RIVERINE PALEOFLOOD ANALYSES IN RISK-INFORMED DECISION MAKING

IMPROVING HYDROLOGIC LOADING INPUT FOR USACE DAM SAFETY EVALUATIONS

Keith Kelson
Brian Hall
Justin Pearce
Reuben Sasaki
US Army Corps of Engineers

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US Army Corps of Engineers

“SO YOU MEAN A PALEOFLOOD STUDY IS JUST…

finding a site…

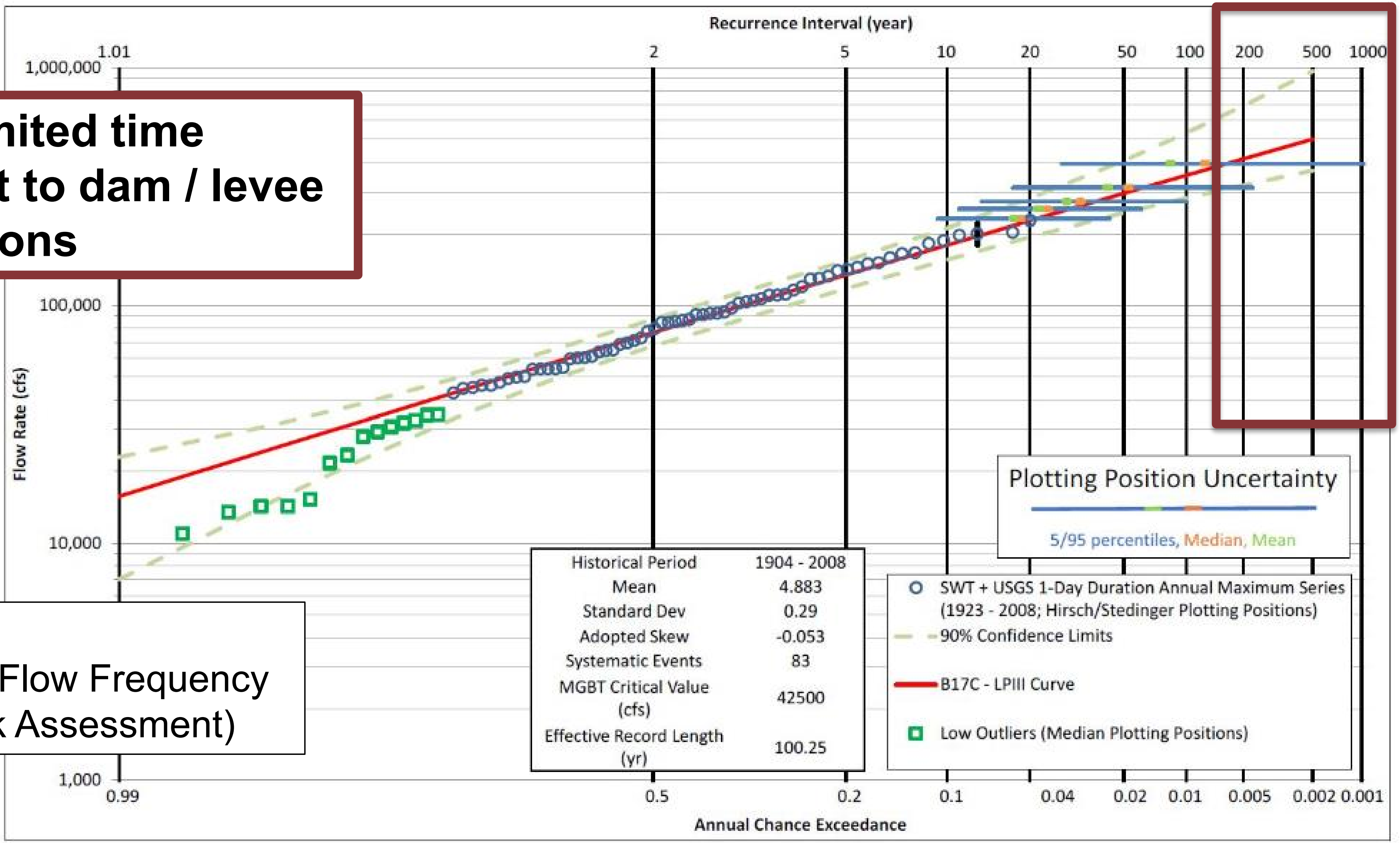
digging a hole…

and pulling a log out?”

Yep, about right.

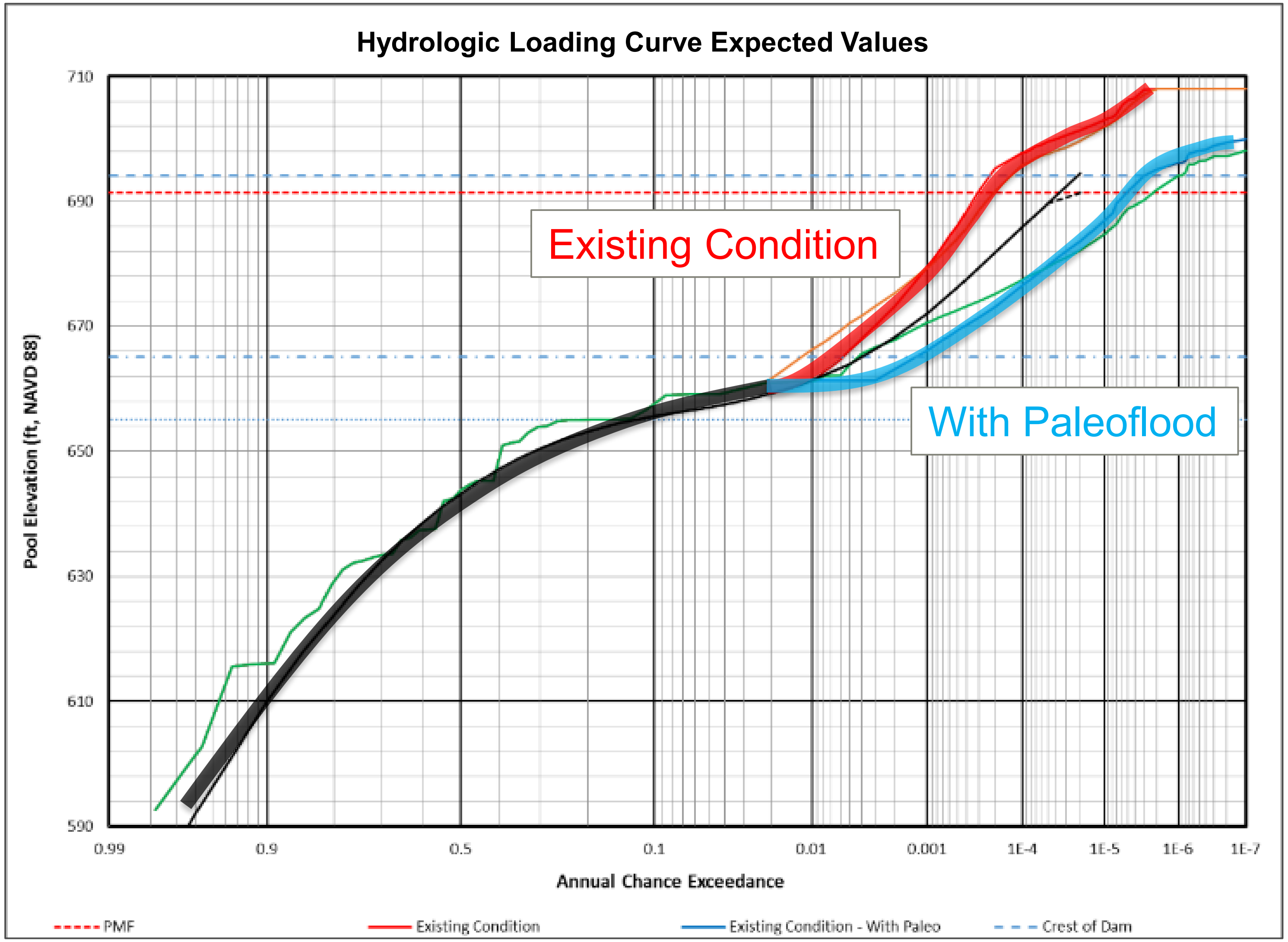
PALEOFLOOD ANALYSES FOR DAM / LEVEE EVALUATIONS

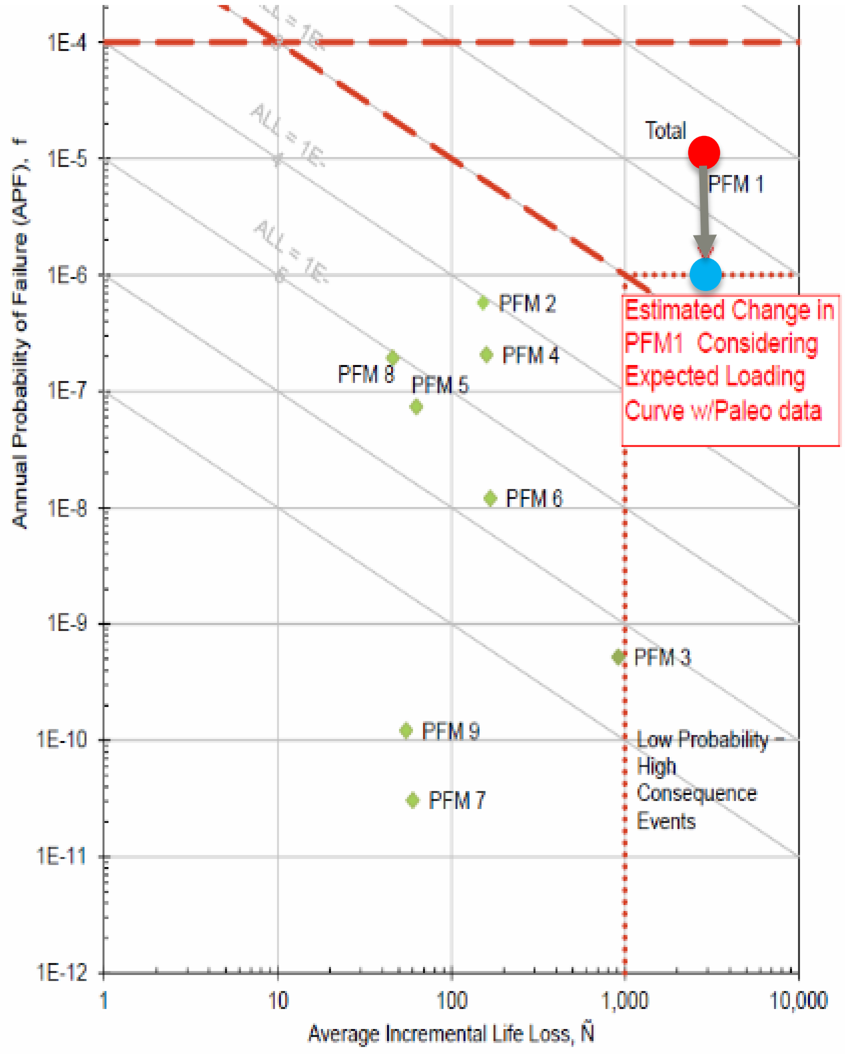
Focused on limited time scales relevant to dam / levee safety evaluations



Arkansas River
Unregulated Peak Flow Frequency
(USACE 2017 Risk Assessment)

IMPROVE CONFIDENCE IN HYDROLOGIC LOADING



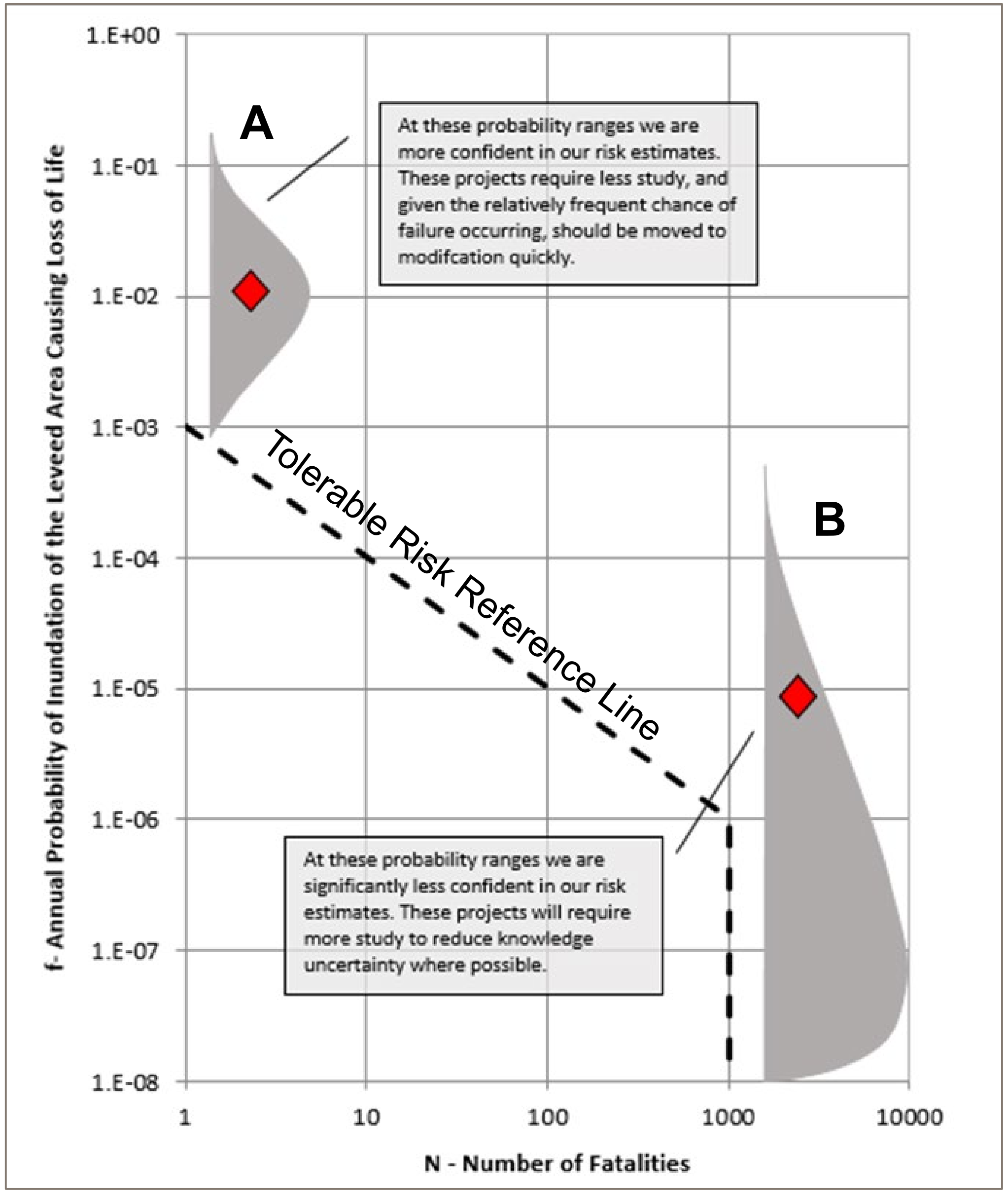


ADDRESS UNCERTAINTY IN HYDROLOGIC LOADING

Projects “A” and “B” have similar risk, but different failure probabilities and different consequences

