HEPEX Tenth Anniversary Workshop
24-26th June 2014, Maryland, USA

Using Ensemble Forecasts to Minimize Risk and Support Decision Making Under Uncertainty in Hydroelectric Power Operations

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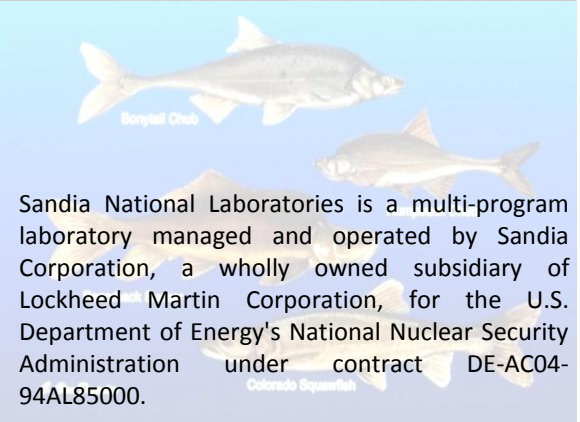

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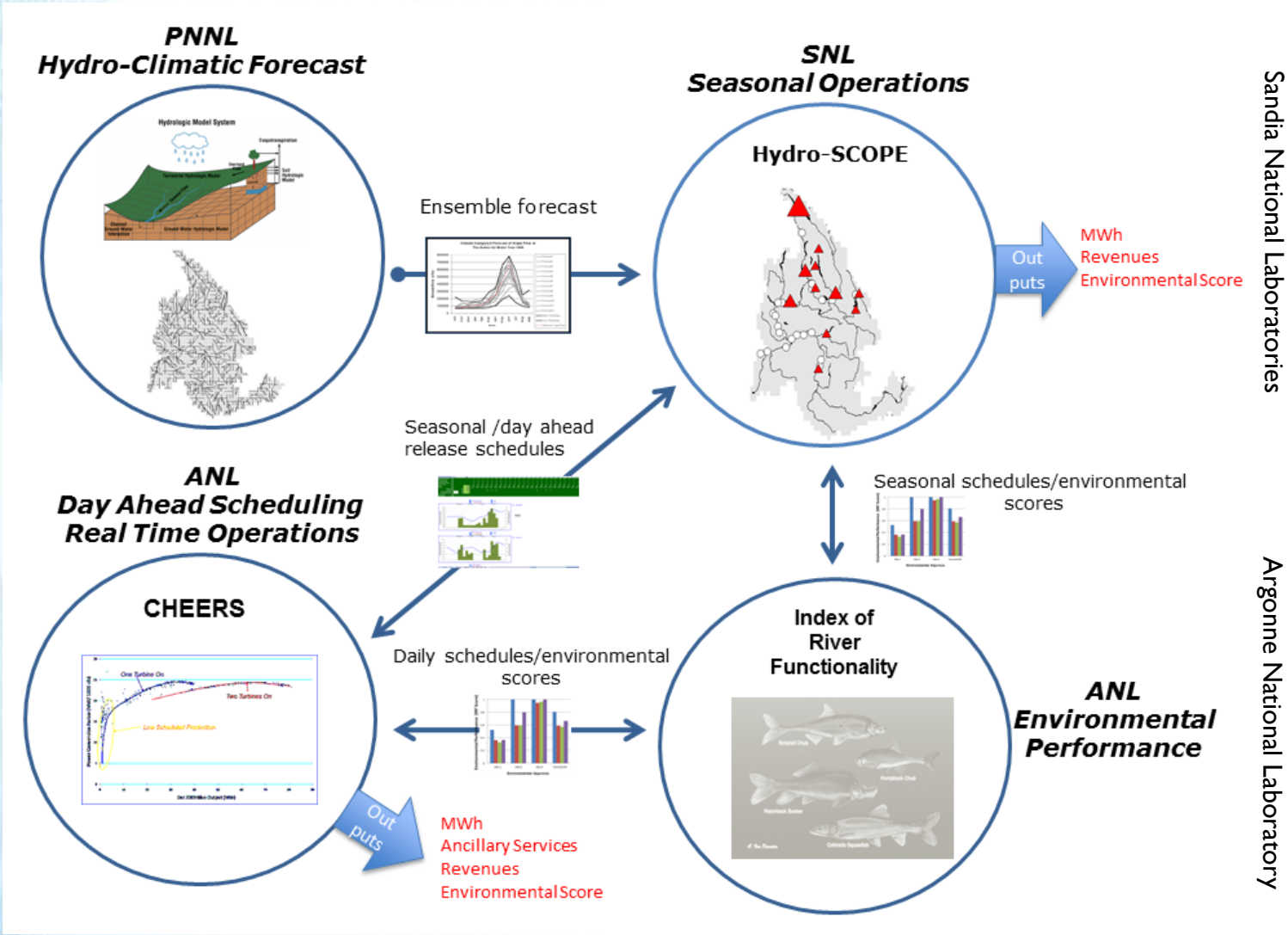
Introduction

QUESTION:

For hydroelectric power operators and managers, which trace from an ensemble of *n* future predictions provides the least amount of risk to the system?

