

**CONSIDERATIONS FOR LOCATING A WATER QUALITY
MONITOR IN THE TAILWATER OF WYLIE DAM**



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February 24, 2003

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INTRODUCTION

An assessment of alternatives to provide aeration and minimum flow for Wylie tailwater indicated that turbine venting and unit pulsing would probably be the most cost-effective management approaches, subject to additional site evaluations. One of the observations from this assessment indicated that the current location of the water quality monitor for Wylie tailwater might not be representative of the turbine discharges from Wylie Hydro. Therefore Duke Power undertook a project to determine if the current location of the water quality monitor was acceptable and, if not, to determine an acceptable location. The objective of this project was to

Determine the most representative location in the tailrace for long-term continuous DO and temperature monitoring.

This report presents the results of data collection and analyses that address this objective.

Methods. Hydrolab monitors were deployed in the tailrace as shown in Figure 1 during the turbine venting tests conducted during the period July 22 through July 26. Some of these same locations were monitored during the river study over the period August 6 through August 16, i.e., in the discharge of Unit 3, in front of the spillway gates, at the private boat dock on the island (CRM 140.7), and immediately downstream from Johnnytown Branch (CRM 140.2). The current “permanent” monitor (also shown in Figure 1) was operated during the study so that its readings could be compared to those from the other monitors deployed during the study. It should be noted that the permanent monitor was installed in 1995 and placed in its current location based mainly on convenience (cost of installation, maintenance, security, etc.)

MONITOR LOCATION CONSIDERATIONS

Locating a water quality monitor in the tailrace of Wylie Dam involves a wide range of considerations, and the following criteria should be considered for selecting an acceptable location:

1. The monitor should be reasonably representative of water quality conditions in the tailrace for the discharges from all units;
2. The monitor should be located such that its readings are reasonably responsive to operations at the powerhouse;
3. It needs to be in a secure area of the tailwater, preferably not readily accessible to the public;
4. It needs to be located where it will be submerged in the tailwater under the full range of operating conditions;
5. It needs to be in a main part of the flow from the project;

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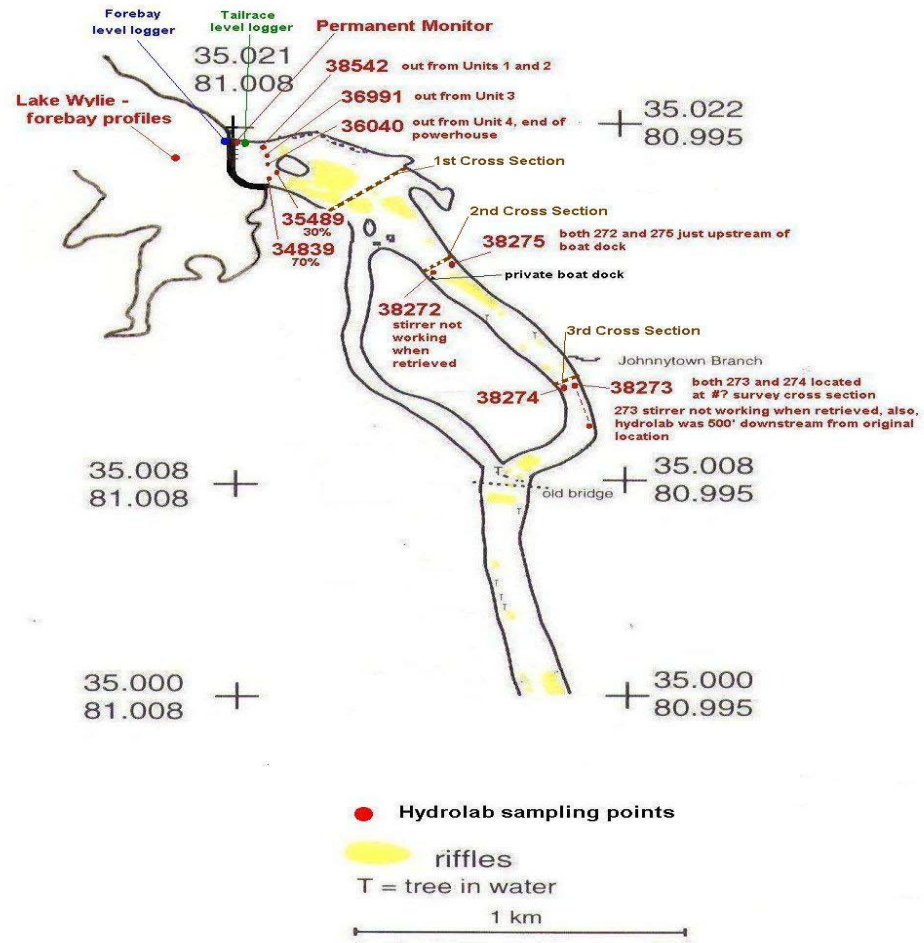


Figure 1: Monitoring Locations During July, 2002 Turbine Venting Tests

6. It should be readily accessible for servicing and maintenance; and
7. It would be desirable if it was located where it was visible to the operators at the powerhouse

The locations of the monitors for this study were selected based on consideration of these criteria, but most of the emphasis was placed on items 1, 2, 4, and 5.

STUDY RESULTS

Evaluation of the current monitor location. Figures 2 through 5 present comparisons between the readings from the various monitors in the tailrace during the turbine testing. These figures show that readings by the permanent monitor were usually 0.5 to 2 mg/L lower than DO values measured directly downstream from the units, even for the DO in the discharge from Unit 1. The error usually was greatest when the air supply valves were open on Unit 3 and the highest DO levels were measured in the tailrace. Thus, the current monitor significantly under-represents the higher DO conditions in the tailrace when Unit 3 is aerated. While there are obvious advantages for the current location (considering the above criteria items 2, 3, 4, 6, and 7), the monitor needs to be moved to another spot that better complies with the location criteria listed above.

Wylie has site-specific operational characteristics that need to be considered in locating the monitor, i.e., the DO in the discharges from each unit is different due to the effects of the withdrawal zone for each unit as well as the turbine aeration characteristics of each unit (Ruane, et al, 2003). These considerations suggest that the monitor be located downstream from the point where the discharges from all the units mix and water quality is similar across the river channel.

