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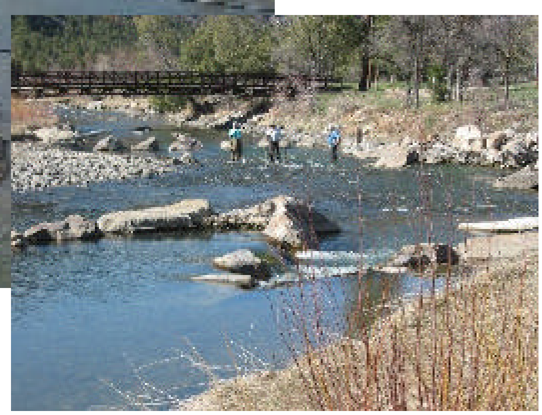
Managing Water in the West

Hydraulic Laboratory Report HL-2006-03

Dissolved Gas and Fishery Investigations at Ridgway Dam

Final Report



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14. ABSTRACT
This report documents the findings of the gas supersaturation and fishery investigations in the Uncompahgre River below Reclamations' Ridgway Dam in western Colorado. Releases from the outlet works and bypass structures both produce increased levels of gas supersaturation in the river reach below the dam. Gas bubble trauma is resulting in the fishery. Both gas levels and severity of gas bubble trauma decrease in the river with distance downstream. A gas abatement structure is proposed.

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Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Co-author Juddson Sechrist, Fisheries Biologist, in the Fisheries Application Research Group of the TSC assisted with fisheries data collection, analysis and reporting. This document was peer reviewed by a consultant, Perry Johnson, retired Reclamation employee from the Water Resources Research Laboratory and Steven D. Hiebert, Manager, Fisheries Application Research Group.

Hydraulic Laboratory Reports

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Disclaimer

Funding for this project was provided by Reclamation's Science and Technology Program through the Western Colorado Area Office.

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Executive Summary

Gas bubble trauma (GBT) in fish has been documented below Ridgway Dam in Colorado for many years. Nitrogen gas levels have also been documented in the river since 1998. Reclamation's Western Colorado Area Office requested and received funding under Science and Technology Research Project No. 581 entitled "Nitrogen Supersaturation Levels Below Ridgway Reservoir CO: Causes and Remedies" to investigate the problem and determine recommended solutions. This was a three year project with the first product being a progress report entitled "Dissolved Gas and Fishery Investigations at Ridgway Dam – Phases 1, 2 and 3 Report." This progress report [1] provided analysis of historical and recent dissolved gas data gathered throughout the project limits and fisheries data in the river downstream from the dam. This report may be referenced on the Water Resources Research website at http://www.usbr.gov/pmts/hydraulics_lab/pups/PAP/PAP-0919.pdf.

A brief summary is presented of the project final report "Dissolved Gas and Fishery Investigations at Ridgway Dam – Final Report." This final report discusses the results of the final two seasons of dissolved gas and fishery investigations and provides conclusions regarding the gas production and effect on the fishery and a recommendation for gas abatement.

Recently measured reservoir inflow gas levels do not indicate that the inflow gas levels are excessively high. Inflows and outflows from the dam are great enough to refresh the lake and prevent anaerobic conditions that would affect the water quality. There is no consistent data to conclude that the reservoir is causing the problem by increasing gas levels due to a chemical or other environmental occurrence. The data still show quite a bit of scatter and no specific trend in the data near the bottom of the reservoir, but an expected baseline below 115 percent saturation would be expected.

Dissolved gas levels below Ridgway Dam on the Uncompahgre River are a result of the releases from the dam. The levels are high nearest the dam and decrease with distance downstream. Gas levels produced by outlet works releases seem more consistent than the levels produced by the bypass structure releases and show a trend of increasing gas with increasing flow.

Fish surveys have indicated that the incidence of GBT is higher at the dam and decreases with distance downstream. In addition, the severity is higher at the dam and decreases downstream.

The population of the two most common salmonids in the sampled sections of the Uncompahgre River varied during the 2003 and 2005 investigations. Nitrogen saturation levels indicated about a 3 percent difference in nitrogen levels for roughly the same period of time leading up to the sampling effort. The two species appeared to respond differently, not only to different nitrogen supersaturation levels, but also to effects of GBT. Brown trout abundance apparently increased even under the deleterious effects of increased saturation levels and higher ambient GBT infection, whereas rainbow trout abundance declined. This comparison of these two years of population

sampling shows the difficulty of drawing conclusions about the effects of supersaturation and GBT on fish populations in an open, infrequently sampled system. Especially when stocking rates, angling pressure and other variables are considered. True population effects could be determined on resident fish only if stocking was reduced for a season.

Sustainability of the fishery could be a function of many other parameters and is outside the scope of this project. Should this become an issue, the TSC would be able to partner with the CDOW on a more in depth study.

A small rock drop gas abatement structure is recommended and a conceptual design is provided. The structure can be placed downstream of the bypass and outlet works release points in the river channel to abate releases from either structure.

The parameters of the rock drop gas abatement structure and its expected performance may be used in discussions with CDOW, the State Park personnel, or other interested parties if complaints about the condition of the fishery continue.

The project does not need to continue gas or fish monitoring at this time. If gas monitoring is continued by hand-held devices, then the improved locations determined as a result of this work should be used. Information on potential gas monitoring instrumentation is provided should the project personnel decide to install a fixed monitoring station or replace existing hand held devices.

If operations change or if a gas abatement structure is installed, then hourly gas monitoring and frequent fish surveys should be performed for a season to determine the effects of the structure on the water quality and fish habitat.

This final project report is available on the Water Resources Research website at http://www.usbr.gov/pmts/hydraulics_lab/pubs/HL/HL-2006-03.pdf.

Background

The research project began in 2003 with fact-finding, gathering of gas and fish survey data in the river downstream from the dam, gathering gas levels for inflows to the reservoir, and reservoir gas data. This data was summarized with initial analysis in the first report entitled: "Dissolved Gas and Fishery Investigations at Ridgway Dam – Phases 1, 2 and 3 Report, February 2003, by Kathleen H. Frizell and Steven D. Hiebert [1]. This report may be found on the Water Resources Research Laboratory website at http://www.usbr.gov/pmts/hydraulics_lab/pubs/PAP/PAP-0919.pdf.

Objective

The objective of the research remained the same over the course of the three year study. The objective is:

- to determine the cause of the dissolved gas issue,
- to determine the effect of the gas levels on the fishery, and,
- to develop a gas abatement proposal.

The tasks to achieve the research objective have changed as the project has progressed. To accomplish the overall project goals recommendations from the previous year's work in 2003 were followed. In 2004, the following tasks were performed:

- Investigation of the river cross section to ensure proper measurement locations were being used,
- Collection of more gas data at the adjusted river measurement sites, and
- Two additional fish surveys throughout specific reaches to compare with the trends in the gas data.

In 2005, the objectives were:

- Gather verification gas data in the reservoir and river,
- Determine instrumentation for a fixed gas monitor or new hand-held device,
- Perform an additional fish survey in the river below the dam, and,
- Develop a concept for a gas abatement rock weir for the river.

This report summarizes the result of this completed research project and provides conclusions and recommendations.

Conclusions

Supersaturation and Gas Bubble Trauma

The dissolved gas and fishery surveys greatly improved the knowledge and understanding of the problems being experienced below Ridgway Reservoir on the Uncompahgre River. The gas investigations are then separated into three categories: 1) the inflows to the reservoir, 2) the reservoir, and 3) the downstream river.

Inflows

The inflows into Ridgway reservoir are from the Uncompahgre River and Dallas Creek. The majority of the flow enters the reservoir through the Uncompahgre River. Usually the Uncompahgre flow during the spring runoff period is several hundred cubic feet per second whereas Dallas Creek is less than 100 ft^3/s and usually less than 25 ft^3/s for the year. Therefore, the Uncompahgre flows influence dissolved gas levels much greater than Dallas Creek flows. At this time, it is felt that the inflows into the reservoir are not the cause of the elevated dissolved gas levels in the river below the dam and gas bubble trauma experienced by the fishery.

Reservoir

The water quality of Ridgway reservoir was extensively studied even before the dam was constructed. The heavy metals in the upper drainages were a concern for the impoundment. The findings revealed that the water quality was expected to be very clean. Early, numerical studies looking at projected inflows, outflows, and assumed gas transfer rates predicted no problem with oxygen depletion or nitrogen accumulation.

The reservoir dissolved gas and temperature data show a weakly stratified reservoir in the summer months. The dissolved oxygen data do not show stratification. There have not been reported incidents of gas bubble trauma in the fish in the reservoir. The reservoir does not seem to be the factor contributing to the dissolved nitrogen and gas bubble trauma incidence in the fishery downstream.

River Downstream from the Dam

Releases from Ridgway Dam are the cause of the dissolved gas problem in the river below the dam. Releases are made from either the bypass (<100 ft^3/s) or the outlet works (>100 ft^3/s). The spillway is rarely, if ever, used. The outlet works discharges into a stilling basin that releases into a channel downstream. The bypass discharges into a small vault near the surface of the water in the same channel as the outlet works.

Both nitrogen gas supersaturation and GBT are present in the Uncompahgre River below Ridgway Dam. Both supersaturation and external GBT decrease downstream from the tailrace toward the confluence with Cow Creek. Severity of individual trauma also appears to follow this trend. However, the relationship between cumulative GBT exposure and mortality is unknown in this system at this time. For example, sample sizes of fish close to the bypass and outlet works structures were always small in comparison to other sites, but the percentage of infection among these fish was always highest, figures 27-28. To assume that these fish are fewer in number due to mortality caused by relatively higher percentage of GBT incidence may not be correct in this case, because we were unable to sample the much deeper plunge pool immediately upstream of the bypass, where many fish were observed. Also, the change in flow conditions just prior to fish sampling may have caused movement of fish and had an effect on the fish distribution.

A conceptual design of a gas abatement rock structure has been provided and could be used to decrease gas levels and corresponding GBT symptoms.

Public Perception

Fish survey data from the years 2003 – 2005 (Table 5 and [1]) indicate that size ranges of salmonids with GBT vary; however, the average size of all affected salmonids was greater than 200 mm (8 inches). Often, the average size of GBT infected fish was greater than that of non-infected fish. These larger fish are sought after and are susceptible to angling pressure. The problem of catching fish exhibiting GBT may be more of an aesthetic issue than one of GBT based population declines. The heavy stocking of the Uncompahgre River below the dam, as noted in the previous report [1], also makes it difficult to assess how important the issue of GBT in the fishery is. Stocking probably masks the affects of supersaturation and reduces the percentage of fish that show signs of GBT on fish.

Fish Population Estimates - Year 2003 versus 2005

The question "How do fish populations in the Uncompahgre River below Ridgway Dam respond to fluctuating levels of saturation?" is complicated by stocking, angling, highly variable annual flow, operational constraints, and natural fish emigration / immigration. However, population estimates offer some insight regarding long-term population trends that can be referenced to gas and GBT data collected.

Population estimate data for this report were provided by Dan Kowolski, CDOW Fisheries Biologist, Montrose office. The results are based on a two-pass depletion estimate conducted in the immediate vicinity of the Footbridge measurement site in 2003 and 2005. Population (by species) estimates and the variance associated with the estimates are calculated.

The population of the two most common salmonids in the sampled sections of the Uncompahgre River during 2003 and 2005 fluctuated. Nitrogen saturation levels indicated about a 3 percent difference in nitrogen levels for roughly the same period of time leading up to the sampling effort. The two species appeared to respond differently, not only to different nitrogen supersaturation levels, but also to effects of GBT. Brown trout abundance apparently increased even under the deleterious effects of increased saturation levels and higher ambient GBT infection, whereas rainbow trout abundance declined. This comparison of these two years of population sampling shows the difficulty of drawing conclusions about the effects of supersaturation and GBT on fish populations in an open, infrequently sampled system. Especially when stocking rates, angling pressure and other variables are considered. True population effects could be determined on resident fish only if stocking was reduced for a season.

2004 Season Monitoring Investigation

Analysis of the previous year's data sets showed a great amount of data scatter. The first task for the 2004 monitoring season was to investigate the location in the cross section of the river station where data were collected and to discuss measurement methods to try to reduce the data scatter by improving gas measurements. Also, the fish survey taken in 2003 was for a long reach and no correlation could be made to the gas data. TSC personnel accompanied the Grand Junction Area Office personnel down river to investigate the flow conditions and gas levels at each normal monitoring river station. In addition, guidance on location of reaches to be sampled and assistance with fish sampling was provided to the Colorado Division of Wildlife (CDOW). Gas monitoring and fish sampling were performed the week of March 29th, 2004. The purpose of the trip was two-fold:

- To perform a side-by-side comparison of water quality measurement instruments while performing cross-sectional measurements to determine the best location for measurement at each station and evaluating measurement techniques;
- To perform a series of fish samples starting at the outlet and moving downstream. Shocking occurred for 500 minutes on average. Fish collected were then inspected for signs of gas bubble disease.

Figure 1 shows the flow release through the outlet works bypass during the monitoring and sampling period. The exit of the bypass is a concrete box downstream from the standpipe and is located on the left bank of the outlet works exit channel. The bypass flow was 45 ft^3/s during the water quality monitoring and 30 ft^3/s during the fish sampling. River flow had already been increased to 300 ft^3/s for irrigation needs downstream prior to this testing period. The flow was reduced each morning and maintained at the lower level throughout the day to do the monitoring and fish sampling. The flow was increased again at the end of each day. The higher flows and the change in flow just before the fish survey could have had a residual effect on the fish location and health.

There were three components to the gas monitoring investigation:

- Evaluating flow conditions,
- Performing cross section measurements,
- Evaluating measurement techniques and instrumentation.

The fish survey results are discussed in another section.

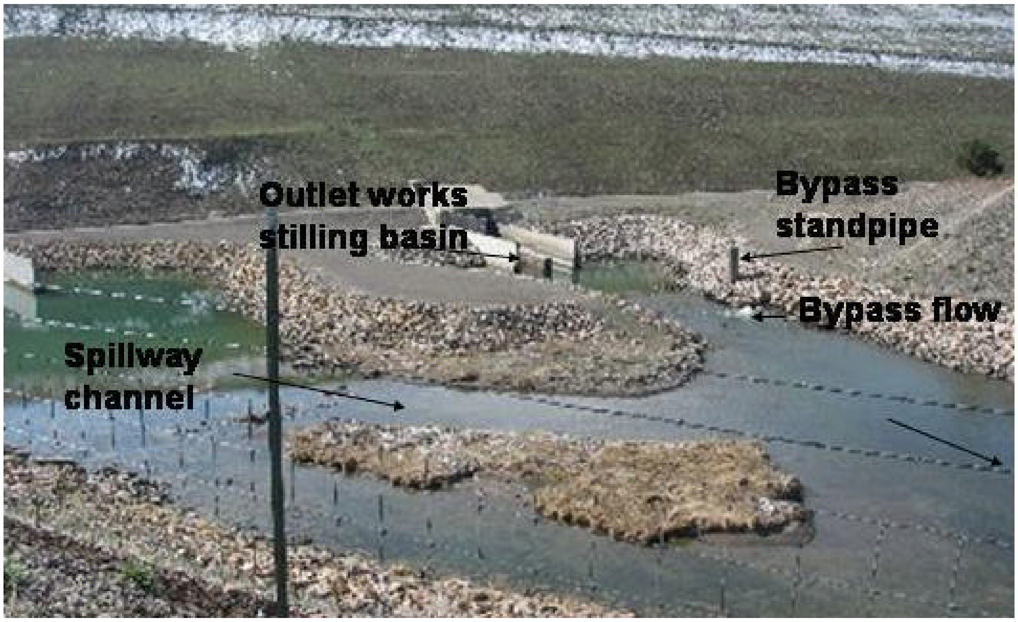

Figure 1. - Overall view of the downstream face of Ridgway Dam in March 2004 showing the spillway exit channel on the right and the outlet works stilling basin and bypass exit on the left looking downstream.

River Transects

Photographs of major river measurement stations at the USGS site, Big Rock, and Kiva are shown in figures 2 through 5. Gas sampling was performed as transects across the river at each of these and the other historical river station measurement sites to determine the best measurement location laterally at each station. Generally, measurements were taken side-by-side by TSC and field personnel at three locations across the river; the normal location, one where most of the river flow was passing, and an additional adjacent location usually near the opposite bank. The data from the river transects are shown in table 1 and were used to compute the percent oxygen, nitrogen and total dissolved gases.

Comparisons were made between the readings obtained with the different instruments after returning to the TSC in Denver. The dissolved oxygen (DO) and either the barometric and ? P or total pressure and ? P were measured by both field and TSC personnel with YSI DO meters and Sweeney or Aquanet gas meters, respectively. The dissolved oxygen readings were the most inconsistent even though the instruments had been recalibrated together in the field. This is not entirely unexpected. Extensive studies have been performed on gas measurement devises and found that, in general, with well calibrated equipment and qualified personnel, an error of ±2.3 percent about the average is usually obtained **[2]**. Therefore, the measurements gathered during this project have reasonable accuracy and should be of adequate quality to determine what is happening in the river.

Table 1. - Comparison of gas data from the March 2004 field trip during a discharge of 45 ft^3/s. The recommended measurement locations across the river section are highlighted in yellow and represent the locations of greatest current in the river

Station	TSC % N2	Field % N2	N2 %difference	TSC %O2	Field %O2	O2 %difference	TSC % TDG.	Field %TDG	TDG %difference
Bypass -rt	112.63	112.67	-0.03	120.48	110.45	8.33	114.10	112.05	1.80
Bypass-normal	116.29	121.05	-4.09	122.70	113.23	7.72	117.41	119.17	-1.50
Bypass - lt	115.85	121.22	-4.63	123.68	111.79	9.61	117.28	119.01	-1.48
USGS - rt- normal	115.56	113.15	2.09	132.84	117.19	11.78	118.91	113.79	4.30
USGS - center	115.78	115.02	0.66	127.08	115.54	9.08	117.91	114.93	2.53
USGS- center	116.36	115.23	0.98	128.83	114.03	11.48	118.74	114.78	3.33
USGS- lt	115.44	114.41	0.89	128.35	114.73	10.61	117.91	114.29	3.07
USGS below drop	116.95	120.75	-3.25	131.45	121.25	7.76	119.73	120.60	-0.72
Big Rock-rt -normal	114.52	117.81	-2.86	127.83	114.12	10.72	117.08	116.81	0.24
Big Rock-center	117.33	120.07	-2.34	121.25	117.61	3.00	117.91	119.30	-1.18
Big Rock - lt	116.35	117.92	-1.35	126.53	120.91	4.44	118.24	118.30	-0.05
Kiva - rt -pool-normal	112.29	114.29	-1.79	121.87	115.22	5.46	114.10	114.29	-0.17
Kiva- center	111.95	114.83	-2.57	124.74	117.34	5.93	114.43	115.14	-0.62
Kiva-lt	111.15	113.94	-2.51	122.94	114.94	6.51	113.43	113.95	-0.46
Riffles above Bridge	109.18	112.94	-3.44	122.39	114.72	6.27	111.77	113.12	-1.21

Flow Conditions

Figures 2 and 3 show the outlet works and bypass flows at the release points and the corresponding flow conditions at the USGS measurement site. The river is very tranquil between these two locations, but often showed inconsistent gas readings with higher gas levels at the USGS site. The higher flow of 300 ft^3/s at the USGS site in figure 2 definitely shows more flow to the center and left of the river. The normal measurement location has been just off the right bank, looking downstream. Figure 3 shows a typical bypass flow rate and condition at the bypass and at the USGS station. There is really no indication in the river of where the major flow current is at this low of a flow, but the data in table 1 indicated the even under this low flow rate that a more representative gas measurement would be obtained in the center or slightly left of center in the river. Measurements should be taken at the center or left of center at the USGS site for all flow rates.