- Project Background: Water Use Optimization Toolset
- Uncertainty = Risk, ΔRisk = Regret
- Example Application
- Conclusions

Background: Water Use Optimization Toolset



Acknowledgements

- **Sandia National Laboratories**
  - Thomas Lowry
  - Marissa Reno
  - Dirk Vanwestrienen
  - La Tonya Walker
- **Pacific Northwest National Laboratory**
  - Mark Wigmosta
  - Nathalie Voisin
  - Andre Coleman
- **Argonne National Laboratory**
  - Matt Mahalik
  - Tom Veselka
  - John Hayse
  - Sam Saha
- **Department of Energy, Water Power Program**

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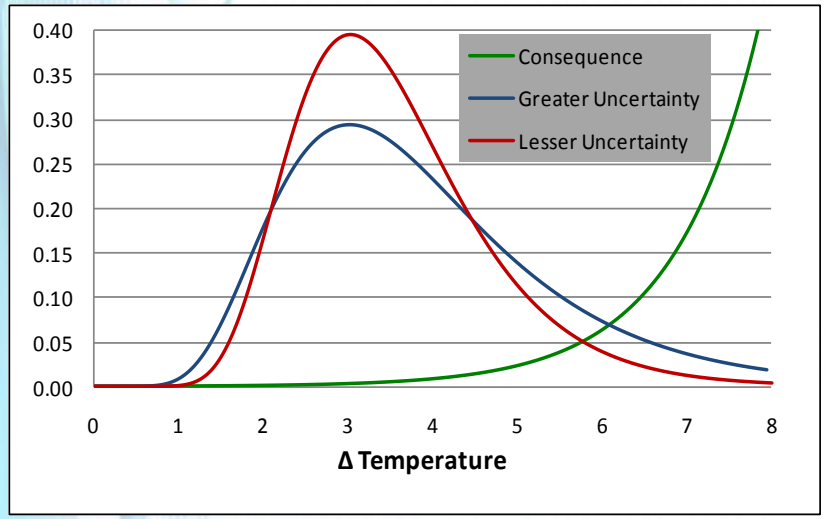
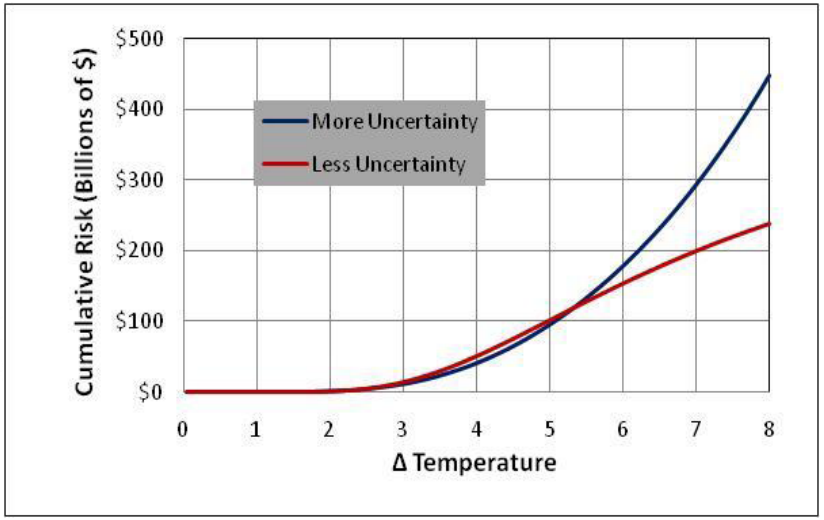
Uncertainty = Risk, ΔRisk = Regret