Considerations for lateral mixing during high flow conditions. The worse case condition for lateral mixing of water across a channel like that below Wylie Dam is during high flow conditions, because under high flow conditions water moves further downstream before mixing laterally across the channel. During the turbine venting testing on July 26 when Units 1, 3, and 4 were operating at 80 percent gate, water quality was measured across the channel at three locations downstream from the rock island that is in the tailrace (see the identified cross-sections in Figure 1):

1. Immediately downstream from the rock island
2. At the private boat dock on the island (CRM 140.7), and
3. Immediately downstream from Johnnytown Branch (CRM 140.2).

Figures 6 through 8 show that the discharges from the different units did not entirely mix even by the time the water reached the transect location downstream from Johnnytown Branch (CRM 140.2), i.e., DO, temperature, and TDG were higher on the left descending side of the river while conductivity was lower. These variations in water quality across the channel were consistent with water quality measured in the discharges from Units 1, 3, and 4, respectively (see Figure 5.)

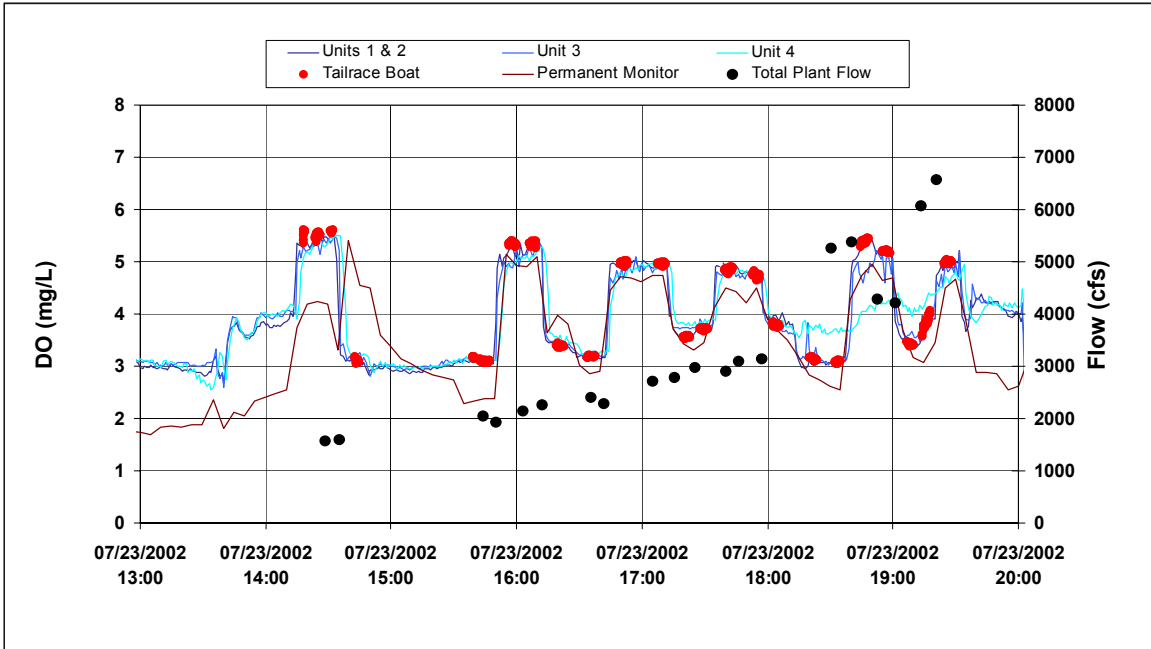


Figure 2: Tailrace DO Measurements During Tests On Unit 1 (plus Unit 4 after 18:00), July 23, 2002

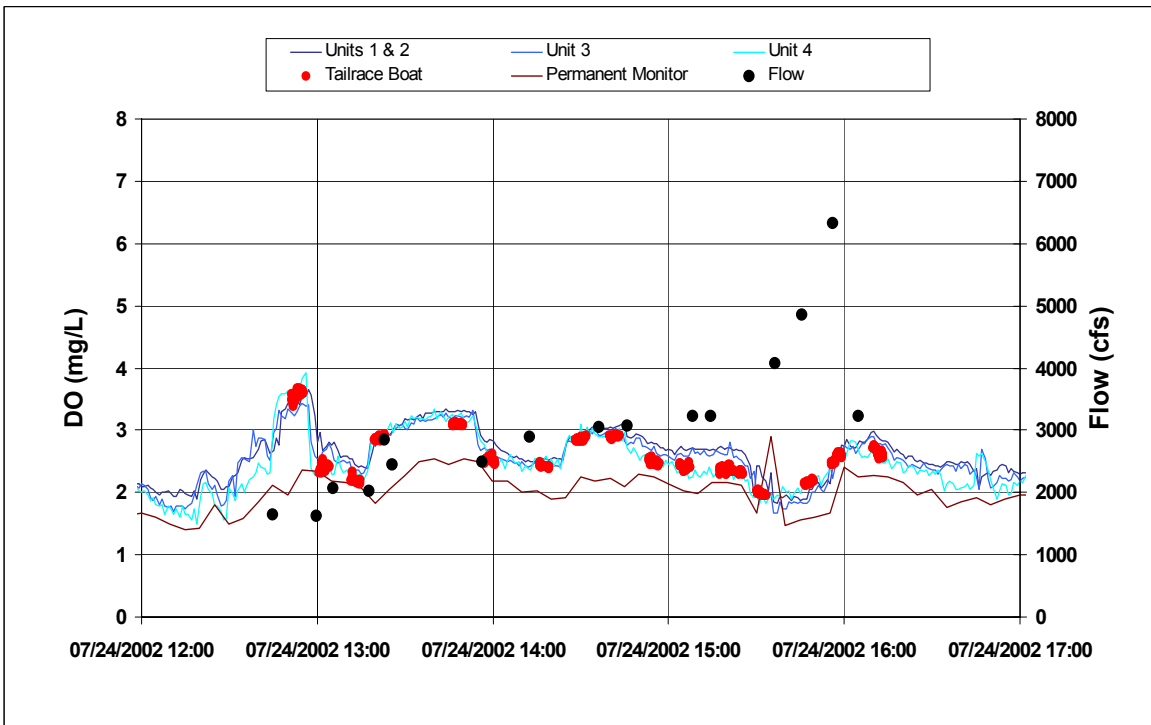


Figure 3: Tailrace DO Measurements During Tests On Unit 4 (plus Unit 1 after 15:30), July 24, 2002