Figure 2.–The photograph on the left shows the right bay of the outlet works structure (looking upstream) operating at 300 ft^3/s. The USGS site about 750 ft downstream is shown in the right photograph (looking downstream). Note the white water just to the left of the center of the channel which should be where the measurement is taken. The normal location for measuring was on the right bank looking downstream.

Figure 4 shows the Big Rock measurement site with the normal measurement location on the bottom where little flow is passing and the location of the majority of the flow toward the left bank


Figure 3. - The photograph on the left shows the bypass operating at 35 ft^3/s for the fish sampling. The photograph on the right shows the USGS measurement site. Notice that a major flow current is not distinguishable at the USGS site at this low flow rate.

in the top photograph. The Big Rock site often showed an increase in gas levels above those from the release point or the USGS site. The flow conditions and the gas readings from table 1 indicate the measurement should be taken nearer the left bank, looking downstream, where the current is higher.

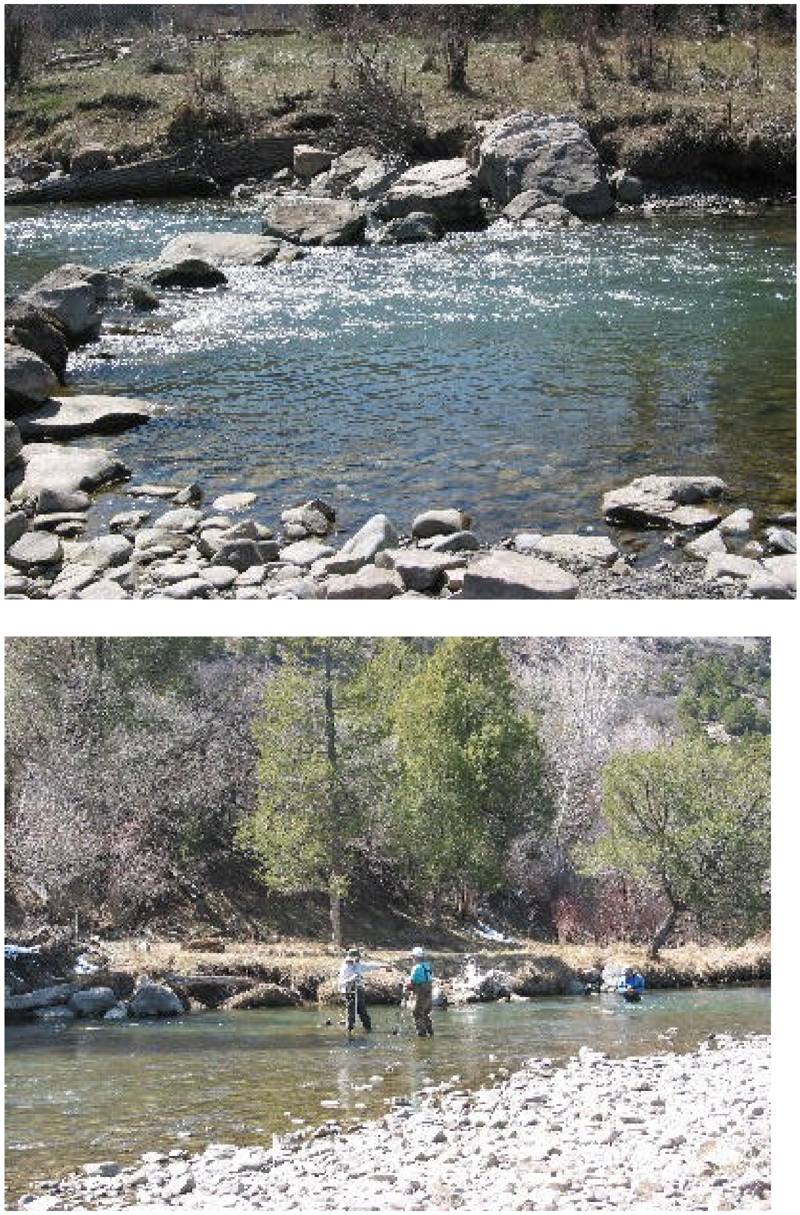

Figure 4. - Both photographs show the Big Rock site downstream from the secured boundary below the dam. Notice the white water in the top photograph, indicating the majority of the flow is to the left side of the river cross section. The TDG measurement location should be changed to where the majority of the flow is in the river as shown in the upper photograph.

Figure 5 shows the Kiva measurement site with the normal measurement location behind the stump near the right bank in the left photograph and bottom of the right photograph.   There is clearly a stronger current in the middle of the river at the Kiva station and is where the measurement should be taken. Although this far down river the gas data did not show unexpected readings, the measurement should be improved at the new location.

Figure 5. – These photographs show the Kiva measurement site. The previous measurement site was in the pool behind the stump in the left photograph, which was in a stagnant area. The right photograph shows the better measurement site is where the water is moving, out in the center of the channel.

Performing the river transects improved the understanding of how the gas levels are transported down river. The ability of the field personnel to gather data that will consistently capture the maximum gas levels at each river location will be improved by taking measurements in the swiftest moving water location or where the majority of the flow is located in the river. An interesting factor in this river is the addition of the fish habitat structures that generally increase turbulence and reduce gas levels, but may depending upon the geometry and depth of the pool downstream actually locally increase the gas levels. In addition, the measurement techniques were discussed and evaluated as the group traveled downstream from station to station.

The gas measurements and flow observations during the monitoring were reviewed. The following recommendations were made regarding gas monitoring locations to improve the quality of the dissolved gas data:

- Make sure barometric pressure is known for TDG meter and that meter is reading correctly.
- Make sure elevation is entered correctly into DO meter.
- Make sure enough time is spent in calibration of DO meter to get a matching reading with the calibration setting before starting.
- Make sure that the first reading of the day is not rushed. The bypass/stilling basin reading is the one that seems to show the most scatter. It could be because the meters are going from air to water for the first time and they will take longer to equilibrate then.
    - Good practice is being used by keeping the meters in the water when moving from place to place that will help the meters equilibrate quicker.
- Readings are not needed at two depths (top and bottom) in the shallow flow that exists when the bypass is operating.
    - Even when the flow increases, a single depth measurement may be used with the meter positioned at least 6 inches below the surface of the water.
- Continue taking the bypass reading to the left (looking downstream) of the rock.
- At the USGS site move to the center of the river for the reading.
- At Big Rock, and all sites, try to take the readings where the main part of the river is flowing or where it looks like the velocity of the flow is the highest. Taking the reading in the area of fast-moving water, not a backwater area will consistently get the maximum reading and improve accuracy.

These recommendations were forwarded to the field personnel and used throughout the remainder of the sampling over the 2004 and 2005 seasons.

Performing the cross-section investigations also would allow selection of a location for a fixed monitor at a later date if so desired. The secure boundary below the dam is indicated by a fence across the river between the USGS site and the Big Rock site. Public assess is restricted from this boundary to the dam. The location of this boundary could be considered when considering the effects of fish gas bubble trauma (GBT) and the visibility of the problem to the public and when looking at a location for a gas abatement structure. In addition, if a fixed monitoring station were installed by the Western Colorado Area Office then the location could be secured in this area.

All Nitrogen Gas and Discharge Data

The nitrogen gas and discharge data collected during the time period from 1998 to mid 2003 was discussed extensively in the previous progress report [1]. This section will show the previous data with the additional nitrogen gas and discharge data gathered through the later part of the 2003, and the entire 2004, and 2005 seasons in tables 2-4. The project has always reported the dissolved gas issue in terms of percent nitrogen saturation. Nitrogen is the primary and most stable component in the water so this is a reasonable way to report the data; however, the total dissolved gas saturation is what is normally reported. The total dissolved gas saturation is the sum of all the gases present in the water. The nitrogen component may or may not be larger than the total saturation depending upon the measured dissolved oxygen level and the final computation. The gas data in tables 2-4 show the percent nitrogen saturation to be consistent with the project request.

These tables include not only the nitrogen gas and discharge data collected below the dam in the Uncompahgre River, but also the data gathered upstream from the dam in the Uncompahgre River and Dallas Creek. USGS records were sometimes used to fill in discharge data. Three stations were referenced:

- Site # 09146200 Uncompahgre River Near Ridgway, CO upstream from the reservoir
- Site # 09147000 Dallas Creek Near Ridgway, CO upstream from the reservoir
- Site # 09147025 Uncompahgre River Below Ridgway Reservoir, CO downstream from the reservoir and dam.

The tables include all the stations where data has been historically gathered and the river distance downstream from the dam of those stations. Columns two and three show the percent N_2 value written in the column where the flow was released, either the outlet works or bypass, i.e. on May 13, 2003 the flow was being released by the outlet works with a measured percent nitrogen saturation of 115.2. Sometimes "top" and "bottom" is shown in the opposite column from the percent N_2 location, indicating readings taken near the river surface or the bottom, respectively. The columns after the percent nitrogen data in the downstream river are percent nitrogen saturation upstream of the reservoir in Dallas Creek and the Uncompahgre (u/s river) and the "CFS" columns are the discharge values, when known, for downstream and upstream in the Uncompahgre (u/s river), and upstream in Dallas Creek. One small spillway flow is shown on May 4, 2000.

From an operations standpoint, stream flow requirements are maintained downstream from the confluence with Cow Creek using bypass releases from the fall through the early spring. The bypass is used for all flows below 100 ft^3/s. Releases are made throughout the spring and summer for irrigation purposes and generally are made through the outlet works as flows exceed the 100 ft^3/s capacity of the bypass structure. The project does not want to use the spillway for releases unless necessary due to potential entrainment of small fish and to avoid releasing higher temperature water. One data point is shown during a time the spillway was operating. Springtime runoff is also filling the reservoir with increased flows from the Uncompahgre River and Dallas Creek.

Figure 6 shows all the data collected immediately below the bypass structure and the outlet works stilling basin for the entire time that data has been collected in the Uncompahgre River below Ridgway Dam. The upstream river data shown in the tables are discussed in a following section.

Table 2. Percent nitrogen saturation data gathered about monthly below Ridgway Dam for the 1998-2001 seasons.

UNCOMPAHGRE RIVER near RIDGWAY RESERVOIR

river distance	0.00	0.00	750.00	1100.00	1840.00	2920.00	3720.00	5350.00	5930.00					
Sample Date	% N_2 Sat. Oultlet	% N_2 Sat. Bypass	% N_2 Sat. USGS	% N_2 Sat. Big Rock	% N_2 Sat. Kiva	% N_2 Sat. Bridge	% N_2 Sat. Pond	% N_2 Sat. B.C.	% N_2 Sat. Confluence	% N_2 Sat. Dallas Cr	% N_2 Sat. u/s River	CFS d/s dam	CFS u/s River	CFS Dallas Cr
11/03/98		114.86	113.71		103.57									
11/04/98		115.80	116.64											
11/04/98	110.54		111.13											
03/16/99		112.68	112.65	114.84	114.07	112.53	111.41					81		
04/14/99		105.67	109.51	108.07	107.27	104.50	104.19					73		
05/21/99	126.45		125.54	126.44	130.80	134.68	132.28				116.81	345	369	
09/16/99	116.77		118.09	118.47	116.92	119.55	114.33				115.69	496	139	
10/18/99	119.55		121.06	119.42	117.15	108.10	108.28				115.36	149	71	
11/23/99		125.57	125.76	121.12	121.86	117.36	117.32					46		
01/06/00		112.98	113.08	114.91	112.73	111.01	109.28					45		
02/15/00		118.32	118.33	118.07	116.89	114.85	112.76	110.72	109.92			55		
04/03/00		112.64	116.53	115.48	114.63	111.84	110.20	109.03	107.50			45		
05/01/00	117.21		119.92	119.95	117.60	115.85	114.80	114.30	114.02		114.05	100	198	
05/04/00	108.17		109.18	109.01	108.69	107.68	107.41	106.08	105.84			254	spillway flow	
06/14/00	114.63		117.24	117.79	117.69	115.22	115.09	112.60	112.12		114.88	400	300	
07/12/00	116.61		119.93	116.97	116.61	116.53	114.59	112.00	111.97		115.86	320	159	
08/10/00	114.26		118.33	117.09	116.28	114.39	113.82	110.82	106.19		115.19	285	77	
09/12/00	113.17		116.32	114.93	112.36	111.11	110.43	108.07	106.92		113.52	106	97	
10/12/00		126.78	124.11	121.55	116.15	116.81	114.86	112.75	112.07			68		
12/01/00	bottom	115.92	112.65	119.43	114.58	114.99	113.59	112.41	109.45			50		
12/01/00	top	108.88		115.04	114.93	114.42	113.17	108.58				50		
12/19/00	bottom	115.79	112.38	118.08	113.82	104.40	110.43	108.12	107.00			50		
01/19/01	bottom	120.05	120.13	124.08	120.96	116.51	117.92	114.94	112.71			52		
02/16/01	bottom	118.72	114.23	113.24	113.20	110.57	112.59	110.24	108.89			52		
05/30/01	116.58	bottom	116.14	115.84	115.91	114.59	114.05	111.17	111.99		118.70	300	492	
05/30/01	117.15	top				114.11	112.52	111.31	111.69			300		
06/21/01	115.57	bottom	113.28	116.33	114.45	114.50	112.96	110.73			119.08	350	408	
06/21/01	115.33	top		116.57		113.98	112.92	110.40				350		
9/6/2001	116.66	bottom	109.98	114.50		112.41	112.16	110.04	109.01		115.74	235	78	
9/6/2001	115.43	top	115.46	113.88	113.11	111.28	110.46	108.97	108.28			235		

Table 3. - Percent nitrogen saturation data gathered about monthly below Ridgway Dam for the 2002--2003 seasons.

UNCOMPAHGRE RIVER near RIDGWAY RESERVOIR												Page 2 of 3		
river distance	0.00	0.00	750.00	1100.00	1840.00	2920.00	3720.00	5350.00	5930.00					
Sample Date	% N_2 Sat. Oultlet	% N_2 Sat. Bypass	% N_2 Sat. USGS	% N_2 Sat. Big Rock	% N_2 Sat. Kiva	% N_2 Sat. Bridge	% N_2 Sat. Pond	% N_2 Sat. B.C.	% N_2 Sat. Confluence	% N_2 Sat. Dallas Cr	% N_2 Sat. u/s River	CFS d/s dam	CFS u/s River	CFS Dallas Cr
1/22/2002	bottom	117.53	101.93	115.83	111.81	113.84	113.25	108.16	107.61			45		
1/22/2002	top				112.47		111.92					45		
2/22/2002	bottom	116.98	104.51	119.31	118.36	115.66	114.91	109.94	112.79			45		
2/22/2002	top	105.26			108.26		114.36					45		
3/28/2002	bottom	112.19	111.58	115.04	106.81	110.03	111.26	106.03	108.91			45		
3/28/2002	top				105.93		109.79					45		
04/24/02	115.13	bottom	105.28	110.86	110.50	108.58	107.93	106.02	105.28	105.79	105.79	250	110	2
04/24/02	113.77	top			110.17		106.25	103.57	105.15			250		
05/22/02	120.63	bottom	117.70	121.25	115.22	112.10	112.84	108.57	108.42		117.17	250	175	
05/22/02	120.04	top		120.71	113.97		111.06					250		
07/02/02	118.97	bottom	123.15	121.87	121.11	117.88	117.02	113.51	112.42		116.17	162	55	
07/02/02	118.73	top			119.37	117.67	116.28					162		
07/02/02	98.51	hydrolab	97.60	103.22	102.66	104.60	104.32	97.44	96.49			162		
09/05/02	116.61	bottom	117.94	114.68	116.04	110.98	110.90	108.05	107.32		115.53	120	44	
09/05/02	116.58	top			107.49		110.92					120		
01/09/03	bottom	111.62	113.31	104.82	114.21	110.04	109.18	108.01	105.62			30		
02/12/03	bottom	107.45	96.38	115.90	111.98	109.05	109.28	104.69	102.34			30		
03/25/03	bottom	123.17	103.09	117.25	119.65	117.21	116.89	108.88	113.67			30		
03/27/03	bottom	111.11	112.80	112.20	109.10	106.40	106.90	104.60	103.50	99.90		30		24
05/13/03	115.18	bottom	116.94	113.71	114.91	111.91	110.38	107.86	107.89		116.06	120	152	
05/13/03	115.20	top			112.60		108.96	106.53				120		
06/25/03	116.83	bottom	114.72	116.54	114.78	113.17	112.69	110.11	109.28		118.19	300	231	
06/25/03	116.30	top			114.94	112.99	112.22	109.50				300		
			Above data in pages 1 and 2 were reported in the previous phase 1, 2, and 3 report.											
07/29/03	114.74	bottom	115.15	114.29	112.90	111.04	110.08	108.35	107.72			240		
07/29/03	114.39	top			112.84		108.75	107.95				240		
08/29/03	112.92	bottom	102.70	111.83	111.64	109.85	109.80	107.20	106.57			200		
08/29/03	112.25	top			103.06		109.16	104.89				200		
12/03/03	bottom	144.92	105.17	111.95	116.44	111.55	111.94	109.32	108.47			45		
12/03/03	top				116.71									

Table 4. - Percent nitrogen saturation data gathered about monthly below Ridgway Dam for the 2004--2005 seasons.

