

2001 California Weather Symposium  
Sierra College

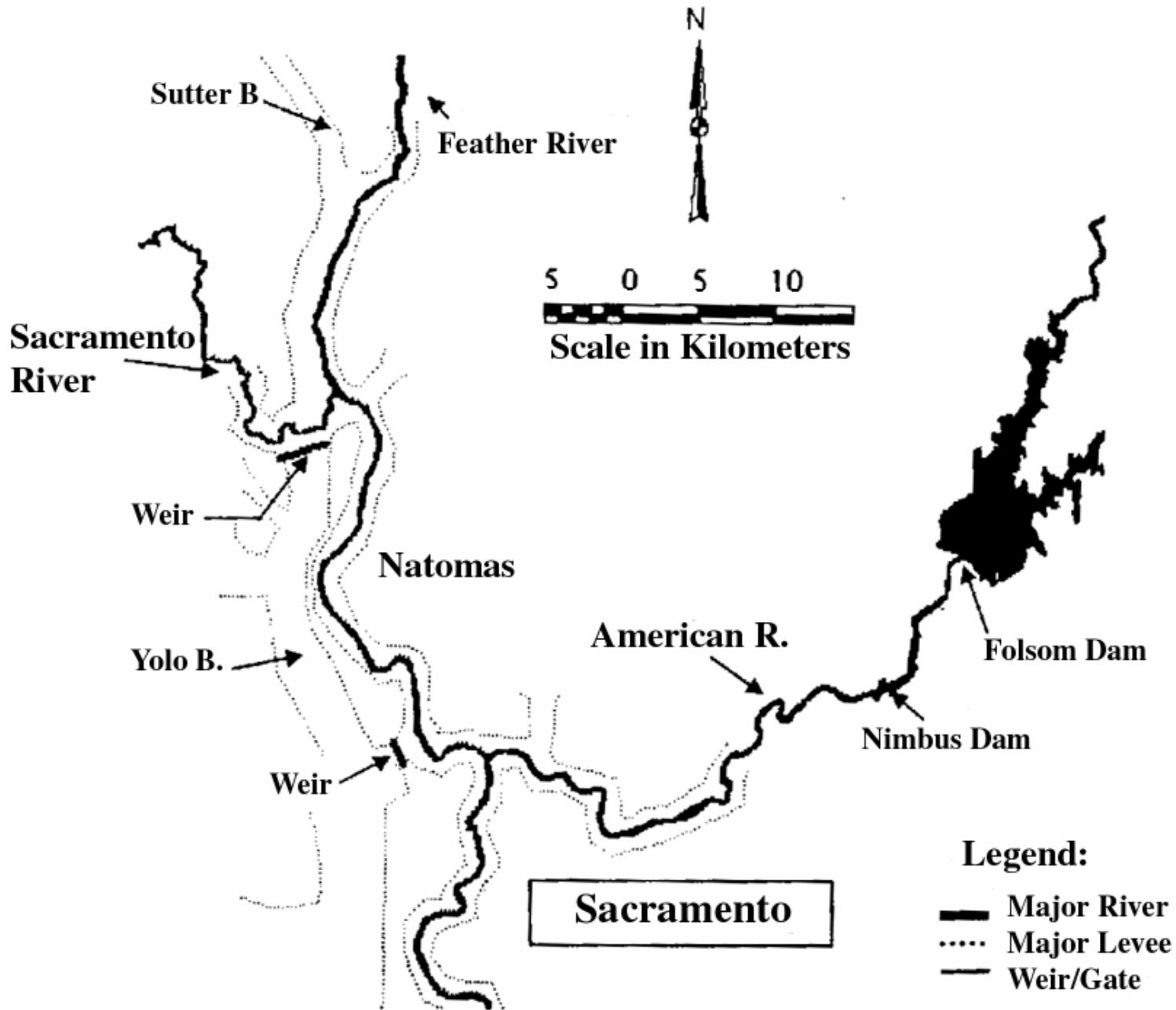
# Forecast Based Operation: Folsom Reservoir Release Forecast Model RRFM-U

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June 22, 2001





# Outline

- 1) Reservoir release lead times
- 2) Overall Modeling System
- 3) Inflow Forecast Model
- 4) Reservoir Release Forecast Model
  - a) Operational Version
  - b) Simulation Version
  - c) COM Version
- 5) Benefits and Status

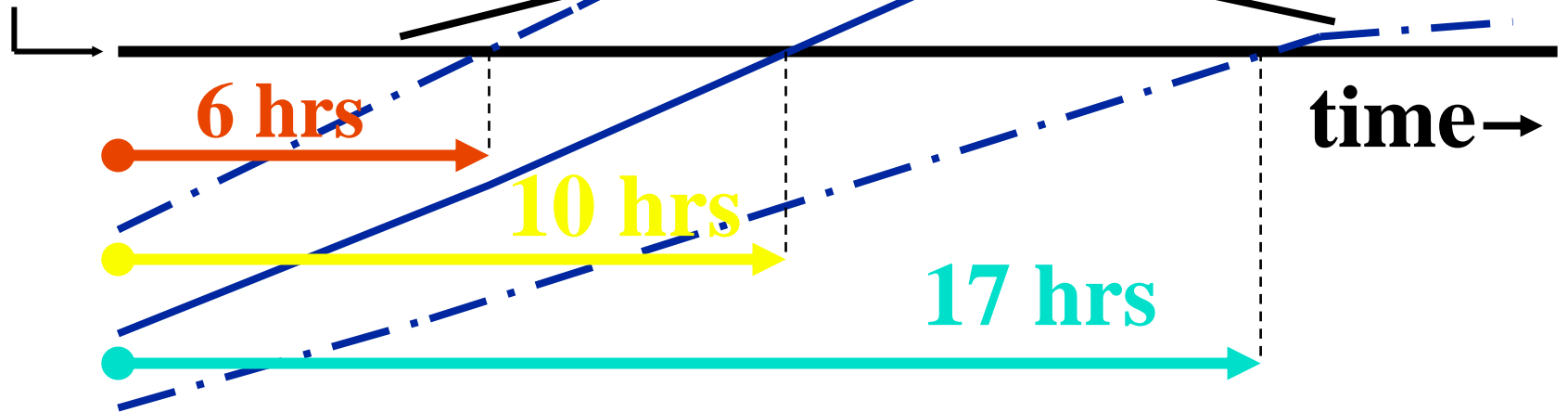
# 1) Reservoir Release Lead Times

# Objective

A forecast system for **lead times to reach release flow levels**, which are critical for initiating downstream warning and evacuation