- Project A has lower knowledge uncertainty.
  - More data will likely not change mitigation decision.
  - Should progress from evaluation to preliminary design

- Project B has greater knowledge uncertainty.
  - More data could be beneficial and have an increased chance of changing the decision.
  - Project may progress slowly from evaluation to preliminary design



PALEOFLOOD ANALYTICAL FRAMEWORK

Portfolio Screening
- Which sites are viable for yielding paleoflood data?
- For which facilities would paleoflood data be useful?

Reconnaissance
- Is it possible to obtain paleoflood data?
- Would data result in narrower uncertainty or better confidence?
- Results should not be considered in risk assessments

Issue Evaluation
- Obtain expected values and estimate reasonable range
- Will additional data narrow level of uncertainty and/or improve confidence?
- If uncertainties are acceptable, may be considered in risk assessments

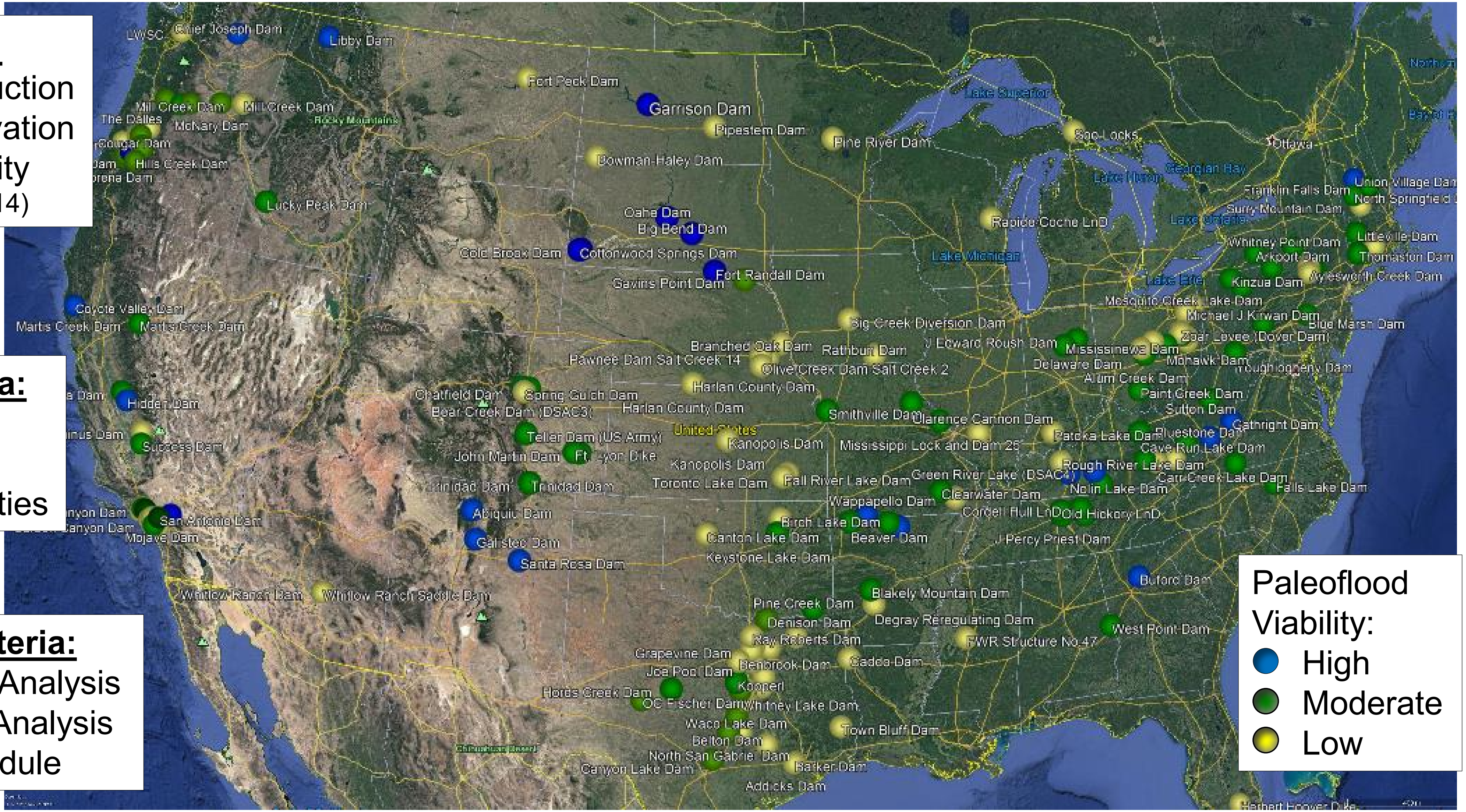
Detailed Characterization
- Focus on characterizing uncertainties in hydrologic loading
- Develop understanding sufficient to support modification / design

PORTFOLIO SCREENING: PALEOFLOOD VIABILITY

Geologic Criteria:
- Sediment Production
- Deposit Preservation
- Valley Stationarity
  (O'Connor et al., 2014)

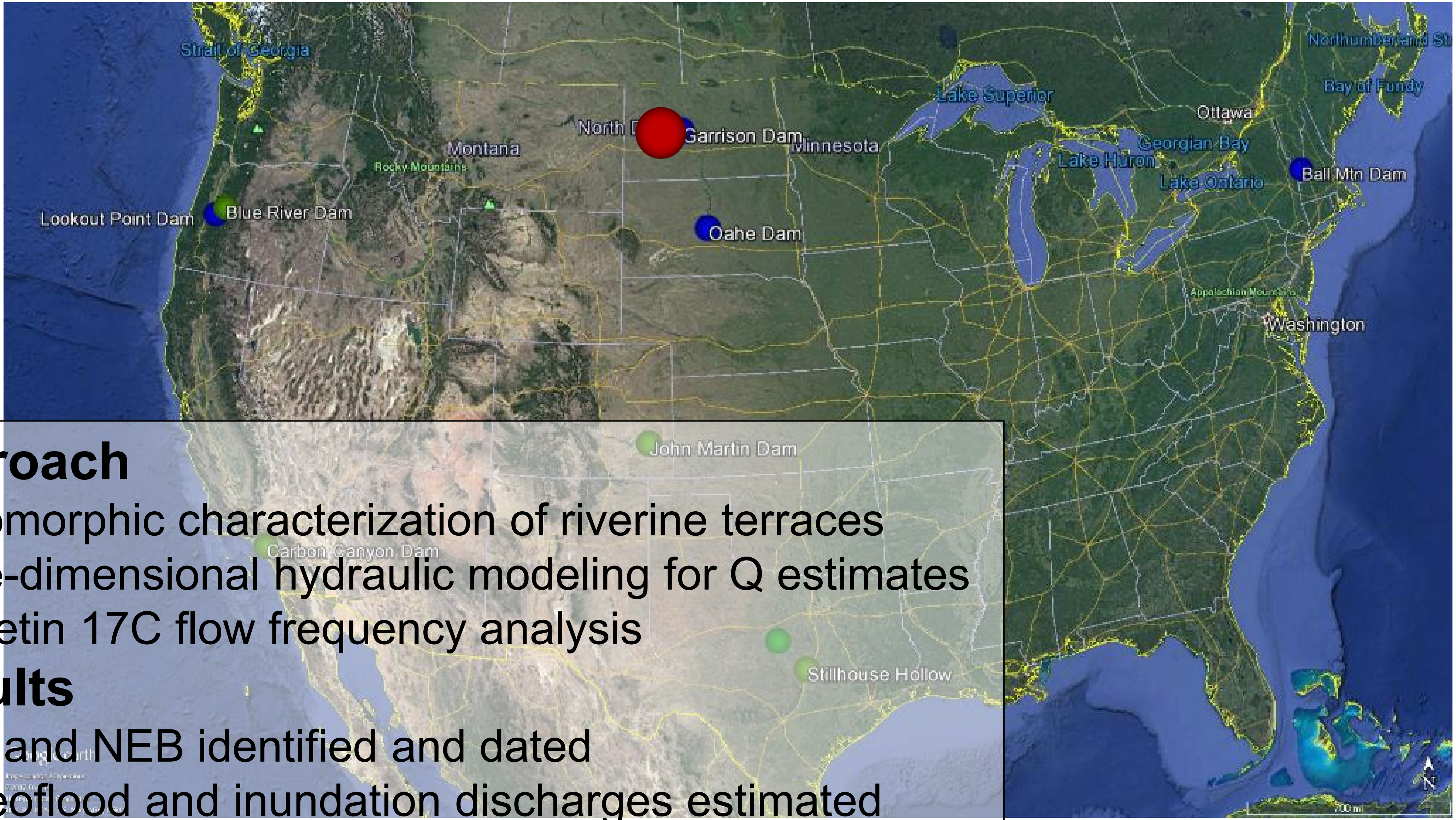
Hydrologic Criteria:
- Credible PFM
- OT Risk Driver
- Large uncertainties

Programmatic Criteria:
- Upcoming Risk Analysis
- Imminent H&H Analysis
- Favorable Schedule



Paleoflood Viability:
- High
- Moderate
- Low

FIRST: GARRISON DAM (ND)



Approach

- Geomorphic characterization of riverine terraces
- One-dimensional hydraulic modeling for Q estimates
- Bulletin 17C flow frequency analysis

Results

- PSI and NEB identified and dated
- Paleoflood and inundation discharges estimated