UNCOMPAHGRE RIVER near RIDGWAY RESERVOIR													Page 3 of 3	
river distance	0.00	0.00	750.00	1100.00	1840.00	2920.00	3720.00	5350.00	5930.00					
Sample Date	% N_2 Sat. Oultlet	% N_2 Sat. Bypass	% N_2 Sat. USGS	% N_2 Sat. Big Rock	% N_2 Sat. Kiva	% N_2 Sat. Bridge	% N_2 Sat. Pond	% N_2 Sat. B.C.	% N_2 Sat. Confluence	% N_2 Sat. Dallas Cr	% N_2 Sat. u/s River	CFS d/s dam	CFS u/s River	CFS Dallas Cr
1/27/2004	bottom	112.25	112.52	115.39	114.11	115.74	116.77	114.11	114.62		110.30	45	53	
1/27/2004	top				108.81							45		
2/24/2004	bottom	113.83	105.64	113.48	111.37	106.12	113.20	109.23	111.56	105.20	106.97	45	51	25
2/24/2004	top				108.31							45		
3/30/2004	bottom	121.05	115.23	120.07	114.83					99.86	100.67	45	110	31
5/27/2004	121.44	bottom	120.98	120.50	120.14	118.35	115.12	108.11	105.85	102.63	108.16	400	457	15
5/27/2004	121.48	top			119.70	117.60	114.91	108.11	106.27		107.79	400		
7/8/2004	117.90	bottom	117.92	117.85	116.89	114.47	113.23	110.22	109.93	106.20	105.44	325	206	15
7/8/2004	117.83	top		117.27	113.61	113.75	110.06	109.43				325		
8/12/2004	119.15	bottom	118.82	118.48	116.69	114.91	113.99	111.23	110.42	102.81	105.07	350	91	7
8/12/2004	118.33	top		118.11	115.93	114.27	112.73	110.58				350		
9/27/2004	115.07		116.07	114.58	112.70	109.77	109.58	106.73	104.89	103.10		100		
3/10/2005	bottom	105.86	104.53	109.44	116.44	112.55	112.83			103.98	97.48	46	54	15
3/10/2005	top	111.46												
3/17/2005	bottom	102.90	108.99	104.04	102.09	100.70	99.46	96.52	96.99			30		
5/10/2005	116.98	bottom	117.55	116.42	116.00	114.42	112.43	109.13	108.86	97.90	98.99	384	257	10
5/10/2005	117.90	top			115.21	113.77	112.27	109.79	109.00					

Data collected on 3/30/04 and following were collected at the same stations but at some revised locations in the cross section.

Column entitled "Confluence" is assumed below the confluence with Cow Creek.

Data were found on the USGS website.

Data collection 3/27/03 was performed by TSC personnel during a fish survey trip.

Data collection on 3/30/04 and was a combination of data collected by field and TSC personnel while reviewing the influence of the location in the river cross section that the data was gathered.

Data collection 9/27/04 was performed by TSC personnel during a fish survey trip.

Data reported on 3/17/05 were collected by TSC personnel during fish survey trips with an Aquanet total dissolved gas meter.

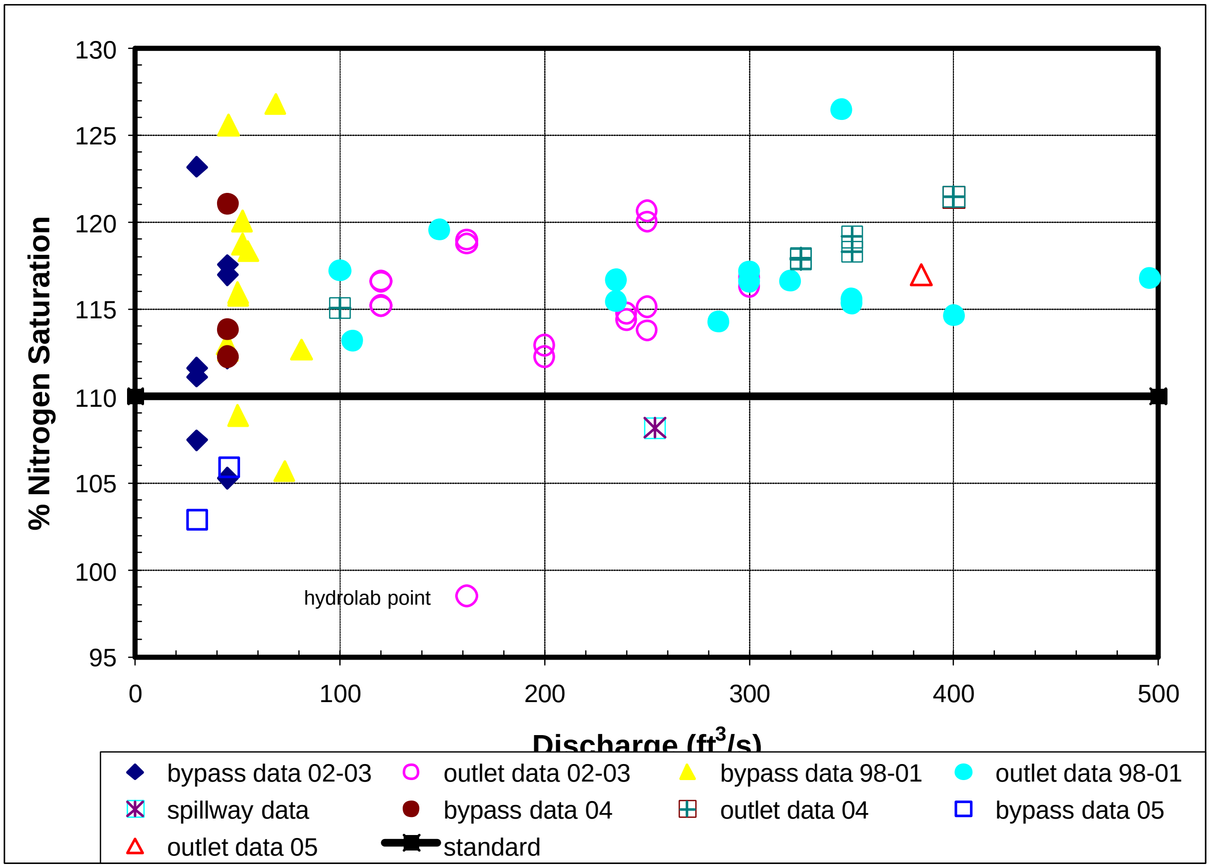

Figure 6. - All nitrogen saturation data collected over the time of record at the station immediately below the outlet works or bypass structure for the releases in the Uncompahgre River below Ridgway Dam. (Bypass data in 2004 and 2005 were gathered by TSC personnel.)

This plot still shows the same scatter in the bypass data and outlet works data as seen previously. The bypass data is for a very small range of flow and the saturation values should not change as drastically as shown, unless there is a reason from a reservoir water quality or temperature standpoint. The flow has just been released from the reservoir with the low level intake at El. 6741 so the water has not been exposed to warming in the river long enough for the water temperature to increase. Higher temperature water holds less gas or the solubility of gas decreases as the temperature increases; therefore, the rate of gas transfer decreases and the gas concentration is less when the water temperature is higher. Temperature in the reservoir is low in the spring and higher in the fall and this might account for some of the bypass data scatter. The two highest readings were in the fall, but there were also some fall readings that were similar to the other spring data points. Reservoir water quality and its effect are discussed in a later section; however, there does not appear to be a link between poor reservoir water quality and the bypass gas levels.

The outlet works data does show a slight trend of increasing gas saturation with flow as would be expected given the theoretical predictions **[1]**, but there is still a great deal of scatter over the history of the project data. Less scatter is evident in the data for 2004 and 2005 seasons under either the bypass or outlet works operation at the point of release. Additional trends down river are explored in the next section which discusses trends after improvements were made in data gathering techniques.

2004 and 2005 Gas Data Gathered After Cross Section Relocation

The gas data for the 2004 and 2005 seasons was specifically analyzed separately to see if improved measurement techniques and locations would help clarify some of the lingering questions regarding the data scatter. Figure 7 shows the data from the 2004 and 2005 seasons gathered in the Uncompahgre River below the dam for both outlet works and bypass releases after the suggested monitoring improvements had been utilized.

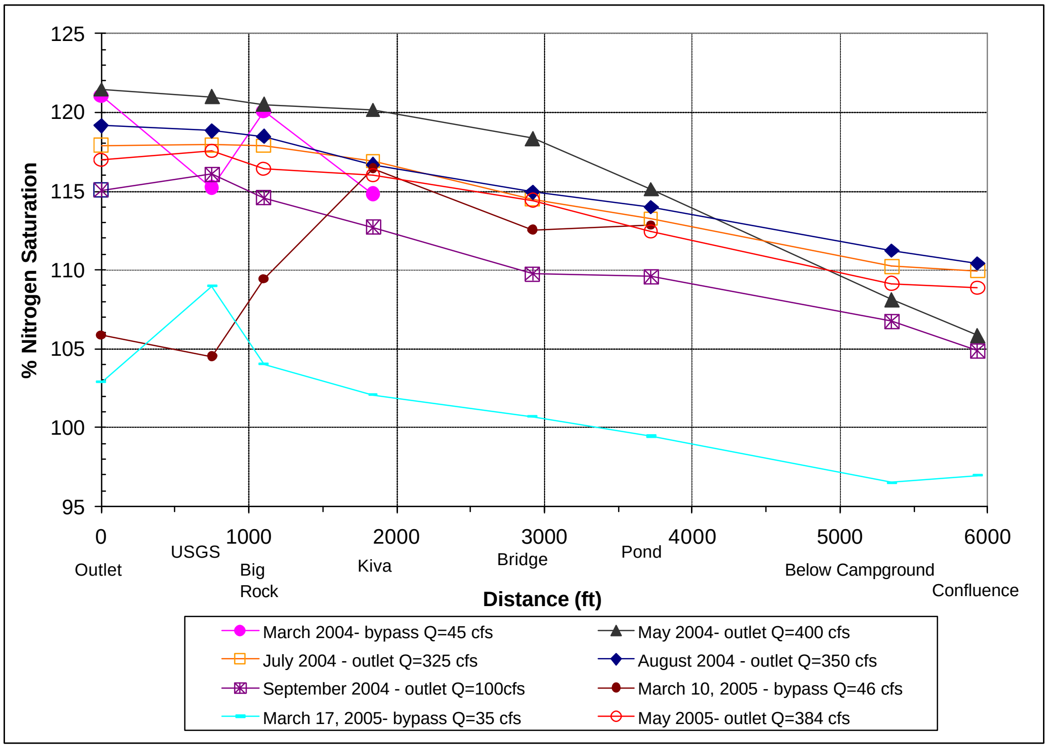

Figure 7. - Percent nitrogen saturation produced by flow from the bypass and outlet works below Ridgway Dam for the time period of March 2004 through 2005 after the change in measurement location.

Previously, nitrogen gas levels seemed to increase and produce a maximum at either the USGS or Big Rock locations as may be seen on a figure 8 from the data collected during 2000 that was representative of the data reported in the previous 2003 report [1]. That phenomenon was always puzzling as there didn't seem to be any reason based upon the river for the gas levels to increase between the release point and the next downstream stations. It was hoped that the intensive investigation of the river sites would help with the understanding of the data and produce results that would more closely match what was expected by experience. Figure 7 still shows some scatter with both release locations; therefore, the data was plotted separately for outlet works and bypass flows in figure 8 and 9, respectively.

In figure 8, the outlet works gas data only is shown for the 2004 and 2005 seasons after the monitoring locations had been improved. There was a minimal or no increase in gas saturation between the release point and the USGS or Big Rock sites that had been occurring with data from previous years. The trend of decreasing gas levels with distance downstream is also seen, but with less overall scatter in the data than previously reported. In addition, there also seems to be a correlation between flow rate and gas levels. The May 2004 data, with the highest flow, shows a higher degassing rate at the last two stations as would be expected. The September flow of 100 ft^3/s produced quite a bit less gas saturation when compared to the 300-400 ft^3/s flow range at the outlet works basin. Theoretical computations also predict gas levels in the stilling basin would be higher for higher flows [1, 3]. Gas levels are still above the standard of 110 percent at the release point and downstream for several thousand feet.

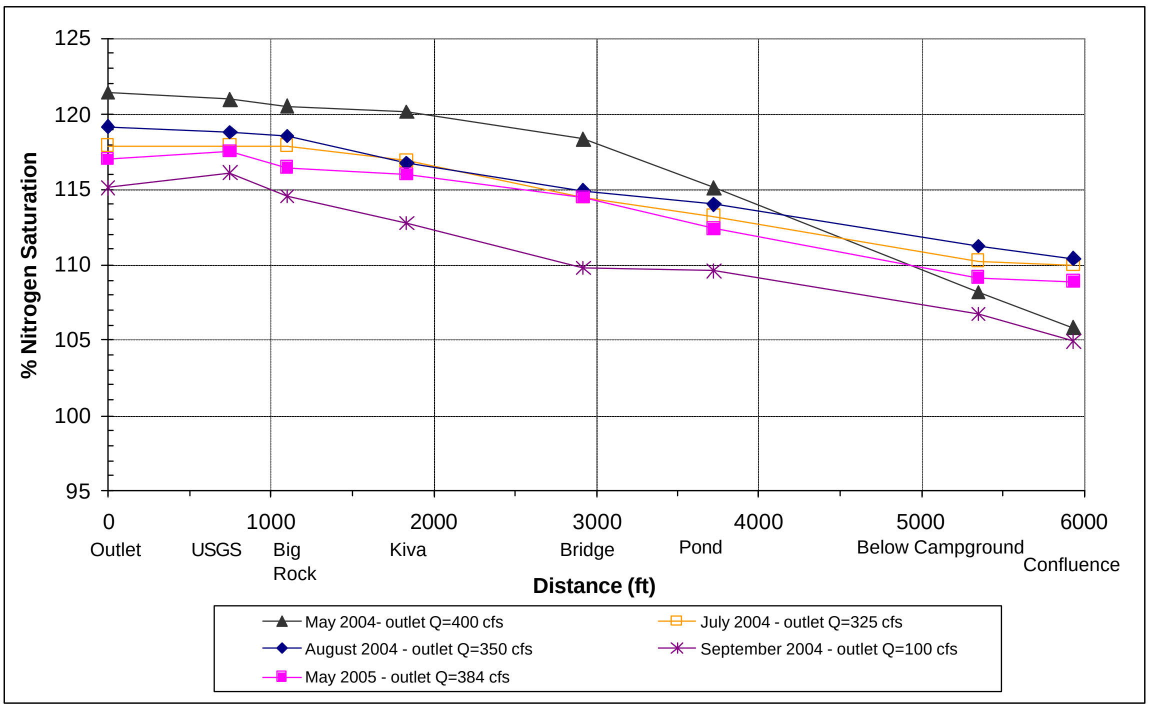

Figure 8. - Percent nitrogen saturation produced by flow from the outlet works below Ridgway Dam for the time period of March 2004 through 2005 after the change in measurement location. These data are much more consistent compared to the previous years' data with the improved measurement locations.

Linear regressions were fit to the outlet data for each month of data gathered in 2004 and 2005 in figure 8. The slope and intercept values were very similar for the Aug 2004, July 2004, and May 2005 data corresponding to flows of 350, 325, and 384 ft^3/s, respectively. Therefore, the following one regression equation was fit to the data for releases between 300 to 400 ft^3/s:

$$\%Nitrogen = -0.0016 \times Distance + 118.95$$

The regression equation for the September 2004 data showed almost the same slope with a lower intercept for the 100 ft^3/s flow rate and indicated a similar degassing trend in the river with less initial supersaturation:

$$\%Nitrogen = -0.0018 \times Distance + 116.16$$

The correlation coefficients showed both equations were very good fits with R^2 of 0.94 and 0.96 for the 300-400 ft^3/s range flows and the 100 ft^3/s flow, respectively.

Figure 9 shows gas data gathered in March 2004 and 2005 from bypass releases using the new measurement locations. Unfortunately, there have only been three times data were gathered under bypass flows since the measurement sites were adjusted. Data gathered in January and February were recorded at the previous locations that changed some during the March 2004 investigations and were not reported here. March data still shows a spike at either the USGS or the Big Rock sites. The March 2004 data were gathered by both the field and TSC staff while investigating flow conditions and measurement techniques and produced the highest gas readings for this period. The March 10, 2005 data by field personnel shows a spike at the Kiva site then a decrease in percent nitrogen downstream. Two days of data were gathered by TSC personnel in March of 2005. There were problems with the barometric pressure reading at the site for the March 15, 2005 data and it cannot be used. The instrumentation seemed to be working correctly when the data for March 17, 2005 were gathered. The data were gathered with a different TDG meter, but the same type of DO meter than normally used by the field personnel. The March 17 data shows a gas level at the bypass similar to that recorded by the field personnel the week earlier, but remains low and decreases downstream unlike that of any previous data.

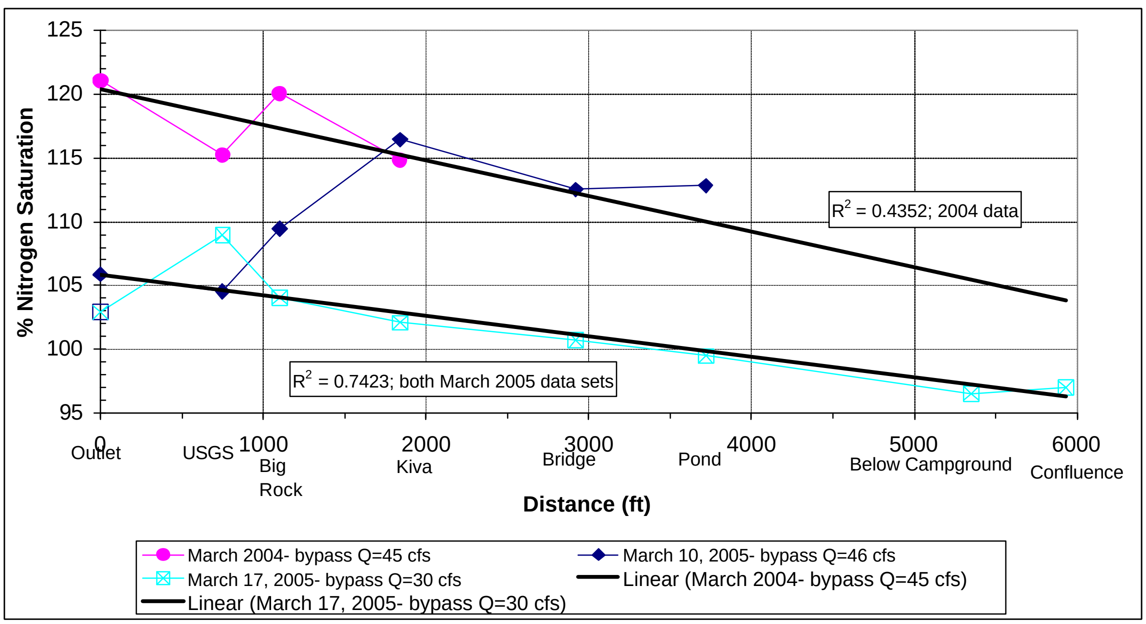

Figure 9. - Percent nitrogen saturation produced by flow from the bypass below Ridgway Dam for the March 2004 and March 2005 after the change in measurement location.

It is still puzzling why the bypass data seems to be so scattered. The bypass pipe does entrain air at the vent located upstream in the pipe. The standpipe allows some of the air to be released, but the flow is still highly aerated while under pressure, thus saturating the water. Perhaps the explanation is just that the flow is so small and the depths so shallow that readings are difficult to obtain. As a result, the entire bypass data set was then reexamined and analyzed with a series of linear regression curves. The average of these regression curves produced the following equation for bypass flows:

$$\%Nitrogen = -0.00114 \times Distance + 115.17$$

This equation of the trend for decreasing gas with river distance downstream for bypass flows is very similar to that for the outlet works. However, the data that produced this equation were very scattered with a large difference in initial dissolved gas values at the bypass. The average regression correlation coefficient, R^2, was only 0.48 for the data set and varied from 0.004 in February 2004 to 0.977 in February 2000. The slope for degassing is a little flatter with a slightly less initial gas value at the bypass than the outlet works.