Probability Distributions with constant modes and consequence



Uncertainty changes the 'tail' of risk

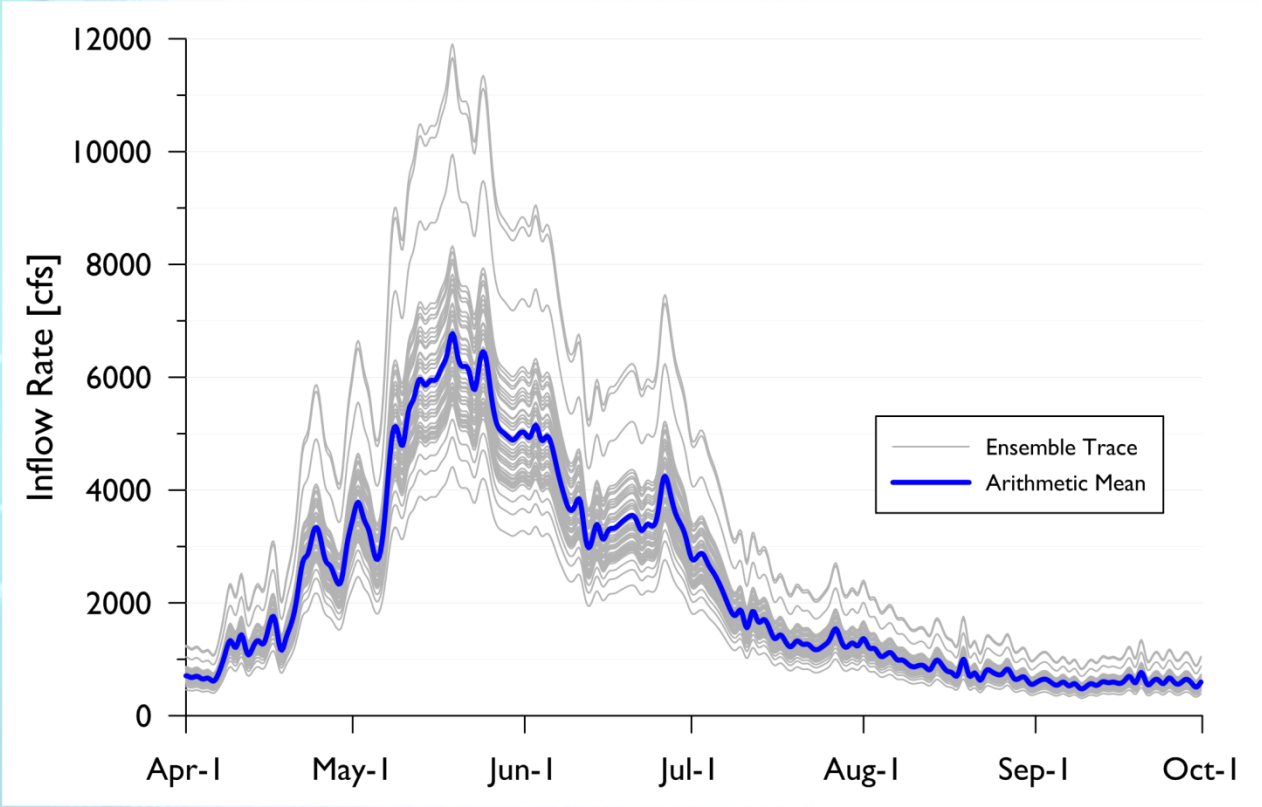


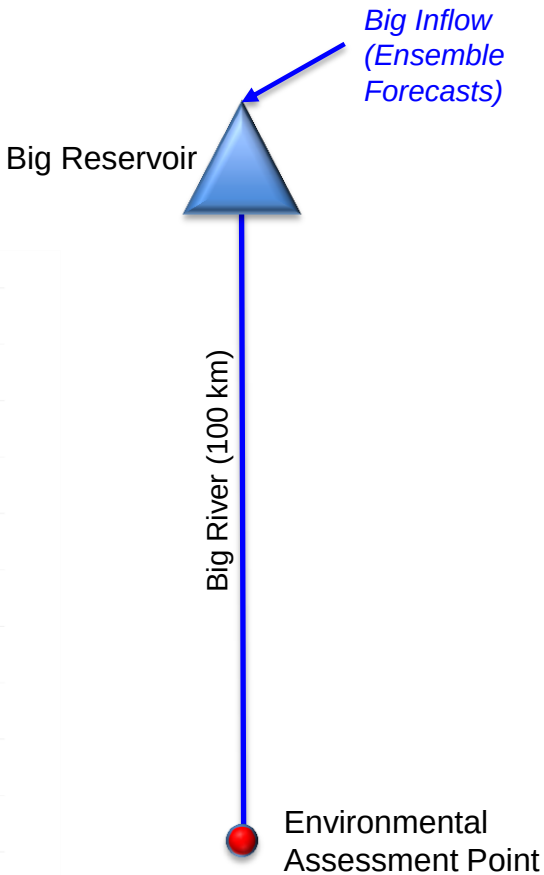
Risk = Probability x Consequence

Regret is the difference in risk of assuming one possible future and realizing another

Example Application

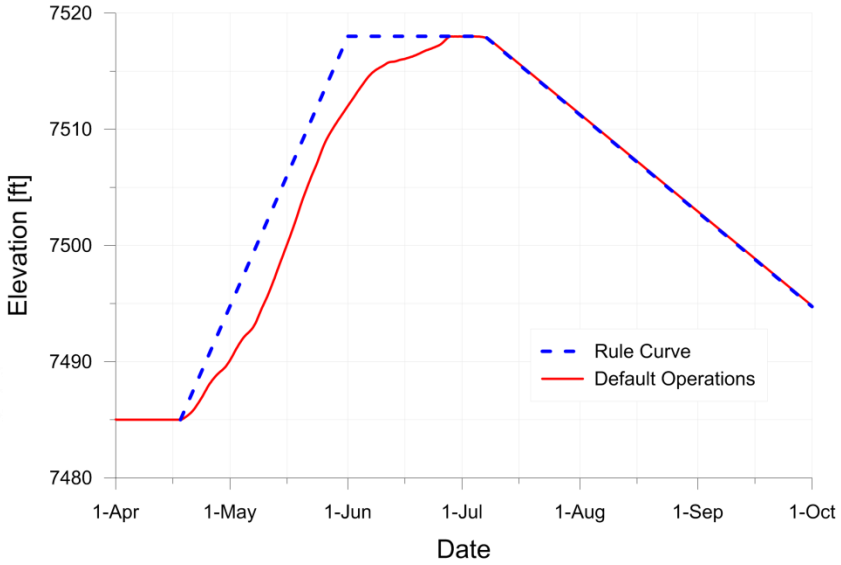
- One Reservoir System
- One River Reach
- One Env. Assessment Point