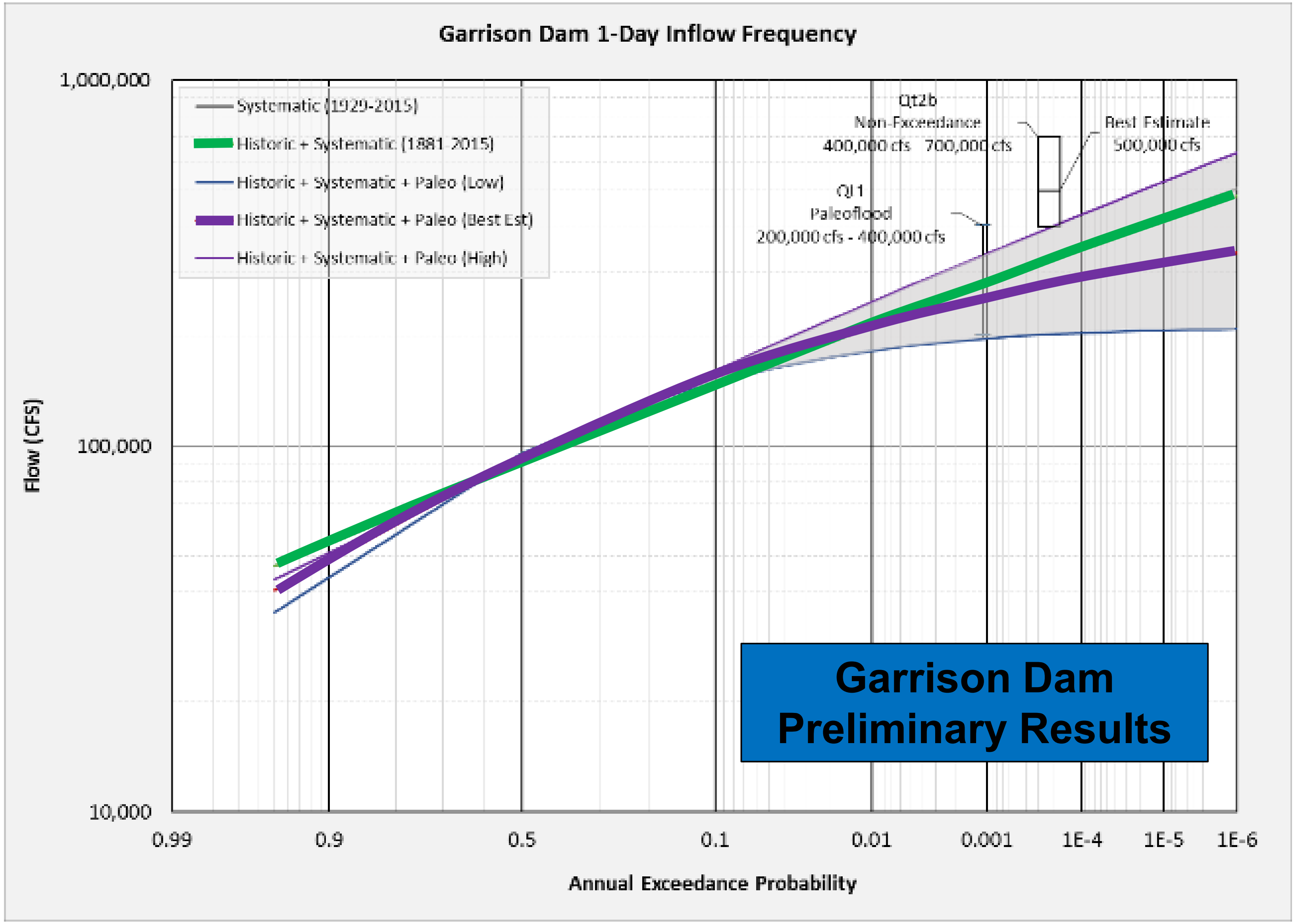
GARRISON DAM (ND) PALEOFLOOD SUMMARY

Conclusions

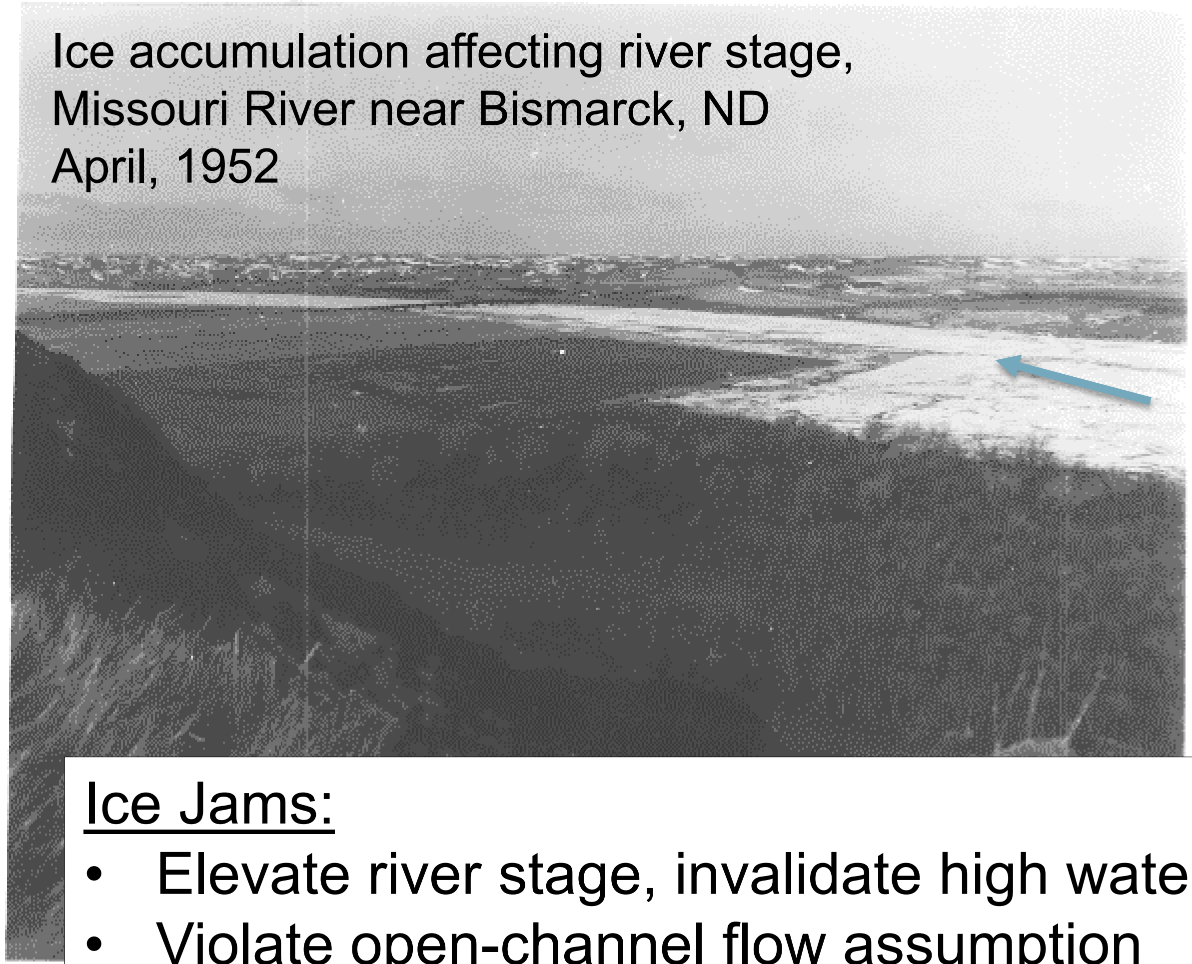
- Paleodischarge estimates are **consistent with** frequencies predicted by systematic + historic data within range of uncertainty
- 1D HEC-RAS model is good approximation of 2D model

Lessons Learned

- Pre-field preparation is mandatory
- Coordinate with local dam operations personnel
- Avoid systems affected by ice jams



COMPLICATIONS: BEWARE OF ICE JAMS

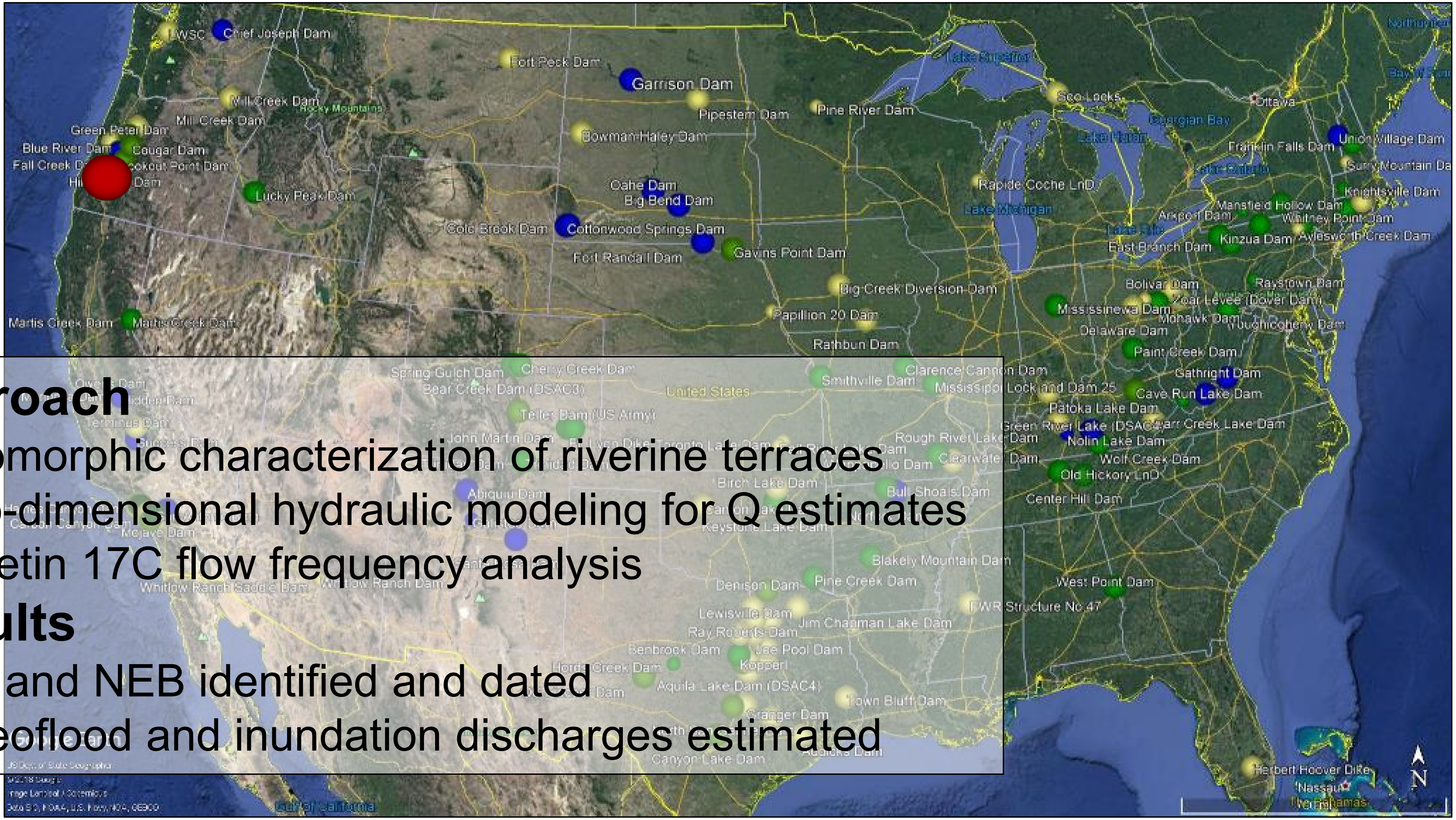


Ice accumulation affecting river stage,
Missouri River near Bismarck, ND
April, 1952

<u>Ice Jams:</u>

- Elevate river stage, invalidate high water marks
- Violate open-channel flow assumption
- Affect stage-discharge curve
- Complicate paleodischarge estimation

SECOND: LOOKOUT POINT DAM (OR)