The September data shown in figure 8 is a smaller flow value than the early releases and show less gas. Some data years showed a seasonal variation in gas levels with the releases in the fall producing less gas than those in the spring for nearly the same flow rate. This implies that the reservoir has turned over and is no longer stratified. In addition, the small inflows and outflows through the late fall and winter months might be influencing stagnation in the reservoir at low levels and thus provide a greater initial gas value for bypass releases that could be related to flow situations. It does seem like this gas data may define the upper envelope for expected gas levels below the dam.

The Uncompahgre River below the dam is a fairly steep mountain stream with natural riffles and bends in addition to the constructed Rosgen habitat improvement structures. The natural turbulence in the river should produce some degassing once past the USGS station. The Rosgen structures could have an influence either way, depending upon how concentrated the water flow though the rocks is and how much the flow plunges into pools formed below the structures. Dissolved gas measurements taken in 2003 [1] and 2005, immediately above and below the structures, showed some degassing at some structures, but not at all structures.

The project does not need to continue gas monitoring at this time. It is not felt that additional information will be gained. If operations change or if a gas abatement structure is installed, then gas monitoring and fish surveys should be performed for a season to determine the effects of the structure on the water quality and fish habitat.

Inflows and Gas Measurements from Upstream Rivers

Gas levels and the accompanying flow data for inflows into the reservoir were investigated to determine if flow volumes through the system and gas levels entering the reservoir are contributing to the problem.

Figures 10-16 show the average monthly Uncompahgre River flows into and out of Ridgway Reservoir, for the years that consistent water quality monitoring has been conducted. The USGS monthly records stopped at September 2004 from the web site. Additional daily flow records were available that indicated that 2005 was an above average flow year in the system with flows substantially higher than the mean throughout the year. The Uncompahgre River is by far the greatest contributor to the reservoir compared to Dallas Creek. Therefore, only the Uncompahgre River flows are tracked in the following figures. The large flow volumes entering the reservoir could have an important contribution to the overall gas picture.

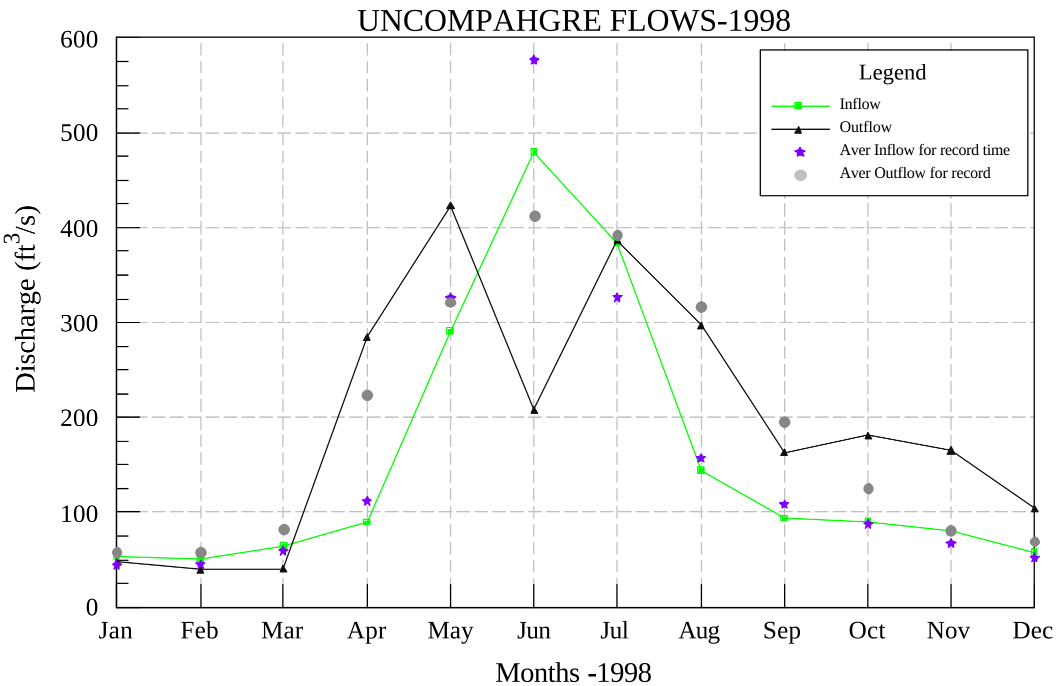

Figure 10. - Plot of the average monthly inflows to and outflows from Ridgway Dam on the Uncompahgre River in 1998. The average inflows and outflows for the entire record are also shown for reference.

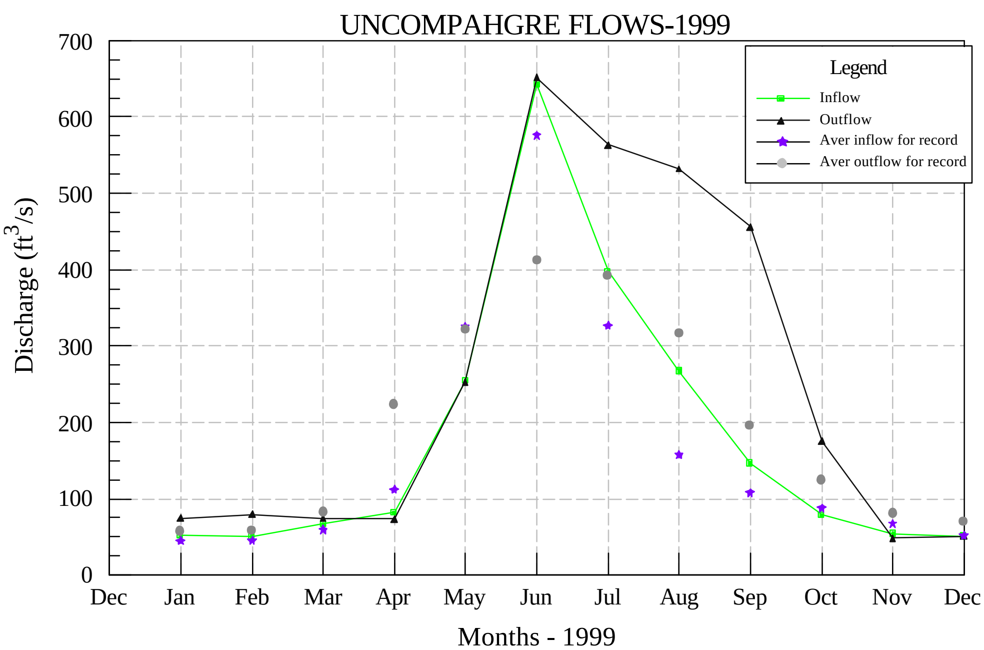

Figure 11. - Plot of the average monthly inflows to and outflows from Ridgway Dam on the Uncompahgre River in 1999. The average inflows and outflows for the entire record are also shown for reference.

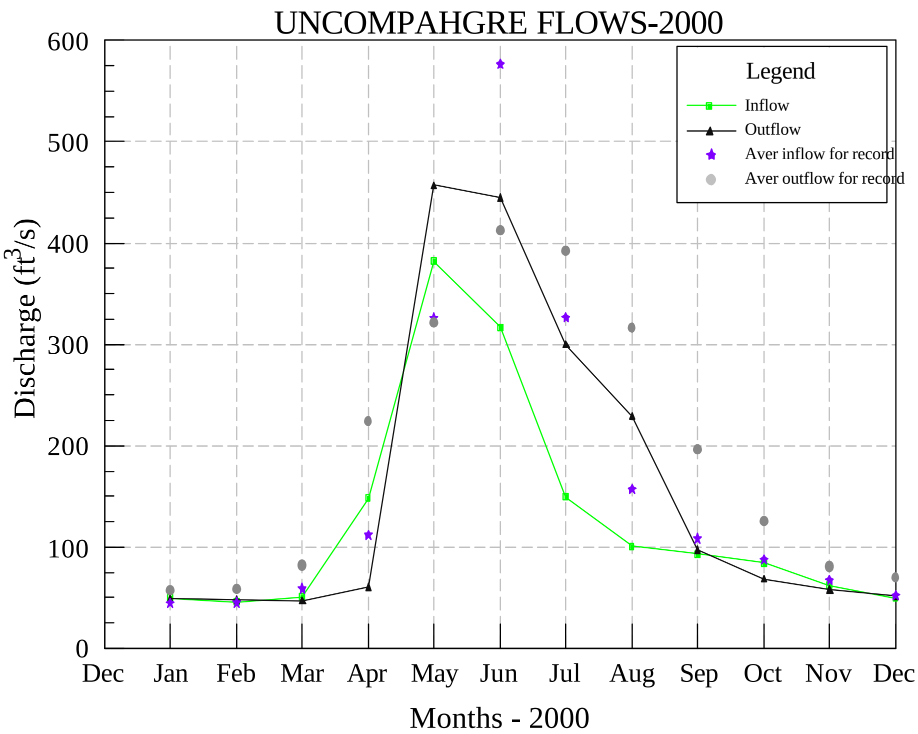

Figure 12. - Plot of the average monthly inflows to and outflows from Ridgway Dam on the Uncompahgre River in 2000. The average inflows and outflows for the entire record are also shown for reference.

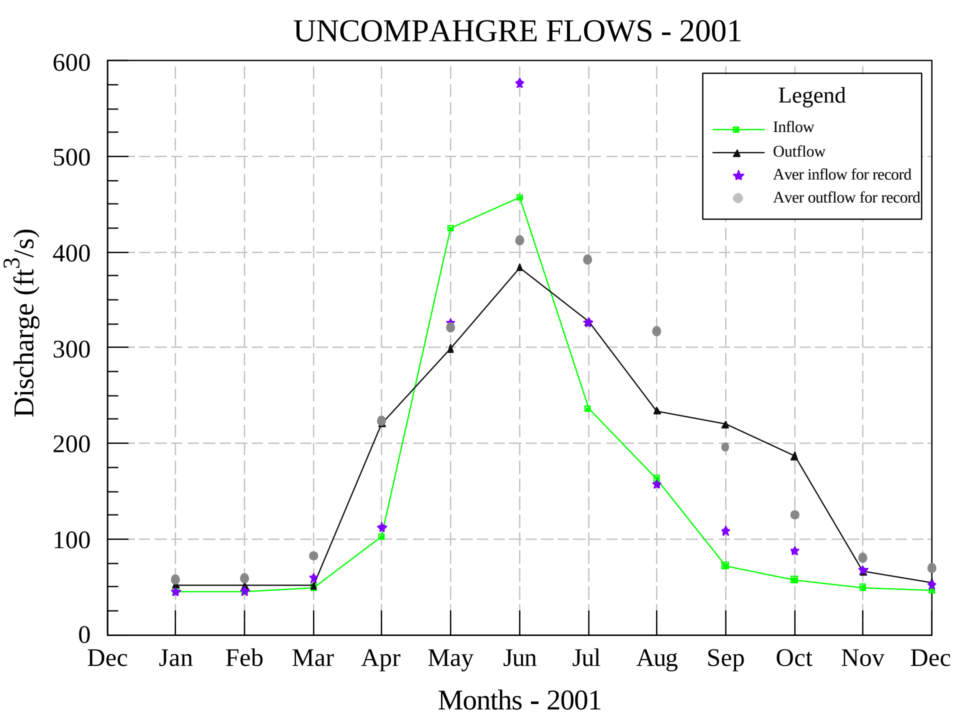

Figure 13. - Plot of the average monthly inflows to and outflows from Ridgway Dam on the Uncompahgre River in 2001. The average inflows and outflows for the entire record are also shown for reference.

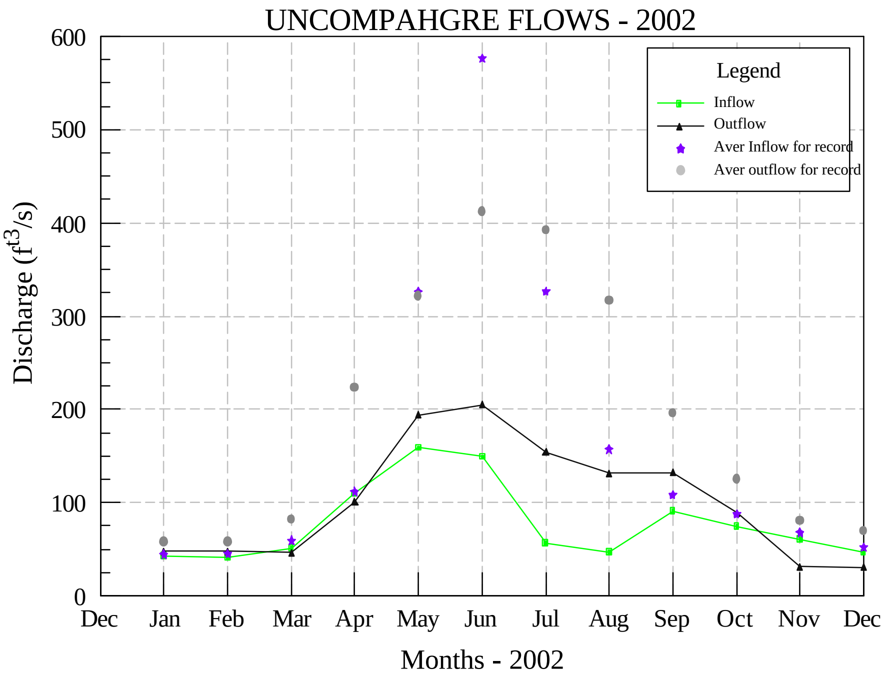

Figure 14. - Plot of the average monthly inflows to and outflows from Ridgway Dam on the Uncompahgre River in 2002. The average inflows and outflows for the entire record are also shown for reference.

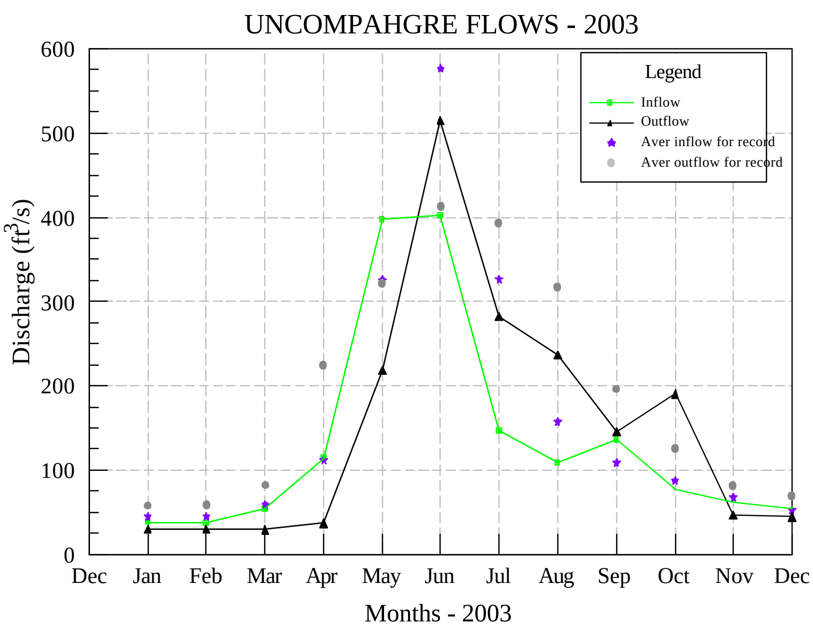

Figure 15. - Plot of the average monthly inflows to and outflows from Ridgway Dam on the Uncompahgre River in 2003. The average inflows and outflows for the entire record are also shown for reference.

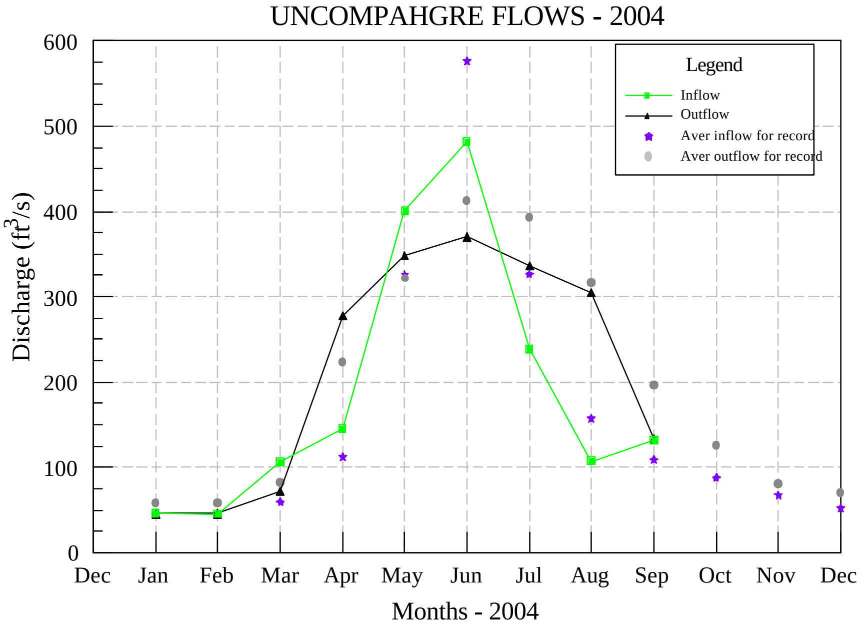

Figure 16. - Plot of the average monthly inflows to and outflows from Ridgway Dam on the Uncompahgre River in 2004. The average inflows and outflows for the entire record are also shown for reference.

As expected, the inflows are highly indicative of the spring runoff time, beginning to increase in late March and dramatically increasing to the peak in May or June, then dropping off through July and August, eventually leveling off to about 50 ft^3/s through the late fall and early winter. Outflows from the dam are driven by downstream demands and the goal of not allowing spillway flow over the uncontrolled crest. Generally, flows are small and closely match the inflows through the late and early months of the year. This is generally when only the bypass is used to make releases from the dam. Outflows seem to track the inflows as the spring runoff is ramping up and then generally exceeds inflow for the remainder of the summer irrigation season.

This inflow and outflow pattern is very typical of controlled reservoir systems. Ridgway Reservoir is only about 3.2 miles long and the water quality should respond fairly quickly to changes of inflow and outflow if they are going to have an influence. If anything can be noted it would be that small inflows and outflows in the fall and early winter might produce some stagnation of the water and potentially low dissolved oxygen content at depth. However, the substantial spring inflows and outflows will produce substantial freshening and the reservoir should not become anaerobic. Thus, if inflows are high in nitrogen, then outflows could be also, but it is not felt that operations will contribute to the problem.

The flows were also compared to average flows in the Uncompahgre River over the historical range of data. Inflows have been recorded since 1958; outflows are releases from the dam and have been recorded since 1988 after filling of the reservoir. In general, the average for the entire record for winter and fall flows matched the annual inflows and outflows to and from the reservoir as these flow events are not related much to variations in snow pack and runoff. Also, the peak flows seem to have been larger in the past than recently, with the exception of 1999 when the peak flows were very similar and outflows from the dam were much higher than normal. The drought years of 2002 and 2003 showed substantially less inflow and outflow than normal over the period of record.