Example Application

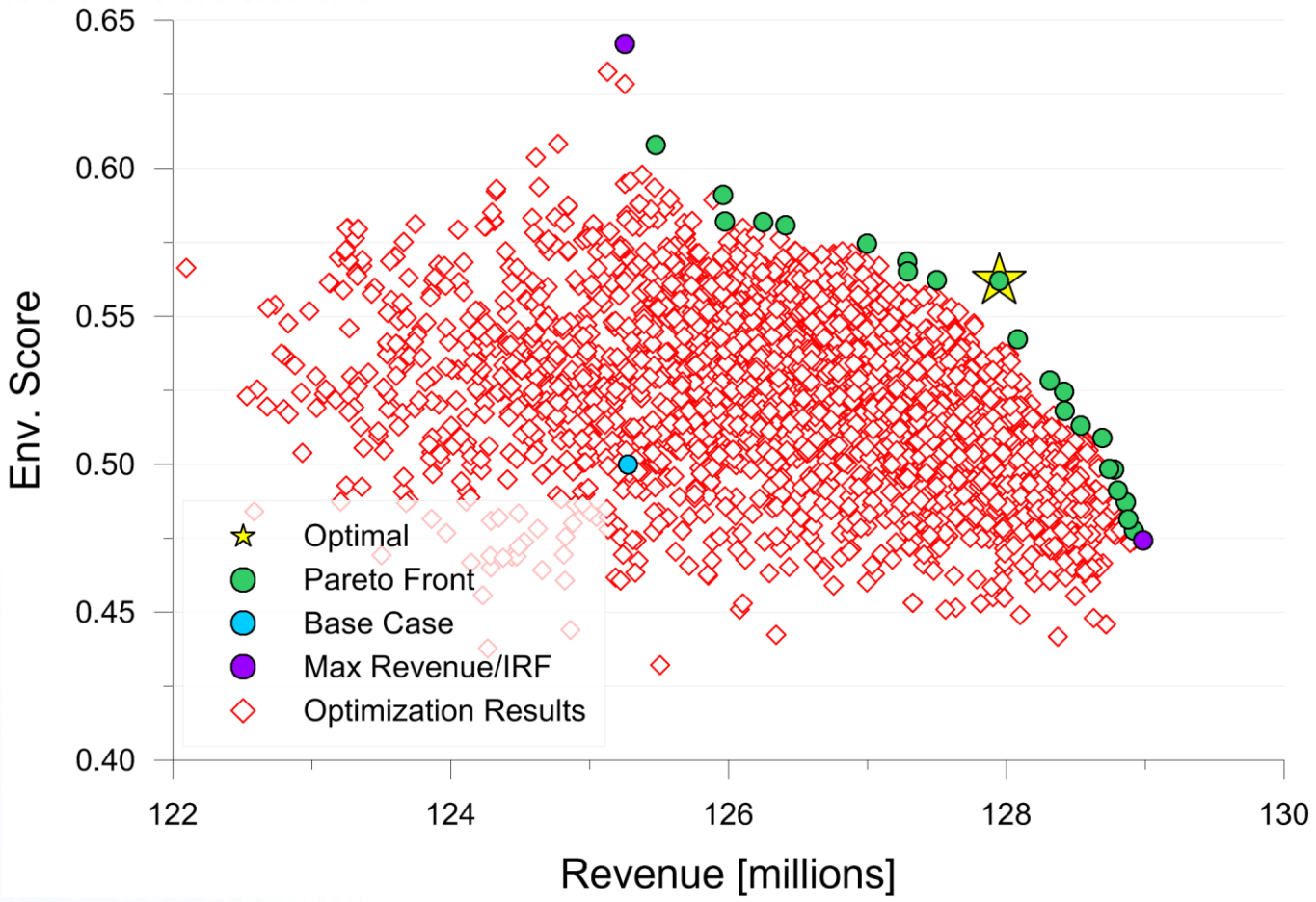
- April thru September
  - 183 days
  - 6-hr timestep (732 timesteps)
- Operations Based on Rule Curve
  - 28 day average inflow forecast
  - 28 day elevation target
  - Adjustments for:
    - Exceeding rule curve
    - Meeting minimum flow requirement (375 cfs)



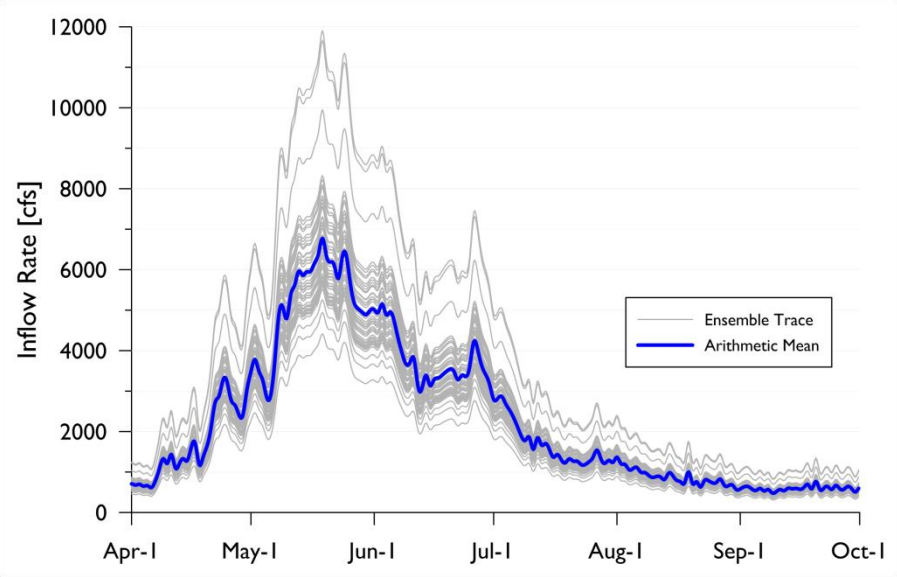
- Environmental Score
  - Minimize June-Aug average maximum daily temp
  - Minimize stage changes > 1ft/day
  - Relative to base case scenario
- Base Case Inflow = Ensemble Arithmetic Mean