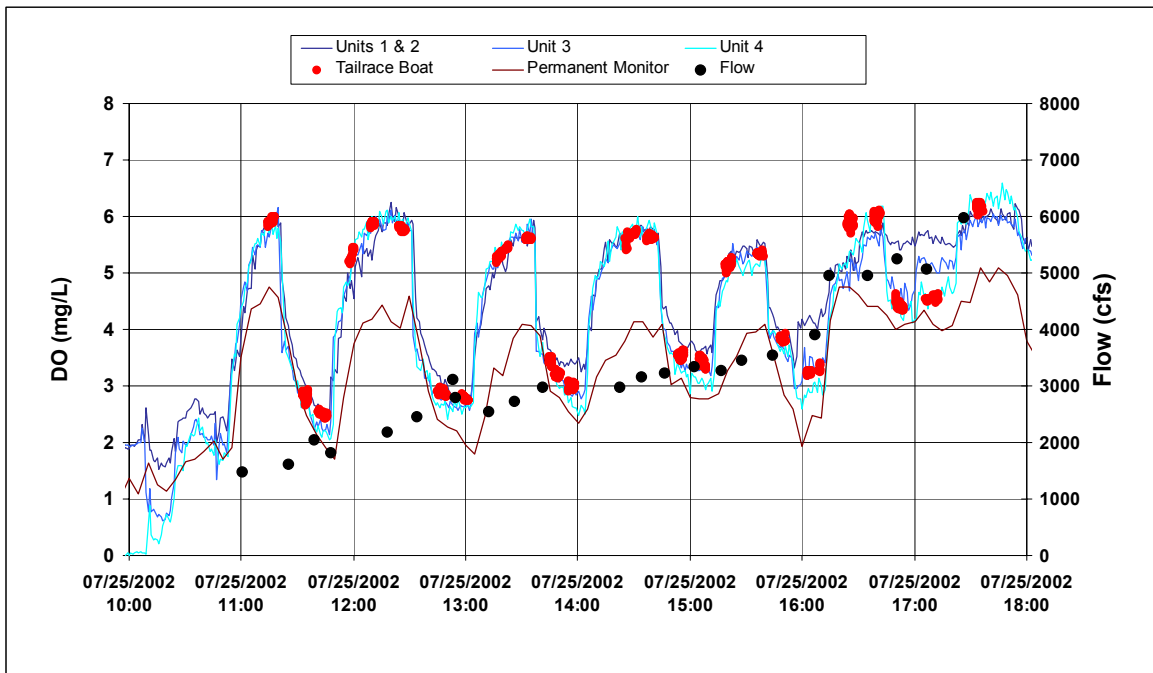


Figure 4: Tailrace DO Measurements During Tests On Unit 3 (plus Unit 1 after 16:00), July 25, 2002

