Managing Reservoirs for Atmospheric Rivers

The Uneven Balance of Flood Risk and Water Supply

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2016 International Atmospheric River Conference

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BUILDING STRONG®

Flood Risk Management

Empty flood pool

Flood peak captured and stored (48 hrs, Nov 2006)

Water Supply

Water year: 2015

Water year: 2016

Lake Shasta, California

What is the uneven balance?
(risk / consequences)

- **Flood risk** uncertain, quickly changing
  (safety/property damage – priority)

- **Water supply** uncertain, issues slower to evolve – competing interests and increasing hardship

Rural valley south of Seattle, becomes urban

1959 flood - before dam, no development

Dam built 1962:

to mange floods/water supply.

Now protecting:

10-20 billion dollars infrastructure

30,000 plus people

Water supply : > 200,000 people

Reservoir space limited

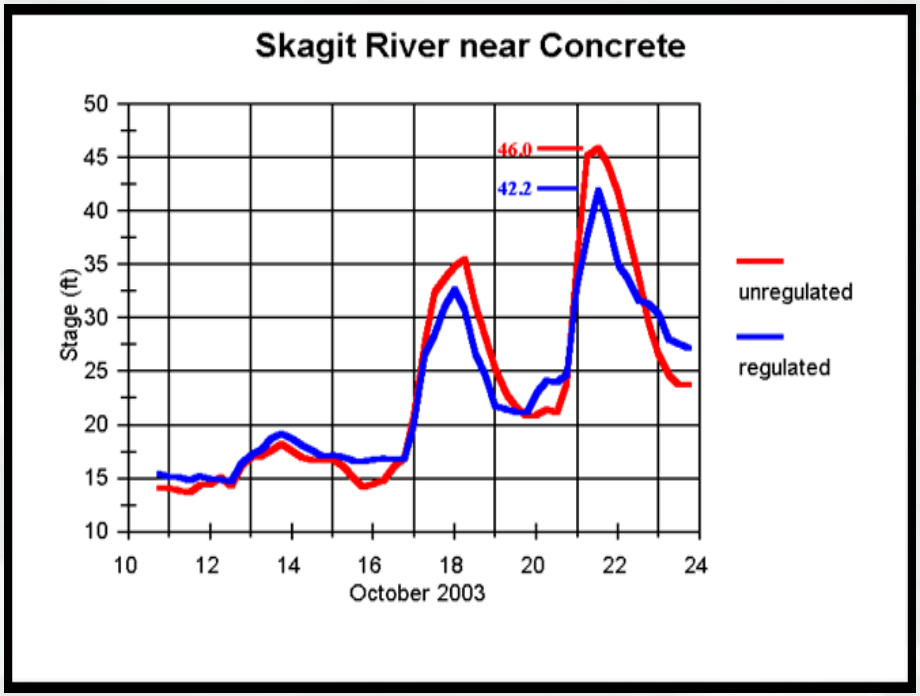
Need reservoir space **available** to store flood waters