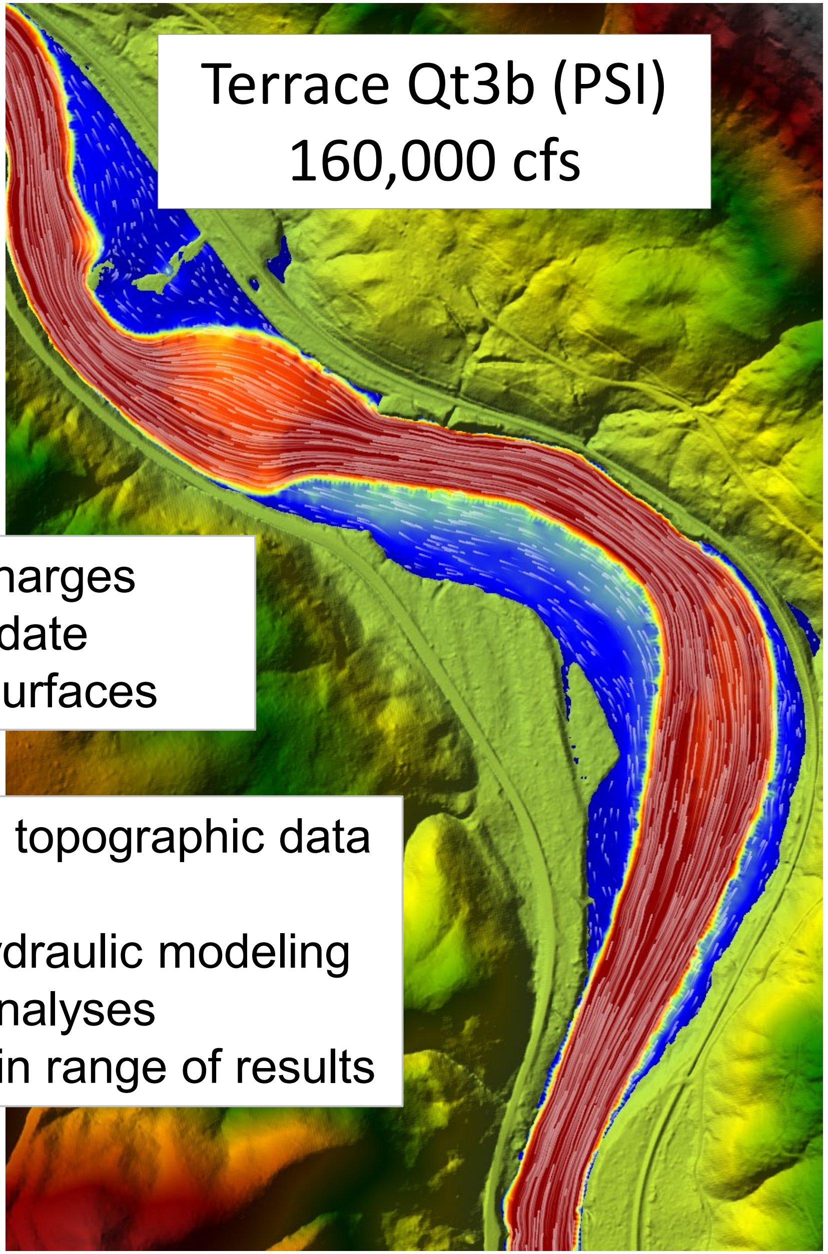
Approach

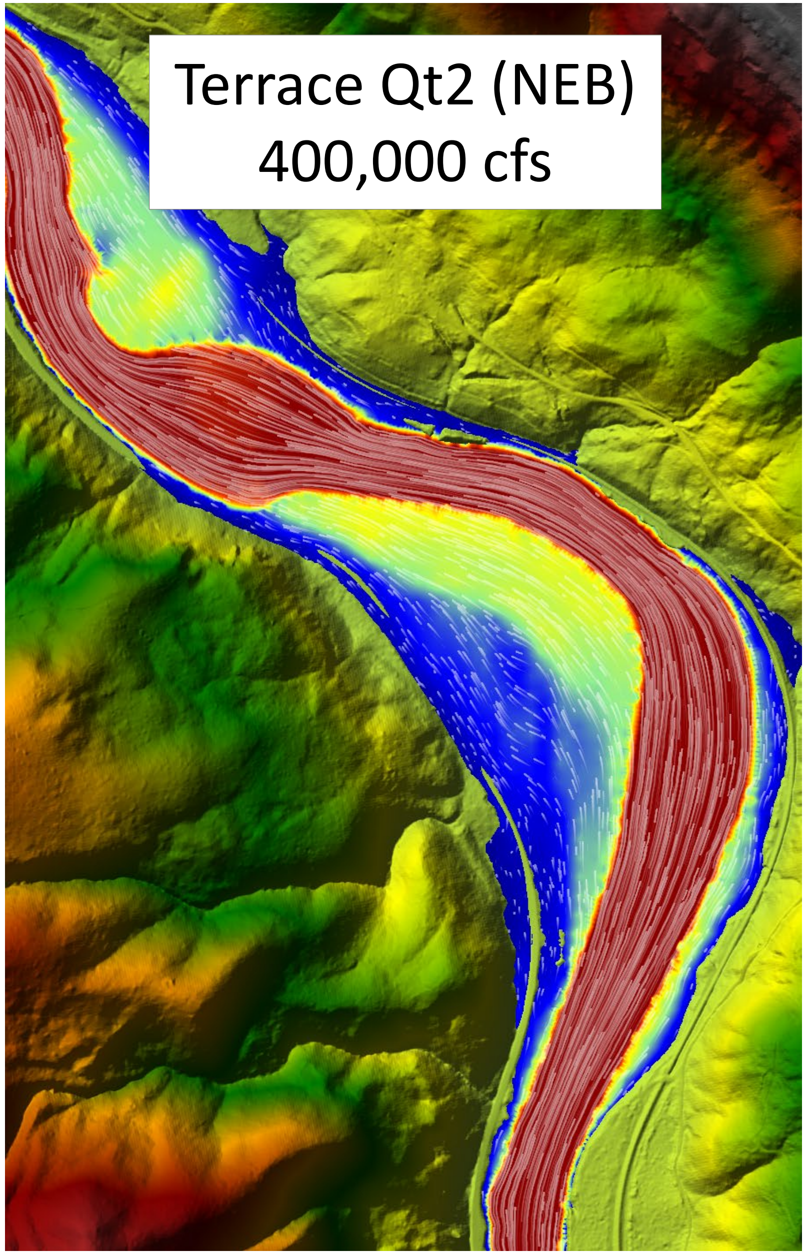
- Geomorphic characterization of riverine terraces
- Two-dimensional hydraulic modeling for Q estimates
- Bulletin 17C flow frequency analysis

Results

- PSI and NEB identified and dated
- Paleoflood and inundation discharges estimated

2D HEC-RAS DISCHARGE ESTIMATION





Estimated discharges needed to inundate fluvial terrace surfaces

High-resolution topographic data allows for

- Improved hydraulic modeling
- Sensitivity analyses
- Confidence in range of results

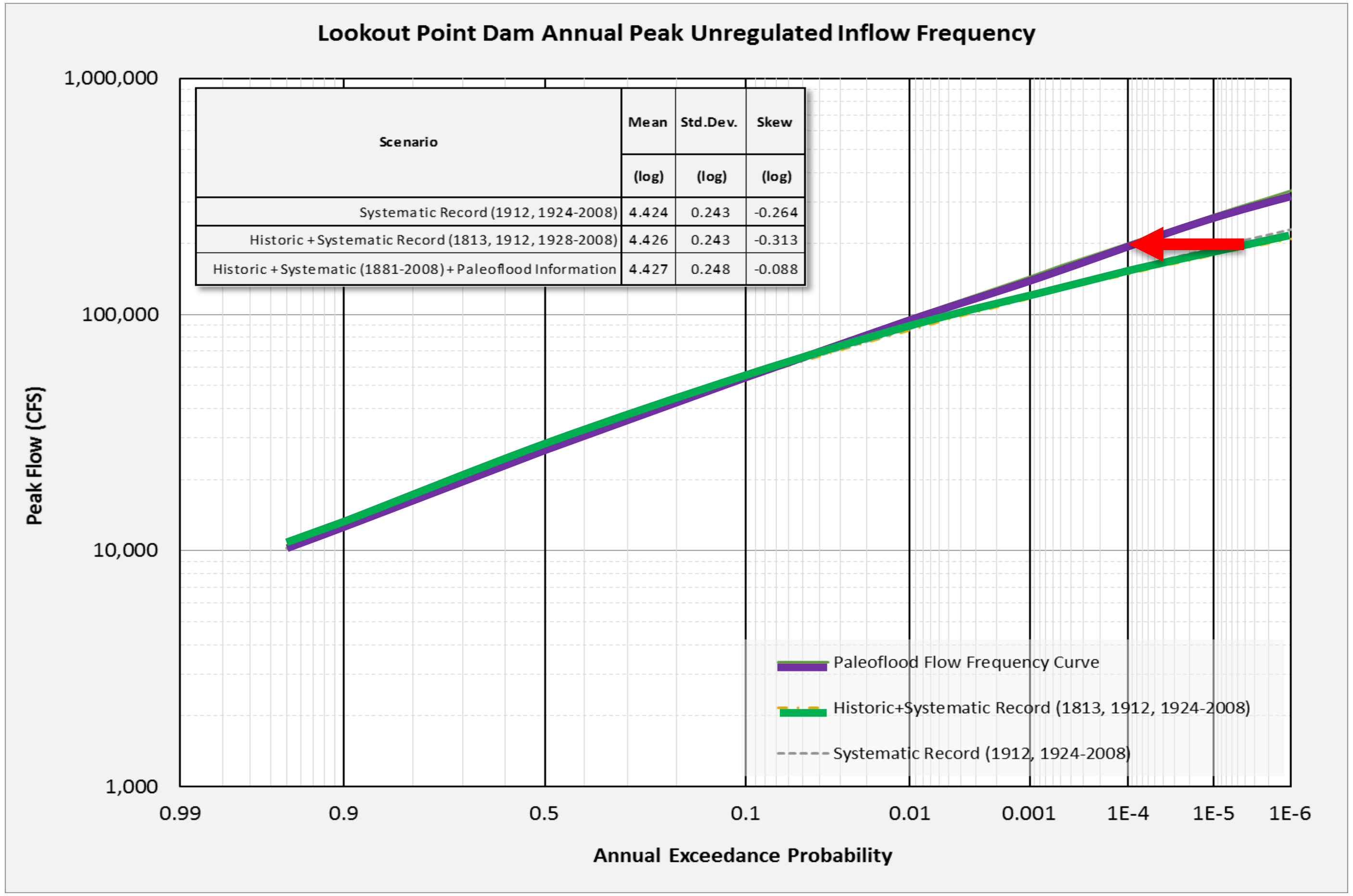
LOOKOUT POINT DAM (OR) PALEOFLOOD SUMMARY

Conclusions

- Very high discharges are **more frequent** than predicted by systematic + historic data within range of uncertainty
- Increased equivalent record length

Lessons Learned

- Pre-field HEC-RAS model helps identify key localities
- Team with local hydrologic experts



Scenario	Mean (log)	Std.Dev. (log)	Skew (log)
Systematic Record (1912, 1924-2008)	4.424	0.243	-0.264
Historic + Systematic Record (1813, 1912, 1928-2008)	4.426	0.243	-0.313
Historic + Systematic (1881-2008) + Paleoflood Information	4.427	0.248	-0.088

