Stacia Hoover

From: Alison Guth
Sent: Thursday, October 05, 2006 5:32 PM
To: Ray Ammarell; Alan Stuart; Bill Argentieri; Bob Olsen; Bret Hoffman; Bud Badr; Feleke Arega (aregaf@dnr.sc.gov); Larry Turner (turnerle@dhec.sc.gov); Mike Waddell; Patrick Moore; Mike Schimpff; Jon Quebbeman
Cc: Tony Bebber; Alison Guth; Amanda Hill; Bill Hulslander; Bill Marshall; Charlene Coleman; Dave Landis; Dick Christie; George Duke; Gerrit Jobsis (American Rivers); Gina Kirkland; Hank McKellar; Jeff Duncan; Jennifer O'Rourke; Joy Downs; Kristina Massey; Mark Leao; Mike Summer (msummer@scana.com); Parkin Hunter; Randal Shealy; Randy Mahan; Russell Jernigan; Steve Bell; Suzanne Rhodes; Theresa Thom; Tom Ruple; Tom Stonecypher; Bret Hoffman
Subject: Saluda Technical Memo

Hello Operations Group

On behalf of Jon Quebbeman, attached is the Saluda technical memo discussing the calibration of the HEC-ResSim model as well as a brief summary paragraph. This is for review before the October 12th meeting. Please forward any comments or questions that you may have about this document to Jon. Thanks and take care, Alison

Summary:

We recently completed assembling and testing two separate methods of determining the inflow hydrographs for Lake Murray over a 16 year period. Within these two methods, the data was organized and tested to provide the best correlation between calculated results, and observed (recorded from USGS gages) results. The two methods were:

1)Mass Balance Method
2)Gage Rating Method

The Mass Balance method uses historical stage data, and discharge data, to compute the required inflow to satisfy the 'mass balance'. Conversely, the Gage Rating method uses three upstream gages, and multiplies the flow rates to account for the ungaged drainage areas for a total inflow into the reservoir. These two methods were compared to determine which produces an inflow hydrograph that results in better correlation of data using HEC-ResSim to observed data.

In summary, more consistent results to observed data were calculated in ResSim using the Mass Balance methodology. At this point, with an acceptable inflow hydrograph determined, we are ready to assemble operational constraints to model various scenarios.

-JAQ

Jon Quebbeman, P.E.
Kleinschmidt Associates
Energy & Water Resource Consultants
75 Main Street
PO Box 576
Pittsfield, ME 04967
P 207-487-3328
F 207-487-3124
Jon.Quebbeman@KleinschmidtUSA.com

001-Saluda Model Development M...

Stacia Hoover

From: Bret Hoffman
Sent: Monday, July 24, 2006 12:43 PM
To: 'Tommy Boozer'; 'Aaron Small'; 'Alan Axson'; Alan Stuart; Alison Guth; 'Amanda Hill'; 'Bill Argentieri'; 'Bill Marshall'; 'Bill Mathias'; Bret Hoffman; 'Charlene Coleman'; Dave Anderson; 'David Price'; 'Dick Christie'; 'Edward Schnepel'; 'George Duke'; 'Gerrit Jobsis (American Rivers)'; 'Jennifer O'Rourke'; 'Jerry Wise'; 'Jim Devereaux'; 'John and Rob Altenberg'; 'Joy Downs'; 'Karen Kustafik'; 'Ken Uschelbec'; 'Kenneth Fox'; 'Larry Turner (turnerle@dhec.sc.gov)'; 'Lee Barber'; 'Malcolm Leaphart'; 'Mark Leao'; 'Mike Waddell'; 'Miriam Atria'; 'Norm Nicholson'; 'Norman Ferris'; 'Patrick Moore'; 'Randy Mahan'; 'Roger Hovis '; 'Skeet Mills '; 'Steve Bell'; 'Suzanne Rhodes'; 'Tom Eppink'
Subject: Saluda cross-sections

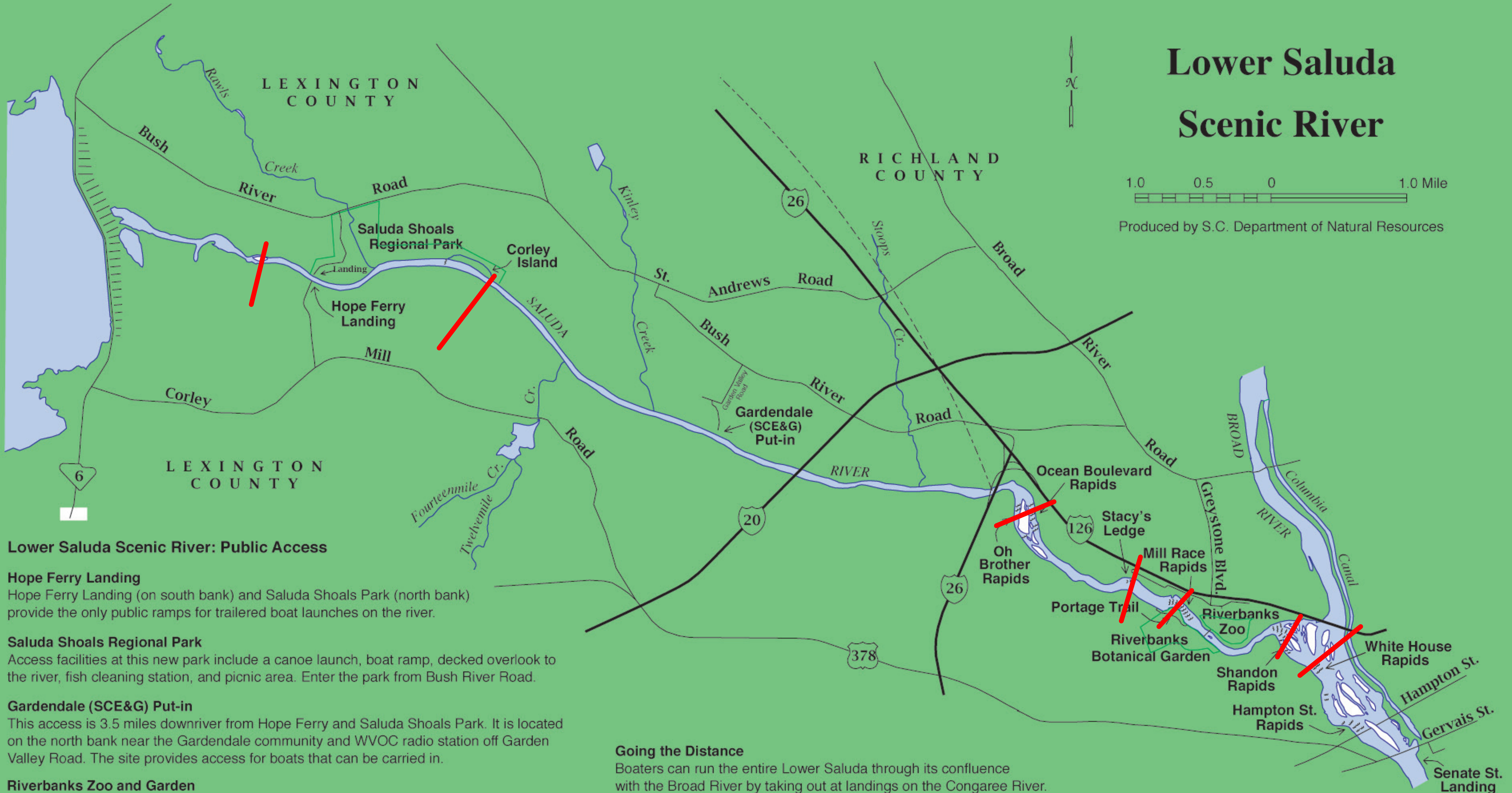
Good afternoon,

At the request of Mike Waddell during last Thursday's Safety RCG meeting, I am forwarding the map of cross-sections on the lower Saluda River that will be evaluated by the HEC Res-Sim model.

Thanks,

Bret Hoffman, P.E.
Mechanical Engineer
Kleinschmidt
Energy & Water Resource Consultants
101 Trade Zone Drive, Suite 21A
West Columbia, SC 29170
(803) 822-3177
FAX (803) 822-3183
Bret.Hoffman@KleinschmidtUSA.com

cross-sections.pdf
(1 MB)



Lower Saluda Scenic River: Public Access

Hope Ferry Landing
Hope Ferry Landing (on south bank) and Saluda Shoals Park (north bank) provide the only public ramps for trailered boat launches on the river.

Saluda Shoals Regional Park
Access facilities at this new park include a canoe launch, boat ramp, decked overlook to the river, fish cleaning station, and picnic area. Enter the park from Bush River Road.

Gardendale (SCE&G) Put-in
This access is 3.5 miles downriver from Hope Ferry and Saluda Shoals Park. It is located on the north bank near the Gardendale community and WVOC radio station off Garden Valley Road. The site provides access for boats that can be carried in.

Riverbanks Zoo and Garden
In addition to a zoo and botanical garden, Riverbanks offers nature trails and a pedestrian bridge with views of Mill Race Rapids, historic structures, and native wildlife. Carry-in boat access is available at the west end of the parking lot by walking a short trail to the river. Riverbanks is located off Greystone Blvd. Open daily from 9-5 pm, admission is charged.

Going the Distance
Boaters can run the entire Lower Saluda through its confluence with the Broad River by taking out at landings on the Congaree River. Senate Street landing below Gervais Street bridge provides access only for boats that can be carried in (and parking is limited). Senate Street landing is 10 miles downstream from Hope Ferry and Saluda Shoals Park. Public landings with ramps are located 2 and 3 miles downstream on the east and west banks of the Congaree.

Stacia Hoover

From: Alan Stuart
Sent: Tuesday, June 06, 2006 9:10 PM
To: Alan Stuart; 'Amanda Hill (Amanda_Hill@fws.gov)'; 'Dick Christie (dchristie@infoave.net)'; 'Hal Beard'; 'Prescott Brownell (Prescott.Brownell@noaa.gov)'; 'gjobsis@americanrivers.org'; 'Patrick Moore'; 'Gina Kirkland - DHEC'; 'cdwood@usgs.gov'; 'Sarah W Ellisor'; 'Richard Roos-Collins'; 'Julie Gantenbein'
Cc: BARGENTIERI@scana.com; 'Jim Ruane'; RMAHAN@scana.com; 'Ray Ammarell (RAmmarell@scana.com)'; 'Steve Summer'; 'Tom Eppink'; 'Brian J. McManus'; 'BOWLES, THOMAS M'; Alison Guth; 'EPPINK, THOMAS G'
Subject: 2006 Draft Operations Guidelines

Good evening all,

Attached for your review is the draft report on the 2006 Operations Guidelines during the low dissolved oxygen season for Saluda Hydro. Please review the report and provide any comments you may have by June 26, 2006. The Operating guidelines incorporate updated Look-up Tables based on the findings of the turbine testing work conducted on Units 1 and 5 last October.

A friendly reminder, to date I have not received any comments on the turbine testing report. Comments on that report are due by June 17, 2006.

Don't forget that SCE&G must file the 2006 Operating Guidelines with the FERC by June 30, 2006. This date is established per the Settlement Agreement.

Thank you for your efforts and patience. If you have questions please give me a call.

Regards,
Alan

2006 Draft Aeration Operations...

GUIDELINES FOR OPERATION OF THE SALUDA PROJECT FOR DISSOLVED OXYGEN MANAGEMENT IN 2006

June 30, 2006

PURPOSE

These Guidelines for Operation of the Saluda Project for Dissolved Oxygen Compliance are prepared pursuant to the *Offer of Settlement On Complaint Regarding Water Quality In Lower Saluda River* (May 19, 2004) (Settlement Agreement). Paragraph 9.3 of the Settlement Agreement provides the following:

> To the extent within SCE&G's reasonable control, each Operating Plan will seek to enhance existing water quality in the lower Saluda River and, more specifically, seek to achieve DO concentrations of 4 mg/1 minimum, 5 mg/l daily average, and 5.5 mg/1 monthly average in the lower Saluda River. In seeking to achieve this goal, each Operating Plan will preserve SCE&G's right or duty to modify operations as necessary to: (A) protect life and property, (B) respond to changed hydrologic or other circumstances not addressed in the Operating Plan, (C) maintain the use of the Project to meet system reserve obligations of 200 MW, and (D) comply with a lawful orders of the Commission or other authorities. SCE&G will provide notice of such modification to the Conservation Groups, [South Carolina Department of Health and Environmental Control], and Other Agencies in advance of such modification if practicable, and otherwise, as soon as practicable thereafter. The Parties will then use their best efforts to modify the Operating Plan in response thereto.

SCE&G will implement these Guidelines consistent with paragraph 9.3.

LIMITATIONS

Paragraph 9.3 of the Settlement Agreement includes limitations and these limitations are more fully explained here. Operation of the Saluda Project affects dissolved oxygen (DO) levels in the Saluda River downstream of the Saluda Project. Factors affecting achievement and maintenance of the DO standard include: (1) the limited capability for aeration of water discharged through the turbine units, (2) the requirement that SCE&G manage water levels in Lake Murray for safety and other reasons, (3) the need to use Saluda Hydro for the special operating needs specified under paragraph 9.3 of the Settlement Agreement, and (4) the need to meet SCE&G's

reserve obligations as a member of the Virginia-Carolinas Southeastern Electric Reliability Council sub-region (VACAR).

Generating units occasionally fail, and these generation failures are not generally capable of prediction. These often sudden failures upset the load-generation balance. Because electricity cannot be stored, any such sudden reduction in generation cannot be made up by an inventory, as would be the case in most other kinds of business. Instead, generation losses must be met by reserve generation that can be dispatched instantly, before voltage sags or frequency excursions lead to local or widespread blackouts. VACAR members are bound in a reserve-sharing agreement by which each has agreed to assist any other member in generation emergencies. SCE&G must employ its reserves to meet its own generation emergencies before calling on assistance from other VACAR members, and it must be constantly ready to provide reserve generation to other VACAR members. Generally, the reserves required to be maintained by SCE&G are in the range of 190-200 MW, which matches the capacity of the Saluda Project and its ability to respond quickly to any generation outage on its system.

As done in 2004 and 2005, , SCE&G will provide via email, during 2006, a weekly report to the South Carolina Department of Health and Environmental Control, South Carolina Coastal Conservation League (SCCCL) and other stakeholders documenting the previous week's operation of the Saluda Project.

Unless otherwise specified, these guidelines will be implemented by SCE&G.

TURBINE VENTING OPERATIONS

Use Lookup Tables (LUTs) As Guides To Aerate The Turbine Discharges From the Saluda Project. SCE&G will use the LUTs included in the document, "Lookup Tables for Operating the Saluda Project to Enhance Dissolved Oxygen in the Tailrace to the Extent Practicable for 2006," (Appendix A). These LUTs reflect the best estimate based on field testing and predictive models of how the units at Saluda Hydro can be operated to enhance downstream dissolved oxygen levels and still obtain target MW outputs, given the inflow DO and temperature conditions. (Note: These LUTs may change due to the installation of hub baffles on all the units. Updates to the current LUTs will be generated for 2007 if warranted based on testing of units 2, 3, and 4 in September or October 2006.)

Estimate Inflow DO and Temperature for Units 1-4 and Unit 5. Turbine DO and temperature from inflows change during the course of the low DO period. To track DO and temperature conditions in the turbine inflows, SCE&G will obtain DO and temperature profiles in the Saluda Project forebay every other week and use these profiles to predict conditions in the turbine inflows. SCE&G also will use data collected by the United States Geological Survey (USGS) continuous water quality monitor located near the intake of Unit 5 (U5).[1] These data will also be used to evaluate the presence of conditions that call into operation, constraints to using U5 due to the potential for fish entrainment. If needed, a withdrawal zone model may be used to predict inflow temperature and DO.

Use DO Readings in the Tailrace from the USGS Monitor. During 2006, the USGS monitor (USGS Gage No 02168504) will be used to track DO conditions in the tailrace on a daily basis, supplemented by periodic spot measurements by SCE&G, especially if DO, as measured at the monitor, appears erratic or is lower than expected (*e.g.*, suspected fouling, meter malfunction, *etc.*). It is anticipated that the USGS monitor will be relocated to improve the reliability of the DO readings.

---

[1] As with any *in-situ* continuous monitor, anomalous readings occur from time to time, due to equipment fouling or malfunction. If the USGS determines the data are suspect through their Quality Control/Quality Assurance Program, that data may be ignored, appropriately adjusted, or otherwise dealt with according to their final determination. It is acknowledged that the USGS data is reported initially as "provisional." SCE&G will use it subject to the data error issues discussed here and agreed to during the March 23, 2006 meeting.

<u>Review effectiveness of the turbine venting operations and other data being collected to see if additional data or adjustments in the LUTs are needed before "near-zero" DO inflow conditions occur.</u> Technical peer review between KA/REMI and National Heritage Institute/SCCCL of the tailrace DO data and operational records collected by USGS and SCE&G will be conducted, as needed, to achieve this objective and determine if changes to the LUTs are warranted.

<u>Conduct monthly training of operators in System Control.</u> The System Control Manager will conduct monthly training sessions with operations personnel to ensure proper application of the LUTs. Training of staff will include review of current practices and procedures in the proper application of the LUTs. The training sessions will be adjusted as appropriate each month for changes in monitored DO and temperature inflow conditions, and will include adjustments in the LUTs should any be needed. Any necessary revisions of the LUTs will be shared with the Conservation Groups.

If during the low DO season, conditions are identified that require immediate changes (agreeable to all parties to the settlement) to the 2006 operating guideline, the System Control manager will convene a special training session to ensure changes in the Operating Guidelines are implemented as soon as reasonably possible.

APPENDIX A

LOOKUP TABLES

LOOKUP TABLES FOR OPERATING THE SALUDA PROJECT TO ENHANCE DISSOLVED OXYGEN IN THE TAILRACE TO THE EXTENT PRACTICABLE FOR 2006

June 30, 2006

Lookup Tables (LUTs) will be used as a tool for operating the Saluda Project during the low DO period of 2006 so that the DO standard in the Lower Saluda River may be met continuously, subject to the limitations contained in paragraph 9.3 of the Settlement Agreement,, and to provide optimal aeration when the standard otherwise cannot be met. The LUTs will be used by SCE&G to select the turbine units that will be operated at various total project flow rates and power production levels, under varying inflow DO concentrations and temperatures. These LUTs provide a guide for operations in 2006, but actual practice is likely to deviate somewhat from this guide as tailwater data are collected and evaluated and the LUTs are adjusted as appropriate. Also, during 2006, the aeration system will be manually operated. It is expected that when a final turbine venting system is installed at some point in the future, a computer-controlled automated system may be needed to adjust these operations for more optimal aeration.

The overall process used to develop the LUTs involved the following steps:

1. The aeration characteristics of units 1 and 5 were modeled using the discrete bubble model as described in "Saluda DO Standard Project—Lower Saluda River DO Technical Study Report, Appendix C, Prediction of Dissolved Oxygen Concentrations for Turbine Discharges from Saluda Hydro" 2003.
2. The model for unit 1 was used to represent units 2-4. The two models for units 1-4 and unit 5 were then used to predict DO in the tailrace over the range of turbine gate settings (*i.e.*, turbine flow conditions) for various DO and temperature levels in the inflows.

3. The predicted DO in the tailrace for each set of inflow DO and temperature conditions was then plotted over the range of hydro operations.
4. The LUTs were then developed using these graphs. One set of LUTs was developed assuming that the units were operated several hours per day and the other set of LUTs was developed assuming the units were operated at a constant level over the course of the entire day.
5. LUTs were developed for a range of DO conditions at the intake, but for only one temperature condition that was similar to that expected during the low DO period of 2006. Model predictions were made for other temperature conditions, but the effort was not expended to develop LUTs for all the temperature conditions modeled due to the time required to develop LUTs. Additional LUTs could be prepared on an "as needed basis" depending on the intake actual temperature conditions that develop during the low DO period of 2006.
6. The LUTs were developed using a model that integrates the effects of all the units and predicts DO in the tailrace, assuming full mixing of the discharges from all the units.
7. For project operations, SCE&G System Control normally dispatches Saluda Hydro by power production levels rather than water flow rates; therefore, the flow rates initially determined using the turbine aeration model were supplemented by conversion to MW levels using the results of unit tests conducted in 1997 and 1998.

The assumed conditions for the turbine aeration systems are as follows:

1. Units 1-5 have hub baffles, and aeration characteristics were assumed to be as modeled in 2006 based on data collected on units 1 and 5 in 2005.
2. Unit 2 cannot be operated unless 2500 cfs is being discharged by the other units.

Assumptions used in developing the LUTs:

1. SCE&G plans to operate the Saluda Project at minimal discharge of approximately 400 cfs during the summer of 2006. Under this condition, DO in the discharge from the Saluda Project should be well over the State DO standard. Also, inflow water quality (*i.e.*, DO and temperature) will change slowly over the course of the summer and early autumn. The need for LUTs under this condition is minimal, so LUTs for only one temperature scenario were prepared.
2. Two sets of LUTs were prepared: one set for hourly operations where the DO target is 4 mg/L (see discussion below), and the other set for daily operations where the DO target is 5 mg/L, *i.e.*, the daily operations tables will be applied when Saluda is being operated around the clock under steady state conditions, the hourly operations tables will be applied when special circumstances, as described in paragraph 9.3 of the Settlement Agreement, necessitate operating for brief periods of greater generation. An analysis of historical conditions (see the report supporting the new site-specific standard for DO for the Lower Saluda River) showed that if 4 mg/L was achieved over a period of several hours during a typical day of operations at the Saluda Project, the other requirements of the DO standard (*i.e.*, the daily average of 5 mg/L and the 30-day moving average of 5.5 mg/L) are achieved under almost all conditions. Considering the current aeration systems, the lack of computerized powerhouse controls, and the DO monitoring system, the use of these two sets of LUTs is considered to be what is practicable.
3. Additional sets of LUTs will be prepared for other temperature conditions if temperatures in the intakes are different than assumed for preparation of these LUTs.
4. It was assumed that the target minimum DO would be 4 mg/L during the period of maximum discharge each day. This is because an analysis of historical conditions showed that if 4 mg/L was achieved during the

maximum discharge period, the other requirements of the DO standard (*i.e.*, the daily average of 5 mg/L and the 30-day moving average of 5.5 mg/L) are achieved under almost all conditions.

5. For days when the Saluda Project would be operated through out the day, it was assumed that the target minimum DO would be 5 mg/L. This approach is consistent with the assumption that SCE&G plans to operate the Saluda Project at around 400 cfs during the low DO period of 2006.

Inflow water quality for Unit 5 was assumed to have the same conditions as the inflows for Units 1- 4. This is a conservative assumption in that DO in the inflow to Unit 5 is rarely less than the DO in the inflows to Units 1- 4. This is based upon an extensive review of historical reservoir profile data.

The following LUTs are proposed for the operating guides for achieving aeration objectives during the low DO period of 2006. Figures 1 through 6 show the predicted DO concentrations in the tailrace versus total project discharges for various operating conditions (i.e., number and selection of units operating and inflow water quality conditions) at the Saluda Project. These graphs were used in developing the LUTs.

LOOKUP TABLES FOR HOURLY OPERATIONS

(DO TARGET IS GREATER THAN OR EQUAL TO 4 MG/L)

Turbine Inflow Conditions: DO 3 – 3.9 mg/L; Temperature = 15^{o}C (approximately mid-July to August 1)	
MWs desired	**For Hourly operations, the following is recommended:**
Any MWs	Normal operations with U2 restricted for thermal load and U5 operated in the “last on, first off mode”

* See discussion on Page 1, Paragraph 1, and Items 2 and 4 on Pages 9 and 10.

Turbine Inflow Conditions: DO 2 – 2.9 mg/L; Temperature = 16°C (approximately August 1 to mid-August); DO objective in tailrace is 4 mg/L		
MWs desired	**Approximate flow (cfs)**	**For <u>Hourly</u> operations, the following is recommended:**
≤ 126	≤ 10,000, limit for 4 mg/L	Any unit, except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"
126-148	10,000-12,500	All units except Unit 5—expect DO to be 3.5 to 4 mg/L, or more
> 148	> 12,500	Operate Units 1-4 at full gate and add Unit 5 as needed for desired operations—expect DO to be 3 to 4 mg/L, or more

Turbine Inflow Conditions: DO 1 – 1.9 mg/L; Temperature = 16°C (approximately mid-August to September 1); DO objective in tailrace is 4 mg/L		
MWs desired	**Approximate flow (cfs)**	**For <u>Hourly</u> operations, the following is recommended:**
≤ 37	≤ 3150	Any unit, except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"
37-69	3150-5500	Any 2 units except U5 operated in the "last on, first off mode";
68-84	5500-6700	Any 3 units except U5 operated in the "last on, first off mode"; if 2 units are used, expect DO to be 3.8 to 4 mg/L or more
81-97	6700-7800, limit for 4 mg/L	Any 4 units except U5 operated in the "last on, first off mode"; if 3 units are used, expect DO to be 3.6 to 4 mg/L or more;
97-120	7800-9500	Preferably 4 units except U5 (expect DO to be 3.3 to 4 mg/L, or more); if 3 units are used, expect DO to be 3.3 to 3.6 mg/L, or more)
120-148	9500-12,500	Preferably 4 units except U5 (expect DO to be 2.9 to 3.3 mg/L, or more);
> 148	> 12,500	Operate Units 1-4 at full gate and add Unit 5 as needed for desired operations—expect DO to be 2.2 to 2.9 mg/L, or more

Turbine Inflow Conditions: DO 0 – 0.9 mg/L; Temperature = 16°C (approximately September 1 to mid-September and stays at 0 until lake mixing); DO objective in tailrace is 4 mg/L		
MWs desired	**Approximate flow (cfs)**	**For <u>Hourly</u> operations, the following is recommended:**
$\leq$ 31	$\leq$ 2500	Any unit, except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"
28-51	2500-4100	Any 2 units except U5 operated in the "last on, first off mode"; if 1 unit is used, expect DO to be 3.5 to 4 mg/L or more
47-65	4100-5300	Any 3 units except U5 operated in the "last on, first off mode"; if 2 units are used, expect DO to be 3.3 to 4 mg/L or more
60-76	5300-6400, limit for 4 mg/L	Any 4 units except U5 operated in the "last on, first off mode"; if 3 units are used, expect DO to be 3 to 3.3 mg/L or more;
76-120	6400-9500	Preferably 4 units except U5 (expect DO to be 2.5 to 4 mg/L, or more); if 3 units are used, expect DO to be 2.5 to 3.3 mg/L, or more)
120-148	9500-12,500	Preferably 4 units except U5 (expect DO to be 2 to 2.5 mg/L, or more);
> 148	> 12,500	Operate Units 1-4 at full gate and add Unit 5 as needed for desired operations—expect DO to be 1.5 to 2 mg/L, or more

Turbine Inflow Conditions: DO 0 – 0.9 mg/L; Temperature = 20°C (approximately September 1 to mid-September and stays at 0 until lake mixing); DO objective in tailrace is 4 mg/L		
MWs desired	**Approximate flow (cfs)**	**For Hourly operations, the following is recommended:**
≤ 25	≤ 2000	Any unit, except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"
21- 44	2000-3600	Any 2 units except U5 operated in the "last on, first off mode"; if 1 unit is used, expect DO to be 3.3 to 4 mg/L or more
43-57	3600-4800	Any 3 units except U5 operated in the "last on, first off mode"; if 2 units are used, expect DO to be 3.3 to 4 mg/L or more;
52-70	4800-6000, limit for 4 mg/L	Any 4 units except U5 operated in the "last on, first off mode"; if 3 units are used, expect DO to be 3.3 to 4 mg/L or more; if 2 units are used, expect DO to be 3.0 to 3.2 mg/L or more
70-120	6000-9500	Preferably 4 units except U5 (expect DO to be 2.3 to 4 mg/L, or more); if 3 units are used, expect DO to be 2.3 to 3.2 mg/L, or more)
120-148	9500-12,500	Preferably 4 units except U5 (expect DO to be 2 to 2.3 mg/L, or more);
> 148	>12,500	Operate Units 1-4 at full gate and add Unit 5 as needed for desired operations—expect DO to be 1.4 to 2 mg/L, or more

Lookup Tables for Daily Operations

(DO Target Is Greater Than or Equal to 5 mg/L)

Turbine Inflow Conditions: DO 4 – 4.9 mg/L; Temperature = 14°C (approximately July 1 to mid-July); DO objective in tailrace is 5 mg/L		
MWs desired	**Approximate flow (cfs)**	**For Daily operating conditions (i.e., operating ~ 24 hours per day), the following is recommended:**
Any MWs	Any flow level	Normal operations with U2 restricted for thermal load and U5 operated in the "last on, first off mode"

*See discussion on Page 1 Paragraph 1, and Items 2 and 4 on Pages 9 and 10.

Turbine Inflow Conditions: DO 3 – 3.9 mg/L; Temperature = 15°C (approximately mid-July to August 1); DO objective in tailrace is 5 mg/L		
MWs desired	**Approximate flow (cfs)**	**For <u>Daily</u> operating conditions (i.e., operating ~ 24 hours per day), the following is recommended:**
≤ 120	≤ 9500, limit for 5 mg/L	Normal operations with U2 restricted for thermal load and U5 operated in the “last on, first off mode”
120-148	9500-12,500	Any 4 units except U5 operated in the “last on, first off mode” (expect DO to be > 4.5 mg/L)
>148	>12,500	Operate Units 1-4 at full gate and add Unit 5 as needed for desired operations—expect DO to be 1.4 to 2 mg/L, or more (expect DO to be > 4 mg/L)

Turbine Inflow Conditions: DO 2 – 2.9 mg/L; Temperature = 16°C (approximately August 1 to mid-August); DO objective in tailrace is 5 mg/L		
MWs desired	**Approximate flow (cfs)**	**For <u>Daily</u> operating conditions (i.e., operating ~ 24 hours per day), the following is recommended:**
≤ 59	≤ 4700	Normal operations with U2 restricted for thermal load and U5 operated in the "last on, first off mode"
56-73	4700-5900	Any 3 units except U5 operated in the "last on, first off mode"; if 2 units are used, expect DO to be 4.7 to 5 mg/L
69-89	5900-7200, limit for 5 mg/L	Any 4 units except U5 operated in the "last on, first off mode"; if 3 units are used, expect DO to be 4.6 to 5 mg/L
89-120	7200-9500	Preferably 4 units except U5 (expect DO to be 4.1 to 5 mg/L, or more); if 3 units are used, expect DO to be 4.1 to 4.6 mg/L, or more)
120-148	9500-12,500	Preferably 4 units except U5 (expect DO to be 3.8 to 4.1 mg/L, or more);
> 148	> 12,500	Operate Units 1-4 at full gate and add Unit 5 as needed for desired operations—expect DO to be 3.2 to 3.8 mg/L, or more

Turbine Inflow Conditions: DO 1 – 1.9 mg/L; Temperature = 16°C (approximately mid-August to September 1); DO objective in tailrace is 5 mg/L		
MWs desired	**Approximate flow (cfs)**	**For <u>Daily</u> operating conditions (i.e., operating ~ 24 hours per day), the following is recommended:**
≤ 25	≤ 2000	Any unit, except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"
21- 44	2000-3600	Any 2 units except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"; if 1 unit is used, expect DO to be 4.3 to 5 mg/L or more
39-60	3600-5000	Any 3 units except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"; if 2 units are used, expect DO to be 4.1 to 5 mg/L or more
56-69	5000-5900, limit for 5 mg/L	Any 4 units except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"; if 3 units are used, expect DO to be 4.2 to 5 mg/L or more; if 2 units are used, expect DO to be 4 to 4.1 mg/L or more
69-77	5900-6500	Preferably 4 units except Unit 2 for thermal load restrictions and U5 (expect DO to be 4.7 to 5 mg/L, or more); if 3 units are used, expect DO to be 4.1 to 4.3 mg/L, or more; if 2 units are used, expect DO to be 3.8 to 4 mg/L, or more
77-120	6500-9500	Preferably 4 units except U5 (expect DO to be 3.3 to 4.7 mg/L, or more); if 3 units are used, expect DO to be 3.3 to 4.1 mg/L, or more;
120-148	9500-12,500	4 units except U5 (expect DO to be 3 to 3.3 mg/L, or more)
> 148	> 12,500	Operate Units 1-4 at full gate and add Unit 5 as needed for desired operations—expect DO to be 2.2 to 2.9 mg/L, or more

Turbine Inflow Conditions: DO 0 – 0.9 mg/L; Temperature = 16°C (approximately September 1 to mid-September and stays at 0 until lake mixing); DO objective in tailrace is 5 mg/L		
MWs desired	**Approximate flow (cfs)**	**For <u>Daily</u> operating conditions (i.e., operating ~ 24 hours per day), the following is recommended:**
≤ 18	≤ 1500	Any unit, except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"
14-32	1500-2800	Any 2 units except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"; if 1 unit is used, expect DO to be 3.5 to 5 mg/L or more
29-42	2800-3800	Any 3 units except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"; if 2 units are used, expect DO to be 4.2 to 5 mg/L or more
39-51	3800-4700, limit for 5 mg/L	Any 4 units except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"; if 3 units are used, expect DO to be 4.4 to 5 mg/L or more; if 2 units are used, expect DO to be 3.7 to 4.2 mg/L or more
51-76	4700-6400	Preferably 4 units except Unit 2 for thermal load restrictions and U5 (expect DO to be 4 to 5 mg/L, or more); if 3 units are used, expect DO to be 3.4 to 4.4 mg/L, or more; if 2 units are used, expect DO to be 3 to 3.7 mg/L, or more
76-120	6400-9500	Preferably 4 units except Unit 2 for thermal load restrictions and U5 (expect DO to be 2.5 to 4 mg/L, or more); if 3 units are used, expect DO to be 2.5 to 3.3 mg/L, or more;
120-148	9500-12,500	4 units except U5 (expect DO to be 2 to 2.5 mg/L, or more)
> 148	> 12,500	Operate Units 1-4 at full gate and add Unit 5 as needed for desired operations—expect DO to be 1.5 to 2 mg/L, or more

Turbine Inflow Conditions: DO 0 – 0.9 mg/L; Temperature = 20°C (approximately September 1 to mid-September and stays at 0 until lake mixing); DO objective in tailrace is 5 mg/L		
MWs desired	**Approximate flow (cfs)**	**For <u>Daily</u> operating conditions (i.e., operating ~ 24 hours per day), the following is recommended:**
≤ 15	≤ 1300	Any unit, except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"
11-25	1300-2300	Any 2 units except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"; if 1 unit is used, expect DO to be 3.8 to 5 mg/L or more
22-35	2300-3300	Any 3 units except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"; if 2 units are used, expect DO to be 4.2 to 5 mg/L or more; if 1 unit is used, expect DO to be 3.4 to 3.8 mg/L or more
32-40	3300-3900, limit for 5 mg/L	Any 4 units except Unit 2 for thermal load restrictions and U5 operated in the "last on, first off mode"; if 3 units are used, expect DO to be 4.7 to 5 mg/L or more; if 2 units are used, expect DO to be 3.7 to 4.2 mg/L or more
40-70	3900-6000	Preferably 4 units except Unit 2 for thermal load restrictions and U5 (expect DO to be 4 to 5 mg/L, or more); if 3 units are used, expect DO to be 3.2 to 4.5 mg/L, or more; if 2 units are used, expect DO to be 3 to 3.8 mg/L, or more
70-120	6000-9500	Preferably 4 units except Unit 2 for thermal load restrictions and U5 (expect DO to be 2.3 to 4 mg/L, or more); if 3 units are used, expect DO to be 2.3 to 3.2 mg/L, or more;
120-148	9500-12,500	4 units except U5 (expect DO to be 2 mg/L, or more)
> 148	> 12,500	Operate Units 1-4 at full gate and add Unit 5 as needed for desired operations—expect DO to be 1.5 to 2 mg/L, or more

FIGURES

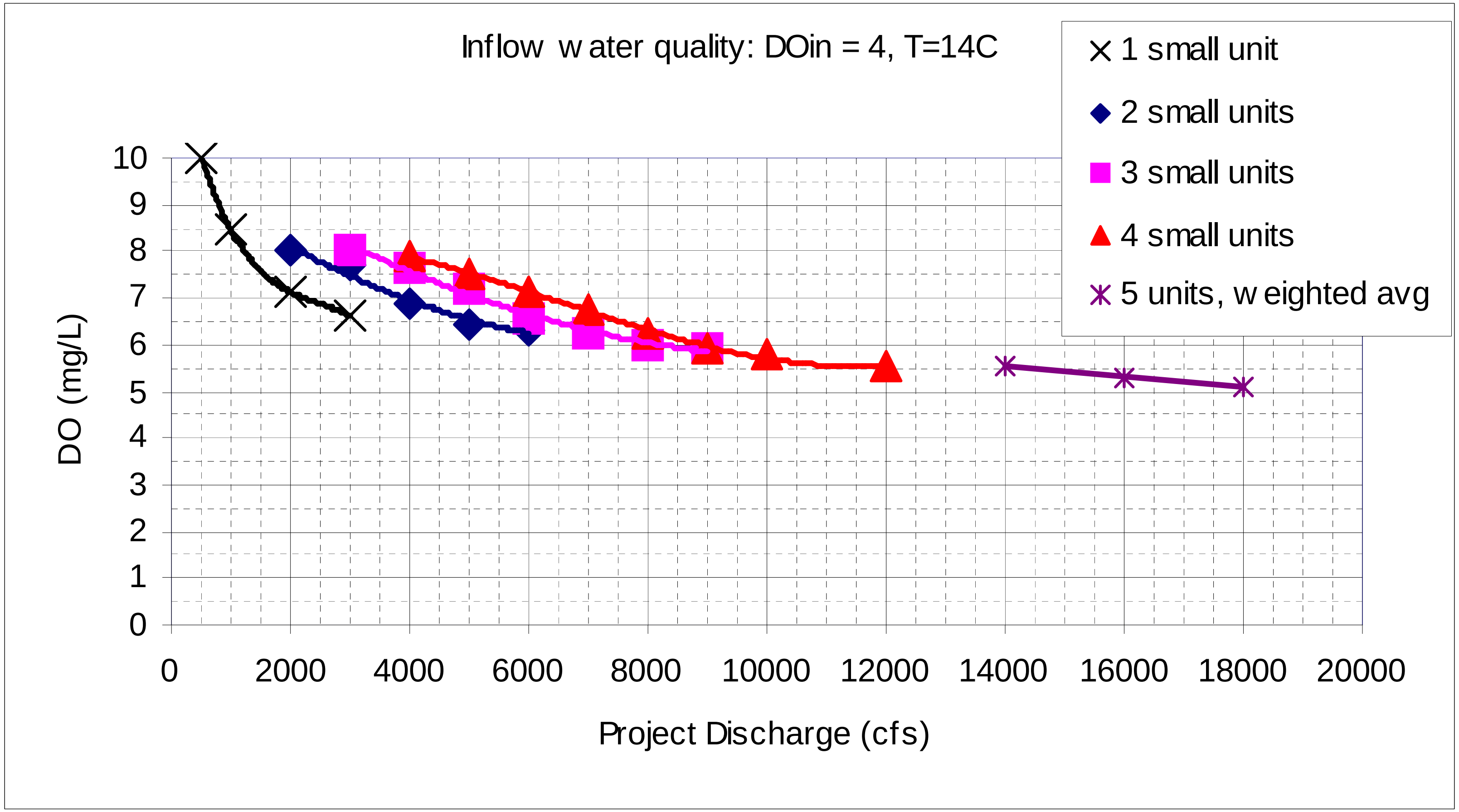


Figure 1: Model predicted DO versus total project discharge for the indicated water quality and operating conditions. This plot was used to develop the LUTs.

