Effects of Reservoir Operations on Water Quality and Fish Habitat in Lake Murray and Saluda Releases

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August 7, 2007
Relicensing Issues Identified by the Water Quality Technical Working Committee

- The causes of striped bass fish kills reported in previous years, especially factors related to Saluda Hydro operations
- The effects of Unit 5 operations on entrainment of blue-back herring
- Determination of operational changes that might increase habitat for striped bass and blue-back herring
- Track any impacts that could occur to the tailwater cold-water fishery due to potential operational changes
Factors Considered to Address Relicensing Issues

- Annual flow regimes
- Pool level management
- Unit 5 operations
- In-lake and release water quality
- Habitat for striped bass and blue-back herring
- Water quality, meteorological, and operations data over the period 1990-2005
- Emphasis will be placed on section of reservoir from Blacks Bridge to Saluda Dam
Plan for Using CE-QUAL-W2 to Address the Water Quality TWC Relicensing Issues

1. Analyze water quality, meteorological, flow, and operations data for the period of study

2. Set up CE-QUAL-W2 for the years when major striped bass fish kills occurred

3. Run models to identify the causes that apparently contributed to the fish kills

4. Use the models to explore ways to avoid such fish kills in the future
Preliminary Findings Reported in March

- High flow, especially during March-August, is the primary cause for fish kills

- Higher flows cause the bottom of the lake to warm which in turn increases the rate of DO depletion

- Meteorological conditions can affect striper habitat

- Model results indicate that the temperature and DO range of tolerable striper habitat in Lake Murray is approximately:

  \[ T < 27^\circ C \text{ and } DO > 2.5 \text{ mg/l} \]

- Preferential use of Unit 5 helps preserve colder bottom water and was predicted to improve DO and increase striper habitat
Preliminary Conclusions Reported in May

- Nutrients are the single dominant factor that can enhance striped bass habitat
- Flow is a dominant factor, but cannot be controlled to avoid fish kills
- Met conditions can be a periodic factor that alleviates otherwise dominant factors like flow
- Striped bass habitat conditions can be improved in some years by maintaining high summer pool levels (~ elev. 358 ft)
- Unit 5 preferential operations can improve striped bass habitat in some years
Next Steps Selected at May Meeting

1. For selected years, finalize assessment (i.e., assess changes in releases) of operating guide for U5 preference for “first on, last off” operation using the hourly releases.

2. For selected years, finalize assessment of maintaining summer pool levels at 358.

3. For selected years, finalize assessment of the combination of maintaining summer pool levels at 358 with U5 preference for “first on, last off” operation using the hourly releases.

4. Analyze additional years, especially a low flow year.

5. Assess effects of minimum winter pool level, including effects on Little Saluda embayment, increased SOD, internal nutrient cycling, aquatic plants, sedimentation in coves.
1998 Model Calibration
1998 Lake Murray Water Surface Model vs. Data

1998 Lake Murray Water Surface
Model Predicted Observed

Elevation (ft)

1996 Date

1/1 1/31 3/2 4/1 5/2 6/1 7/2 8/1 9/1 10/1 11/1 12/1
1998 Lake Murray Temperature Profiles
Forebay
Model vs. Data
1998 Lake Murray Temperature Profiles
6 Kilometers Upstream of Dam
Model vs. Data
1998 Lake Murray Temperature Profiles
19 Kilometers Upstream of Dam
Model vs. Data
1998 Lake Murray DO Profiles
6 Kilometers Upstream of Dam
Model vs. Data
1998 Lake Murray DO Profiles
19 Kilometers Upstream of Dam
Model vs. Data
## Calibration Statistics for Temperature and DO Profiles

### Temperature

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<th>AME</th>
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Release Temperature

