Decision Support for Dam Operations

Arnold Engelmann

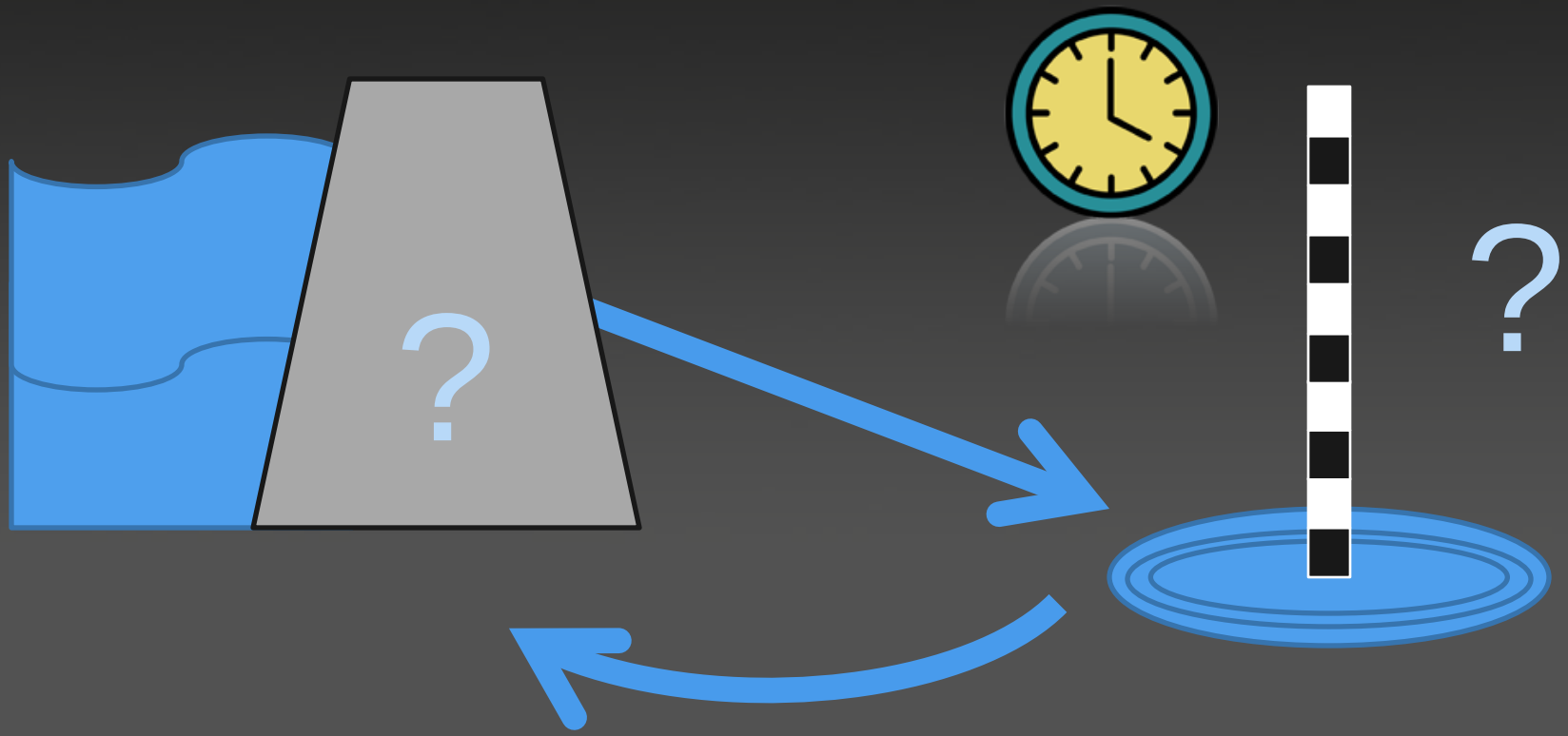
Senior Developer, Solutions Software, DHI Portland

Carter Borden, Senior Hydrologist, DHI Boise

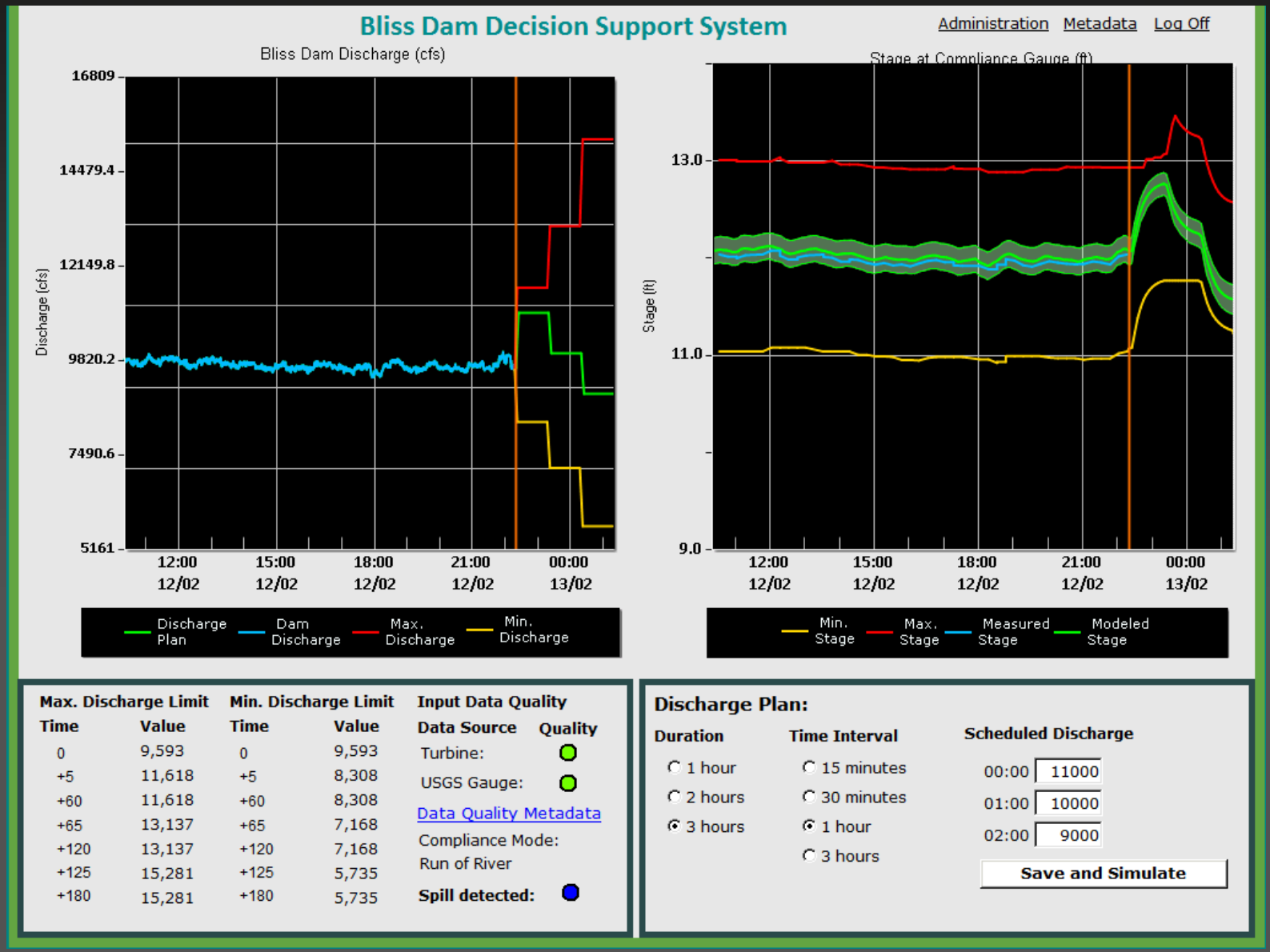
Ryan Kilgren, Water Resource Engineer, DHI Portland