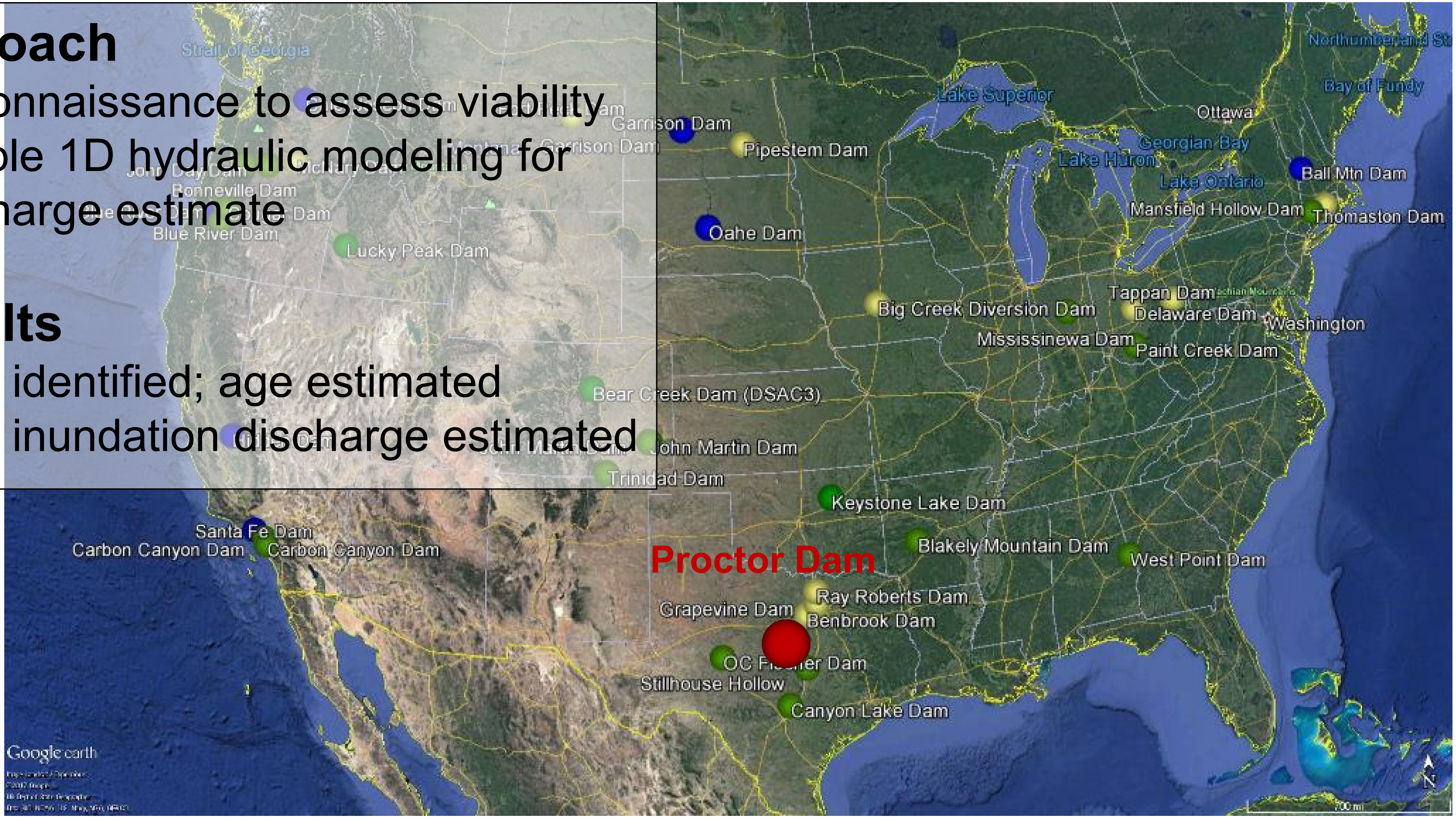
PALEOFLOOD RECONNAISSANCE: PROCTOR DAM

Approach

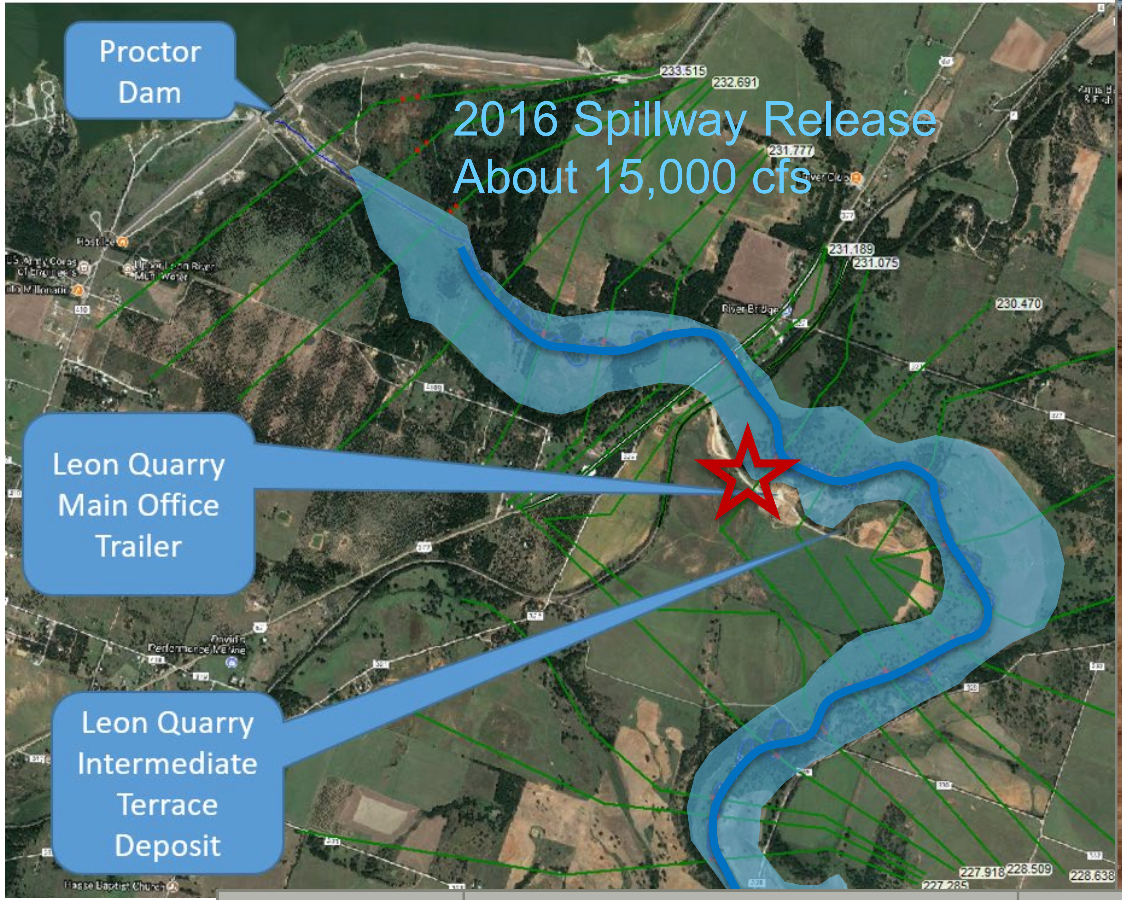
- Reconnaissance to assess viability
- Simple 1D hydraulic modeling for discharge estimate

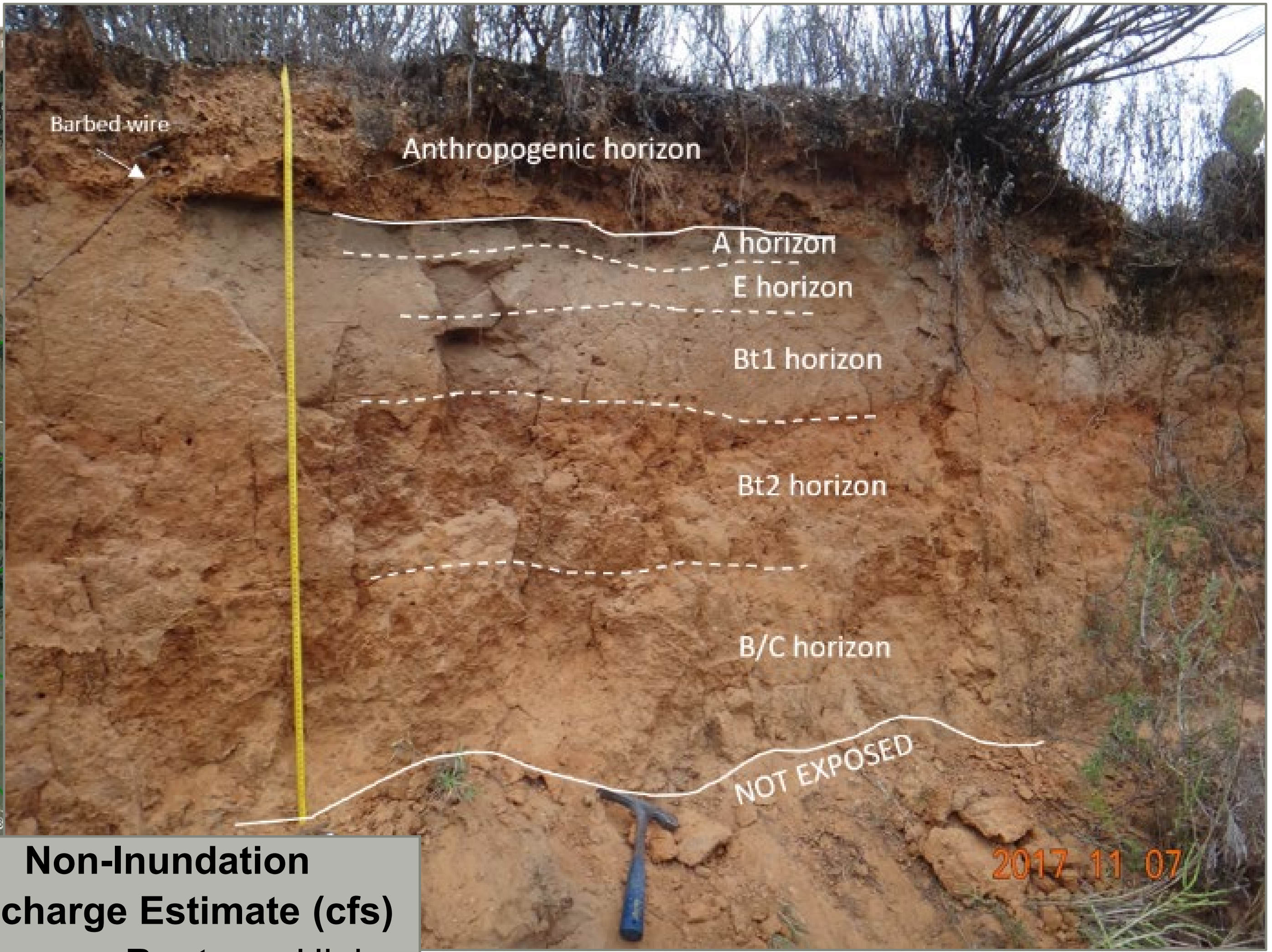
Results

- NEB identified; age estimated
- NEB inundation discharge estimated



PALEOFLOOD RECONNAISSANCE: PROCTOR DAM





Feature	Age Estimate (yrs ago)			Non-Inundation Discharge Estimate (cfs)		
	Young	**Best**	Old	Low	**Best**	High
Eolian deposit, Leon Quarry	2,000	**3,500**	5,000	90,000	**105,000**	160,000

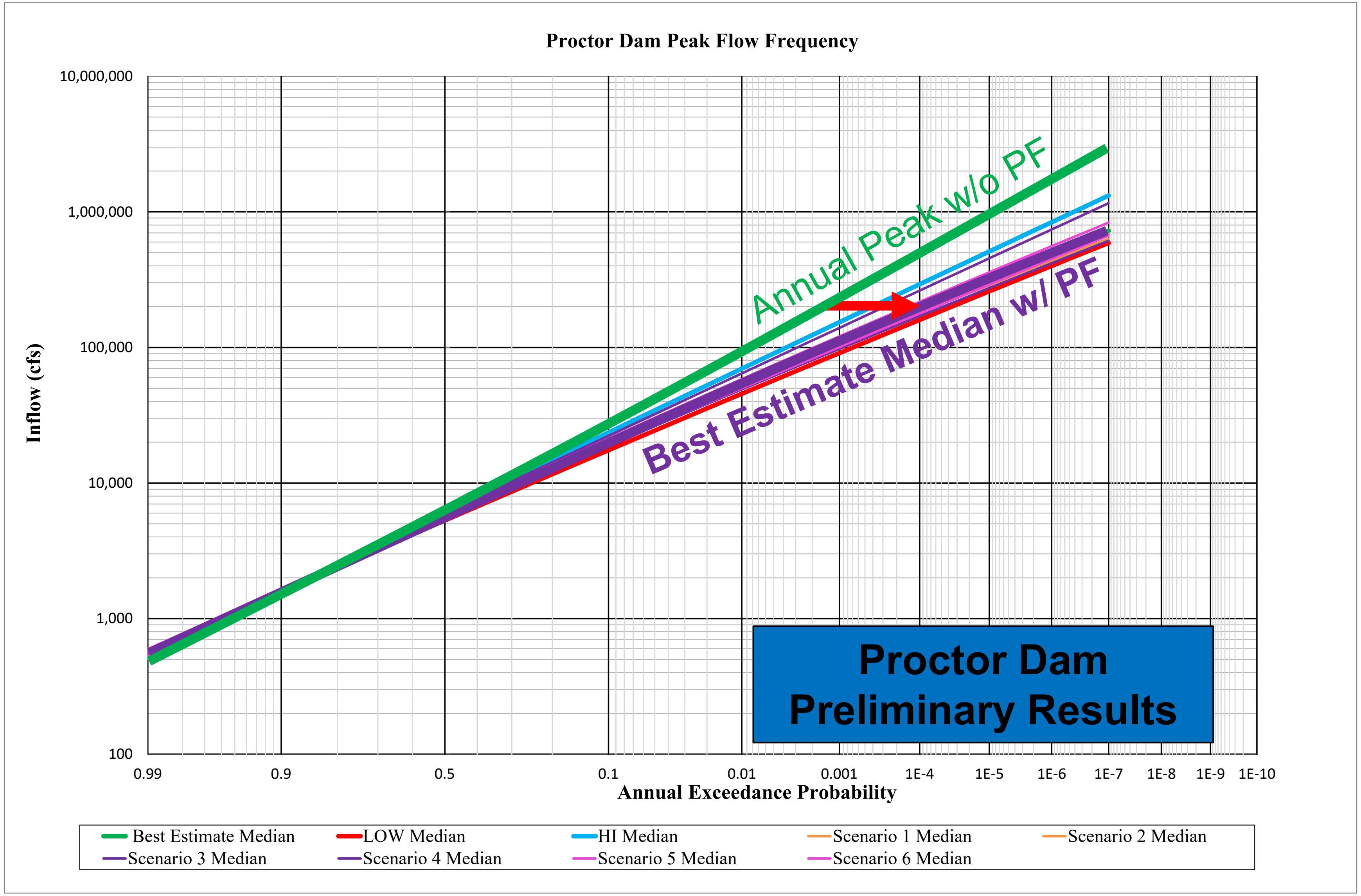
PROCTOR DAM (TX) PALEOFLOOD SUMMARY

Conclusions

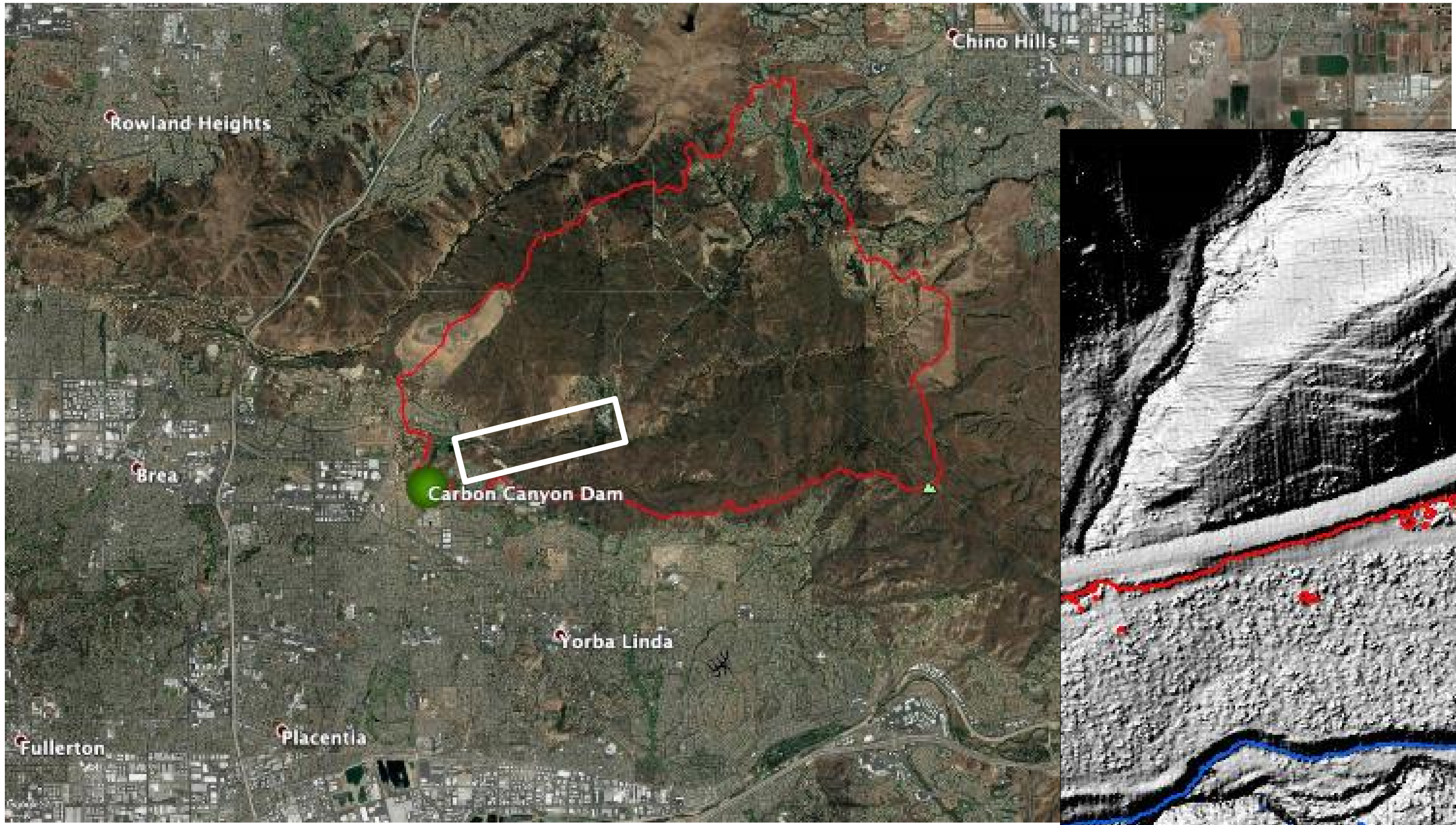
- Successful recon: NEB identified
- Possible shift of FFC to right
- Additional information could be developed with G&G and H&H efforts