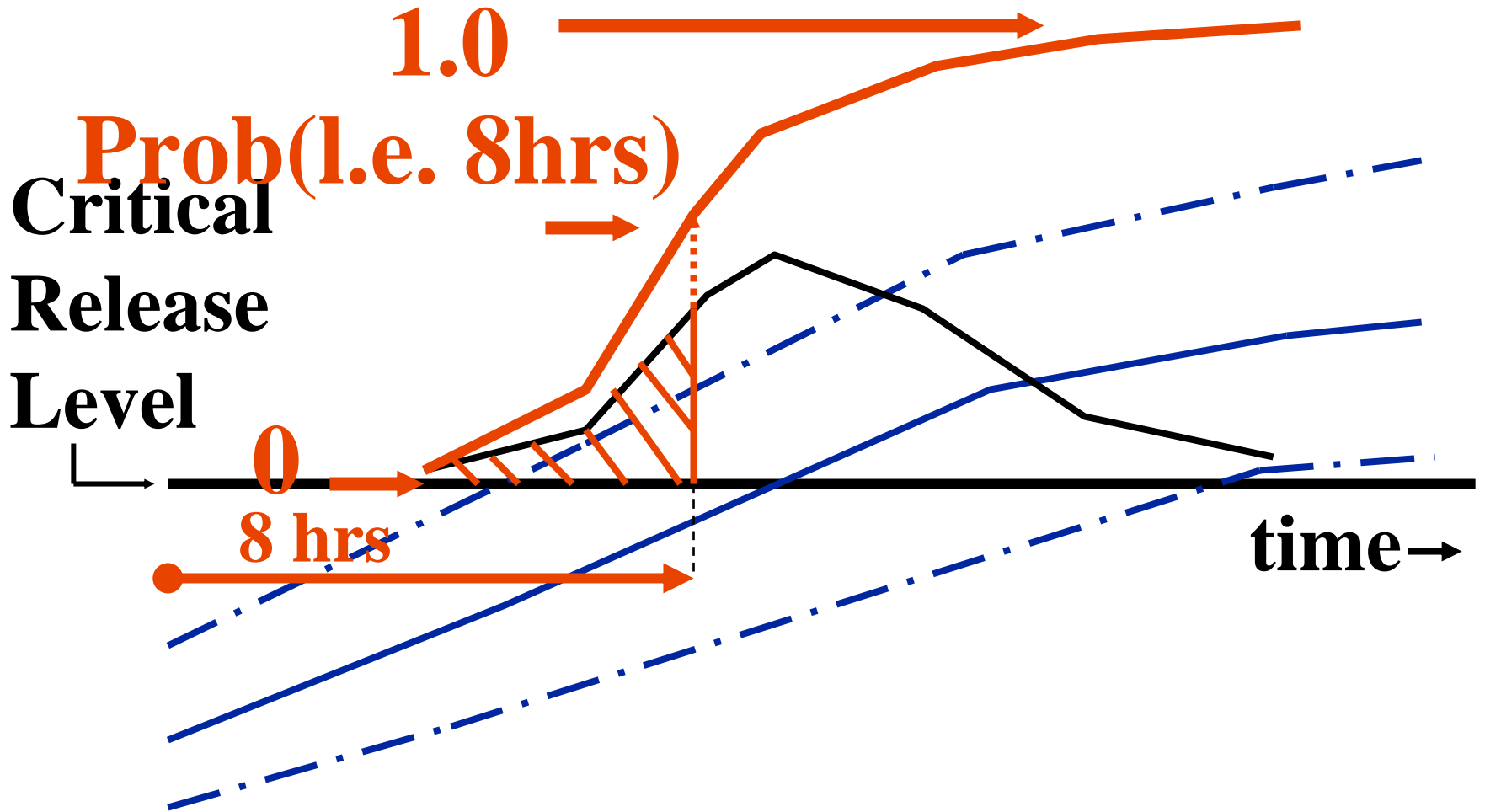
# Forecast Lead Times

**Critical  
Release  
Level**



**time** →

# Forecast Lead Times



## 2) Overall Modeling System



## Two major components:

### □ Inflow Forecast Model

- Dr. Konstantine Georgakakos, Hydrology Research Center (HRC)
- NWS CA/NV River Forecast Center, USU

### □ Reservoir Release Forecast Model

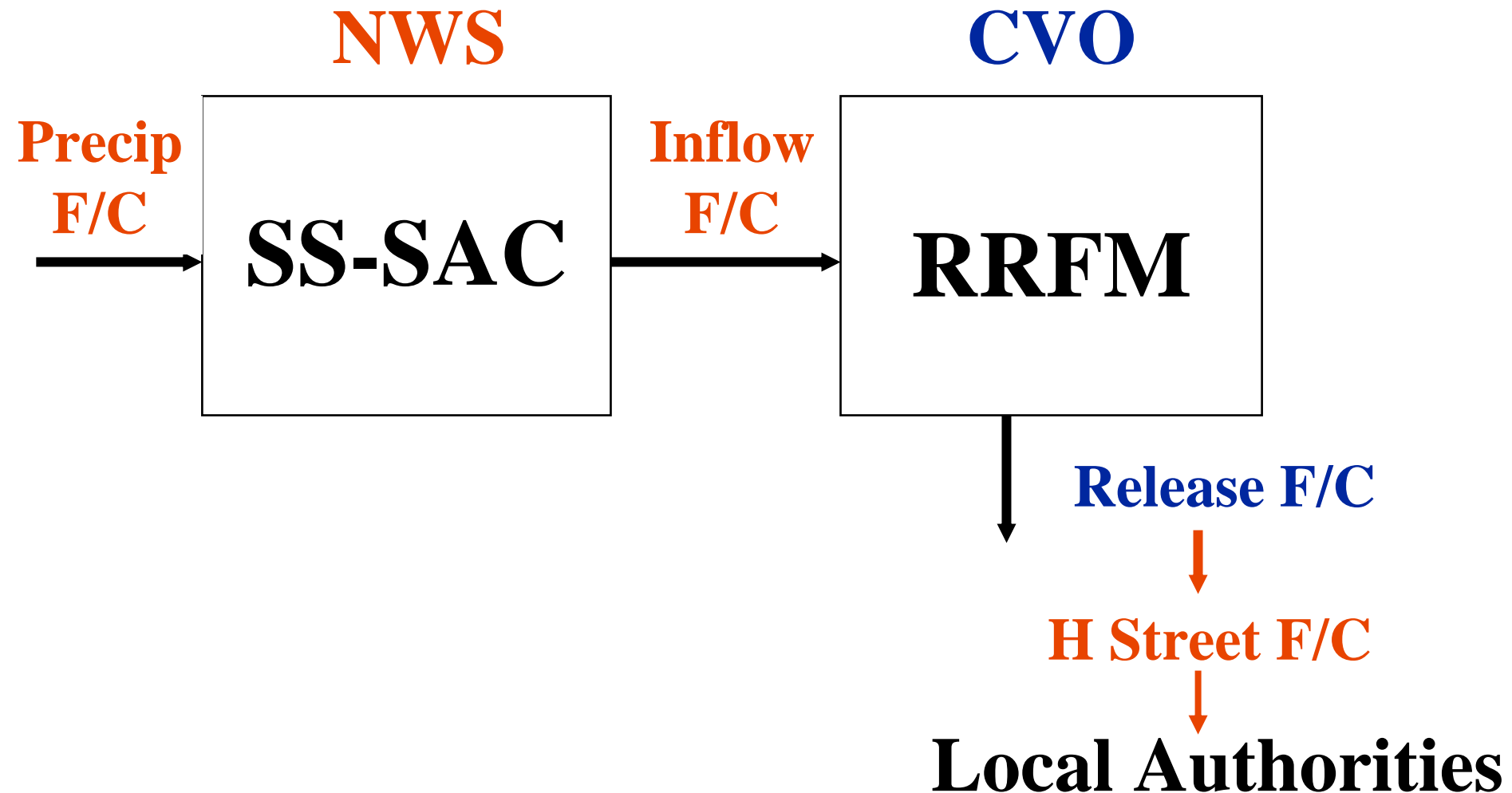
- Utah State University (USU)
- CVO, NWS, HRC, SAFCA, USACE, City, County, American River FCD