Base Case Optimization

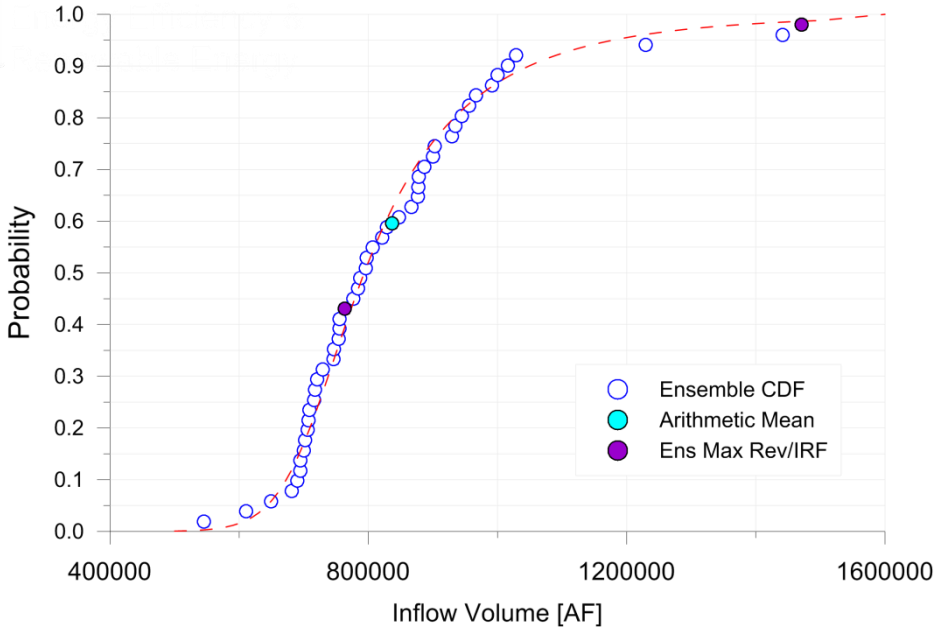
- 2500 simulations
- Pareto Front defines line of tradeoff
- Base Case is default operations before optimization
- 24-hr Release
  - BC = 1366 AF
  - Opt = 1350 AF



Using Ensemble Forecasts



- Convert flow volumes to cumulative distribution function
- Optimize each instance
- Calculate risk as a function of probability and consequence



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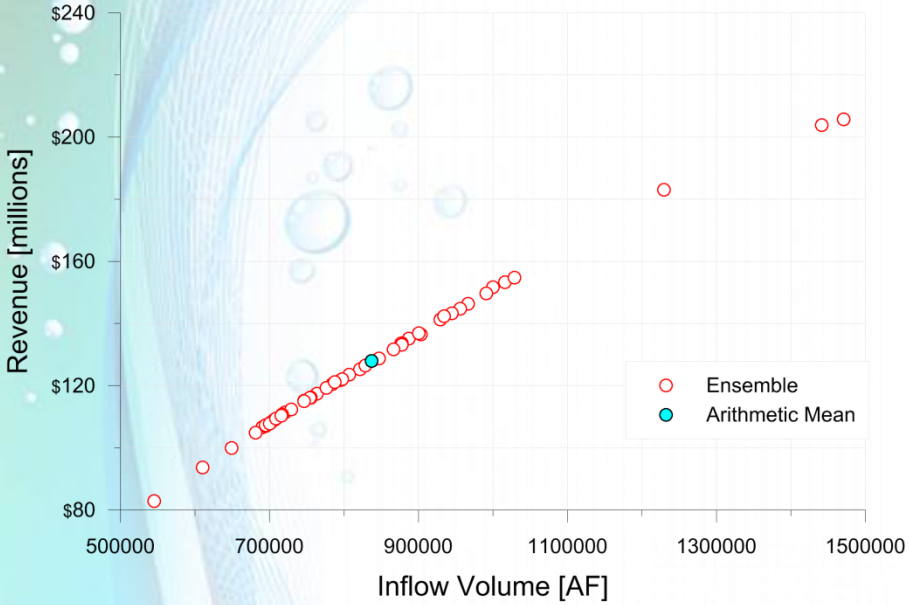
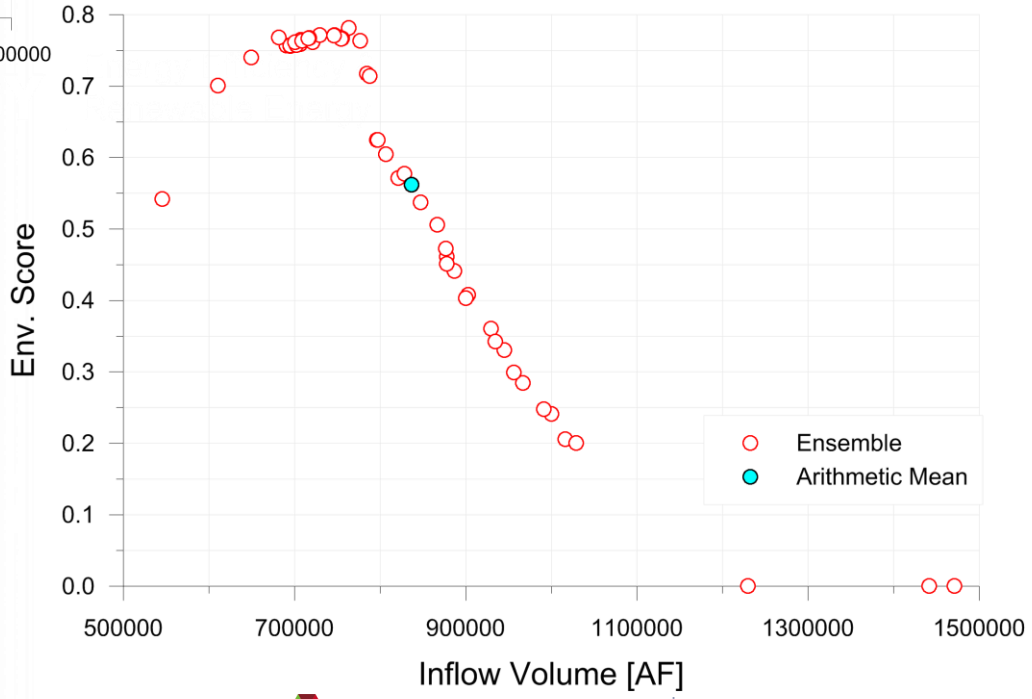
Using Ensemble Forecasts