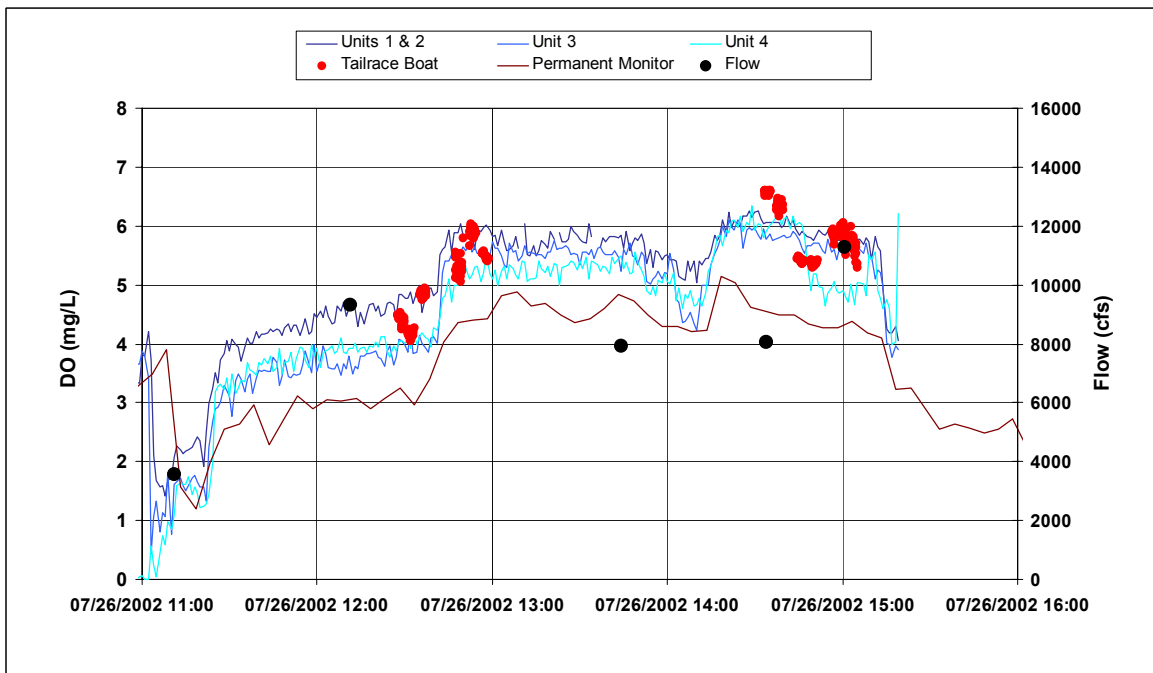


Figure 5: Tailrace DO Measurements During Tests on multiple units, July 26, 2002

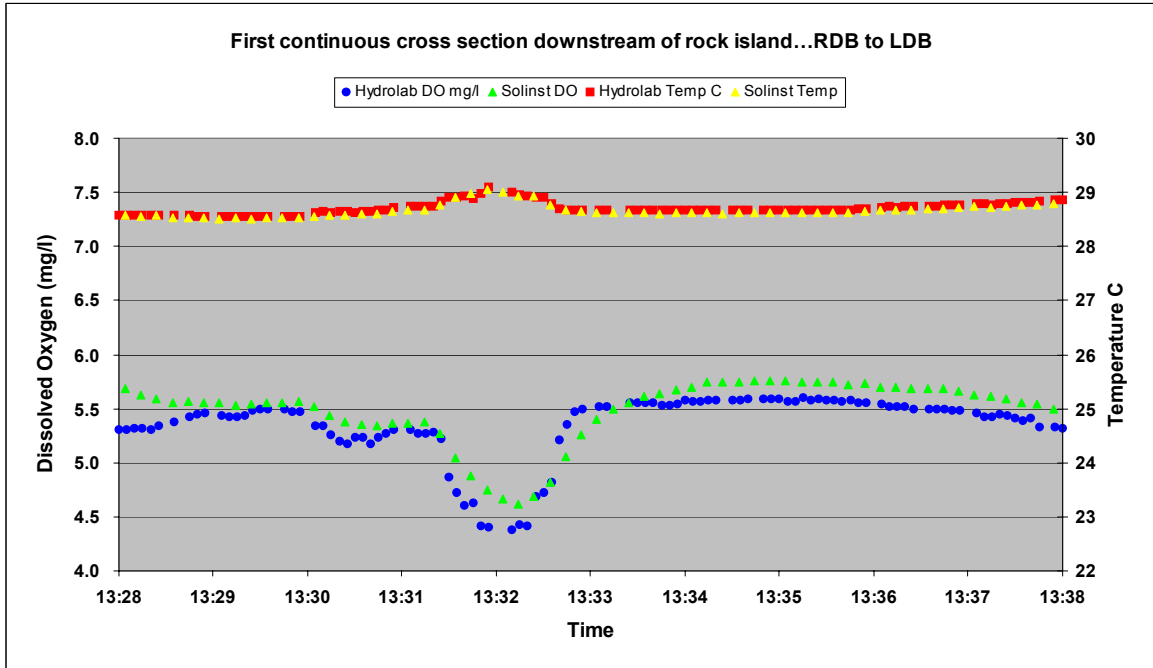


Figure 6: DO and Temperature at Cross Section Downstream of rock island

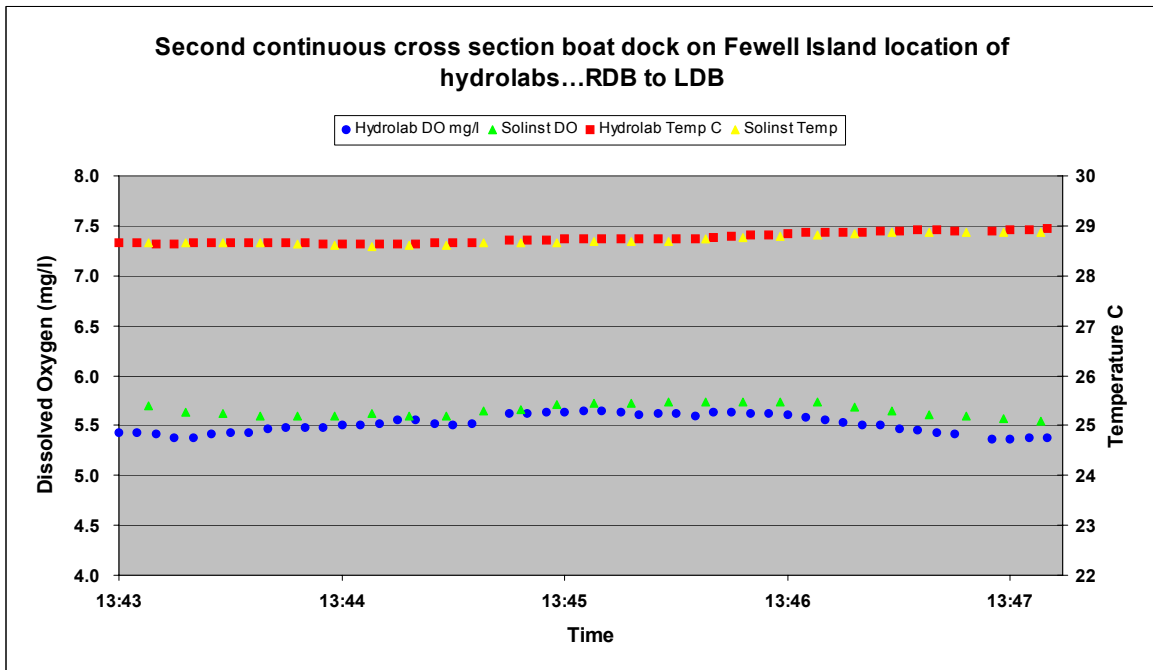


Figure 7: DO and Temperature Near Boat Dock on Fewell Island

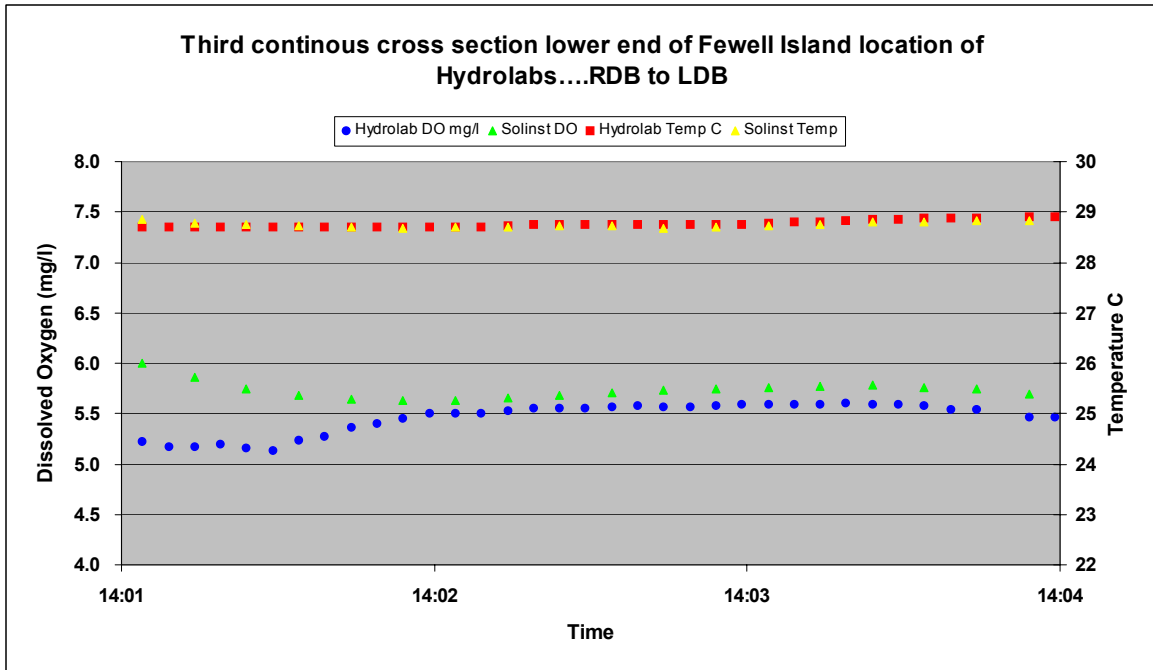


Figure 8: DO and Temperature Lower End of Fewell Island

The water quality variation across the transect located immediately downstream from the rock island was unique compared to the other transects because the water quality at the mid-part of the transect was significantly different. This was caused by a “dead zone” in the area behind the rock island where water did not mix as fast with other water across the transect. The water with lower DO (i.e., about 4.5 mg/L) in the dead zone was the result of previous discharge conditions about an hour earlier when the same three units were operated without air supplied to the units.

Although the water does not completely mix within the first mile as it passes down the river, it is important to note that under high flow conditions (three- or four-unit operation) the DO in the discharge from Unit 4 is not as low as it is when only one or two units are operated (see Figure 3 which shows DO between 2 and 3 mg/L when only Unit 4 or Units 1 and 4 were operating.) Hence, the concern about mixing does not appear to be as significant when three or four units are operating, especially if air is aspirated into the units.

Selection of the best location for a monitor for normal operations. Considering the best locations for a monitor so that it is responsive to changes in operating conditions and representative of the DO in the turbine discharges, it appears that two or three locations have potential: near the end of the spillway on the RDB, CRM 140.75 LDB, and CRM 140.75 RDB. Figures 9 and 10 show the responses of the DO monitors located in front of Units 1 and 3 as well as for monitors located at CRM 140.75 LDB, 140.75 RDB, and near the end of the spillway on the RDB (designated as RC 70 %). These figures show the following:

1. The monitor at RC 70 % was the most responsive during the single unit tests—about a 15-minute response time when Units 1 or 3 were operated at about 80 % gate; however, it did not yield representative results for Unit 1 when Unit 4 was operated near the end of the testing on July 23 (see Figure 9.) It can be assumed that a monitor in the vicinity of RC 70 % would only represent the DO conditions in the discharge from the unit that is operated nearest the RDB. Also, this monitor usually recorded a DO level about 0.2 to 0.5 mg/L less than the DO recorded in the discharge of Unit 1; however, it recorded about the same DO as Unit 3.
2. The next most responsive location was CRM 140.75 LDB—about a 30-minute response time when Units 1 or 3 were operated at about 80 % gate; however, this location did not yield representative results for Unit 3 when Unit 1 was operated near the end of the testing on July 25 (see Figure 10.) It can be assumed that a monitor in the vicinity of CRM 140.75 LDB would only represent the DO conditions in the discharge from the unit that is operated nearest the LDB. Also, this monitor usually recorded a DO level about 0.2 mg/L less than the DO recorded in the discharge of Unit 1; however, it recorded about the same DO as Unit 3.
3. The next most responsive location was CRM 140.75 RDB—about a 45-minute response time when Units 1 or 3 were operated at about 80 % gate; however, this location did not yield representative results for Unit 1 when Unit 4 was operated near the end of the testing on July 23 (see Figure 9.) It can be assumed that a monitor in the vicinity of CRM 140.75 RDB would only represent the DO conditions in the discharge from the unit that is operated nearest the RDB. Also, this monitor usually recorded a DO level about 0.5 to 1 mg/L less than the DO recorded in the discharge of the units, especially when Unit 1 was operated.

