

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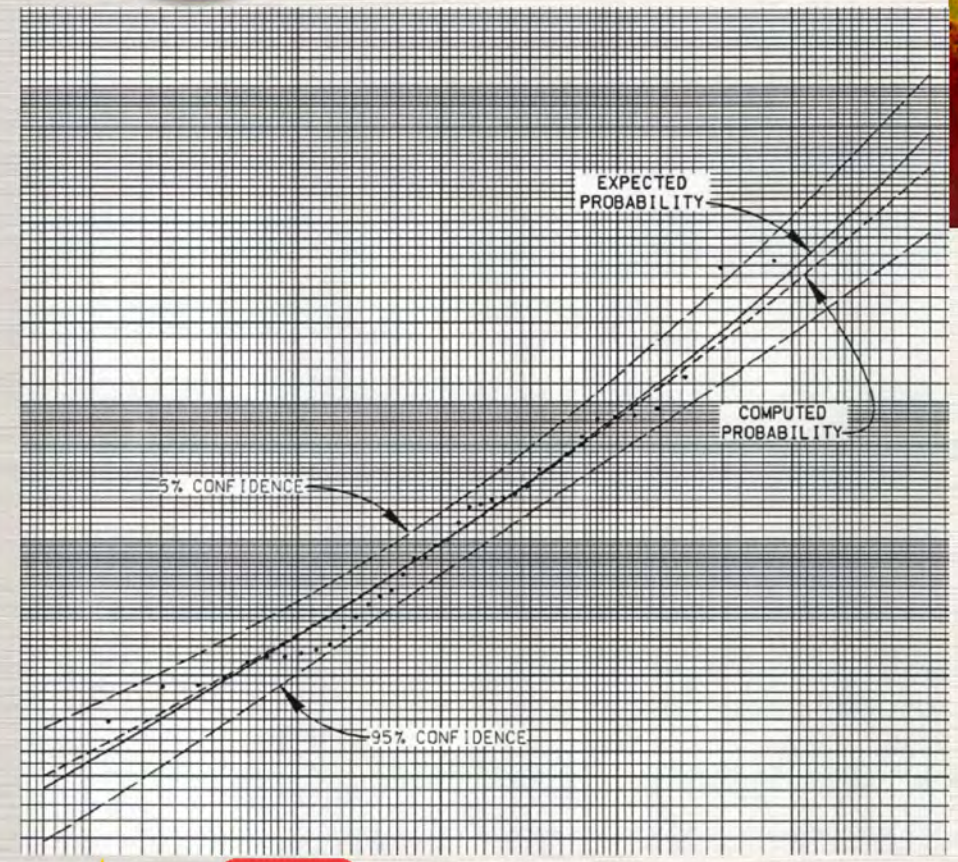
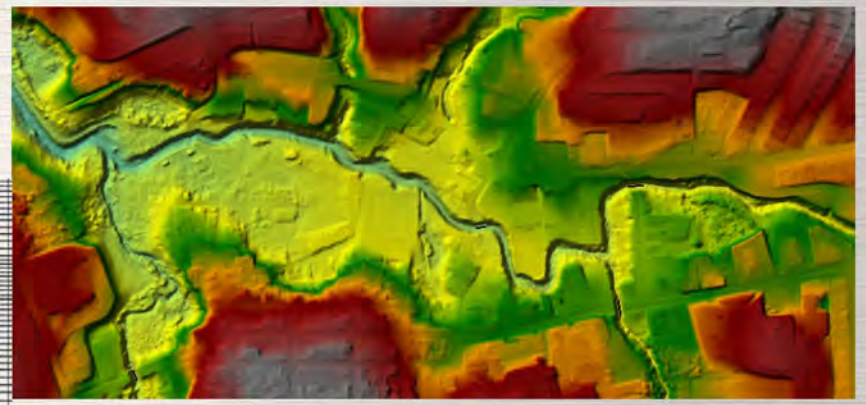
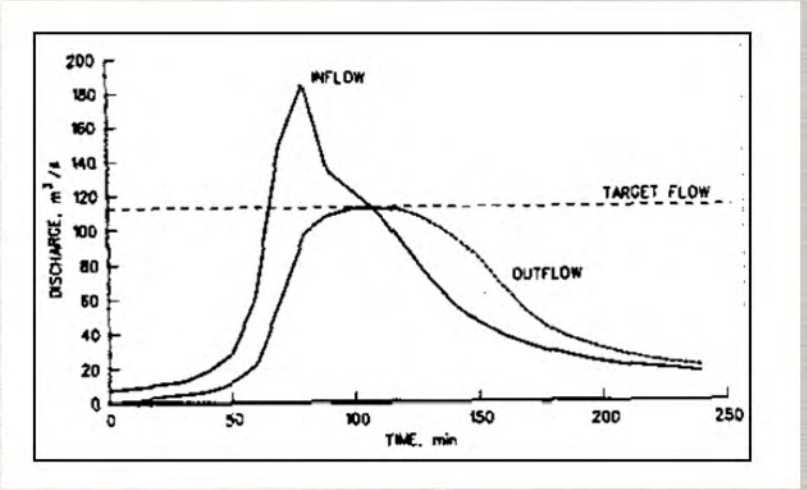
MANAGING UNCERTAINITY
THINGS THAT THE H&H ENGINEER CONSIDERS