Model vs. Data

1998 Model Prediction vs Observed Discharge Temperature

1998 Date

Temperature °C

Model

Hourly Observed
Temperature in Front of Unit 5

Model vs. Data

1998 Model Prediction vs Observed Temperature in front of Unit 5
DO in Front of Unit 5

Model vs. Data

1998 Model Prediction vs Observed DO in front of Unit 5

1998 Model Prediction vs Observed DO in front of Unit 5

- Model
- Observed Daily Mean

1998 Date

1998 Date

DO mg/l
Temperature at the Surface
Model vs. Data

1998 Model Prediction vs Observed Temperature at the Surface

Temperature °C

1998 Date

- Model
- Observed Daily Mean
DO at the Surface

Model vs. Data

1998 Model Prediction and Observed DO at the Surface

![Graph showing model vs. observed dissolved oxygen (DO) at the surface in 1998. The graph plots dissolved oxygen (mg/l) on the y-axis against 1998 date on the x-axis. The graph includes a legend indicating model and observed daily mean data points. The data shows a general decrease in DO levels throughout the year, with both model and observed values closely aligning.]
1998 - Other Water Quality Constituents
Forebay Surface
Model vs. Data

Chlorophyll a in Lake Murray Forebay

- 1998 Model Predicted in the Forebay at the surface
- All 1995-1998 S-204 Observations
- 1998 S-204 Observations

Nitrate in Lake Murray Forebay

- 1998 Model Predicted in the Forebay at the surface
- All 1989-1998 Observations from S-204
- 1998 Observations from S-204
- Comparison Run

Total Phosphorus in Lake Murray Forebay

- 1998 Model Predicted in the Forebay at the surface
- All 1989-1998 Observations from S-204
- 1998 Observations from S-204

pH in Lake Murray Forebay

- 1998 Model Predicted in the Forebay at the surface
- All 1989-1998 Observations from S-204
- 1998 Observations
1998 - Other Water Quality Constituents

Model vs. Data

Inorganic Suspended Solids and Turbidity in Lake Murray Forebay

TKN in Lake Murray Forebay

Alkalinity in Lake Murray Forebay

Total Organic Carbon in Lake Murray Forebay
Evaluation of Raised Pool Levels

**Scenarios Considered:**
- 354 (Jan 1) to 358 (May 1 ⇒ Sept 1) to 354 (Dec 31)
- 350 (Jan 1) to 358 (May 1 ⇒ Sept 1) to 350 (Dec 31)

**Assumptions:**
- Assumed 500 cfs for minimum release
- Assumed reserve generation averaged 3hr every two weeks at 18,000 cfs
- Balance of releases were assumed to be used to supplement system demand

**Approach:**
- The above scenarios were developed by KA using daily average flows using HEC-ResSim
- CE-QUAL-W2 was run using daily average flows and release flows were adjusted so that target pool levels were attained
- Using the daily average flows that were adjusted using the CE-QUAL-W2 model the hourly flows for each day were developed using the assumptions above
1991 Surface Elevation, Volume of Striper Habitat and Discharge Temperature and DO

**1991 Surface Elevation**

**1991 Zone Volume, T<27 and DO>2.5**

**1991 Model Predicted Discharge Temperature**

**1991 Model Predicted Discharge DO**
1992 Surface Elevation, Volume of Striper Habitat and Discharge Temperature and DO

1992 Surface Elevation

1992 Zone Volume, T<27 and DO>2.5

1992 Model Predicted Discharge Temperature

1992 Model Predicted Discharge DO
1996 Surface Elevation, Volume of Striper Habitat and Discharge Temperature and DO

1996 Surface Elevation

1996 Zone Volume, T<27 and DO>2.5

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1998 Surface Elevation, Volume of Striper Habitat and Discharge Temperature and DO