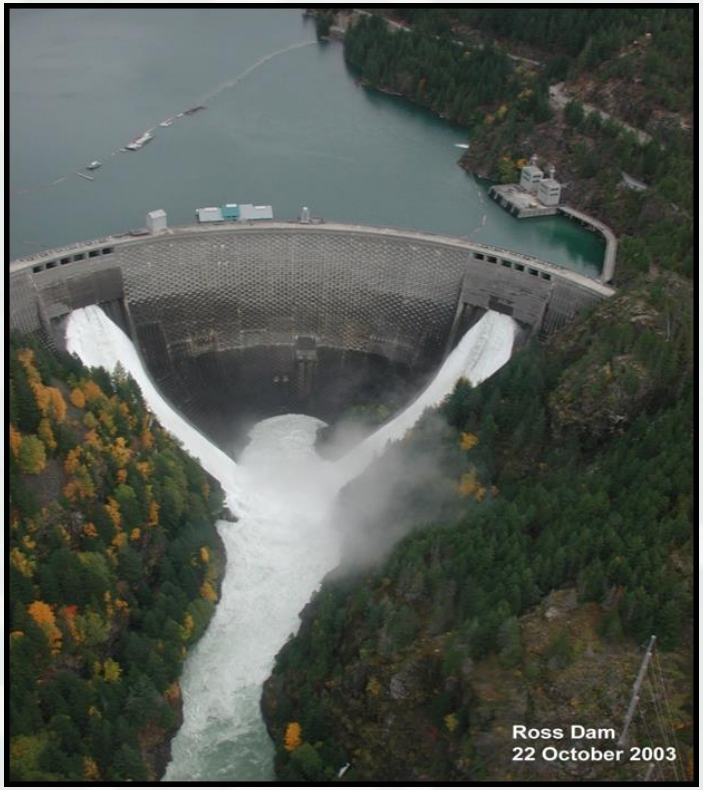
OR

Need reservoir space **used** for water supply

Flood Operations Strategy

Temporally store peak, evacuate quickly when safe





Six day atmospheric river event (Oct 2003)
North to BC, for two days

Dam engineer operator paradox

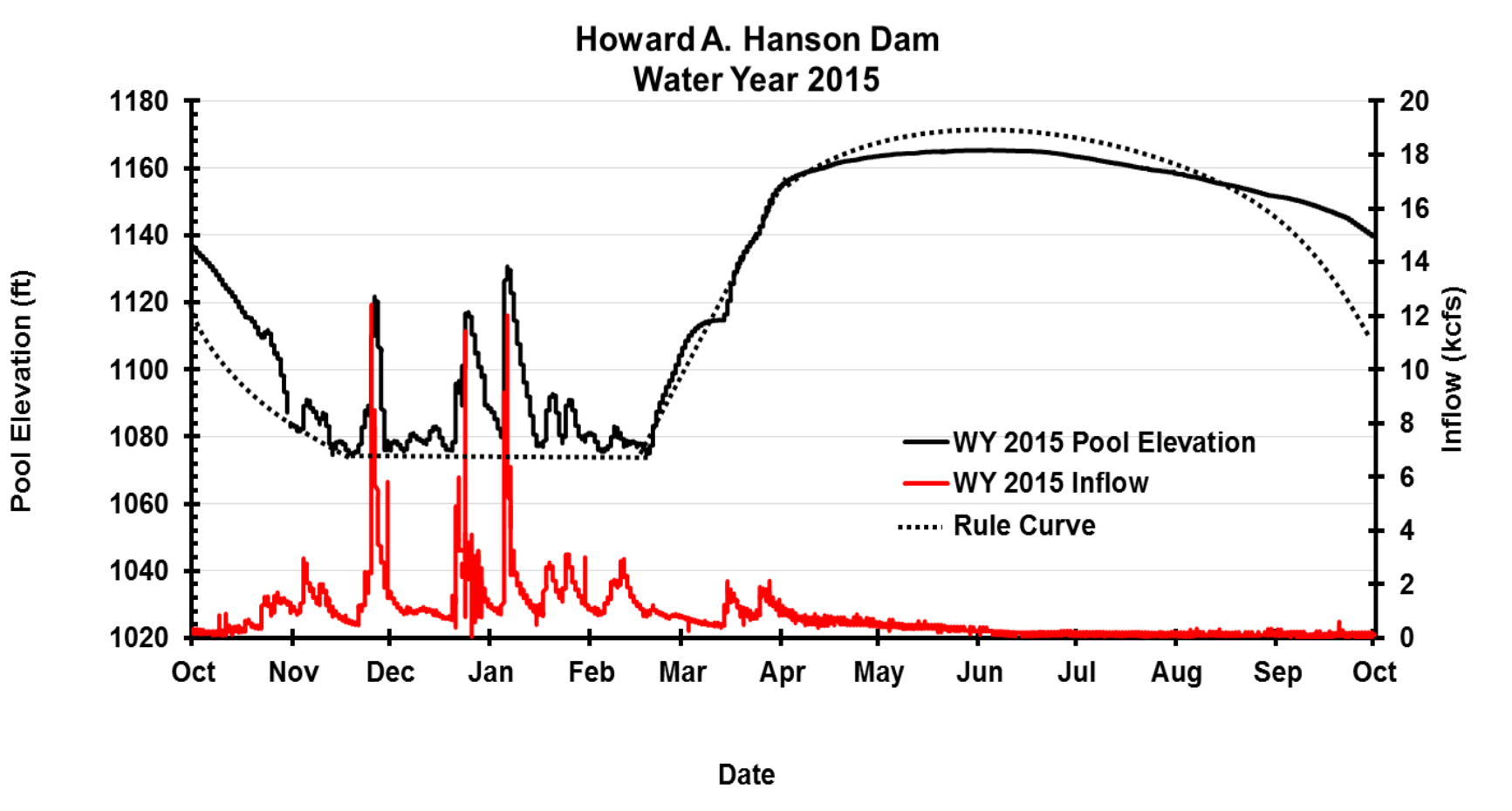
Extreme flood risk dam operations

Intentionally cause flooding, to avoid catastrophic flood

An aerial view of the flooded I-5 overpass looking south Flooding in Chehalis. (Associated Press)

Reservoir draft and fill profile

Flood risk and water supply



Empty on March 1…with no snowmelt and dry spring/summer

Nov 2006 flood: Washington Cascades USACE decisions and actions

Nov 2006 AR Highlights

- Wettest, of any month, on record
  One flood, one AR: 6^{th}-7^{th}
- AR core shifted to Central Cascades
- Storm totals 10” - 38.5”
- Dozen rivers set all time record peaks
- Skagit river threatened with catastrophic flood
- I - 5 closed for flooding – several days