### 3) Inflow Forecast Model

# Inflow Forecast Model (IFM)

- Sacramento Model with updating
  - SS-SAC
- NWSRFS data management
- Three subbasins
- NWS rainfall forecasts and uncertainties
- Updating using observed streamflow at three new gages
- Forecast inflow rates and volumes with confidence limits

# Forecasting System Components



## 4) Reservoir Release Forecast Model (RRFM)

# RRFM-U Applications

- **Operational (Real time, On-line)**
  - rule and user-specified release calculations
  - alternative user-specified release
- **Simulation (Off-line)**
  - real time and planning mode
  - develop guidance for emergency management
  - evaluate alternative rules
- **COM (Off-line)**
  - provides access to RRFM via Excel spreadsheet
  - flexible planning tool

## 4) RRFM

a) Operational Application

# Reservoir Release Forecast Model (RRFM)

- Captures inflow forecasts and other input variables
- Calculates
  - release capacity
  - forecast releases and reservoir levels
    - two flood control diagrams and three emergency spillway release rules, OR
    - operator-specified releases
- Forecasts timing for exceeding critical release rates



## RRFM capabilities (Cont'd)

- Graphical-user interface
- Documents when forecast information is available and records operator's notes
- Provides *on-line and off-line simulation capability*
- *Prepares and transmits release orders from operator-specified releases*
- Provides visualization of key variables
- *Confidence levels on all forecast variables*

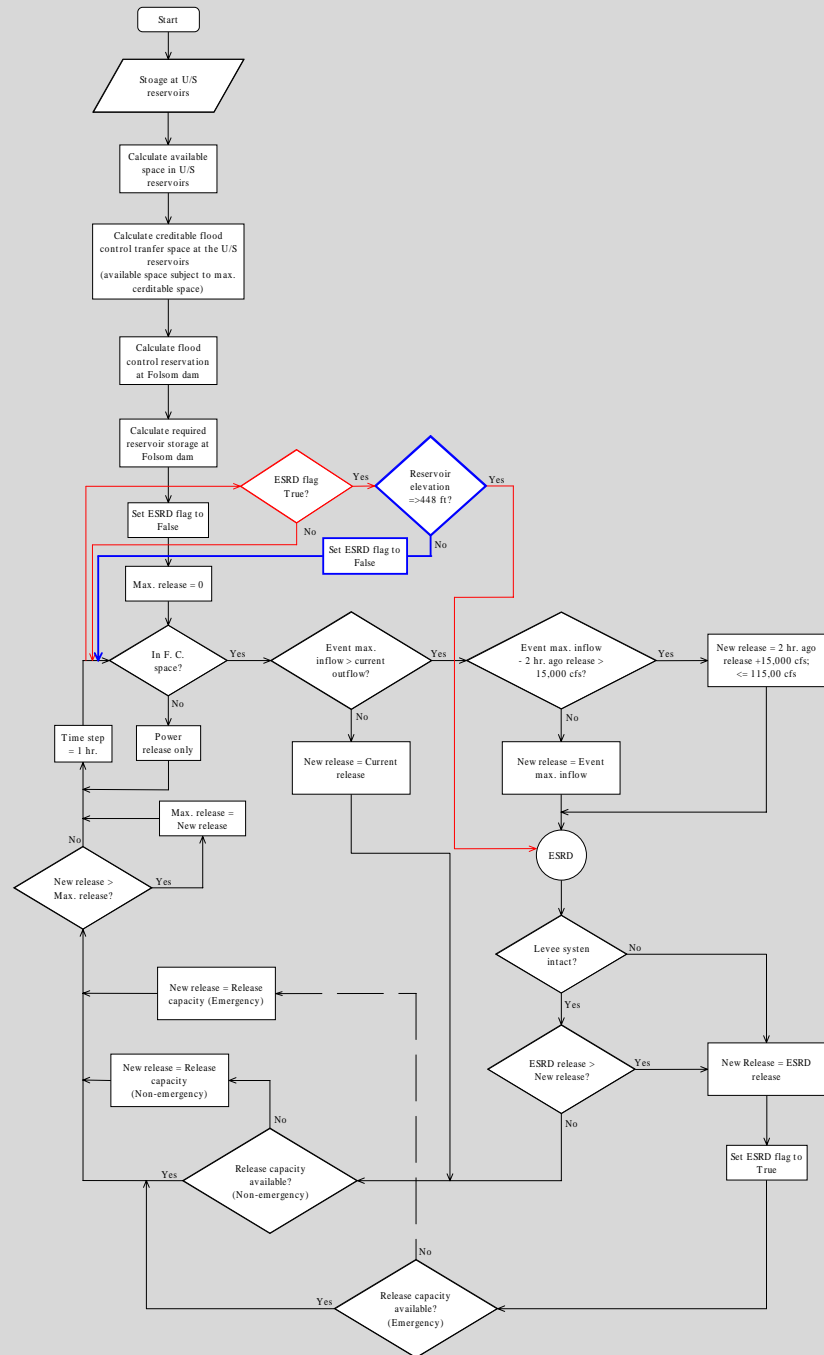
# Operating Rules

- Flood Control Diagram
  - USACE Water Control Manual
  - SAFCA variable space criteria
- Emergency Spillway Release Diagram
  - USACE Water Control Manual
  - Maximum surcharge
  - Maximum release