1998 Surface Elevation

1998 Zone Volume, T<27 and DO>2.5

1998 Model Predicted Discharge Temperature

1998 Model Predicted Discharge DO
2000 Surface Elevation, Volume of Striper Habitat and Discharge Temperature and DO

2000 Surface Elevation

2000 Zone Volume, T<27 and DO>2.5

2000 Model Predicted Discharge Temperature

2000 Model Predicted Discharge DO
2001 Surface Elevation, Volume of Striper Habitat and Discharge Temperature and DO

2001 Surface Elevation

Date
1/1 2/1 3/4 4/4 5/6 6/6 7/8 8/9 9/10 11/11 12/12

Elevation (ft)
349 350 351 352 353 354 355 356 357 358 359

Actual
Elevation 354 Scenario
Elevation 350 Scenario

2001 Model Predicted Discharge Temperature

Temperature oC
7 9 11 13 15 17 19 21 23 25

Current
Elev 354 Scenario
Elev 350 Scenario

2001 Zone Volume, T<27 and DO>2.5

Volume Mm3
0 200 400 600 800 1000 1200 1400 1600 1800 2000

Original Q Assumption
Elev 354 Scenario
Elev 350 Scenario

2001 Model Predicted Discharge DO

DO (mg/l)
0 1 2 3 4 5 6 7 8 9 10 11 12

Current
Elev 354 Scenario
Elev 350 Scenario

2001 Date
1/1 2/1 3/5 4/5 5/7 6/7 7/9 8/9 9/10 10/11 11/12 12/13

2001 Date
1/1 2/1 3/5 4/5 5/7 6/7 7/9 8/9 9/10 10/11 11/12 12/13

2001 Date
1/1 2/1 3/5 4/5 5/7 6/7 7/9 8/9 9/10 10/11 11/12 12/13

2001 Date
5/1 6/1 7/2 8/2 9/2 10/3 11/3
2005 Surface Elevation, Volume of Striper Habitat and Discharge Temperature and DO

2005 Surface Elevation

2005 Zone Volume, T<27 and DO>2.5

2005 Model Predicted Discharge Temperature

2005 Model Predicted Discharge DO
1991 Pool Level Management and Unit 5 on First

1991 Zone Volume, T<27 and DO>2.5

Volume Mm³

1991 Model Predicted Discharge Temperature

Temperature °C

1991 Model Predicted Discharge DO

DO (mg/l)
1992 Pool Level Management and Unit 5 on First

1992 Zone Volume, T<27 and DO>2.5

1992 Model Predicted Discharge Temperature

1992 Model Predicted Discharge DO
1996 Pool Level Management and Unit 5 on First

1996 Zone Volume, T<27 and DO>2.5

1996 Model Predicted Discharge Temperature

1996 Model Predicted Discharge DO
1997 Pool Level Management and Unit 5 on First

1997 Zone Volume, T<27 and DO>2.5

1997 Model Predicted Discharge Temperature

1997 Model Predicted Discharge DO
1998 Pool Level Management and Unit 5 on First

1998 Zone Volume, T<27 and DO>2.5

- Original Q Assumption
- Elev 354 Scenario
- Elev 354-Unit 5 on first

1998 Model Predicted Discharge Temperature

- Current
- Elevation 354 Scenario
- Elev 354 Scenario-Unit 5 on first

1998 Model Predicted Discharge DO

- Current
- Elevation 354 Scenario
- Elev 354 Scenario-Unit 5 on first
2000 Pool Level Management and Unit 5 on First

2000 Zone Volume, T<27 and DO>2.5

2000 Model Predicted Discharge Temperature

2000 Model Predicted Discharge DO
2001 Pool Level Management and Unit 5 on First

2001 Zone Volume, T<27 and DO>2.5

Volume Mn3

5/1 6/1 7/2 8/2 9/2 10/3 11/3

Original Q Assumption
Elev 354 Scenario
Elev 354-Unit 5 on first

2001 Model Predicted Discharge Temperature

Temperature °C

Current
Elevation 354 Scenario
Elev 354 Scenario-Unit 5 on first

2001 Date

2001 Model Predicted Discharge DO

DO (mg/l)

Current
Elevation 354 Scenario
Elev 354 Scenario-Unit 5 on first

2001 Date
2005 Pool Level Management and Unit 5 on First

2005 Zone Volume, T<27 and DO>2.5

2005 Model Predicted Discharge Temperature

2005 Model Predicted Discharge DO
1998 Pool Level Management and Unit 5 on First Until September
When the Bottom Units are used for the first 12,800 cfs

1998 Zone Volume, T<27 and DO>2.5

1998 Model Predicted Discharge Temperature

1998 Model Predicted Discharge DO
Conclusions

- Unit 5 preferential operations can improve striped bass habitat in some years.

- Maintaining the summer pool level at 358 increases striped bass habitat in some years.

- The combination of Unit 5 preferential operations and maintaining the summer pool level at 358 can further increase striped bass habitat in some years. It can also improve water quality in the releases.

- When the discharge temperature from Unit 5 reaches 15° C, the minimum flow should be released through a bottom unit.

- Unit 5 operations after August or September do not effect striped bass habitat.