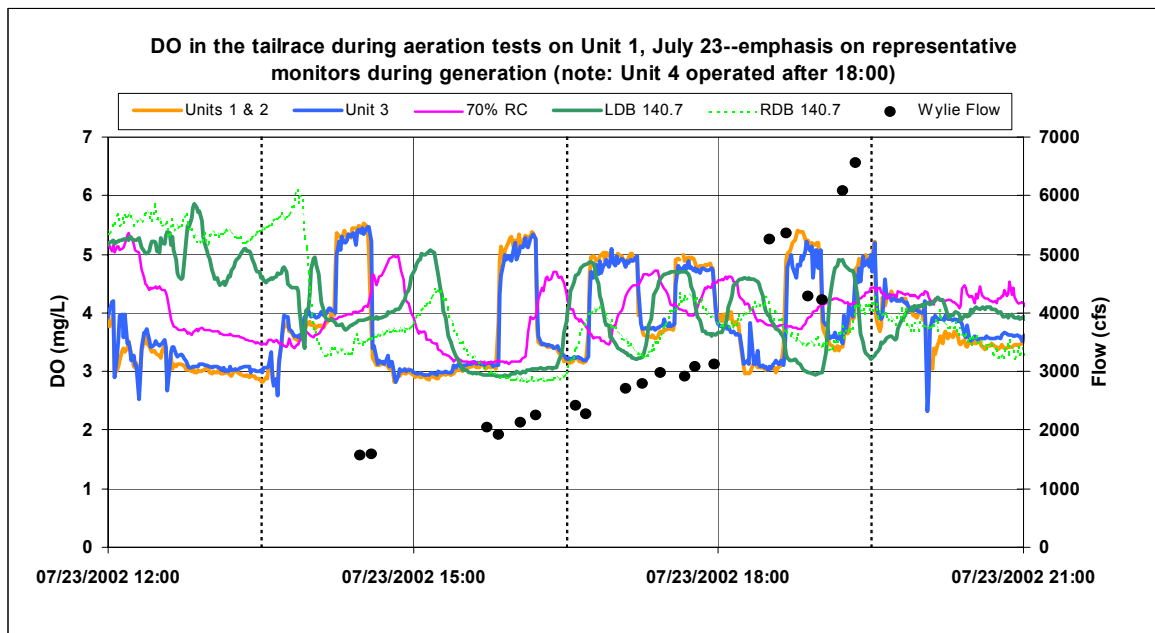


Figure 9: Tailrace DO Measurements, Various Monitors, Unit 1 Tests, July 23, 2002

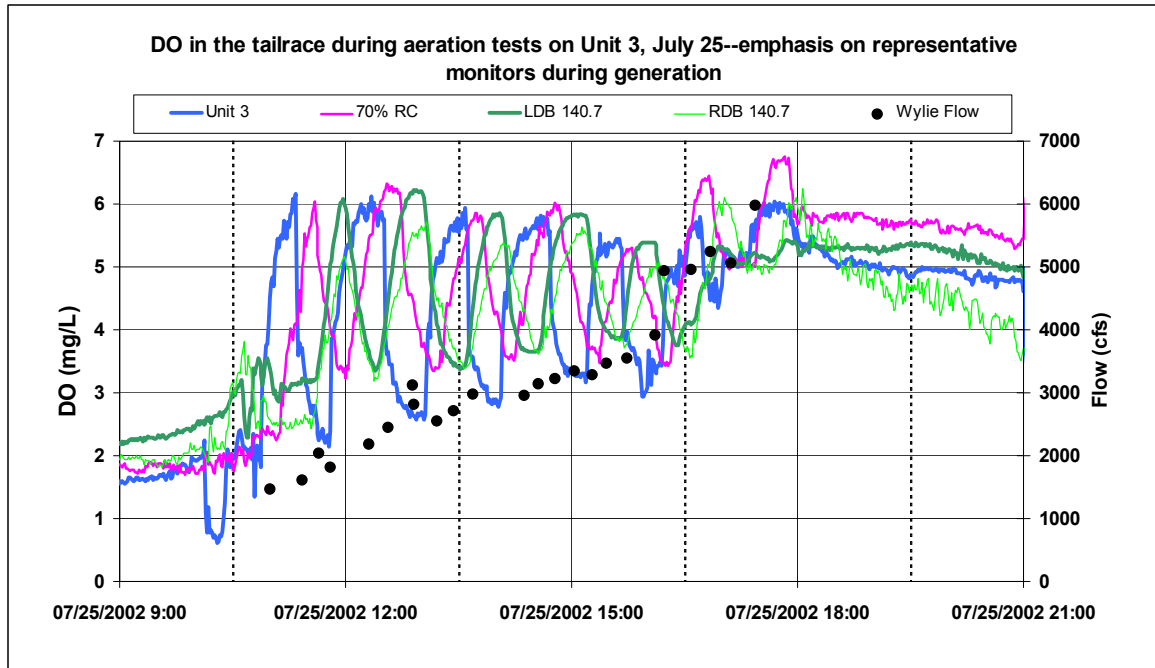


Figure 10: Tailrace DO Measurements, Various Monitors, Unit 3 Tests, July 25, 2002 (note: Unit 1 was operated starting at about 16:00.)

These three locations also were evaluated using data collected on August 12 when Unit 3 was the only unit operated. Figure 11 presents a comparison of the DO monitors from these locations, and the results were somewhat similar to those observed during the turbine venting testing with the following exceptions:

1. The monitor in front of the spillway during the August study was not representative of the Unit 3 discharge, nor was it very responsive like it was during the turbine venting study. The DO at this location was about 1 mg/L less than in front of Unit 3 during generation, and the increase in DO following generation did not persist as long as it did at the other two locations. The difference in the behavior of the monitors located in this area (below the spillway) might have been caused by the monitors being at different depths—the monitor in August was about 4 feet deeper than the monitor located at RC 70 % during the turbine venting study.
2. The response times for DO changes at CRM 140.75 LDB and 140.75 RDB following initiation of generation for Unit 3 were essentially the same instead of 140.75 RDB lagging about 15 minutes after the response at CRM 140.75 LDB. The monitors at both of these locations responded about 30 minutes after Unit 3 initiated generation. The DO readings at both of these locations were about the same as the readings in front of Unit 3 at night but were slightly higher during daylight hours, probably due to algal photosynthesis.