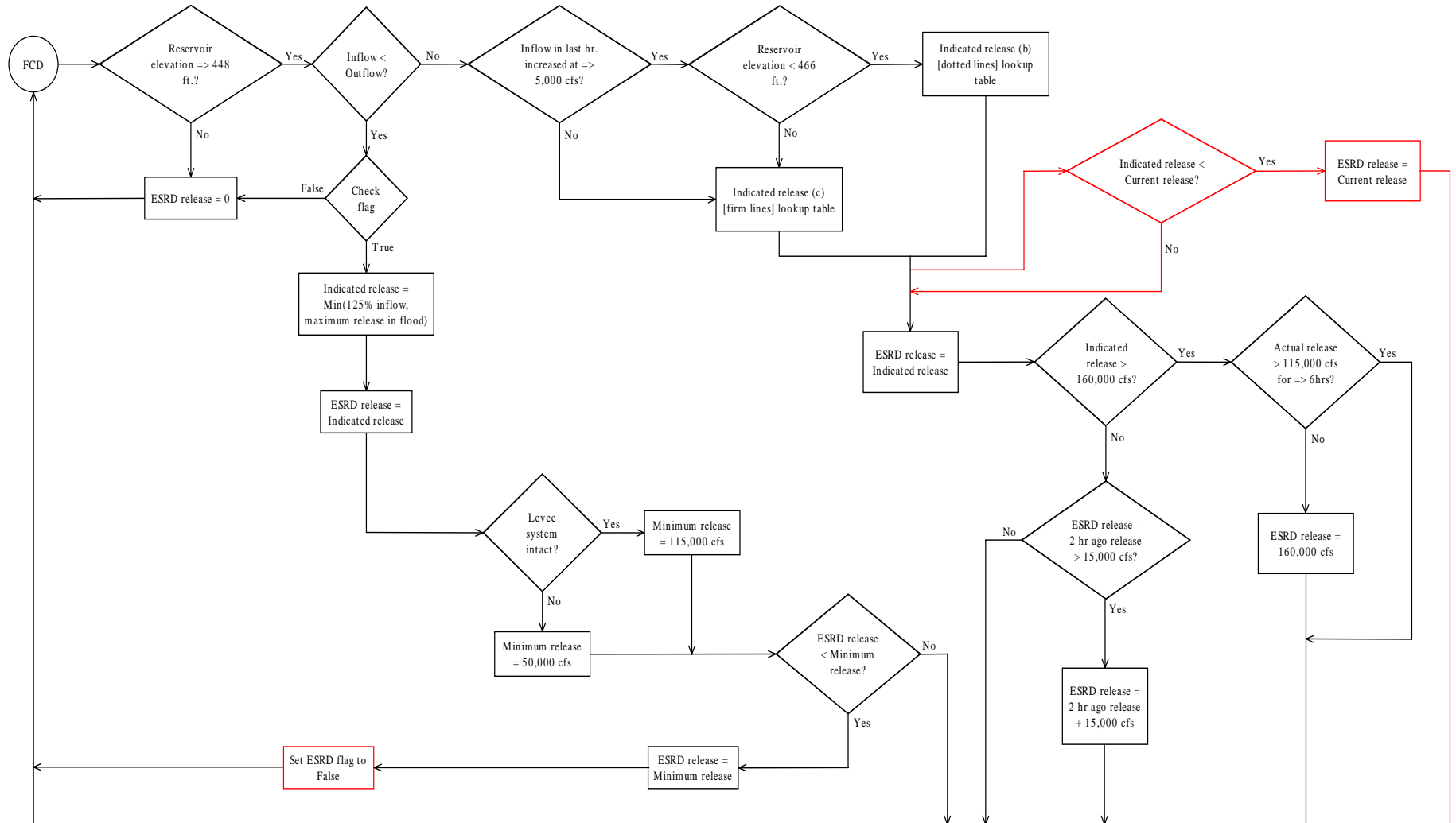
# Mass Balance

$$\text{Change in Storage} = \text{Inflow Volume} - \text{Release Volume}$$

# SAFCA Flood Control Diagram (FCD)



# COE Emergency Spillway Release Diagram (ESRD)



## 4) RRFM-U

b) Simulation (Uncertainty)  
Application

# RRFM-U

```
graph TD; RRFM_U[RRFM-U] --> Operational[Operational (RRFM)]; RRFM_U --> Simulation[Simulation (Uncertainty)]; Operational -.-> StartUp[Start-up conditions]; StartUp --> RealTime[Real-time]; StartUp --> Planning[Planning]; Simulation --> RealTime; Simulation --> Planning;
```

The diagram illustrates the structure of RRFM-U. It is divided into two main branches: Operational (RRFM) and Simulation (Uncertainty). The Operational branch leads to Start-up conditions, which are further divided into Real-time and Planning. The Simulation branch also leads to Real-time and Planning. The Start-up conditions are specifically noted as including storage and release.