Dylan Kime, Developer, DHI South Africa

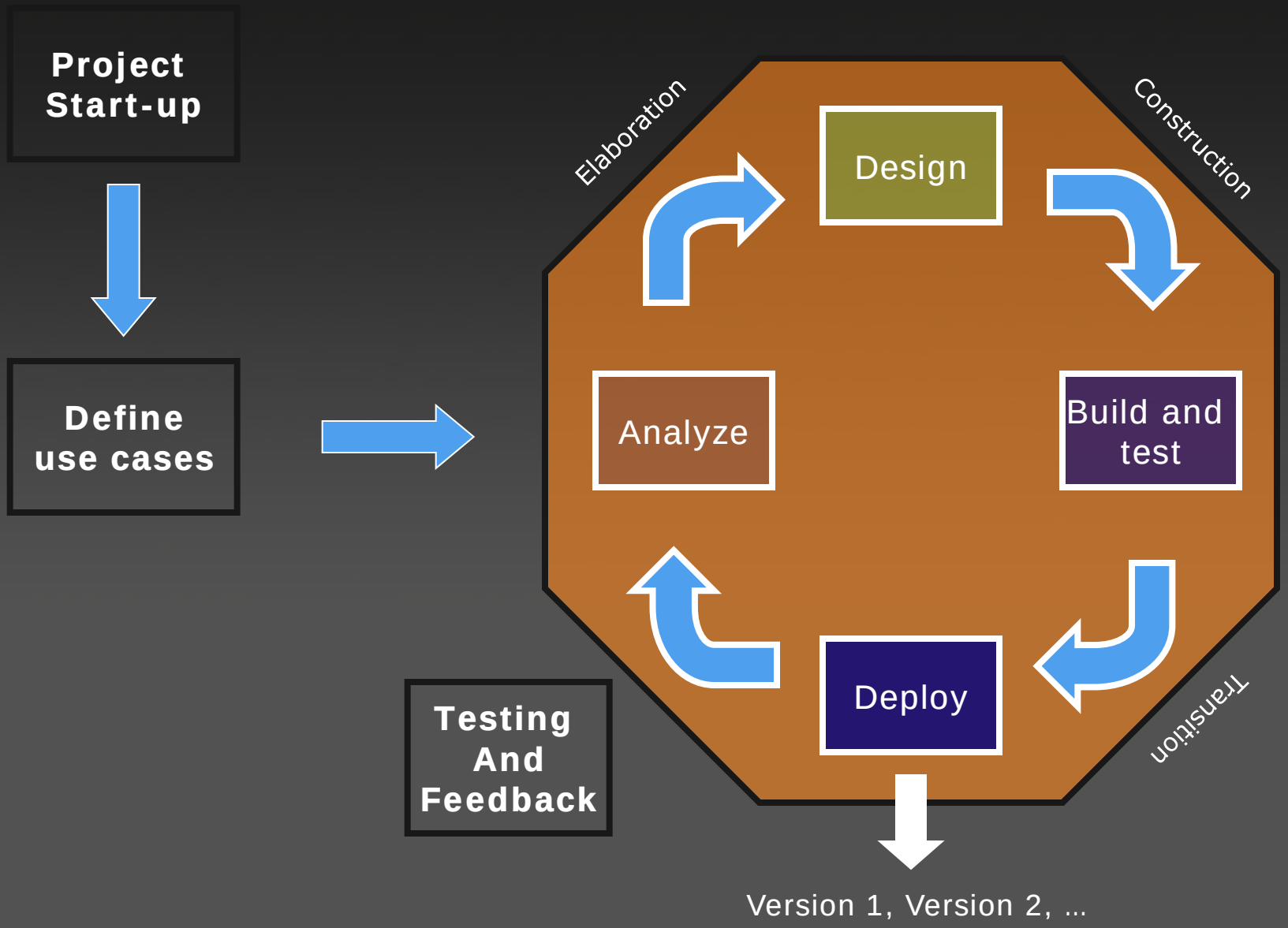
Problem



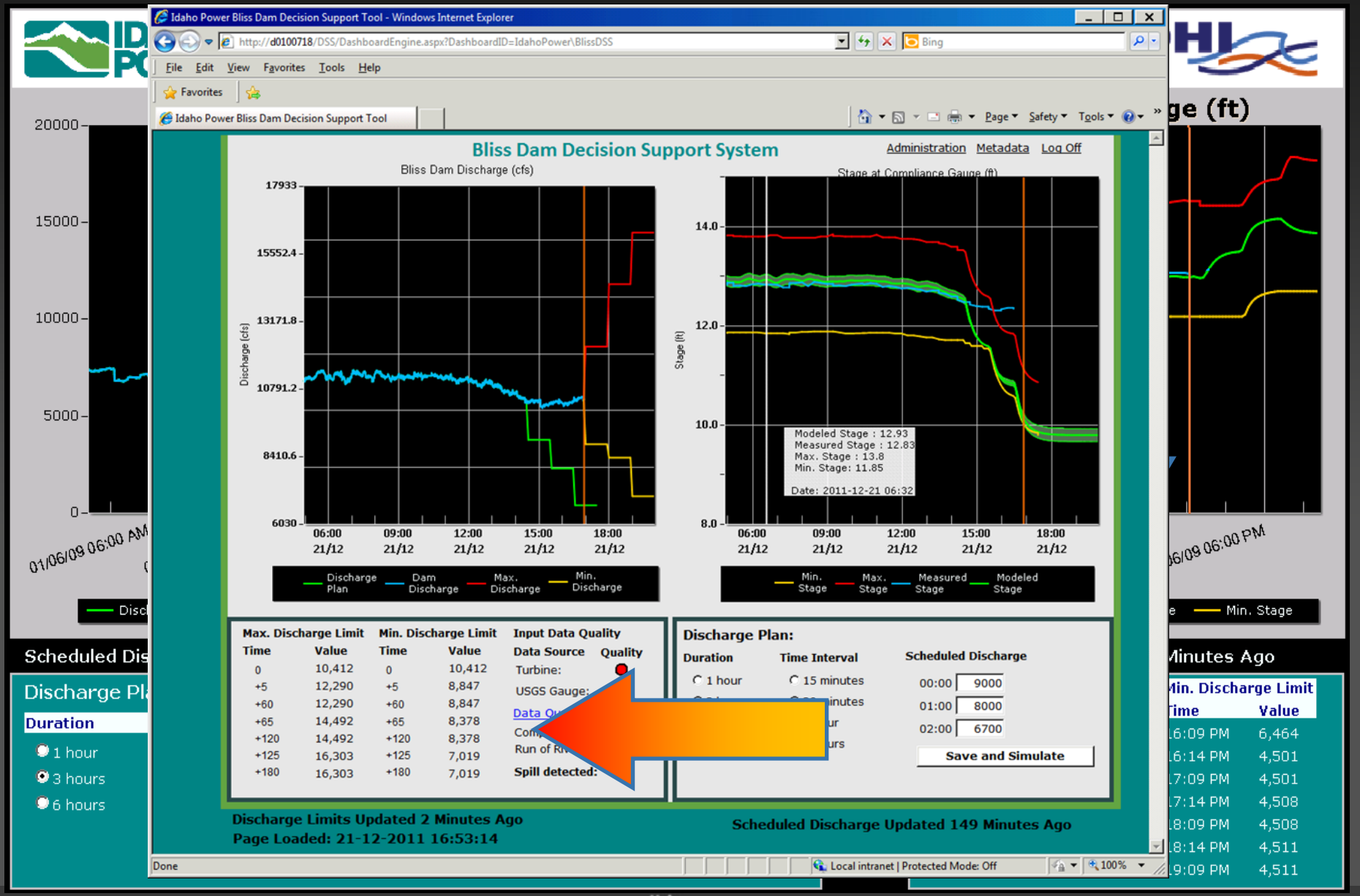
Solution: Bliss Dam DSS



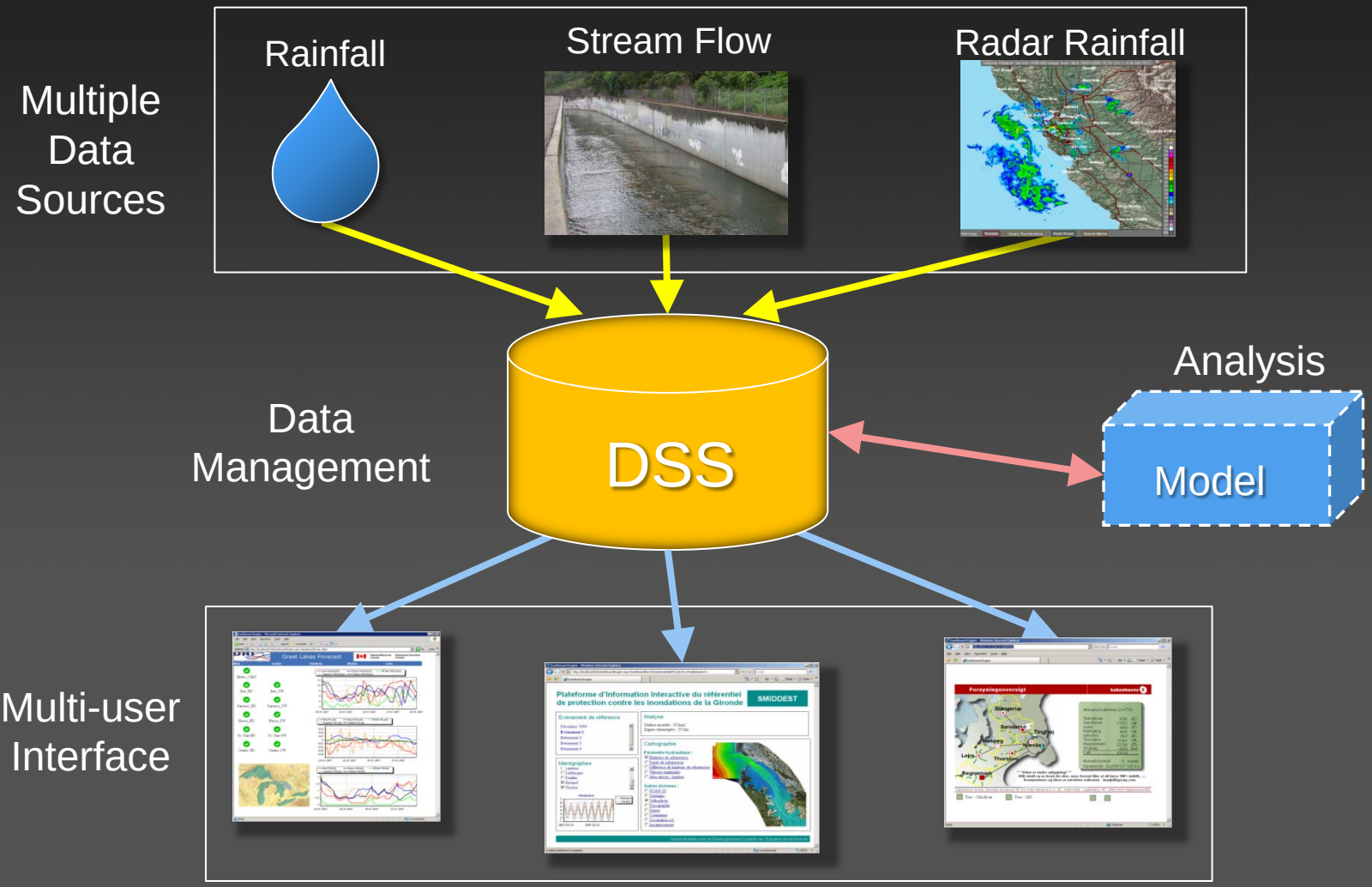
Workflow Analysis



Iterative Design Process

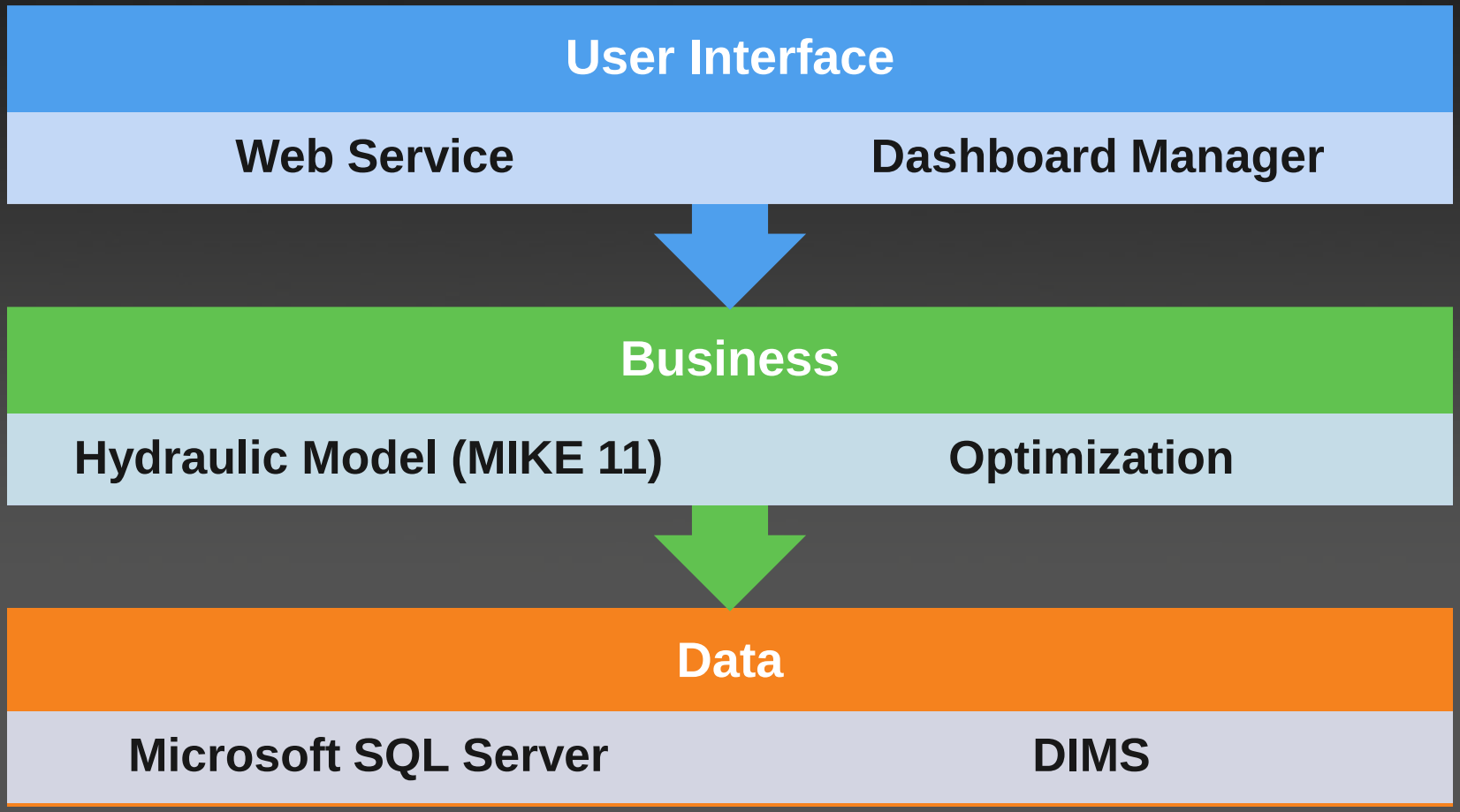


Decision Support Systems (DSS)