Given the above flow information with the available dissolved gas data, a correlation between the flows and gas levels was investigated. The downstream gas levels have already been discussed. The upstream gas levels that reflect spot measurements gathered in the Uncompahgre River and Dallas Creek upstream from the reservoir are shown in the far right columns of tables 2-4. Figure 17 shows the Dallas Creek data included with the Uncompahgre River gas and inflow data for comparison of the influence of the two tributaries. The percent nitrogen is shown on the normal y-axis with flow data shown on the second y-axis. The first impression from the figure 17 is that the gas levels in the Uncompahgre seemed higher in the past than recently.

The data for the Uncompahgre River shows significant gas levels, in the range of 115 to 119 percent nitrogen, for the gas entering the reservoir for 1999 through 2003. Flows about 400 to 500 ft^3/s occurred in the spring and early summer with the peak runoff and produced the highest gas levels in 2001, reaching 119 percent. A lower inflow, of about 70 ft^3/s in the fall, produced a gas level of about 116 percent. The significant drought in 2002 with much lower inflows did not produce much difference in the dissolved gas levels. Overall, for this period, there seemed to be minimal change in the gas levels with discharge which is not typical.

Inflows during 2003 through 2005 had recovered from the drought year of 2002 and were at or above average which should have produced equally high gas readings if all other parameters remained similar. However, gas data gathered in 2003 through 2005 showed the gas levels entering the reservoir are at or below the standard of 110 percent except for two readings in the spring 2003 that do not correspond to particularly high discharges. There was a flow of about 450 ft^3/s in the spring of 2004 that only produced a gas level of 108 percent nitrogen. Dallas Creek flows were very small and did not show high gas levels, as expected.

There does not seem to be any correlation between high flow years and excessive gas levels coming into the reservoir. Higher releases from the dam outlet works does produce more gas in the river downstream, but that is a function of the hydraulic structure, not the inflow gas levels.

Even though gas levels measured in previous year's shows fairly high levels of dissolved gas entering the reservoir, the recent data from 2004 and 2005 does not indicate that levels are excessive and are below the 110 percent standard. The project personnel reported that there had been no change in the measurement location or procedures used to gather the gas data. These gas levels can be naturally occurring in the river. Reconfiguration of the Uncompahgre River was underway near the town of Ridgway in 2004 and this is perhaps the reason for the reduced dissolved gas readings. However, the cross section appeared similar to the undisturbed river sections so it is not likely the reason for the change in the gas levels. At this time, it is felt that the inflows into the reservoir are not the cause of the elevated dissolved gas levels in the river below the dam and gas bubble trauma experienced by the fishery.

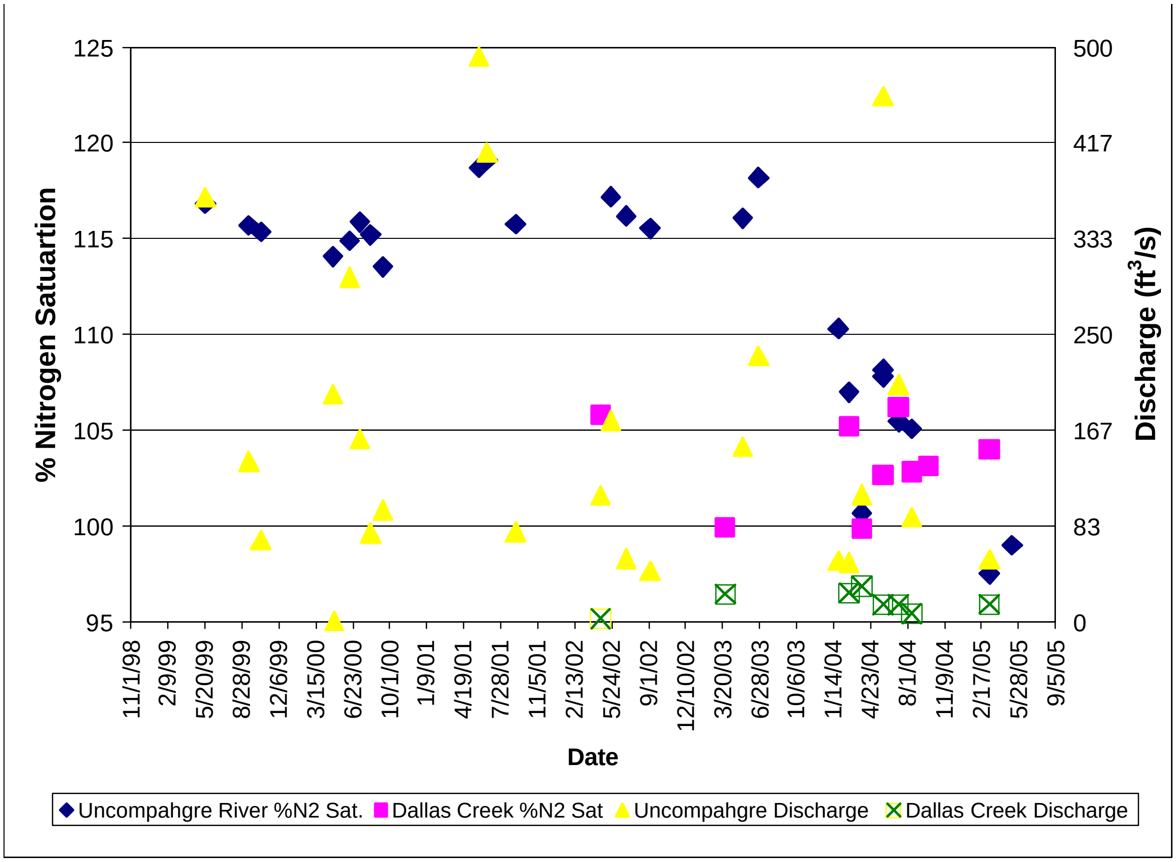

Figure 17. - Shown are dissolved gas measurements upstream from the reservoir on the Uncompahgre River and Dallas Creek with the corresponding flow volumes for the 1998 – 2005 seasons.

Reservoir Gas Monitoring

Investigating the inflows and outflows helped determine whether the lake is refreshing or the flow could become stagnant and anaerobic. The reservoir is 3.2 miles long and during the runoff season should have a fairly quick transfer of inflows to the intake at the dam. During small inflows and outflows the time for flows to travel through the lake will be maximized and water could become stagnant. The previous report [1] showed profiles of percent nitrogen saturation from the inflow location to the dam in June of 2003. The resulting discussion recommended gathering more data near the dam and the intake structure for releases to attempt to determine if the reservoir water quality could be contributing to the problem downstream.

First of all, there have been no complaints of GBT in fishes taken from the reservoir, which would suggest that reservoir water quality is good. Fish can stay at depth to hydrostatically compensate. In addition, a past study, prior to construction of the reservoir was performed by Craft [4] to investigate the potential problem of heavy metals in the inflows to the reservoir and how flow would move through the lake. Craft found that outflows containing the peak amount of nitrates seemed to lag inflows by about 1 month during the runoff season. Craft also observed that stratification and DO depletion at depth was unlikely during the summer months, but could possibly develop during the times of lower inflows and releases as the water would remain in the hypolimnion for longer periods of time. There was also evidence of the flows diving to the bottom of the reservoir and following along the old river channel, thus replacing water at depth. The investigations by Craft, however, indicated that the lake was oligotrophic with a low volume of plant nutrients that would contribute to reduction of DO or production of N_2.

The inflow and reservoir percent nitrogen data gathered for the 2003 and 2004 seasons are shown in figure 18. The inflow data is for the Uncompahgre River. The reservoir data were taken at the dam near the intake structure. The intake structure withdraws from the reservoir at El. 6741. The inflow dissolved gas levels are also shown as vertical lines for the same recording period.

The reservoir profiles show less gas near the surface and higher values near the bottom, as expected, due to surface turbulence. There appears to be a mixing zone where gas levels increase to a higher value near the bottom of the reservoir and the location of the bypass and outlet works intake. The inflow dissolved nitrogen levels do match some of the reservoir values near the bottom, except those in late June 2003 and the March 2004 data. If these data matched then it would be possible to state that the inflows were passing through the reservoir without being influenced by other parameters. The data still show quite a bit of scatter and no specific trend in the data near the bottom of the reservoir, but an expected baseline below 115 percent saturation would be expected.

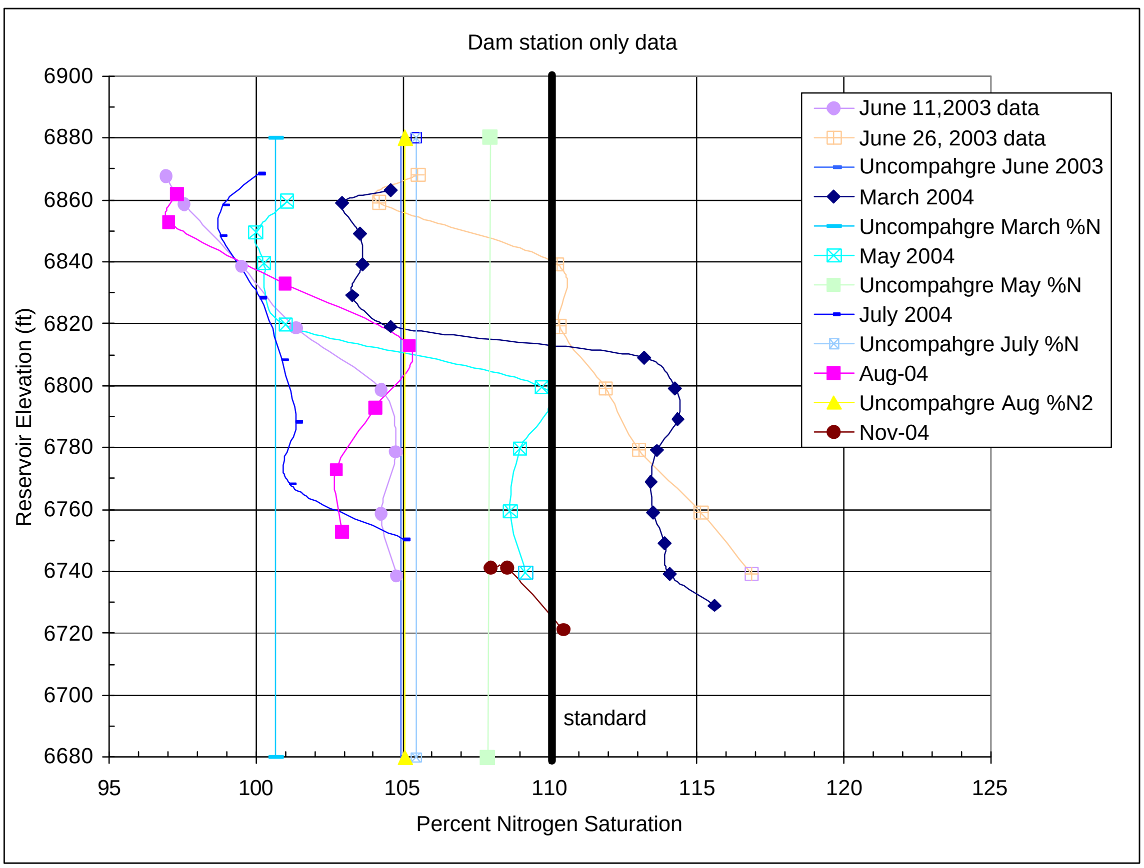

Figure 18.- Percent nitrogen saturation for 2004 in the reservoir near the dam at the location of the intake for the outlet works and bypass releases.

In addition to the data shown in figure 18, data were also gathered at two other stations progressively farther upstream by about 1000 ft each. These data consistently showed decreasing nitrogen levels towards the dam. This trend is probably due to the withdrawal of flow at the dam and that freshening of the lake is occurring.

The problem with obtaining accurate data is probably the capability of the meter to accurately measure at depths up to 150 ft. The tubing forming the membrane on the meter is usually not reliable at depths below specified by the manufacturer due to collapse of the tubing caused by hydrostatic pressure. The depth is usually about 100 ft or so. Therefore, some readings might be attained by waiting a very long time for the collapsed tubing to let gas in, but more than likely the readings are not valid at depth. The membrane on the meter will take a long to reach equilibrium under the head of the reservoir. Only the November 2004 data near the dam were taken after a significant about of time. November reservoir gas readings were taken after the instrument was settled out for intervals of 0, 30, 60 minutes with a 2 percent reduction in the gas reading after the hour settling time. The reading after letting the meter settle out for an hour was 108% and within the water quality standard.

Figure 19 shows the measured dissolved oxygen levels in mg/l in the reservoir at the dam near the intake. The dissolved oxygen content is very constant with depth, if these measurements are considered accurate. The computational modeling performed in 1978 [5] suggested that the reservoir would be somewhat stratified with respect to oxygen in the summer months and de-stratified or more uniform with depth over the fall and winter. The measured DO shows almost constant values with depth throughout the year with some decrease in DO in the summer months, indicating some seasonal variation, but the data, in general, shows the lake has turned over and is not stratified. No excessively low DO values that would cause water quality problems were measured.

The most recent data on the incoming gas levels, the acceptable DO levels, and the unknown ability of the instruments to measure at reservoir depth, leads to the conclusion that the reservoir gas levels should be within standard most of the time and are not the major contributing factor to the high downstream levels.

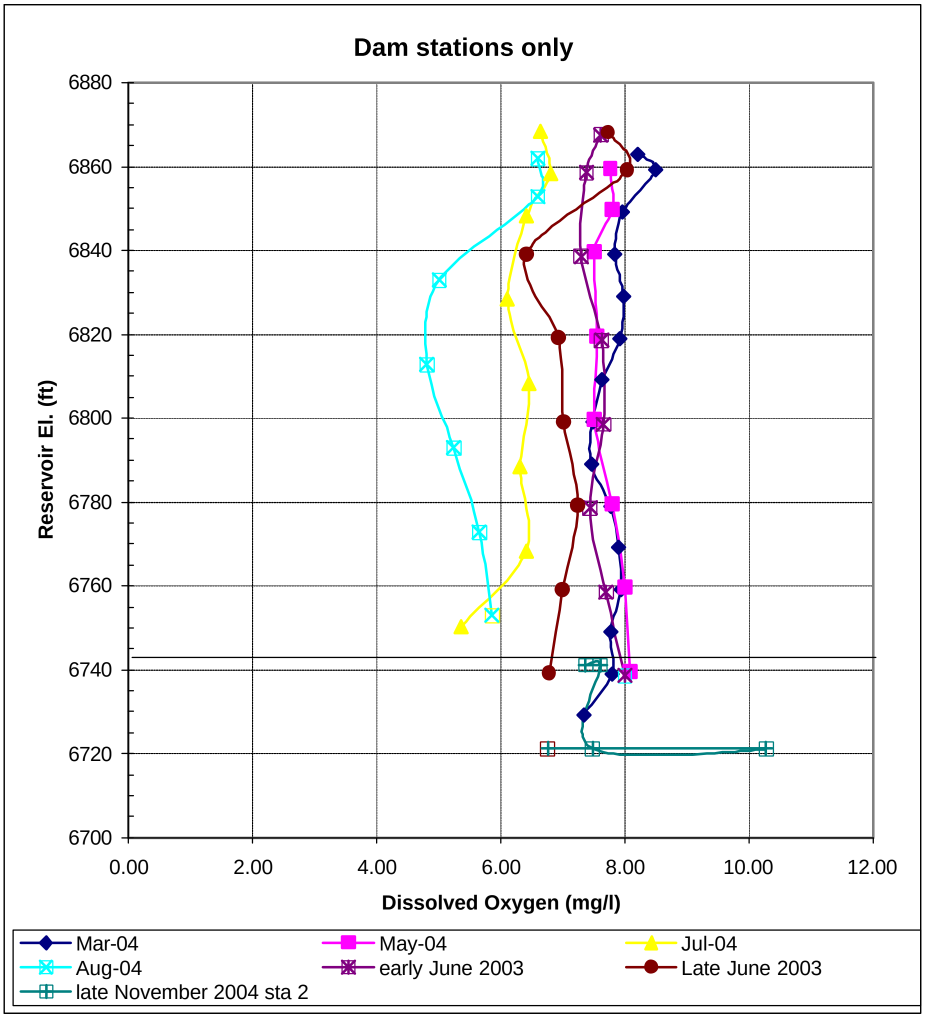

Figure 19. - Dissolved oxygen concentration in the reservoir near the dam for the period of time that data were gathered in June 2003 until November 2004.

Gas Monitoring Instrumentation Recommendations

The existing hand-held YSI oxygen meter and Sweeney total dissolved gas meter have provided adequate results over the years. Both instruments require knowledge of their use and adequate calibration to obtain accurate results. The Sweeney gas meter, in particular, could be problematic as the company that sold the meter is now out of business and the meter cannot be serviced. However, no further monitoring is needed on this project at this time so there is no immediate need to purchase additional equipment. The information attached in appendix A is for reference only and as a place to start should additional hand-held monitors or a fixed monitor be needed. It is recommended that Alpha Designs be contacted as it appears that other major Reclamation sites are being upgraded to this equipment and support would be readily available. Any unit used should include an accurate internal barometer or one should be installed at the dam tender's office. The YSI DO meters are still industry standard if the project's oxygen meter is in need of replacement.

The results from performing the river cross-section gas investigations also would allow selection of a location for a fixed monitor at a later date, if so desired.

Alpha Designs

Sharon Churchill with Reclamation's Ephrata Office is replacing Common Sensing fixed monitoring stations with those from Alpha Designs. They are serviced by Columbia Basin Environmental. The representative is Terry Kirkbride and he is working with Sharon to develop exactly the type of equipment that she wants.

The Tensionometer 300E is $1829US. The T507 is $2595US. The 300E is a meter used for spot measurements while the T507 is intended for monitoring over long periods. I have sent a version of the T507 to a customer who is using it with a Palm Pilot to record measurements. This may also be of interest. All prices are based upon an inquiry in late 2004 and are not guaranteed. The company representative is:

Terry Kirkbride, VP	Internet: tk@alphaDesigns.com
Alpha Designs Ltd.	Toll free: 1-877-565-1192
1034 St.David Street	Phone: 250-595-5051
Victoria, BC, V8S 4Y8	Fax: 250-595-2245
CANADA	

Point Four Systems

The PT4 is the fixed monitor for Point Four Systems and was estimated at $5750 including installation. The full quotation and specification sheets are in Appendix A. The company representative is:

Walter Volberg	Internet: www.pointfour.com
Point Four Systems	sales@pointfour.com
100-13720 Mayfield Place	Toll free: 1-800-267-9936
Richmond, BC V6V 2E4	Phone: 604-273-9939
CANADA	Fax: 604-273-9937

Conceptual Gas Stripping Rock Drop

Both the outlet works and bypass structures release or produce supersaturated water. The gas levels abate as the water flows downstream, but gas levels are usually out of compliance near the dam. One of the outcomes of this research project was to determine an appropriate gas abatement method for the river below the dam. Because flows from both the bypass and the outlet works produce gas, a structure that would abate both is needed. A simple, cost-effective structure to meet this requirement would be a rock drop that would create enough turbulence to strip gas. Therefore, a conceptual design of a rock drop to strip gas is presented here. This structure would operate under flows from either structure and span the entire river below the dam. The principle behind the rock drop is to form a small dam across the river. Flow over the dam would be shallow and the rocks forming the dam would create turbulence that would strip gas from the flow. The dam would be wide and flow would be shallow, still allowing fish passage. The end of the drop would be an apron that limits the flow from plunging to depths that could cause regassing.