**Operational  
(RRFM)**

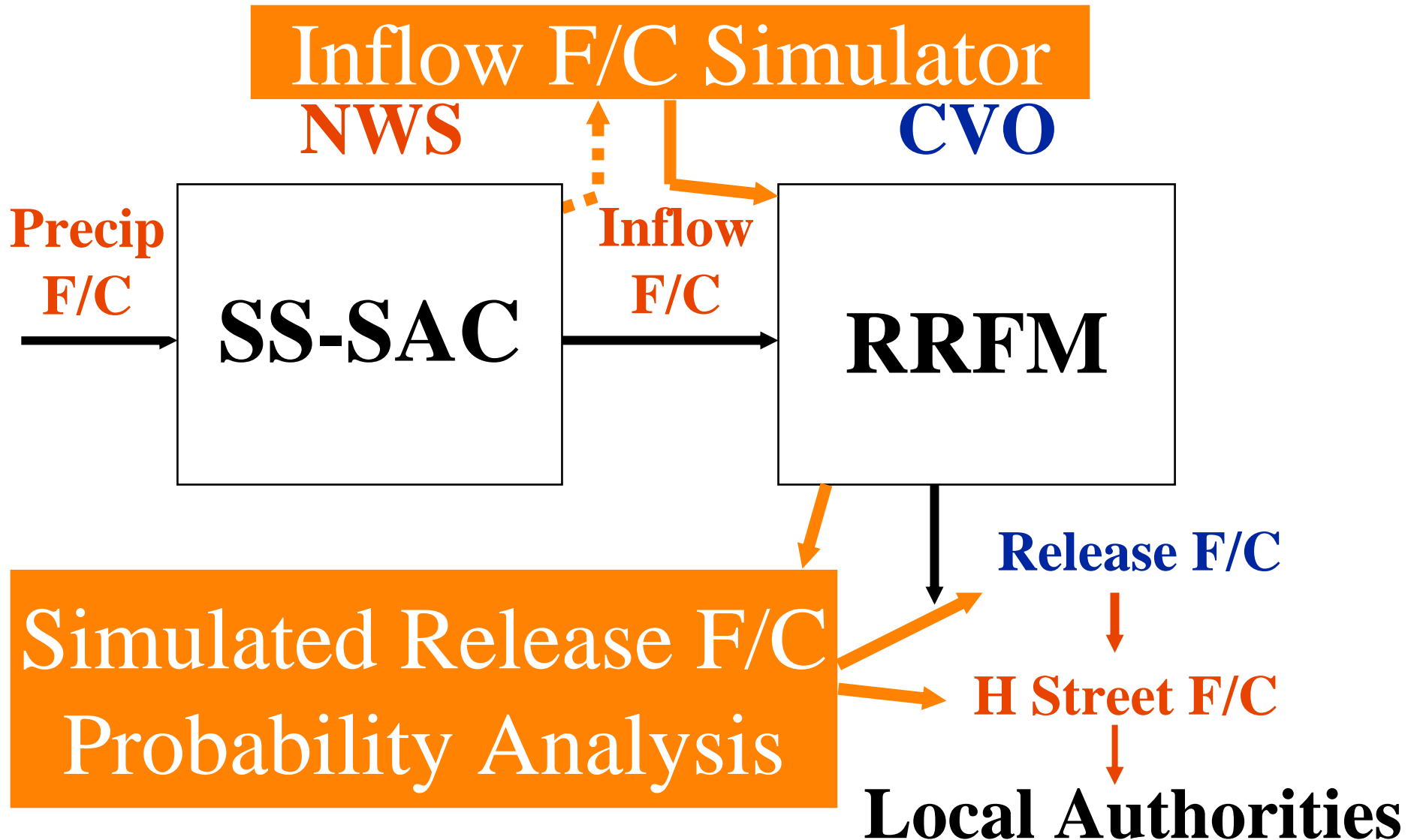
**Simulation  
(Uncertainty)**

**Start-up  
conditions**  
- storage  
- release

**Real-  
time**

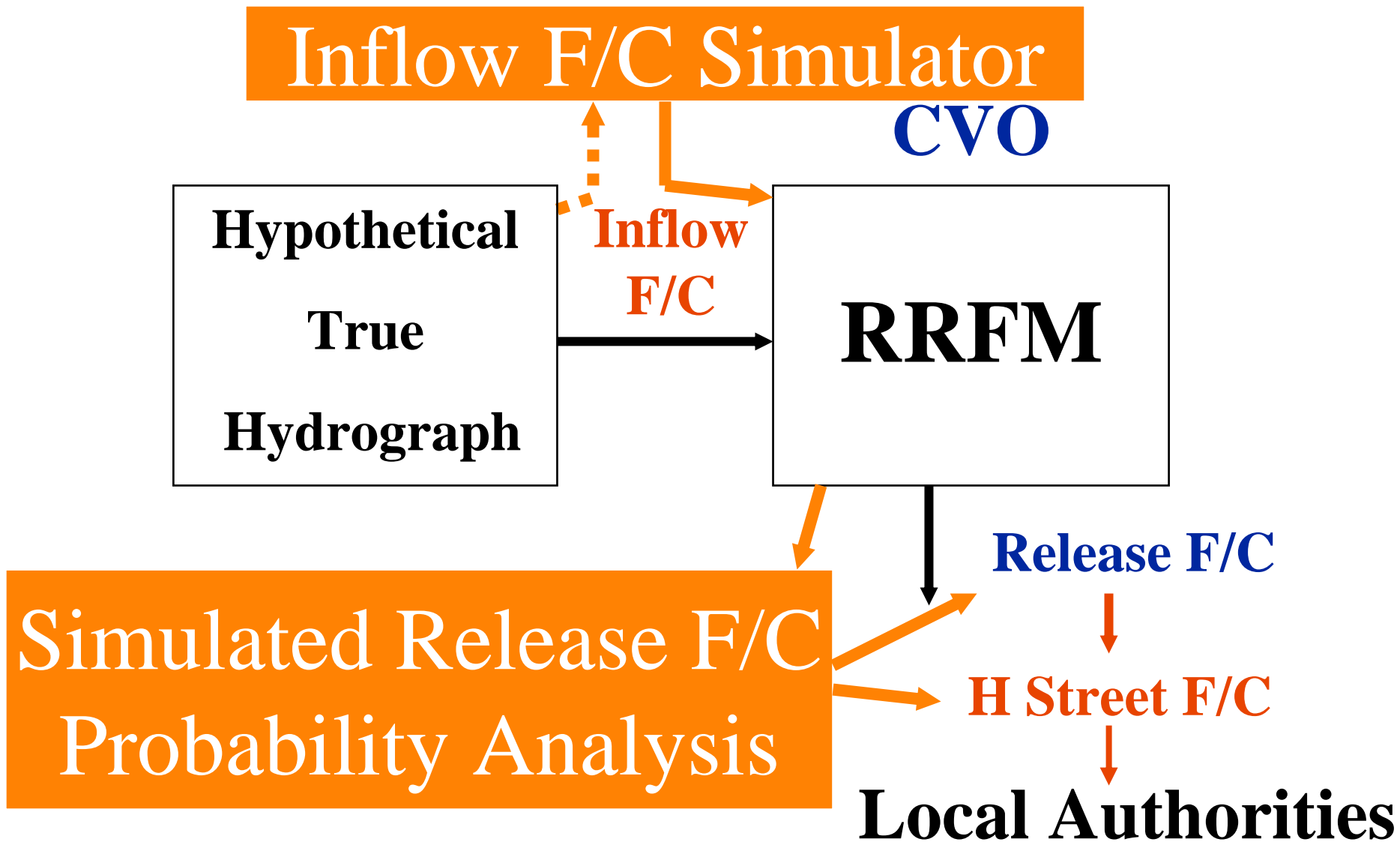
**Plan-  
ning**

# REAL TIME Simulation Forecasting System Components

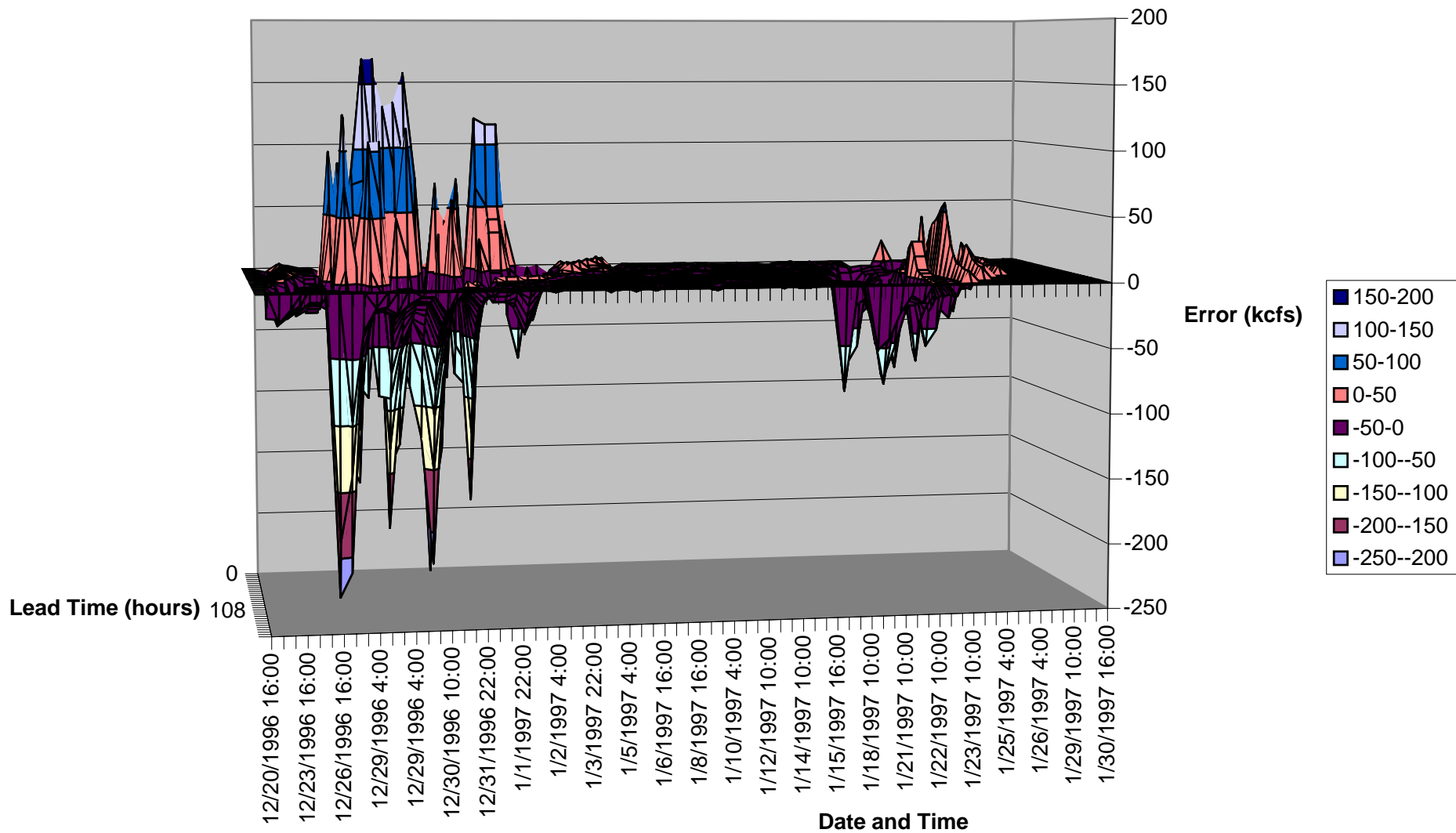