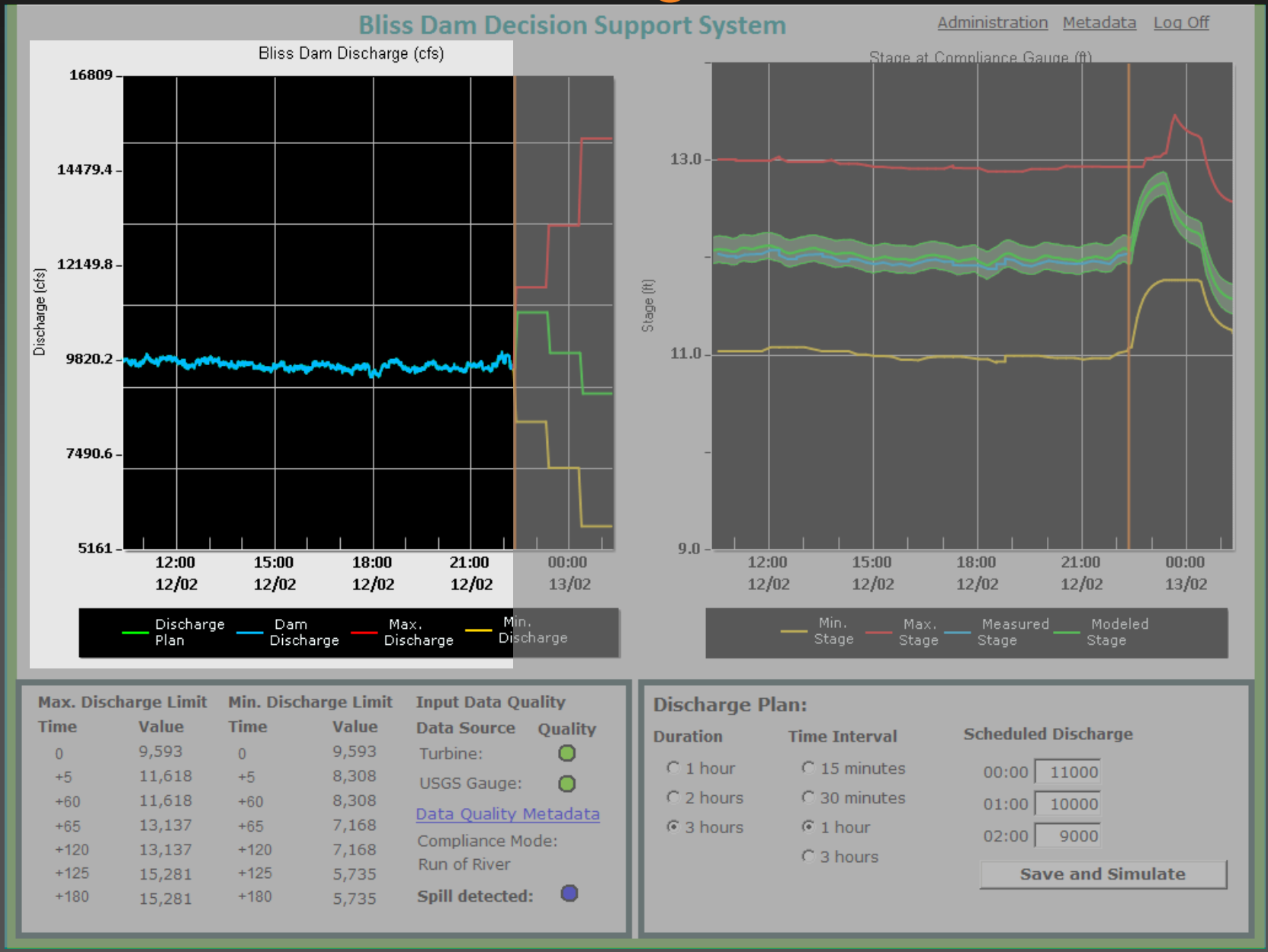
Solution

- 3-Tier Architecture



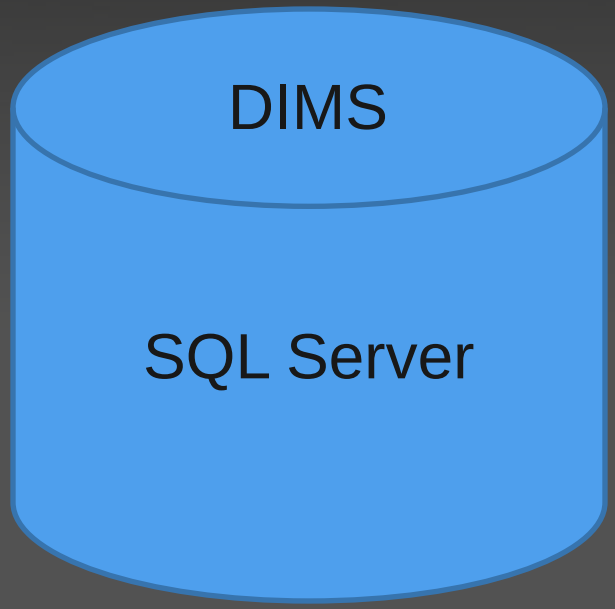
- Monitoring and Notification

Data Sources and Management



Data Sources and Management

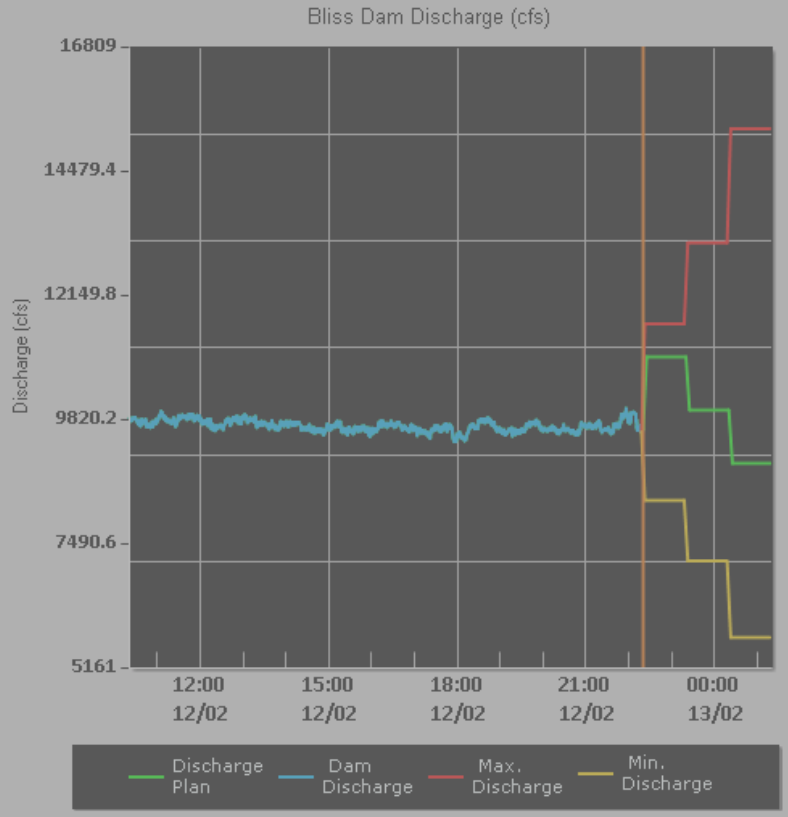
- Problem: How to Manage Data
- Why a separate database?
- DIMS: Dynamic Information Management System
  - Real Time Data Management
  - Data Validation
  - Scheduled Execution
- DIMS Online vs. Offline
  - Data “pushed” to SQL Server
    - Turbine Discharge
    - Spillway Discharge (Calculated)
    - Water Levels

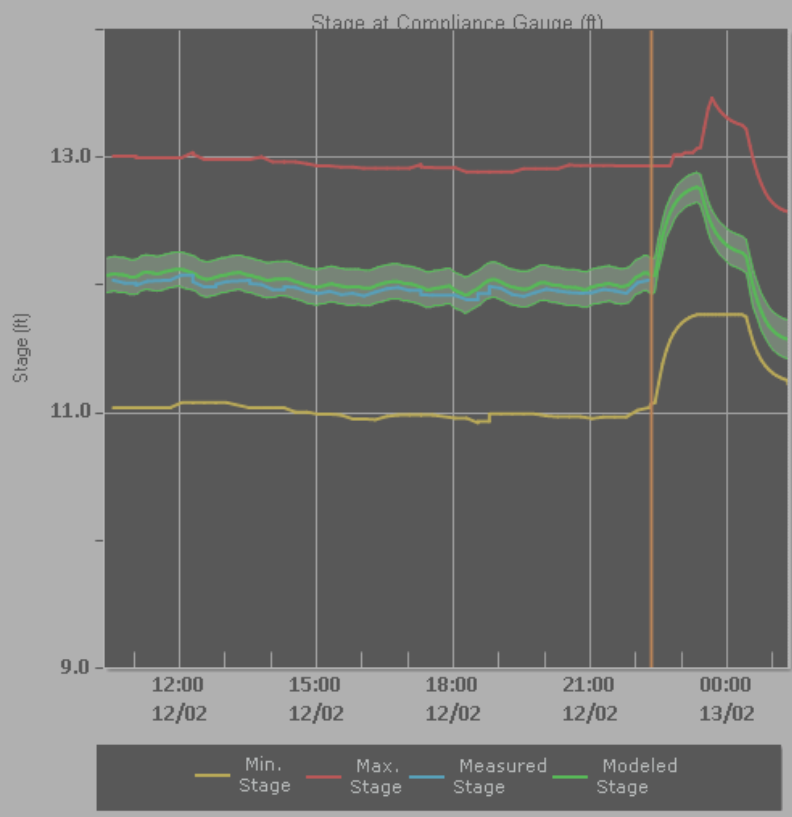


Input Data Quality

Bliss Dam Decision Support System

Administration Metadata Log Off





Max. Discharge Limit		Min. Discharge Limit	
Time	Value	Time	Value
0	9,593	0	9,593
+5	11,618	+5	8,308
+60	11,618	+60	8,308
+65	13,137	+65	7,168
+120	13,137	+120	7,168
+125	15,281	+125	5,735
+180	15,281	+180	5,735

Input Data Quality

Data Source	Quality
Turbine:	
USGS Gauge:	

Data Quality Metadata

Compliance Mode:
Run of River

Spill detected:

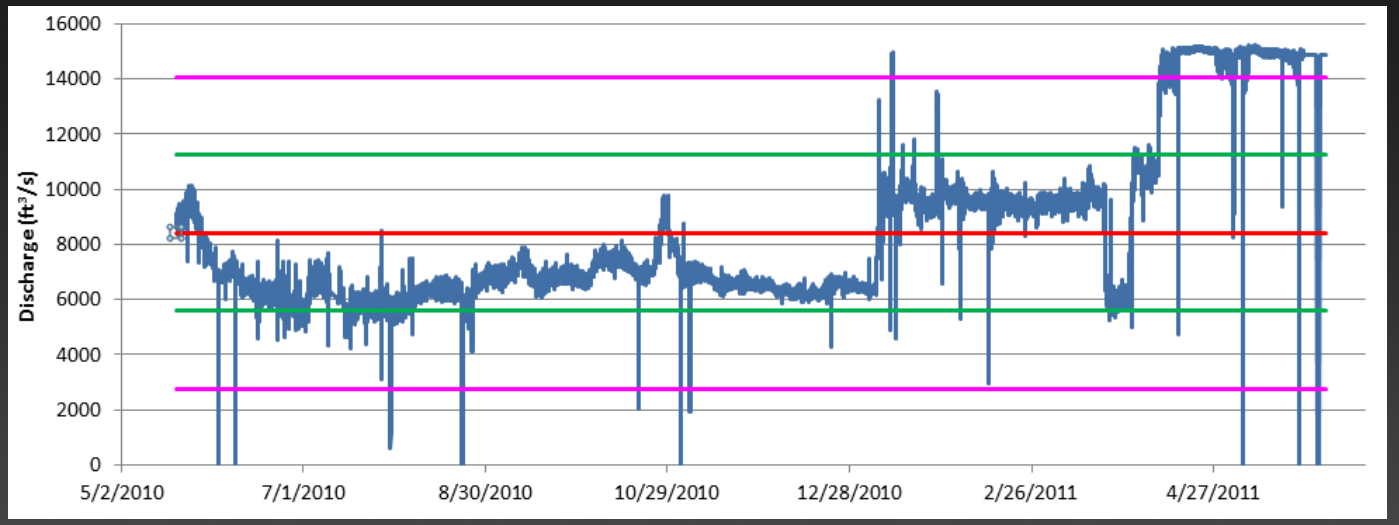
Discharge Plan:

Duration	Time Interval	Scheduled Discharge
1 hour	15 minutes	00:00 11000
2 hours	30 minutes	01:00 10000
3 hours	1 hour	02:00 9000
	3 hours	