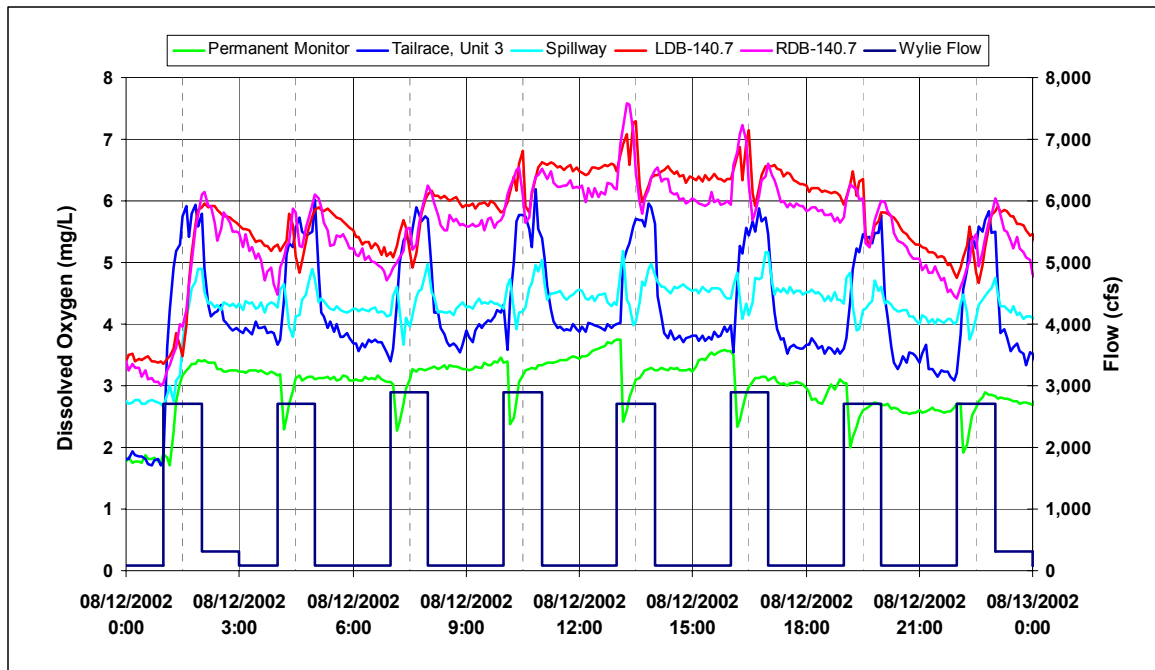


Figure 11: Comparison of DO Measurements, at Various Monitors Locations

It should be noticed in Figure 11 that the permanent monitor recorded lower DO values during the August study similar to how it performed during the week of turbine venting tests (July 23-26). It simply was not representative of DO in the tailrace.

Based on the results from both study periods, it would appear that the location at CRM 140.75 LDB provided the most consistent results and a reasonable representation of and responsiveness to generation conditions at Wylie Hydro. However, other considerations such as security, access for servicing and maintenance, installation considerations (availability of land, site-specific cost factors, etc), and visibility from the powerhouse may lead Duke to consider further water quality studies to evaluate the other two locations.

Considerations for DO monitoring during non-generation. Discussion up to this point has focused on monitoring DO during turbine operations. The selection of the location for a tailrace DO monitor should also consider how well water quality conditions are monitored during non-generation. Figure 12 shows how the most promising monitoring locations (CRM 140.75 LDB and RDB and RC 70 %) performed during non-generation periods for the period July 23 through July 26. The results show that either location appears to represent surface water quality in the tailrace area as determined using all the monitors that were located at or near the water surface. However, the monitor at 140.75 RDB tended to record DO levels lower than 140.75 LDB during non-generation.

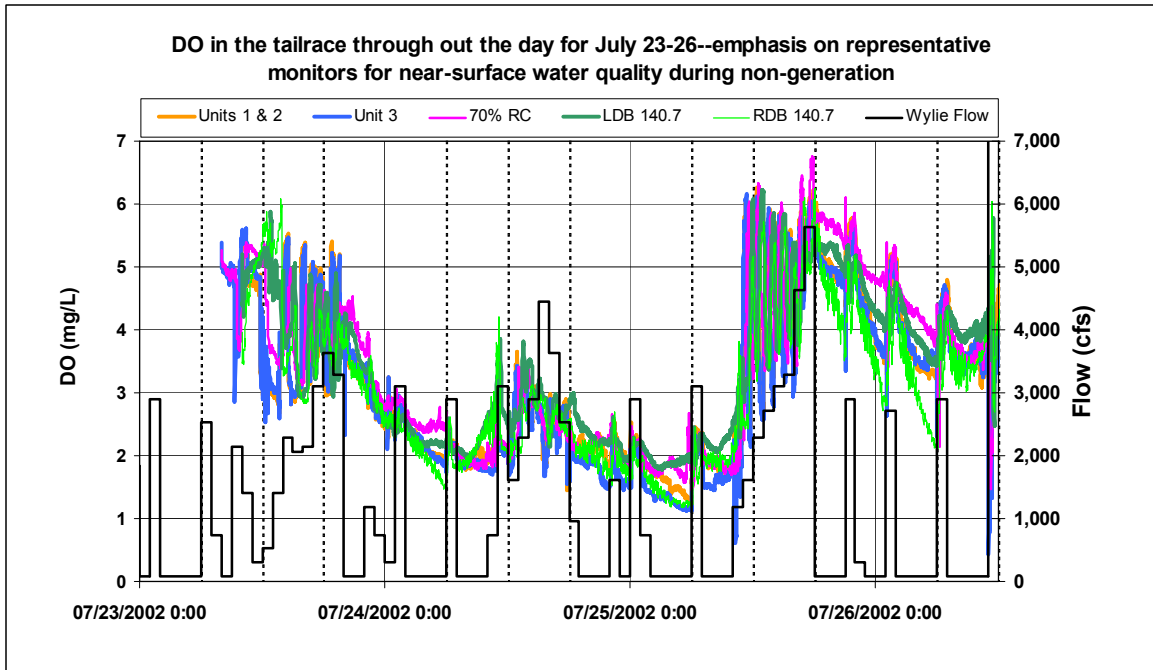


Figure 12: Comparison of DO Monitor Responses During Non-generating Periods

The location at CRM 140.25, about 1 mile downstream from the dam, was considered but found to be unrepresentative of the turbine discharges due to a decrease of about 1 mg/L in DO under nighttime conditions and not very responsive to changes in operations at the dam because it took about three hours for the water quality at this site to respond to changes at the dam.

The nighttime decrease in DO can probably be attributed to DO consumption caused by algal organisms that come from the lake. During the turbine testing, several samples of water were collected from the turbine discharges and the oxygen demand was determined to be at least 6 mg/L over a 10-day period (see Figure 13). Water with this much BOD can exert a high DO demand over a short distance in a river where bacterial growths are attached to the streambed and oxidize organic material over a much shorter period of time (e.g., in hours instead of days.) This drop in DO could also be caused by a deep hole in a portion of the river channel in the vicinity of this location. This hole could result in lower atmospheric reaeration as well as some periodic stratification of the water column when flow is low with associated lower DO readings by the water quality monitors when they are recording DO below the surface of the water.