Stage-Discharge
- Manning's Roughness
- Topographic Data
- Sea Level Change

Flow Frequency
- Period of Record
- Rainfall Intensity
- Infiltration Rates
- Temporal Pattern

Reservoir Inflow-Outflow
- Unregulated runoff
- Outlet Capacity
- Operation

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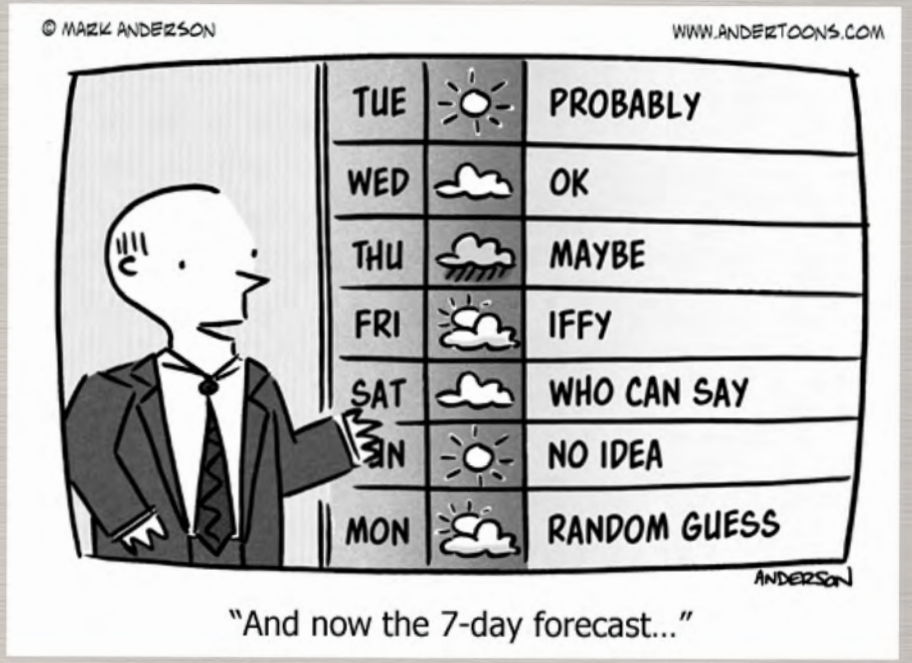
MANAGING UNCERTAINITY
THINGS THE H&H ENGINEER MAY DO

- Evaluate book ends, the maximums and minimums may be closer than thought.
- Sensitivity analysis (scenarios that test the range of possibilities) will be used rather than evaluating every possibility
- Look at uncertainty impacts



"And now the 7-day forecast..."