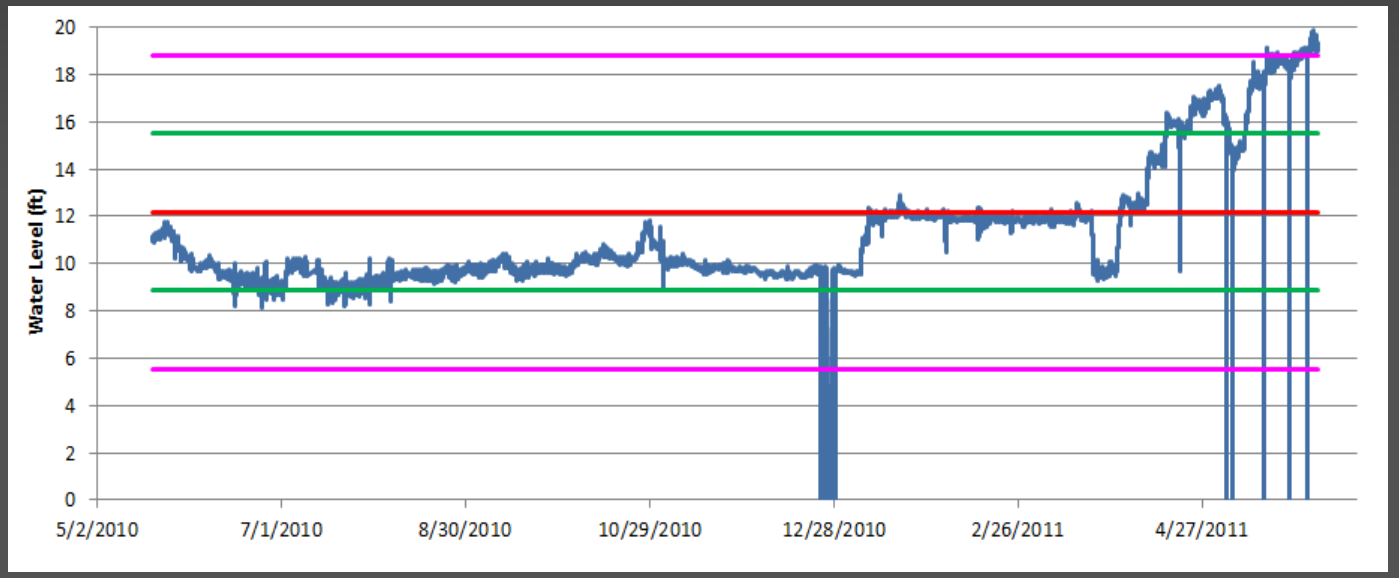
Save and Simulate

Input Data Quality

- Discharge



- Water Level



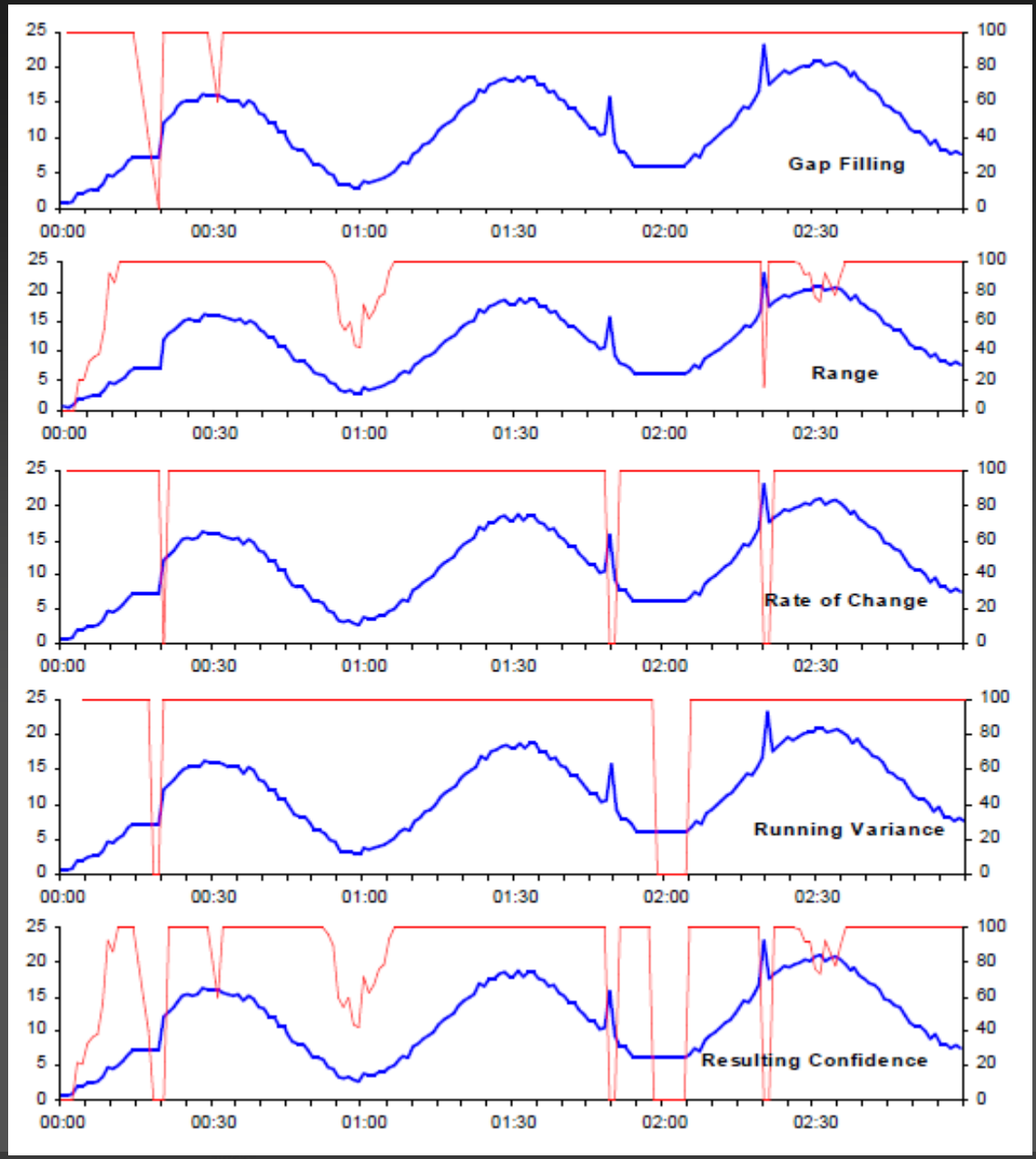
Real Time Data Validation

- Sensor data quality can be inspected, using simple but robust methods, for frequent errors, including:
  - Missing Data
  - Measurement values out of range
  - Peaks (rate of change)
  - Constant measurement values
  - Drift
- Each error type is assessed using confidence functions with physically based thresholds
- Overall confidence is determined as the minimum confidence for the error types assessed

Citation:
Lynggaard-Jensen, A., Frey, M.: Use and Reporting of Data - Data Handling and Validation. In Online Monitoring for Drinking Water Utilities. Published by American Water Works Association Research Foundation and CRS Proaqua (2002). ISBN 1-58321-183-7.