Preparations for flood (Nov 2006)

- Wednesday Nov 1st -- Forecast confidence grows. Draft minor remaining water from storage
- Thursday: Forecast uncertainty arises. What basin is targeted ?
- Friday: Prepare staff – open Reservoir Control Center/ alert management and stakeholders. Emergency Management activated

  Emergency declaration by Colonel for funding
- Saturday: Forecasts consistent - historic event? Meetings/staff up. Take control of Wynoochee dam. Ross dam aggressively draft (voluntary)
- Sunday: Forecast improves – Event begins - Operate five dams

The Main event (Nov 6th 2006)

- New flow forecast: double the record !
- Then AR shifts south
- Major flooding, devastation Central Cascades

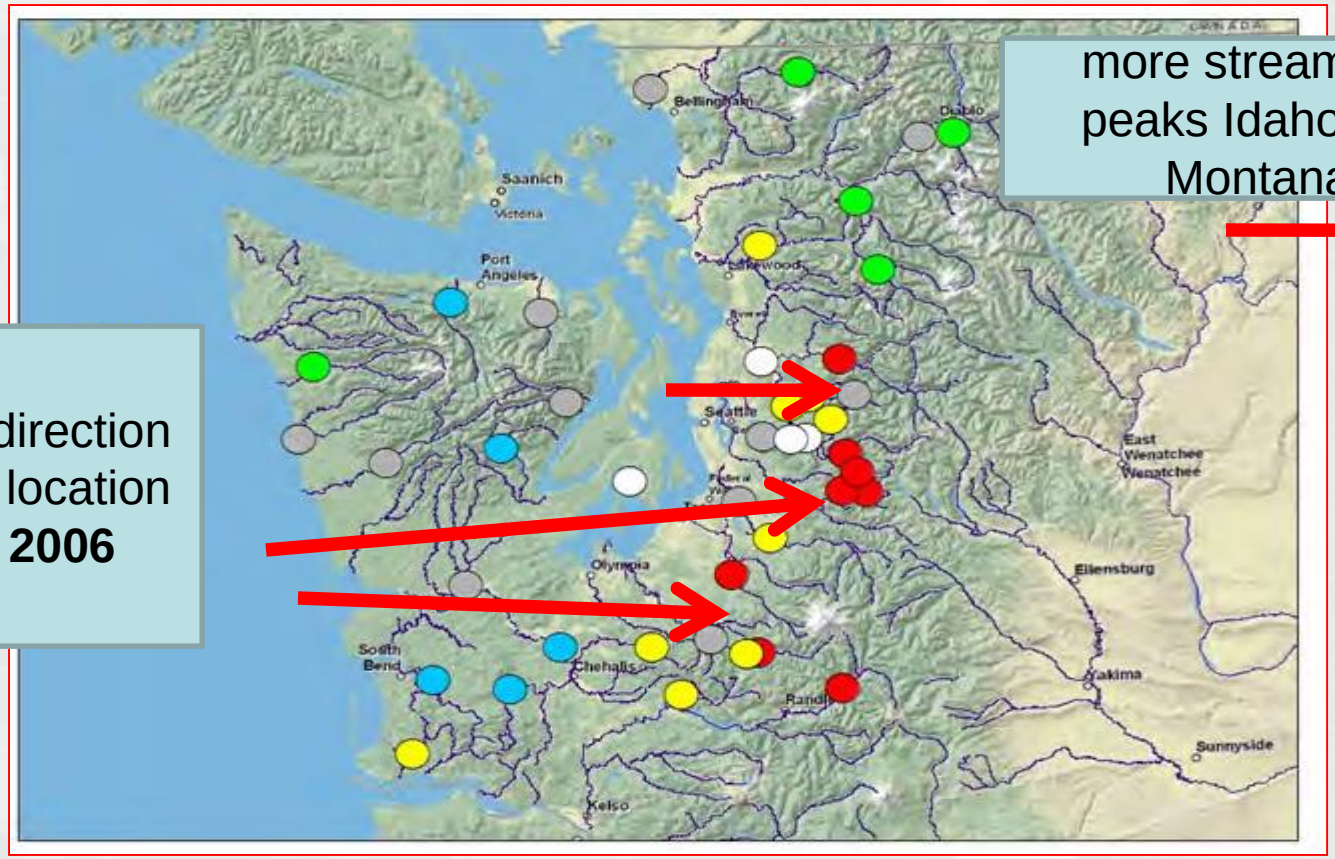
Mt Rainier National Park – $36 million in damage
18 inches of rain – 36 hrs

Reservoir flood storage evacuation after flood

Debris field on reservoir pool (Nov 2006)