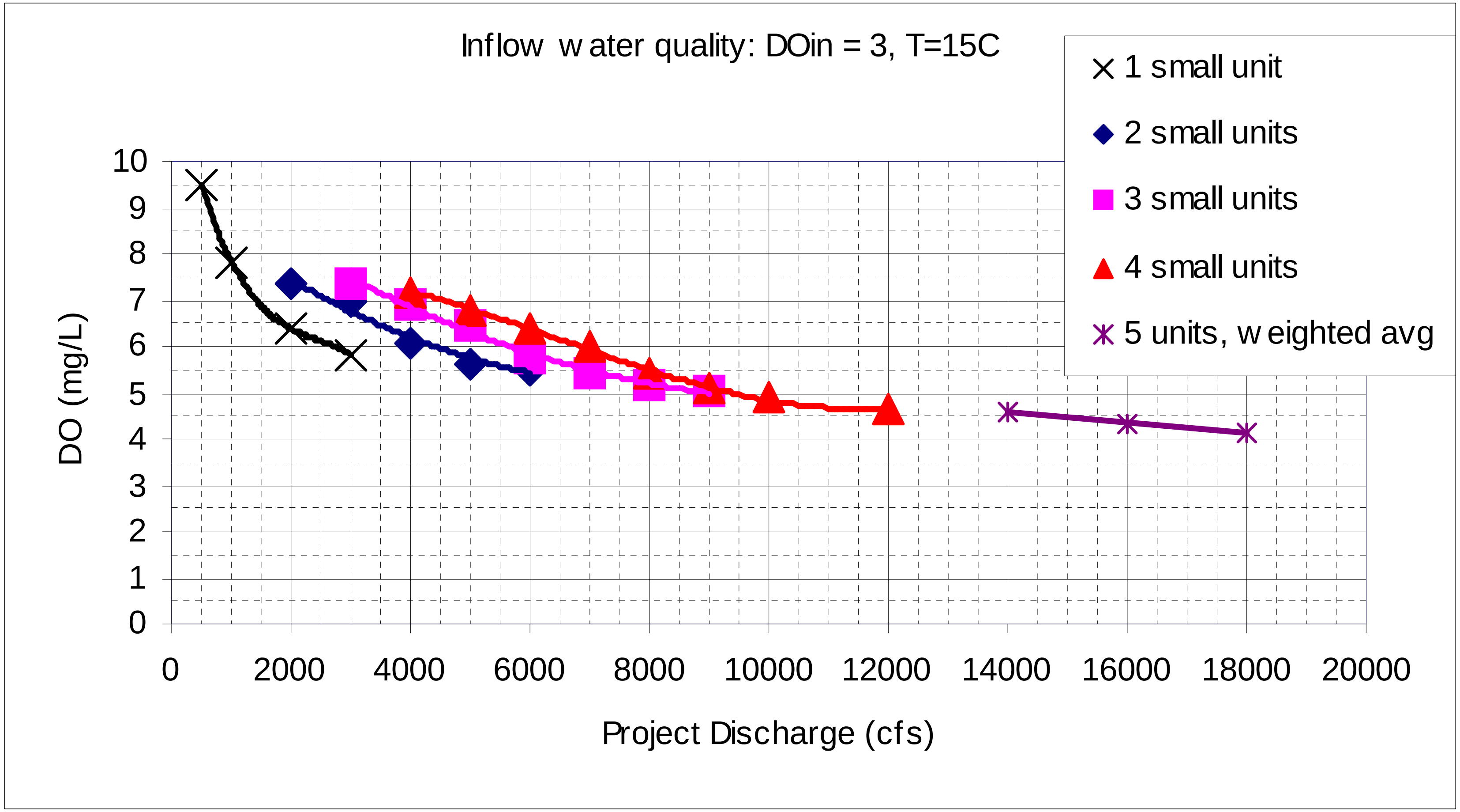


Figure 2: Model predicted DO versus total project discharge for the indicated water quality and operating conditions. This plot was used to develop the LUTs.

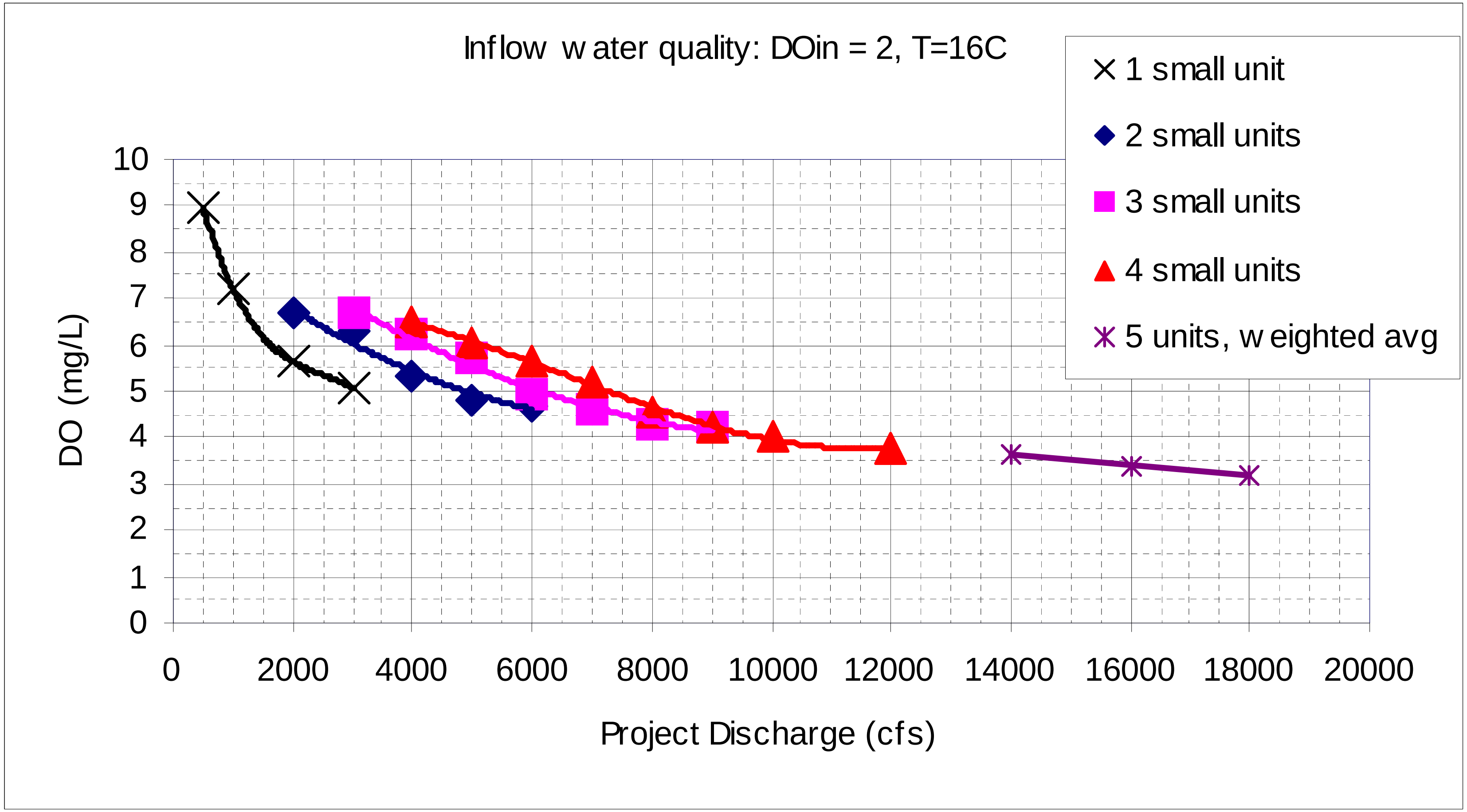


Figure 3: Model predicted DO versus total project discharge for the indicated water quality and operating conditions. This plot was used to develop the LUTs.

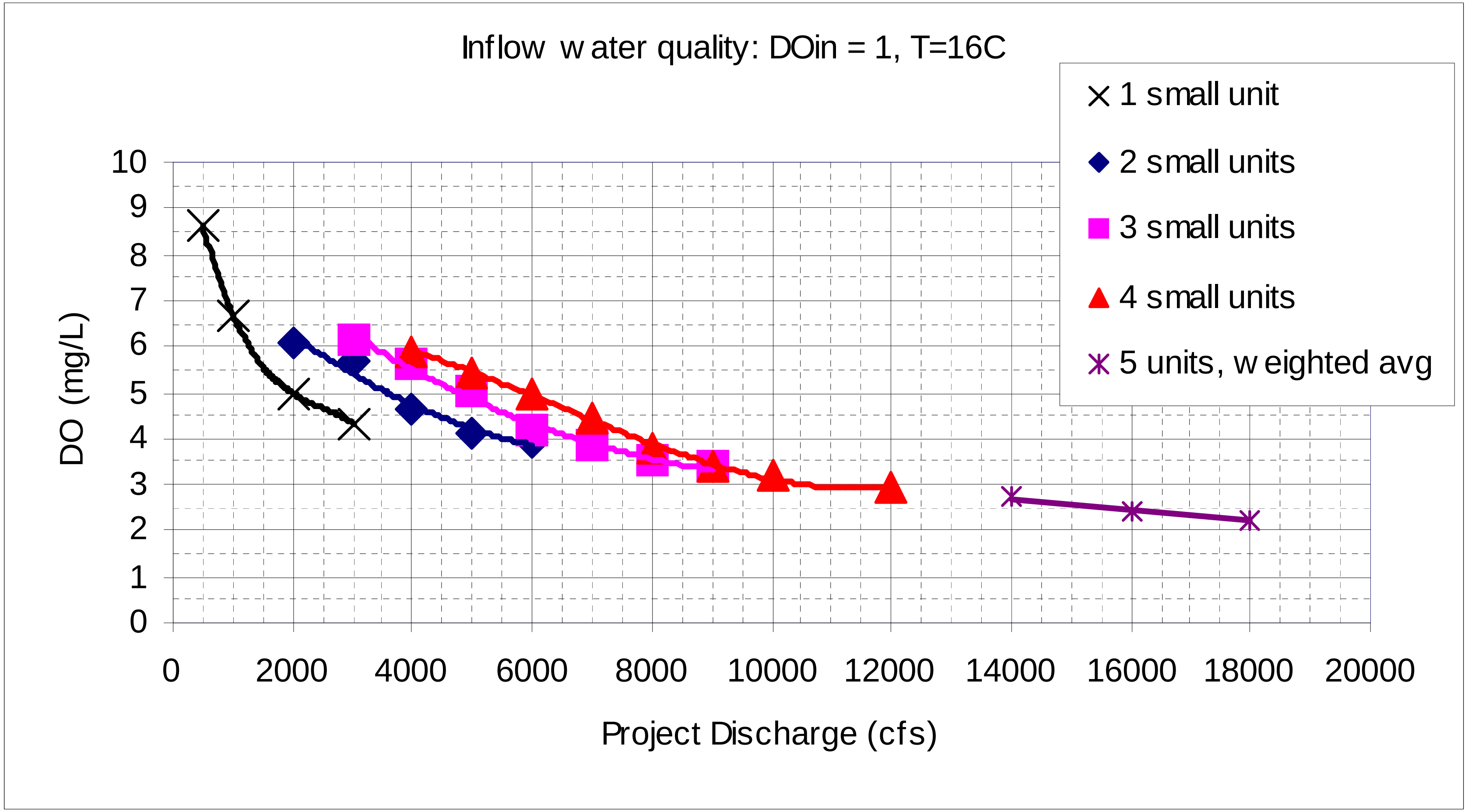


Figure 4: Model predicted DO versus total project discharge for the indicated water quality and operating conditions. This plot was used to develop the LUTs.

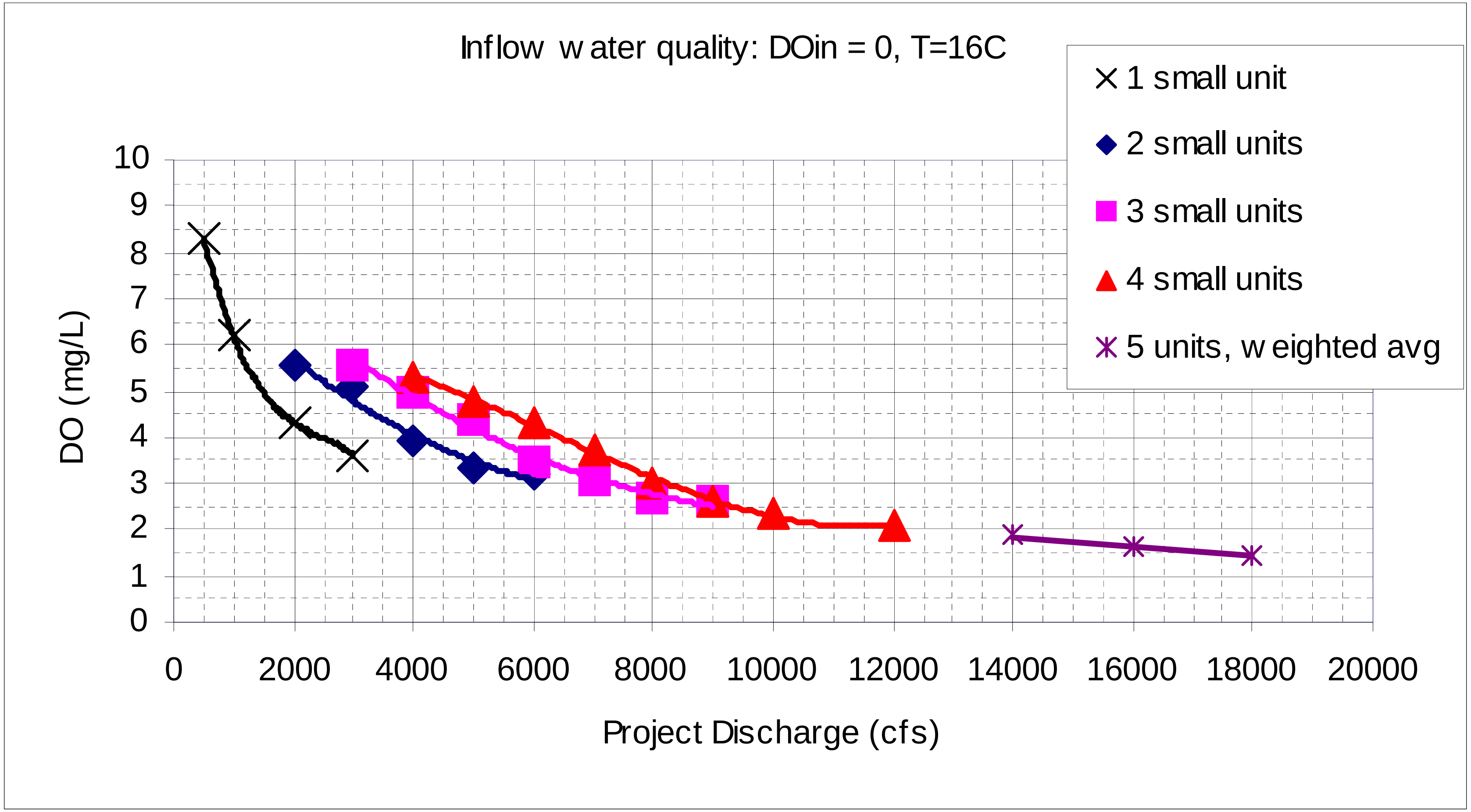


Figure 5: Model predicted DO versus total project discharge for the indicated water quality and operating conditions. This plot was used to develop the LUTs.

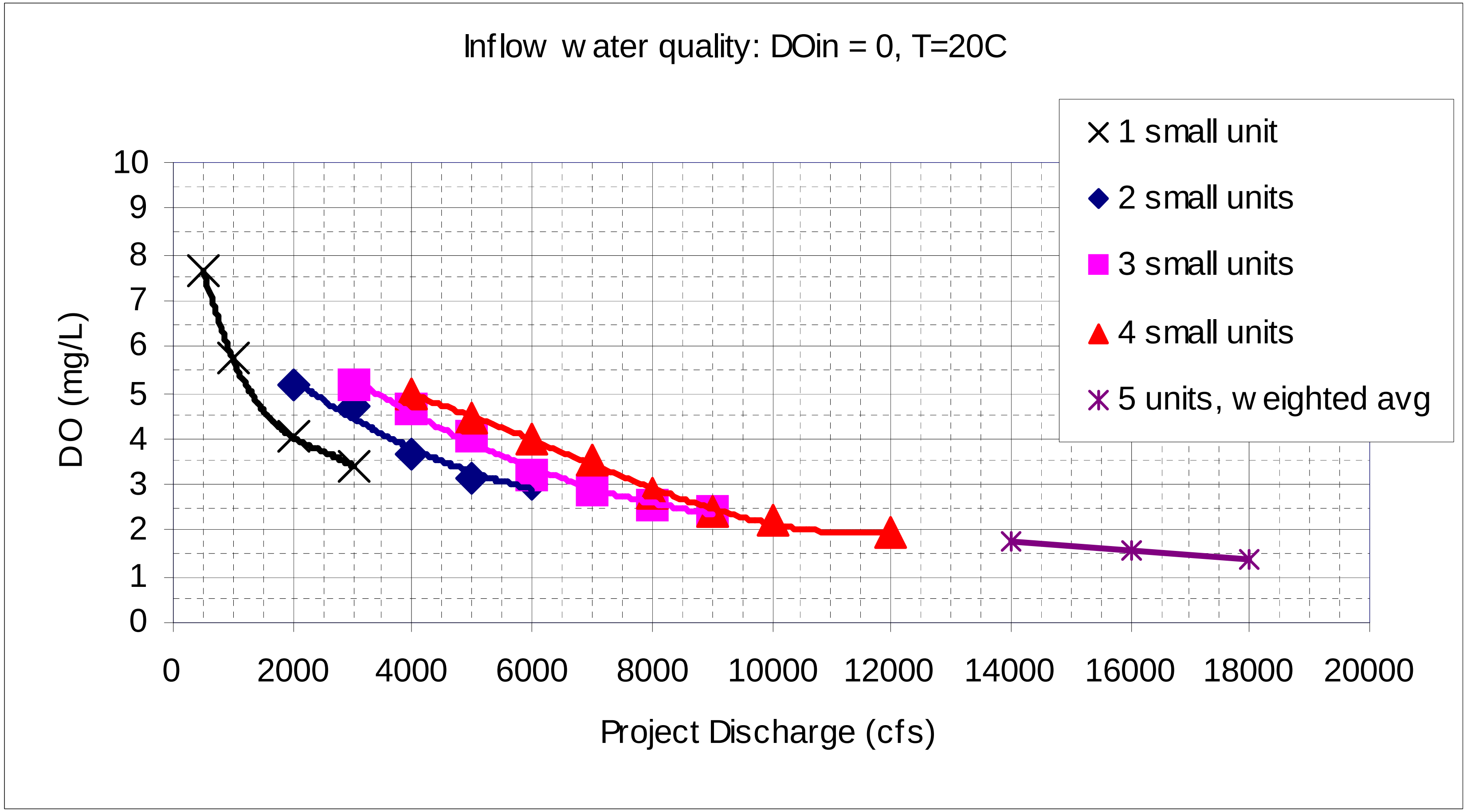


Figure 6: Model predicted DO versus total project discharge for the indicated water quality and operating conditions. This plot was used to develop the LUTs.

Stacia Hoover

From: Alan Stuart
Sent: Tuesday, May 23, 2006 4:21 PM
To: Alan Stuart; 'Amanda Hill (Amanda_Hill@fws.gov)'; 'Dick Christie (dchristie@infoave.net)'; 'Hal Beard'; 'Prescott Brownell (Prescott.Brownell@noaa.gov)'; 'gjobsis@americanrivers.org'; 'Patrick Moore'; 'Gina Kirkland - DHEC'; 'cdwood@usgs.gov'; 'Sarah W Ellisor'; 'Richard Roos-Collins'; 'Julie Gantenbein'
Cc: BARGENTIERI@scana.com; 'Jim Ruane'; RMAHAN@scana.com; 'Ray Ammarell (RAmmarell@scana.com)'; 'Steve Summer'; 'Tom Eppink'; 'Brian J. McManus'; 'BOWLES, THOMAS M'; Alison Guth; 'EPPINK, THOMAS G'
Subject: 2005 Final Operations Plan

Good afternoon,

Attached for your records is the Final 2005 Operations Report for Saluda Hydro. The report reflects the recommendations made during the March 23, 2006 meeting convened at Carolina Research Park.

Thank you for all of your efforts and if you have questions please give me a call.

Thank you,
Alan

2005 Aeration
Operations Repor...

SOUTH CAROLINA ELECTRIC AND GAS COMPANY

COLUMBIA, SOUTH CAROLINA

SALUDA HYDROELECTRIC PROJECT

2005 ANNUAL FINAL REPORT ON WATER QUALITY AND AERATION OPERATIONS AT THE SALUDA PROJECT

MAY 2006

Prepared by:

Kleinschmidt
Energy & Water Resource Consultants

SOUTH CAROLINA ELECTRIC AND GAS COMPANY
COLUMBIA, SOUTH CAROLINA

SALUDA HYDROELECTRIC PROJECT

2005 ANNUAL FINAL REPORT ON WATER QUALITY AND AERATION OPERATIONS AT THE SALUDA PROJECT

MAY 2006

Prepared by:

Kleinschmidt
Energy & Water Resource Consultants

2005 ANNUAL REPORT ON WATER QUALITY AND AERATION OPERATIONS AT THE SALUDA PROJECT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

2005 ANNUAL REPORT ON WATER QUALITY AND AERATION OPERATIONS AT THE SALUDA PROJECT

INTRODUCTION

Section 8.5 of the Settlement requires that SCE&G prepare an annual summary of the following:

1. DO and other water quality monitoring results for Lake Murray and the lower Saluda River;
2. A preliminary evaluation of the implementation of the prior year's Operating Plan; and
3. Preliminary recommendations for the coming year's Operating Plan.

This report will present the results of water quality monitoring[1] for the period July 25 through the time of lake turnover that occurred in late November 2005. Then, an evaluation of maintaining the goal (Sections 9.2 and 9.3 of the Settlement) of the water quality standard will be presented, subject to the conditions identified in Section 9.3.

The following background considerations are restated from the 2004 Operating Plan:

- South Carolina Electric & Gas Company (SCE&G) is committed to complying with the Dissolved Oxygen (DO) standard for the Saluda River downstream from Saluda Project to the extent practicable. Factors affecting the ability to insure continuous compliance include:
    - the limited capability for aeration of water discharged through the turbine units;
    - the requirement that SCE&G manage water levels in Lake Murray for safety and other reasons;

[1] As with any *in-situ* continuous monitor, anomalous readings occur from time to time, due to equipment fouling or malfunction. If the USGS determines the data are suspect through their Quality Control/Quality Assurance Program, that data may be ignored, appropriately adjusted, or otherwise dealt with according to their final determination. It is acknowledged that the USGS data is reported initially as "provisional." SCE&G will use it subject to the data error issues discussed here.

    - the need to use Saluda Hydro for the special operating needs specified under Item 9.3 of the settlement agreement dated May 19, 2004; and
    - the need to meet SCE&G's reserve obligation to maintain electric load-generation balancing and management of local voltages and system frequency in real time.
- Generators sometimes fail, and generation failures generally are unpredicted and sudden, upsetting the load-generation balance. Because electricity cannot be stored, any sudden reduction in generation cannot be handled by an inventory, as might happen in most other kinds of business. Instead, generation losses must be met by reserve generation that can be dispatched instantly, before voltage sags or frequency excursions lead to local or widespread blackouts. SCE&G is a member of the Virginia-Carolinas Southeastern Electric Reliability Council sub-region (VACAR), whose members are bound in a reserve-sharing agreement by which each has agreed to assist any other member in generation emergencies. SCE&G must employ its reserves to meet its own generation emergencies before calling on assistance from other VACAR members, and it must be constantly ready to provide reserve generation to other VACAR members. Generally, the reserves required to be maintained by SCE&G are in the range of 190-200 MW, which matches the capacity of the Saluda Project and its ability to respond quickly to any generation outage on its system.

During the low DO period of 2005, SCE&G implemented the plan in Appendix A:

- The plan addressed the limited objectives identified in the settlement agreement, i.e., doing what reasonably could be done to improve the likelihood that stream-specific DO standards would be met in the Lower Saluda River, while, at the same time, not constraining in any manner SCE&G's ability to use the Saluda Project to meet its reserve obligations.
- The plan also included evaluations of hub baffles and existing water quality monitoring equipment

Overview of 2005 Aeration Operations:

The SC site-specific DO standard was maintained during most of the period July 25 through late November.

Special challenges during 2005 were:

1) Implementation of aeration systems using hub baffles without the benefit of look-up tables to provide the amount of DO enhancement that can be expected at various levels of generation;
2) Special operations at high flows that were greater than that required for generation (i.e., for aeration and monitor location studies and for special requests for rescue training by the City of Columbia);
3) Extended outages for Units 3 and 4, and a short term outage for Unit 2; and
4) Significant apparent fouling of the DO monitor.

A positive development was the implementation of the aeration systems with hub baffles installed and the availability of relatively higher DO levels at the intake of unit 5 starting about October 20. However, when unit 5 was operated in conjunction with any other unit, the DO monitor did not measure the benefit of the higher DO levels in the releases from unit 5.

The DO measured by the USGS monitor was less than the standard on six occasions when the flow through the Saluda Project was greater than flow levels at which current turbine aeration can attain the DO standard:

1. August 25-27, a special pool level draw down for Hurricane Katrina
2. August 31-Sept 8, pool level management
3. October 2-8, aeration studies
4. October 31, a peak flow lasting less than an hour, probably for system reserve
5. October 23-November 2, rescue training
6. November 1-3, monitor location studies

All the excursions are summarized in a summary section following the detailed presentations of each period of excursions.

SUMMARY OF 2005 OPERATIONS AND WATER QUALITY MONITORING RESULTS

Water Management and Spinning Reserve:

The gauged inflows and pool level elevations of Lake Murray over the period of assessment are presented in Figures 1 and 2.

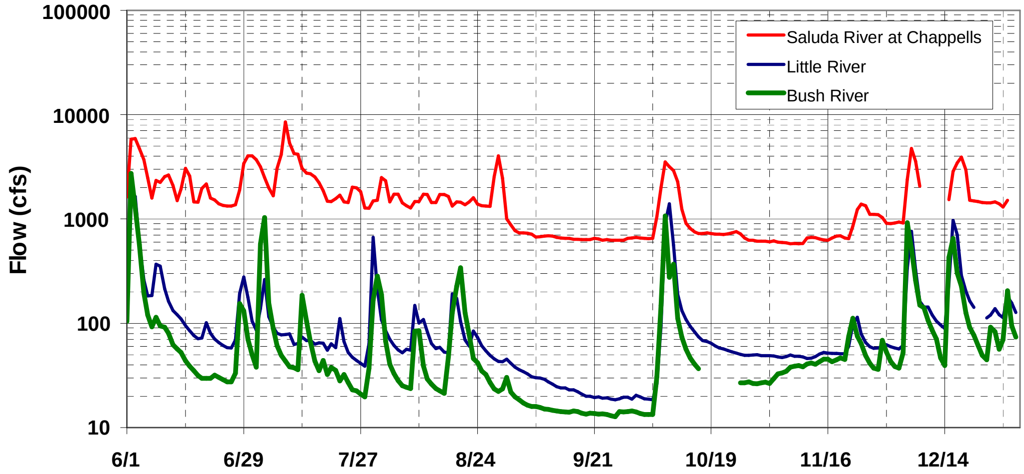


Figure 1: 2005 Lake Murray Gauged Inflows

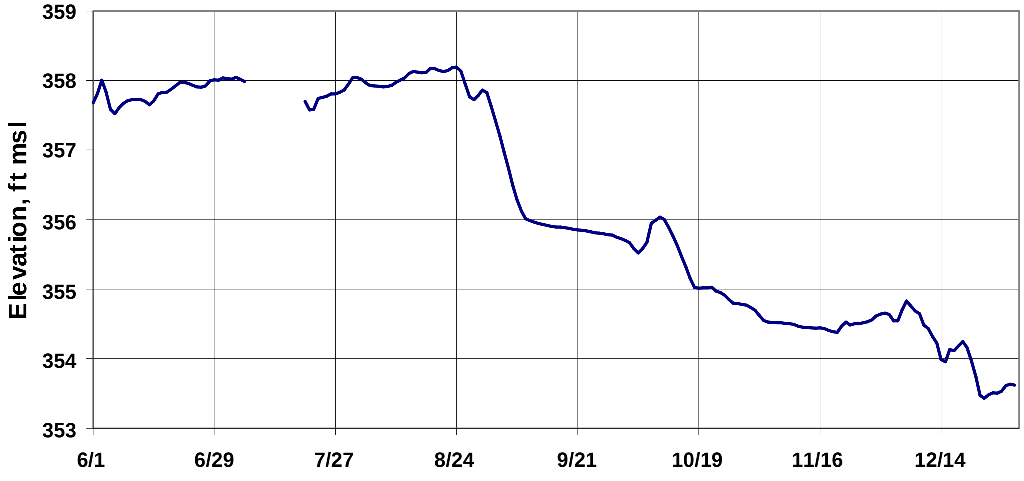


Figure 2: 2005 Pool Elevation of Lake Murray

Generally, the flows in the discharge from the Saluda Project were low except for the following periods when hourly flows equaled or exceeded 8,000 cfs:

1. Generation was increased for about two hours the evening of July 26, due to one of SCE&G's larger coal fired stations tripping off line about 8:38 PM. Peak flow was 12,300 cfs, but indicated USGS DO dropped to a minimum of only 4.5 mg/L due to the relatively high inflow DO to the units.
2. On October 4 and 8 generation flows were increased due to aeration studies. These studies were conducted to develop revised look-up tables considering the addition of hub baffles to all the units.
3. On October 23, October 26, and November 2 generation flows were increased due to high river flows requested by the City of Columbia for swift water rescue training.
4. On November 3 generation flows were increased due to studies for evaluating the location for a new water quality monitoring system.

Over the period August 25-27, median flow was increased to 5400 cfs in anticipation of Hurricane Katrina.

Over the following periods, the respective median flows occurred to maintain the reservoir drawdown plan:

1. August 31 through September 9, 5300 cfs, and
2. October 10-18, 3900 cfs.

On August 31, SCE&G began the process of drawing down the lake for fall. The lake level began the period at about el. 357.73. SCE&G planned to maintain a target elevation of about 356 ft. during September, subject to weather and system requirements. The SCE&G water management plan called for the pool level to be lowered to elevation 354 msl by the end of November. They were attempting to manage the pool level by dropping it about one foot per month during September through November. SCE&G worked with SCDOT and their contractor to coordinate their work on widening S.C. Route 6 with SCE&G's proposed repairs to the upstream face armor (riprap) on the dam. SCE&G tentatively planned to lower the lake to below elevation 350 msl beginning in early January 2006.

Unit Operations and Aeration Systems:

Hub baffles were installed on all the units prior to the low DO period of 2005, and all air valves were 100% open during the entire low DO period.

Unit 5 was operated on the basis of “last unit on, and first unit off” during most of the low DO period, until October 9 when it was used with Unit 1 to manage lake levels. Unit 3 had problems with headcover leakage and was out of service for the period from the week of August 8 through the week of September 19; and, after it was returned to service, the unit did not draw air into the draft tube. Unit 4 was out of service due to generator problems for the period from the week of August 22 through the week of November 14. Unit 2 experienced an outage due to penstock leakage for the starting October 9 through about October 18.

Water Quality Data:

Figures 3 and 4 present the profiles of temperature and DO for the forebay of Lake Murray during the period March 9 through December 1. These profiles show that DO in front of the intakes for Units 1-4 was near zero from the end of August to the end of November, but the USGS tailrace monitor indicated that DO increased on November 21 probably due to withdrawal zone expansion for water from higher in the water column in the lake.

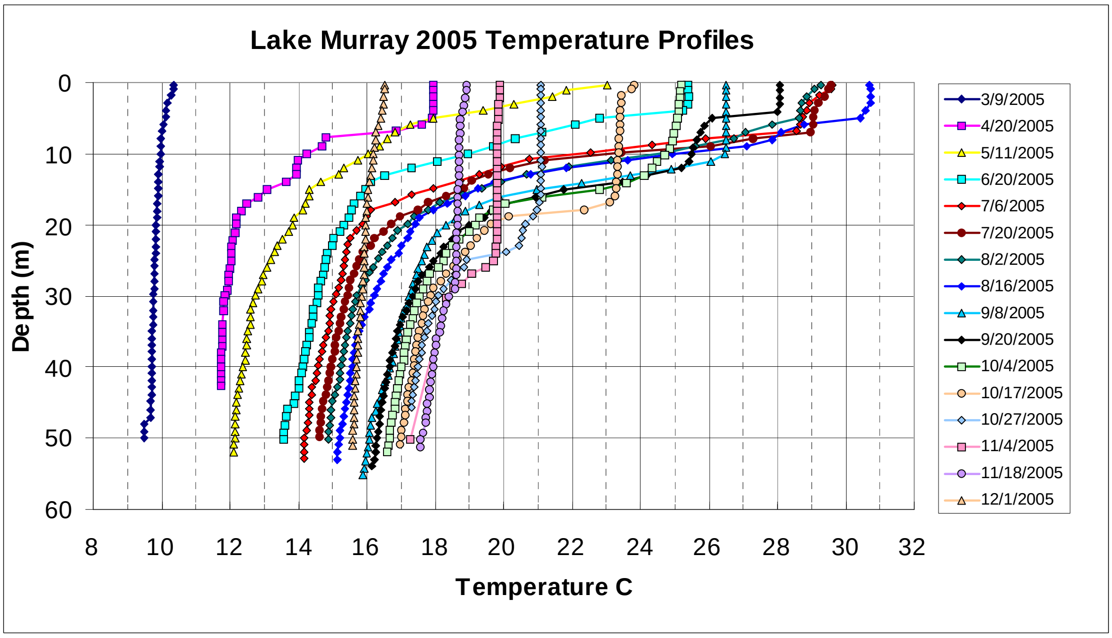


Figure 3: 2005 Temperature Profiles in Lake Murray

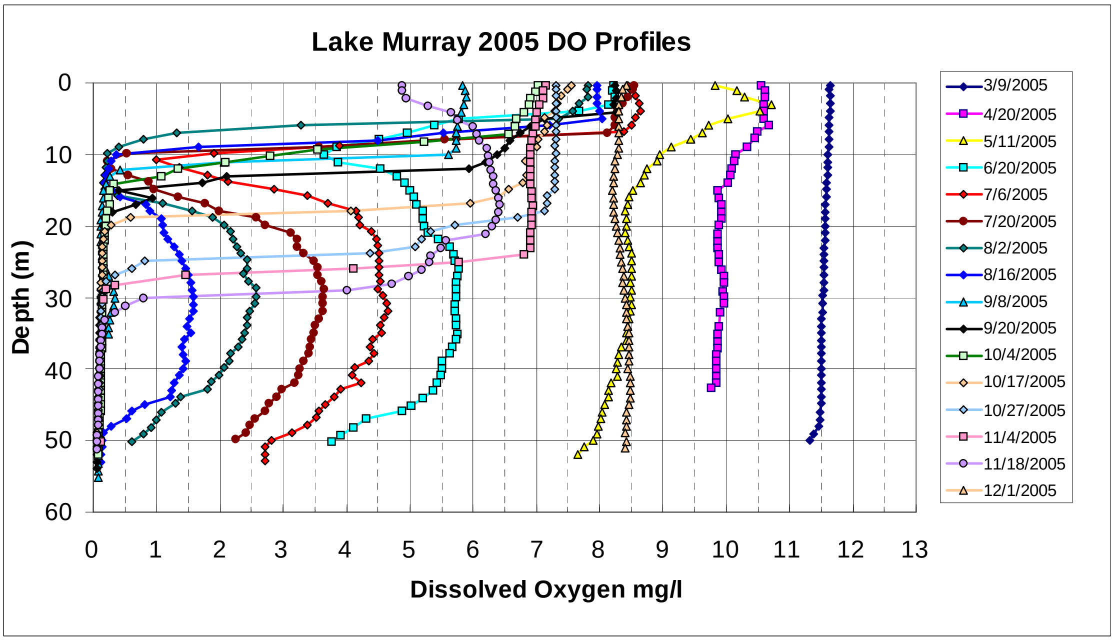


Figure 4: 2005 DO Profiles in Lake Murray

Figure 5 presents the temperature and DO results from the USGS monitors in the forebay of Lake Murray. Figure 5 shows that the temperature and DO at the intake for Unit 5 increased to about the same level as the surface water in the lake on October 25. While the temperature conditions at these two elevations appeared to be about the same, a review of deviations in DO shows that minor differences in temperature resulted in noticeable differences in DO (i.e., DO at the level of Unit 5 was usually lower than a the surface of the lake when the temperature of the lower monitor was ~ 1 C^{o} lower than the surface temperature). These observations are consistent with observations from previous years. Notice that indicated DO at the surface dropped to 1-2 mg/L starting on November 11 and continued to be low until November 20—it is highly unlikely that DO actually dropped to these levels at the surface (i.e., see the DO profile collected on November 18 in Figure 4.)