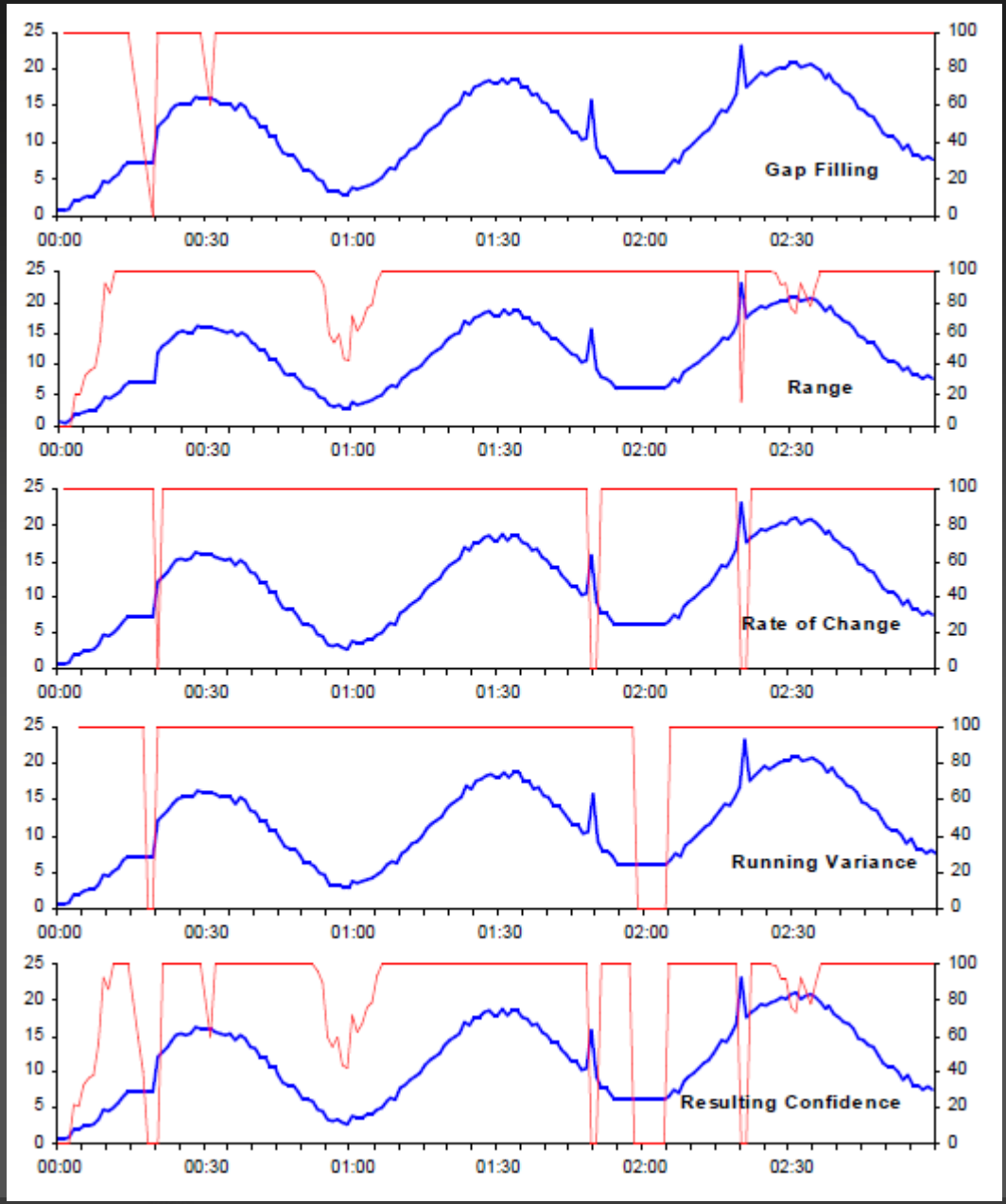
Real Time Data Validation

- Gap Filling
- Range
- Rate of Change
- Running Variance
- Resulting Confidence

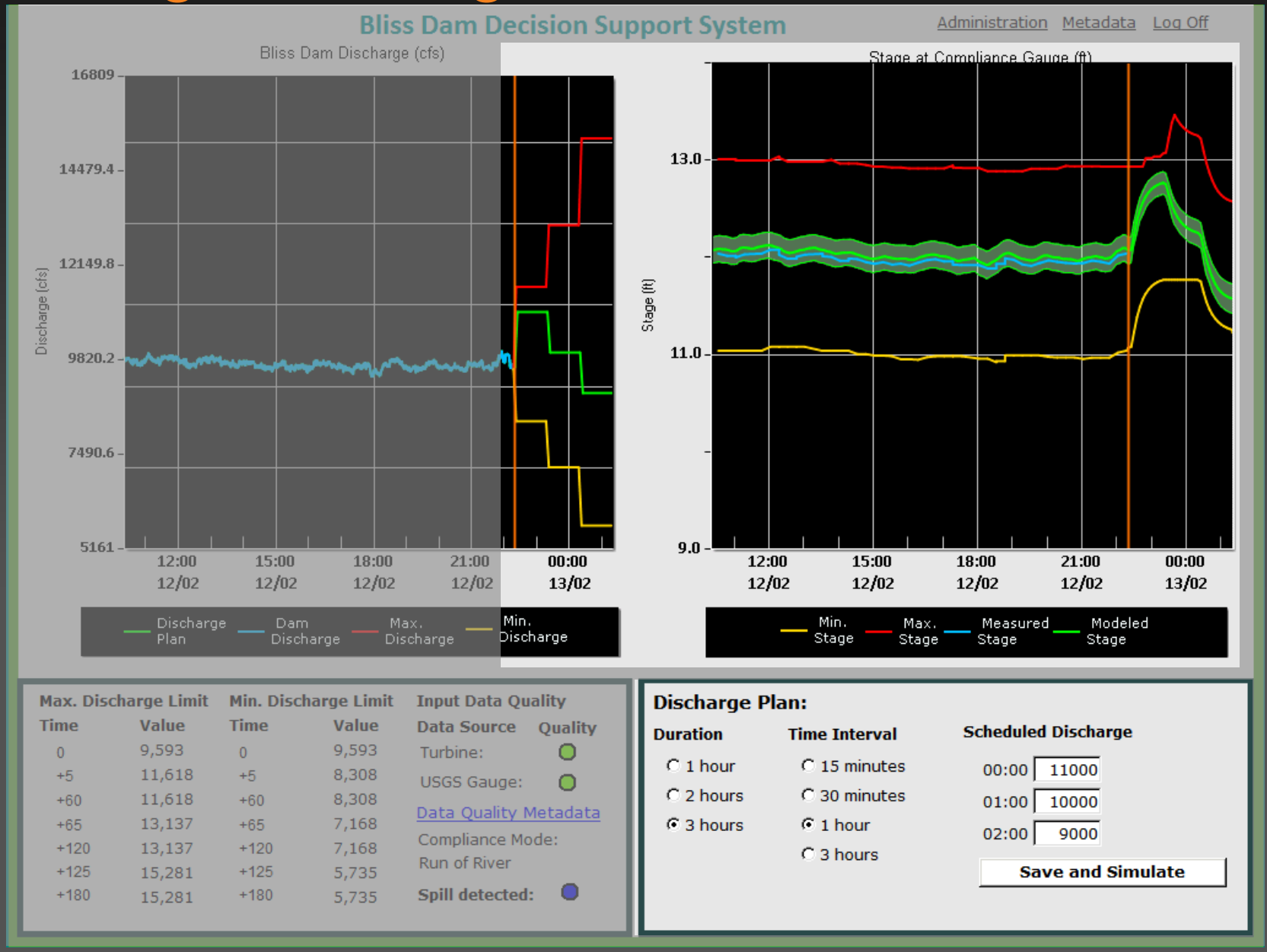


Real Time Data Validation

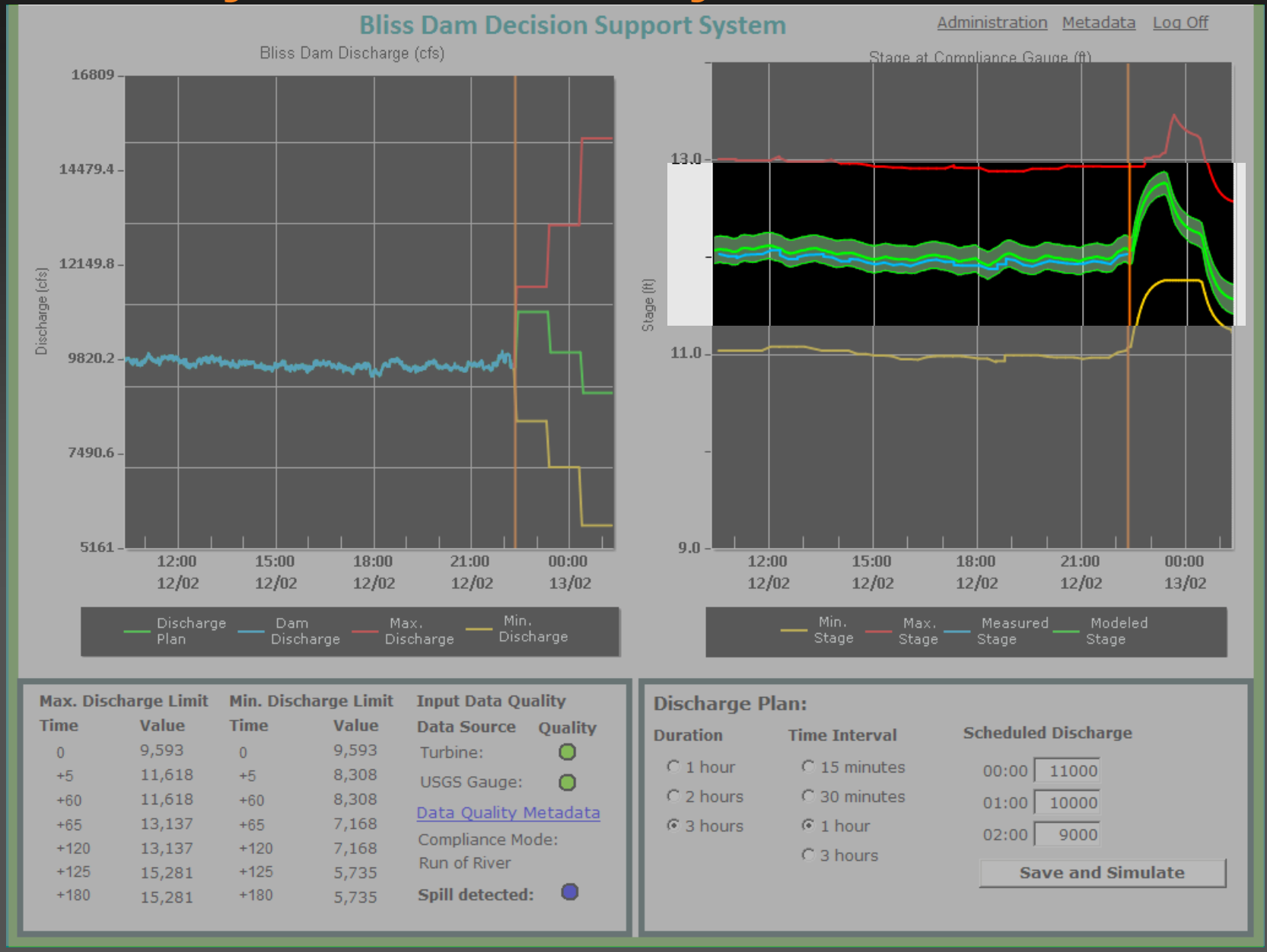
- The database archiving real time data is appended with the overall confidence at each timestep
- Quality descriptions are assigned to overall confidence ranges, such as:
  - > 80 = “Good”
  - 60-80 = “Fair”
  - <60 = “Poor”
- Automated warning messages and actions can be implemented based on specified confidence values



Discharge Planning

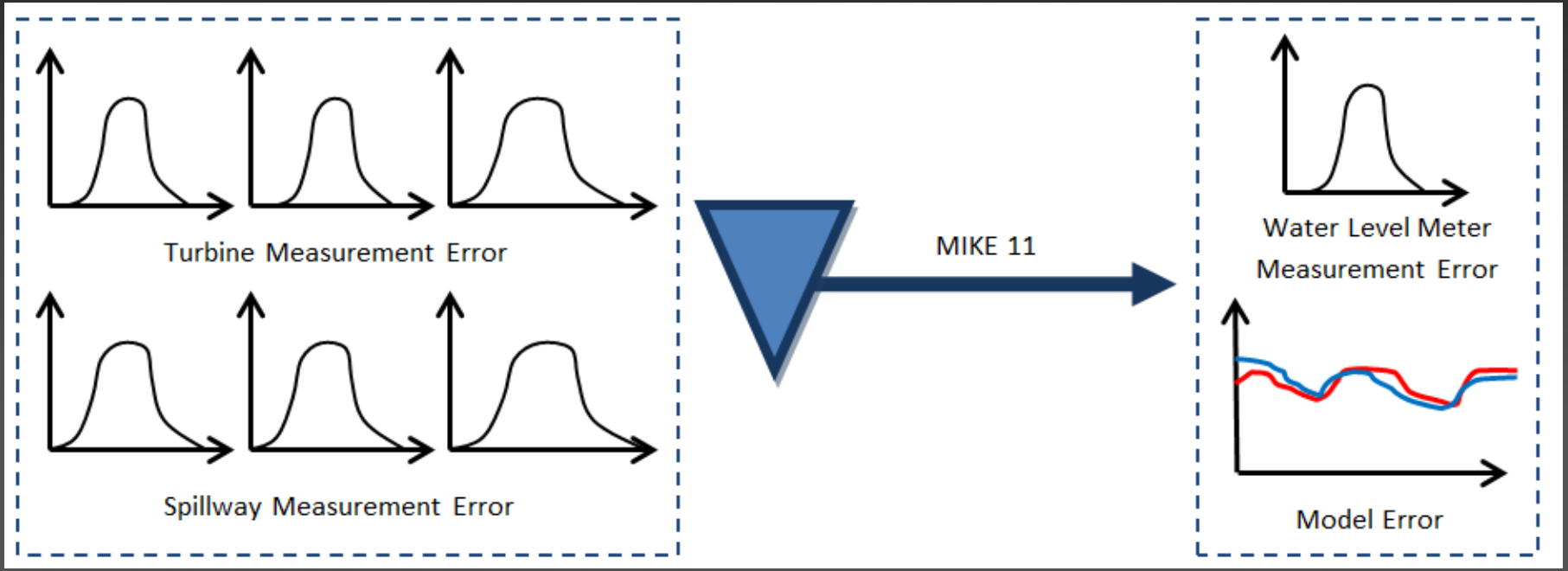


Error Analysis / Uncertainty



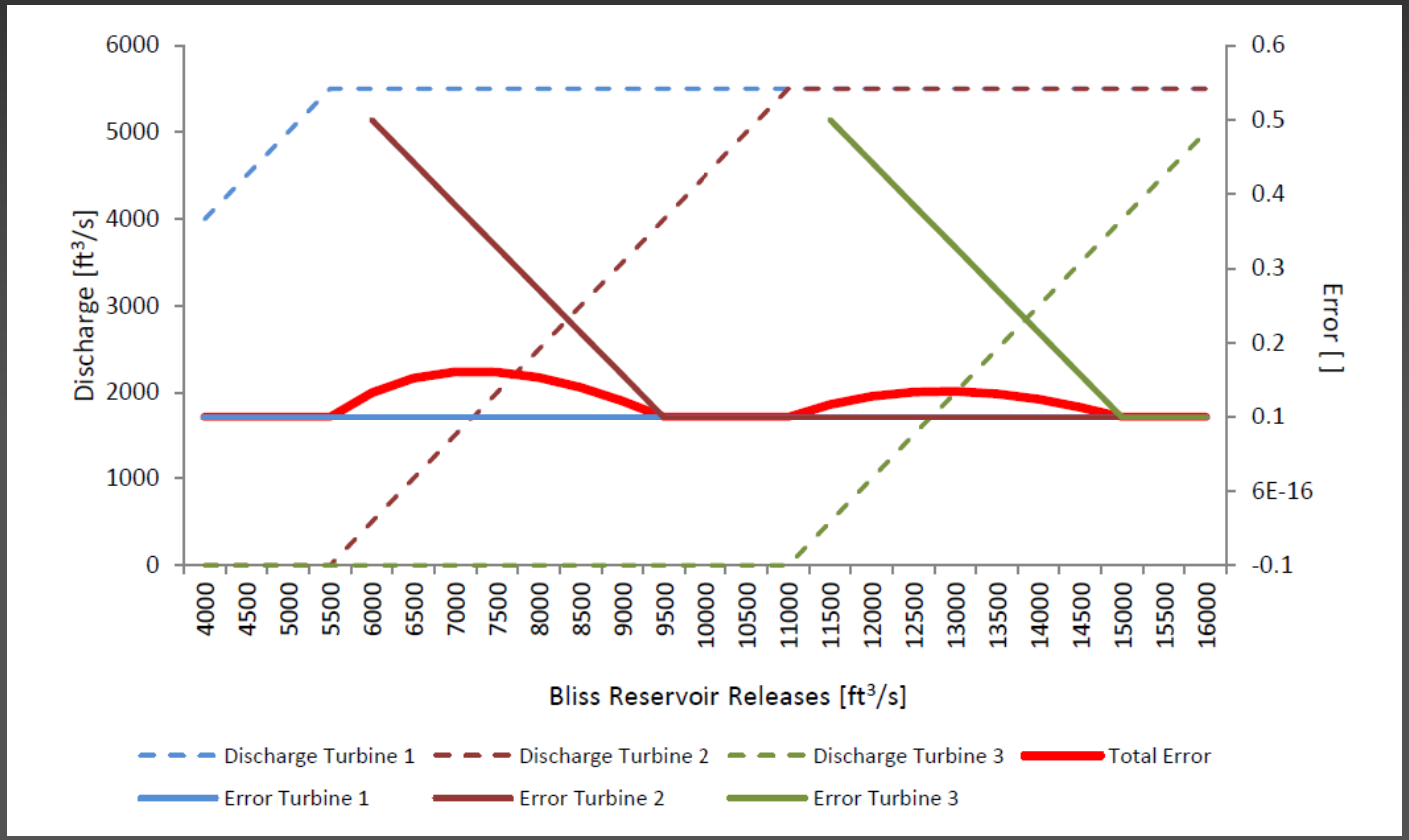
Error Analysis / Uncertainty

- Sources of Error
  - Measurement Error
  - Modeling Error



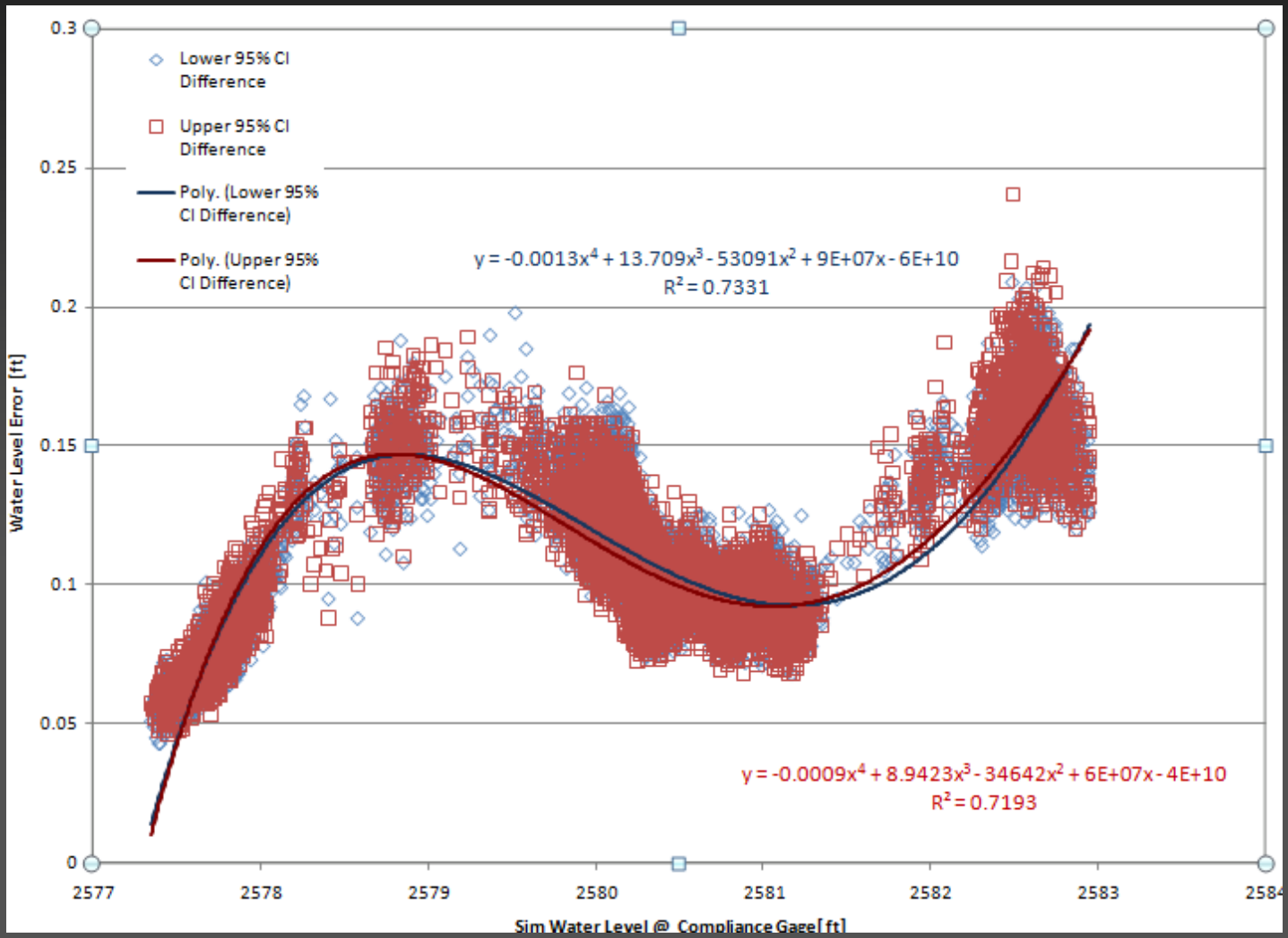
Error Analysis / Uncertainty

- Error is highest during low discharge values on sequentially activated turbines
- Error decrease as turbines releases are increased