- Revenue is monotonic w.r.t. inflow volume

- Environmental performance is more complex



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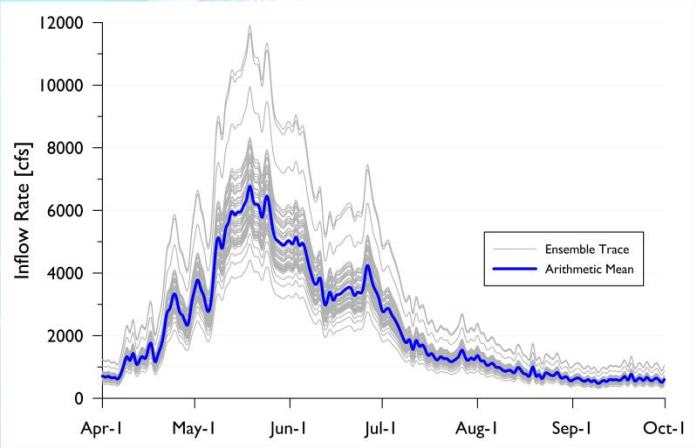
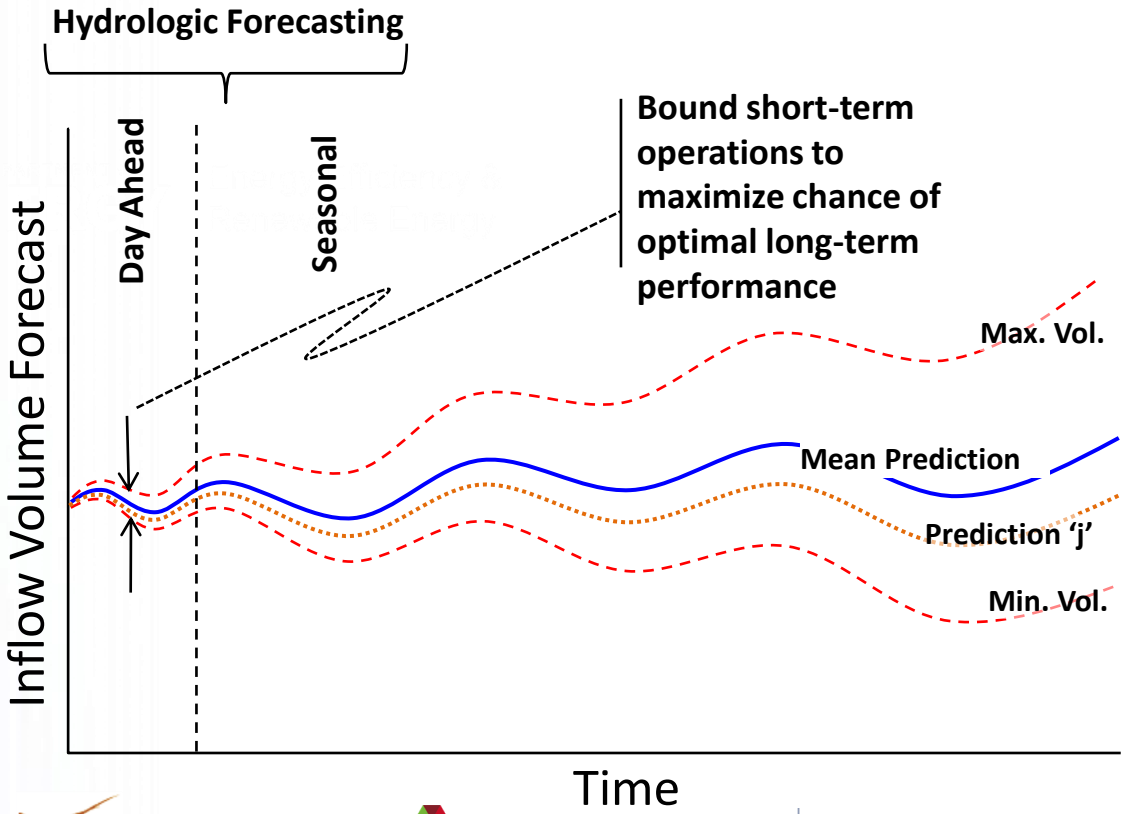
Risk and Regret