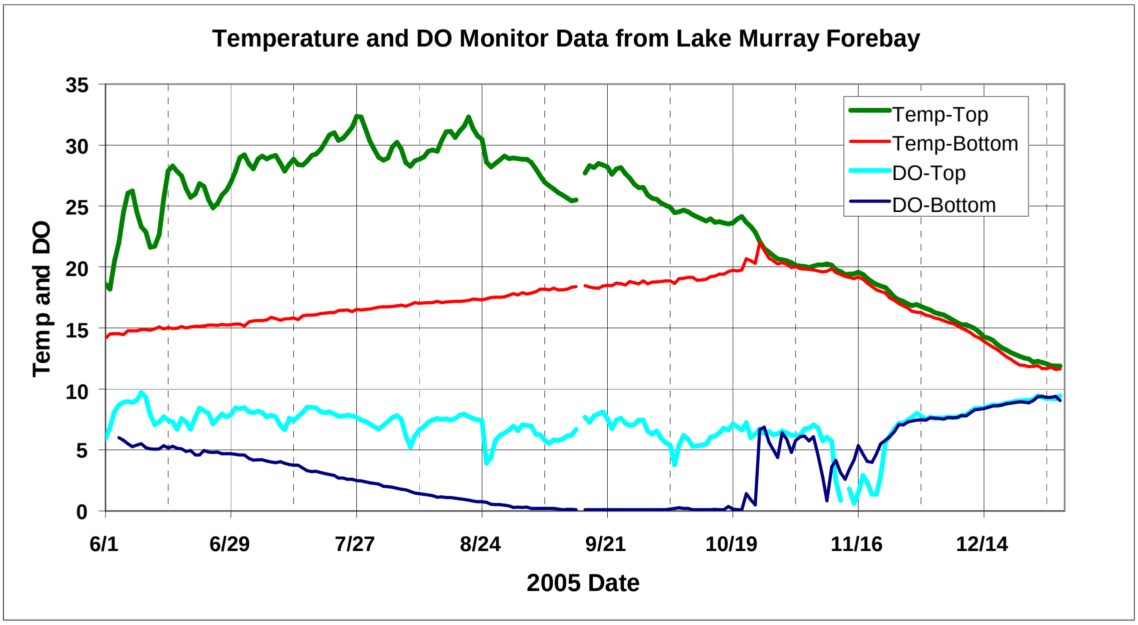


Figure 5: Temperature and DO Monitor Data from Lake Murray Forebay

Figure 6 presents the temperature and DO results of measurements at the USGS monitor (02168504) immediately downstream from the Saluda Powerhouse. The graph includes the data recorded by the monitor as adjusted by USGS and the pre-calibration measurements of the monitor and a separate field monitor by USGS when they maintained the monitor. It also includes the flow measurements by the USGS gauge as well as the daily average and the 30-day average DO values.

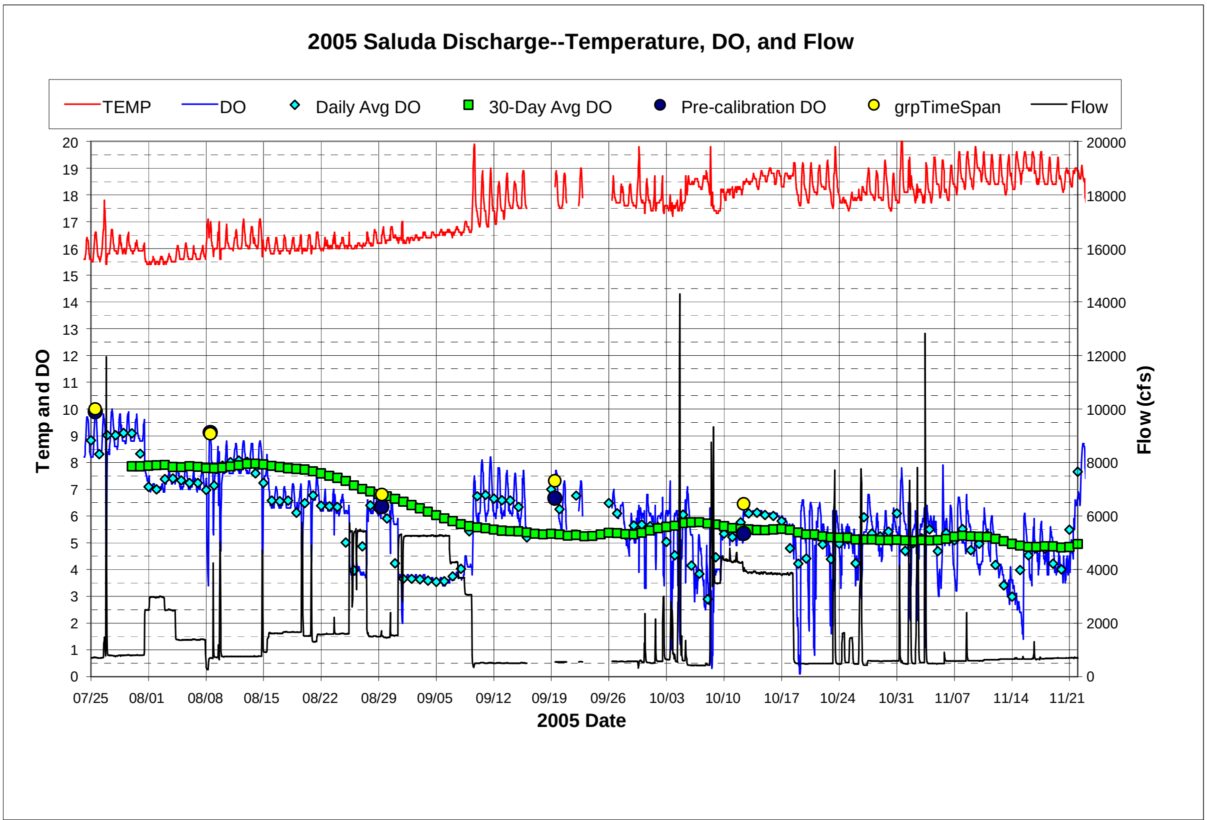


Figure 6: 2005 Saluda Discharge – Temperature, DO, and Flow

Figure 7 presents the temperature and DO results measurements at the USGS monitor (02169000) about eight miles downstream from the Saluda Powerhouse. The graph includes the data recorded by the monitor as adjusted by. It also includes the flow measurements by the USGS gauge as well as the daily average DO values.

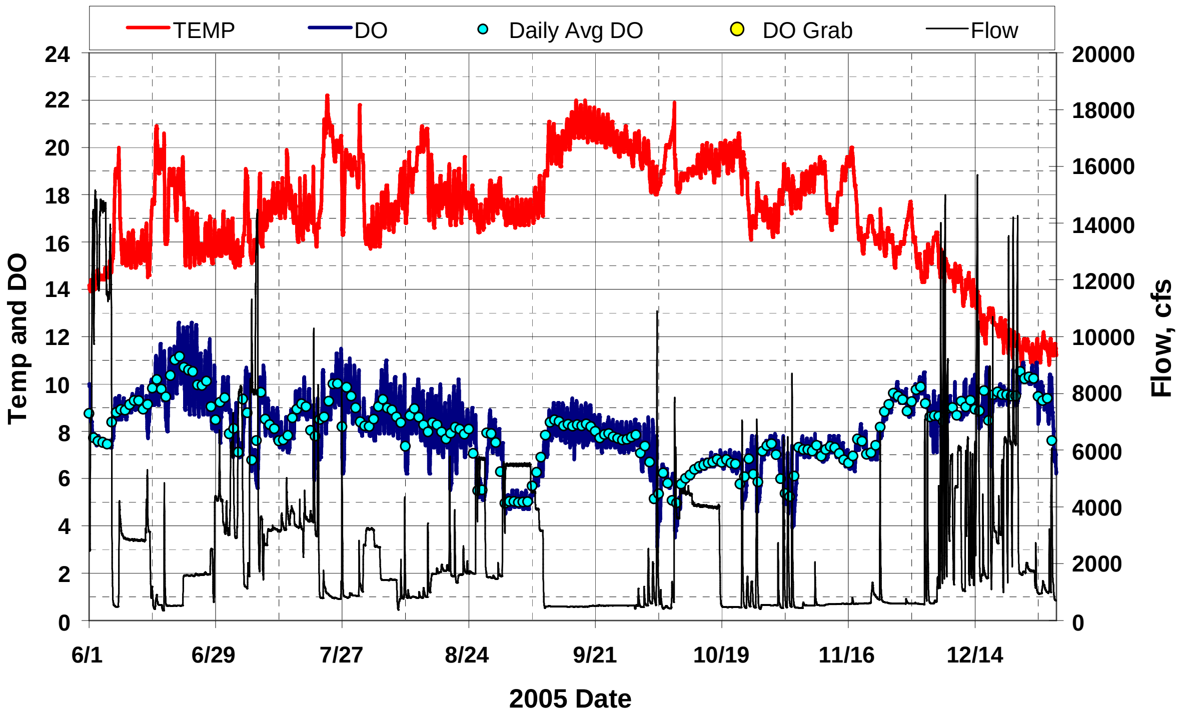


Figure 7: Lower Saluda River – USGS Columbia Gauge

EVALUATION OF 2005 OPERATIONS

In general, DO was better in the tailrace during 2005 considering the benefits of the hub baffles being added to Units 1 through 5. Excursions of DO less than the SCDHEC site-specific DO standard attributed to operations occurred four times, and all these occasions occurred when the flow through the Saluda Project was greater than flow levels at which available turbine aeration could attain the DO standard—two of these times were for pool level management. Excursions of DO less than the DO standard occurred three times during studies requiring less aeration or requested special flows and seven times when the DO monitor was suspected to be fouled or not fully accounting for the benefit of higher DO levels in the discharge from Unit 5.

Figure 6 shows that these excursions occurred over the following time periods:

1. August 8 (Figure 8)
2. August 25-August 27 (Figure 9)
3. August 31-September 9 (Figure 10)
4. September 22-September 24 (Figure 11)
5. September 30 (Figure 12)
6. October 2-October 8 (Figure 13)
7. October 18-October 26 (Figure 14)
8. October 30-November 6 (Figure 15)
9. November 12-November 20 (Figure 16)

Figures 8-16 provide zoomed-in views of the DO and flow conditions on these dates so that the low DO occurrences can be examined in more detail. Following is a more detailed explanation of what happened on these dates.

Turbine vents on Units 1, 2, 4, and 5 were opened to 100 percent during the entire period covered by this assessment. Hub baffles had been installed on Units 1-5 before this same period. The vents on Unit 3 were closed during most of the period (starting the week of August 8-14 due to problems with head cover leakage, and Unit 3 was used only in emergency situations or as requested during studies. Unit 4 went out of service during the week of August 22-28 and remained out of service until the period November 14-27.

August 8 (Figure 8):

The excursion below 4.0 mg/l on the morning of August 8 (minimum DO was 3.4 mg/L and DO was less than 4.0 mg/L about 3 hours) was possibly caused by respiration associated with aquatic plants and related to the discharge from Saluda Hydro dropping below 300 cfs, due to operational issues at the plant. System Control coordinated with Saluda Hydro personnel to avoid minimum flows at 300 cfs.

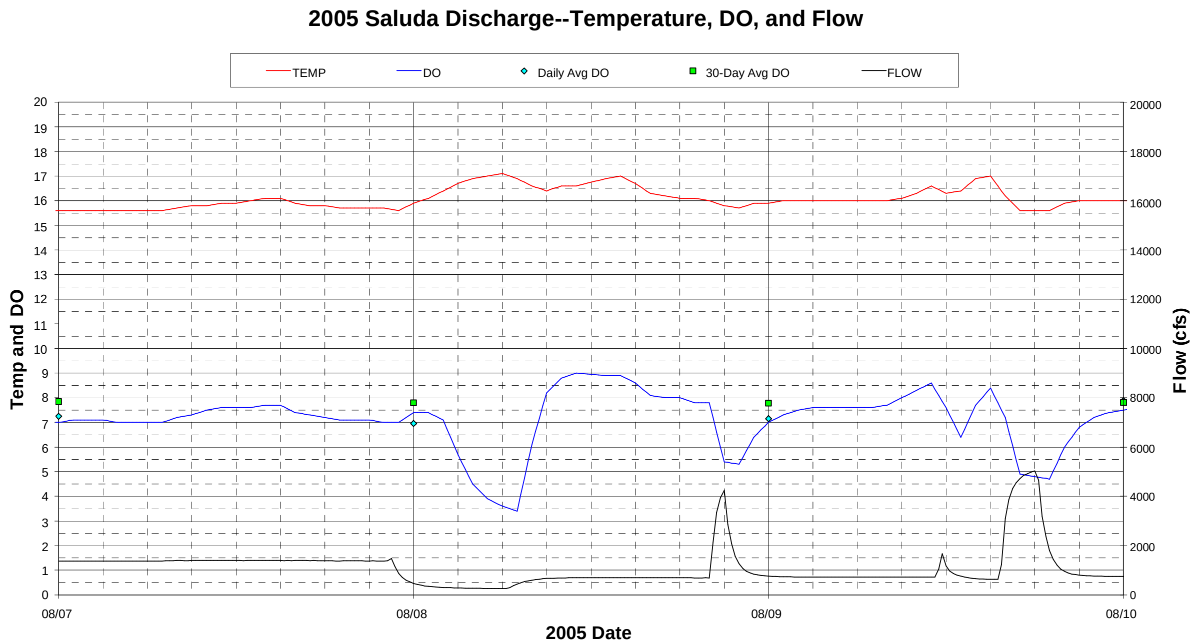


Figure 8: 2005 Saluda Discharge – Temperature, DO, and Flow

August 25-August 27 (Figure 9):

The excursions below 4.0 mg/L were relatively minor (in terms of frequency and duration as well as magnitude—minimum DO was 3.6 mg/L) considering the amount of water that was passed through the plant during this period. Flows were about 5500 cfs over a period of about 2 days because SCE&G was drawing down the pool in anticipation of Hurricane Katrina passing through the area. Units 1 and 2 were used during this period. Prior to the addition of the hub baffles, the DO would have been 1-2 mg/L at this flow level. The DO during this entire generation period was near 4 mg/L.

Generation at Saluda Hydro was increased on August 25, based on forecasts regarding Hurricane Katrina. Generation was reduced when the projected storm track changed. Indicated dissolved oxygen levels in the Saluda Hydro tailrace generally remained between about 6.0 mg/l and 7.0 mg/l during the report period, except during the period of increased generation, when indicated DO dropped around 4.0 mg/L. Unit 4 was unavailable due to electrical problems with the generator. Unit 3 was restricted to emergency use only due to vibrations caused by head cover leakage. Unit 5 was scheduled to be the "last on, first off" unit for normal dispatch to meet reserve generation needs during the low DO period.

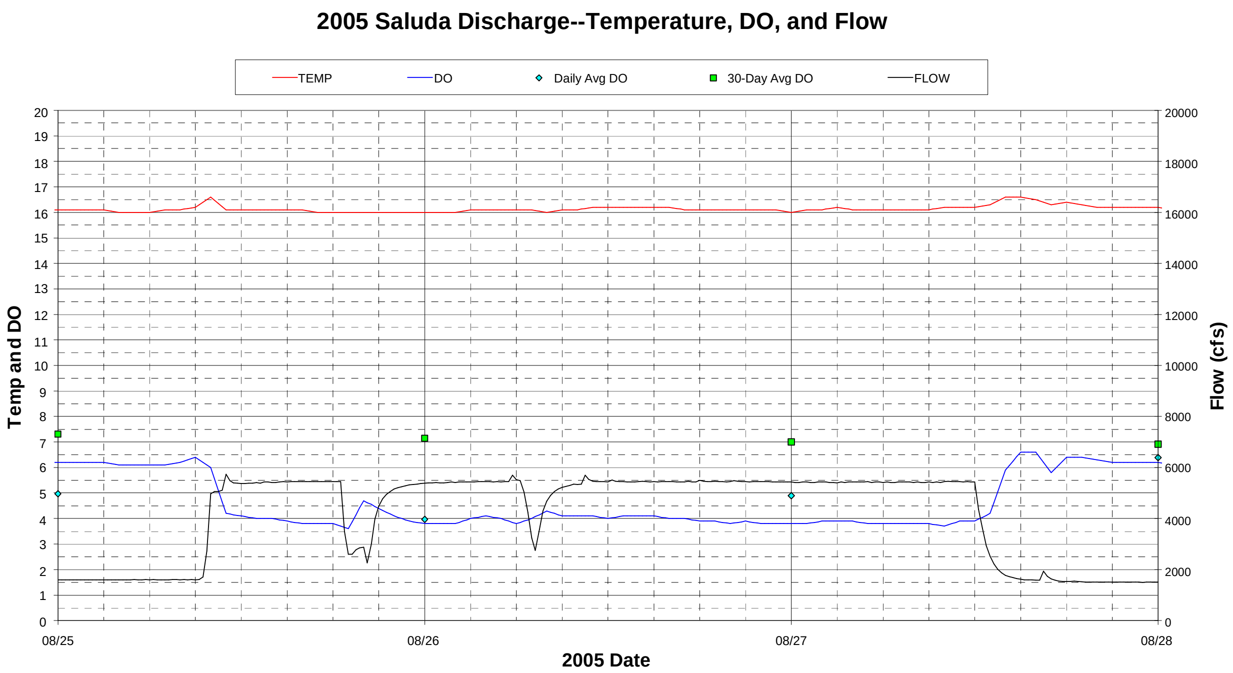


Figure 9: 2005 Saluda Discharge – Temperature, DO, and Flow

August 31-September 9 (Figure 10):

On August 31, SCE&G began the process of drawing down the lake for fall, planning to reduce the lake elevation by about 1 foot each month through December. This plan was subject to adjustment based on weather, system requirements, and other issues as they arose. In the course of implementing the first stage of lake drawdown, SCE&G generated through Units 1 and 2 over a period of 10 days. This resulted in DO levels near 4 mg/L but between 3.5 and 4 mg/L for about 8 days. During a 3-hour event preceding this period, the DO dropped to 2 mg/L while Unit 2 apparently was used. Studies conducted the following month in October revealed that Unit 2 does not draw as much air into the unit and therefore has less aeration capability than Unit 1. As stated for the previous excursion period, the benefits of the hub baffles were significant during the 8-day period since the DO would have been 1-2 mg/L instead of near 4 mg/L.

Indicated dissolved oxygen levels in the Saluda Hydro tailrace remained around 4 mg/l until September 9, when indicated DO increased to between about 6.0 mg/l and 8.0 mg/l. This increase coincided with the target lake level el. 356.0 being achieved and generation being reduced to match inflow.

During this period, USGS checked the monitor and it was reported to be calibrated within an acceptable level.

Unit 4 was unavailable due to electrical problems with the generator. Unit 3 was restricted to emergency use only, due to vibrations caused by head cover leakage. Operations personnel evaluated Unit 3 to see if it could be run at partial load with acceptable vibration levels on a non-emergency basis. Unit 5 continued to be “the last on, first off” unit for normal dispatch to meet reserve generation needs during the low DO period.

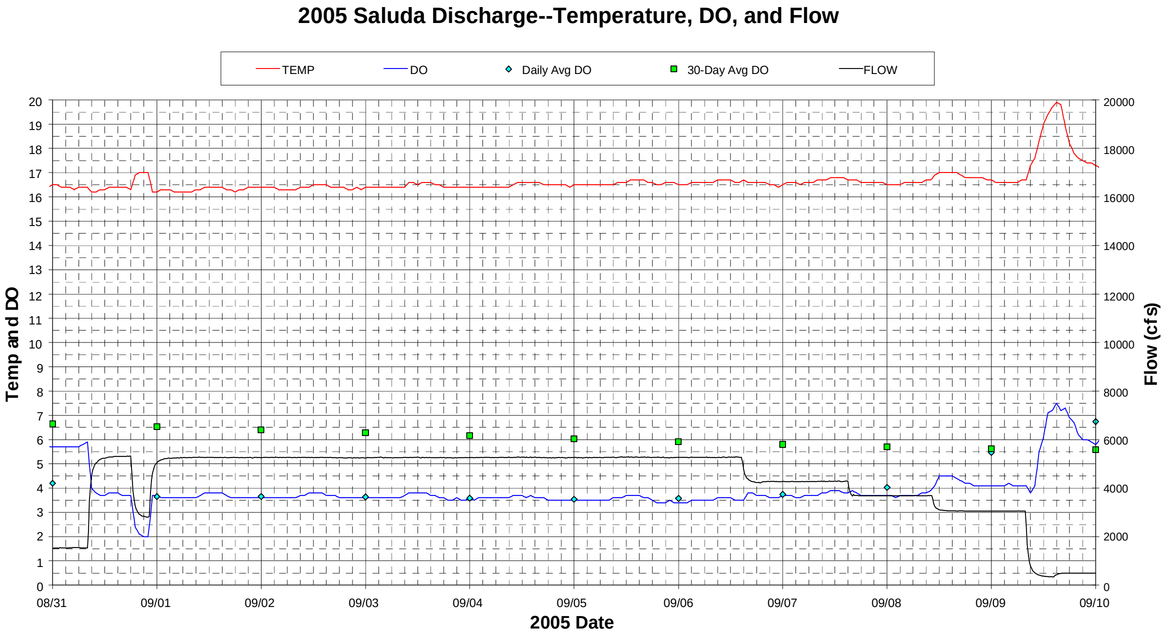


Figure 10: 2005 Saluda Discharge – Temperature, DO, and Flow

September 22-September 24 (Figure 11):

The indicated DO conditions based on provisional USGS data dropped to less than 4 mg/L in the early morning hours of September 23 and 24, indicating that aquatic plant respiration had caused the DO to decrease; however, there also was fouling of the USGS DO monitor during this period. On September 23, the USGS monitor indicated a dissolved oxygen level of 3.0 mg/l at 0900 hours. A SCE&G field reading taken at 0708 hours was 6.4 mg/L using a Hydrolab MS5 with a luminescent dissolved oxygen sensor. A few days earlier (September 19), SCE&G personnel inspected the USGS monitor and reported to the USGS that it appeared to be fouled.

Flows during this whole period were steady at about 550 cfs.

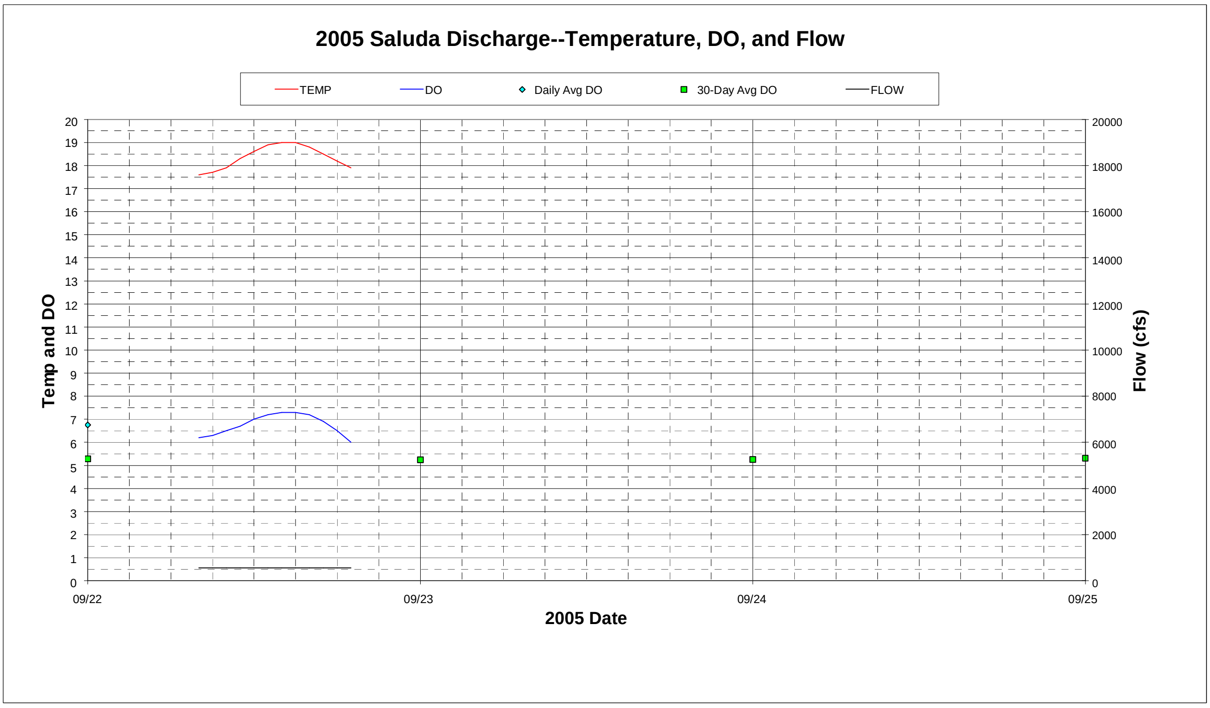


Figure 11: 2005 Saluda Discharge – Temperature, DO, and Flow (excursions were originally indicated by provisional data in the morning hours of September 23 and 24 during a period of continuous flow at ~ 550 cfs)

September 30 (Figure 12):

Indicated DO dropped below 4 mg/L for about two hours on September 30. The indicated minimum DO was about 3.4 mg/L. However, actual DO values were probably 4 mg/L or more considering that Unit 1 was used for generation, and turbine venting studies showed that this unit aerates to > 4 mg/L at the flow levels measured during this time. The values reported at less than 4 mg/L were likely due to aquatic plants and the location of the DO monitor. SCE&G reported "that continued problems with apparent fouling of the USGS dissolved oxygen monitor downstream of Saluda Hydro were encountered again this period."

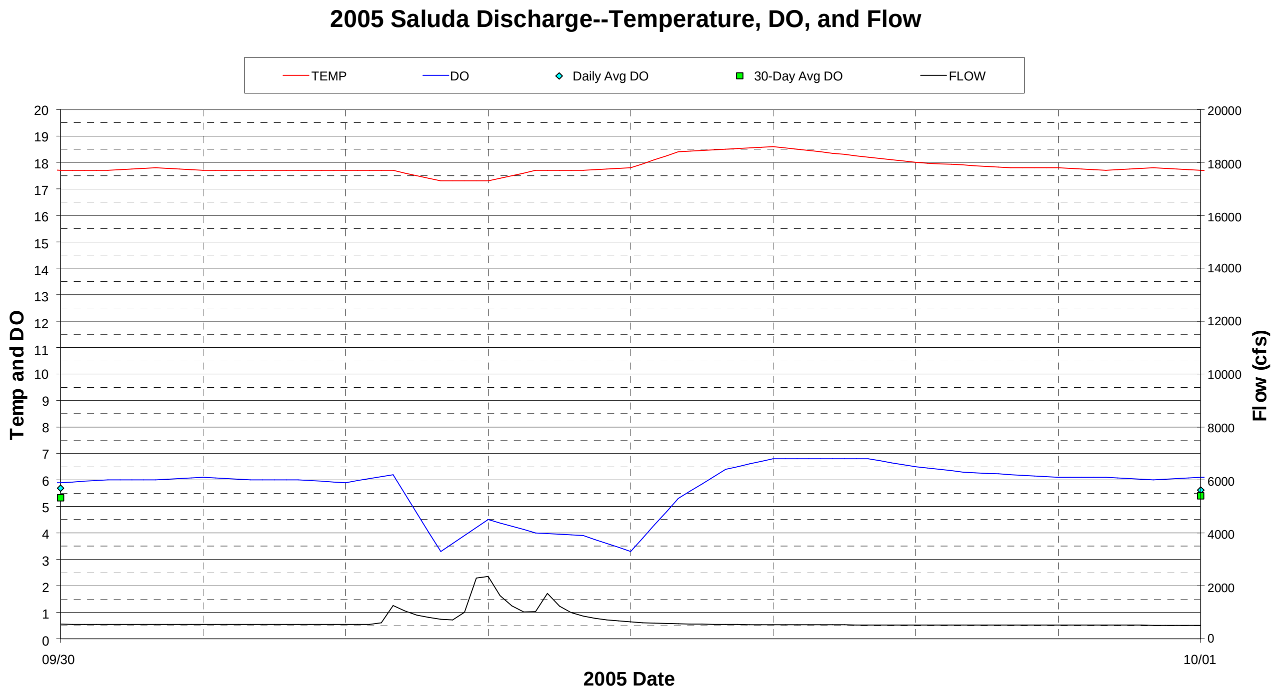


Figure 12: 2005 Saluda Discharge – Temperature, DO, and Flow

October 2-October 8 (Figure 13):

The indicated DO was less than 4 mg/L several times during this period, primarily caused by testing the effectiveness of the new hub baffles and obtaining data for developing the new look-up tables for operating the plant to provide the best DO levels attainable under current plant capabilities. Testing was conducted on October 3, 4, 5, and 8, and the lowest recorded DO levels (i.e., near 1 mg/L) occurred on these dates.

On October 2, the DO dropped to about 3.5 mg/L, and this is the aeration capability of Unit 1 at about 90% gate which appeared to be level of flow measured by the USGS gauge.

The indicated DO dropped to between 2.5 and 3 mg/L on October 6, 7, and 8 (prior to testing on October 8) for no apparent reason since Unit 1 was being operated at about 30% gate and DO should have been about 6 mg/L. During aeration tests on October 8, the indicated USGS DO of less than 0.5 mg/L was lower than the minimum recorded DO levels of 1.6 mg/L during unit tests. During aeration tests on October 4, the indicated USGS minimum DO of 1.2 mg/L was about 0.5 mg/L lower than that recorded during tests. Considering the apparent fouling of the USGS DO monitor on October 6-8 when Unit 1 was operated at 30% gate, it appears reasonable that it was fouled during tests on October 4 and 8.

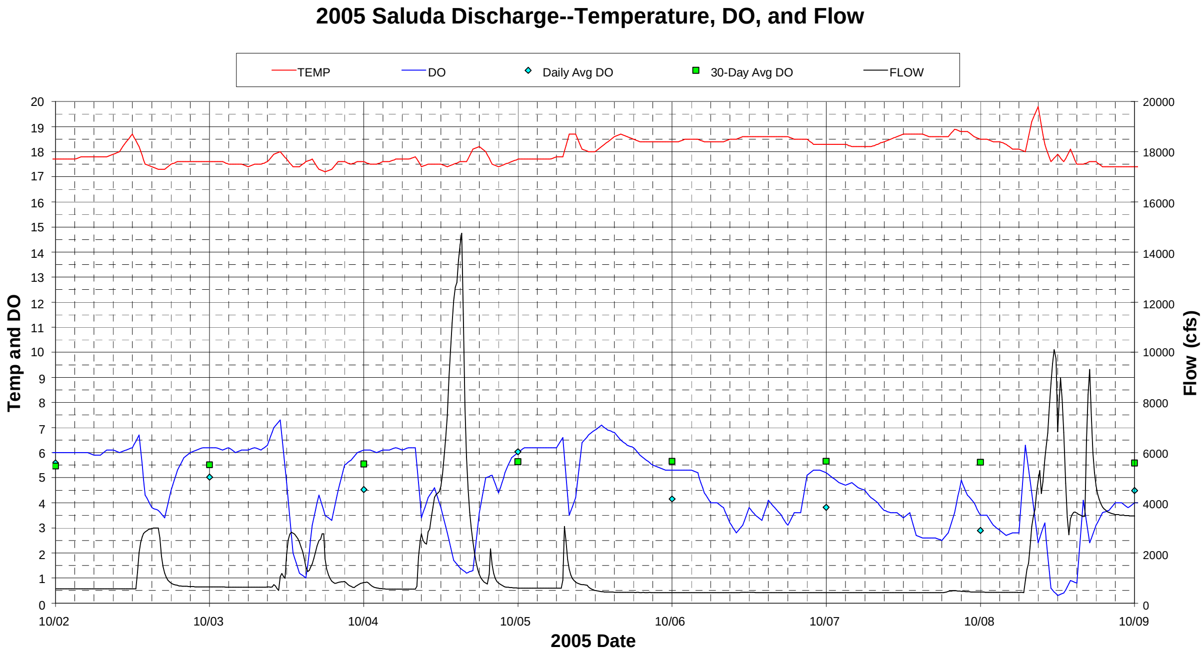


Figure 13: 2005 Saluda Discharge – Temperature, DO, and Flow

October 18-October 26 (Figure 14):

Indicated USGS DO levels were less than 4 mg/L for several hours each day during this nine-day period due to erratic variations unexplained by turbine operations, but higher flow turbine operations caused DO to drop to marginally less than 4 mg/L on two of these days.

Turbine operations at flows up to 8000 cfs occurred on October 23 and 26 (at the request of the City of Columbia for swift water rescue training, and DO dropped to about 3.5 and 3.0 mg/L, respectively. These relatively high DO levels at 8000 cfs are partly attributed to higher DO levels that probably occurred at the intake of Unit 5. Lake temperature and DO profiles indicated that DO at the Unit 5 intake had increased from near zero on October 17 to about 4 mg/L on October 27. Turbine operations at levels of 1500, 3500, and 3900 cfs occurred at various times during this period without the DO dropping below 4 mg/L.

Low flow turbine operations at about 500 cfs were used at all other times during the period, and these operations should have resulted in DO levels of greater than 4 mg/L. However, indicated minimum DO levels dropped to 2 mg/L or less on five days during these operations and less than 4 mg/L on the other days. At other times, the DO was closer to the expected level near 6 mg/L.

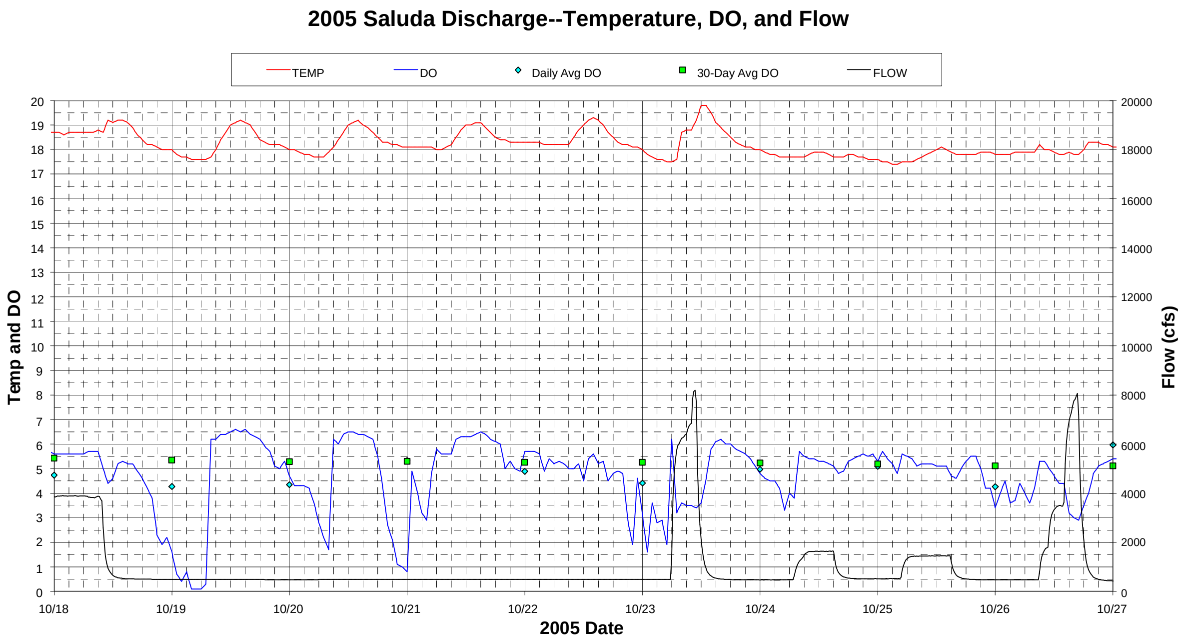


Figure 14: 2005 Saluda Discharge – Temperature, DO, and Flow

October 31-November 7 (Figure 15):

Indicated DO levels dropped below 4 mg/L on six days during this eight-day period. Special operations occurred on three of these days, normal operations occurred on one day, and minimum flow operations occurred on two days. Units 1, 2, 3, and 5 were operational, but U3 air supply valves had to be closed.