Mud Mountain dam evacuates 12,000 cfs Nov 2006

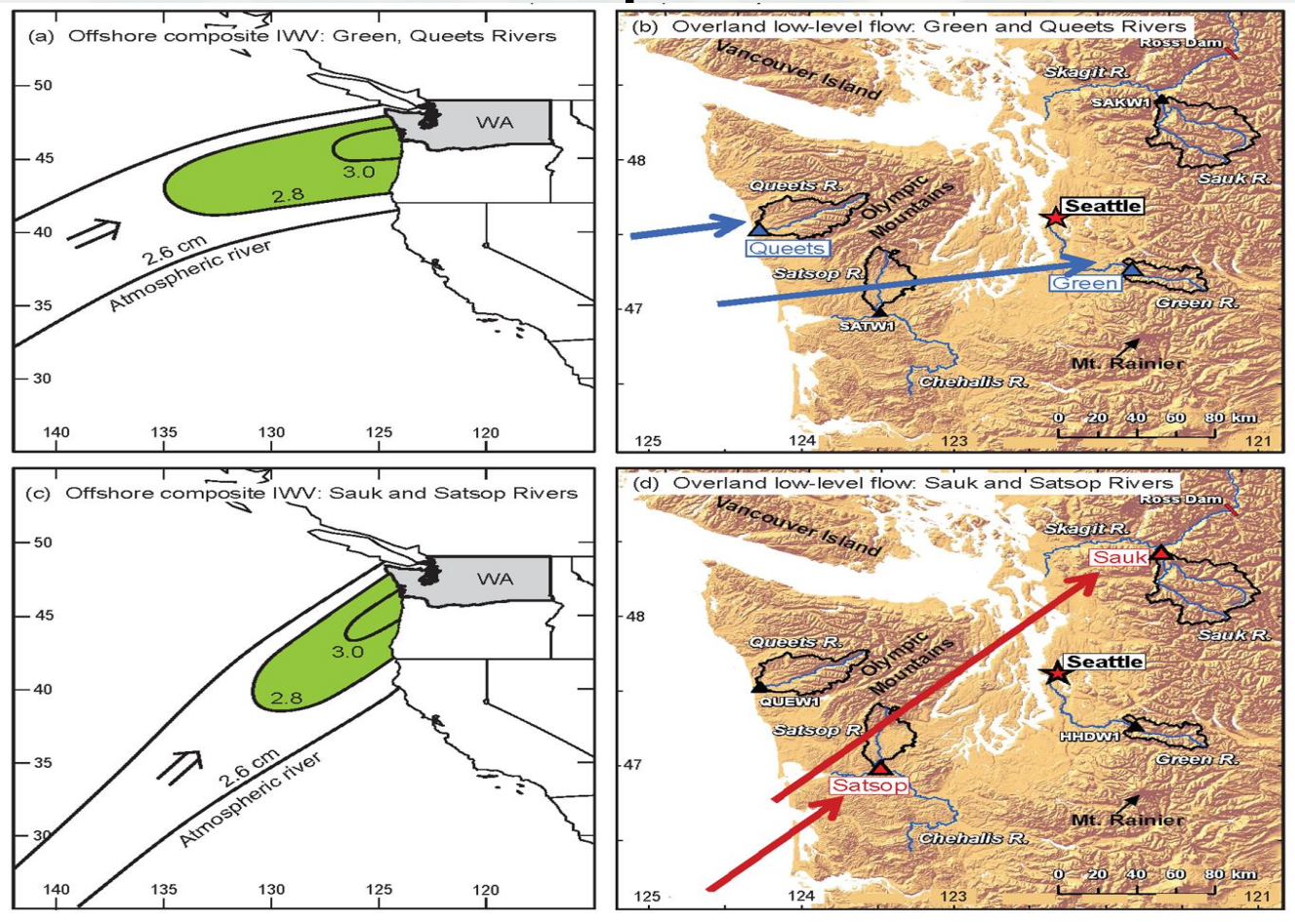
Record all time peak streamflows November 6 & 7 2006



Glacier National Park, Montana
Nov 7, 2006 24hr rainfall: ~ 6”