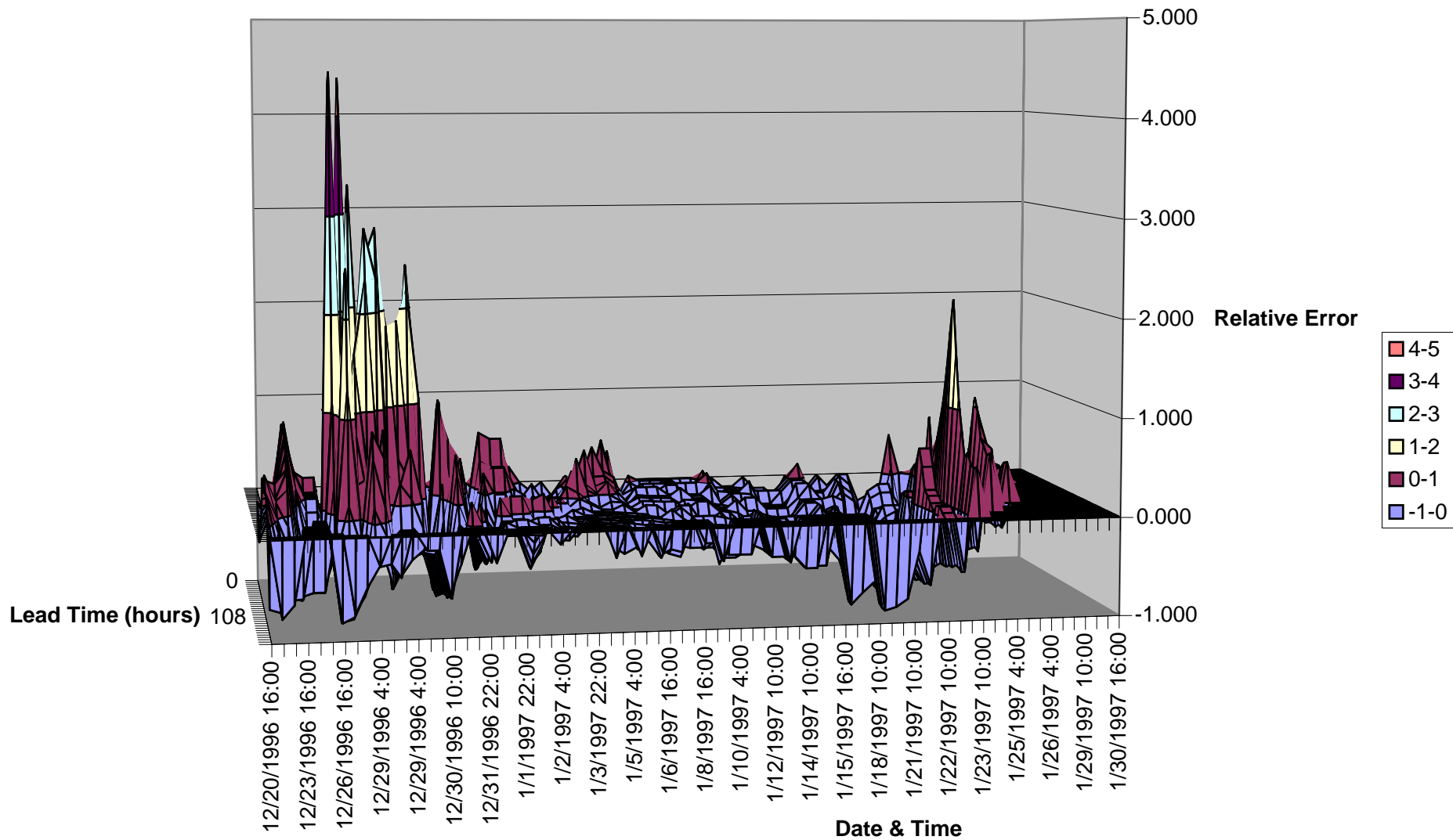
# PLANNING Simulation Forecasting System Components



# Absolute Forecast Errors



# Relative Forecast Errors



# Simulated Instantaneous Forecast Releases X cfs

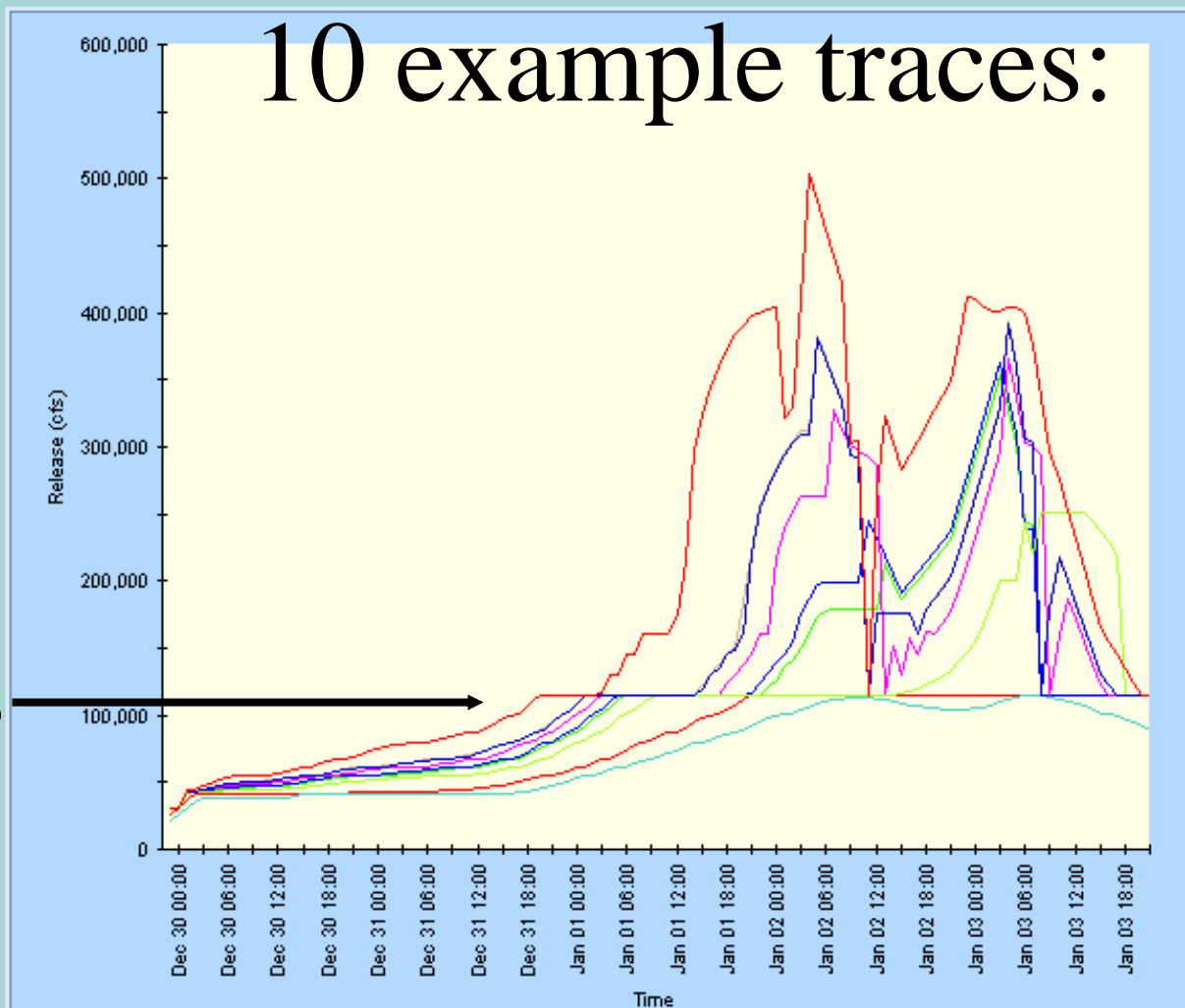
Uncertainty Results - Simulation Releases