The special operations on November 1, 2, and 3 called for higher flow operations than what SCE&G would have used otherwise. Also, the special operations for the monitor location study on November 1 and 3 called for lower DO levels in selected units to allow an assessment of monitoring locations in the tailwater.

On November 1, indicated DO levels dropped to a minimum of 2.2 mg/L. The minimum DO measured by any of the four other monitors located at this transect when the USGS monitor measured 2.2 mg/L was 2.7 mg/L, while the highest minimum DO measured at this transect during this time was 3.7 mg/L.

On November 3, indicated USGS DO levels dropped to a minimum of 1.1 mg/L. The minimum DO measured by any of the three other monitors located at this transect during the time when the USGS monitor measured 1.1 mg/L was 1.5 mg/L, while the highest DO measured at this transect by any of the monitors during the time when the USGS monitor measured 1.1 mg/L was 3.4 mg/L.

The special operations on November 2 were provided to support the City of Columbia Fire Department's swift water rescue training. The flow peaked at 8000 cfs, and the indicated DO dropped to 2.1 mg/L. Based on the turbine aeration studies conducted on October 4, this DO level is close to what would be expected if Units 1, 2, and 3 were used to provide this flow for the City of Columbia. If Units 1 and 5 had been used to provide the flow, the average DO at this transect would have been higher, i.e., about 3.6 mg/L, since the DO at the Unit 5 intake was elevated during this time.

On October 31, SCE&G generated a brief period of time that resulted in a peak flow of 7400 cfs that caused indicated DO to drop to a minimum of 3.1 mg/L and DO was less than 4 mg/L for less than an hour.

On November 5 and 7, indicated DO dropped to less than 4 mg/L for several hours each day (but not less than 3 mg/L); however, these excursions occurred during minimum flow operations when expected DO levels in the discharges from a turbine unit would be much higher. Therefore these excursions are unexplained by turbine operations.

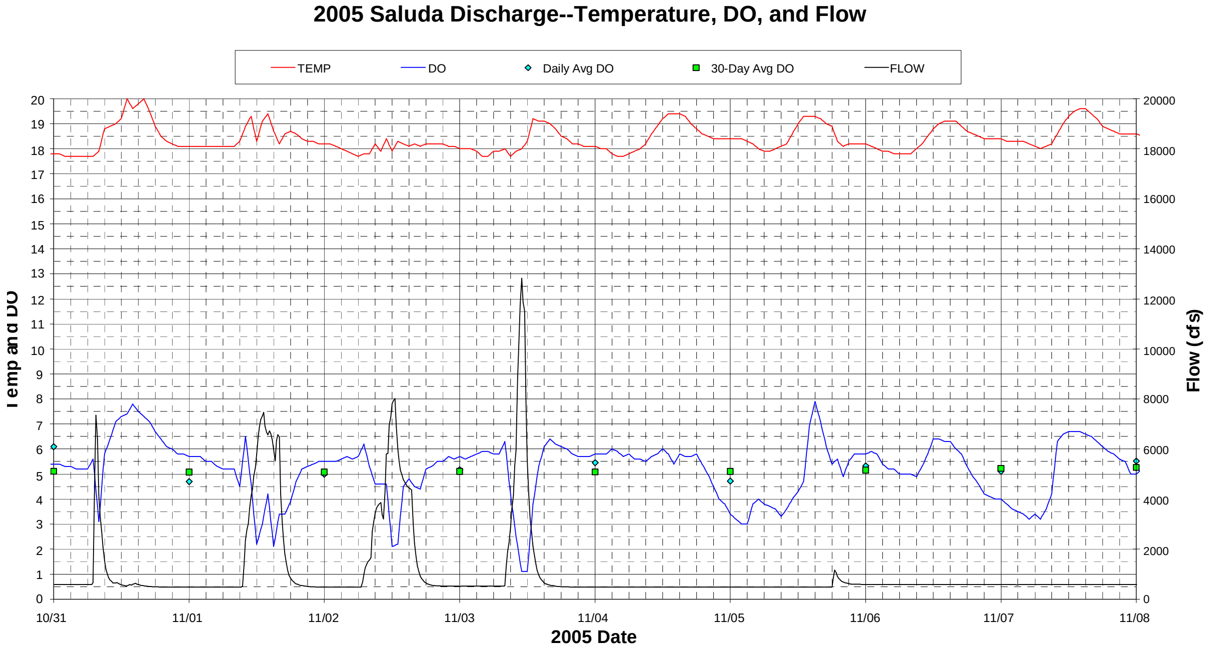


Figure 15: 2005 Saluda Discharge – Temperature, DO, and Flow

November 12-November 20 (Figure 16):

Indicated DO dropped to less than 4 mg/L every day during this nine-day period, especially November 13, 14, and 15 when the DO dropped down to 1.5 mg/L. During the last five days, the daily minimum DO values were between 3.5 and 4 mg/L. During essentially this entire period, the project flow varied from 650 to 700 cfs which is about 20% gate for one of the original units at Saluda. At 20% gate the available units would aerate to 5-6 mg/L. SCE&G personnel obtained a field DO reading of 6.1 mg/l in the Saluda River on Friday, November 11, at 0940 EST, when the USGS monitor read between 5.0 and 5.35 mg/L, at 0930 and 0945, respectively. The gradual decline in the indicated DO readings over the period November 12 to 0900 on November 15 is indicative of probe fouling on a DO monitor. USGS serviced the monitor on November 15. During the last five days of the period, respiration associated with aquatic plants probably caused the DO to drop below 4 mg/L, especially in the early morning hours. The low indicated DO levels through out the days of November 19 and 20 might have been caused by cloudy conditions, senescing conditions, or fouling of the probe on the DO monitor.

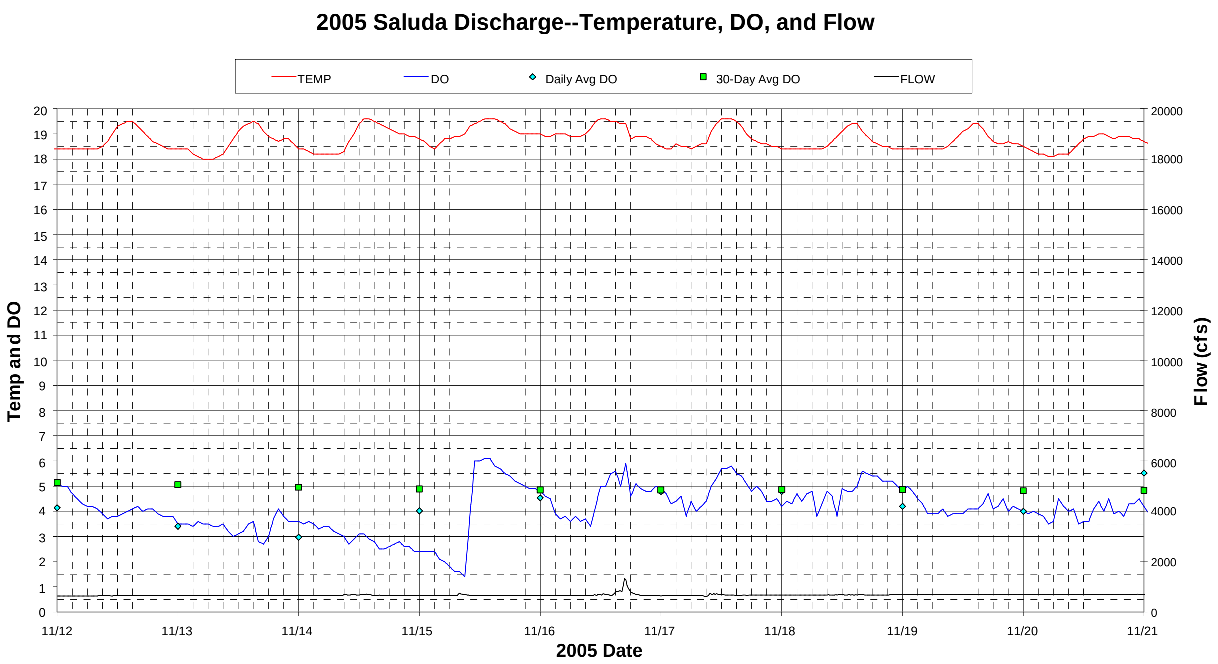


Figure 16: 2005 Saluda Discharge – Temperature, DO, and Flow

Summary of all Excursions during the Period of Study:

The summary is presented in Table 1. All excursions of the DO standard were caused by operations, special studies and flow requests, and monitor fouling as described above. Eighteen of the excursions of the 5 mg/L daily average DO were caused by monitor fouling or undetermined reasons while 11 were caused by operations and 5 were caused by special studies and flow requests. One hundred and eighty-seven of the excursions of the 4 mg/L hourly minimum DO were caused by monitor fouling or uncertain reasons while 224.5 were caused by operations and 54 were caused by special studies and flow requests.

Table 1: Summary of Excursions of DO Less Than the SC Site-Specific DO Standard (Hourly and Daily Standards)

Summary of Excursions--Causes and Metrics, based on USGS indicated DO monitor readings

Causes	Dates		Number of Hours < 4 mg/L	% of Time < 4 mg/L	Average DO during Excursions	Minimum DO during Excursions	Number of Days Avg DO < 5 mg/L	% of Time < 5 mg/L daily Avg	Comments
Operations	Aug 25-27		30.50	0.35	3.84	3.60	2	0.5	Katrina drawdown
	Aug 31-Sept 8		193.25	2.21	3.61	2.00	9	2.5	Lowered pool level
	Oct 31		0.75	0.01	3.53	3.10	0	0.0	
	Totals & Averages		**224.50**	**2.6**	**3.7**	**2.0**	**11**	**3.0**	
Studies or Special Flow Requests	Oct 2-8		30.25	0.35	2.50	0.3	2	0.5	Aeration studies; minimum DO measured by study monitors was 1.6 mg/L
	Oct 23-Nov 2		13.00	0.15	3.28	2.1	2	0.5	Rescue training
	Nov 1-3		10.75	0.12	2.77	1.1	1	0.3	Monitor location studies; minimum DO measured by study monitors was 1.5 mg/L
	Totals & Averages		**54.00**	**0.6**	**2.8**	**1.5**	**5**	**1.4**	Minimum DO measured by other monitors was 1.5 mg/L
Monitor Fouling or Uncertain Reasons	Aug 8		2.25	0.03	na	na	0	0.0	Low flow and aquatic plants
	Sept 30		3.00	0.03	na	na	0	0.0	
	Oct 6-8		32.50	0.37	na	na	2	0.5	
	Oct 18-26		41.25	0.47	na	na	6	1.6	
	Nov 5-7		19.50	0.22	na	na	1	0.3	
	Nov 12-20		88.50	1.01	na	na	9	2.5	
	Totals		**187.00**	**2.1**	**NA**	**NA**	**18**	**4.9**	

Most all of the 55 excursions of the 5.5 mg/L 30-day average DO level were attributed to monitor fouling. Seventeen days were attributed to operations: September 14-30 when the minimum 30-day average was 5.3 mg/L. The period attributed to operations could have been only 12 days if special operations had not been required for Hurricane Katrina. The other 38 days were attributed to monitor fouling and special studies or flow requests: October 19 through November 25 when the minimum 30-day average was 4.8 mg/L.

Performance of the LUTs:

The LUTs need to be revised and implemented to account of the effects of the hub baffles that have been added to all the units.

This report focused on excursions, not an hour-by-hour comparison of aeration performance versus the observed DO results. Such a comparison could be developed using the turbine aeration model to check the results against the DO measurements. However, considering the limitations of the current tailwater DO monitoring system, the benefits of such an analysis would be greatly diminished. SCE&G has the inputs for the model, i.e., flows, the units that were operated, and inflow DO and temperature; but, the current monitoring system does not provide data of sufficient quality to allow a reliable comparison between the model results and the actual DO in the tailwater.

Comments on the current monitoring system:

1. Rated excellent, good, fair, and poor for various periods of the water year 2005;
2. The location is not considered to be representative for all conditions in the tailwater, i.e., it's biased towards the DO in the discharge from the unit that's operating that is on the LDB;
3. The objectives for the current USGS monitor do not include the purpose of providing compliance monitoring;
4. Photosynthesis and respiration by aquatic plants in the tailwater can affect in some years the DO level at the location of the monitor;
5. It occasionally malfunctions for several days;
6. Fouling is a significant issue that affects the reliability of the data; and
7. SCE&G spot measurements during the 2005 study period were usually higher than the USGS monitor.

PRELIMINARY RECOMMENDATIONS FOR 2006

1. Consider the recommendations from the monitor location study conducted in 2005. Improve DO monitoring for 2006 by maintaining the DO monitor more frequently, especially when minimum DO is low (e.g., < 3 mg/L).
2. Implement revised look-up tables accounting for the benefits of the hub baffles and provide options for the System Dispatchers when one or more units are out of service or not available for an environmental issue or agreement with an agency.
3. Conduct additional training within SCE&G so that operators are better prepared to minimize DO excursions—in 2005, training was provided for the System Controllers not only on how to use the LUT's, but also to help them understand the impact of Saluda Operations on the environment. They also had the DO and temps to go through one individual so that only the two applicable tables were given to the controller so that there was no confusion on which table to use. This person also labeled the sheets with "Normal dispatch" and "For Emergency Dispatch" again so that it would be clear which table to use in a particular situation. This training really accomplished a lot to help the System Controllers dispatch the units appropriately. Another training session is proposed for June to go over the tables and review their purpose.
4. SCE&G will develop a water management procedure to allow sufficient aeration to exceed the DO objectives in the tailrace when the pool level is being lowered for normal seasonal operations.
5. Conduct aeration tests on Units 2, 3, 4, and 5; develop LUT's for 2007. The testing plan should minimize the number of runs that are conducted without aeration. DHEC should be notified of the testing plan and schedule at least two weeks in advance. The headcover seals on Units 2 and 3 should be repaired no later than September 15.
6. SCE&G will notify organizations desiring special Saluda operations that might impact DO in the tailwater to schedule their plans during periods of the year when low DO is not normally a concern.

GUIDELINES FOR OPERATION OF THE SALUDA PROJECT FOR DISSOLVED OXYGEN MANAGEMENT IN 2005

June 30, 2005

PURPOSE

These Guidelines for Operation of the Saluda Project for Dissolved Oxygen Compliance are prepared pursuant to the *Offer of Settlement On Complaint Regarding Water Quality In Lower Saluda River* (May 19, 2004) (Settlement Agreement). Paragraph 9.3 of the Settlement Agreement provides the following:

> To the extent within SCE&G's reasonable control, each Operating Plan will seek to enhance existing water quality in the lower Saluda River and, more specifically, seek to achieve DO concentrations of 4 mg/1 minimum, 5 mg/l daily average, and 5.5 mg/1 monthly average in the lower Saluda River. In seeking to achieve this goal, each Operating Plan will preserve SCE&G's right or duty to modify operations as necessary to: (A) protect life and property, (B) respond to changed hydrologic or other circumstances not addressed in the Operating Plan, (C) maintain the use of the Project to meet system reserve obligations of 200 MW, and (D) comply with a lawful orders of the Commission or other authorities. SCE&G will provide notice of such modification to the Conservation Groups, [South Carolina Department of Health and Environmental Control], and Other Agencies in advance of such modification if practicable, and otherwise, as soon as practicable thereafter. The Parties will then use their best efforts to modify the Operating Plan in response thereto.

SCE&G will implement these Guidelines consistent with paragraph 9.3.

LIMITATIONS

Paragraph 9.3 of the Settlement Agreement includes limitations and these limitations are more fully explained here. Operation of the Saluda Project affects dissolved oxygen (DO) levels in the Saluda River downstream of the Saluda Project. Factors affecting achievement and maintenance of the DO standard include: (1) the limited capability for aeration of water discharged through the turbine units, (2) the requirement that SCE&G manage water levels in Lake Murray for safety and other reasons, (3) the need to use Saluda Hydro for the special operating needs specified under paragraph 9.3 of the Settlement Agreement, and (4) the need to meet SCE&G's

reserve obligations as a member of the Virginia-Carolinas Southeastern Electric Reliability Council sub-region (VACAR).

Generating units occasionally fail, and these generation failures are not generally capable of prediction. These often sudden failures upset the load-generation balance. Because electricity cannot be stored, any such sudden reduction in generation cannot be made up by an inventory, as would be the case in most other kinds of business. Instead, generation losses must be met by reserve generation that can be dispatched instantly, before voltage sags or frequency excursions lead to local or widespread blackouts. VACAR members are bound in a reserve-sharing agreement by which each has agreed to assist any other member in generation emergencies. SCE&G must employ its reserves to meet its own generation emergencies before calling on assistance from other VACAR members, and it must be constantly ready to provide reserve generation to other VACAR members. Generally, the reserves required to be maintained by SCE&G are in the range of 190-200 MW, which matches the capacity of the Saluda Project and its ability to respond quickly to any generation outage on its system.

As done in 2004, during 2005, SCE&G will provide via email a weekly report to the South Carolina Department of Health and Environmental Control, South Carolina Coastal Conservation League (SCCCL) and other stakeholders documenting the previous week's operation of the Saluda Project.

Unless otherwise specified, these guidelines will be implemented by SCE&G.

TURBINE VENTING OPERATIONS

Use Lookup Tables (LUTs) As Guides To Aerate The Turbine Discharges From the Saluda Project. SCE&G will use the LUTs included in the document, "Final Lookup Tables for Operating Saluda Hydro to Achieve Standards for Dissolved Oxygen in the Tailrace to the Extent Practicable for 2004," dated ~ March 21, 2005 (Appendix A). These LUTs reflect the best estimate based on field testing and predictive models of how the units at Saluda Hydro can be operated to enhance downstream dissolved oxygen levels and still obtain target MW outputs, given the inflow DO and temperature conditions. (Note: These LUTs may change based on installation of hub baffles presently scheduled for early autumn 2005. Updates to the current LUTs will be generated based on any testing following the installation of the hub baffles.)

Estimate Inflow DO and Temperature for Units 1-4 and Unit 5. Turbine DO and temperature from inflows change during the course of the low DO period. To track DO and temperature conditions in the turbine inflows, SCE&G will obtain DO and temperature profiles in the Saluda Project forebay every other week and use these profiles to predict conditions in the turbine inflows. SCE&G also will use data collected by the USGS continuous water quality monitor located near the intake of Unit 5 (U5).[2] These data will also be used to evaluate the presence of conditions that call into operation, constraints to using U5 due to the potential for fish entrainment. If needed, a withdrawal zone model may be used to predict inflow temperature and DO.

Use DO Readings in the Tailrace from the USGS Monitor. During 2005, the USGS monitor (USGS Gage No 02168504) will be used to track DO conditions in the tailrace on a daily basis, supplemented by periodic spot measurements by SCE&G, especially if DO, as measured at the monitor, appears erratic or is lower than expected (*e.g.*, suspected fouling, meter malfunction, *etc.*). As discussed in a following section, additional monitoring will be conducted by USGS and SCE&G during the low DO period of 2005 so that improvements can eventually be made to obtain more representative DO conditions in the tailrace.

---

[2] As with any *in-situ* continuous monitor, anomalous readings occur from time to time, due to equipment fouling or malfunction. If the USGS determines the data are suspect through their Quality Control/Quality Assurance Program, that data may be ignored, appropriately adjusted, or otherwise dealt with according to their final determination. It is acknowledged that the USGS data is reported initially as "provisional." SCE&G will use it subject to the data error issues discussed here and agreed to during the March 21, 2005 meeting.

Review effectiveness of the turbine venting operations and other data being collected to see if additional data or adjustments in the LUTs are needed before "near-zero" DO inflow conditions occur. Technical peer review between KA/REMI and National Heritage Institute/SCCCL of the tailrace DO data and operational records collected by USGS and SCE&G will be conducted, as needed, to achieve this objective and determine if changes to the LUTs are warranted.

Conduct monthly training of operators in System Control. The System Control Manager will conduct monthly training sessions with operations personnel to ensure proper application of the LUTs. Training of staff will include review of current practices and procedures in the proper application of the LUTs. The training sessions will be adjusted as appropriate each month for changes in monitored DO and temperature inflow conditions, and will include adjustments in the LUTs should any be needed. Any necessary revisions of the LUTs will be shared with the Conservation Groups.

If during the low DO season, conditions are identified that require immediate changes (agreeable to all parties to the settlement) to the 2005 operating guideline, the System Control manager will convene a special training session to ensure changes in the Operating Guidelines are implemented as soon as reasonably possible.

TAILRACE DO MONITORING

The current USGS water quality monitor in the tailrace has served its purpose well with respect to providing information on temperature and DO conditions. Also, the USGS is now correcting provisional data following calibration checks that are made at about two-week intervals, although the corrections may not be made on the web site for about one month following data collection. USGS has also developed and implemented a procedure to rate the accuracy of their monitors. The monitor below Saluda Hydro is rated as "good" and has an accuracy of ±0.3-0.5 mg/L.

However, additional measures which include equipment testing and additional *in situ* measurements are planned for 2005 to look for ways to improve water quality monitoring in the Saluda tailrace: SCE&G plans to coordinate with the SCCCL and the USGS in developing site specific study plan(s) prior to conducting these additional analyses. Once final, study plans will be distributed to all interested parties.

Hub Baffle Installation Schedule

SCE&G has secured a contractor to oversee the installation of hub baffles on Units 1-4. As of date of these proposed guidelines, the installation of the hub baffle has been completed for Units 1, 3, and 4. The installation of the hub baffle for Unit 2 is scheduled for completion by July 31, 2005.

C:\DOCUME~1\jp952403\LOCALS~1\Temp\MetaTemp\WAI_2169678_2_Saluda Operating Plan (June 2005).DOC

APPENDIX A

LOOKUP TABLES

LOOKUP TABLES FOR OPERATING THE SALUDA PROJECT TO ENHANCE DISSOLVED OXYGEN IN THE TAILRACE TO THE EXTENT PRACTICABLE FOR 2005

June 30, 2005

Lookup Tables (LUTs) will be used as a tool for operating the Saluda Project during the low DO period of 2004 so that the DO standard in the Lower Saluda River may be met continuously, subject to the limitations contained in paragraph 9.3 of the Settlement Agreement,, and to provide optimal aeration when the standard otherwise cannot be met. The LUTs will be used by SCE&G to select the turbine units that will be operated at various total project flow rates and power production levels, under varying inflow DO concentrations and temperatures. These LUTs provide a guide for operations in 2005, but actual practice is likely to deviate somewhat from this guide as tailwater data are collected and evaluated and the LUTs are adjusted as appropriate. Also, during 2005, the aeration system will be manually operated. It is expected that when a final turbine venting system is installed at some point in the future, a computer-controlled automated system may be needed to adjust these operations for more optimal aeration.

The overall process used to develop the LUTs involved the following steps:

1. The aeration characteristics of each unit were modeled using the discrete bubble model as described in "Saluda DO Standard Project—Lower Saluda River DO Technical Study Report, Appendix C, Prediction of Dissolved Oxygen Concentrations for Turbine Discharges from Saluda Hydro" 2003.
2. The individual models for each unit were used to predict DO in the tailrace over the range of turbine gate settings (*i.e.*, turbine flow conditions) for various DO and temperature levels in the inflows.
3. The predicted DO in the tailrace for each unit was then plotted for each inflow condition.

4. The LUTs were then developed using these graphs. One set of LUTs was developed assuming that the units were operated briefly for special purposes and the other set of LUTs was developed assuming the units were operated at a constant level over the course of the entire day.
5. LUTs were developed for a range of DO conditions at the intake, but for only one temperature condition that was similar to that expected during the low DO period of 2005. Model predictions were made for other temperature conditions, but the effort was not expended to develop LUTs for all the temperature conditions modeled due to the time required to develop LUTs. Additional LUTs will be prepared on an "as needed basis" depending on the intake actual temperature conditions that develop during the low DO period of 2005.
6. The LUTs were checked using a model that integrates the effects of all the units and predicts DO in the tailrace, assuming full mixing of the discharges from all the units.
7. For project operations, SCE&G System Control normally dispatches Saluda Hydro by power production levels rather than water flow rates; therefore, the flow rates initially determined using the turbine aeration model were supplemented by conversion to MW levels using the results of unit tests conducted in 1997 and 1998.

The assumed conditions for the turbine aeration systems are as follows:

1. Unit 5 has hub baffles, and aeration characteristics were assumed to be as modeled in 2003.
2. Units 1- 4 have no hub baffles, so the aeration characteristics are the same as were measured during field tests in 1997 and 1998. There are indications that Unit 2 may not aerate as much as was measured in 1998 and that aeration at 400 cfs may not be as much as predicted by the model; but, DO uptake data were not collected under these conditions. Therefore,

the results of the tests in 1997 and 1998 were used for calibrating the turbine aeration models for each unit.

3. Unit 2 cannot be operated unless 2500 cfs is being discharged by the other units.

Assumptions used in developing the LUTs:

1. SCE&G plans to operate the Saluda Project at minimal discharge of approximately 400 cfs during the summer of 2005, while attempting to refill Lake Murray. Under this condition, DO in the discharge from the Saluda Project should be well over the State DO standard. Also, inflow water quality (*i.e.*, DO and temperature) will change slowly over the course of the summer and early autumn. The need for LUTs under this condition is minimal, so LUTs for only one temperature scenario were prepared.
2. Two sets of LUTs were prepared: one set for brief periods of higher flow hourly operations where the DO target is 4 mg/L (see discussion below), and the other set for daily operations where the DO target is 5 mg/L, *i.e*., the daily operations tables will be applied when Saluda is being operated around the clock under steady state conditions, the hourly operations tables will be applied when special circumstances, as described in paragraph 9.3 of the Settlement Agreement, necessitate operating for brief periods of greater generation. An analysis of historical conditions (see the report supporting the new site-specific standard for DO for the Lower Saluda River) showed that if 4 mg/L was achieved over a period of several hours during a typical day of operations at the Saluda Project, the other requirements of the DO standard (*i.e.*, the daily average of 5 mg/L and the 30-day moving average of 5.5 mg/L) are achieved under almost all conditions. Considering the current aeration systems, the lack of computerized powerhouse controls, and the DO monitoring system, the use of these two sets of LUTs is considered to be what is practicable.

3. Additional sets of LUTs will be prepared for other temperature conditions if temperatures in the intakes are different than assumed for preparation of these LUTs.
4. For special operating conditions, which typically last only a few hours on days when they occur, it was assumed that the target minimum DO would be 4 mg/L during the period of maximum discharge. This is because an analysis of historical conditions showed that if 4 mg/L was achieved during the maximum discharge period, the other requirements of the DO standard (*i.e.*, the daily average of 5 mg/L and the 30-day moving average of 5.5 mg/L) are achieved under almost all conditions.
5. For days when special operation is not required, it was assumed that the target minimum DO would be 5 mg/L. This approach is consistent with the assumption that SCE&G plans to operate the Saluda Project at around 400 cfs during the low DO period of 2005.

Inflow water quality for Unit 5 was assumed to have the same conditions as the inflows for Units 1- 4. This is a conservative assumption in that DO in the inflow to Unit 5 is rarely less than the DO in the inflows to Units 1- 4. This is based upon an extensive review of historical reservoir profile data.

The following LUTs are proposed for the initial operating guides for achieving aeration objectives during the low DO period of 2005. Figures 1 and 2 show the predicted DO concentrations in the tailrace based on operating the Saluda Project according to the LUTs. The technical processes used in developing the LUTs are provided on the Appendix.

LOOKUP TABLES FOR HOURLY PEAKING OPERATIONS

(DO TARGET IS GREATER THAN OR EQUAL TO 4 MG/L)

Turbine Inflow Conditions: DO 3 - 4 mg/L; Temperature = 14^{o}C	
If peak MWs are anticipated to be:	**Then operate Unit(s) hourly:**
Any MW	Normal operations

* See discussion on Page 1, Paragraph 1, and Items 2 and 4 on Pages 9 and 10.

Turbine Inflow Conditions: DO 2 - 3 mg/L; Temperature = 15°C		
If peak MWs are anticipated to be:	**Approximate peak flow associated with MW (cfs):**	**Then operate Unit(s) hourly:**
≤ 21	≤ 1750	Any unit, except Unit 2; if unit 5 is used, 22 MW could be generated
≤ 30	≤ 2350	Any unit; except Units 2 and 3
≤ 34	≤ 2700	Units 1 or 5
≤ 50	≤ 4000	Unit 5; or flow split between any combination of two of Units 1, 3, or 4;
≤ 60	≤ 4700	Unit 5; or flow split between Units 1 and 3 or 4;
≤ 63	≤ 5000	Flow split between Units 5 and 1, 3, or 4; flow split between Units 1 and 4; flow split between 2 and any other 2 units
≤ 93	≤ 7400	Flow split between Units 1 and 5, but flow in Unit 1 limited to 2700 and flow in Unit 5 limited to 4700; flow split between Units 1 and 5 with Units 2, 3, or 4; flow split between Units 1, 2, and 4
≤ 126	≤ 10,000	Flow split between any four Units
≤ 151	≤ 12,000, limit for 4 mg/L	Flow split between any four Units, with Unit 5 operating up to 4500 cfs and the other 3 units operating at 2500 cfs; flow split between 5 units
≥ 151	≥ 12,000	Flow split between all five units, with Unit 5 operating at peak flow

Turbine Inflow Conditions: DO 1 - 2 mg/L; Temperature = 16°C		
If peak MWs are anticipated to be:	**Approximate peak flow associated with MW (cfs):**	**Then operate Unit(s) hourly:**
≤ 15	≤ 1350	Any unit, except Unit 2; if unit 5 is used, 17 MW could be generated
≤ 21	≤ 1850	Units 1 or 4; or flow split between Units 3 and 5
≤ 27	≤ 2300	Unit 1; or flow split between Unit 5 and unit 3 or 4;
≤ 31	≤ 2750	Flow split between any combination of two of Units 1, 3, 4, or 5;
≤ 43	≤ 3700	Flow split between Units 1 and 4; flow split between Unit 5 and units 1 and 3 or units 4 and 3
≤ 48	≤ 4100	Unit 1 maximum flow of 2500 and Unit 2 or 4 at maximum flow of 1600; or flow split between Unit 5 any other two Units;
≤ 70	≤ 6000	Flow split between Units 1, 2, and 4; flow split between any four units
≤ 91	≤ 7400	Flow split between Units 1, 4, 2, and 3 or 5.
≤ 109	≤ 8800, limit for 4 mg/L	7400 cfs split between Units 1- 4 with 1400 cfs through Unit 5
≤ 146	≤ 12,000	Flow split between all five units, with Unit 5 operating at peak flow
≤ 175	≤ 15,000	Flow split between Units 1, 2, 4, and 5, using equal gate settings (*i.e.*, U5 would have ~ twice as much flow)
≥ 175	≥ 15,000, min. DO ~ 2.5 mg/L	See previous policy, except when flow > 15,000 all additional flow goes through Unit 3 (*i.e.*, Unit 3 is the last unit turned on)

Turbine Inflow Conditions: DO 0 - 1 mg/L; Temperature = 16°C		
If peak MWs are anticipated to be:	**Approximate peak flow associated with MW (cfs):**	**Then operate Unit(s) hourly:**
≤ 11	≤ 1050	Any unit, except Unit 2; if unit 5 is used, 13 MW could be generated
≤ 18	≤ 1600	Units 1 or 4; or flow split between Units 3 and 5
≤ 23	≤ 2000	Unit 1; or flow split between any combination of two of Units 3, 4, or 5;
≤ 36	≤ 3200	Flow split between Units 1 and 4; flow split between Unit 5 and units 1 and 3 or units 4 and 3
≤ 60	≤ 5200	Flow split between Units 1, 2, and 4; flow split between Unit 5 and any three Units;
≤ 64	≤ 5600	Flow split between Unit 1 and any other three units
≤ 76	≤ 6400	Flow split between Units 1, 4, 2, and 3 or 5.
≤ 89	≤ 7500, limit for 4 mg/L	6400 cfs split between Units 1- 4 with 1100 cfs through Unit 5
≤ 151	≤ 12,000, min. DO ~ 2.5 mg/L	Flow split between Units 1, 2, 4, and 5, using equal gate settings (*i.e.*, U5 would have ~ twice as much flow as any other unit)
≤ 184	≤ 15,000, min. DO ~ 1.6 mg/L	Flow split between Units 1, 2, 4, and 5, using equal gate settings (*i.e.*, U5 would have ~ twice as much flow)
≥ 184	≥ 15,000, min. DO ~ 1.5 mg/L	See previous policy, except when flow > 15,000 all additional flow goes through Unit 3 (*i.e.*, Unit 3 is the last unit turned on)

Turbine Inflow Conditions: DO 0 - 1 mg/L; Temperature = 20°C		
If peak MWs are anticipated to be:	**Approximate peak flow associated with MW (cfs):**	**Then operate Unit(s) hourly:**
≤ 6	≤ 700	Any unit, except Unit 2; if unit 5 is used, 8 MW could be generated
≤ 12	≤ 1200	Units 1 or 4; or flow split between Units 3 and 5
≤ 17	≤ 1600	Unit 1; or flow split between Unit 5 and unit 3 or unit 4
≤ 25	≤ 2400	Flow split between Units 1 and 4; flow split between Unit 5 and units 1 and 3 or units 4 and 3
≤ 43	≤ 4000	Flow split between Units 1, 2, and 4; flow split between Unit 5 and any three units, preferably with Unit 1 if both Units 3 and 5 are operated.
≤ 49	≤ 4600	Flow split between Units 1, 2, 4, and Unit 3 or 5.
≤ 57	≤ 5300, limit for 4 mg/L	Flow split between five units
≤ 89	≤ 7500, limit for ~ 3 mg/L	6400 cfs split between Units 1- 4 with 1100 cfs through Unit 5
≤ 126	≤ 10,000, min. DO ~ 2	6000 cfs split between Units 1, 2, and 4, and all additional flow goes through Unit 5
≤ 151	≤ 12,000, min. DO ~ 1.5	6000 cfs split between Units 1, 2, and 4, and all additional flow goes through Unit 5 until it peaks at maximum flow
≤ 175	≤ 15,000	Same as previous, except increase flow through Units 1, 2, and 4 until they reach peak flow
≥ 175	≥ 15,000, min. DO ~ 0.5	See previous policy, except when flow > 15,000 all additional flow goes through Unit 3 (*i.e.*, Unit 3 is the last unit turned on)

Lookup Tables for Daily Operations

(DO Target Is Greater Than or Equal to 5 mg/L)

Turbine Inflow Conditions: DO = 4 mg/L; Temperature = 14^{o}C		
If peak MWs are anticipated to be:	**Approximate peak flow associated with MW (cfs):**	**Then operate Unit(s) daily:**
≤ 20	≤ 1700	Any unit except Unit 2.
≤ 28	≤ 2250	Units 1, 4, or 5;
≤ 33	≤ 2650	Units 1 or 5; flow split between units 3 and 4, but MWs need to be limited to 30
≤ 43	≤ 3400	Unit 5; flow split between any two units, except Unit 2, but MWs need to be limited to 41
≤ 57	≤ 4550	Unit 5; flow split between units 1 and 4; flow split between any three units, but MWs need to be limited to 53
≤ 90	≤ 7200	Unit 5 up to 4550 and Unit 1 up to 2650; flow split between any three units except Unit 3
≤ 148	≤ 11,700	Unit 5 up to 4550 and flow split between Units 1, 2, and 4
≤ 168	≤ 13,400, limit for 5 mg/L	Unit 5 up to 4550, flow split between Units 1, 2, and 4 (as in previous level for 11,700 cfs), and add flow through Unit 3 as needed up to 1700 cfs
≥ 168	≥ 13, 400, min. DO ~ 4.4 mg/L	Flow split between five units

*See discussion on Page 1 Paragraph 1, and Items 2 and 4 on Pages 9 and 10.