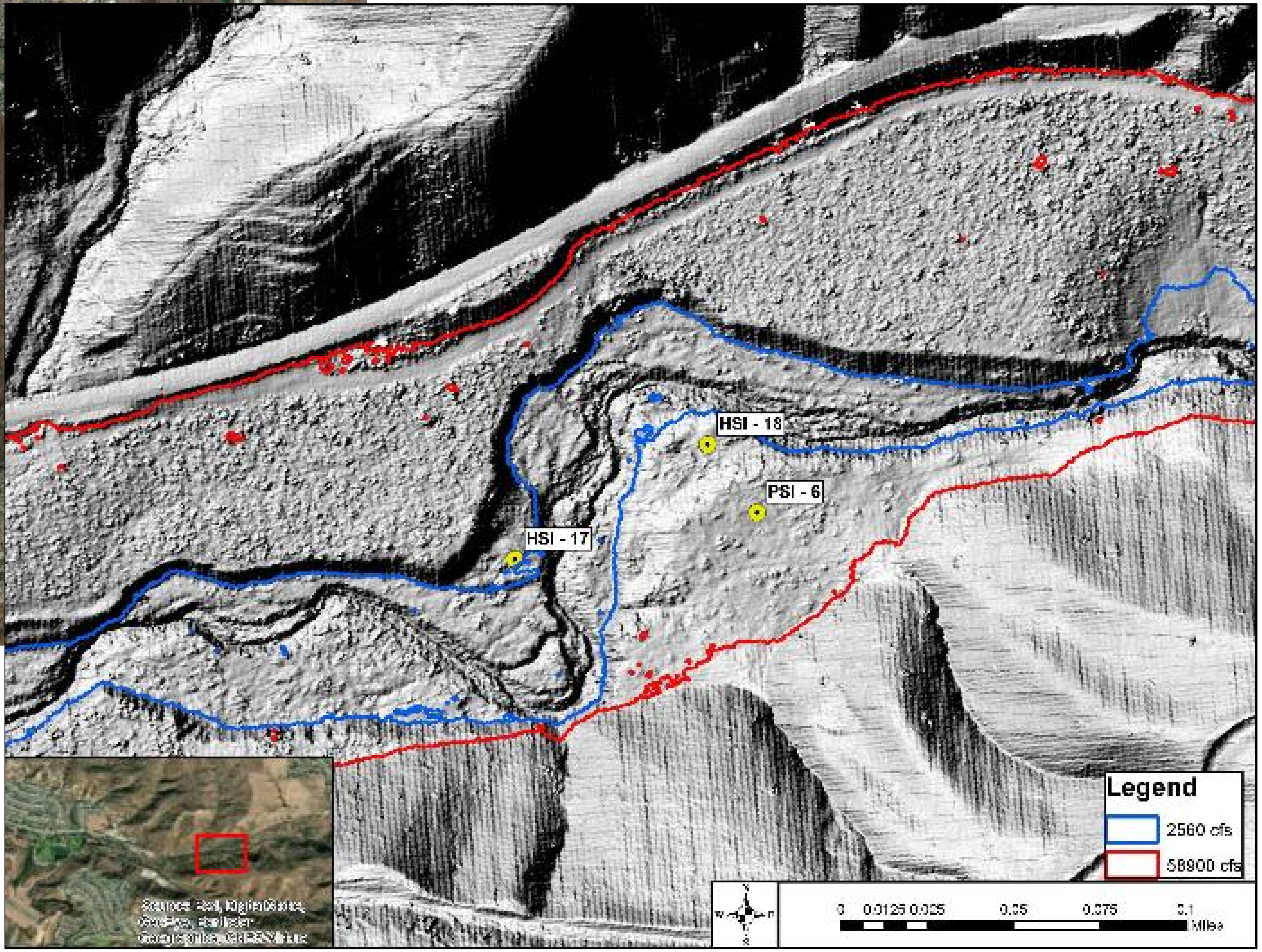
Lessons Learned

- Caution needed when using reconnaissance-level information
- Preliminary data should not be considered in decision process