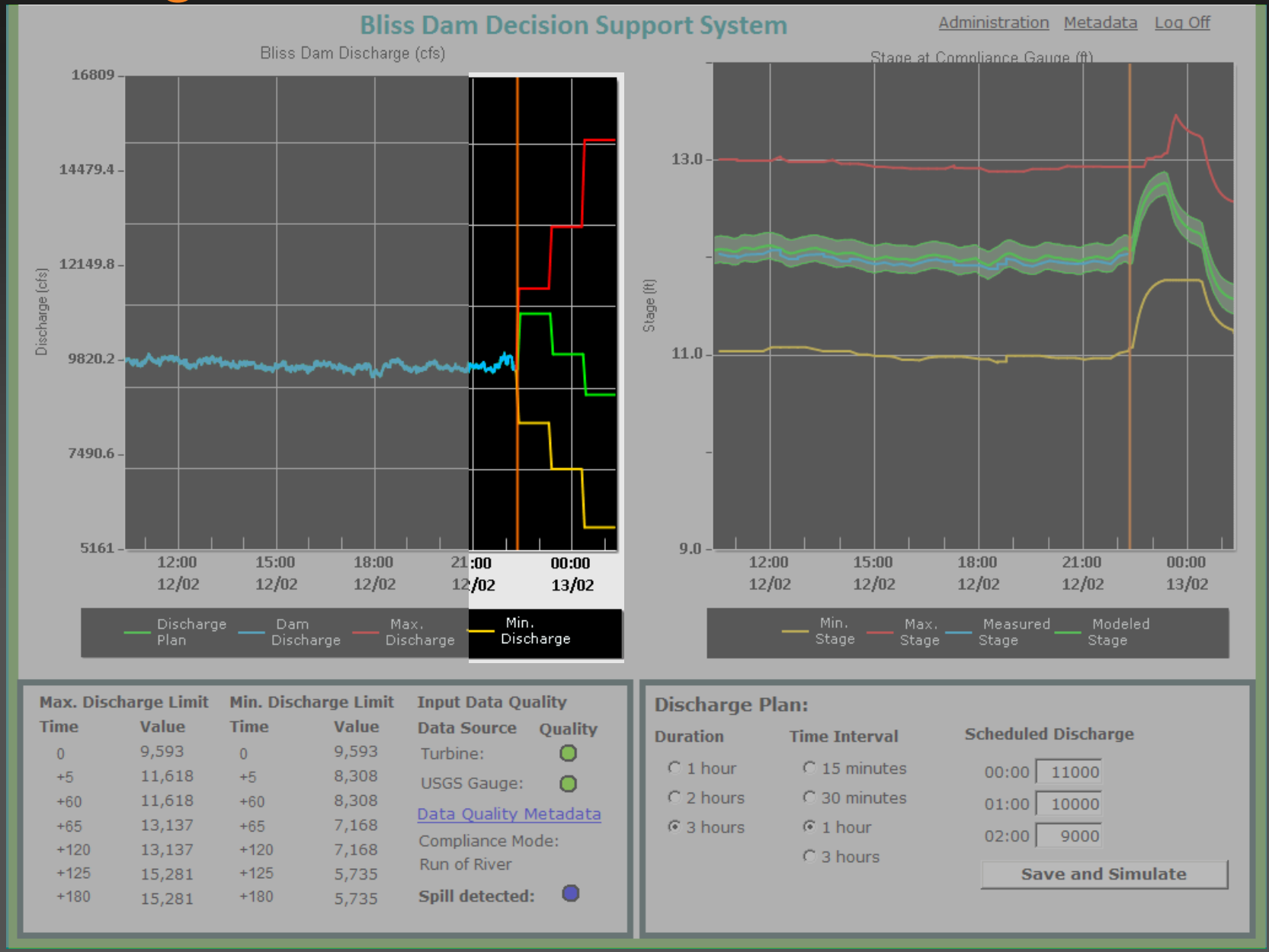


Error Analysis / Uncertainty

- Monte Carlo Results



Discharge Limits



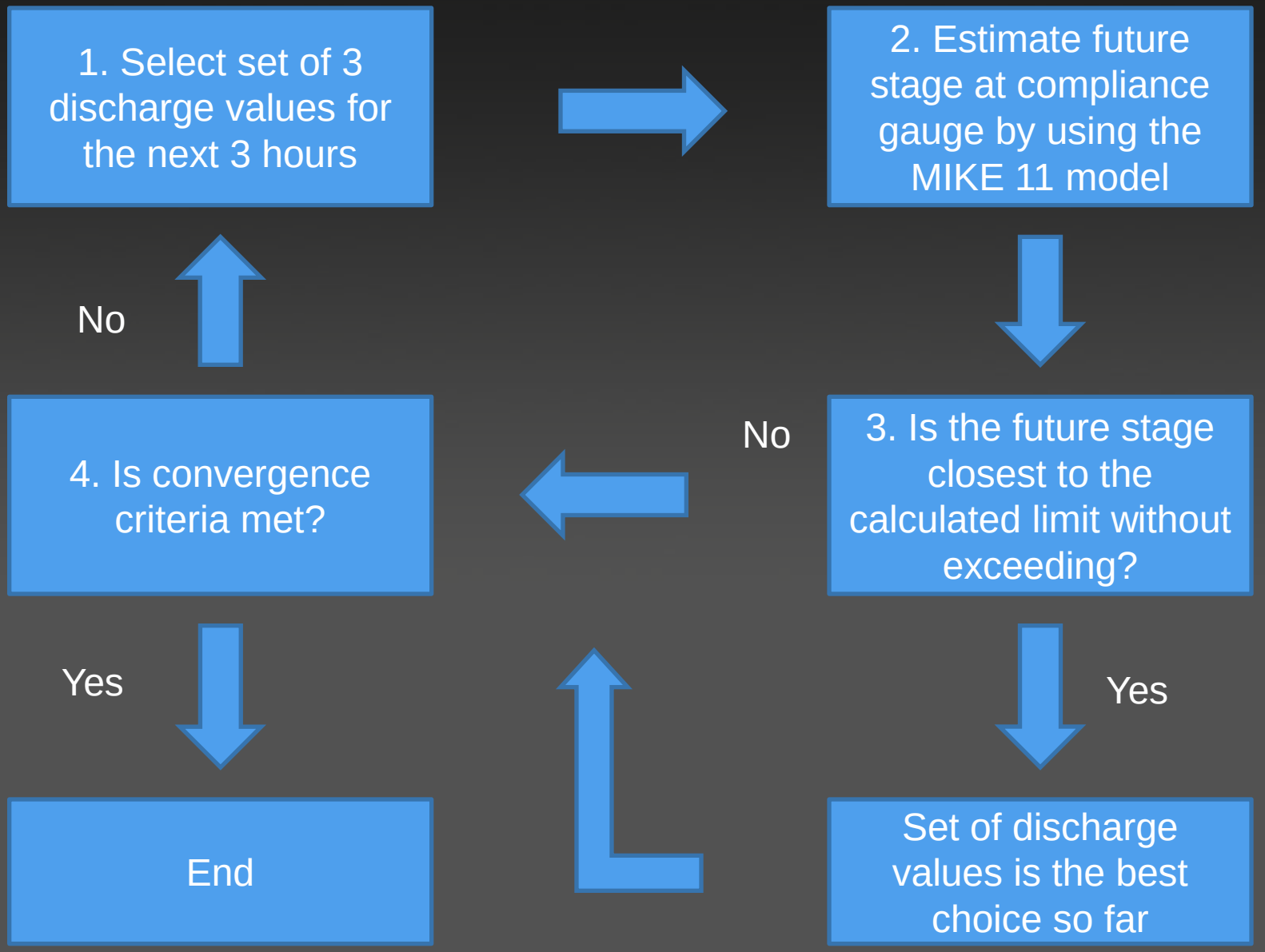
Optimization Routine

- Objective = find maximum and minimum allowable discharge operations that meet the compliance rules for downstream location

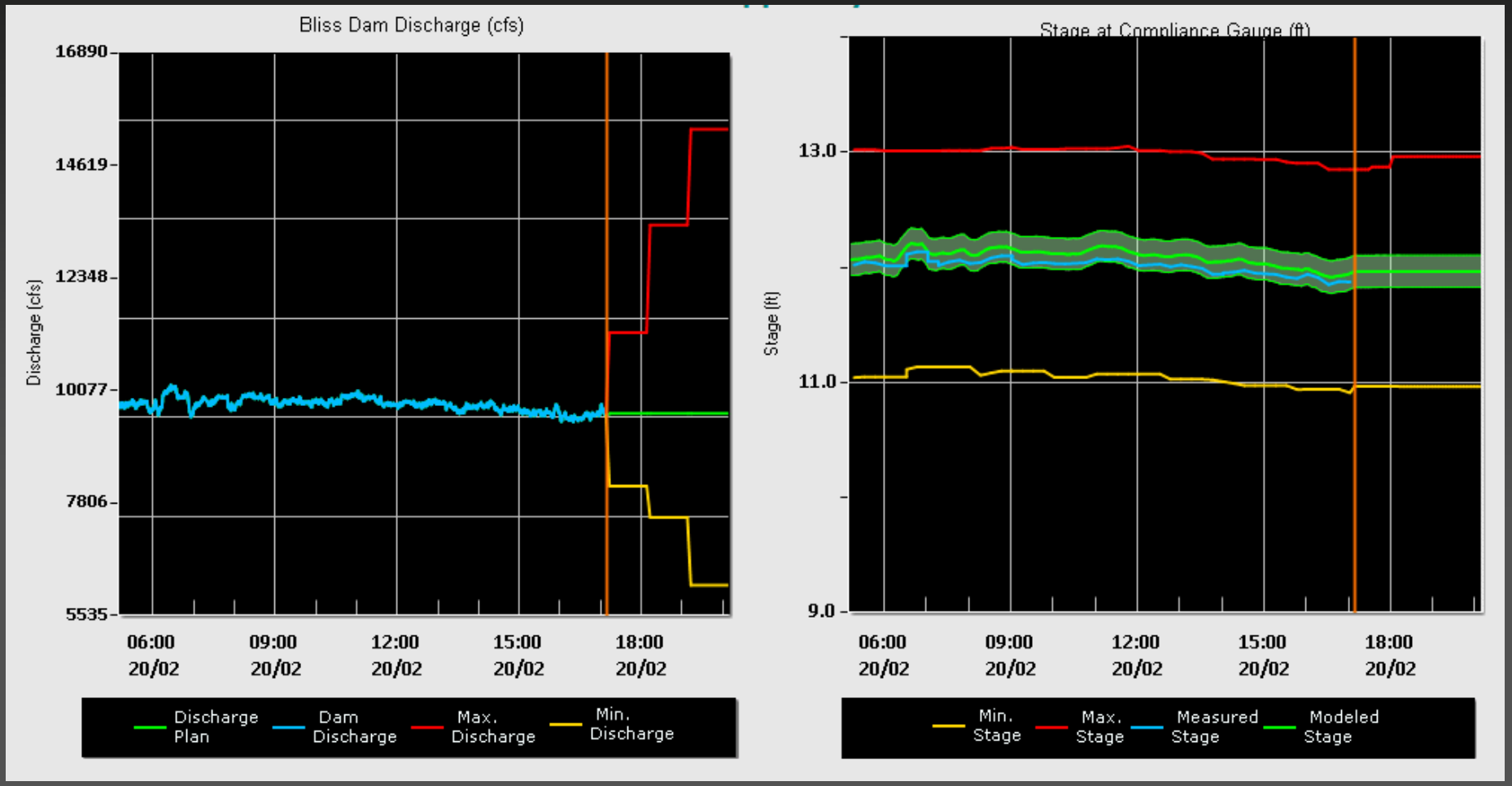
- Compliance Rules
  - Stage increases ±3 feet / hour OR ±1 feet / hour (continuous limit)
  - Stage increases ±6 feet / day OR unlimited (daily limit)
  - Discharge ≥ 4500 cubic feet /second (provides 8.12 feet of depth at compliance location)

- Optimization steps
  1. Select a set of three discharge values, which is the proposed solution.
  2. Estimate the future stage at the compliance gauge by using the MIKE11 model.
  3. Check how the future stage at the compliance gauge compares to the calculated limit. It is considered the best choice so far when it is closest to the calculated limit without exceeding it.
  4. Evaluate a convergence criteria to stop the iteration, or to go back to guess another solution (i.e., step 1).