Turbine Inflow Conditions: DO = 3 mg/L; Temperature = 15°C		
If peak MWs are anticipated to be:	**Approximate peak flow associated with MW (cfs):**	**Then operate Unit(s) daily:**
≤ 15	≤ 1300	Any unit; except Unit 2; if unit 5 is used, 16 MW could be generated
≤ 22	≤ 1800	Units 1 or 4; flow split between units 3 and 5 but MWs need to be limited to 20
≤ 27	≤ 2200	Unit 1; flow split between any two units, except Unit 2, but MWs need to be limited to 23 unless Unit 5 is one of the units and then the MW limit would be 25
≤ 50	≤ 4000	Flow split between Units 1 and 4; flow split between units 2, 3, and 5 but MWs need to be limited to 47
≤ 70	≤ 5700	Flow split between Units 1, 2, and 4; flow split between any four units but MWs need to be limited to 65
≤ 88	≤ 7200	Flow split between Units 1, 2, 4, and Unit 3 or 5; flow split between Unit 1 and any three of the other units
≤ 103	≤ 8500, limit for 5 mg/L	Flow split between all five Units
≥ 103	≥ 8500, min. DO ~ 3.4 mg/L	Flow split between all five Units

Turbine Inflow Conditions: DO = 2 mg/L; Temperature = 16^{o}C		
If peak MWs are anticipated to be:	**Approximate peak flow associated with MW (cfs):**	**Then operate Unit(s) daily:**
≤ 9	≤ 900	Any unit; except Unit 2; if unit 5 is used, 11 MW could be generated
≤ 17	≤ 1500	Units 1 or 4; flow split between units 3 and 5 but MWs need to be limited to 16
≤ 22	≤ 1850	Unit 1; flow split between unit 5 and unit 3 or 4 but MWs need to be limited to 20; flow split between units 3 and 4 but MWs need to be limited to 18
≤ 40	≤ 3300	Flow split between Units 1 and 4; flow split between any three units, except Unit 2, but MWs need to be limited to 37
≤ 57	≤ 4800	Flow split between Units 1, 2, and 4; flow split between any four units but MWs need to be limited to 52 unless unit 5 is one of the units and then MWs need to be limited to 54
≤ 64	≤ 5600	Flow split between Units 1, 2, 4, and Unit 3 or 5; flow split between Unit 1 and any three of the other units
≤ 78	≤ 6750, limit for 5 mg/L	Flow split between all five Units
≥ 78	≥ 6750, min. DO ~ 2.4 mg/L	Flow split between all five Units

Turbine Inflow Conditions: DO = 1 mg/L; Temperature = 16°C		
If peak MWs are anticipated to be:	**Approximate peak flow associated with MW (cfs):**	**Then operate Unit(s) daily:**
≤ 6	≤ 700	Any unit, except Unit 2; if unit 5 is used, 8 MW could be generated
≤ 9	≤ 900	Any unit, except Units 2 and 3
≤ 13	≤ 1200	Units 1 or 4; flow split between units 3 and 5
≤ 19	≤ 1600	Unit 1; flow split between unit 5 and 4 or 3, but MWs need to be limited to 17; flow split between units 3 and 4 but MWs need to be limited to 15
≤ 32	≤ 2800	Flow split between Units 1 and 4; flow split between any three units, except Unit 2, but MWs need to be limited to 30
≤ 43	≤ 3900	Flow split between Units 1, 2, and 4; flow split between any four units but MWs need to be limited to 42
≤ 50	≤ 4600	Flow split between Units 1, 2, 4, and Unit 3 or 5; flow split between any five units but MWs need to be limited to 48
≤ 53	≤ 5000, limit for 5 mg/L	Flow split between all five Units
≤ 89	≤ 7500, min. DO ~ 4 mg/L	6400 cfs split between Units 1- 4 with 1100 cfs through Unit 5
≤ 151	≤ 12,000, min. DO ~ 2.5 mg/L	Flow split between Units 1, 2, 4, and 5, using equal gate settings (*i.e.*, U5 would have ~ twice as much flow)
≤ 184	≤ 15,000, min. DO ~ 1.6 mg/L	Flow split between Units 1, 2, 4, and 5, using equal gate settings (*i.e.*, U5 would have ~ twice as much flow)
≥ 184	≥ 15,000, min. DO ~ 1.5 mg/L	See previous policy, except when flow > 15,000 all additional flow goes through Unit 3 (*i.e.*, Unit 3 is the last unit turned on)

Turbine Inflow Conditions: DO = 0 mg/L; Temperature = 20^{o}C		
If peak MWs are anticipated to be:	**Approximate peak flow associated with MW (cfs):**	**Then operate Unit(s) daily:**
≤ 7	≤ 800	Any unit; except Units 2 and 3; if unit 5 is used, 10 MW could be generated
≤ 11	≤ 1100	Unit 1; or flow split between any two units, except Unit 2, but MWs need to be limited to 9
≤ 19	≤ 1600	Unit 1; or flow split between unit 5 and 4 or 3, but MWs need to be limited to 17; flow split between units 3 and 4 but MWs need to be limited to 15
≤ 19	≤ 1900	Flow split between Units 1 and 4; flow split between any three units, except Unit 2
≤ 30	≤ 3000	Flow split between Units 1, 3, 4, and 5 (Unit 2 cannot be used)
≤ 40	≤ 4000, limit for 5 mg/L	Flow split between five units
≤ 57	≤ 5300, limit for 4 mg/L	Flow split between five units
≤ 89	≤ 7500, limit for ~ 3 mg/L	6400 cfs split between Units 1- 4 with 1100 cfs through Unit 5
≤ 125	≤ 10,000, min. DO ~ 2	6000 cfs split between Units 1, 2, and 4, and all additional flow goes through Unit 5
≤ 151	≤ 12,000, min. DO ~ 1.5	6000 cfs split between Units 1, 2, and 4, and all additional flow goes through Unit 5 until it peaks at maximum flow
≤ 184	≤ 15,000	Same as previous, except increase flow through Units 1, 2, and 4 until they reach peak flow
≥ 184	≥ 15,000, min. DO ~ 0.5	See previous policy, except when flow > 15,000 all additional flow goes through Unit 3 (*i.e.*, Unit 3 is the last unit turned on)

APPENDIX B

FIGURES

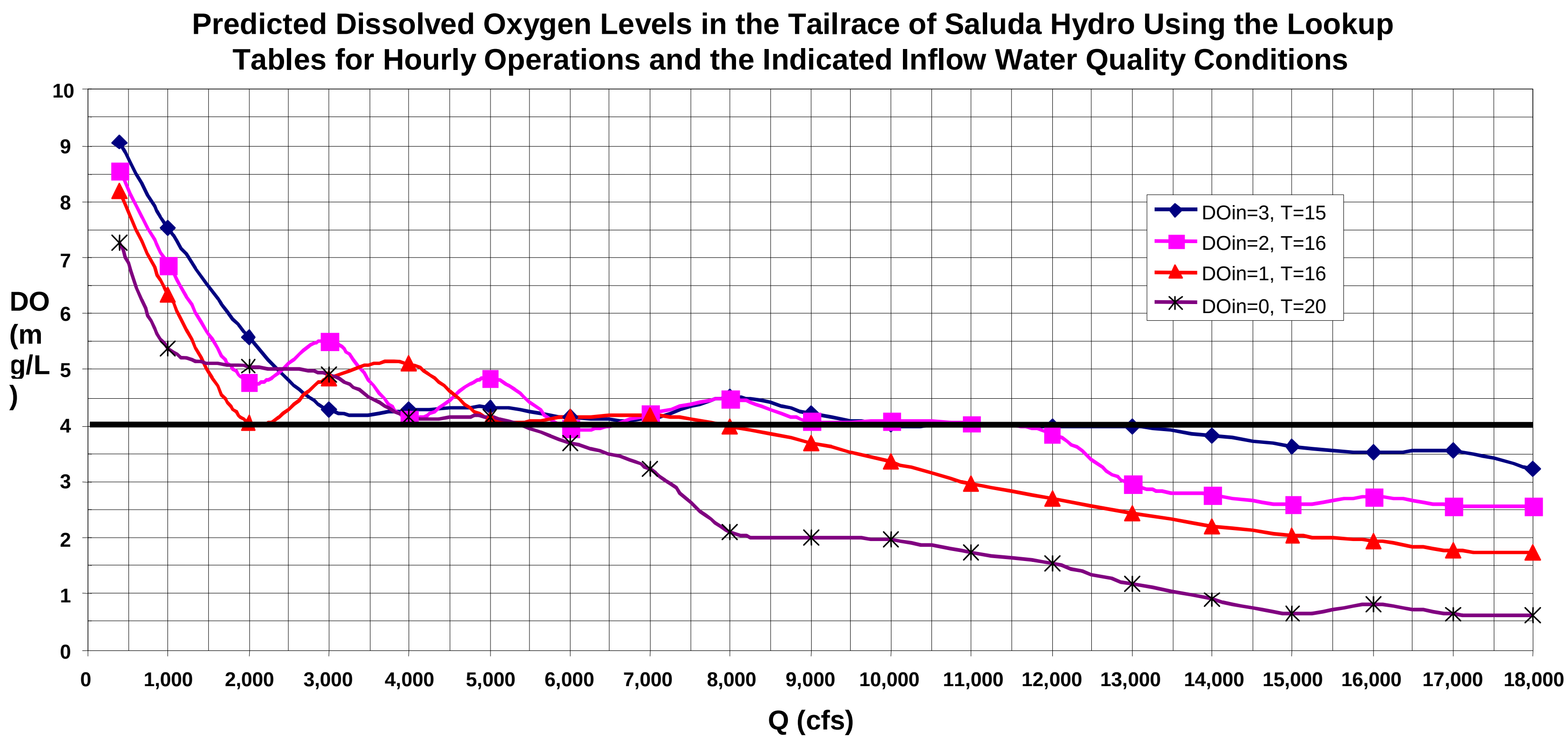


Figure 1: Predicted DO in the tailrace based on the LUTs for hourly operations, *i.e.*, for peaking operations

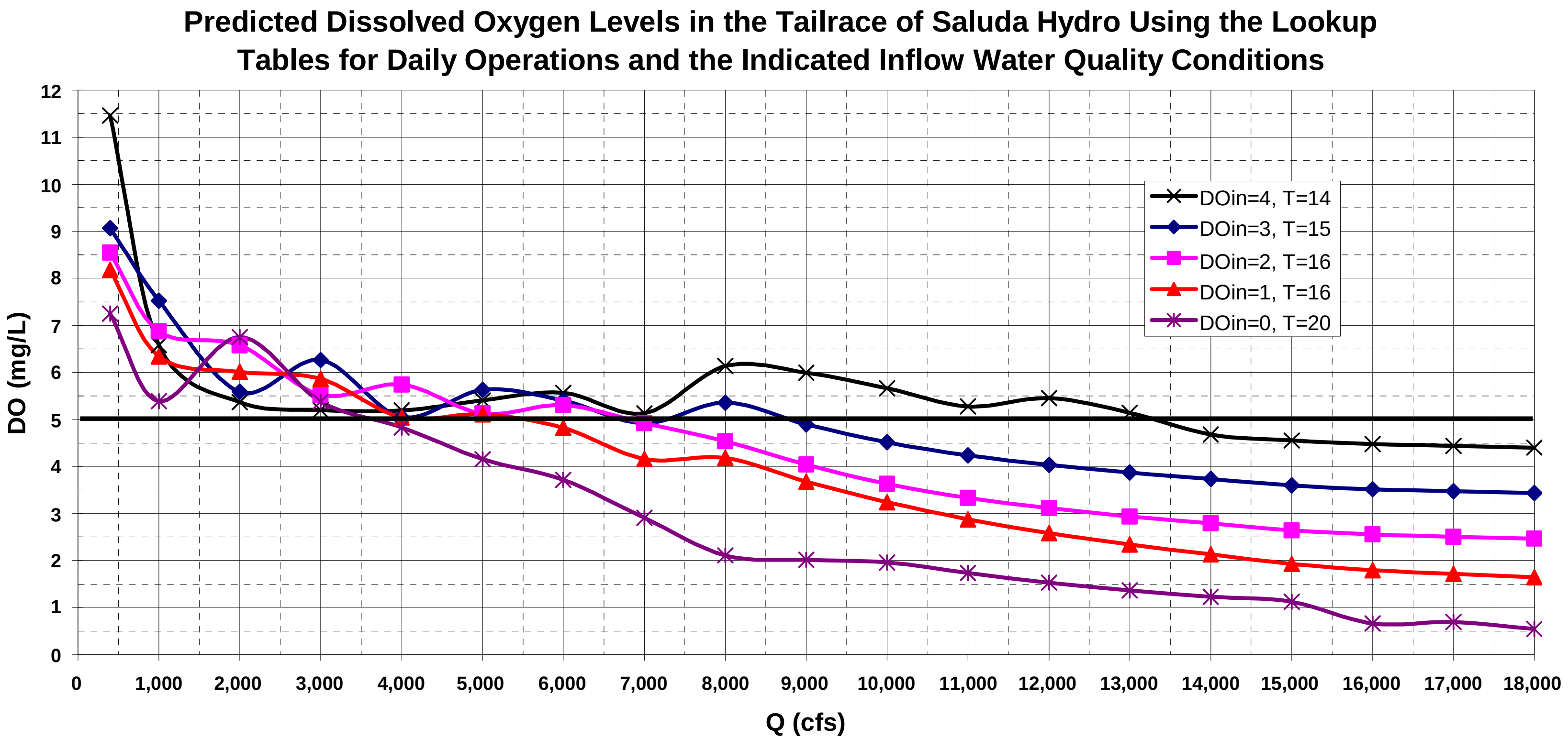


Figure 2: Predicted DO in the tailrace based on the LUTs for daily operations, *i.e.*, for low flow and high flow operations for water management.

APPENDIX C

ADDITIONAL BACKGROUND

ADDITIONAL BACKGROUND ON DERIVATION OF THE LOOKUP TABLES FOR OPERATING THE SALUDA PROJECT TO ACHIEVE DO STANDARDS

This appendix provides the technical procedure used to develop the LUTs.

The overall process used to develop the LUTs involved the following steps:

1. The individual models for each unit were used to predict DO in the tailrace over the range of turbine gate settings (*i.e.*, turbine flow conditions) for various DO and temperature levels in the inflows
2. The predicted DO in the tailrace for each unit was then plotted for all the inflow conditions on one graph—see Figures A1-A5.
3. Then the predicted DO in the tailrace for each inflow DO and temperature condition was plotted for all the turbines on one graph—see Figures A6-A10.
4. The LUTs were then developed using these graphs. One set of LUTs was developed assuming that the units were operated for peaking purposes and the other set of LUTs was developed assuming the units were operated in a similar pattern over the course of the entire day.
5. LUTs were developed for a range of DO conditions in the inflow, but for only one temperature condition that was similar to that expected during the summer of 2004. Model predictions were made for other temperature conditions, but the effort was not expended to develop LUTs for all the temperature conditions modeled due to the time required to develop LUTs (about 17 additional LUTs would be needed to cover the full range of temperature conditions, and each LUT takes two-three hours to develop and check.) Also, it appears from the model runs at other temperature conditions that adjustments in LUTs would be minor and even if the LUTs were not adjusted the impact to DO would be immeasurable (*i.e.*, 0.1-0.2 mg/L). Additional LUTs could be prepared on an "as needed basis" depending on the actual temperature conditions that develop during the summer of 2004. The results of the model runs at other temperature conditions are shown in Figures A11-27 for temperatures of up to 3 C^{o} different from the expected temperatures used for the LUTs.

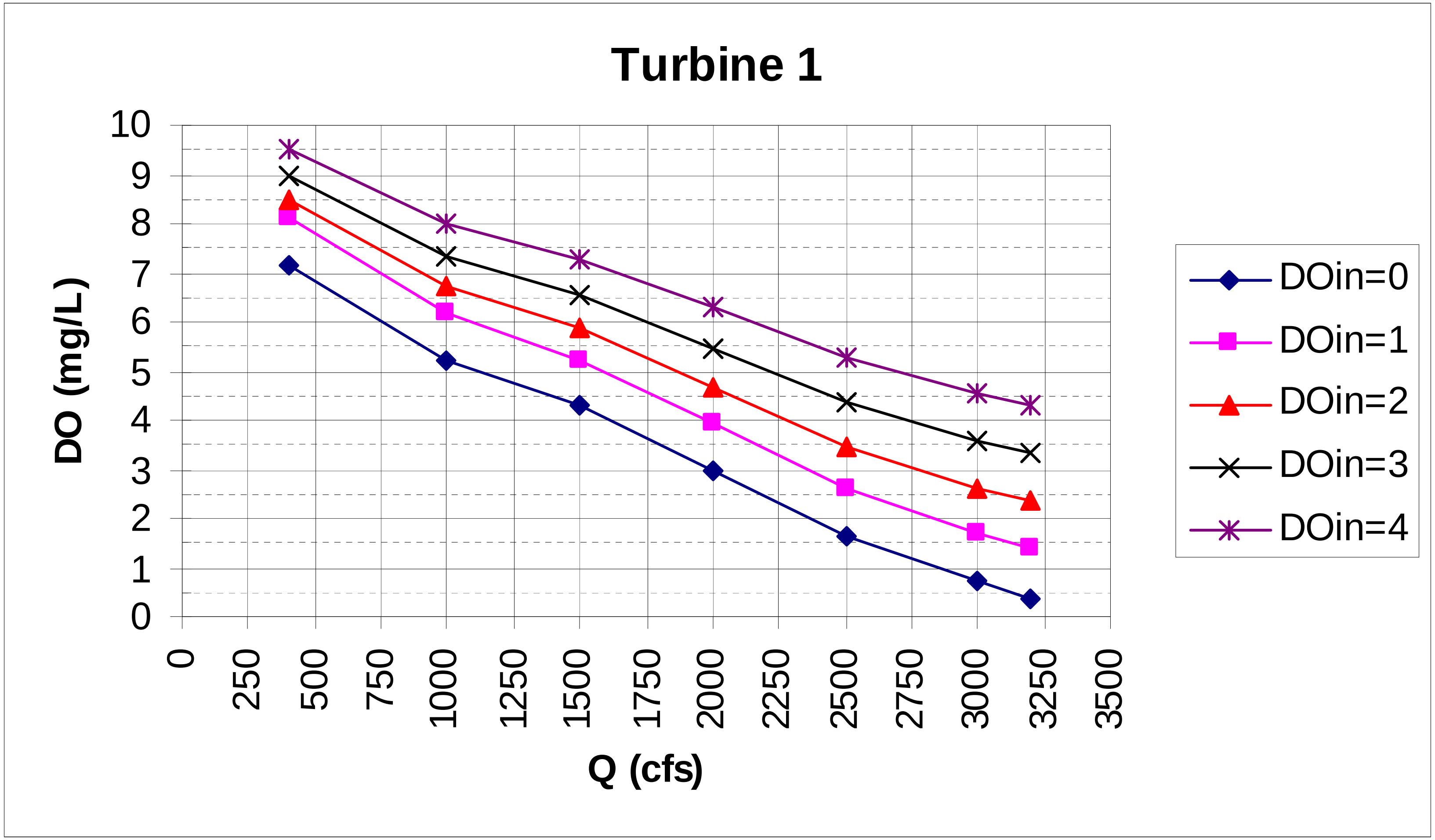


Figure A1: DO in the tailrace of Unit 1 for various DO levels in the inflow. The respective temperature conditions for these DO levels are the following: DO_{in} = 0, T=20 ^{o}; DO_{in} = 1, T=16 ^{o}; DO_{in} = 2, T=16 ^{o}; DO_{in} = 3, T=15 ^{o}; DO_{in} = 4, T=14 ^{o}.

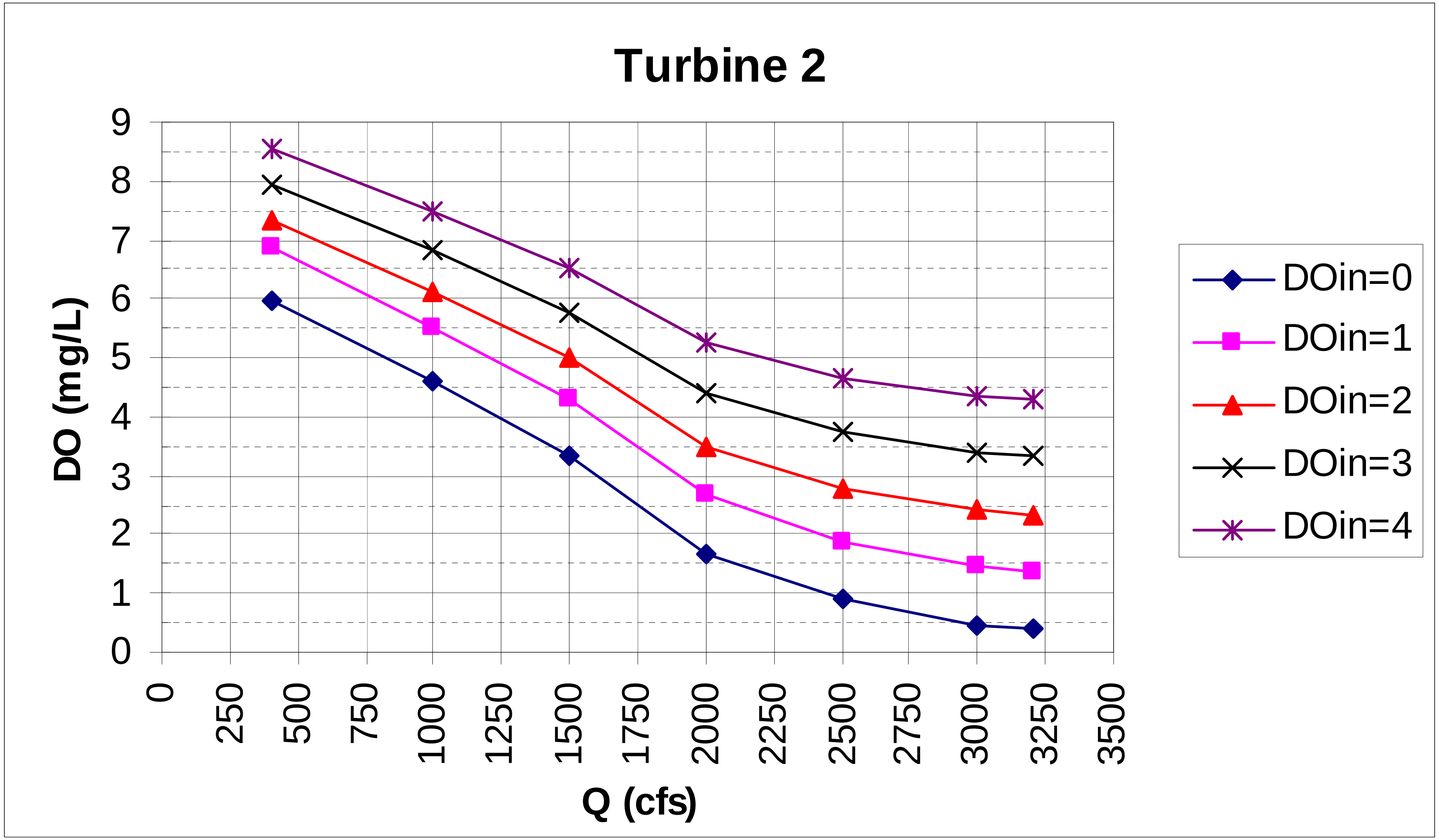


Figure A2: DO in the tailrace of Unit 2 for various DO levels in the inflow. The respective temperature conditions for these DO levels are the following: DO_{in} = 0, T=20 ^{o}; DO_{in} = 1, T=16 ^{o}; DO_{in} = 2, T=16 ^{o}; DO_{in} = 3, T=15 ^{o}; DO_{in} = 4, T=14 ^{o}.

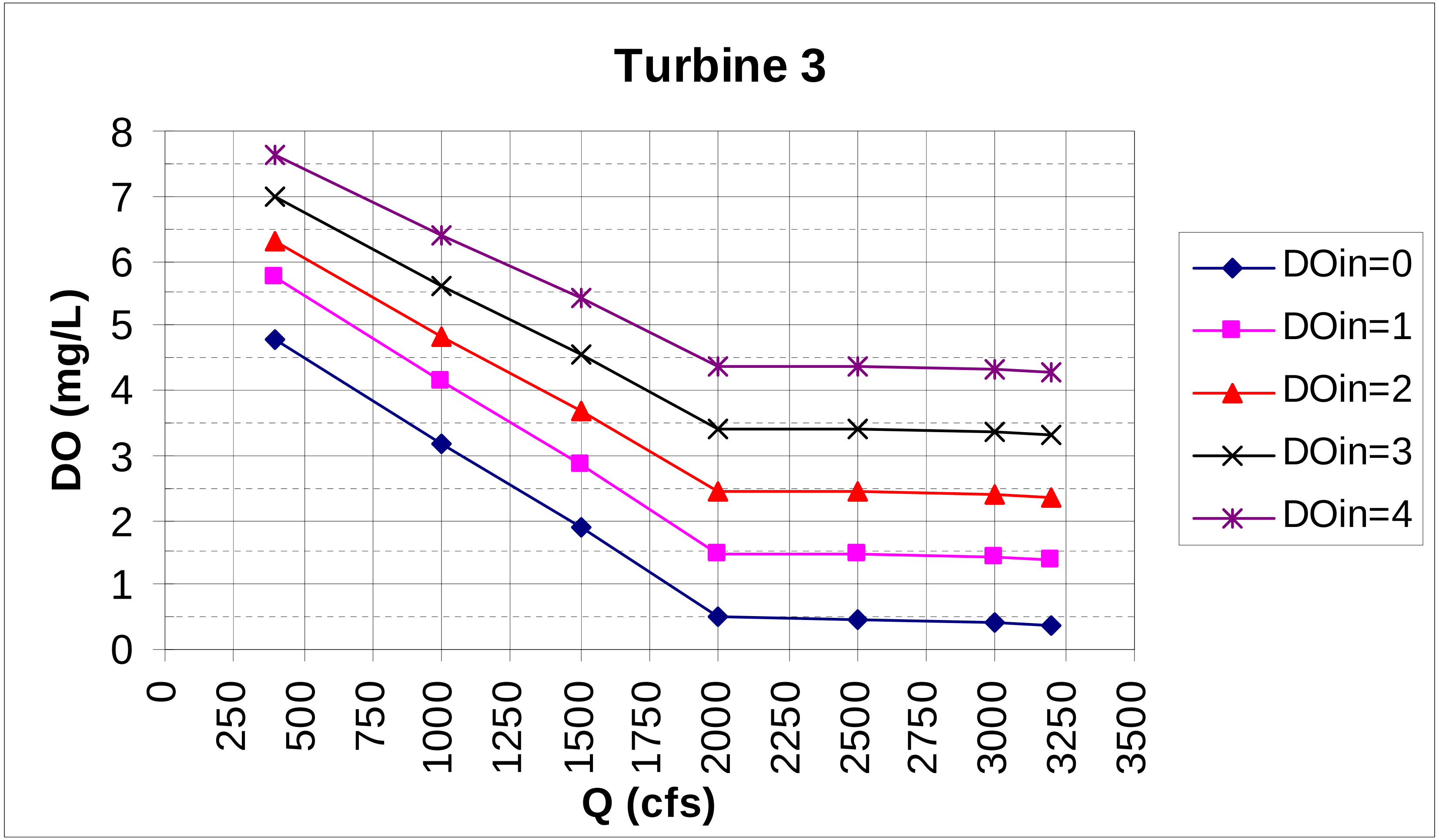


Figure A3: DO in the tailrace of Unit 3 for various DO levels in the inflow. The respective temperature conditions for these DO levels are the following: DO_{in} = 0, T=20 ^{o}; DO_{in} = 1, T=16 ^{o}; DO_{in} = 2, T=16 ^{o}; DO_{in} = 3, T=15 ^{o}; DO_{in} = 4, T=14 ^{o}.

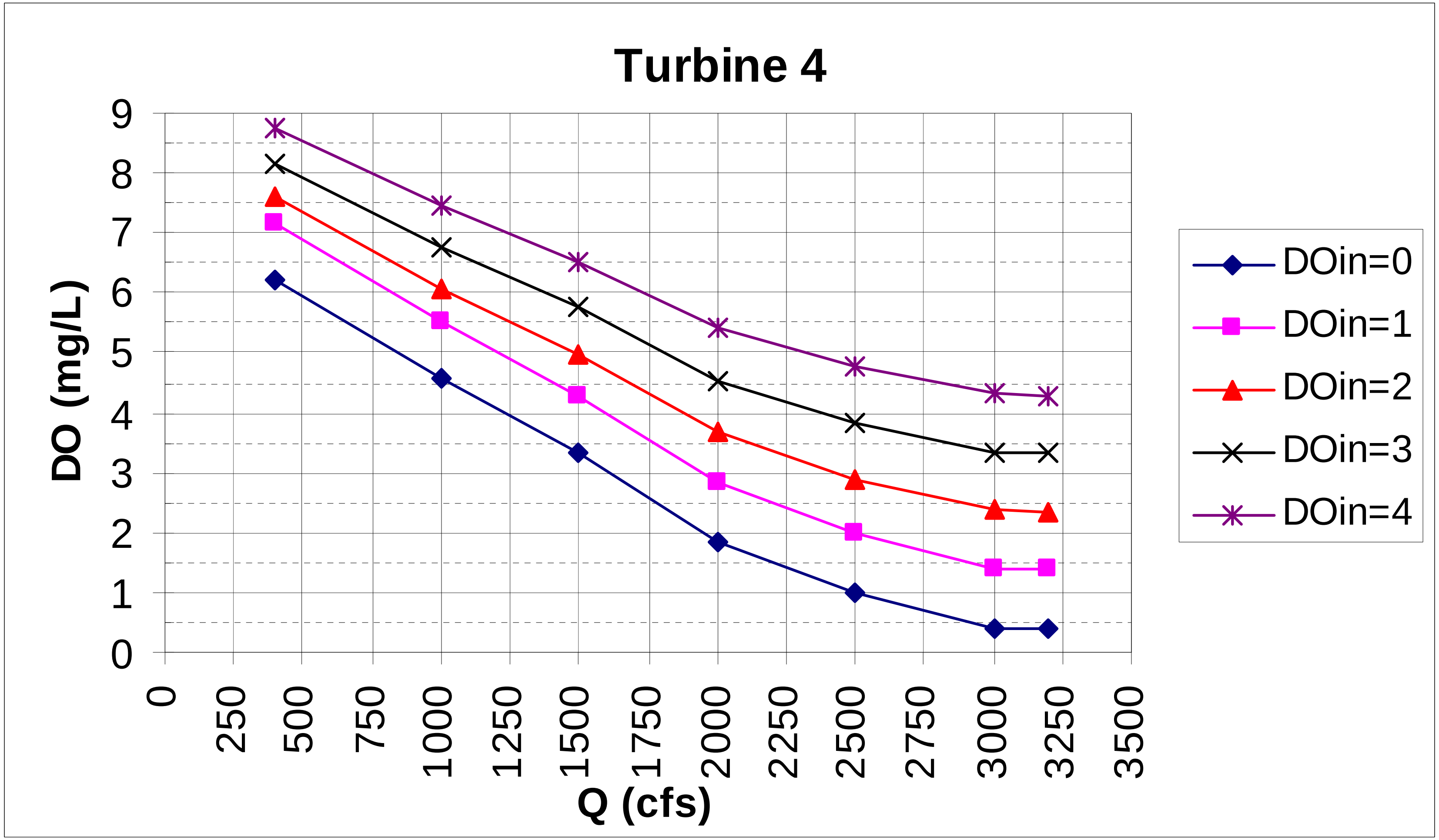


Figure A4: DO in the tailrace of Unit 4 for various DO levels in the inflow. The respective temperature conditions for these DO levels are the following: DO_{in} = 0, T=20 ^{o}; DO_{in} = 1, T=16 ^{o}; DO_{in} = 2, T=16 ^{o}; DO_{in} = 3, T=15 ^{o}; DO_{in} = 4, T=14 ^{o}.

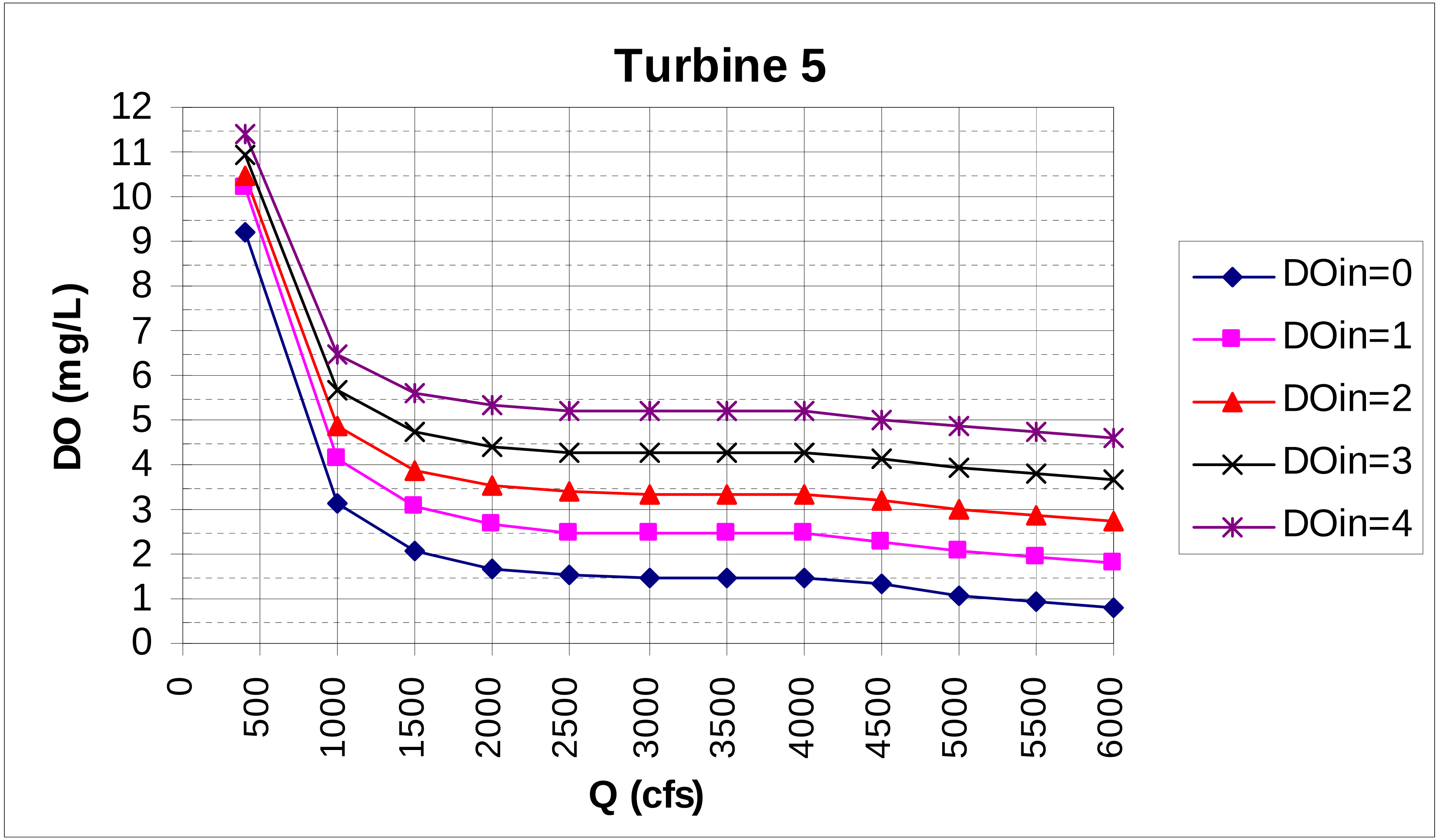


Figure A5: DO in the tailrace of Unit 5 for various DO levels in the inflow. The respective temperature conditions for these DO levels are the following: DO_{in} = 0, T=20 ^{o}; DO_{in} = 1, T=16 ^{o}; DO_{in} = 2, T=16 ^{o}; DO_{in} = 3, T=15 ^{o}; DO_{in} = 4, T=14 ^{o}.

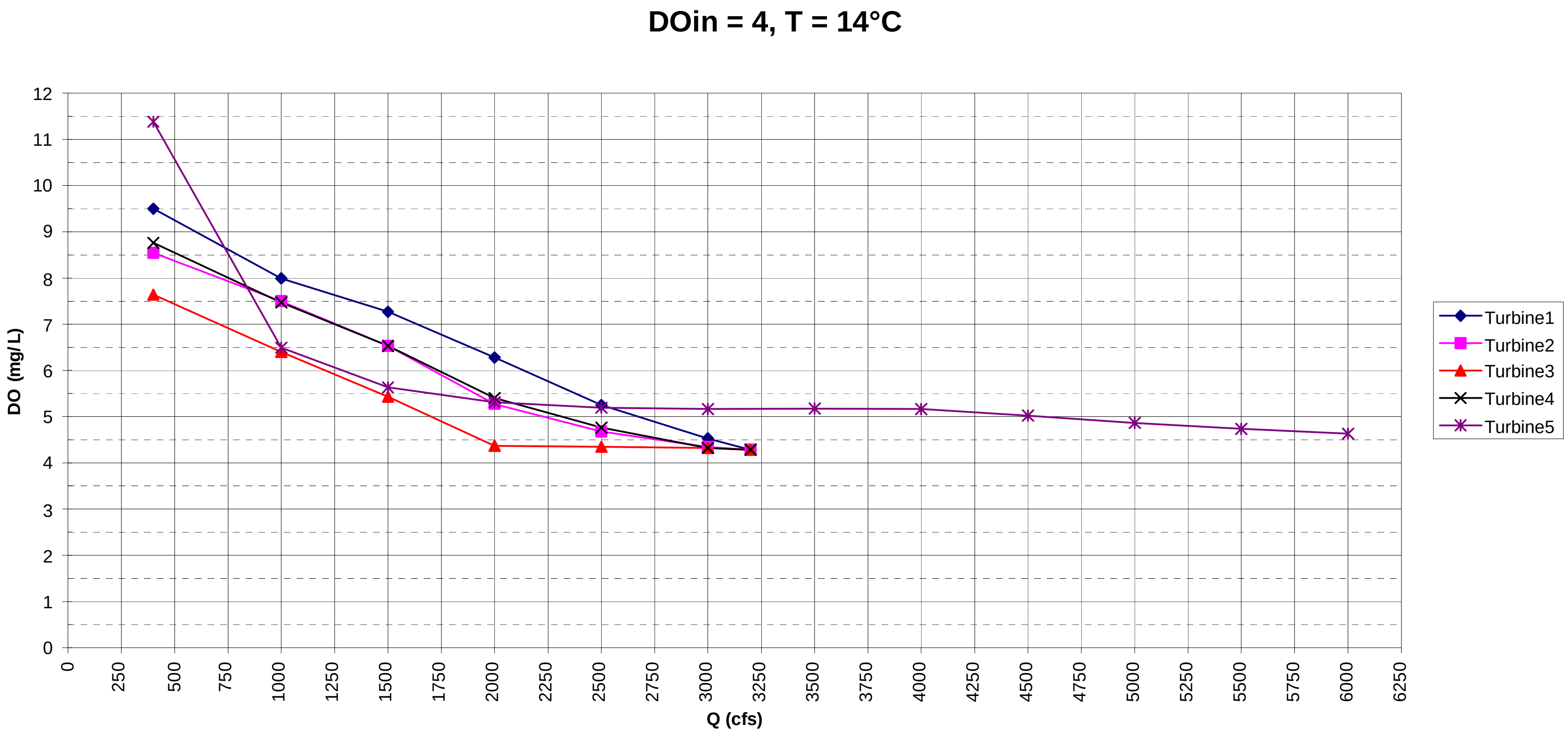


Figure A6: Predicted DO in the tailrace for the range of flow levels for each unit, for the indicated inflow conditions.