AR inland penetration: 1000 km / over two mountain ranges

Incoming storm angle of attack is important



Flooding in Western Washington: The Connection to Atmospheric Rivers

PAUL J. NEIMAN, LAWRENCE J. SCHICK, F. MARTIN RALPH,MIMI HUGHES, GARY A. WICK

Using Forecasts

- Forecasts are generally good

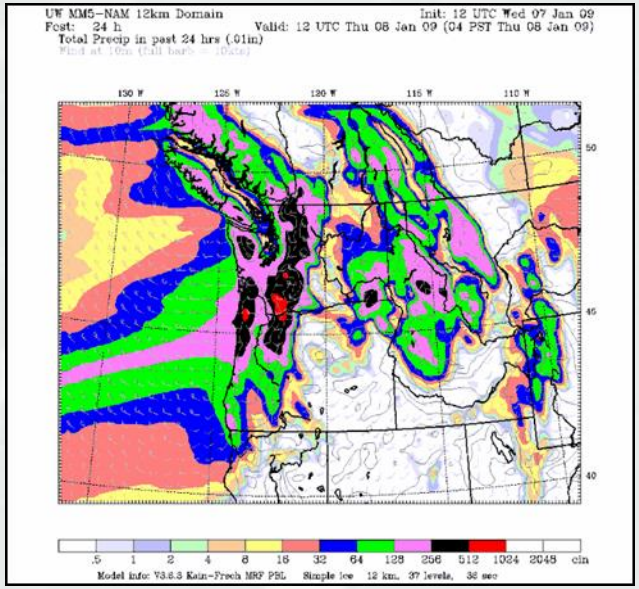
  Don’t know when a poor forecast is unfolding

  – we follow forecast until not trending with observations

- Biggest events

  -most uncertainty

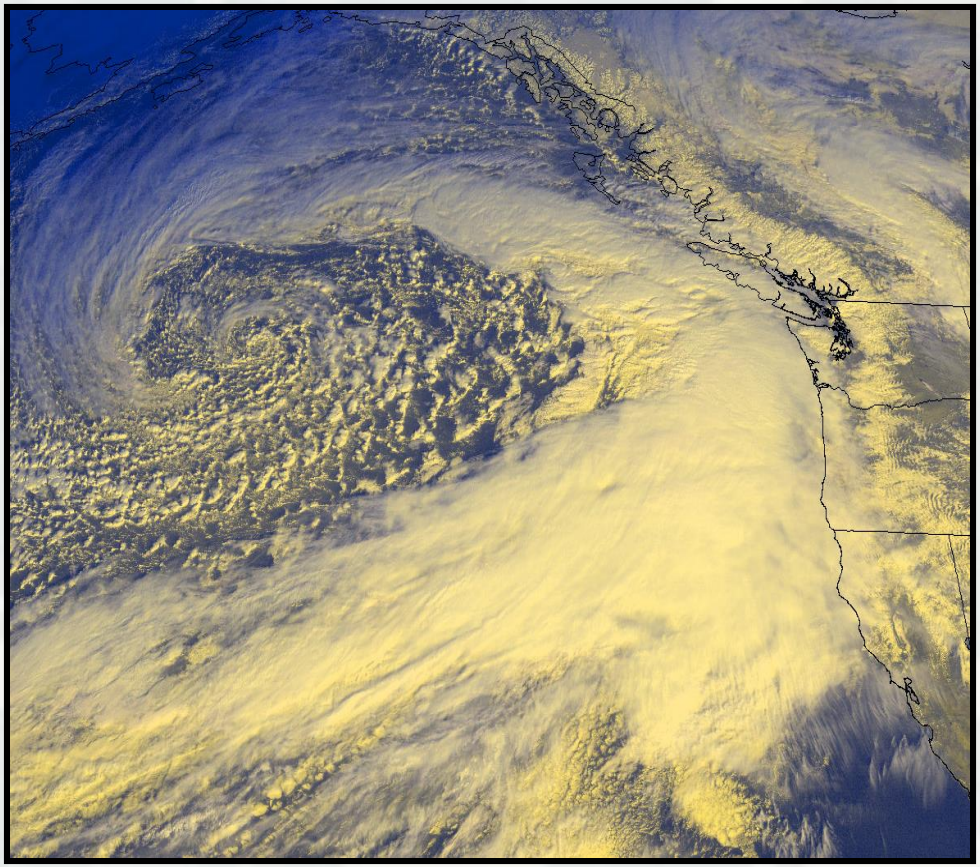
  -extreme rainfall difficult to forecast



Flood Risk Management

- Goal: Manage flood risk
- Method: Capture flood peak, store in reservoir, evacuate asap
- Adaptive management: Blend forecasts with reality

ARs and the PMP



Atmospheric river – November 24, 1998

What is Probable Maximum Precipitation (PMP)?

“ the theoretical maximum precipitation for a given duration under modern meteorological conditions” (WMO, 2009)

It’s an estimate, no known way to calculate

Why do we need a PMP?

PMP is used to develop the Probable Maximum Flood (PMF) – understand flood risk

Used for dam design (spillway capacity, etc.)

Design safety vs cost – for new and aging dams (spillway modifications)

ARs and the PMP

- Most West Coast U.S. “controlling” PMP storms are ARs
- It’s likely the PMP will be an AR
- If future AR magnitude increases, so will the PMP estimates

ARs and the PMP

- Current PMP estimates – confusing, incomplete storm list, methodology subjective not documented
- Use of new precip data: radar, satellite
- Investigate use of weather modeling to produce defensible PMP estimates

What is an ARs max rainfall potential?