The criteria for citing the drop were chosen from existing flow and gas records and from a topographic survey of the river for a short section below the dam. The goal chosen for the design was to lower the gas levels from the potential of 125 to 110 percent for a discharge range from 35 to 400 ft^3/s. It was felt that this discharge range would adequately cover the average low flow through the bypass and the irrigation seasonal mean flow. The river topography was surveyed on March 28, 2005 by the Grand Junction Area Office personnel from the USGS station to about 1250 ft downstream. Figures 20 and 21 show the plan and profile of the contours along a proposed river centerline. The average flow for the day during the survey was obtained from the USGS website as 247 ft^3/s. The topography was used to find the slope and general width of the river within the area where the structure could potentially be placed. A reasonable design width for the rock drop would be 100 ft from review of the survey data. Therefore, the design unit discharge was 4 $ft^3/s/ft$. The temperature ranges from about 4 to 13°C from the winter to the summer. Because more gas can be held at a colder temperature than a warmer one, the analysis was perform using 4°C to be conservative. Perry L. Johnson was contracted to perform this conceptual design.

The equation for gas transfer is:

$$C(t) = C_s + (C_i - C_s)e^{-Kt}$$

Where C (t) is the gas concentration created by the flow in mg/l (110%XC_s in this case)
C_s is the gas concentration adjusted for temperature and barometric pressure in mg/l at 760 mmHg
C_i is the gas concentration of the initial condition in mg/l (125%XC_s in this case)
K is the gas transfer coefficient
T is the length of time gas is transferred in seconds

The important portion of this equation is the definition of the gas transfer coefficient, K. The coefficient was computed using a reference by the Tennessee Valley Authority [6] and selecting the following equation:

$$K = 2.075V^{1.111} / \left(R^{1.972} f^{0.45}\right)$$

Where V is the mean velocity, R is the mean depth, and f is the resistance coefficient defined by:

$$f = \left(\sqrt{8gRS} \big/ V\right)^2$$

Where S is the energy slope.

The mean depth, R, was assumed to be equal to critical depth, computed to be 0.8 ft. Critical depth and unit discharge were then used to compute the mean velocity, V. An energy slope of 0.5 ft was then assumed and used to determine the resistive coefficient, f. With the resistive coefficient determined, the gas transfer coefficient, K, was determined to be 14.1.

The gas transfer equation is then used to determine the time needed to strip gas from the maximum assumed level of 125 percent saturation down to the target 110 percent. Using Colt [7], C_s for nitrogen at sea level at 4°C = 20.8 mg/l and adjusting for the elevation at Ridgway would give C_s= 16.3 mg/l. Solving the gas transfer equation for time gives t= 0.065 s. The drop or length of the stripping structure is then determined by L= Vxt = 0.33 ft. A brief sensitivity analysis was performed by varying the energy slope and the gas transfer coefficient and resulted in a similar result.

This is a very small drop or length of structure required to perform the gas stripping necessary to bring supersaturated gas down from 125 to 110%. Therefore, the again be conservative a drop of about 1 ft would be recommended for the river below Ridgway Dam to assist with reducing nitrogen supersaturation. This would mean a drop of 1.8 ft from upstream to downstream water surfaces.

The drop should be placed as close to the stilling basin and bypass as possible to obtain the maximum benefit for the fishery below. If possible the drop should be constructed on Reclamation property below the dam that ends at the fence line shown on the river survey. The drop needs to be constructed of rock or other roughness elements that are large enough to create turbulence or white water. The depth of 0.8 ft is relatively small but this flow depth needs to experience a uniform roughness that will not concentrate the flow. The drop could be incorporated into one of the existing Rosgen habitat improvement structures if desired by damming the flow with sheet pile then filling with rock of about an average diameter or D_{50} of ½ ft. Larger roughness elements, similar to a D_{100} equal to twice the critical depth, embedded by ½ or 2/3 their size would then create additional roughness. The end of the drop must be a flattened apron to prevent replunging of the flow to a depth larger than 2 ft.

The Rosgen structures with the singular large rocks concentrate flow in between the rocks that can then plunge to depth in downstream holes. The large holes that are desirable for fish are not wanted below this structure because of potential to increase dissolved gas concentration.

Another way to create the drop, since it is relatively small, might be to prefabricate a structure and install it in the river.

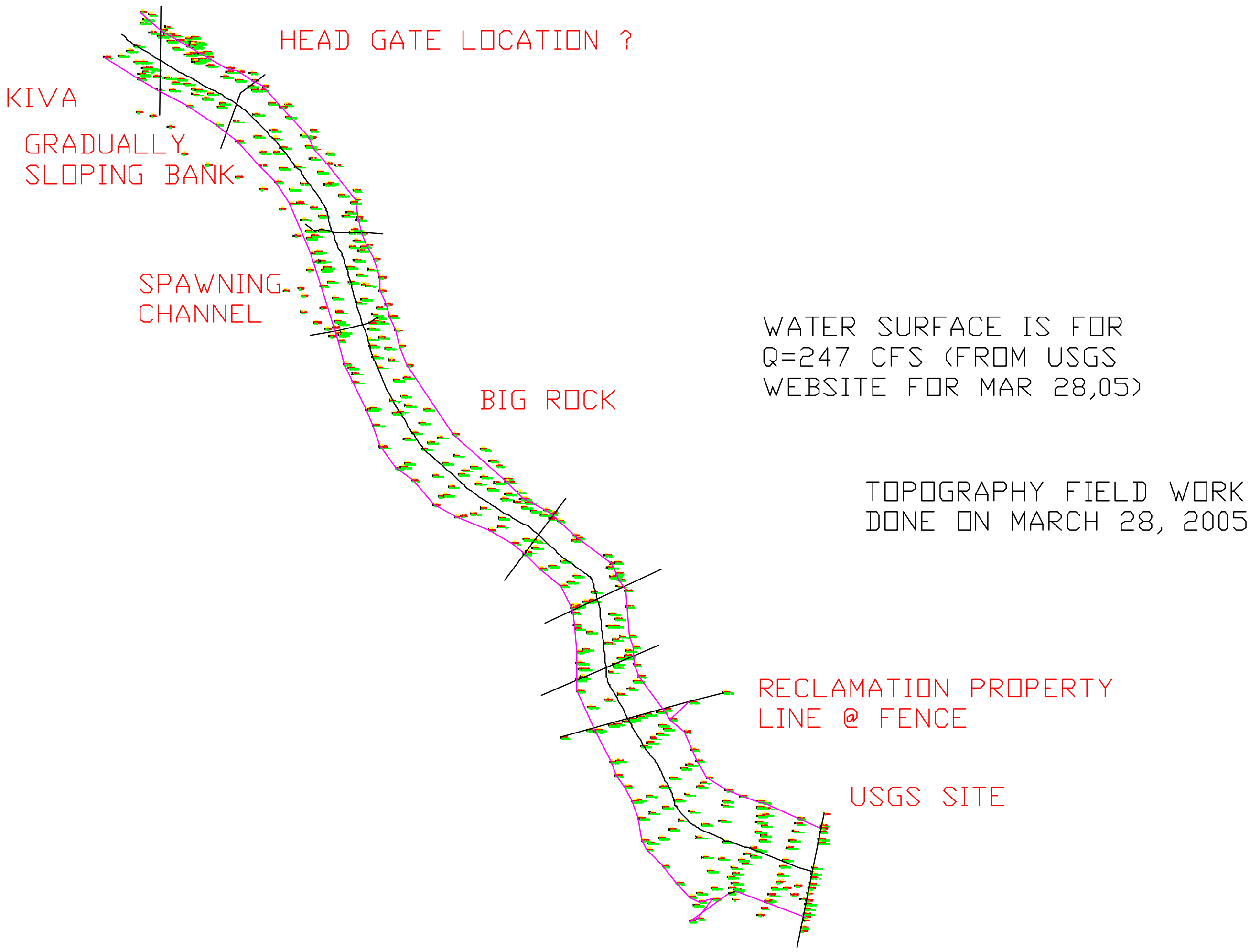

Figure 20. - Plan view of the contours mapped below Ridgway dam. The centerline was added based upon the bank locations. The lines drawn across the river are approximate locations of existing habitat structures based upon the aerial photograph that accompanied the contours.

Further Investigations

The design is conceptual and would need further refinement prior to construction. In addition, the data regarding the water surface at other flow rates and tailwater depths is needed. Backwater could form near the dam that would influence the outlet and bypass releases. Hydraulic behavior of the structure under large flow events could be critical. The design assumptions regarding acceptable nitrogen levels, structure width, and operating flow range need verifying by the agencies concerned with the project. In addition, the fish passage potential, or lack thereof, should be investigated or discussed. If the structure is located close to the dam, then the structure need only provide downstream passage of fish. If the structure is located down river then perhaps upstream and downstream passage may be an issue. The conceptual design can be used to discuss the pros and cons of such a system and to get some idea of the potential cost to construct.

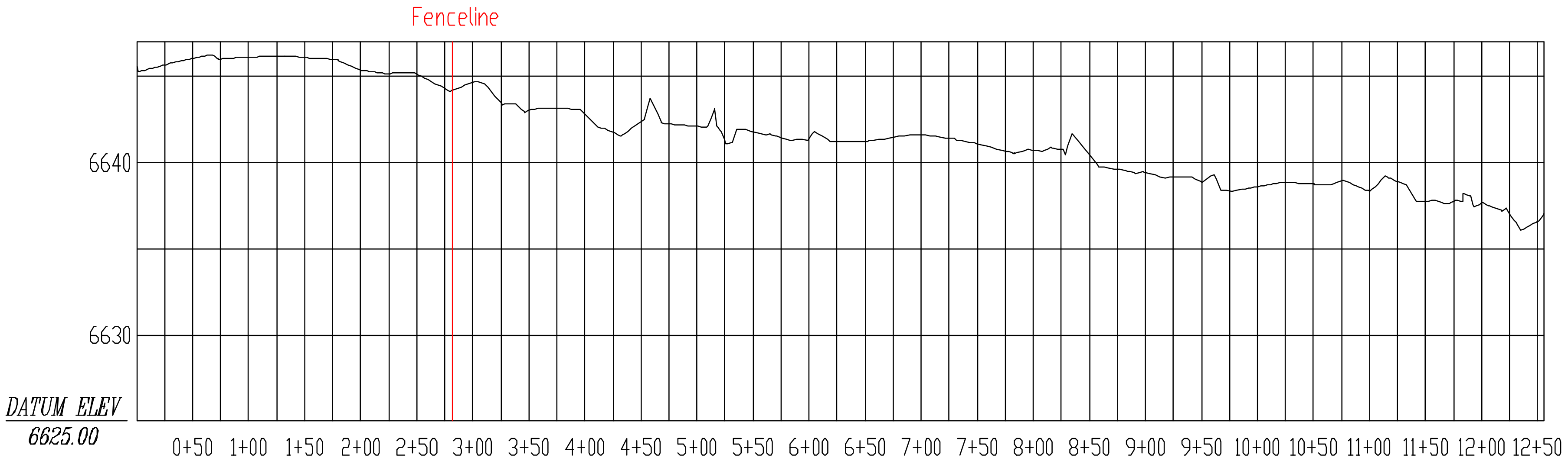

Figure 21. - Profile of the river survey from the USGS station down to about the Kiva measurement station. The x-axis is stationing starting with 0+00 at the USGS site for reference. The y axis is elevation with a datum elevation of 6625 ft. The fence line indicates the downstream location of Reclamation property.

Fish Survey Results

Background

In 2003, fish were sampled from the tailrace of the dam downstream to just above the confluence with Cow Creek. This effort provided a population estimate and information on general condition of fish, but did not provide trend data with regard to GBT based on varied flow and exposure or GBT in relation to long term longitudinal distribution [1]. Therefore, additional surveys in 2004 and 2005 were needed to gather data pertinent to these issues.

2004 Fish Surveys

Two trips, in March and September, were made to survey the fishery below Ridgway Reservoir in 2004. No population estimates are available for 2004; however, electrofishing efforts were similar to that in 2003 (e.g. from the bypass to an area of the river that is below the north campground of the State Park and just above the confluence with Cow Creek). Flows in the Uncompahgre River were lowered to 30-35 ft^3/s through the outlet works bypass for both sampling efforts. Fish were shocked, collected and revived, measured (total length, mm), weighed (g), examined, and graded for signs of external GBT. GBT severity was ranked 1-4, with 4 being the most severe condition. Figures 22 and 23 show examples of fish sampled with GBT and an essentially healthy fish. The fish were then released back into the section of river where they were collected. March and September fish sampling began at the most downstream site and finished at the bypass near the dam. Distance between fish sampling areas was believed to be adequate to prevent re-sampling of fish.

Figure 22. - Rainbow trout with severe GBT visible on opercula. White lesions are scar-tissue associated with GBT.

Figure 23. -Healthy brown trout with a small lesion on opercula.

March 2004 Survey

The March survey was intended to be completed prior to ramping up flows associated with irrigation demands; however, reservoir drawdown began earlier than anticipated due to higher than normal runoff expectation. For example, discharge in the Uncompahgre on March 30th (the day before the survey) was 45 ft^3/s. Overnight the river flow increased to 130 ft^3/s, and was dropped the next morning to 35 ft^3/s to facilitate sampling. These flow changes could effect the resulting fish distribution, but there was no way to know. All releases were made through the outlet works or the bypass, not the spillway. Gas readings were taken in the stagnant channel below the spillway stilling basin, though no fish sampling occurred there.

Three backpack shockers were used to collect fish. Two individuals with nets trailed each electrofishing operator. Netted fish were collected into a floating, perforated collection box. Attempts were made to standardize voltage and shocking durations for consistent sampling effort per pass. In each location, the sampling crew began downstream in the river and worked up to an established end-point. For example, at the USGS site, the sampling crew began downstream of the gage, at an established GPS coordinate and worked upstream, netting fish until coming parallel to or just above the gage.

Table 5 shows that in the March sampling 161 fish were collected representing 6 species. Of these, 34 fish, representing 5 species exhibited external GBT. Proportionally, brown trout had the highest incidence of GBT, and sculpins showed the lowest.

Table 5. - Annotated data (capture, length means, and GBT exposure) for all species collected on the Uncompahgre River (tailrace to Cow Creek) during the March 2004 – September 2005 electrofishing effort.

	Species	*Capture*	*Total length Range (mm)*	*Mean length (mm)*	*GBT capture*	*GBT Total length range (mm)*	*GBT mean length (mm)*	*Percent GBT occurrence*
Mar-04	Rainbow trout- *Onchorhynchus mykiss*	44	82-490	229	12	112-490	248	27
	Brown trout- *Salmo trutta*	40	70-471	95	14	70-471	282	35
	Mottled sculpin- *Cottus bairdi*	65	41-110	85	6	82-95	90	9
	Cutthroat trout- *Onchorhynchus clarki* ssp.	7	321-436	377	1	412	N/A	14
	Yellow perch- *Perca flavescens*	4	77-118	91	1	83	N/A	25
	White sucker- *Catostomus commersonii*	1	170	N/A	0			
	March 2004 Totals	**161**			**34**			
Sep-04	Rainbow trout- *Onchorhynchus mykiss*	27	176-387	270	6	205-387	288	22
	Brown trout- *Salmo trutta*	30	116-442	251	3	228-408	294	10
	Mottled sculpin- *Cottus bairdi*	24	57-110	92	1	103	N/A	4
	Cutthroat trout- *Onchorhynchus clarki* ssp.	12	279-424	332	1	424	N/A	8
	White sucker- *Catostomus commersonii*	1	241	N/A	0			
	September 2004 Totals	**94**			**11**			
Mar-05	Rainbow trout- *Onchorhynchus mykiss*	33	110-377	257	3	212-255	236	9
	Brown trout- *Salmo trutta*	128	312-495	383	18	126-487	296	14
	Mottled sculpin- *Cottus Bairdi*	113	Pass 1* : 70-132	98	1	132	N/A	1
	Cutthroat trout- *Onchorhynchus clarki* ssp.	5	312-495	383	1	495	N/A	20
	Bluehead Sucker- *Catostomus discobolus*	1	281	N/A	0			
	March 2005 Totals	**280**			**23**			

*Sculpin morphometric data tabulated from pass 1

Figure 24 shows decreasing GBT manifestations and nitrogen saturation with increasing distance downstream from the bypass release. The GBT values given are grouped by site not species. For example, 28 fish were sampled at the USGS site, and 11 or 39 percent, showed external GBT. Gas bubble trauma severity, with the highest severity being greater than three-quarters coverage of a fish's body and fins, also declined downstream. Actual fish survey data are shown for March 2004 in Appendix B.

The fish survey data is indicative of a snapshot of the nitrogen saturation at the time the fish were sampled, whereas the GBT could be a function of the cumulative effect of months of exposure. There is not really any way to identify if that might be the case for the March sampling, but it is assumed that these fish over-wintered in the river.

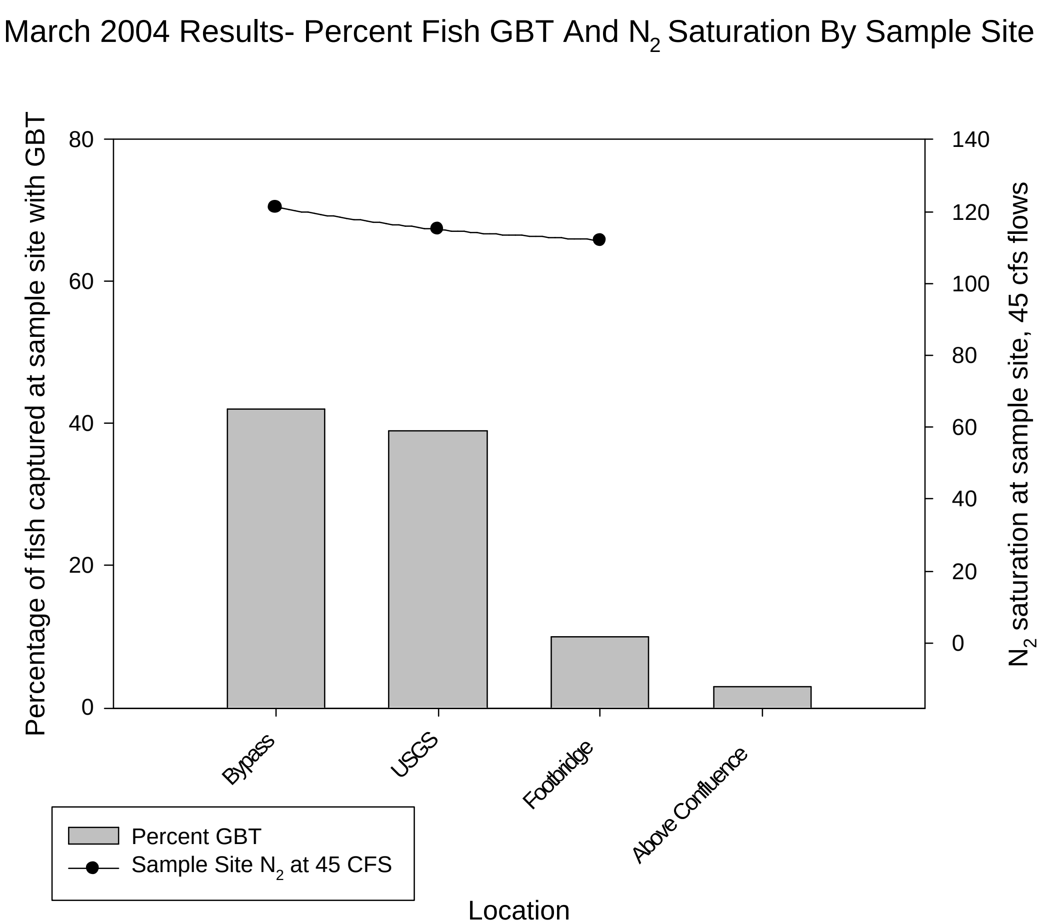

Figure 24. - March 2004 GBT and nitrogen saturation trends by site.