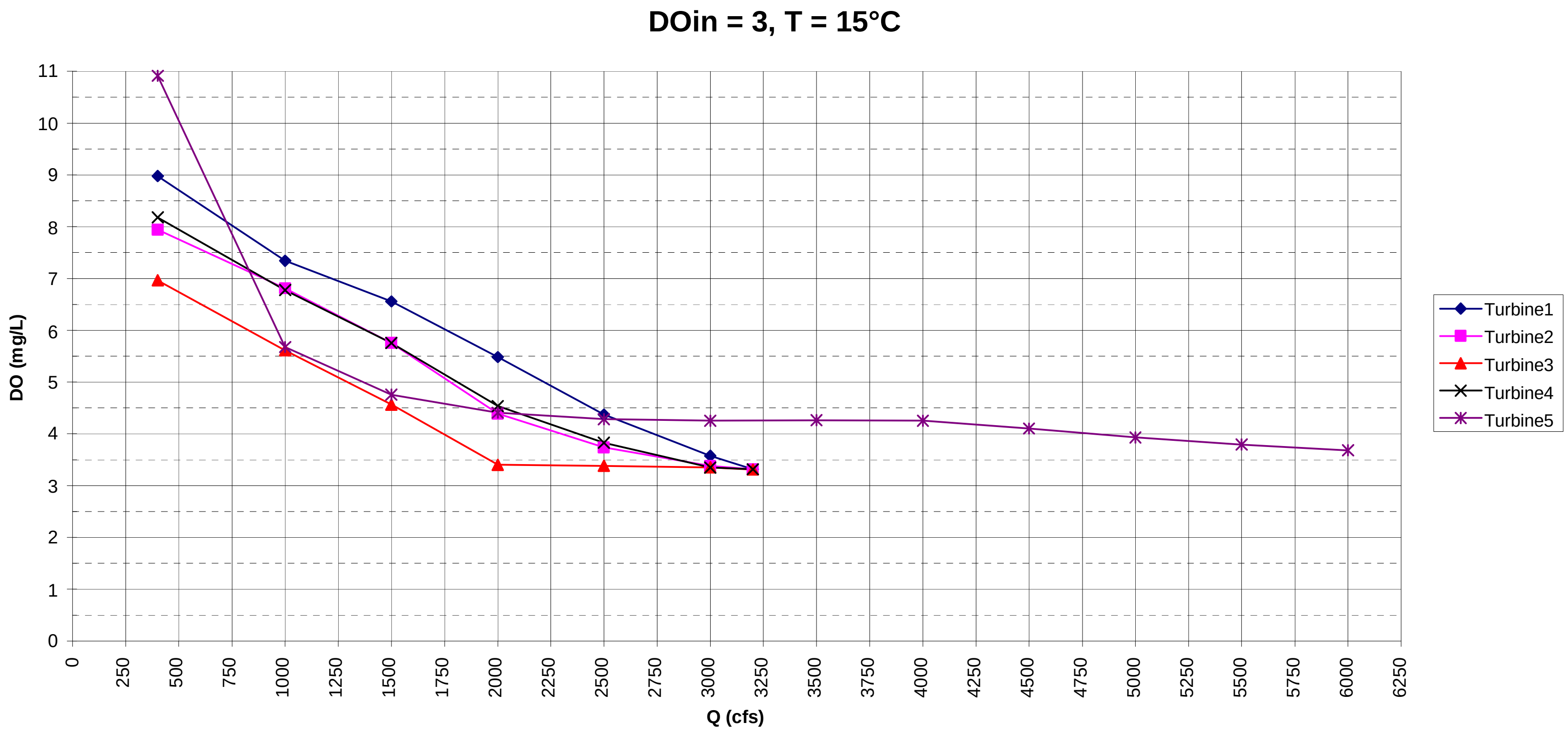


Figure A7: Predicted DO in the tailrace for the range of flow levels for each unit, for the indicated inflow conditions.

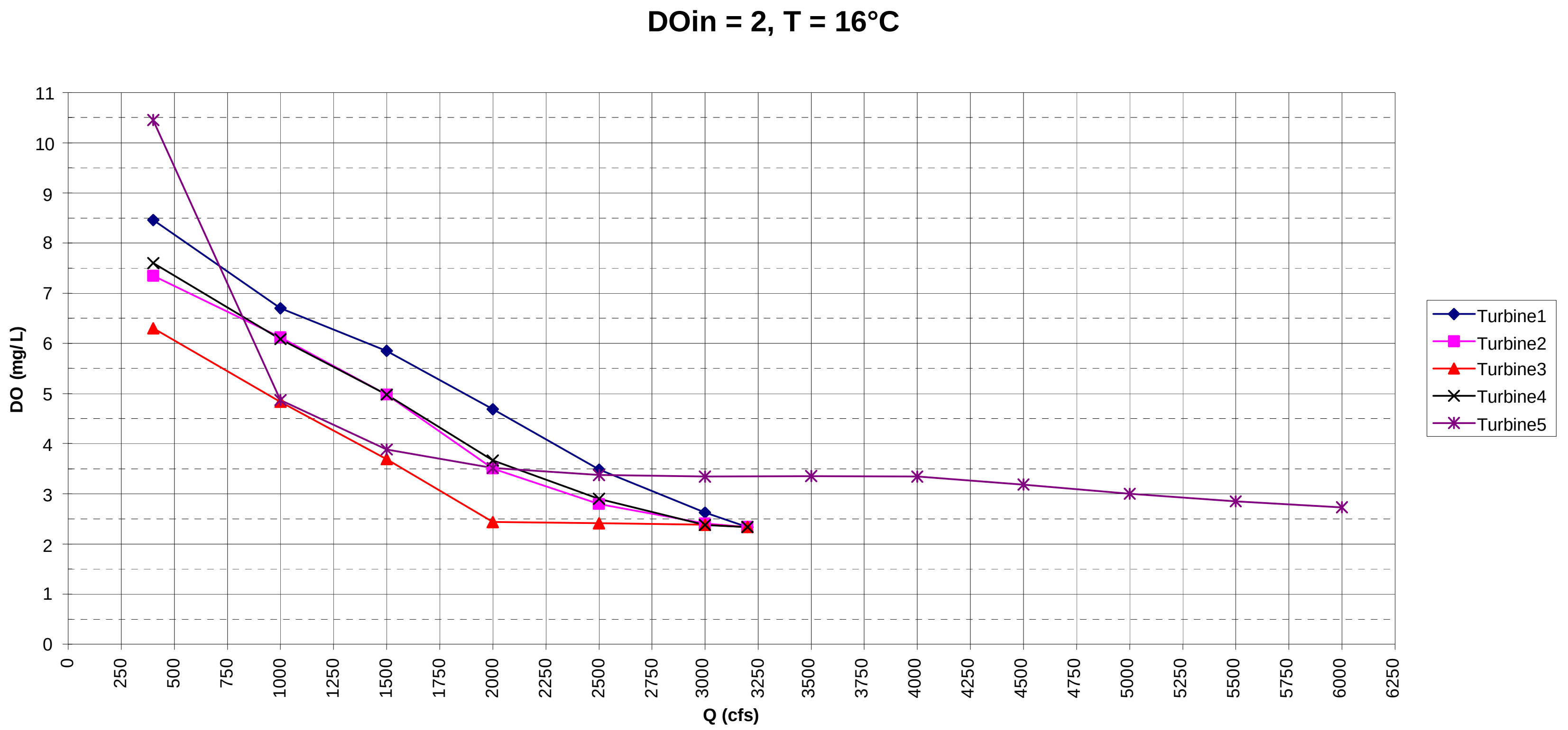


Figure A8: Predicted DO in the tailrace for the range of flow levels for each unit, for the indicated inflow conditions.

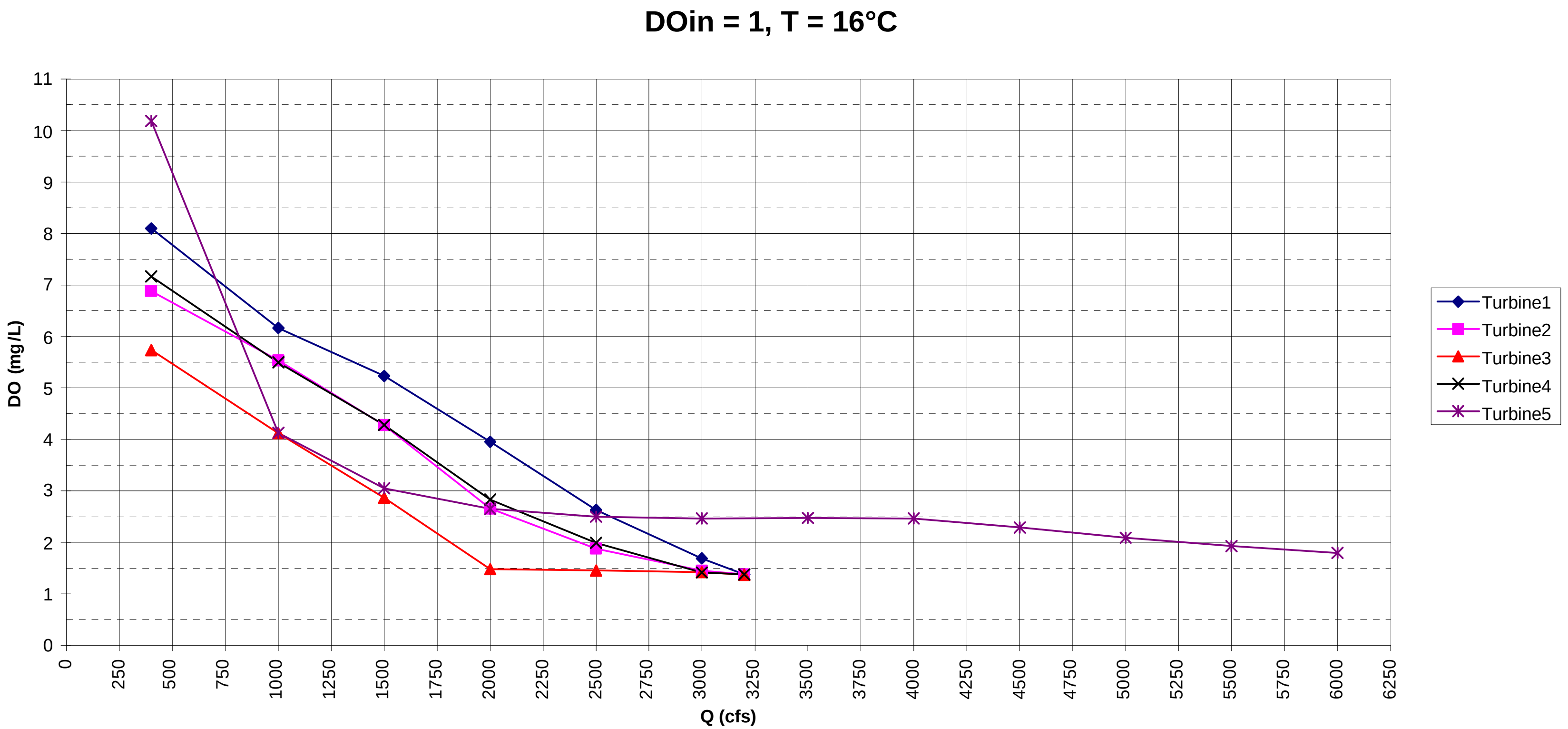


Figure A9: Predicted DO in the tailrace for the range of flow levels for each unit, for the indicated inflow conditions.

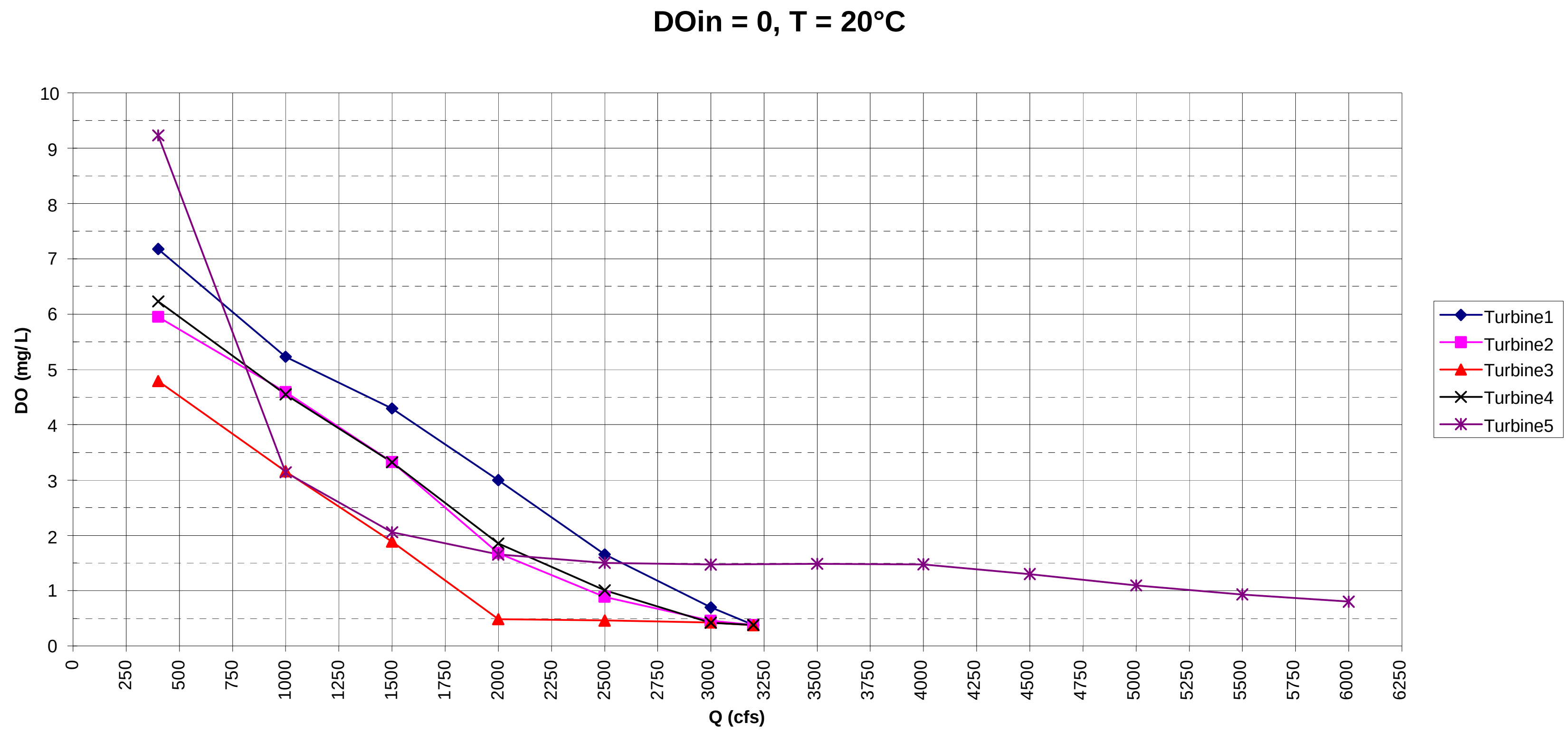


Figure A10: Predicted DO in the tailrace for the range of flow levels for each unit, for the indicated inflow conditions.