What can be done with ARs and PMP?

Use numerical modeling…

- Understanding rainfall, coverage, duration
- catalog historic AR storms
- use physically based drivers for PMP maximization and transposition
- consider climate change
- correlate basin attributes to AR impacts

Reservoir flood operations extreme drought to historic flood

Brisbane, Australia January 2011

Wivenhoe dam and reservoir (almost filled -1.9 MAF)

The Conflict

Storage for water supply /drought

Storage availability for floods

Too little or too much

The Brisbane Flood – January 2011

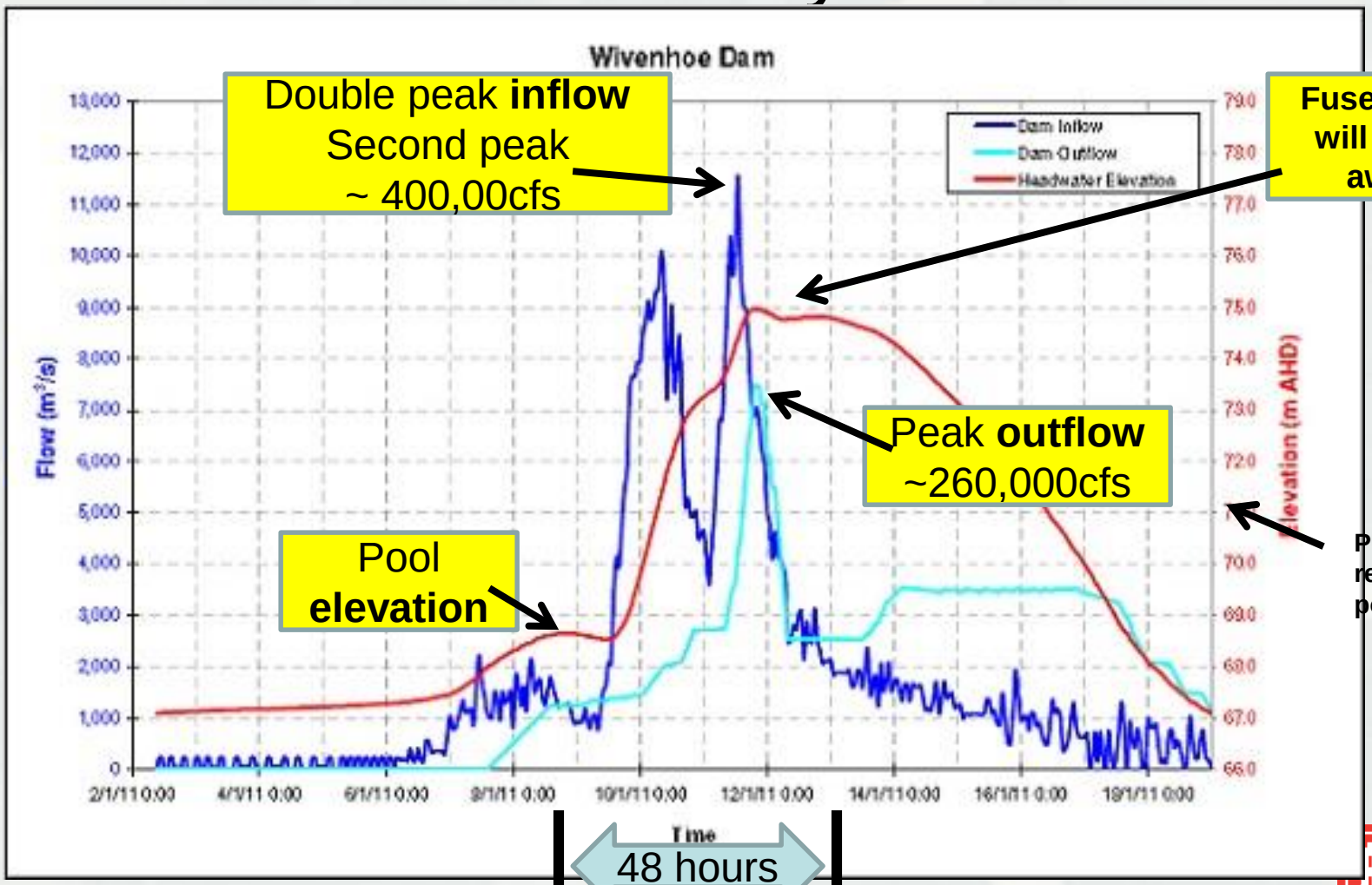
historic flood for Brisbane

criminal charges for engineers

2.38 billion in damages, 37 dead

75% of Queensland: disaster area

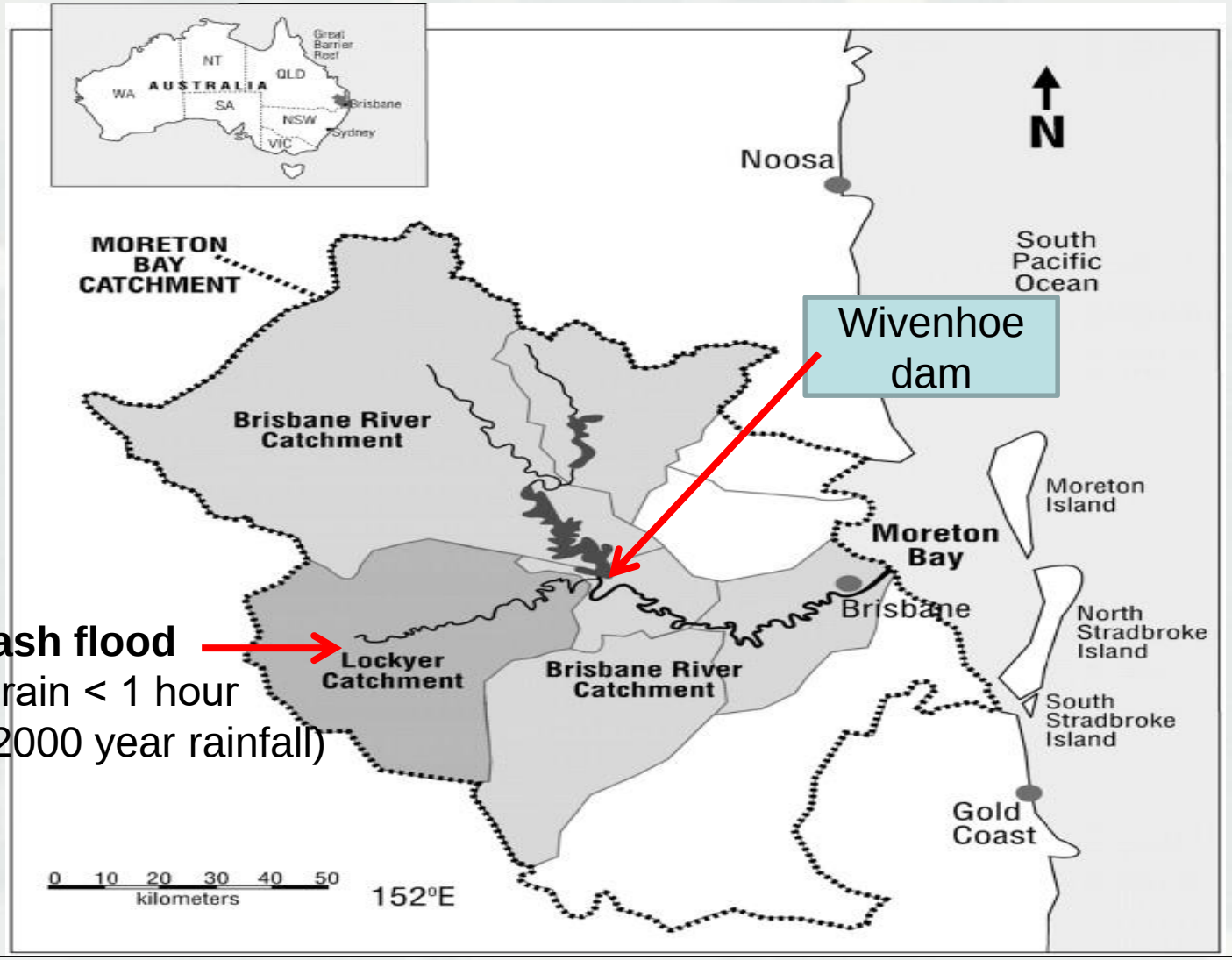
Wivenhoe Dam – hydrologic profile mid January 2011