September 2004 Survey

Gas measurements were again taken in the Uncompahgre River from the tailrace to an area of the river that is below the north campground of the State Park and just above the confluence with Cow Creek. Gas measurements were taken with the outlet works (not the bypass) operating at 100 ft^3/s, but flows were dropped to 30 ft^3/s, and released through the bypass, to facilitate sampling on the same day. Sampling effort, methodologies, and locations were similar to those in March 2004, except that a site slightly below the USGS site was shocked (e.g. Big Rock site upstream to the spawning channel headgate), because maintenance was being performed on the USGS gage. Also, no gas data was collected in the channel below the spillway stilling basin.

Table 5 shows there were 94 fish collected representing 5 species. Of these, 11 fish, representing 4 species, exhibited external GBT. Proportionally, rainbow trout had the highest incidence of GBT, and sculpins showed the lowest.

Figure 25 shows decreasing GBT manifestations with increasing distance downstream from the dam. The GBT values shown are grouped by site not species. This same general trend is also seen with nitrogen saturation. However, the March and September flow volumes and structure making the releases was different, with the smaller March release using the bypass and the higher September release using the outlet works. Severity of GBT for all fish sampled in September was low with all fish that had GBT having less than 25 percent coverage of their bodies and fins. Actual fish survey data are shown in Appendix C for September 2004.

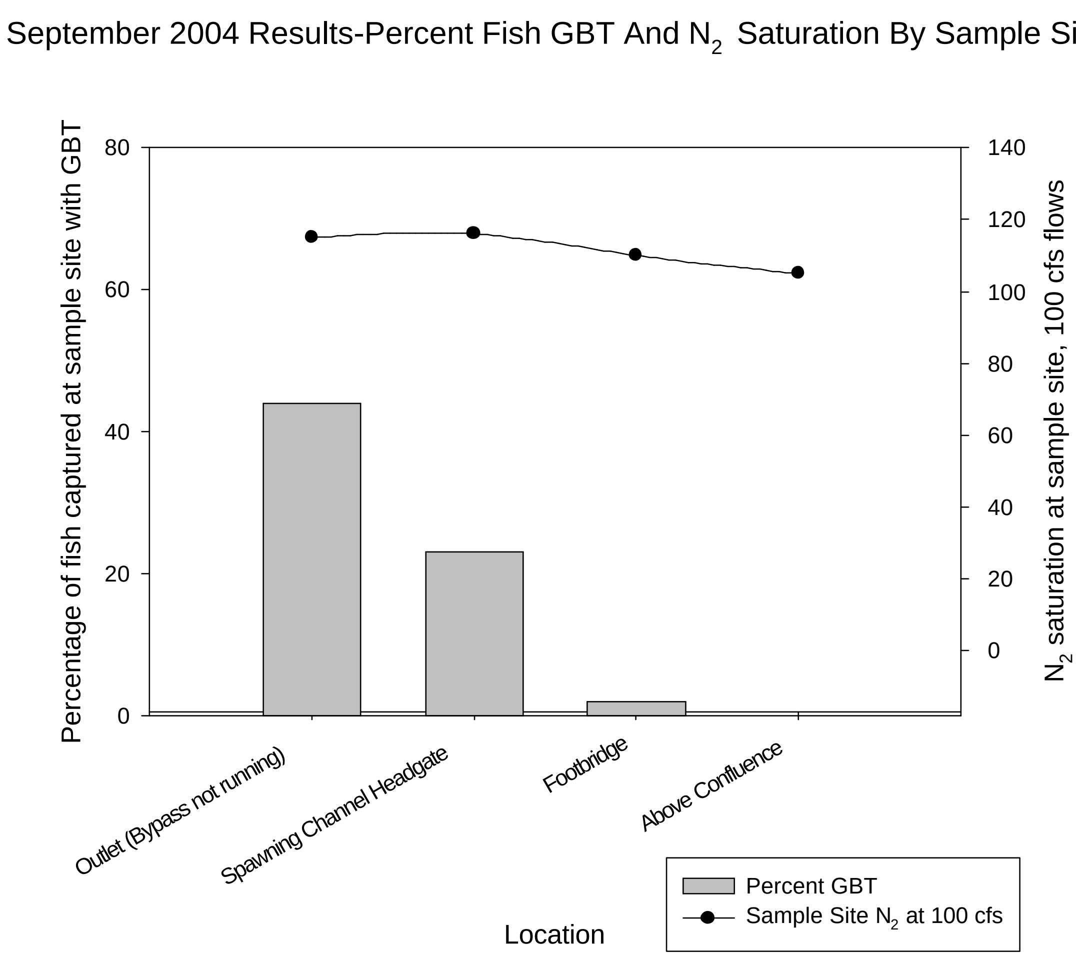

Figure 25. - September 2004 GBT and nitrogen saturation trends by site.

Note- Fish sampling did not occur at the Above Confluence site in September 2004. The site is given to illustrate gas trend data.

2005 Fish Survey

The March 2005 fish survey was performed in several reaches of the river, though not all reaches that were sampled in 2003 and 2004. Sampling methodologies were similar to previous years; however, a bank electrofishing unit was employed at the Footbridge site. Bypass flow was lowered to 30 ft^3/s during the sampling period. Fish were shocked, collected and revived, measured (total length, mm), weighed (g), examined for signs of external GBT, then released back into the section of river where they were collected. A population estimate was also incorporated into the sampling effort and provided a comparison to the 2003 estimate. One pass sampling occurred from the USGS gage to the bypass release at the dam, and from Big Rock to the spawning channel headgate. A two-pass depletion population estimate was performed from just below to just above the Footbridge location. The population estimate sampling occurred first, followed by sampling from Big Rock to the spawning channel headgate, and then the USGS gage to the bypass structure near the toe of the dam.

March 2005

Gas measurements were taken in the Uncompahgre River from the tailrace to an area of the river that is below the north campground of the State Park and just above the confluence with Cow Creek. Bypass flows were 45 ft^3/s during gas measurements, but flows were dropped to 30 ft^3/s to facilitate fish sampling on March 16th. In addition, river flows had already be increased to 300 ft^3/s to provide for irrigation requests downstream that could have a residual effect on the location and condition of the fish.

Table 5 shows there were 280 fish collected representing 5 species. Of these, 23 fish, representing 4 species, exhibited external GBT. Proportionally, brown trout had the highest incidence of GBT, and sculpins showed the lowest.

Figure 26 shows decreasing GBT manifestations with increasing distance downstream from the bypass. The GBT values shown are grouped by site, not species. This is also the general trend with nitrogen saturation. Severity of GBT also declined downstream, with only 1 fish in the reach by the headgate exhibiting high severity. Actual fish survey data are shown for March 2005 in Appendix D.

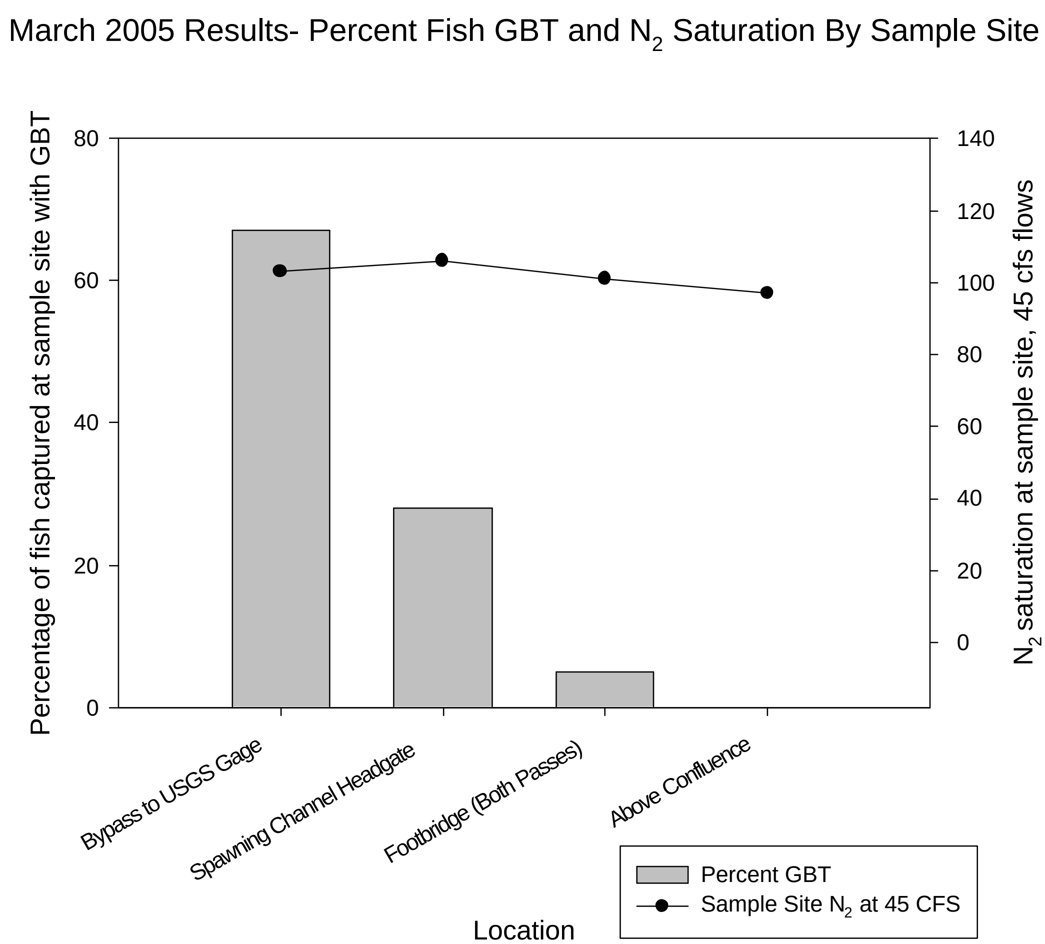

Figure 26. - September 2004 GBT and nitrogen saturation trends by site.

Note- Fish sampling did not occur at the Above Confluence site in March 2005. The site is given to illustrate gas trend data.

Case Study: Population Estimates - Year 2003 versus 2005

The question "How do fish populations in the Uncompahgre River below Ridgway Dam respond to fluctuating levels of saturation?" is complicated by stocking, angling, highly variable annual flow, operational constraints, and natural fish emigration / immigration. However, population estimates offer some insight regarding long-term population trends that can be referenced to gas and GBT data collected.

Population estimate data for this report were provided by Dan Kowolski, CDOW Fisheries Biologist, Montrose office. The results are based on a two-pass depletion estimate conducted in the immediate vicinity of the footbridge site in 2003 and 2005. Two pass depletions are used in situations where streams are small, expediency is important, and the population sampled is relatively small. The effort requires that an adequate number of fish are removed on the first sampling pass so that measurably fewer fish are available for capture and removal on a subsequent pass. Population (by species) estimates and the variance associated with the estimates are calculated.

Figure 27 shows the population fluctuations between the two most common salmonids in the sampled sections of the Uncompahgre River during 2003 and 2005. Nitrogen saturation levels are provided as a reference, and indicate a 3 percent difference in nitrogen levels for roughly the same period of time leading up to the sampling effort. For 2003, nitrogen readings from 01/09/03 and 02/12/03 were averaged to provide the average March nitrogen levels, and the 03/10/05 reading was used to provide the March 2005 nitrogen level. The two species appear to respond differently not only to different nitrogen supersaturation levels, but also to effects of GBT, figure.28. Brown trout abundance apparently increased even under the deleterious effects of increased saturation levels and higher ambient GBT infection, whereas rainbow trout abundance declined.

This example illustrates the difficulty of drawing concrete conclusions about the effects of supersaturation and GBT on fish populations in an open, infrequently sampled system. Especially when stocking rates, angling pressure and other variables are considered. True population effects could be determined on resident fish only if stocking was reduced for a season.

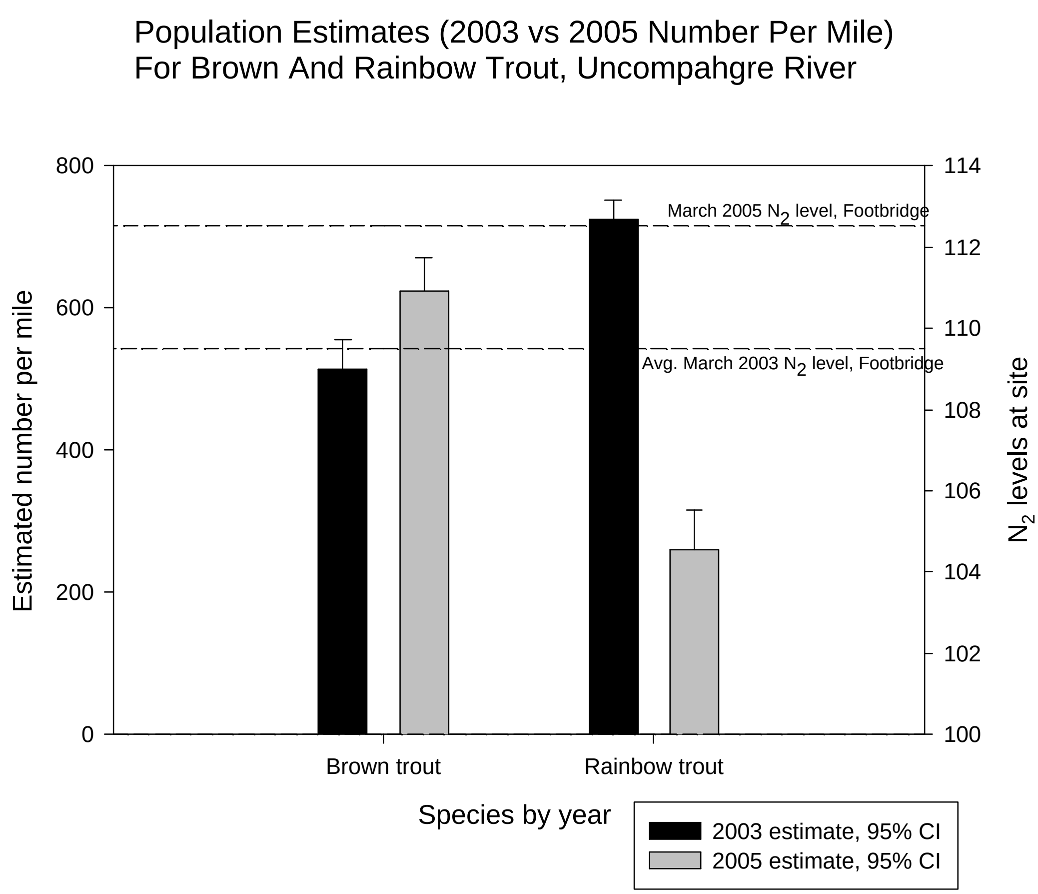

Figure 27. - Colorado Division of Wildlife population estimate with nitrogen gas levels referenced. Estimate represents fish per river mile, error bars are for a 95% confidence interval.

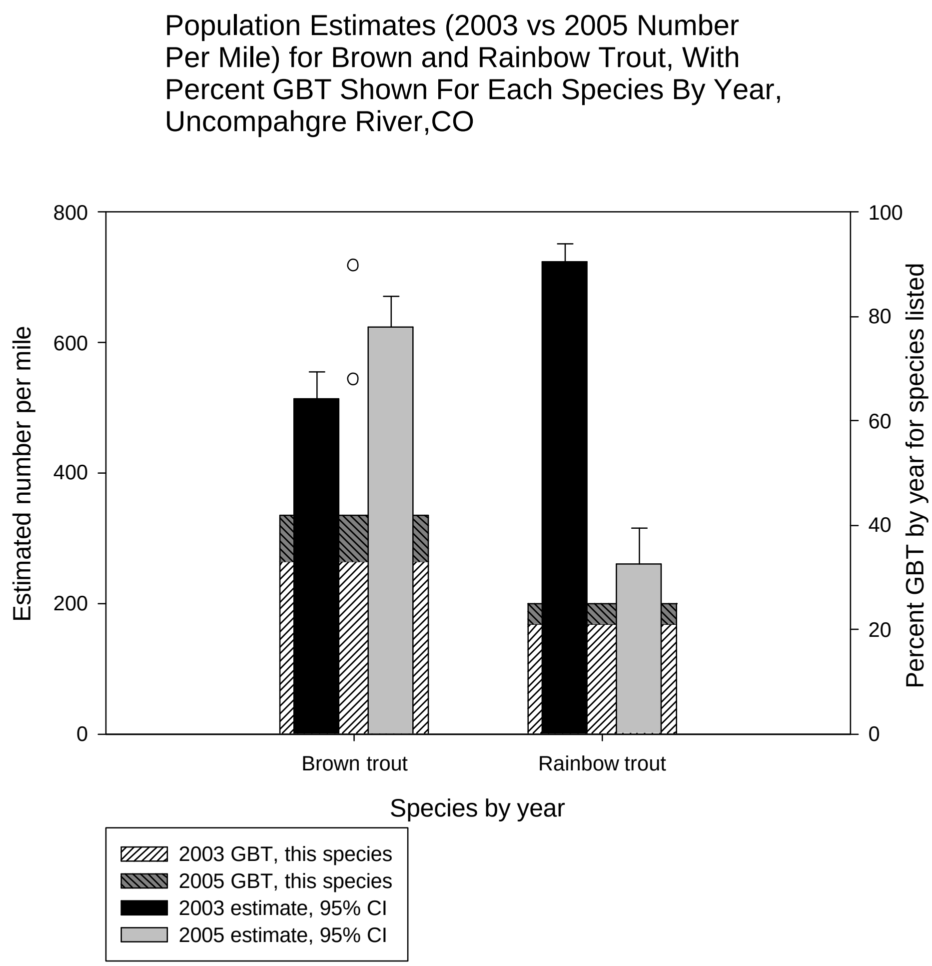

Figure 28. - Colorado Division of Wildlife population estimate with annual percent GBT shown as a stacked bar. Estimate represents fish per river mile, error bars are for a 95% confidence interval.