CARBON CANYON DAM (CA) PF APPROACH

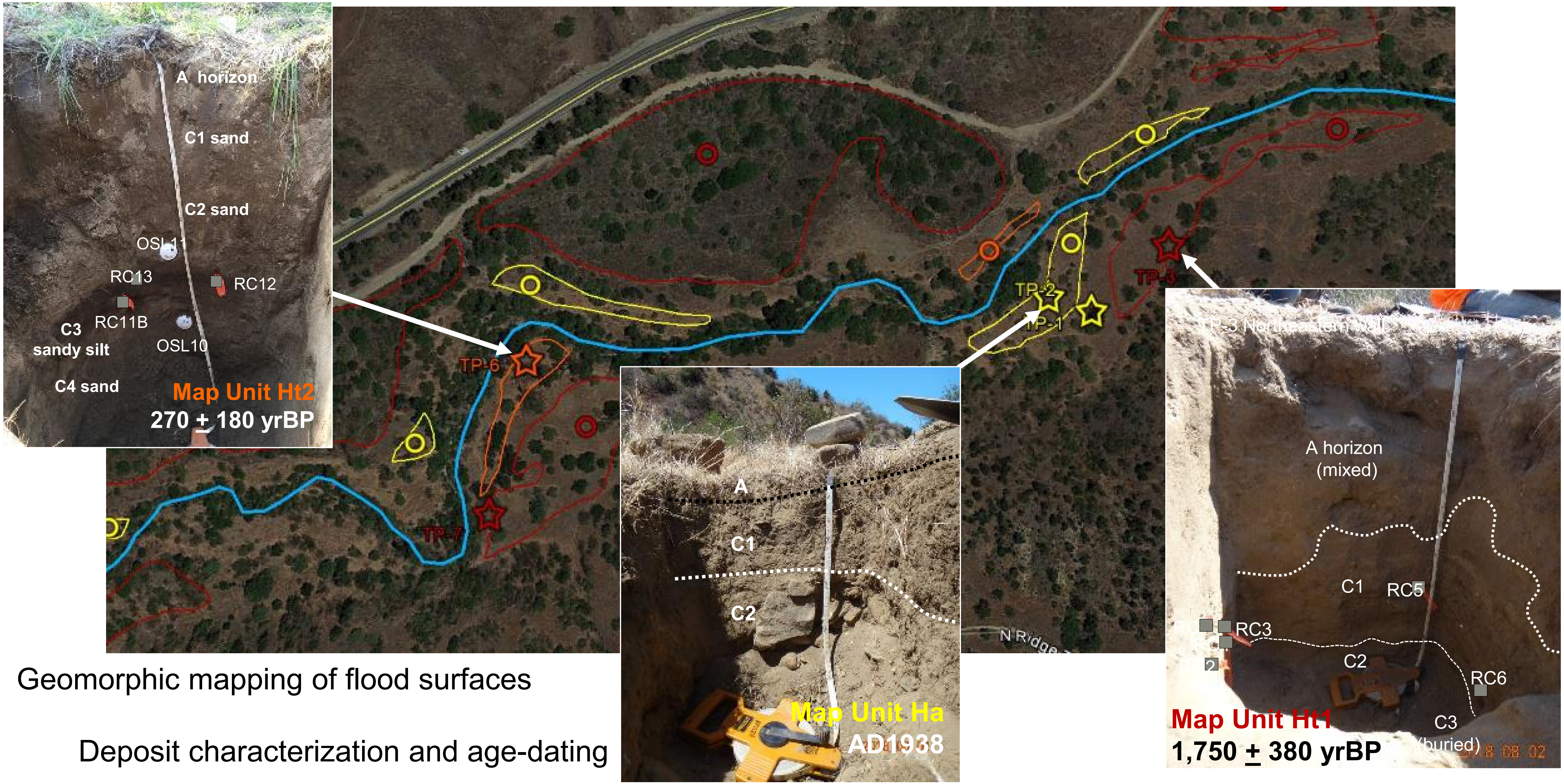




Highly urbanized downstream inundation zone
Orange County, California

Pre-field HEC-RAS model of FOR and PMF
using existing LiDAR topography

CARBON CANYON DAM (CA) PF RESULTS



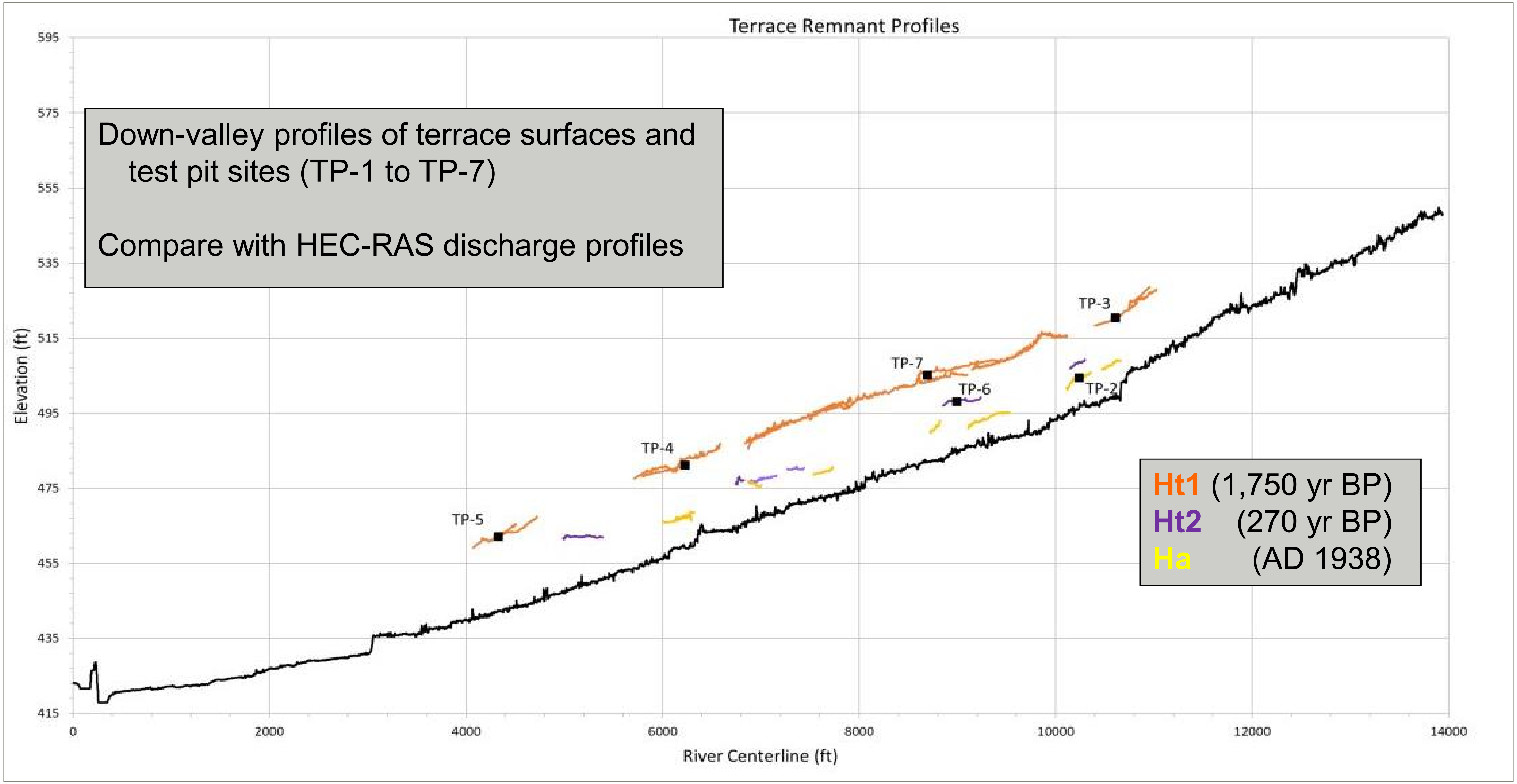
Geomorphic mapping of flood surfaces

Deposit characterization and age-dating

CARBON CANYON DAM (CA) PF RESULTS

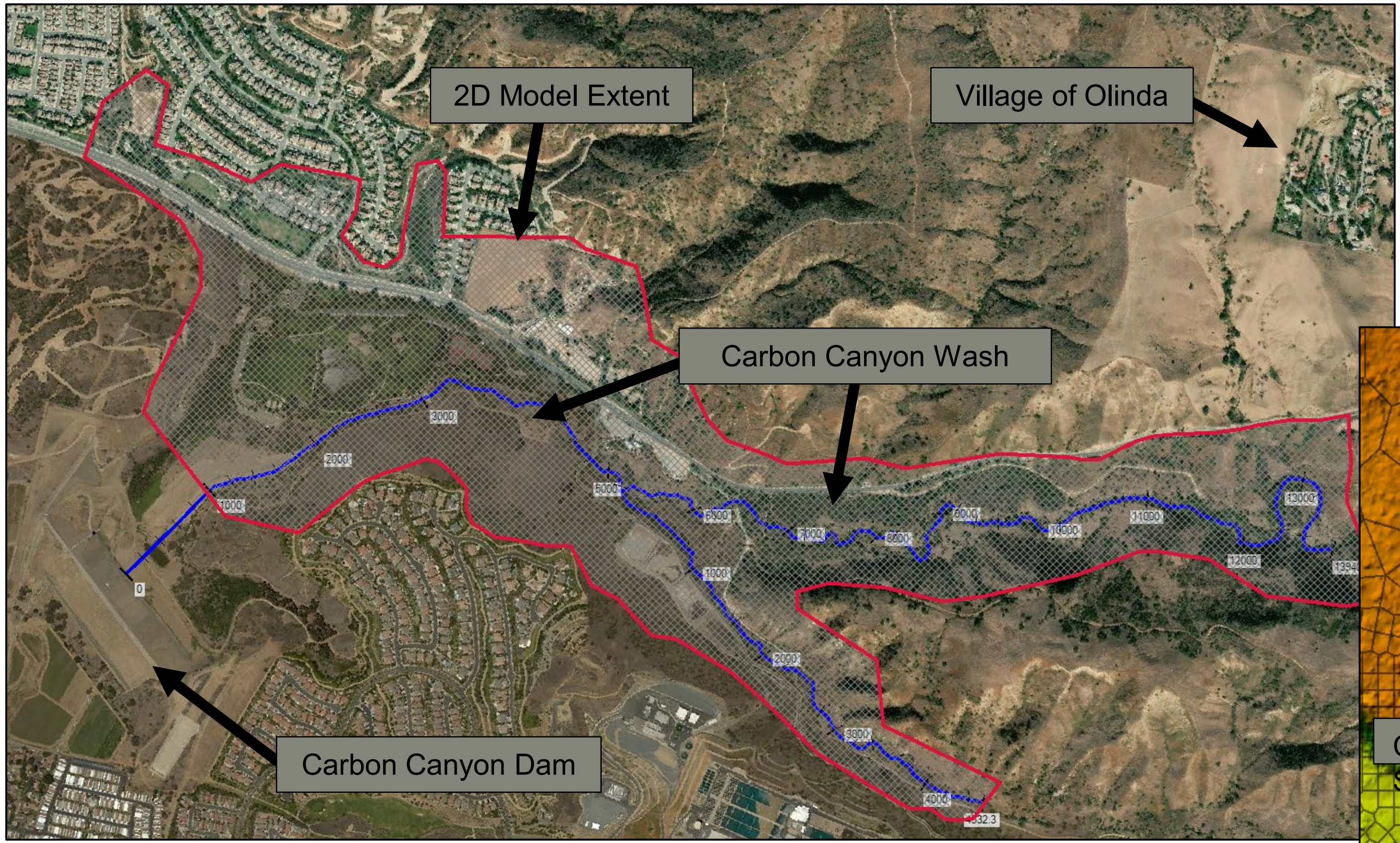
Down-valley profiles of terrace surfaces and test pit sites (TP-1 to TP-7)

Compare with HEC-RAS discharge profiles

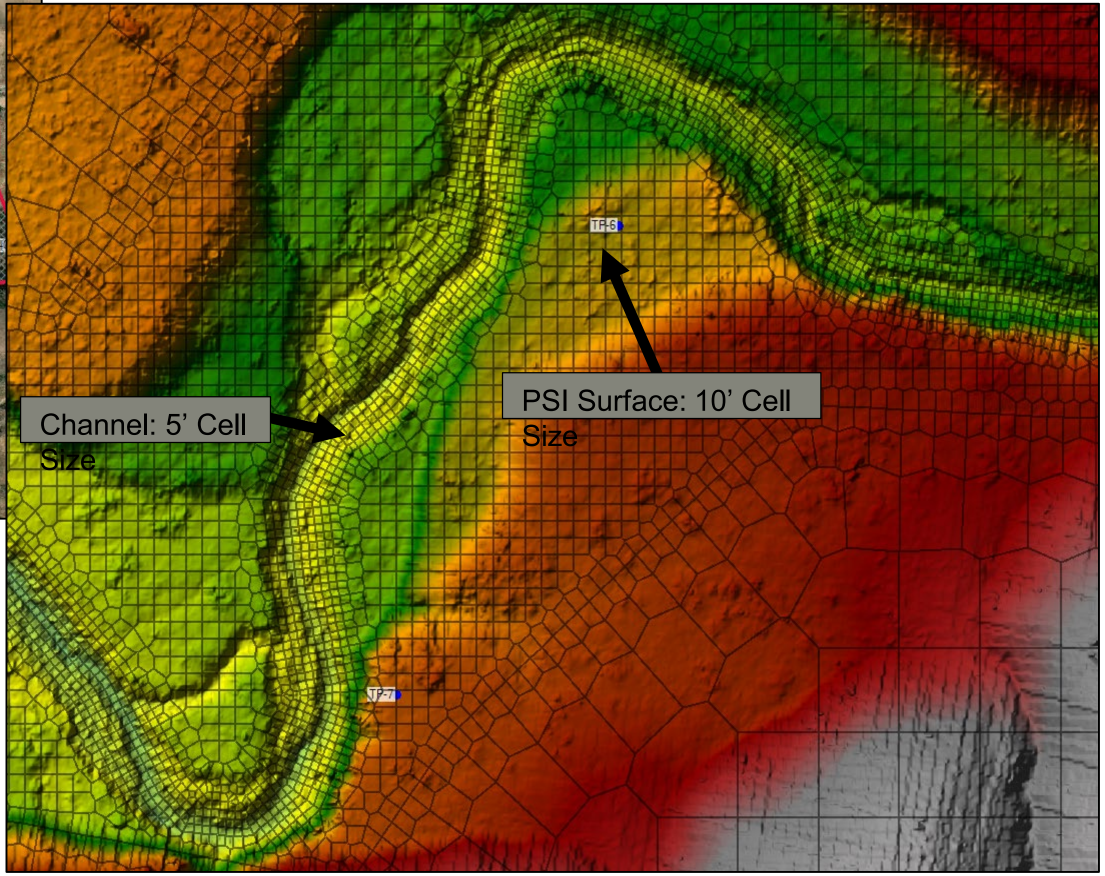


Ht1 (1,750 yr BP)
Ht2 (270 yr BP)
Ha (AD 1938)