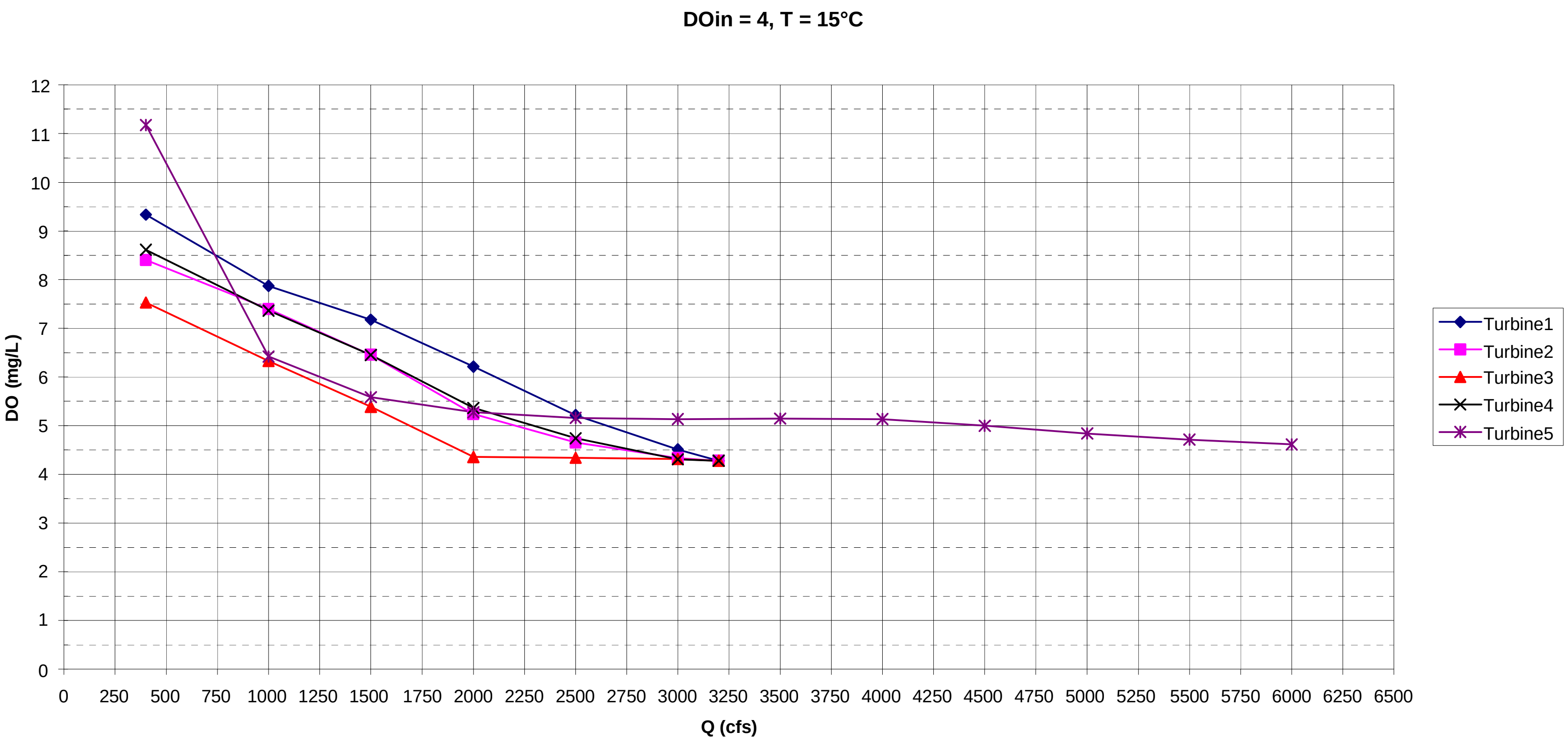


Figure A11: Sensitivity of DO uptake for DO_{in} = 4 and temperature = 15°C

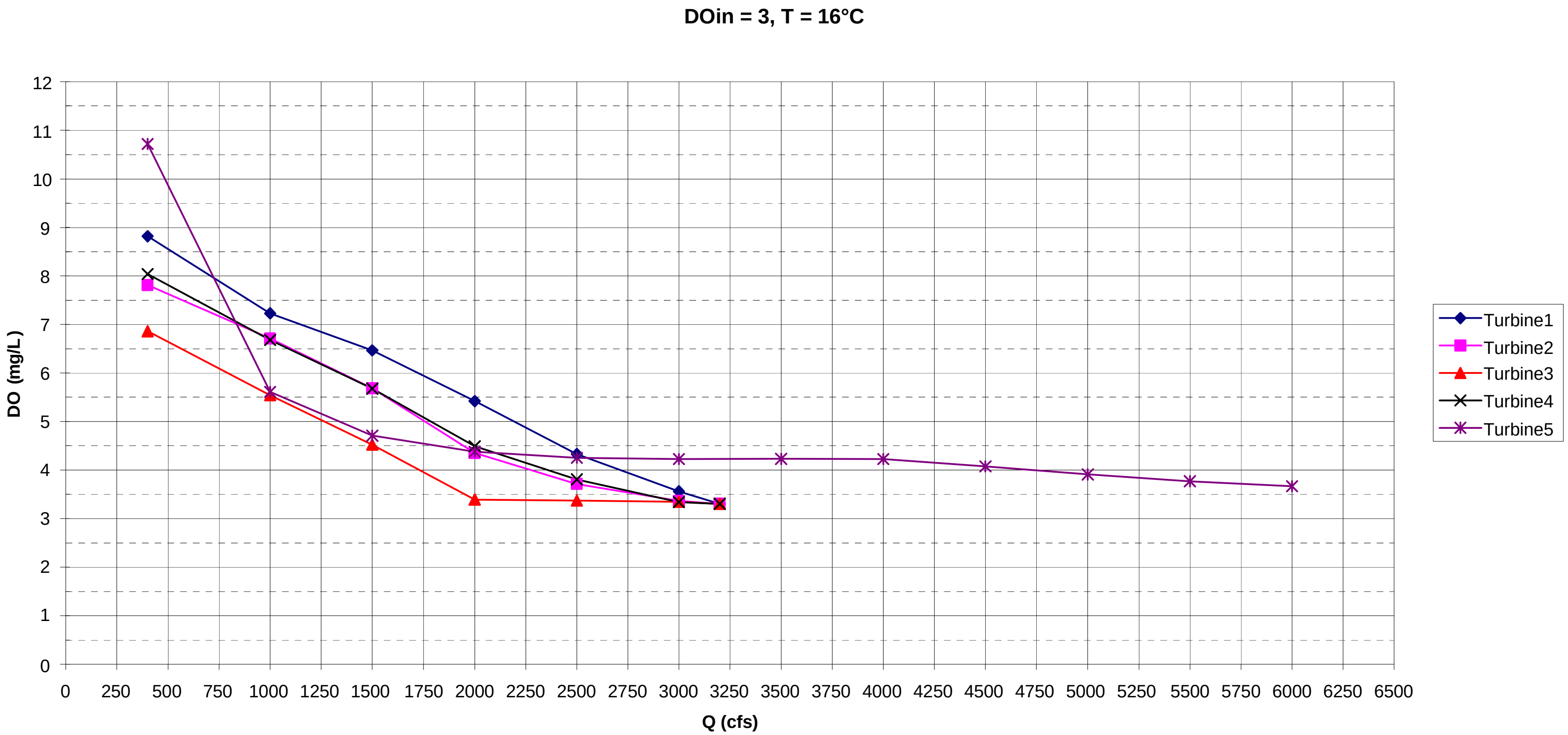


Figure A12: Sensitivity of DO uptake for DO_{in} = 3 and temperature = 16°C

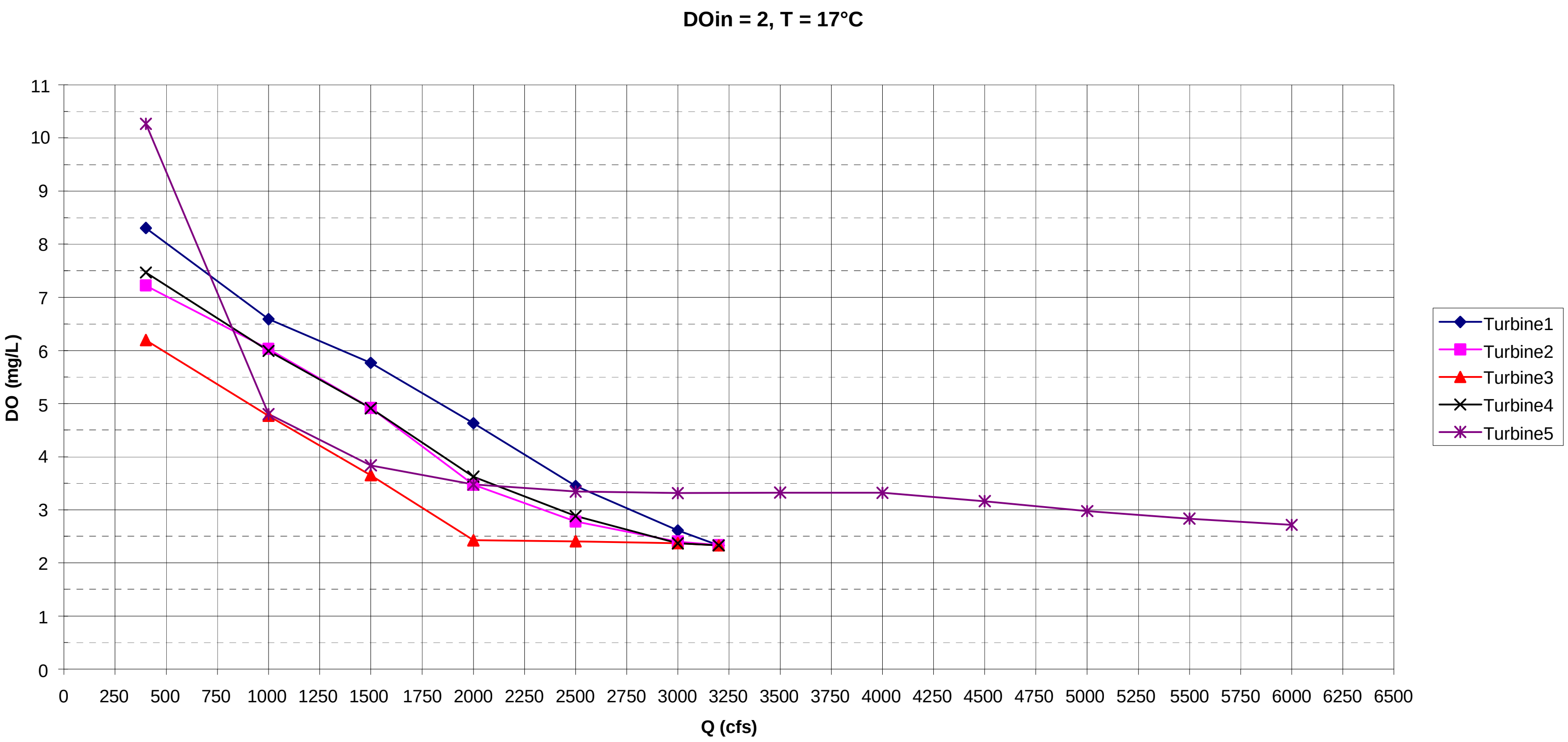


Figure A13: Sensitivity of DO uptake for DO_{in} = 2 and temperature = $17^{o}C$

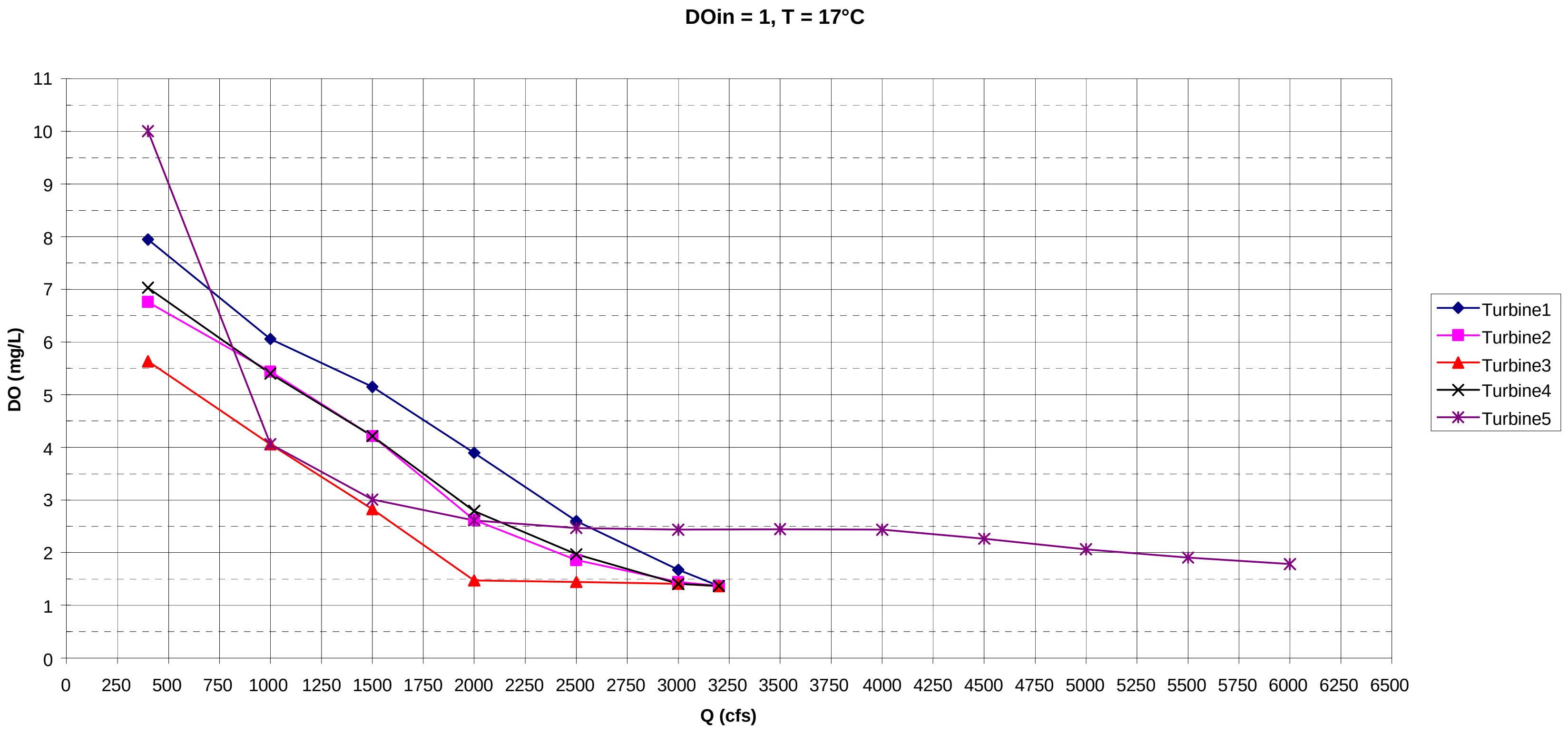


Figure A14: Sensitivity of DO uptake for DO_{in} = 1 and temperature = 17^{o}C

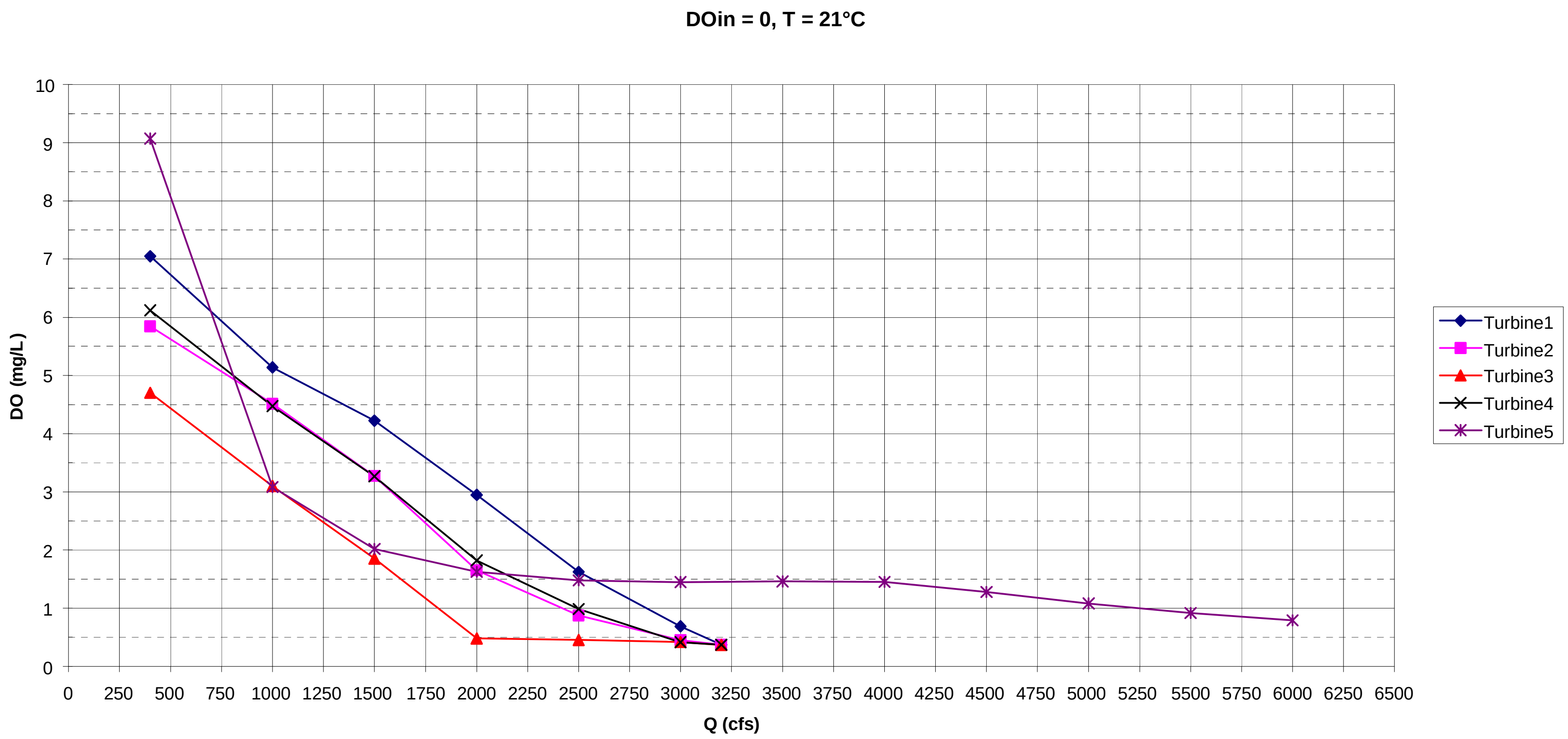


Figure A15: Sensitivity of DO uptake for DO_{in} = 0 and temperature = $21^{o}C$

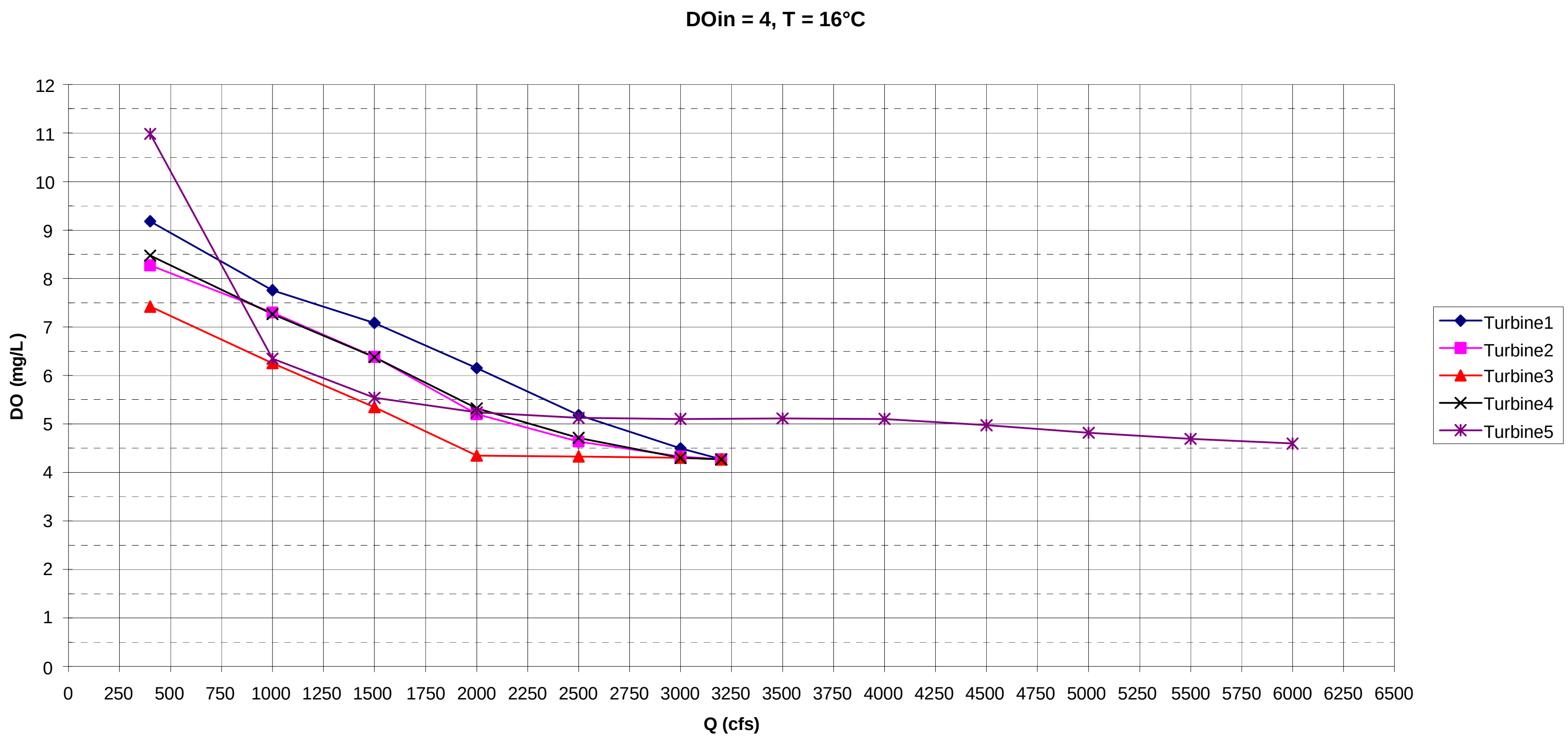


Figure A16: Sensitivity of DO uptake for DO_{in} = 4 and temperature = $16^{o}C$

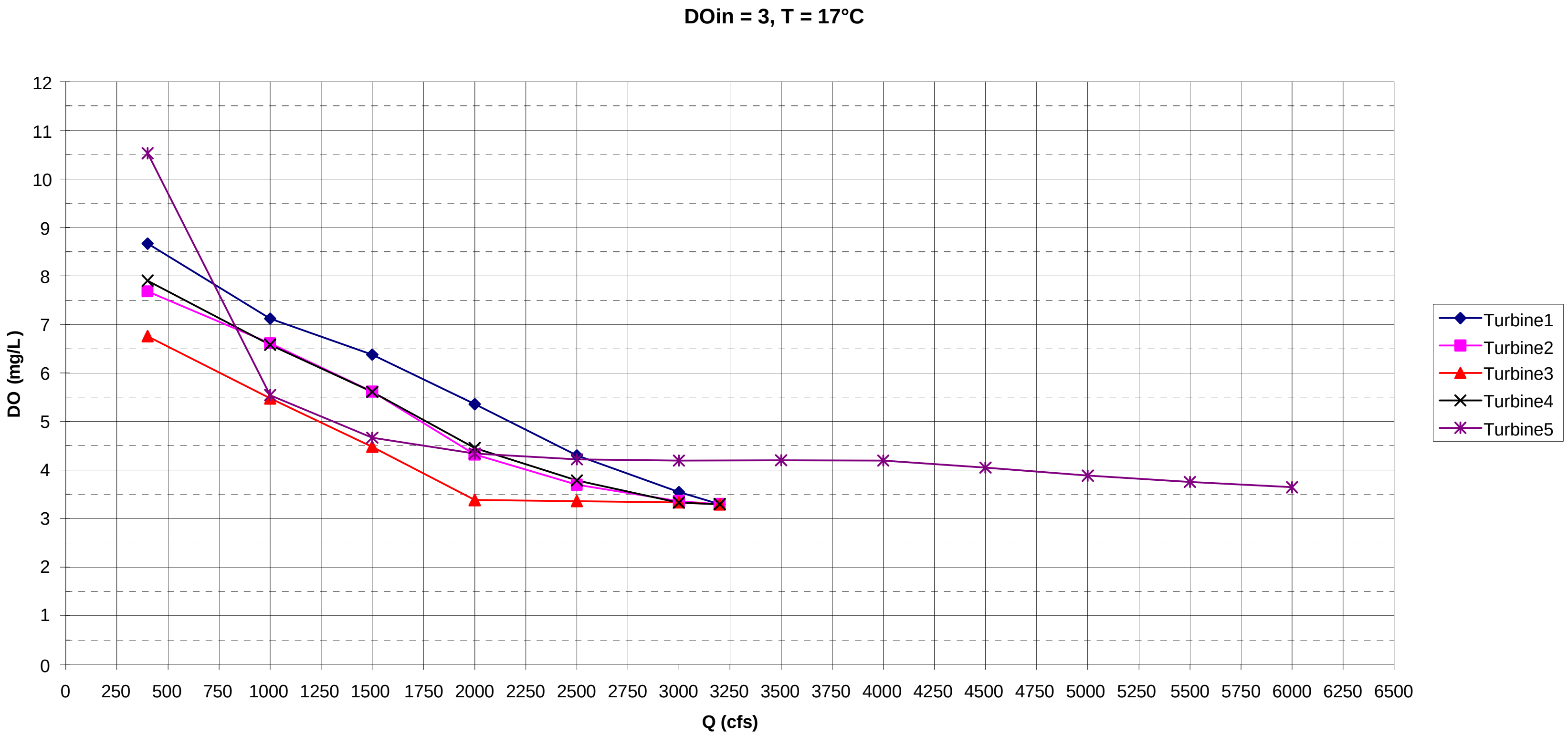


Figure A17: Sensitivity of DO uptake for DO_{in} = 3 and temperature = 17^oC

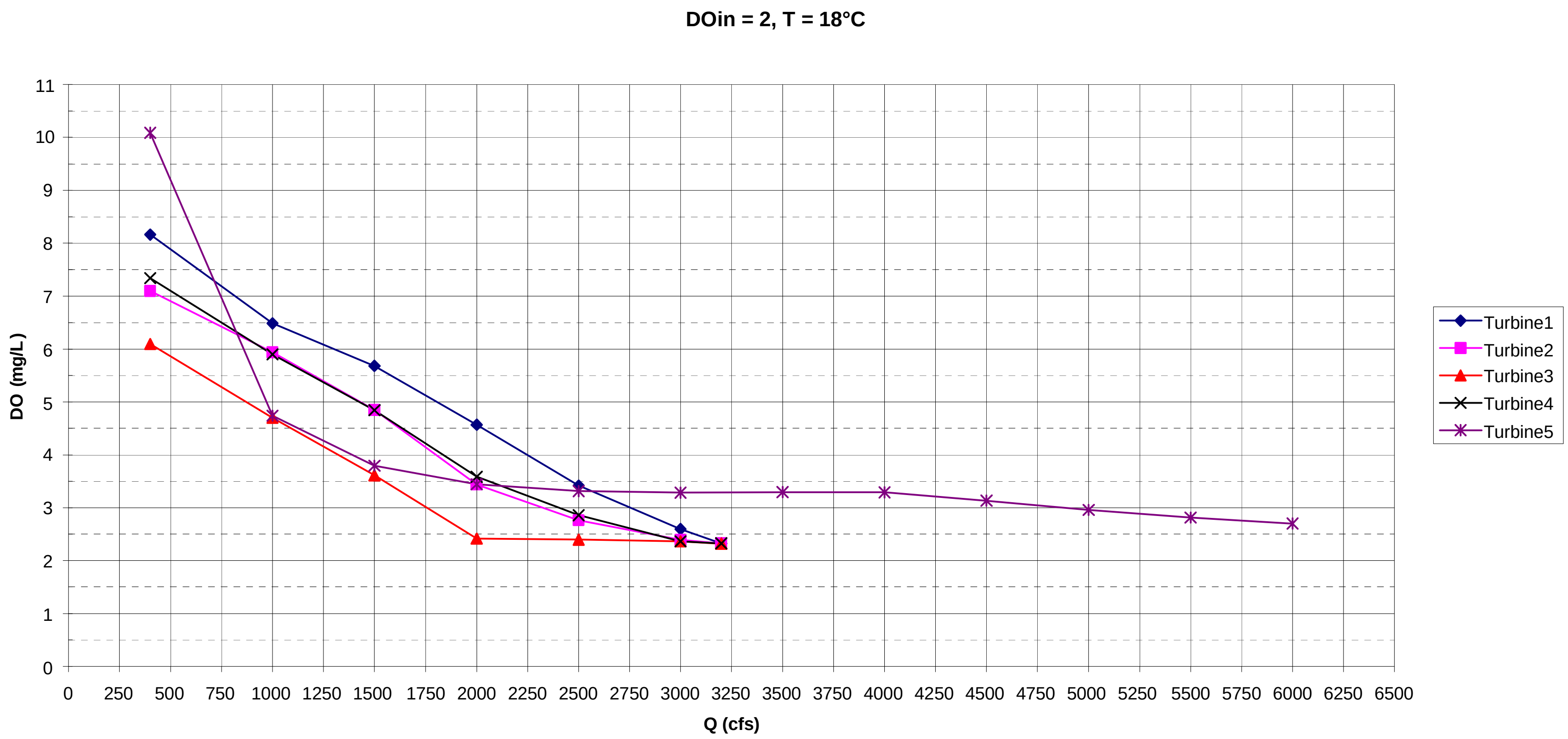


Figure A18: Sensitivity of DO uptake for DO_{in} = 2 and temperature = 18°C

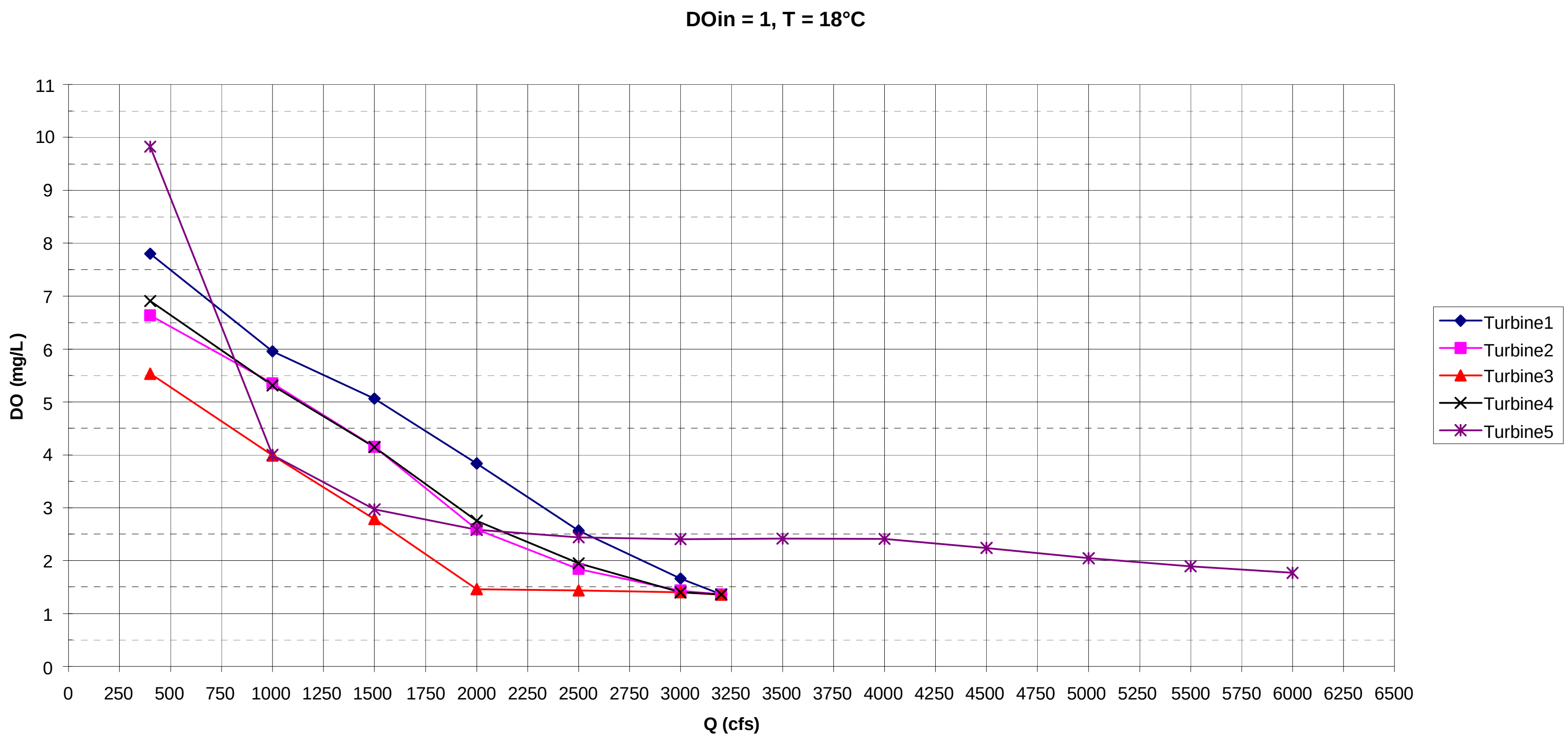


Figure A19: Sensitivity of DO uptake for DO_{in} = 1 and temperature = 18^{o}C

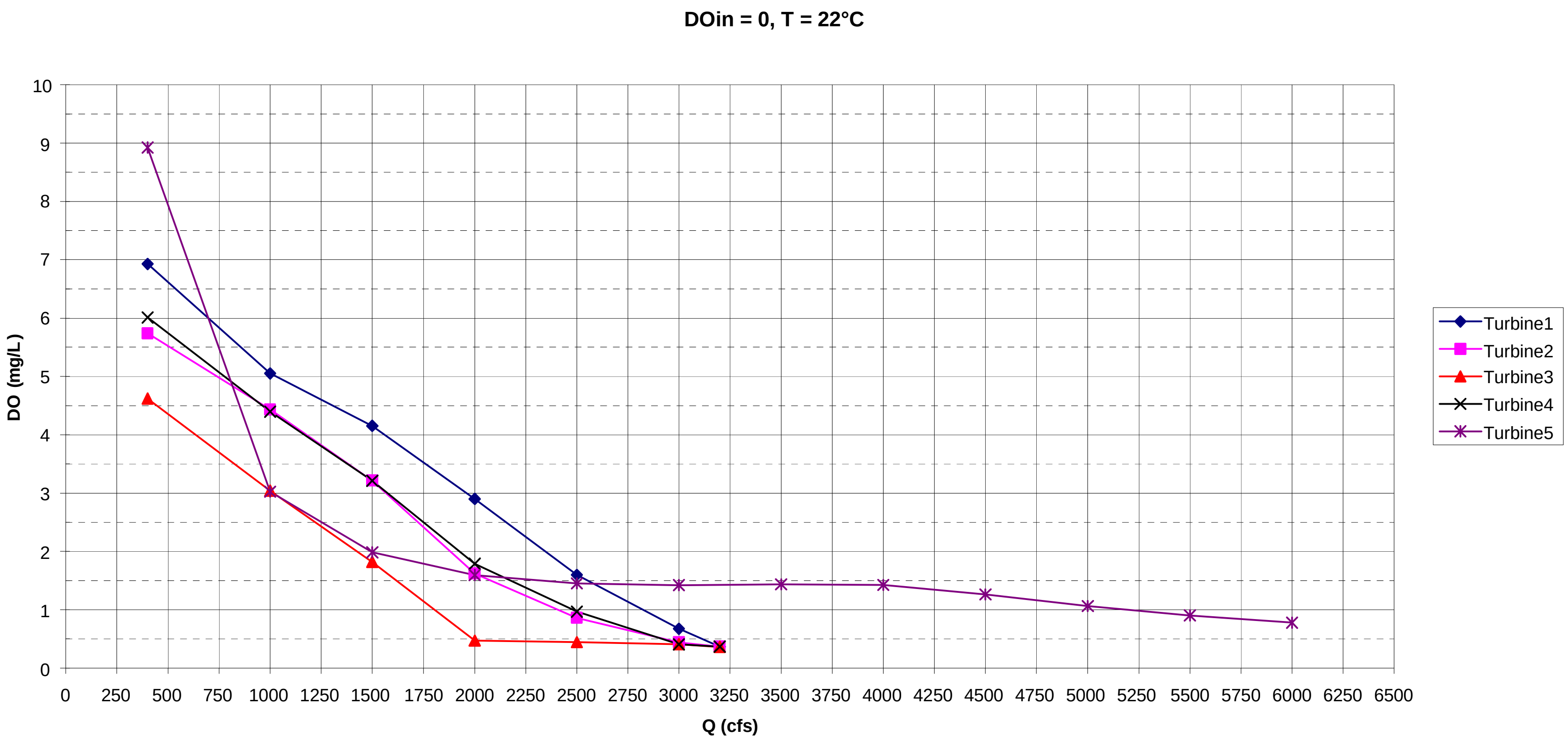


Figure A20: Sensitivity of DO uptake for DO_{in} = 0 and temperature = 22^{o}C

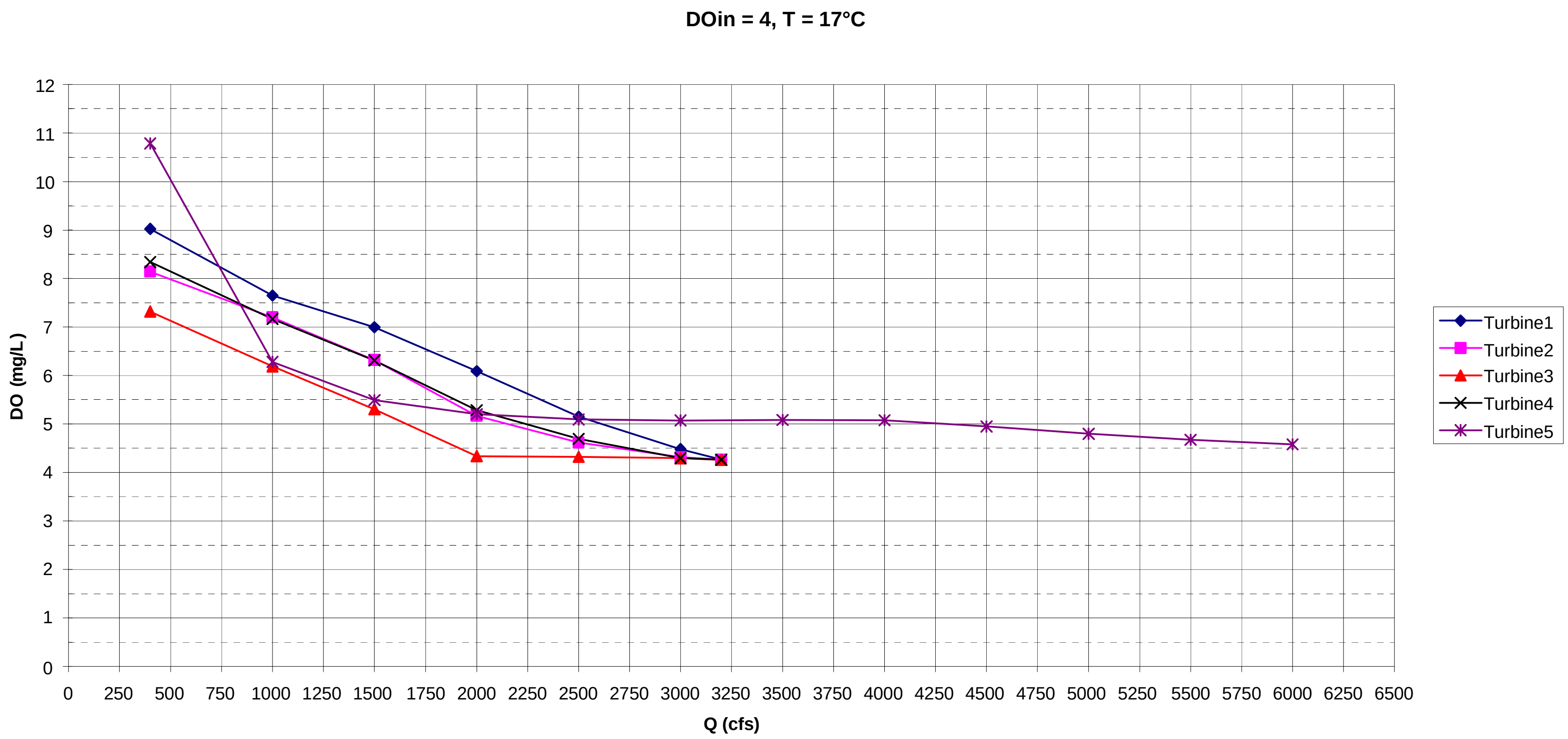


Figure A21: Sensitivity of DO uptake for DO_{in} = 4 and temperature = 17^{o}C

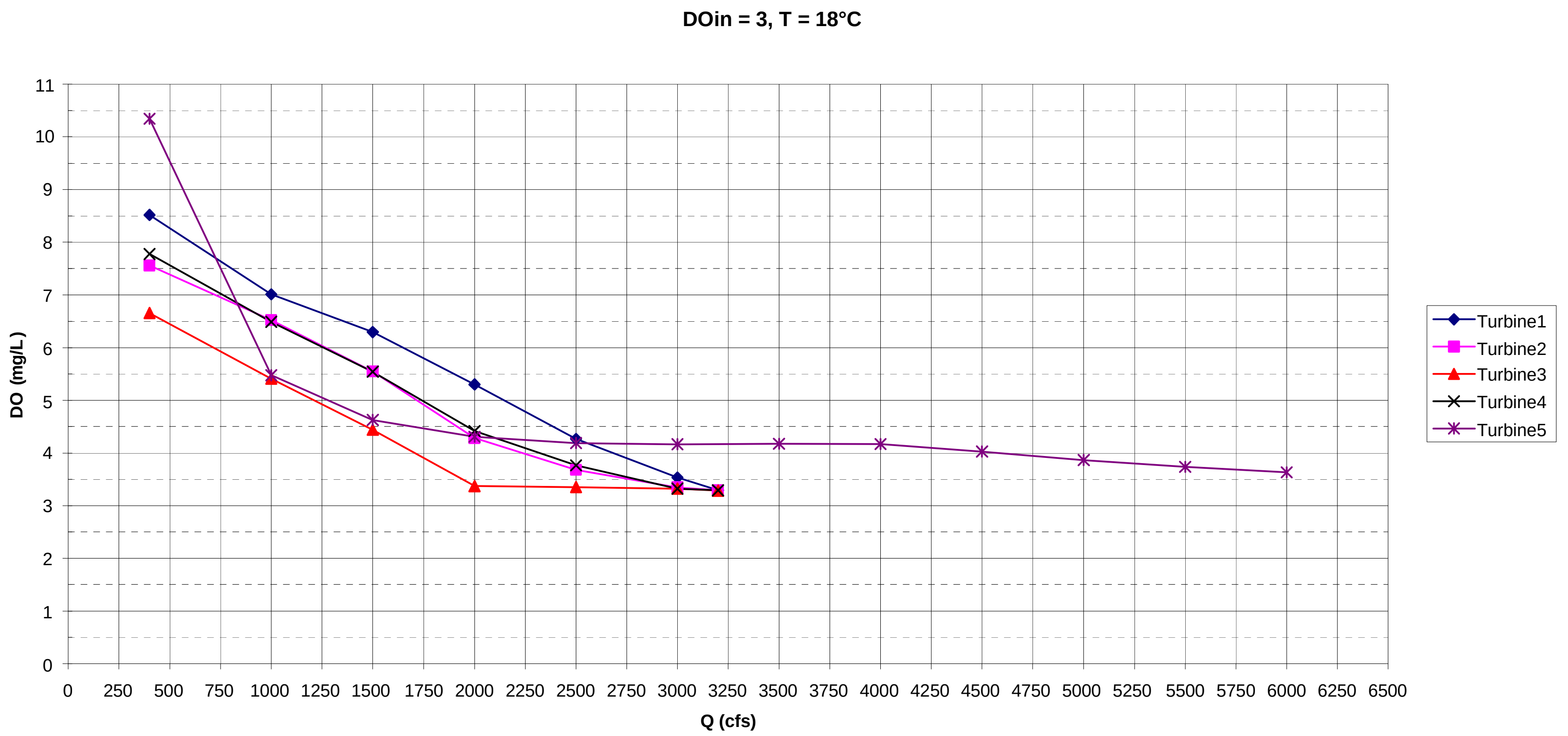


Figure A22: Sensitivity of DO uptake for DO_{in} = 3 and temperature = 18°C

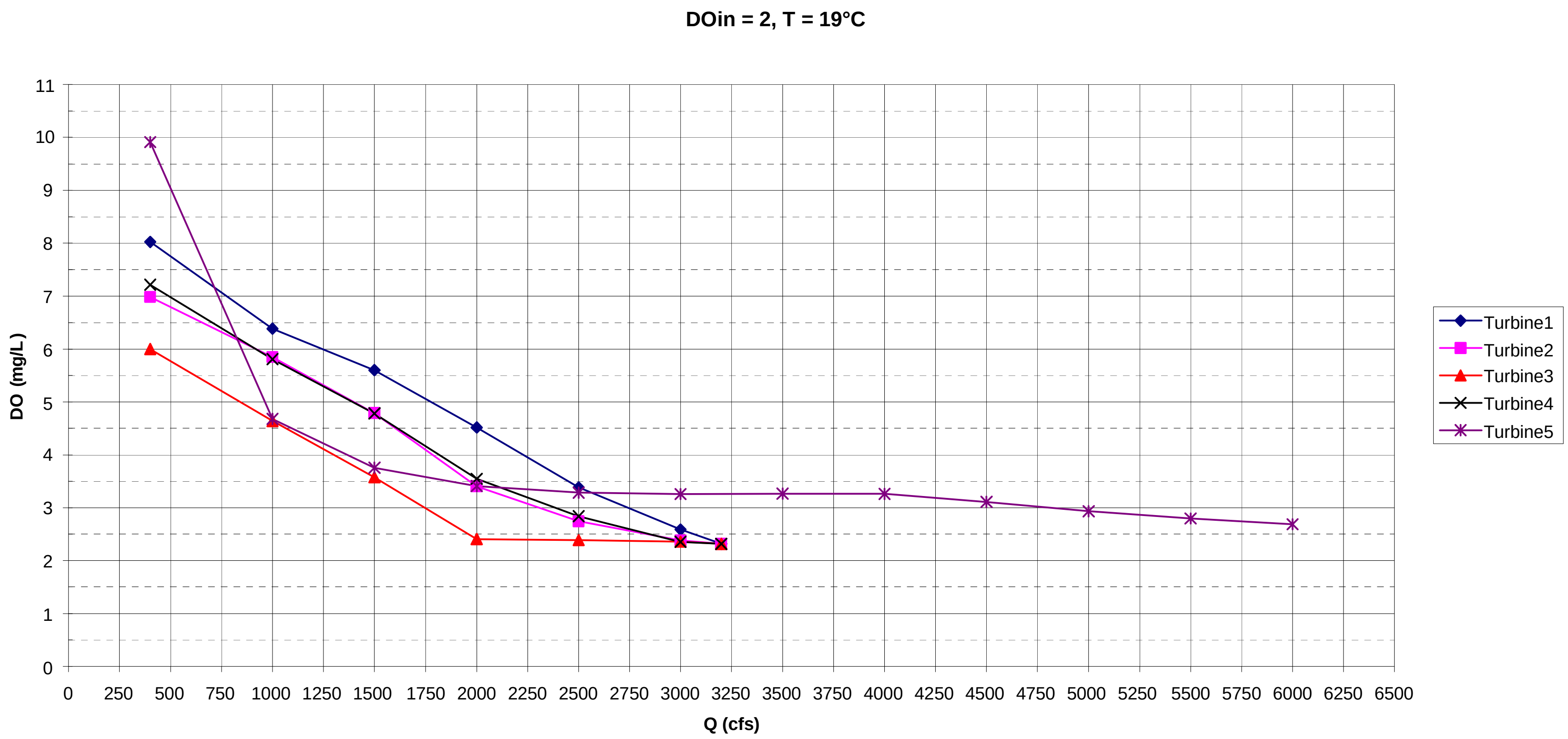


Figure A23: Sensitivity of DO uptake for DO_{in} = 2 and temperature = 19°C

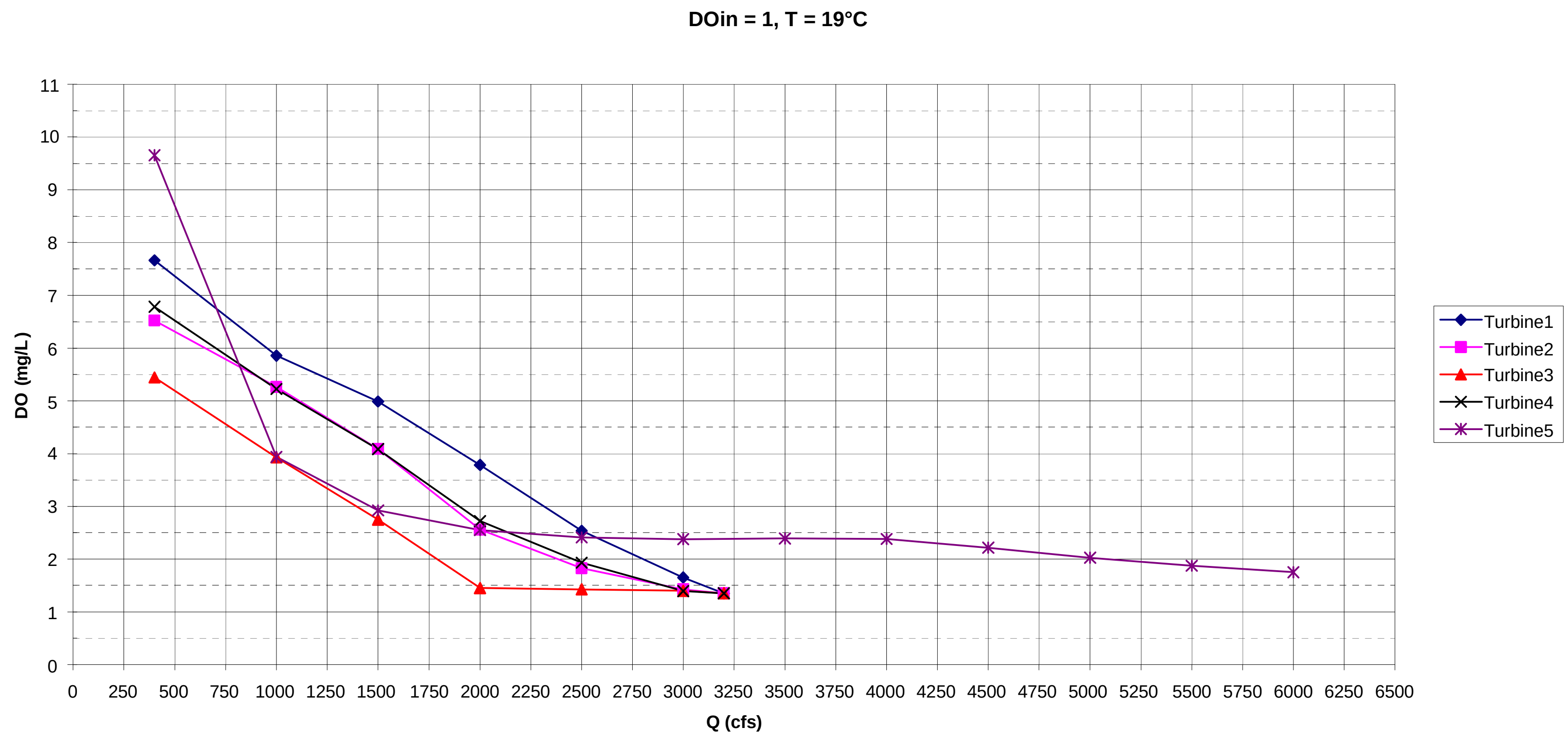


Figure A24: Sensitivity of DO uptake for DO_{in} = 1 and temperature = 19°C

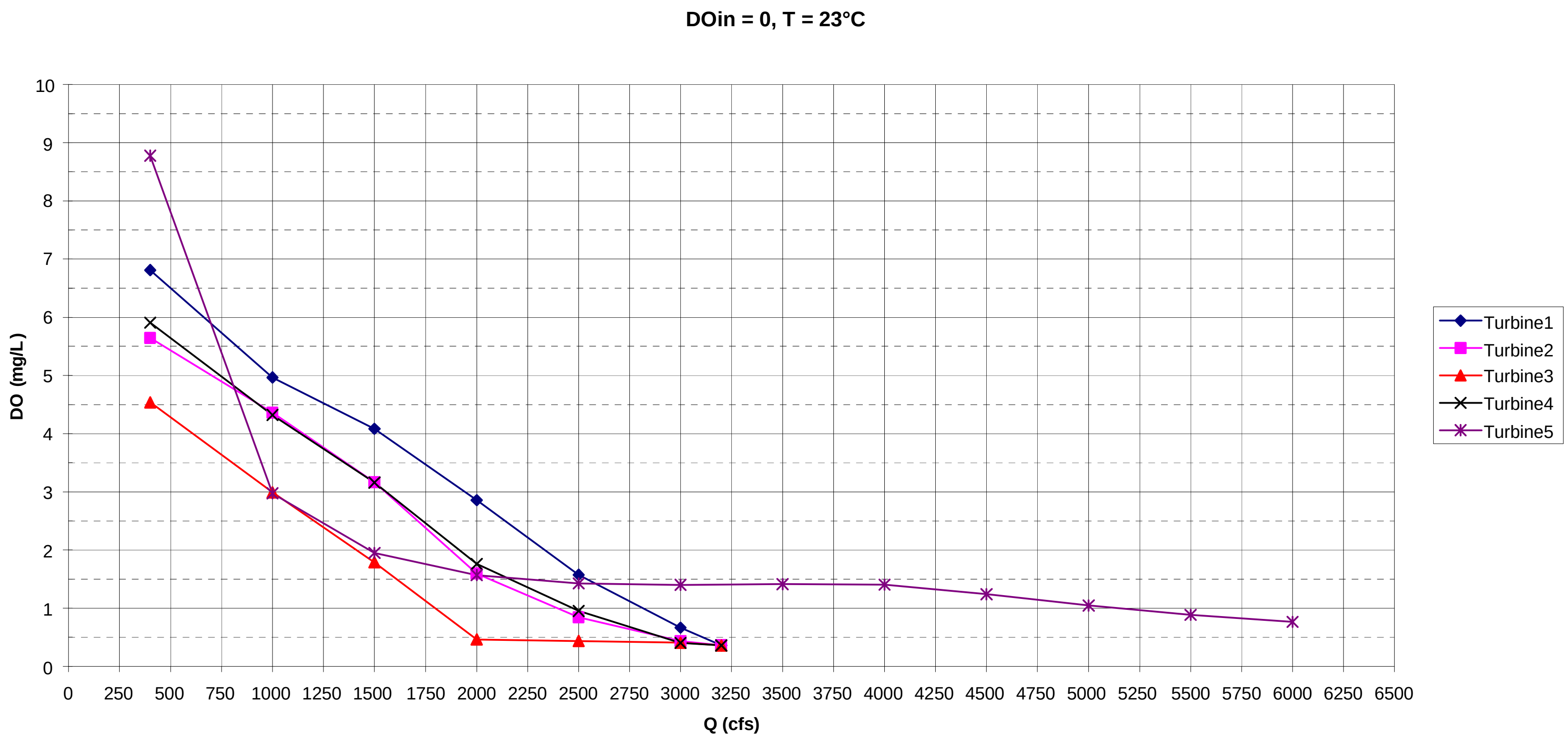


Figure A25: Sensitivity of DO uptake for DO_{in} = 0 and temperature = 23^{o}C

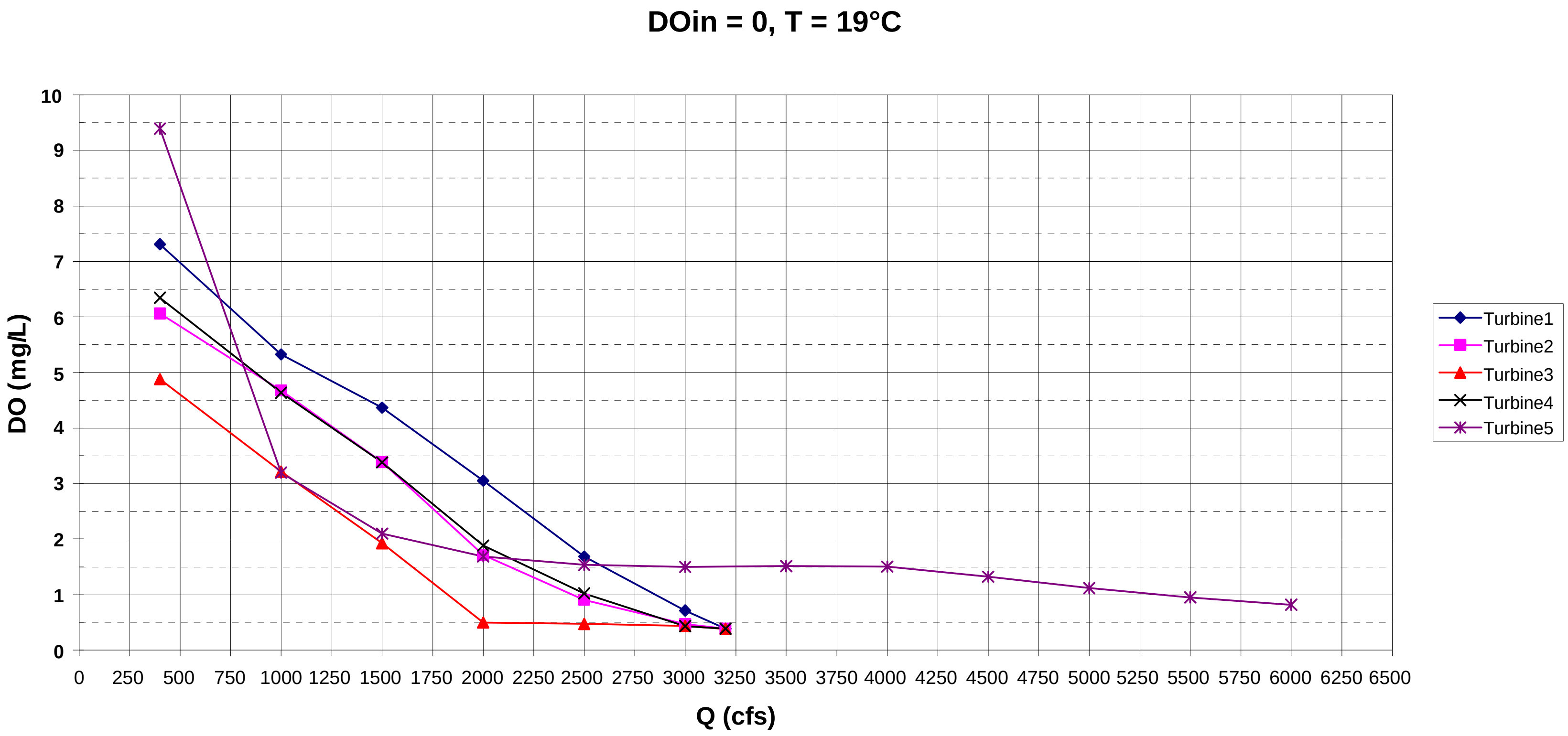


Figure A26: Sensitivity of DO uptake for DO_{in} = 0 and temperature = 19^{o}C

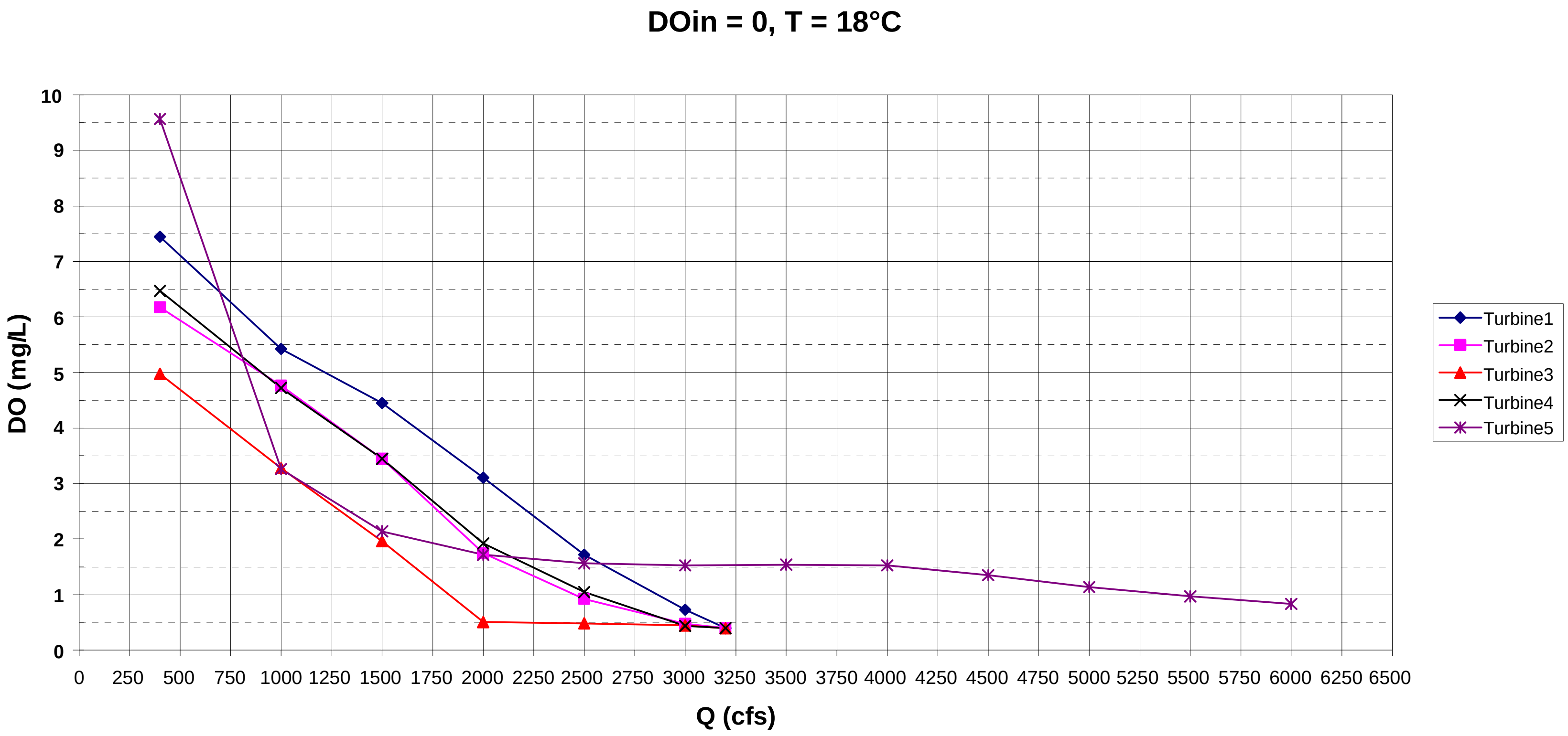


Figure A27: Sensitivity of DO uptake for DO_{in} = 0 and temperature = 18°C

MEMORANDUM

TO: Operations Committee – Technical Working Group

FROM: M. Schimpff, PE, J. Quebbeman, PE – Kleinschmidt Associates

DATE: October 5, 2006

RE: HEC-ResSim Model Calibration

---

1. Introduction

The technical working committee, tasked with the development of an operations model, met at Saluda on August 23, 2006 to discuss the progress of the model development and calibration. During that meeting, several ideas were discussed to determine a best-fit approach for determining the Lake Murray inflow hydrograph over a long period of record. This memo is a discussion of these various approaches in addition to results of the best-fit data.