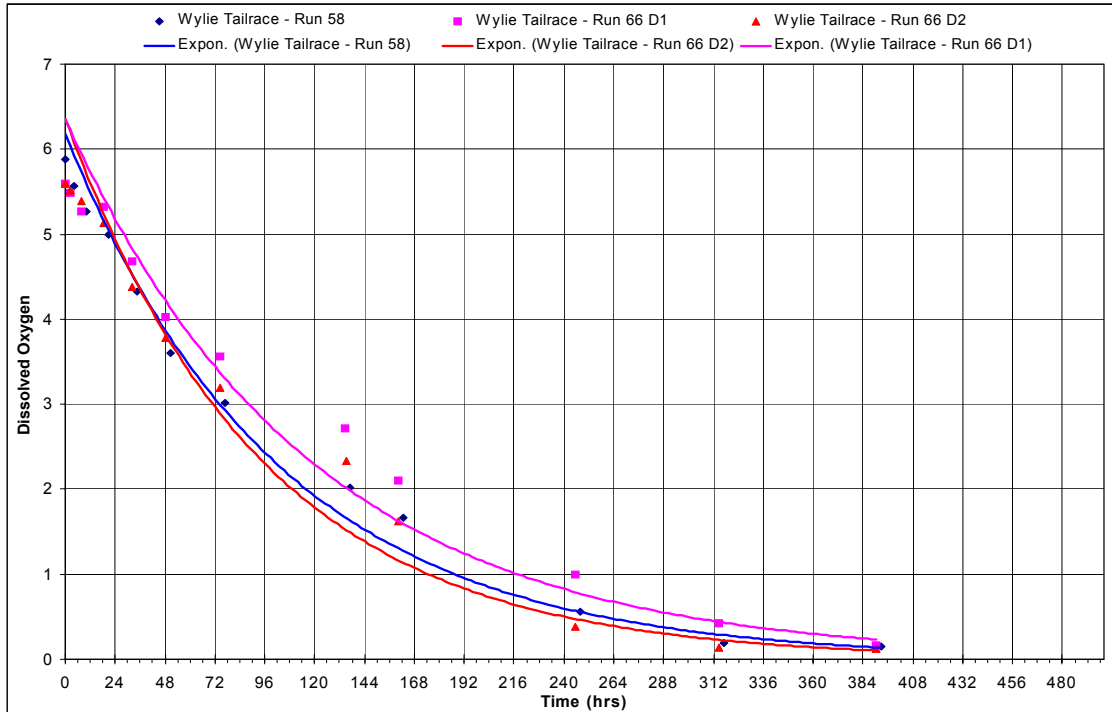


Figure 13: Oxygen Demand in Wylie Tailrace

CONCLUSIONS

The studies revealed that the current permanent monitor location is unacceptable for determining compliance with water quality standards. The results of this study showed that readings by the permanent monitor were usually 0.5 to 2 mg/L lower than DO values measured directly downstream from the units, even for the DO in the discharge from Unit 1. The error usually was greatest when the air supply valves were open on Unit 3 and the highest DO levels were measured in the tailrace. Thus, the current monitor significantly under-represents the higher DO conditions in the tailrace when Unit 3 is aerated. This monitor needs to be relocated using information gained during this study.

A significant concern regarding the problem with the current monitor reading DO levels that are less than actual DO levels in the tailrace is that the historical baseline minimum DO as recorded by this monitor is lower than the actual baseline minimum DO. The baseline minimum DO is used to evaluate and design aeration systems for increasing the DO to the water quality standard. It would appear that the amount of DO increase that is needed to achieve the water quality standard would be less than is indicated based on the available historical data. The actual baseline could be estimated using the data collected during this study in conjunction with a withdrawal zone model.

The river does not mix laterally within the first mile when three to four units are operated; however, the DO is relatively high in the discharges from all the units operating

under these conditions and the variation in DO across the channel was low. Therefore, the lack of complete mixing under these conditions is insignificant.

Based on monitoring results from two study periods, it appears that the location at CRM 140.75 LDB provided the most consistent results and a reasonable representation of and responsiveness to generation conditions at Wylie Hydro. However, other considerations such as security, access for servicing and maintenance, installation considerations (availability of land, site-specific cost factors, etc), and visibility from the powerhouse may lead Duke to consider further water quality studies to evaluate the other two locations that have potential (i.e., 140.75 RDB and in the vicinity of the spillway.)

The location at CRM 140.25, about 1 mile downstream from the dam, was considered but found to be unrepresentative of the turbine discharges due to a decrease of about 1 mg/L in DO under nighttime conditions. The nighttime decrease in DO can probably be attributed to DO consumption caused by algal organisms that come from the lake. Part of this drop in DO could also be caused by a deep hole in a portion of the river channel in the vicinity of this location.

RECOMMENDATIONS

Based on the results of this study, it appears that the best location for a water quality monitor would be in the vicinity of CRM 140.75. The location near the spillway has a number of advantages, but it would need to be complemented by another monitor on the other side of the river in order to record the higher DO levels that occur in the releases from Units 1-3. It is recommended that Duke consider deploying two temporary monitors during the low DO period of 2003 at 140.75 LDB and RDB to allow additional evaluation of the locations at 140.75 as well as a more complete evaluation of the turbine operational scheme that Duke would implement if the recommendation in the turbine venting report is accepted. Having two monitors deployed while the turbine operational scheme is tested would allow a more thorough evaluation than would occur with only one monitor in place. Also, both 140.75 LDB and RDB needs further evaluation considering other criteria not emphasized in this study (especially items 3, 6, and 7).

It is recommended that Duke estimate a new value for the baseline minimum DO value using the results from this study to calibrate a withdrawal zone model and forebay temperature and DO profiles from historical data. This analysis would serve a purpose similar to that suggested in the recommendations in the Wylie turbine venting report.

Concerning the lower DO values measured during non-generation, it is recommended that Duke determine the cause for these low DO values to determine if these observations can be attributed to “natural conditions” that occur in the reservoir or in the river channel. If the lower DO conditions can be attributed to natural conditions, it is possible for DHEC to allow minimum DO levels less than the current water quality standard. It is recommended that these determinations be conducted with considerations for concerns and issues that DHEC might provide.