CARBON CANYON DAM (CA) PF RESULTS

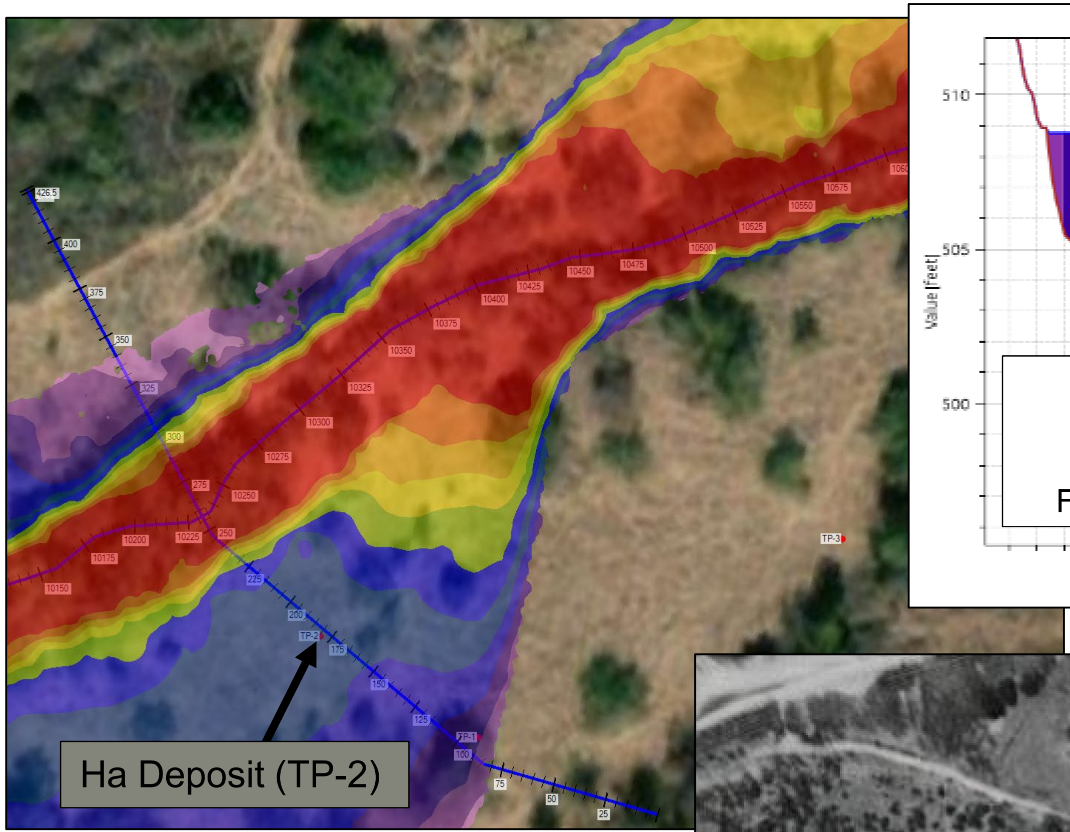


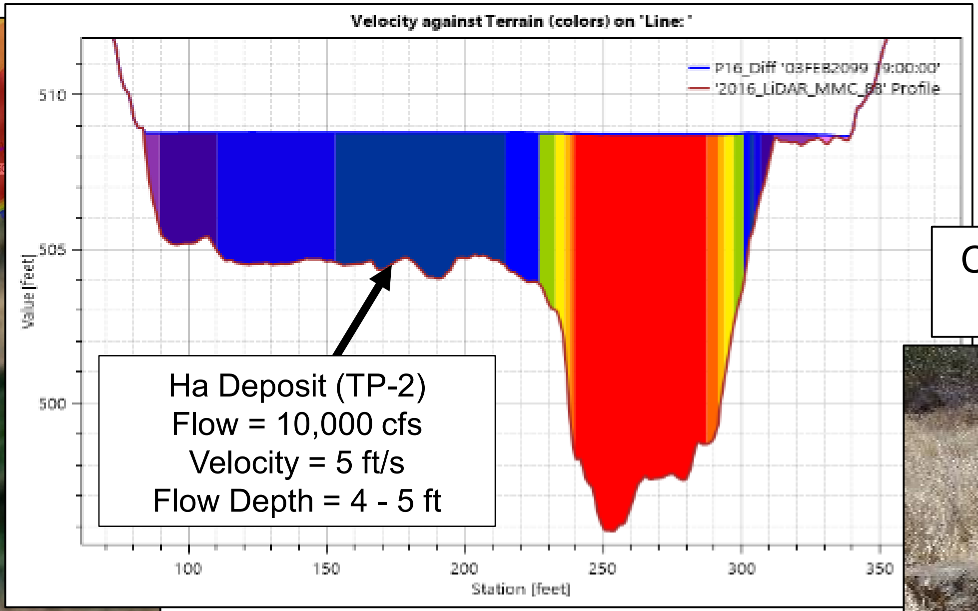
HEC-RAS 2D model extent



HEC-RAS 2D model grid sizing to best represent LiDAR topography

CARBON CANYON DAM (CA) PF RESULTS





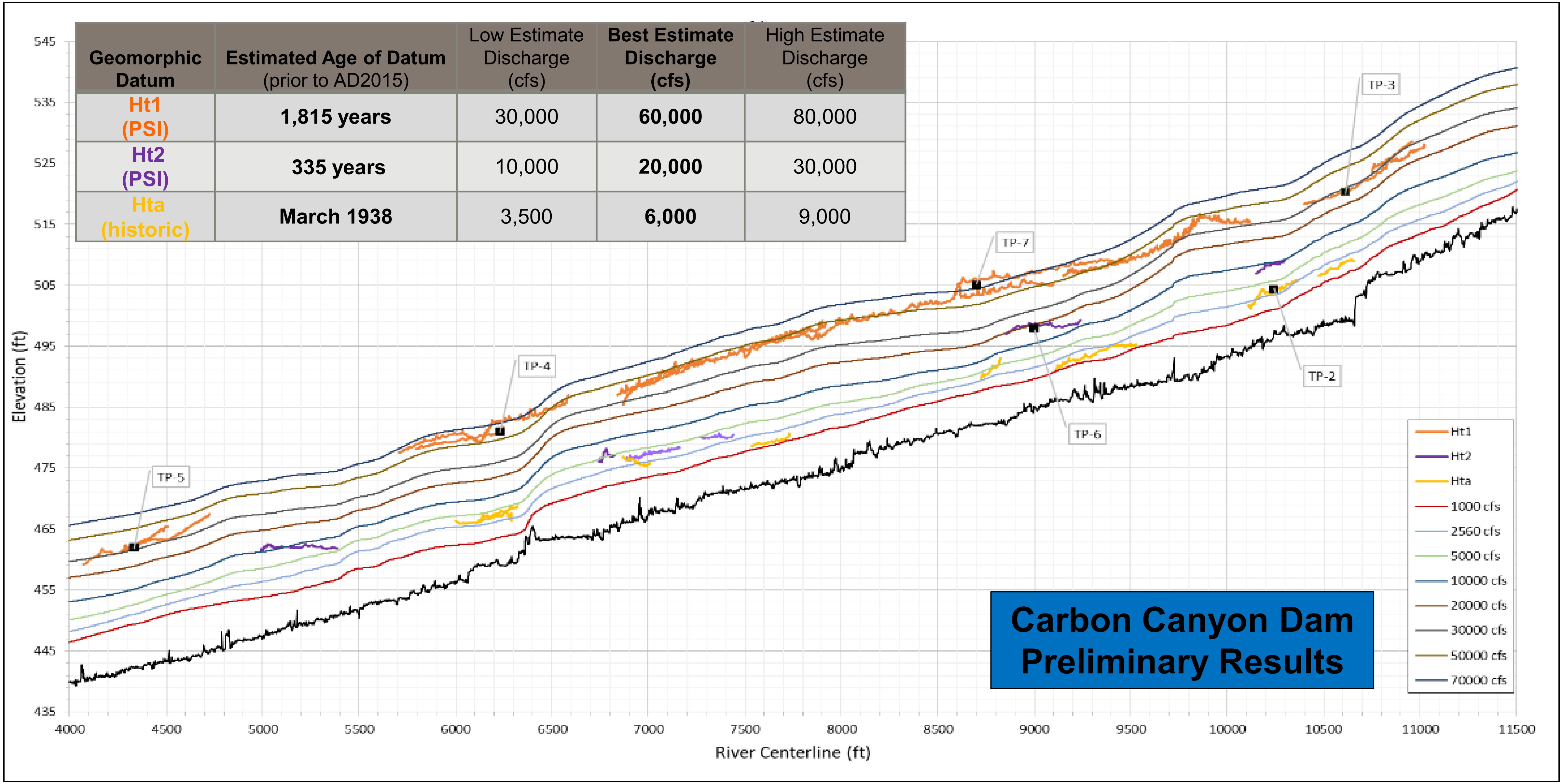
HEC-RAS cross-sections used for estimating flow velocities and bedload transport

Large concrete boulder in TP-2 deposit coincides with 1938 flood extent

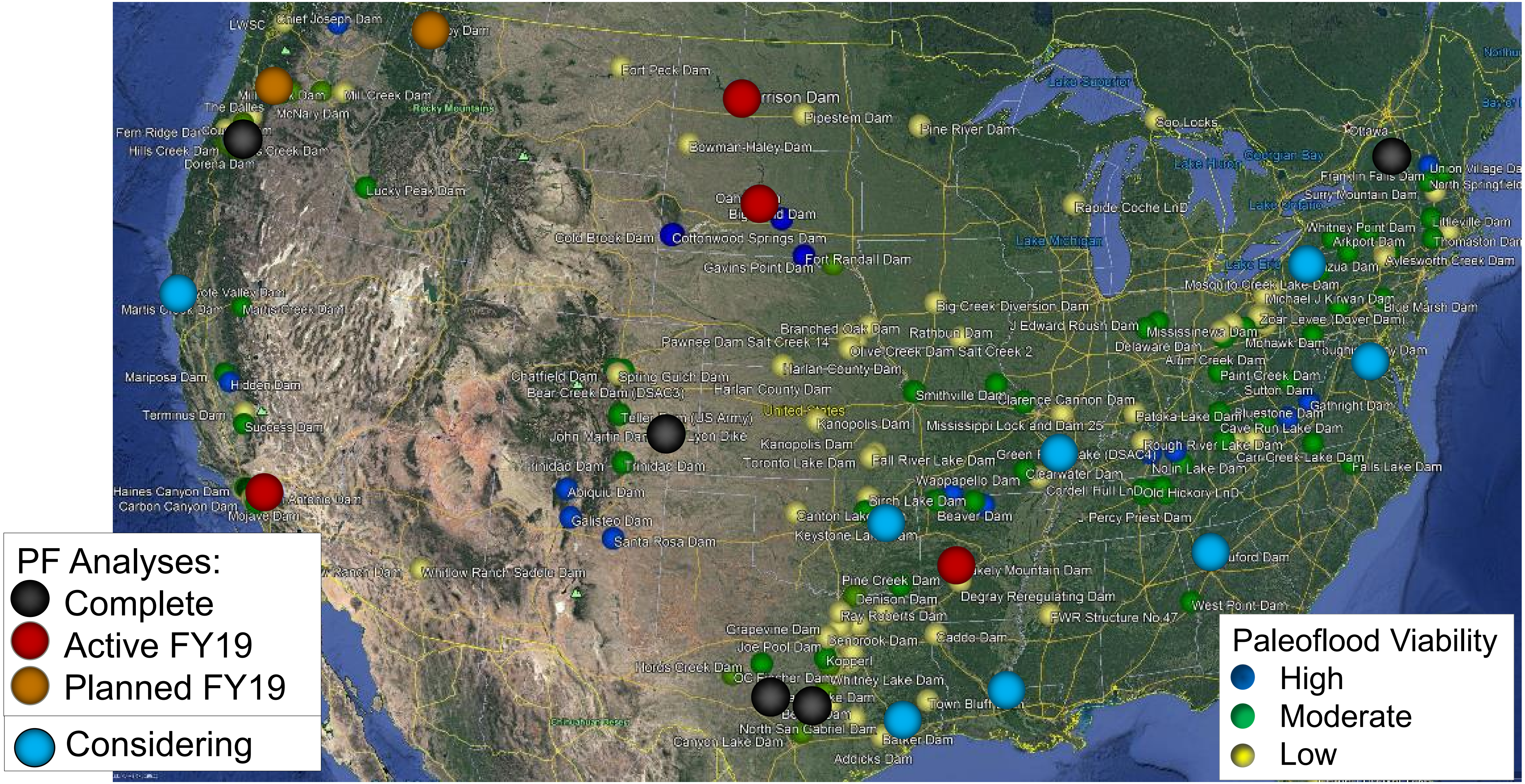
Carbon Canyon Flood Terrace
1938 flood

CARBON CANYON DAM (CA) PF SUMMARY

Geomorphic Datum	Estimated Age of Datum (prior to AD2015)	Low Estimate Discharge (cfs)	Best Estimate Discharge (cfs)	High Estimate Discharge (cfs)
Ht1 (PSI)	**1,815 years**	30,000	**60,000**	80,000
Ht2 (PSI)	**335 years**	10,000	**20,000**	30,000
Hta (historic)	**March 1938**	3,500	**6,000**	9,000

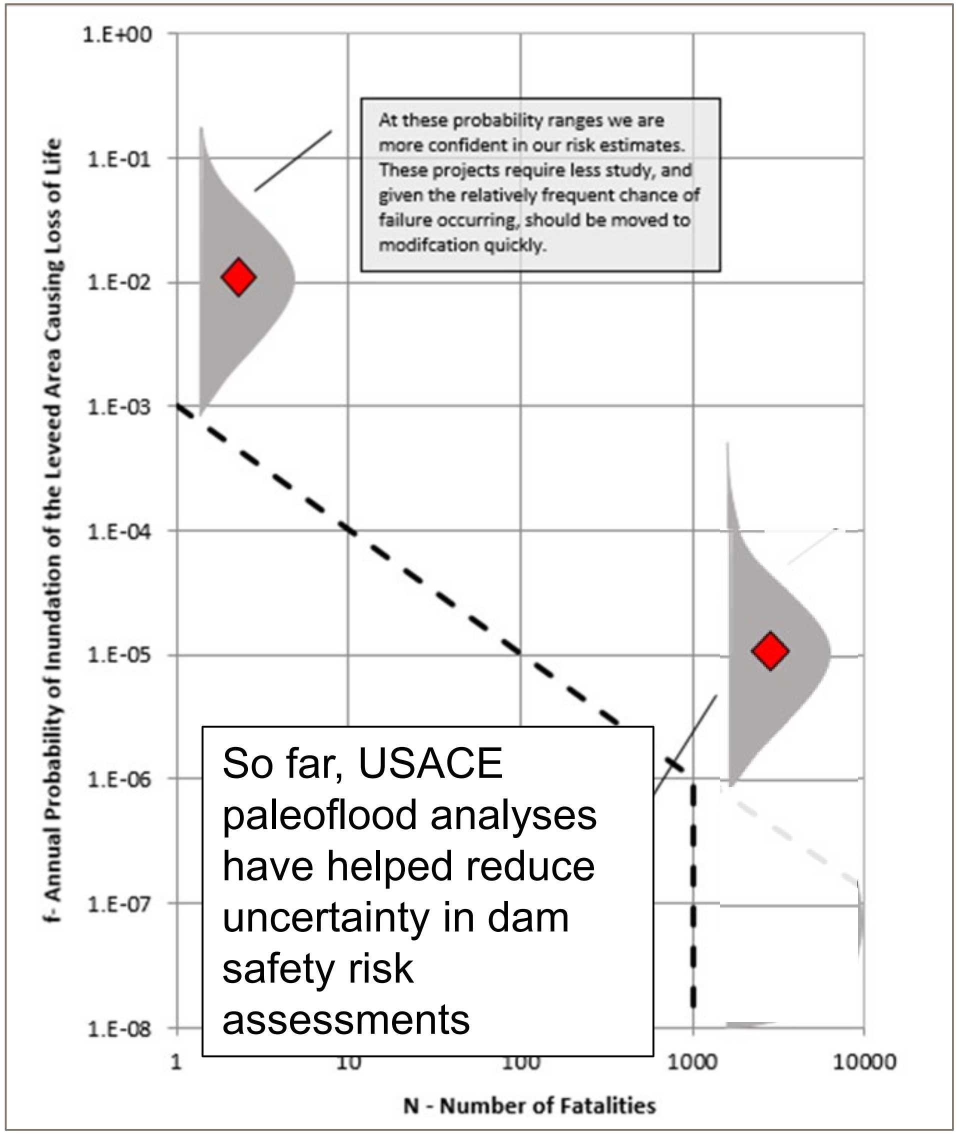


RECENT, CURRENT, AND POSSIBLE FUTURE ANALYSES



CONCLUSIONS

- **Screening criteria** appear effective for USACE dam portfolio
- **Paleoflood analytical techniques** are viable across range of site conditions
- **Riverine terraces** are just one of several viable tools available for paleoflood analyses
- **Uncertainties** in paleodischarge magnitude and timing can be captured and documented
- **Analytical uncertainties** do not invalidate paleoflood analyses



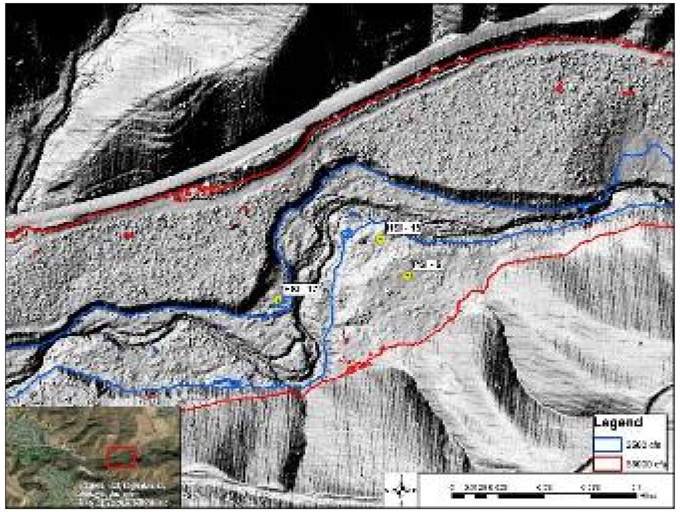
LESSONS LEARNED

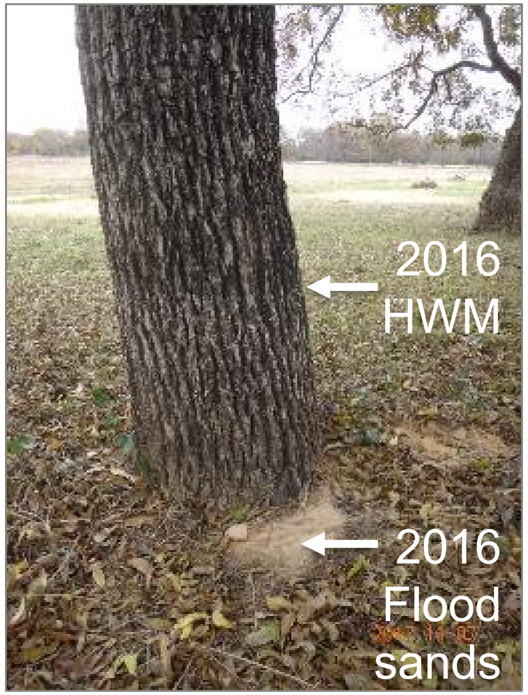
- **Overall approach** has to be flexible and opportunistic
  - should include more than just G&G and H&H (historians, archaeologists, botanists, …)

- **Reconnaissance** data are just that, not a decision-making tool

- **Pre-field activities** should include many technical components (G&G, H&H, others…)

- **Unique treatment** needed for every reach (e.g., ice jams matter)





THANK YOU