The main focus of this study is to determine the best methodology for hind-casting the inflow hydrograph. From the technical committee discussions, two main methodologies were evaluated:

1. Use the reservoir lake level data (instantaneous daily) data in conjunction with the gaged outflow immediately downstream of the dam.

2. Use the available gaged upstream inflows, (Chappels, Little River and Bush River gages), and prorate the gaged flows to account for the ungaged contributing drainage areas. The common period of record is from 1990 to present.

Releases from Lake Murray, into the Saluda River, are controlled through the operations of the Saluda Dam Hydroelectric Facility. Constraints on operations with respect to seasonal lake level 'guide curves', minimum flow discharges and min/max operating levels can affect the discharges and/or the resulting lake levels throughout the year. The affects of these constraints are especially apparent during extremely wet or dry years, where operating constraints can create situations where these guidelines may be violated. In order to assess various constraints over a historic period of operation, a HEC-ResSim model has been developed to assess various guidelines, in addition to their impacts on allowable operations and lake levels over an extended period of record, approximately sixteen years.

The first step in this process was to develop a model which determines the approximate inflow to Lake Murray over this historic period of record. Calibration of the model is determined by the 'fit' of both the resulting lake stage and outflow data as compared to observed lake stage and outflow data as recorded by the respective USGS gages. Once calibrated, the model will be, used to hind-cast inflow and apply a series of operational and seasonal constraints to determine the effects on the reservoir operation. It is important to note that when calibrating this model, matching specific daily inflows is not as critical as matching the overall reservoir volumes for the period of record, or matching the observed stage levels which are considered the 'guide curve'. If there is any erroneous data, it will be applied equally amongst all evaluated scenarios.

2. Model Development

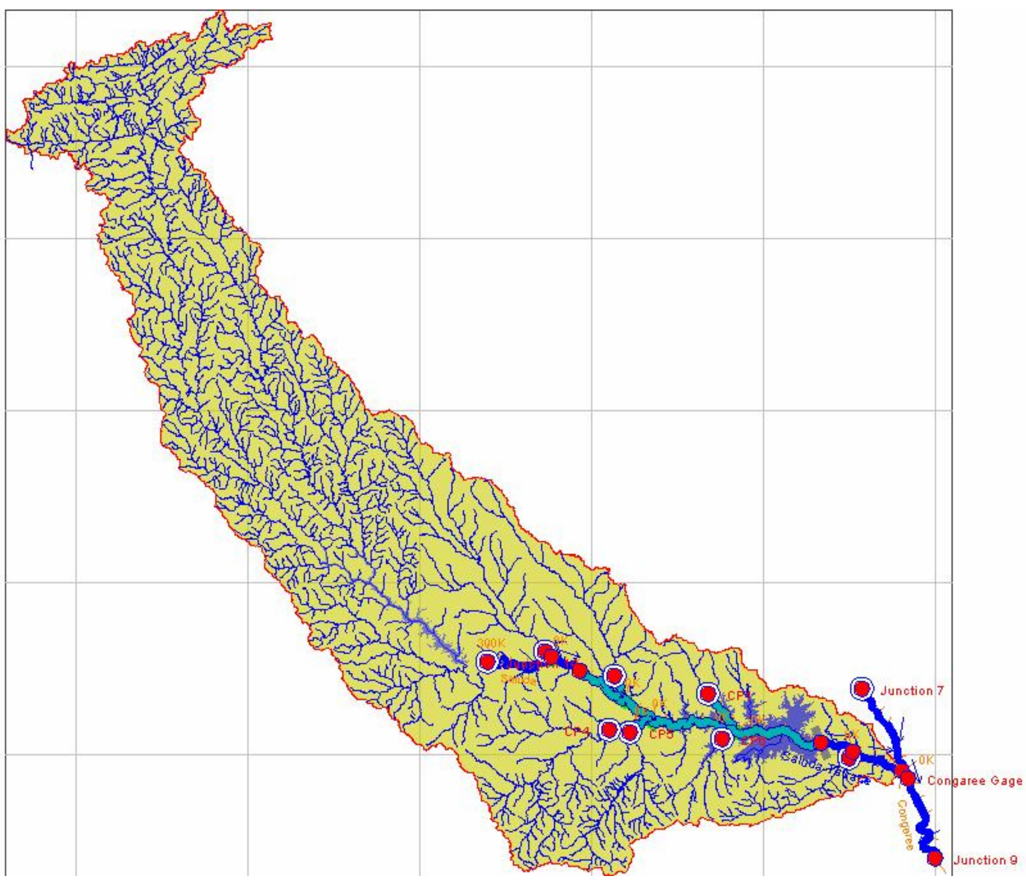
The model was developed to consider the whole of the Saluda River drainage basin. Review of available gage data however, indicated that a long term gage (Chappels gage), located immediately downstream of Lake Greenwood, would represent this major portion of the basin. On this basis, the model framework consisted of the Saluda River basin downstream of the gage, through Lake Murray to the confluence with the Broad River.

The model was developed using publicly available and accepted software created by the Army Corp of Engineers called HEC-ResSim[1]. This software is specifically designed to model reservoir operations with multiple constraints and is considered the latest version of HEC-5.

A Geographic Information System (GIS) was used to assemble and develop basemap information, which was then imported as a background for the ResSIM model. This allows easy navigation of inflow reaches and downstream routing when required.

The figure below displays the watershed used as a basemap in addition to the layout of the model with the locations of several gages used in inflow trials.

Figure 2.1 – HEC-ResSim Basemap Background Layout



[1] More information can be found at http://www.hec.usace.army.mil/software/hec-ressim/hecressim-hecressim.htm

3. Site Specific & Historical Data

Several sources of data were reviewed to develop this model, which include both historical flow and physical mapping data. The following is a list of inputs used in the development of this model:

- USGS Daily Average Stream Gages[2]
  - Chappels River (Gage #2167000)
  - Bush River (Gage #2167582)
  - Little River (Gage #2167450)
  - Saluda River @Lk Murray (Gage #2168504)
  - Saluda River @ Columbia (Gage #2169000)
  - Congaree River (Gage #2169500)
- USGS Lake Level Data[2]
  - Lake Murray (Gage #2168500)
- USGS NHD Flowline[3]
- USGS 1/3 Second Digital Elevation Map (DEM)[4]

This information was used to aid in the development of the basemaps used for the model, in addition to the development of the flow data required by the model.

4. Calculations of Inflow Values

Lake Murray is a large reservoir (approximately 75 square miles) with a total contributing watershed of approximately 2,422 square miles. There are no direct measurements of *all* the flows that enter or exit the reservoir. There are however several gages located upstream of the reservoir which monitor portions of the watershed. For example, the Chappels gage, Bush River and Little River account for 1,705 square miles of the total 2,422 total area.

Two separate methods were evaluated for determining a total historical observed inflow into the reservoir as follows.

4.1. Method 1 – Use of storage data and outflow (Mass Balance Method)

4.1.1. Data Assembly and Calculations

Recorded dam discharge values used in conjunction with observed lake levels and stage-storage data was noted to potentially be the most reliable method in hind-casting inflow hydrographs. This method accounts for inflows without using upstream gages, inflows directly into the reservoir in the form of rainfall, and evaporation from the reservoir (which can be significant during the summer months). Using this approach, a single daily average inflow value for the reservoir was back calculated rather than assigning several points of inflow, some gaged and others not gaged.

[2] http://waterdata.usgs.gov/nwis
[3] http://nhd.usgs.gov/
[4] http://seamless.usgs.gov/

Kleinschmidt
Energy & Water Resource Consultants

Inflow is calculated using the standard mass balance approach which evaluates the observed outflow and the change in reservoir storage to determine a required inflow. The following equation displays this balance:

$$Q_{in} = \Delta Storage - Q_{out}$$

To determine the change in storage volume, the differences between reservoir stages over two days was converted into a resulting change of volume. Similarly, the daily average flow as measured by the stream gage just downstream of the Saluda Dam was used to determine a daily volume of discharge. The difference between the change in storage and the volume discharged is the volume flowing into the reservoir on a daily timestep. This volume is averaged over a 24-hour period to determine a daily average flow in cubic feet per second (cfs). The following stage-storage data was used for the development of the changes in storage volume:

Saluda Stage-Storage Data

Stage (ft)	Storage (ac-ft)	Area (acre)
190	0	41
200	764.64	160
210	3447.44	436
220	8739.17	637
230	16218.89	1,051
240	29557.17	1,898
250	52319.22	2,869
260	85591.02	4,146
270	132664.21	5,540
280	195100.2	7,387
290	277895.76	9,572
300	385182.61	12,465
310	524587.3	16,123
320	703680.06	20,615
330	930668.09	25,551
335	1064796.29	28,526
340	1214565.74	31,866
345	1381667.03	35,510
350	1567093.68	39,186
355	1771028.97	42,757
360	1992948.86	48,162

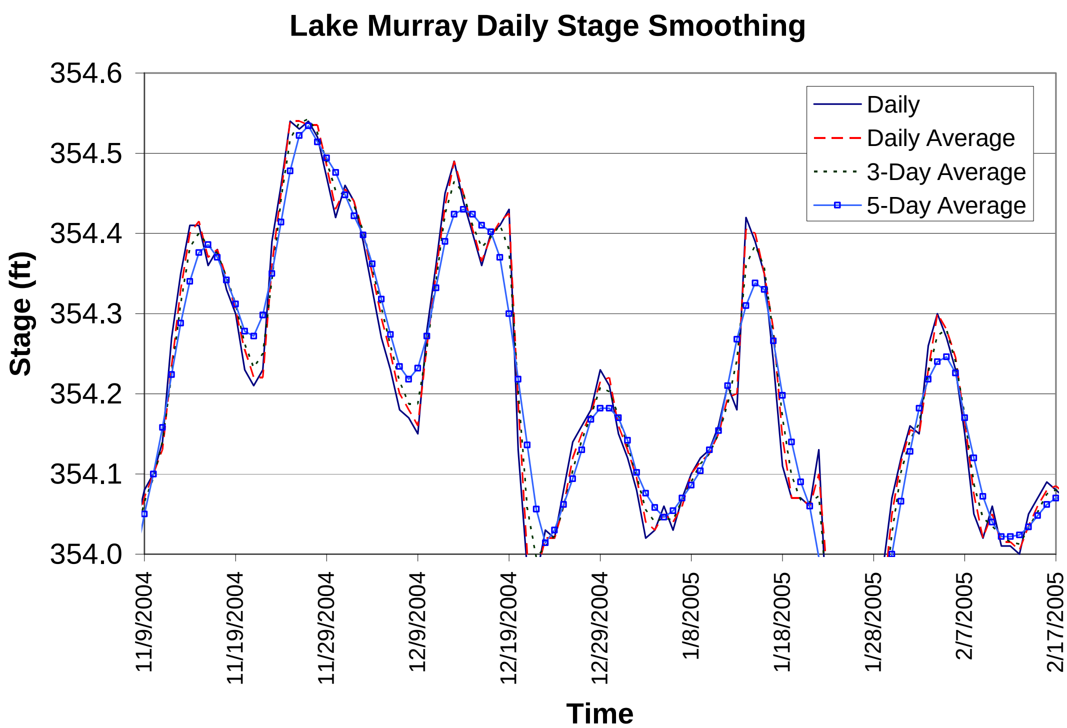
Daily stage readings were acquired from the USGS Lake Murray stage gage (#2168500). Data provided includes daily average data in addition to measurements taken at midnight. A very small change in measured lake elevation can produce an extremely large difference in storage volume change. Assuming typical levels, a 0.1 foot variation in lake level equates to a 2,200 cfs (4,360 ac-ft) flow variation over a 24-hour period. For this reason, the recorded stage data had to be 'smoothed' to account for abnormal readings from wave action or other such disturbances. Four different methods of smoothing were developed and evaluated in the model as described below:

- Daily Measurements (no smoothing)
- Daily Averaged (Daily Reading & Midnight Reading)

- 3-Day Moving Average of Daily Measurements
- 5-Day Moving Average of Daily Measurements

A sample displaying the various smoothing methods of the daily stage values is shown below. The reservoir can fluctuate on a daily basis dependant on demands, inflows and even evaporation, but localized variation in stage readings can create significant rapid changes in storage which may not be realistic. The graph below shows, for a sample period of record, increased levels of smoothing over time, but peak level detail over a period of days becomes lost with increased periods of moving average smoothing.

Figure 4.1 – Sample Daily Stage Smoothing Comparison



With the daily values of reservoir stage smoothed, the resulting daily change in storage was used to calculate the daily average inflow. This data, for each of the four cases above, was then used as input for the hydrologic model to compute the variation between the value of calculated outflow to the value of recorded outflow from Saluda Dam.

4.1.2. <u>Determination of Best Fit</u>

The model was used to calculate lake levels and outflows from the Saluda Dam, following the observed historical lake level stage data as a guide curve. Outflows are determined according to rules set in the operation schemes, which for calibration purposes, was to follow ‘observed’ pool as a guide curve. Outflows calculated were then compared to recorded values at the USGS stream gage just downstream from the Saluda Dam. This process was repeated for each of methods noted above.

The model will not always match exact daily average outflows measured at the stream gage downstream, although in general, operations appear to follow the general pattern observed by the gage, and volumes of historic data versus calculated are relatively close.

Values for discharge were compared using the computed volume R^2 to determine the best correlation between data pairs. Correlation values closest to 1.0 represent the best fit. The figure below (Figure 4.1) shows data comparisons for each of the four different stage smoothing conditions, in addition to the trend lines with R^2 values. It can be seen from the R^2 values that the 3-day average allows for the best correlation to recorded USGS discharge values.

4.1.3. Discussion of Method-1 Mass Balance Results

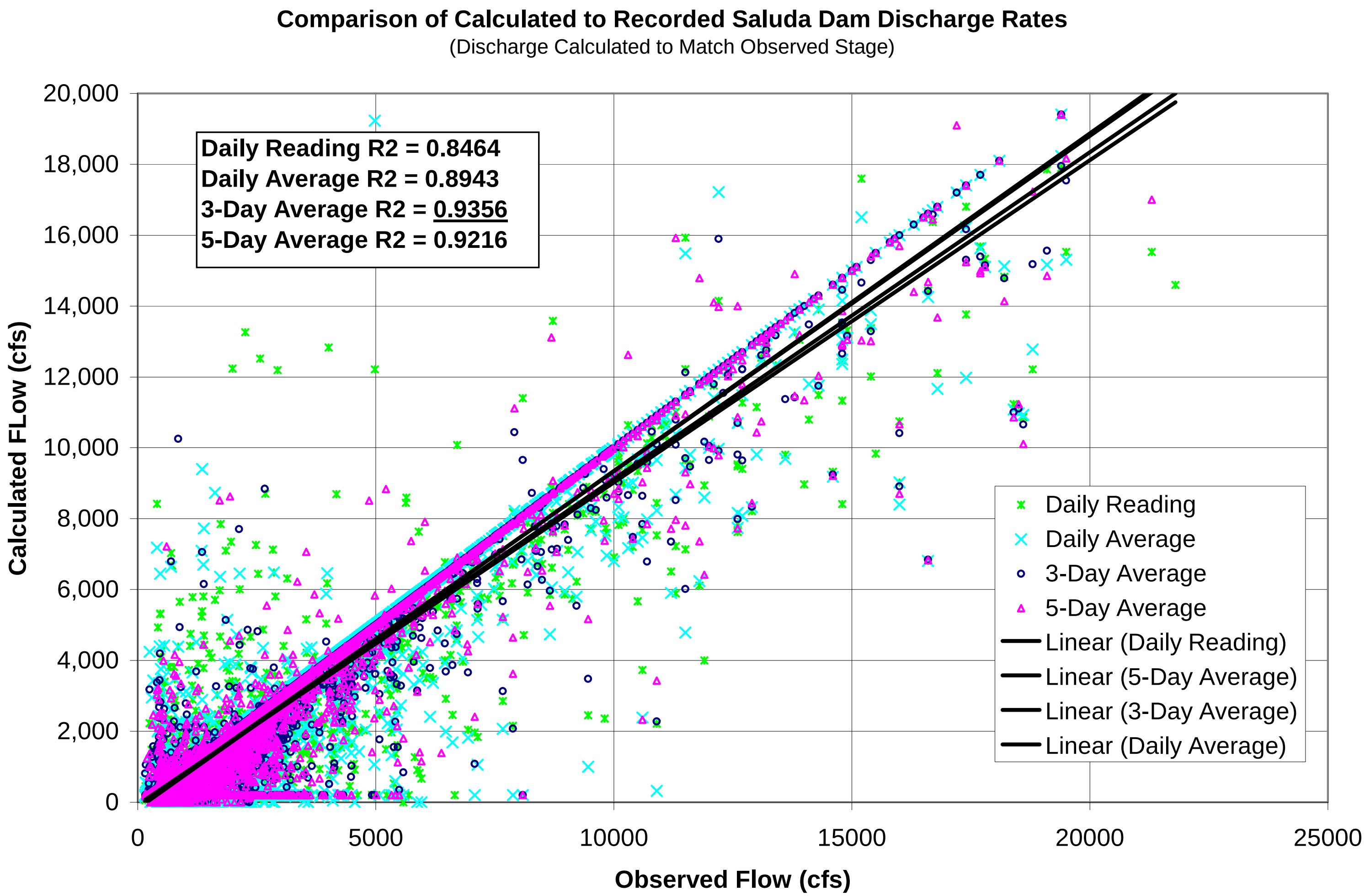
Applying this method, several issues surrounding the model calibration were noted. The first was the significant impact variations in the lake level had on the potential inflow. As noted above, a 0.1 foot change in lake level corresponds to approximately 2,200 cfs variation in inflow. It has been reported that up to 0.06 feet of variation in the gage is the normal "noise" in the readings. Another potential issue is the reliance on a single recording station for stage, and a single outflow station for flow values. Errors or anomalies in data recording can significantly effect the accuracy of the results with no 'buffer' from other sources.

This method does however allow for the automatic accounting of evaporation rates. Whether inflows are from direct rainfall on the reservoir, from further up in the watershed, or actually losses from evaporation, the only value that is calculated is an absolute change in storage volume independent of source.

Figure 4.2 shows a result of the model runs using the mass balance method. The upper curve is a measure of stage relationships, plotting both the calculated stage and the observed stage. There is a very close correlation between the data sets under most circumstances, but there is a slight variation of data at lower stages. It can be seen that the calculated values at low reservoir stages tend to be slightly higher than observed. This could potentially be from variations between actual and accepted stage-storage values.

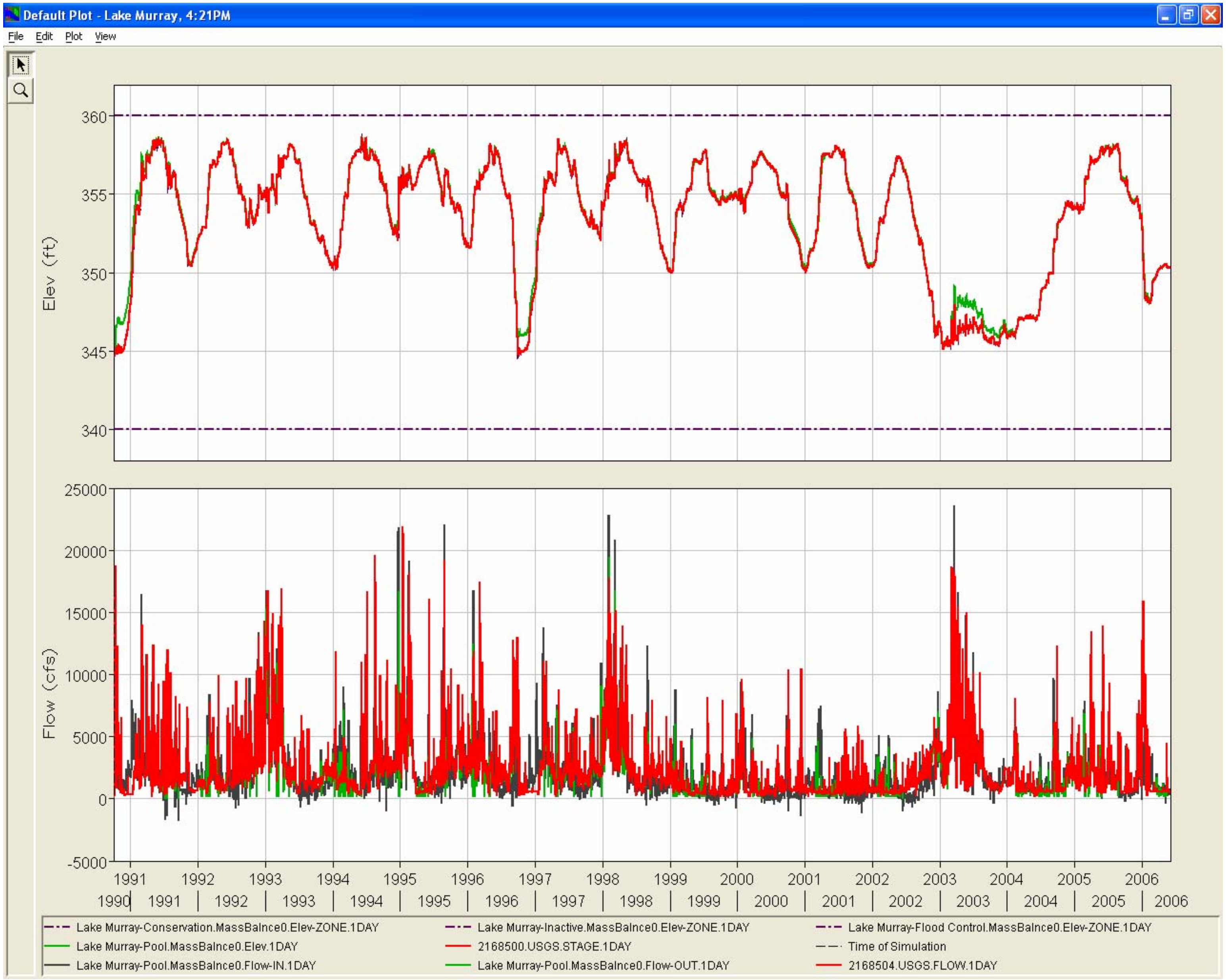
In general, there is a very close correlation between the calculated and recorded stage and discharge values using the mass balance method with smoothing of the recorded gage data using a three-day moving average.

Figure 4.1 – Comparison of Outflow Values with Various Methods of Smoothing



Kleinschmidt
Energy & Water Resource Consultants

Figure 4.2 - Plot of HEC-ResSim Stage/Discharge Output (Mass Balance)



Kleinschmidt
Energy & Water Resource Consultants

4.2. Method 2 – Pro-Ration of Upstream Gaged Inflows

4.2.1. Data Assembly and Calculations

There are several gages located upstream of Lake Murray which include the Chappels gage on the Saluda River just downstream of Lake Greenwood, the Bush River gage, and the Little River Gage. The technical working committee determined that these three gages may provide a good correlation for determining the total inflow into Lake Murray. These three gages monitor 1,705 square miles of the total Lake Murray watershed (approximately 2,422 square miles) and have a common period of record of sixteen years (1990-present).

Various factors have been applied to the three gages located upstream in the reservoir and were used as inflows in the model. Comparison of the historical levels versus the computed levels, along with total inflow volume versus outflow volume, were used as the means of calibration.

4.2.2. Determination of Best Fit

This data is derived entirely through observed and recorded inflow data and accounts for a majority of the area of inflows into the reservoir. This method is accurate at it resembles recorded values and negates the potential for negative inflows into the reservoir (as potentially recorded from the determination of the mass balance). Conversely, the methodology does not directly account for the temporal variation in evaporation from the reservoir, which during summer months can be substantial.

Evaluation of the 'best-fit' was performed using variations of ratios applied to the recorded gages. Daily average flow values for the various gages were multiplied by certain factors to obtain the best correlation of data from the perspective of inflow and outflow correlations. The following is a table of trial results performed using various pro-ration factors to obtain the 'best-fit'.

Table 4.2 – Gage Weighted Value Determination

	Multiplication Factor			
Little River Gage	3.5	3.6	3.7	3.8
Bush River Gage	1.0	1.0	1.0	1.0
Chappels River Gage	1.0	1.0	1.0	1.0
Outflow Volume (cfs-days)	12,153,952	12,255,100	12,358,230	12,457,727
Stage R^2	0.982	0.978	0.976	0.970
Volume R^2	0.837	0.841	0.812	0.843

From Table 4.2, it can be seen that there is an inverse relationship between the stage correlation, and the volume correlation (discharge from the reservoir is approximately 14 million cfs-days). There does not appear to be a direct relationship between observed and calculated values dependent on the variation of the Little River gage.

4.2.3. Discussion of Method-2 Gage Rating Results

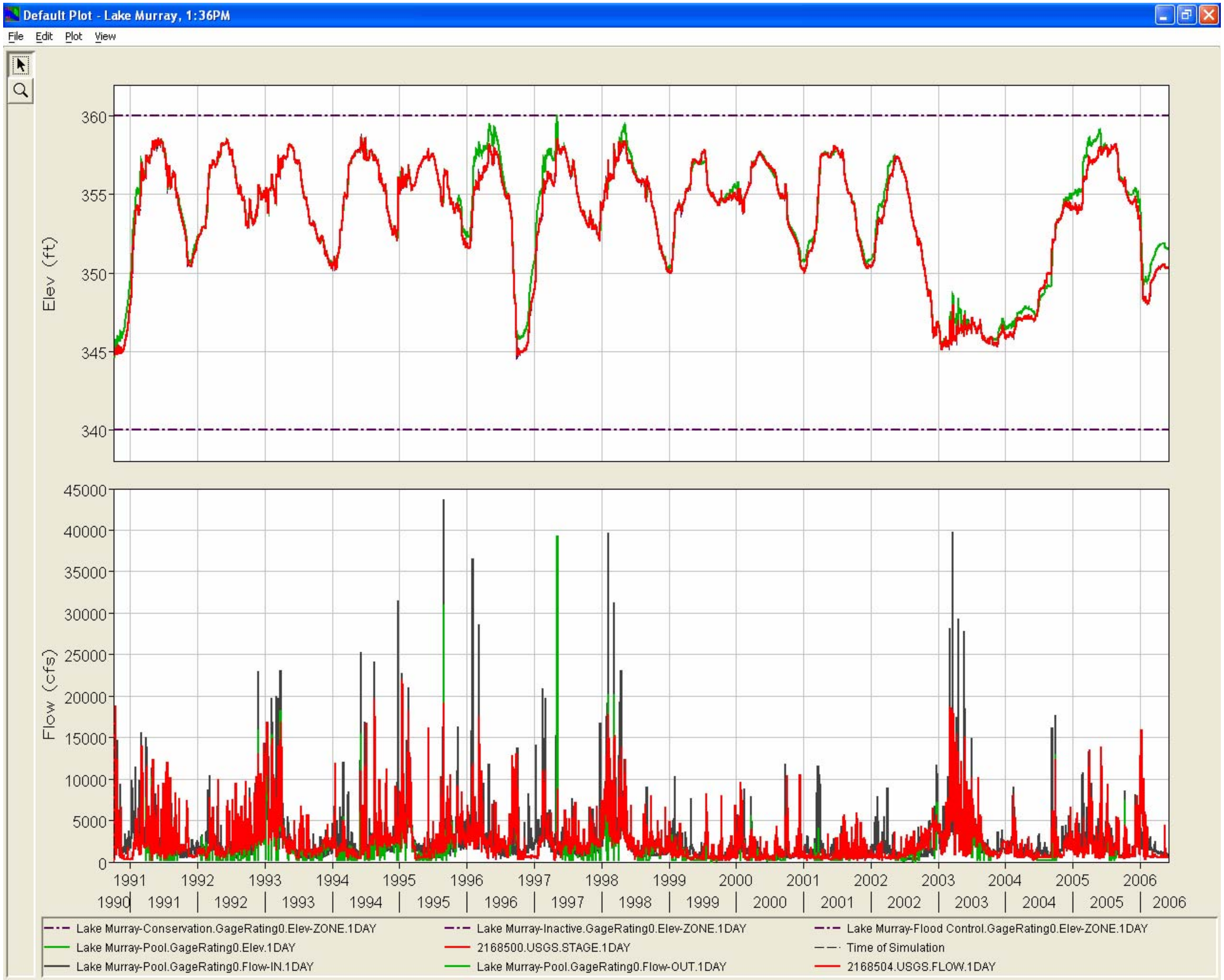
When applying this method, determining the factors to apply to the gages to represent the 715 square miles of additional un-gaged drainage area is critical. It was determined that use of the Chappels gage would not be a good representation because this flow is regulated by the operation of Lake Greenwood, whereas the 'missing' gaged areas are direct runoff from smaller subcatchments. Additionally, the factors must account for the direct precipitation on the 75 square mile reservoir which has effectively no lag time for a response in the reservoir.

In order to derive the applied factors to address the ungaged drainage area, an analysis of the inches runoff versus annual precipitation was completed. Review of the NOAA weather gage at Columbia Airport noted an annual average precipitation value of 48.3 inches. Data for the Bush River for the period 1990-2005 reported an average annual flow of 106 cfs which reduced to 12.51 inches of runoff, per gage records. Similar data for the Little River noted an average annual inflow of 187 cfs with a total runoff of 11.03 inches. The annual values of the gage downstream of Lake Murray reported an average annual flow of 2,495 cfs with a corresponding inches runoff of 14.01.

Using these values, the initial pro-ration factors were developed for the Bush and Little River by evaluating the percentage of ungaged area to the area available from the various gages. The values determined were a factor of 3.5 for the Little River and 1.0 for the Bush River, and for all conditions Chappels remained un-rated with a multiplication value of 1.0.

Figure 4.3 illustrates the comparison for the sixteen year period. Several checks were also made in regards to the statistical correlation between computed and actual values. An R squared value of 0.982 was calculated when comparing calculated stages using this method, which is considered a very close correlation and is shown below.

Figure 4.3 – Plot of HEC-ResSim Stage/Discharge Output (Gage Rating)



5. Results & Discussion

Both of these methods used 'observed' data for the determination of the inflow hydrographs. One method used observed data in the stages and accounted for losses, whereas the other method looked at recorded values and accounted for actual recorded inflows and adjusted ratings to create a 'best-fit'. In either condition, data is heavily reliant upon the quality of the data.

Recorded stage data may skew the volumes because of wind setup, whereas a localized storm directly of the reservoir may not be accounted for by the USGS gages upstream and missed as an inflow. Both methodologies develop datasets that are estimations of the potential inflow into Lake Murray, but a determination of the best-fit data must be made.

The following is a table of model results using the best available data from the two methodologies.

Table 5.1 – Summary of Model Results

	Observed Gage Data	Mass Balance Method	Gage Weighting Method
Total Volume In (cfs-days)	n/a	13,262,703	14,000,921
Total Volume Out (cfs-days)	13,960,366	13,262,703	12,183,398
Stage R^2	n/a	0.993	0.982
Discharge R^2	n/a	0.902	0.810

It can be seen in this table that the best correlation for both the stage data and the discharge data is from using the Mass Balance methodology. This method presents errors with respect to the reliance on the recorded stage values and daily average outflow rates, but provides the best correlation of datasets.

Using this methodology, the data appears to follow a relatively decent correlation using a 3-day moving average smoothing of the daily stages. It also can be seen that there is a greater variability, or scatter, of the data at lower flow conditions, which is consistent with the difficulty of estimating low flows from small changes in lake level. Similarly, the greatest variations of stage data from observed values occur at low reservoir stages (Figure 4.2). Very subtle changes in lake stage can produce very large differences in lake volumes averaged over a 24-hour period and there is a heavy reliance on the accuracy of the stage-storage relationships.

The ultimate goal of utilizing this sixteen years of data is to evaluate various operating conditions and flow/stage constraints; the respective frequencies that these 'guidelines' may be violated according to historic inflows under certain operating constraints will be applied equally for all scenarios. With this in mind, we feel that the calculated inflow as described above, using the Mass Balance Methodology, would sufficiently determine the inflow hydrograph for the modeling period of record.