Print Copy Preferences Archive

Forecast	# Runs
12/29/1996 10:00	51
12/29/1996 22:00	1500
12/31/1996 22:00	1500

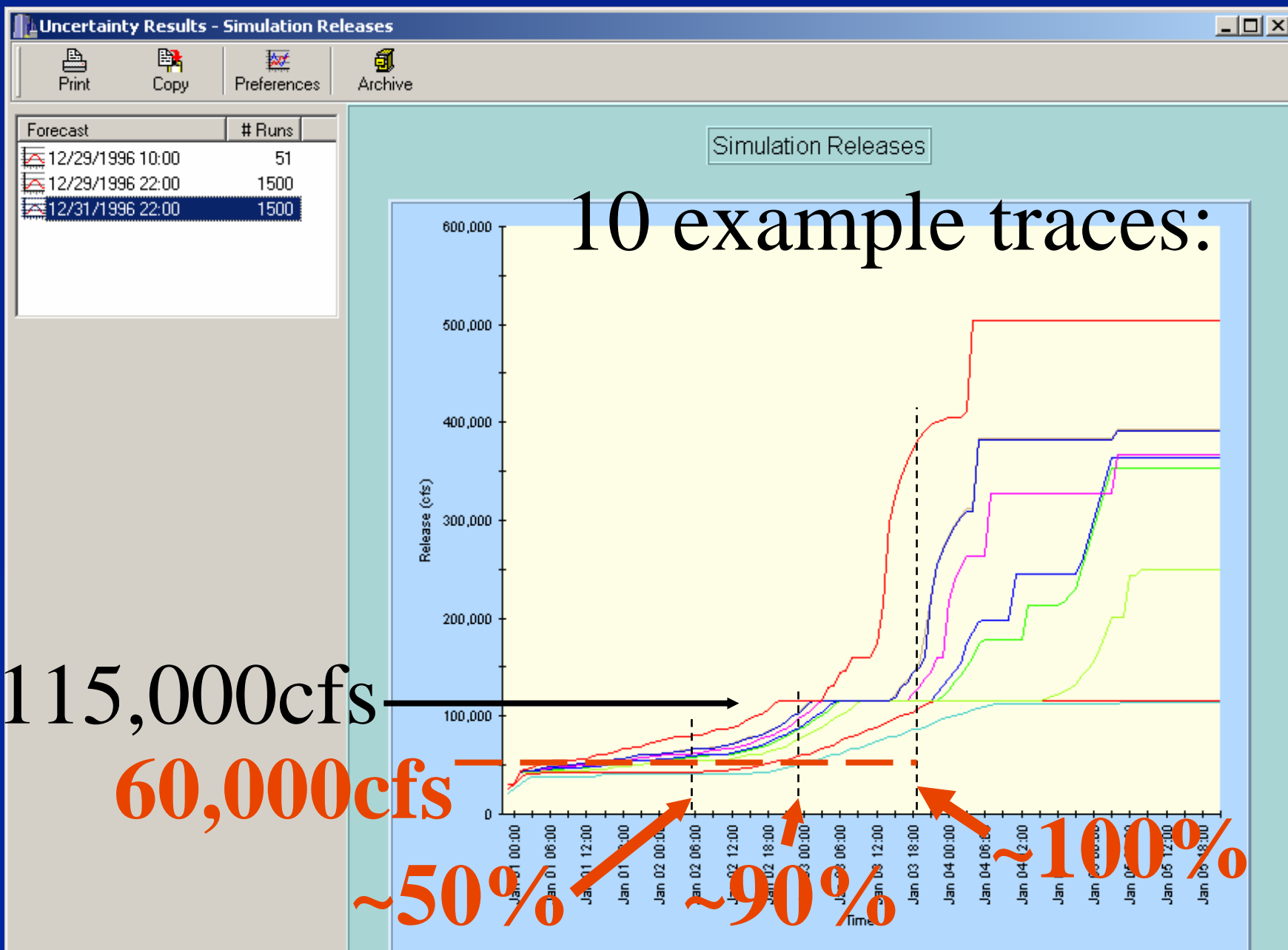
Simulation Releases

10 example traces:



115,000cfs

# Simulated Maximum Forecast Releases X cfs



# Prob. P of Max. Rel. exceeding X cfs by Time T

Uncertainty Results - Lead Time vs Probability



Print



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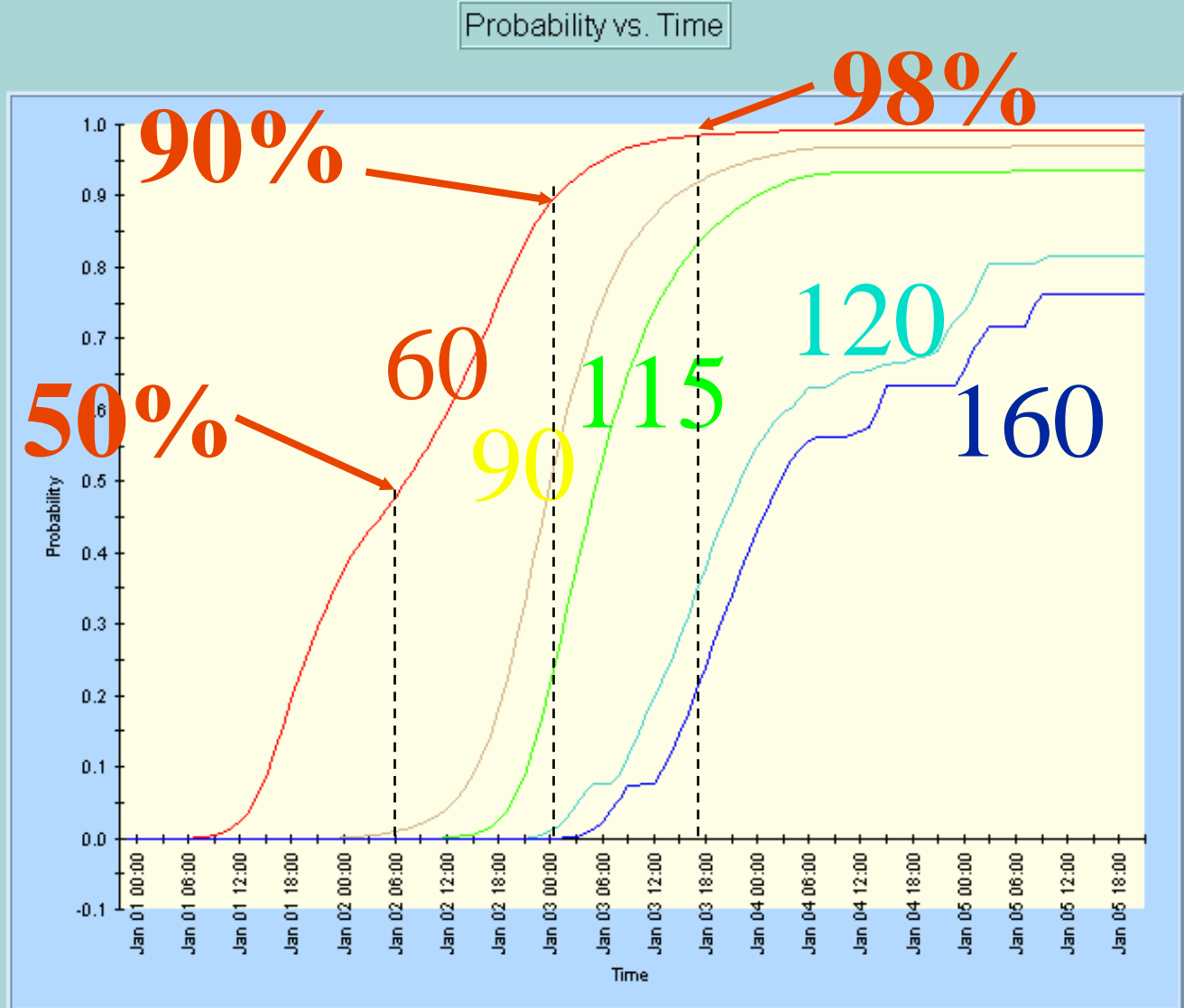