Brisbane Flood – 1893

Queensland – a history of extreme floods and extreme droughts. Dams could help

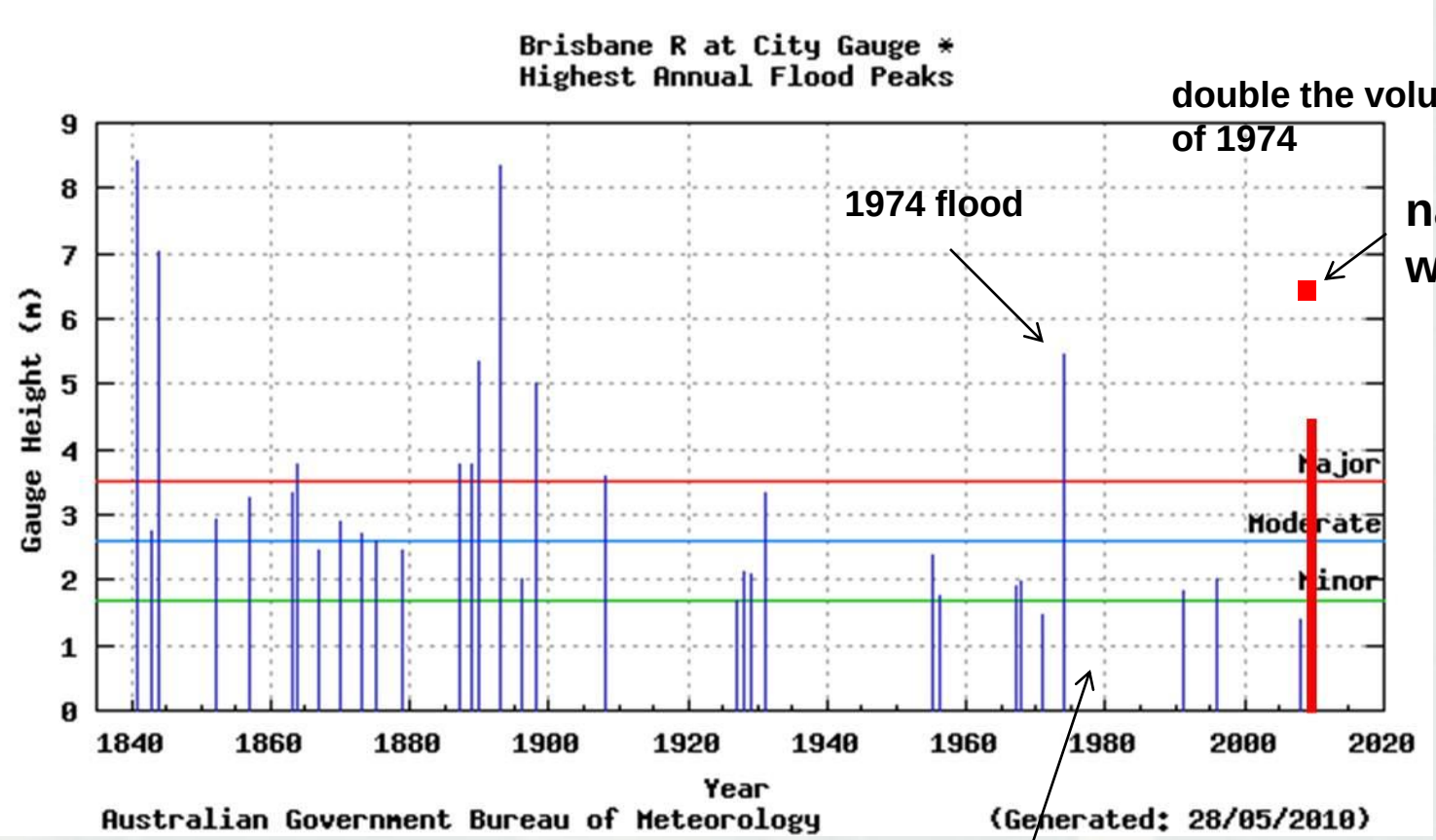
Brisbane Basin



Flash flood
6” rain < 1 hour
(2000 year rainfall)

Historic flood peaks (Brisbane gauge)

Climate change or natural variation?



In the end….

- Dam did not fail, Brisbane saved
- Severe, but not catastrophic flood
- Damages prevented: 5 billion dollars
- Consider balance of flood and water supply risk – favor protecting for flood risk

Changes: since our report in 2011

- Class action law suit in progress (one billion dollars) Seqwater dam ops not follow forecast?
- Flood pool 25% larger - less for water supply
- Store water supply in other dams (pump storage)
- Big events, activate fuse plug sooner

Lessons for California

- Major floods can quickly follow long droughts (ENSO driven in California and Australia)
- Water supply (save water) vs. flood risk (save storage) What is your priority/risk?
- Dam flood storage has limits, dam safety
- Understand flood risk – regulated & unregulated

Flood and water supply risk management

Cannot control flood or water supply – only manage risk

Uncertainty – use flood and water supply space wisely with informed decisions

Improved AR forecasting and research can help by understanding AR uncertainty

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Communicate risk and consequences

AR weather hazard

Flood mitigation (limits of levees, dams)

Life, property, environmental (fish)

What water supply managers need to know

- When does the AR flood season begin and end?

- What are the uncertainties in supply?

  AR rainfall, general rainfall, snowmelt

- Water demand, short and long term

  Demands: irrigation, people, recreation, environment

What flood operations need to know

- Extreme AR rain forecast: what basins? when start, how much, when end – anything next?
- During AR: Are river forecasts tracking accurately?
- Reservoir storage space available