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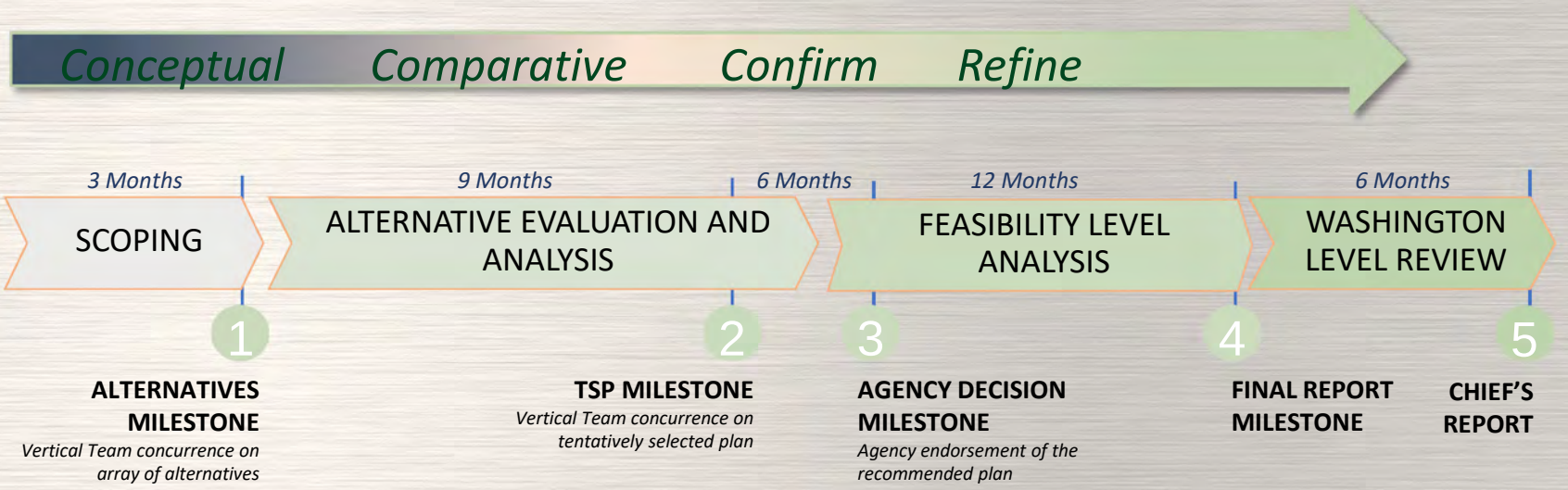
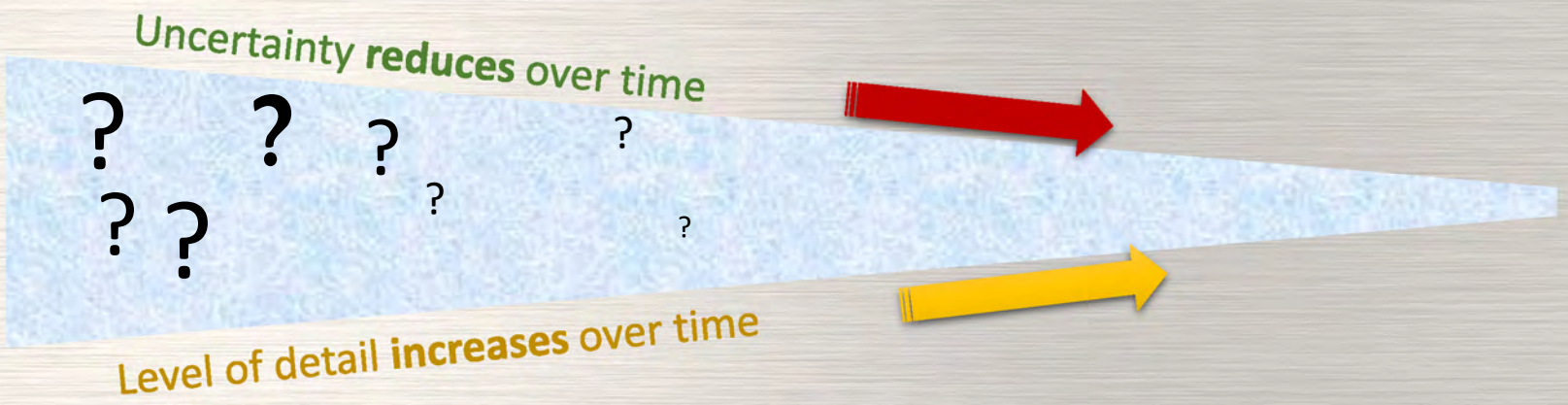
MANAGING THE STUDY UNCERTAINITY





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SUCCESFUL WORKING RELATIONSHIPS

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SUCCESSFUL WORKING RELATIONSHIPS BETWEEN PLANNING AND H&H

- Set aside controlling behaviorism. This is a team effort.
- Acknowledge guidance/requirements for both planning and HH
- Apply the right level of detail
  - Message to the Planner: The HH engineer must provide the level of detail to meet design maturity, to assure the TSP will not change with further refinement and can be defendable for a takings analysis.
  - Message to the HH engineer: The project needs to be cost effective and have timely completion. This is not the place for deep dives or experimenting with untried methods (typically).
- Understand the planning process
  - Message to the Planner: Understand that the term “iteration” sounds like an inefficient looping to a H&H engineer. The engineer sees there is nothing more inefficient than redoing work just to add detail that should have been there to start with.
  - Message to the HH engineer: Make wise judgement as to how much detail you put into your work. Look for quick and easy efforts for screening up to the AMM. The Existing Conditions/FWOP needs to be the quality of the final product. Limit detail on Alternatives that show little promise.

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SUCCESSFUL WORKING RELATIONSHIPS BETWEEN PLANNING AND H&H

- Planners: DON'T EXPECT THAT YOUR TEAM WILL HAVE THE DISTRICT EXPERT H&H ENGINEER DOING THE MODELING. Every engineer has to start somewhere. Your office may be assigning someone to mentor the junior H&H engineer in the background that you are not aware of.

- H&H Engineers: DON'T EXPECT THAT THE PLANER SHOULD KNOW ENGINEERING DECISION MAKING AND WHY YOU ARE DOING THINGS THE WAY YOU ARE. Take time to explain why you are following a particular course of action.

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