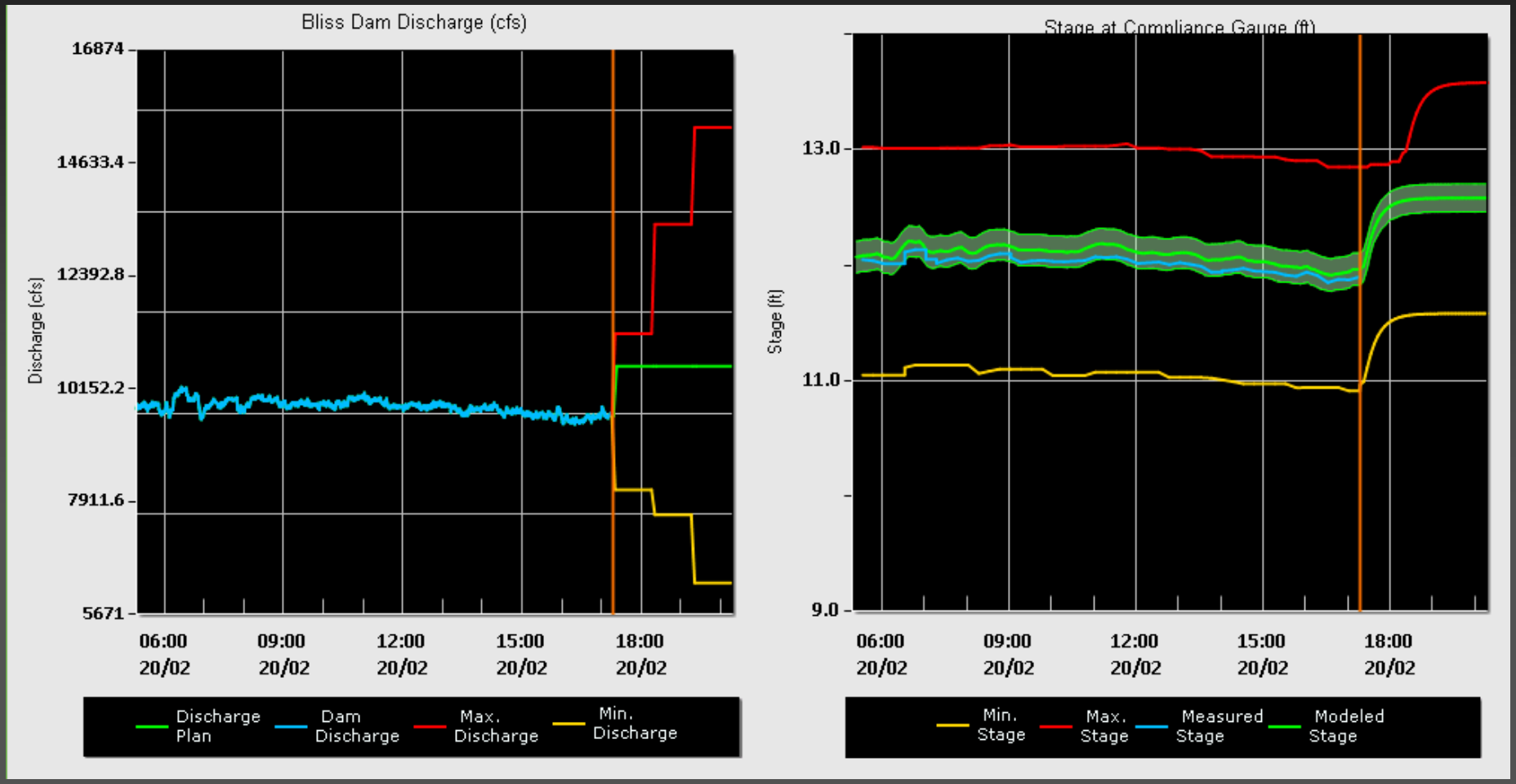
Optimization Routine



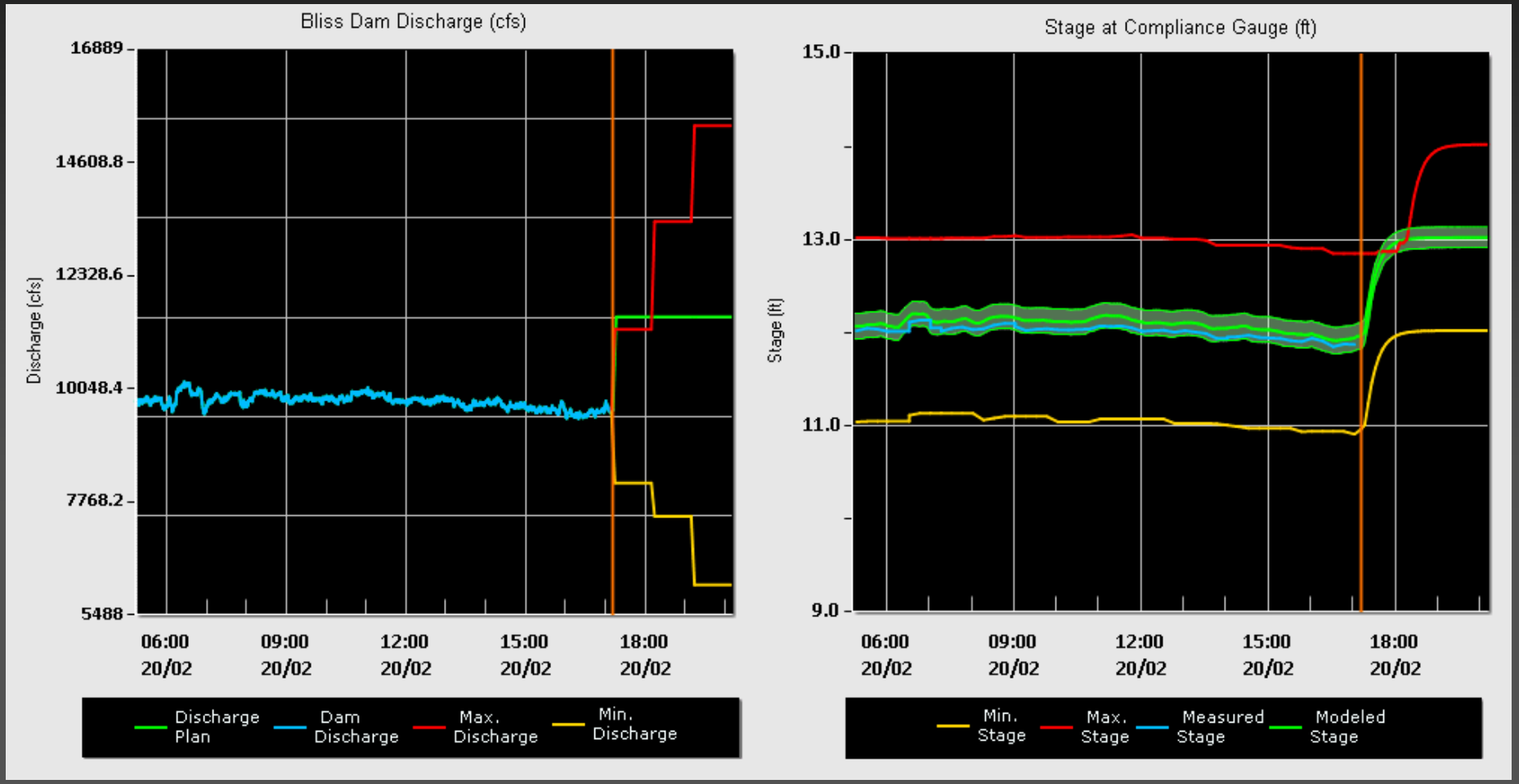
Optimization Routine



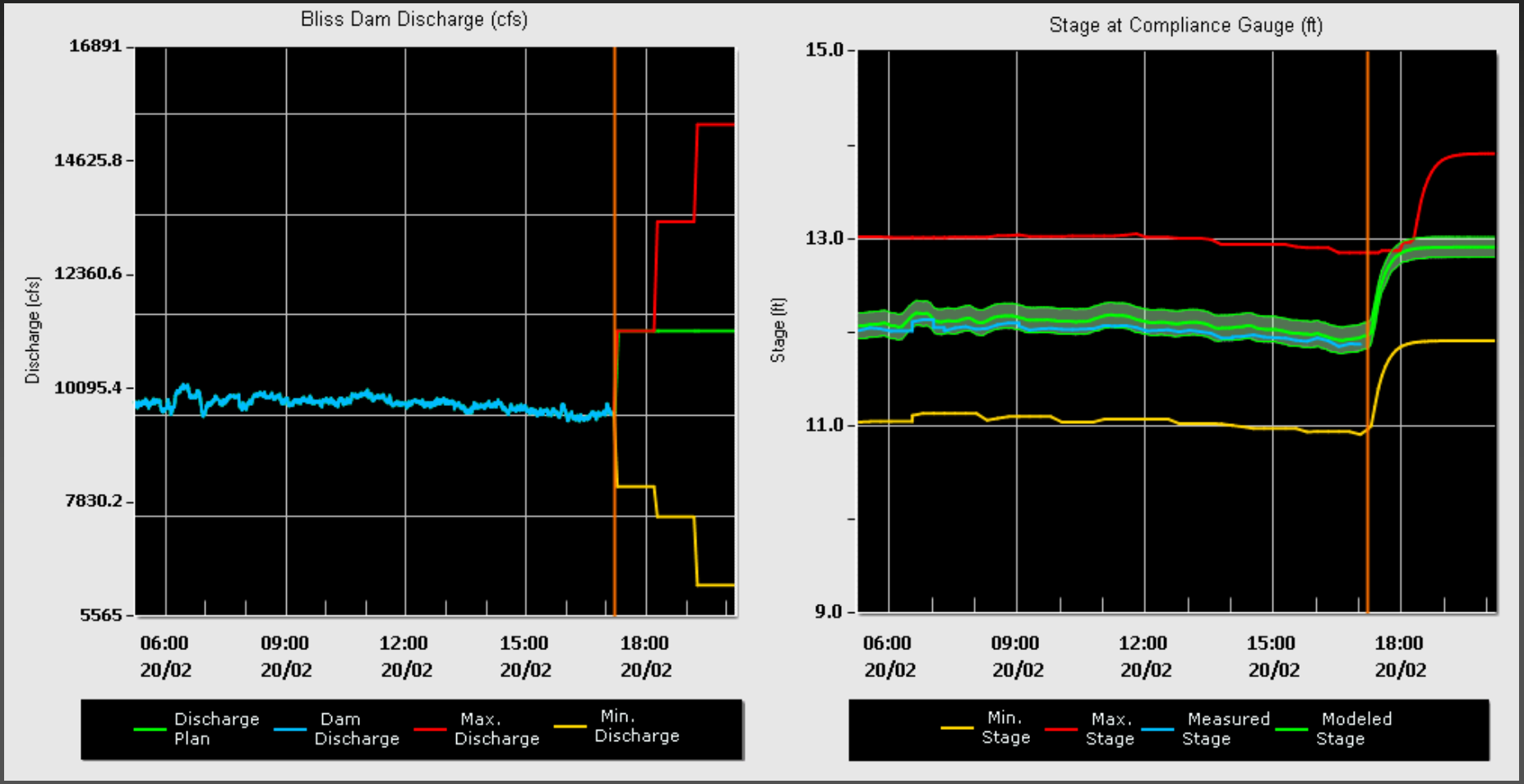
Optimization Routine



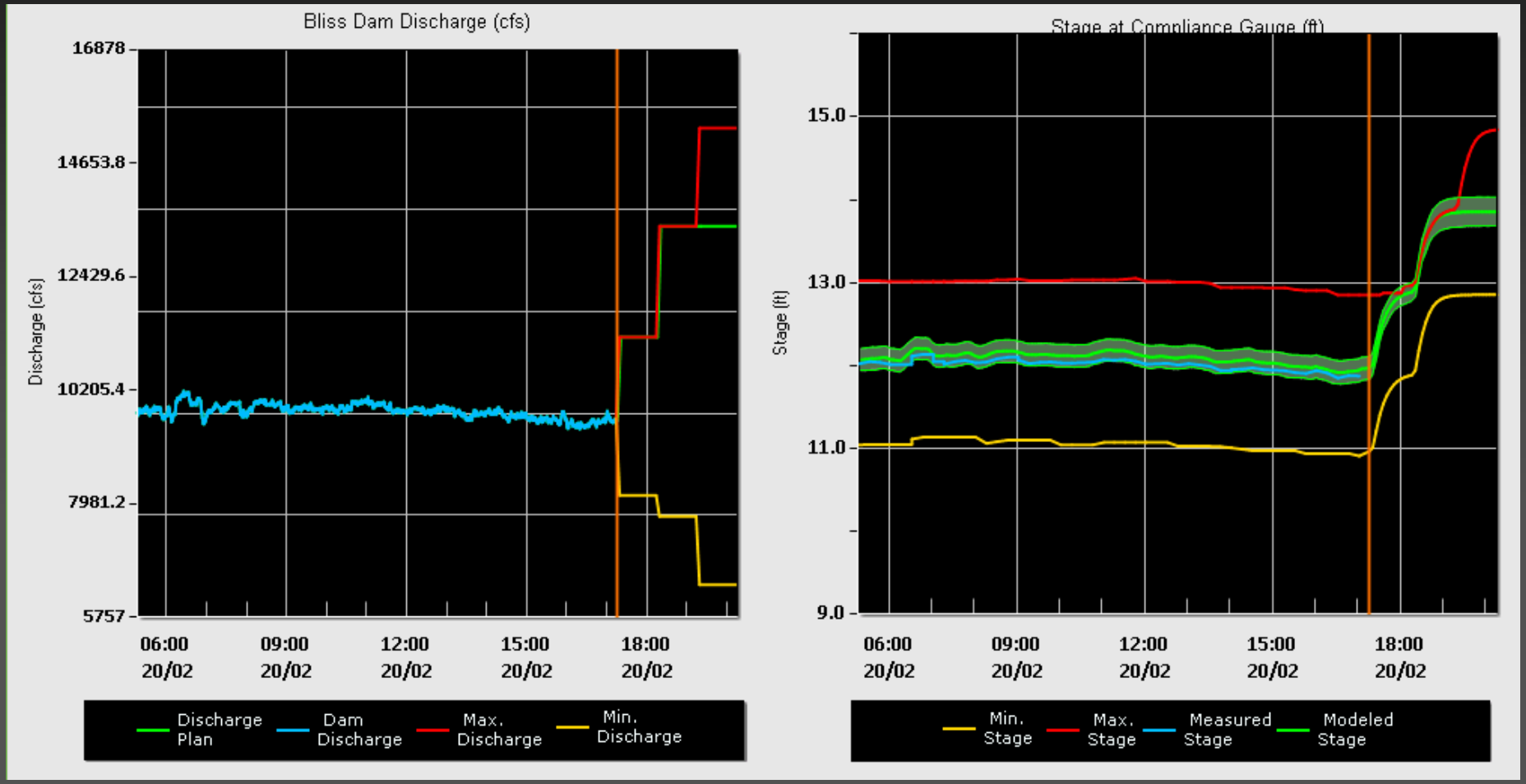
Optimization Routine



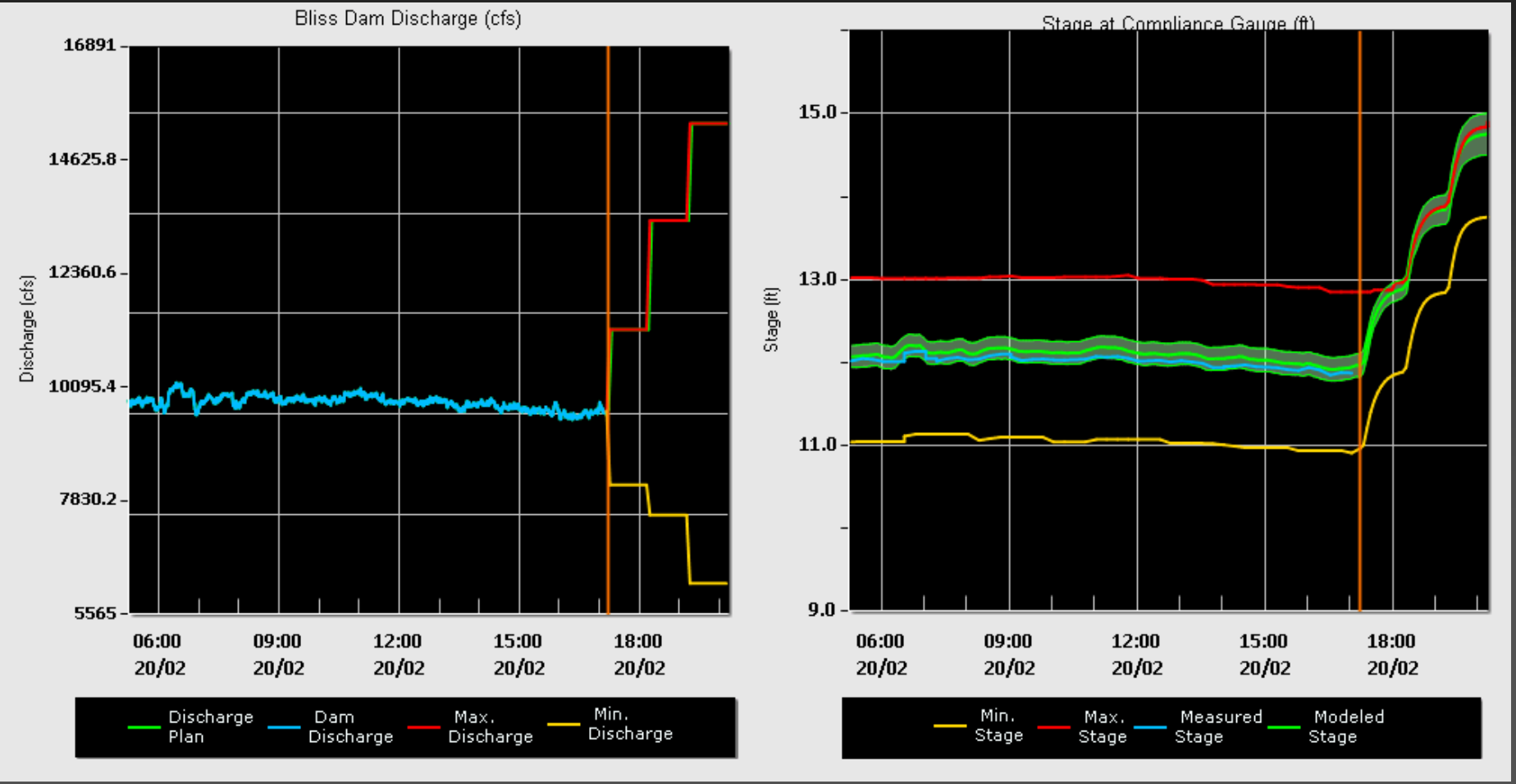
Optimization Routine



Optimization Routine



Optimization Routine

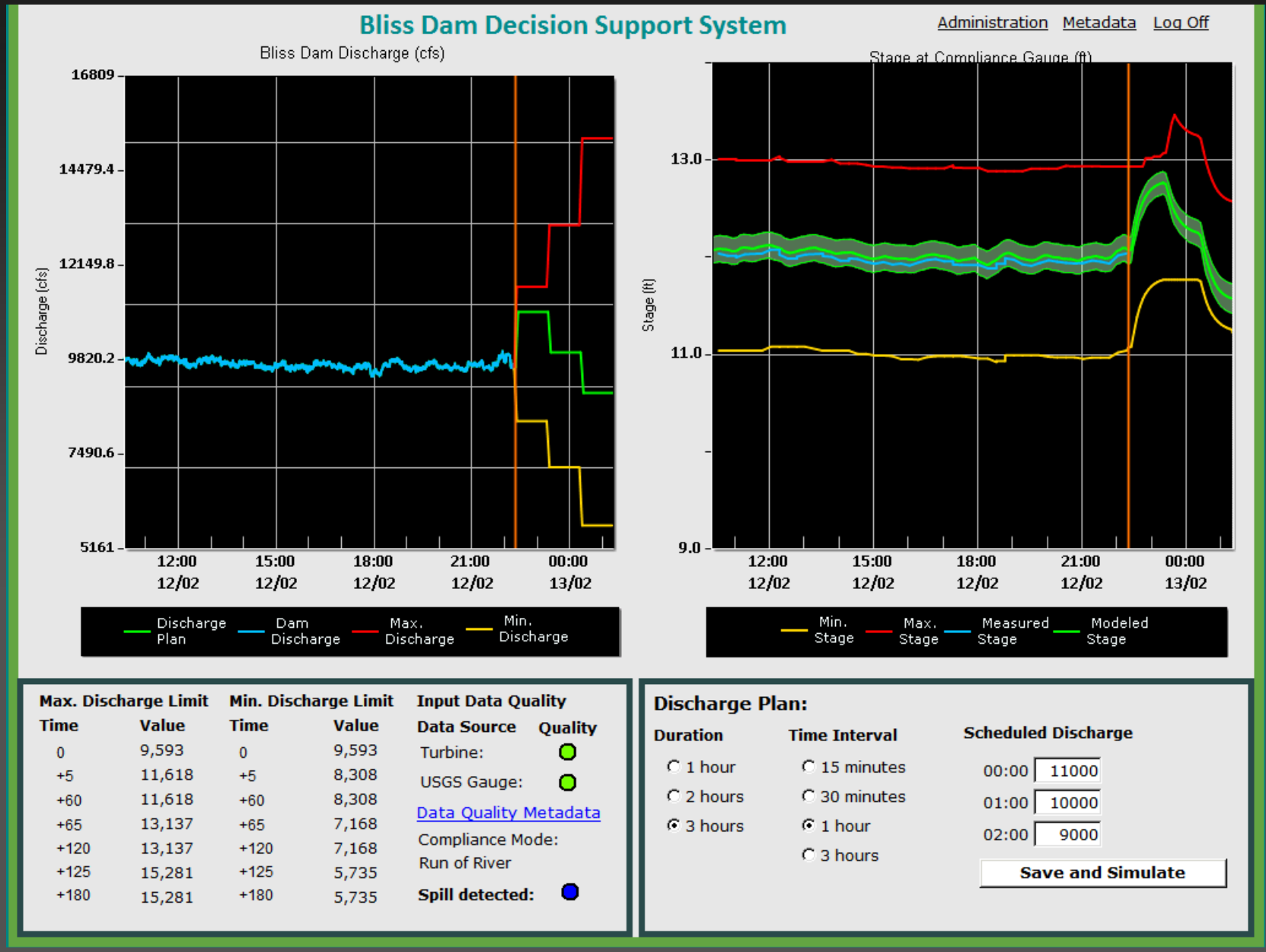


User Interface

- Web Interface
  - One Screen
  - Dashboard Manager
  - Customized Components

- System Monitoring and Notification Application
  - Configurable
  - Web Service
  - Items Checked
    - Server Running
    - Model Service Running
    - Data Validation Running
    - Data Quality Warning
    - Gap Check
    - Age of Optimization Results

Questions?


Bliss Dam Decision Support System
Administration
Metadata
Log Off
Bliss Dam Discharge (cfs)
16809
14479.4
12149.8
9820.2
7490.6
5161
Discharge (cfs)
12:00 12/02
15:00 12/02
18:00 12/02
21:00 12/02
00:00 13/02
Discharge Plan
Dam Discharge
Max. Discharge
Min. Discharge
Stage at Compliance Gauge (ft)
13.0
11.0
9.0
Stage (ft)
12:00 12/02
15:00 12/02
18:00 12/02
21:00 12/02
00:00 13/02
Min. Stage
Max. Stage
Measured Stage
Modeled Stage
Max. Discharge Limit
Time Value
0 9,593
+5 11,618
+60 11,618
+65 13,137
+120 13,137
+125 15,281
+180 15,281
Min. Discharge Limit
Time Value
0 9,593
+5 8,308
+60 8,308
+65 7,168
+120 7,168
+125 5,735
+180 5,735
Input Data Quality
Data Source Quality
Turbine:
USGS Gauge:
Data Quality Metadata
Compliance Mode:
Run of River
Spill detected:
Discharge Plan:
Duration
1 hour
2 hours
3 hours
Time Interval
15 minutes
30 minutes
1 hour
3 hours
Scheduled Discharge
00:00 11000
01:00 10000
02:00 9000
Save and Simulate