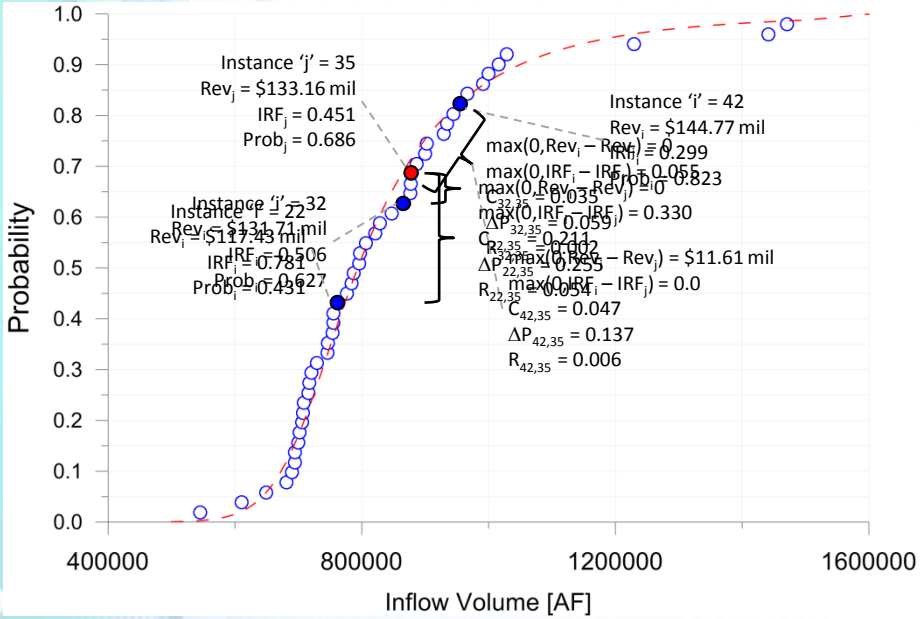
- Risk
  - Given an ensemble of ‘n’ forecasts, what is the risk of assuming forecast ‘j’ and realizing forecast ‘i’?
  - We want to minimize regret when we are wrong





Calculating Risk / Regret

- Risk
  - Given an ensemble of ‘n’ forecasts, what is the risk of assuming forecast ‘j’ and realizing forecast ‘i’?
  - We want to minimize regret when we are wrong



$$R_j = \sum_{i=1}^{n} R_{ij} = \sum_{i=1}^{n} C_{ij}\Delta P_{ij}$$

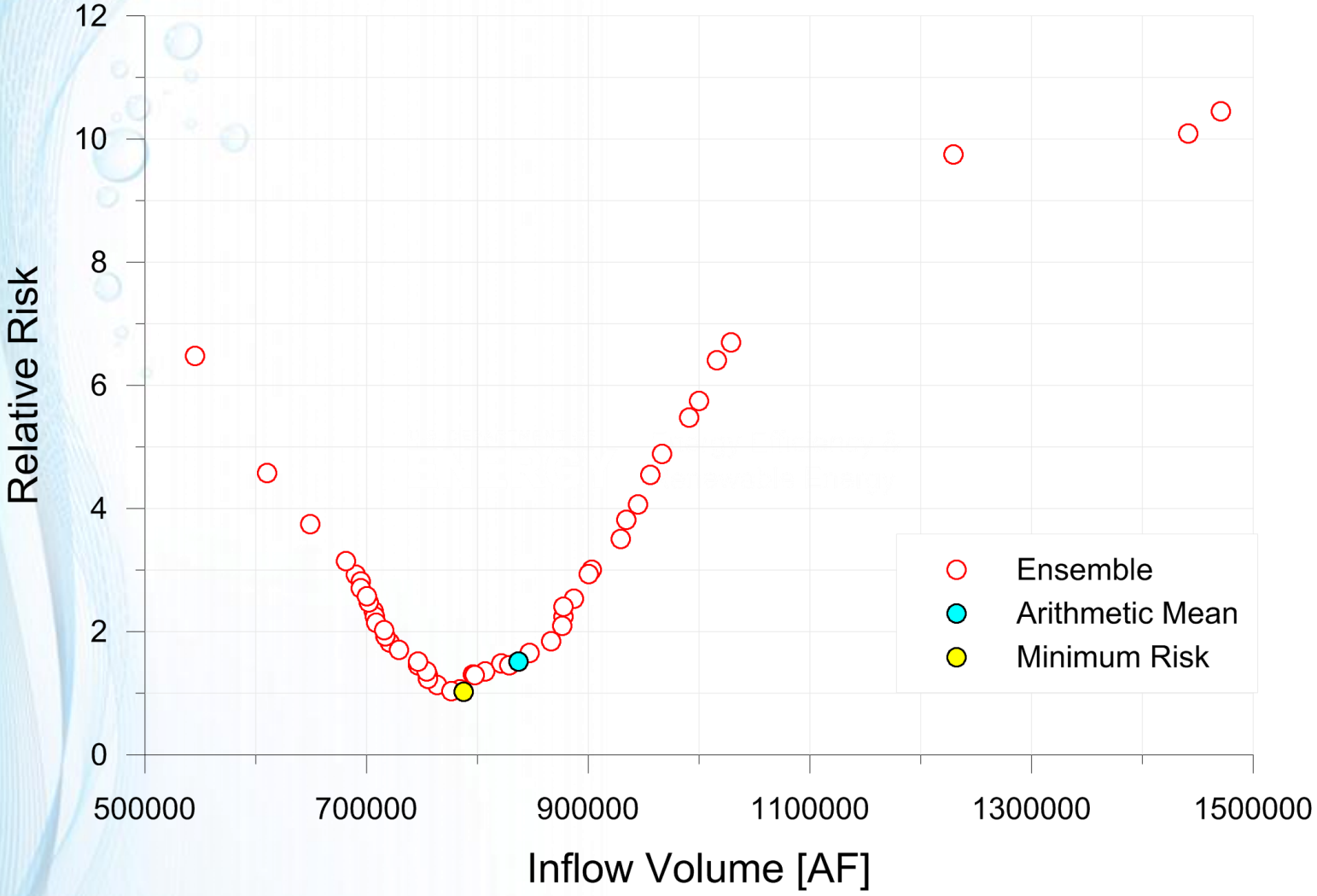
$$\Delta P_{ij} = \left|P_i - P_j\right|$$