Preferences

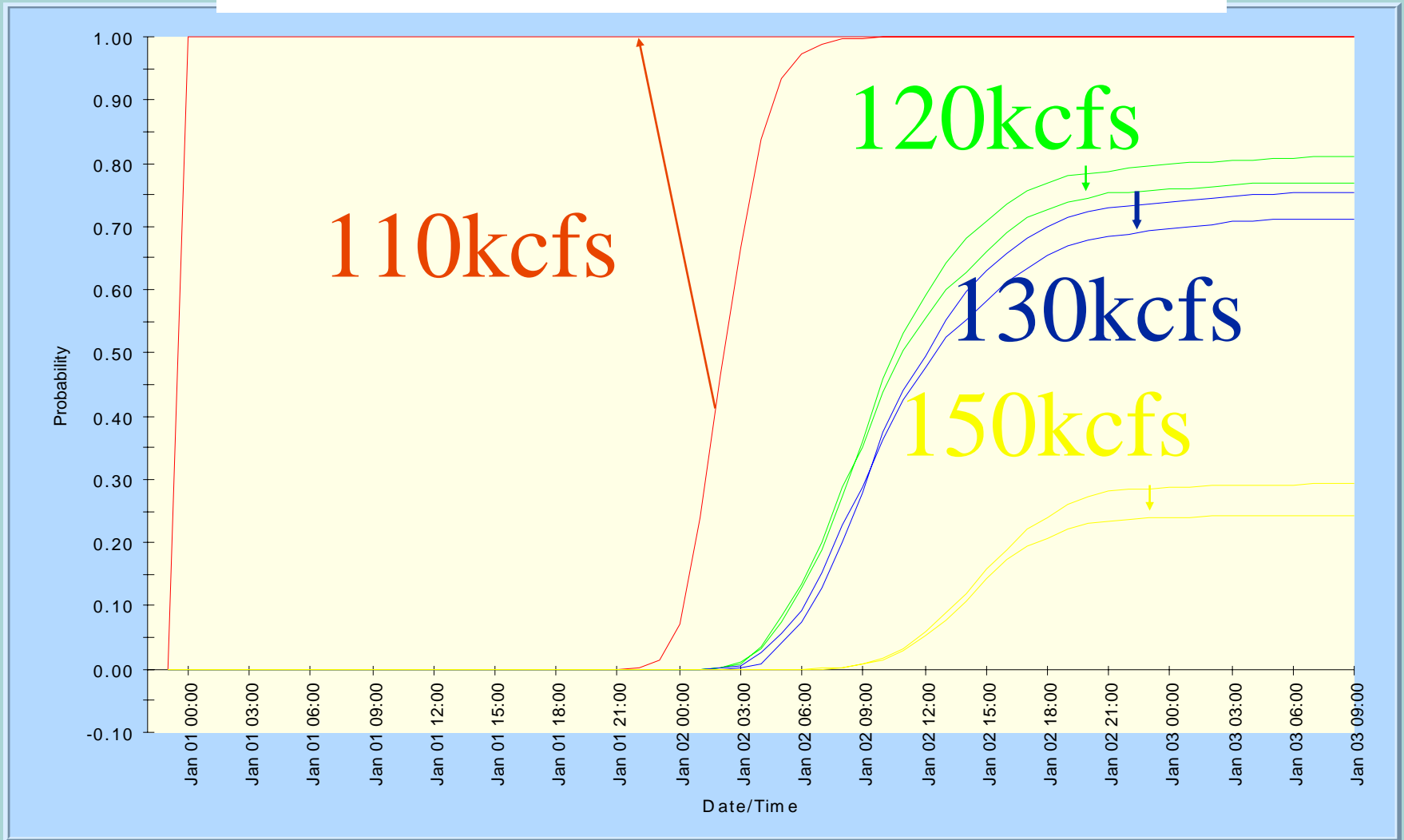


Archive

Forecast	# Runs
12/29/1996 10:00	51
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12/31/1996 22:00	1500



# Pre Release Illustration



—	Init St 700k (Max) (110)	—	PreRel Init St 700k (Max) (110)
—	Init St 700k (Max) (120)	—	PreRel Init St 700k (Max) (120)
—	Init St 700k (Max) (130)	—	PreRel Init St 700k (Max) (130)
—	Init St 700k (Max) (150)	—	PreRel Init St 700k (Max) (150)

4c) RRFM-COM



# RRFM-COM – Technical Explanation

- Component Object Model (COM)
  - Microsoft component technology
  - Develop and re-use core components of larger software systems within many different development environments and applications
- RRFM Database and Analytical code in Visual C++
  - Utilize this code from a RAD (Rapid Application Development) programming tool called Borland C++ Builder

# RRFM-COM –User Explanation

- Run RRFM from Microsoft Excel
- Uses Visual Basic to access RRFM database and analytical code directly, even though written in Visual C++
- Take advantage of the RRFM database and analytical code to build other client applications in MS Excel, Visual Basic, and MC Access
- In use by Corps/Sacramento District since July 2000
  - Routing hypothetical floods
  - Assessing changes in outlet works

## 5) Benefits and Status

# Expected Benefits of RRFM-U/SS-SAC

- Improved information:
  - reservoir operations
  - community emergency management
  - USBR dam safety emergency management
- Improved speed and reliability of reservoir rule calculation
- Improved inflow and reservoir release forecasts
  - updating using observed streamflow
  - inflow release forecast uncertainties
  - probability of refilling for prereleases

# Expected Benefits of RRFM-U/SS-SAC (Cont'd)

- Simulation - “what if” release scenarios:
  - comparisons with various operating rules
  - operator training
  - testing possible operating rule changes
- Improved understanding of system operation over range of events
- Evaluation of gaging network adequacy
  - Recommended additional gages

## RRFM is operational:

- Operational Application
  - IT'S RUNNING IN CVO
  - Without uncertainty
  - Training provided in June 2000
- COM Application
  - Corps/Sacramento District using since July 2000
  - USBR/TSC using since June 2001
- Technical Support provided by USU

# What needs to be done to make Uncertainty Application of RRFM fully operational?

- Develop Inputs:
  - Inflow forecast uncertainties for simulation
  - Precipitation forecast uncertainties estimation needs further development
- Refine Monte Carlo Algorithm
- Develop Applications Protocols:
  - Reservoir Operations - CVO/NWS
    - Prerelease rules
  - Community Emergency Management
    - Evacuation levels
  - Power Station safety and Dam Safety - USBR EAP