Decision Support for Dam Operations

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Solution: Bliss Dam DSS

Bliss Dam Decision Support System

Discharge Limit:
- Time: 0
  - Value: 9,593
- +5
  - Value: 11,618
- +50
  - Value: 11,618
- +85
  - Value: 13,137
- +120
  - Value: 13,137
- +125
  - Value: 15,281
- +180
  - Value: 15,281

Discharge Limit:
- Time: 0
  - Value: 9,593
- +5
  - Value: 8,308
- +50
  - Value: 8,308
- +85
  - Value: 7,168
- +120
  - Value: 7,168
- +125
  - Value: 5,735
- +180
  - Value: 5,735

Input Data Quality:
- Data Source: USGS Gauge
- Quality: Excellent

Discharge Plan:
- Duration: 1 hour
- Time Interval: 15 minutes
- Scheduled Discharge:
  - 00:00: 11000
  - 01:00: 10000
  - 02:00: 9000

Save and Simulate
Workflow Analysis

Project Start-up

Define use cases

Elaboration

Design

Construction

Build and test

Transition

Analyse

Deploy

Testing And Feedback

Version 1, Version 2, ...

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Iterative Design Process
Decision Support Systems (DSS)
Solution

- 3-Tier Architecture

User Interface

- Web Service
- Dashboard Manager

Business

- Hydraulic Model (MIKE 11)
- Optimization

Data

- Microsoft SQL Server
- DIMS

- Monitoring and Notification
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

<table>
<thead>
<tr>
<th>Time</th>
<th>Max. Discharge Limit</th>
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<tbody>
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Input Data Quality

Data Source: USGS Gauge

Quality:
- Turbine: ●
- Data Quality Metadata

Compliance Mode:
- Run of River

Spill detected: ●

Discharge Plan:

<table>
<thead>
<tr>
<th>Duration</th>
<th>Time Interval</th>
<th>Scheduled Discharge</th>
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<tbody>
<tr>
<td>1 hour</td>
<td>15 minutes</td>
<td>11000</td>
</tr>
<tr>
<td>2 hours</td>
<td>30 minutes</td>
<td>10000</td>
</tr>
<tr>
<td>3 hours</td>
<td>1 hour</td>
<td>9000</td>
</tr>
</tbody>
</table>

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:
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
Error Analysis / Uncertainty

Bliss Dam Decision Support System

Bliss Dam Discharge (cfs)

Stage at Compliance Gauge (ft)

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Input Data Quality
- Data Source: Turbine
- Quality: USGS Gauge
- Data Quality Metadata
- Compliance Mode: Run of River
- Spill detected: No

Discharge Plan:
- Duration: 1 hour
- Time Interval: 15 minutes
- Scheduled Discharge: 11000
- Duration: 2 hours
- Time Interval: 30 minutes
- Scheduled Discharge: 10000
- Duration: 3 hours
- Time Interval: 1 hour
- Scheduled Discharge: 9000

Save and Simulate

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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 decreases as turbines releases are increased.
Error Analysis / Uncertainty

- Monte Carlo Results

\[
y = -0.0013x^4 + 13.709x^3 - 53091x^2 + 9E+07x - 6E+10 \\
R^2 = 0.7331
\]

\[
y = -0.0009x^4 + 8.9423x^3 - 34642x^2 + 6E+07x - 4E+10 \\
R^2 = 0.7193
\]
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

1. Select set of 3 discharge values for the next 3 hours

2. Estimate future stage at compliance gauge by using the MIKE 11 model

3. Is the future stage closest to the calculated limit without exceeding?
   - No
   - Yes

4. Is convergence criteria met?
   - No
   - Yes

Set of discharge values is the best choice so far

End
Optimization Routine

Bliss Dam Discharge (cfs)

Stage at Compliance Gauge (ft)

Discharge [cfs]
- 16874
- 14633.4
- 12392.8
- 10152.2
- 7911.6
- 5671

06:00 09:00 12:00 15:00 18:00 20/02

Stage (ft)
- 13.0
- 11.0
- 9.0

06:00 09:00 12:00 15:00 18:00 20/02

Legend:
- Green: Discharge Plan
- Blue: Dam Discharge
- Red: Max. Discharge
- Yellow: Min. Discharge
- Black: Min. Stage
- Brown: Measured Stage
- Cyan: Max. Stage
- Olive: Modeled Stage
Optimization Routine

Bliss Dam Discharge (cfs)

Stage at Compliance Gauge (ft)
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

Bliss Dam Discharge (cfs)

Stage at Compliance Gauge (ft)

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

Save and Simulate

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