$$C_{ij} = \left(\frac{max\left(0, Rev_i - Rev_j\right)}{Rev_{max} - Rev_{min}} + \frac{max\left(0, IRF_i - IRF_j\right)}{IRF_{max} - IRF_{min}}\right)\frac{1}{2}$$

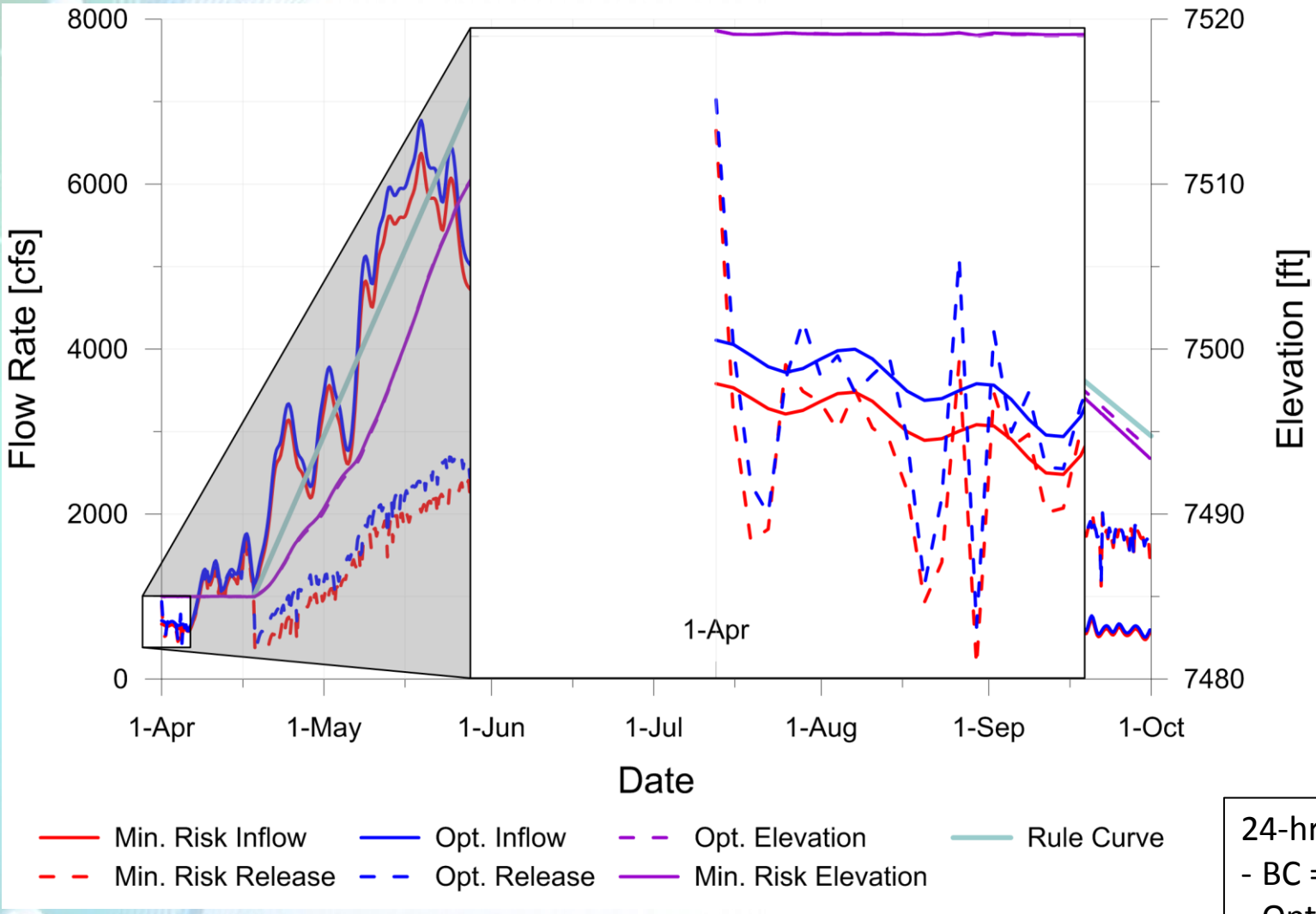
$Rev_{max} - Rev_{min}$ = $122.80 mil

$IRF_{max} - IRF_{min}$ = 0.781

Minimum Risk / Regret



Short-term Implications



24-hr Outflows
- BC = 1366 AF
- Opt. = 1350 AF
- Min. Risk = 1283 AF

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Conclusions

- Risk is the product of the probability of an event occurring and the consequence of that event
- Regret is the difference in risk between assuming one possible future and realizing another
- Minimizing regret means minimizing our exposure to consequence/loss when we are wrong
- Using a mean of an ensemble does not include the impact of uncertainty – it misses the ‘tail events’