Summary

Recently measured reservoir inflow gas levels do not indicate that the inflow gas levels are excessively high. Inflows and outflows from the dam are great enough to refresh the lake and prevent anaerobic conditions that would affect the water quality. There is no consistent data to conclude that the reservoir is causing the problem by increasing gas levels due to a chemical or other environmental occurrence. Dissolved gas levels below Ridgway Dam on the Uncompahgre River are a result of the releases from the dam. The levels are high nearest the dam and decrease downstream.

Gas bubble trauma is present in the Uncompahgre River below Ridgway Dam. Fish surveys have indicated that the incidence of GBT is higher at the dam and decreases downstream. In addition, the severity is higher at the dam and decreases downstream.

If deemed necessary by the project, gas levels and resulting gas bubble trauma could be abated. The gas abatement structure recommended is a conceptual design only. The parameters of the structure and its expected performance may be used in discussions with CDOW, the State Park personnel, or other interested parties if complaints about the condition of the fishery continue.

The project does not need to continue gas or fish monitoring at this time. If operations change or if a gas abatement structure is installed, then hourly gas monitoring and frequent fish surveys should be performed to determine the effects of the structure on the water quality and fish habitat.

References

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2. Geldert, D.A., J.S. Gulliver, "Dissolved Gas Measurement Uncertainty," Proceedings of the 11th Seminar Water Quality '96, U.S. Army Corps of Engineers Waterways Experiment Station, Seattle, WA, pp. 234-239.

3. Johnson, Perry L., "Prediction of Dissolved Gas at Hydraulic Structures", GR-8-75, US Department of Interior, Bureau of Reclamation, Denver, Colorado, July 1975.

4. Craft, Doug, and Miller, Jerry, "Reservoir Sediment-Water Microcosm Simulation: Pre-Impoundment Predictions vs. Observed Water Quality at Ridgway Reservoir, Ridgway, Colorado", US Department of Interior, Bureau of Reclamation, Denver Colorado, September 2001.

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6. Churchill, M.A., Buckingham, R.A., and Elmore, H. L., "The Prediction of Stream Reaeration Rates", Tennessee Valley Authority, Division of Health and Safety, Environmental Hygiene Branch, Chattanooga, Tennessee, July 1962.

7. Colt, John, "Computation of Dissolved Gas concentrations in Water as Functions of Temperature, Salinity, and Pressure", American Fisheries Society Special Publication 14, Bethesda, Maryland, 1984.

Appendix A

Gas Monitoring Instrumentation

Alpha Designs

T507 Tensionometer Probe

Total Dissolved Gas and Temperature Transducer

FEATURES

- High Accuracy
- Low Power
- Measures P_t and Temperature Directly
- Calibrated and Temperature Compensated
- Wide supply voltage
- Digital RS-232 Output
- Analog High-Level Voltage Output
- Field Interchangeable Membrane Cartridges
- Field Interchangeable Probe

APPLICATIONS

- Water and Wastewater Management
- EPA Compliance
- Hydrology Research
- Aquaculture Research

GENERAL DESCRIPTION

The model T507 Tensionometer Probes are submersible total dissolved gas pressure/temperature transducers intended to monitor total dissolved gas pressures and temperatures in a variety of natural waters. The probe utilizes a gas permeable membrane tube which is permeable to all gases including water vapor. As such, the probe measures Total Gas Pressure (TGP) directly. This type of analysis is commonly called the membrane diffusion method (MDM) and most closely models the behavior of fish gills.

The T507 utilizes digital signal processing techniques to provide a calibrated and temperature compensated high level analog voltage outputs which are directly proportional to the applied dissolved gas pressure and the temperature. A proprietary signal analysis method also enables the probe to respond to large changes in gas pressure within one minute. Precision electronics allow the probe to be powered from an unregulated 8.6 to 13.6 volt source without any effect on the probe's accuracy. The probe also features very low power consumption and is especially suitable for battery powered instruments and data loggers.

Maintenance of the T507 probe requires cleaning of the membrane tubing occasionally to remove bio-fouling. The bio-fouling affects only the response time of the probe, and not the calibration. Membrane cartridges may be easily replaced in the field. Changing the membrane has no effect on the calibration. Probes can be calibrated in the field without being disassembled.

PHYSICAL DIMENSIONS

Dimensions in Millimetres

T507 Tensionometer Probe - Total Dissolved Gas and Temperature Transducer

PHYSICAL SPECIFICATIONS

Media Compatibility The T507 series TENSIONOMETER Probe may be used in any natural water either fresh, brackish or saline.

Material Wettable components are: delrin, stainless steel, silicon rubber compounds, polyurethane. (these contain no toxic chemicals)

Weight n/d grams

Interconnect Connector/Cable Oceanographic grade underwater connector. Cable is 5.6 mm diameter, polyurethane jacket

Probe dimension 45 mm diameter, 310 mm length (does not include connector fitting in dimension)

ELECTRICAL SPECIFICATIONS

Settling time (electronics and sensor combined) 20 seconds

Supply Voltage (unregulated, for voltage output options)

Minimum	+8.6 VDC
Maximum	+13.6 VDC
Power consumption	7 mA (at all voltages)
Output impedance	<1Ω @ 3Hz
Cable DC resistance	0.098Ω/metre
Cable nominal impedance	<44Ω
Output voltage range	5.0VDC

PERFORMANCE SPECIFICATIONS

Accuracy TDG(L+H+R) (linearity + hysteresis + repeatability)	±0.07% of span, BFSL (best fit straight line)
Accuracy TEMP (-5°C to +50°C)	±0.10°C
Stability at rated accuracy	6 mo.
Response to step increase in pressure	5 minutes to within 5% of final value
Output resolution	1 : 65,536

FUNCTIONAL SPECIFICATIONS

Environmental

Temperature Limits

Storage	
without membrane attached	-40°C to +60°C
with membrane attached	-4°C to +60°C (non freezing)
Operating	-4°C to +45°C (non freezing)
Depth max	30 Metres
Internal humidity	0% to 100% RH non condensing
Vibration	10Gs RMS @ 20 to 2000Hz
Proof pressure	T507 3000 mm Hg

ORDERING INFORMATION

T507 □-□□-□□-□□□

Model
Transducer type
Output
Pressure range
Cable length (metres)

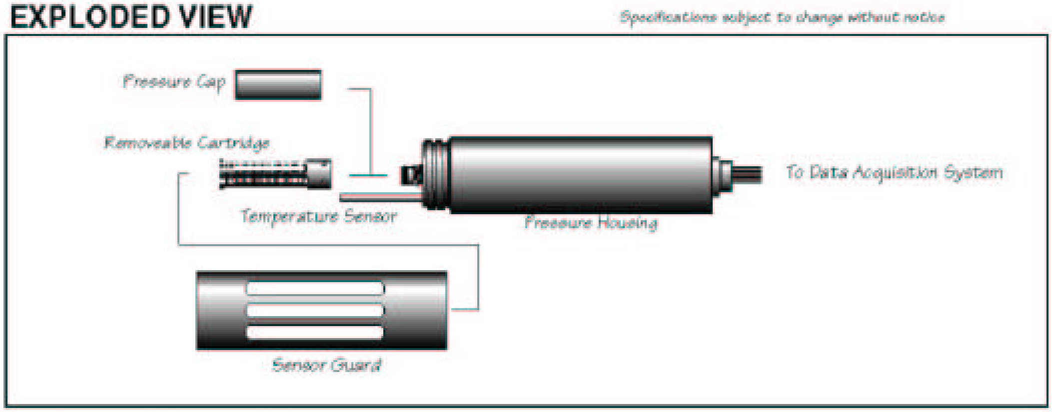
Transducer type
A = TGP (absolute)

Pressure range, (absolute)
01 = 400 to 1400mmHg

Output
02 = 0 to 5.0VDC

EXPLODED VIEW

Specifications subject to change without notice



 Printed in Canada

Point Four Systems

Point Four Systems Inc.

Oxygenation and Water Management

Quotation

To: Kath Frizell Ph 303.445.2144
US Bureau of Reclamation
PO Box 25007
Denver CO 80225

7 Sep 2004

From: Walter Volberg

Re: **PT4 Monitor**

- PT4 Monitor (5 channels activated) complete with OxyGuard Oxygen probe, Temperature sensor, Gas pressure sensor (psig) and Total Gas Pressure (TGP) sensor. Power supply with back up battery to reduce false alarms caused by momentary power outages. Adjustable set points with 5 channel relay output card and one Solenoid valve for oxygen injection. Lightning protection will be quoted separately as there are a number of options to discuss. PC software includes trending screens.

Quantity	Item	Unit	Extension
1	PT4 Monitor, c/w 1 ea, oxygen, Gas pressure, Temperature, and TGP sensor, all with 25' of sensor cables & daughter cards.	3,782.00	3,782.00
1	Extended Rose Jct. C/w 5 relay's	476.00	476.00
1	4-20 mA out-put card w 10' cable	40.80	40.80
1	120vac/12vdc 6 Amp Power Supply with Battery back up	122.40	122.40
1	PVC Mounting plate	75.00	75.00
1	PC Software program incl. 3' cable & RS485-RS232 conv.	1,250.00	1,250.00
1	Solenoid Valve for oxygen service with inline fittings & 10' calble	0.45	0.45
		TOTAL US $	**5,746.65**

Options Radio transmitter and pagers, price on request

The PT4 monitor system is assembled and tested prior to delivery. Installation is essentially plug and play. Final on-site sensor calibration will commission the system.

When requested our service department will install and commission the system and supply on-site training at regular rates.

Prices: FOB Blain WA, US $, firm for 30 days
Terms: TBA
Delivery: 4 weeks
Warranty: 1 year factory parts warranty
Commissioning: On-site service US$350 per day plus travel expenses.

Yours truly,

Walter Volberg

Point Four Systems Inc., 100 – 13720 Mayfield Place, Richmond BC V6V 2E4 Canada
Tel: 604.273.9939
Toll Free: 800.267.9936
Fax: 604.273.9937
E-Mail: Sales@pointfour.com
Web: www.pointfour.com

The PT4 Monitor is an aquaculture monitoring system designed for use in commercial fish farming, grow-out operations and live fish transportation. It measures dissolved oxygen, temperature, pH and can be used with any sensor providing a 4-20 mA output. The multichannel system displays up to eight measurements and monitors up to eight digital inputs simultaneously. The PT4 has data logging, PC connectivity and control capabilities and includes a multiple display monitor and a junction box to which the various sensors are connected. It is designed for outdoor use and can be supplied with a number of mounting and enclosure options.

For technical details see the Specifications page.

- Ideal for aquaculture applications - fish farming, grow-out operations and live fish transportation.
- Multiple channel functionality - up to 8 measurements simultaneously monitored and displayed. Up to 8 digital inputs monitored.
- Easy to read - all measurements clearly displayed on a large LCD in bold 9 mm characters.
- Easy to use - the operator sets high and low limits for each channel as well as common alarm. One alarm light per channel and common alarm with built-in buzzer notifies

To order please complete our on-line PT4 Quotation Form or contact one of our sales representatives -

sales@pointfour.com

(+1) 604.273.9939

operator of out-of-range conditions.

- Adaptable for different inputs - will accept direct inputs from oxygen and temperature sensors as well as any 4-20mA input for other measurements such as pH or salinity.
- Automatic calibration for oxygen probes - no need for look-up tables; calibrate with a few simple key strokes.
- Data logging & PC connectivity - store data with built-in logger and download to a PC to capture and view data directly.
- Relay output option - control solenoid valves, blowers etc. or activate external alarm. Features a 4-20 mA analog output.

Point Four Systems Inc.

oxygenation and water management specialists

PRODUCTS OVERVIEW

DIFFUSERS
PRESSURIZED COLUMNS
PORTABLE METERS
MONITORS
PROBES + ACCESSORIES
FITTINGS
LAKE BED AERATION
FISH FEEDERS

CUSTOMER SUPPORT
ABOUT POINTFOUR
INDUSTRY LINKS
CONTACT US

PT4 MONITOR + CONTROL SYSTEM

OVERVIEW SPECIFICATIONS

Operation

Eight channel microprocessor based monitor and controller. Two channels provided in the base unit. Plug-in PCB cards for each additional channel. Programmed instruction-set includes channel set-up; setting high & low alarm limits for each channel and common alarm; auto-calibration of oxygen channels; and numerous units of measurement such as: mg/l, %Sat, °C/°F, pH, ppt, mmHg. Up to 8 digital inputs (DI) activate common alarm; DI can be configured to display a variety of alarm messages such as "low level", "high level", "no power", "no flow", "low O_2 pressure".

Data Logging & PC Connectivity

Communication package enables RS232 or RS485 connection to a PC for viewing the displayed values and for downloading data from the PT4's internal memory. Data transmission is ASCII comma separated (CsV) format. Data logging capability, for all active channels, with selectable log interval (3 sec. to 18hrs). Data stored in internal (32K) non-volatile memory. Logging capacity depends on configuration. From 4000 single channel time-stamped recordings to 320 recordings for all 8 channels including ave., max., min values per recording. selectable averaging window, from 2 seconds to half log interval.

User Interface

Display	4 line X 20 Character LCD with 9 mm high characters with back light.
Indicators	Instrument status light (bi-color). 8 alarm lights, one for each channel, common alarm light
Audible Alarm	Audible alarm: Built-in buzzer sounds when common alarm is active.
Keypad	1 x 5 tactile keypad includes On/Off switch.
Inputs	Up to eight, 2-wire terminals for direct connection of oxygen and temperature probes (0-250 mV) or from 4-20 mA transmitters. Each channel galvanically isolated. Measured with 15-bit resolution. Up to eight digital inputs.
Outputs/Relays (optional)	
4-20 mA output	Scalable and invertible; max load 500 ohms; non-isolated. 0.08 mA resolution.
Relays	Up to 10 relays, 1 per channel SPDT contacts, 8amp 30V DC/ 10 amp 250 V AC resistiveload, and 2 common alarm DPDT contacts, 10amp 30V DC/250 V AC resistive load. Relays can be pre-wired energized 12V DC or as dry contacts. User selectable Fail Safe - normally. Open (NO)/NC modes and common alarm relay can be cancelable or not. Alarm and corresponding relay is active if the channel value is greater than or less than user selectable values for at least the selected delay time (0-999 minutes). Relays available separately, in bank of 4 plus common alarm, bank of 5, or bank of 8 with 2 common alarm relays.
Power	12V DC (-1 +2)
Mechanical Specifications	
Monitor	Polycarbonate, watertight, with plastic laminated front label. **Dimensions** 120 mm H x 200 mm W x 90 mm D, (4-3/4" x 7-7/8" x 3-1/2") Powder coated mounting bracket supplied, adjustable mounting pedestal optional.
Junction Box	Size and number depend upon system configuration

Standard	PVC NEMA 4X (IP66)
Dimensions	127mm H x 127 mm W x 51 mm D, (5" x 5" x 2").
Extended (standard)	Polycarbonate NEMA 4X (IP66)
Dimensions	120 mm H x 200 mm W x 90 mm D, (4-3/4" x 7-7/8" x 3-1/2").
Extended (Long)	Polycarbonate NEMA 4X (IP66)
Dimensions	120 mm H x 240 mm W x 100 mm D, (4-3/4" x 9-1/2" x 4").
Small	Polycarbonate NEMA 4X (IP66)
Dimensions	120 mm H x 160 mm W x 90 mm D, (4-3/4" x 6-1/4" x 3-1/2").

Operating Conditions

Operating Temp.	-5°C to 50°C (23°F to 120°F).
Relative Humidity	90% max. with no condensation.

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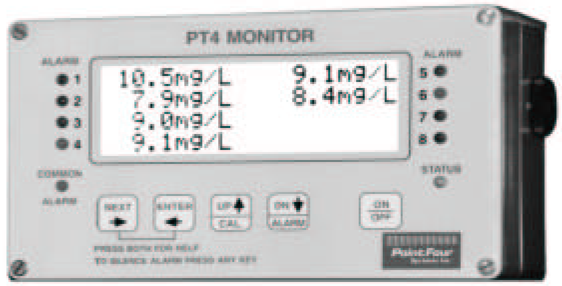
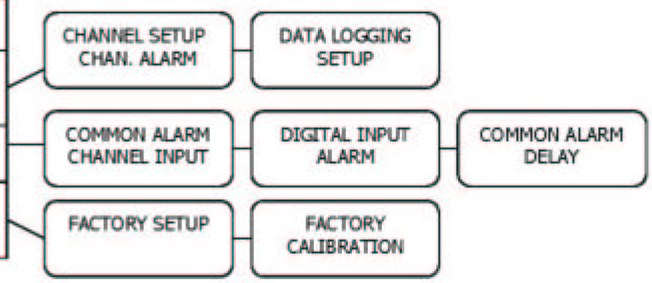
Quick Reference Guide

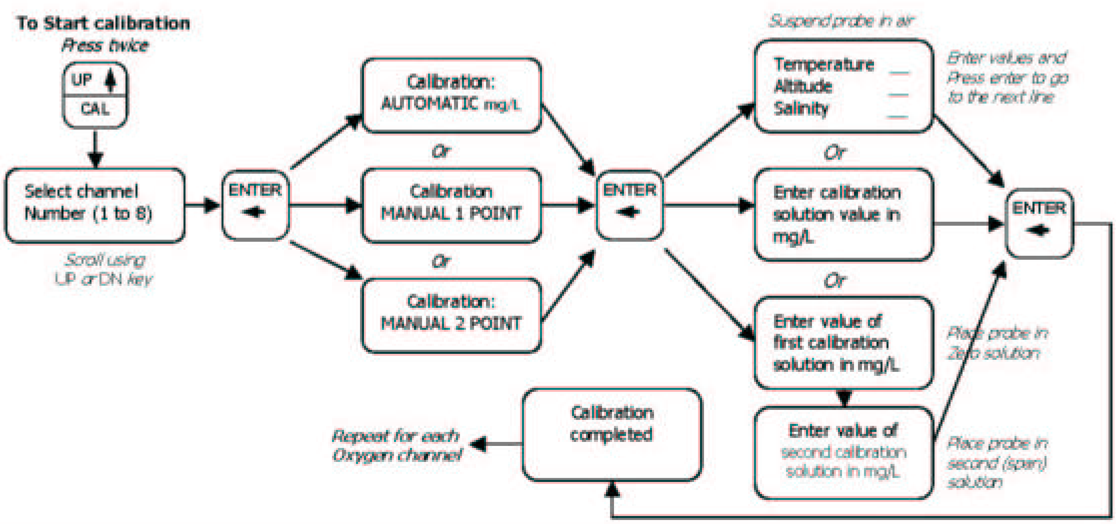
PT4 MONITOR

ON / OFF	Turns the Monitor on and off.
NEXT →	Scroll through the main data pages in sequence and returns display from a submenu page to the main page.
ENTER ←	Store in memory the displayed value on the line where the cursor is flashing.
UP ↑ / CAL	-Sensor Calibration - Access **submenus**, when used in conjunction with the NEXT → key Hold down the NEXT key, press UP/CAL key momentarily
DN ↓ / ALARM	-Set Common Alarms - Access **submenus**, when used in conjunction with the NEXT → key scroll sub menus using the UP and DN arrow keys





OXYGEN SENSOR CALIBRATION



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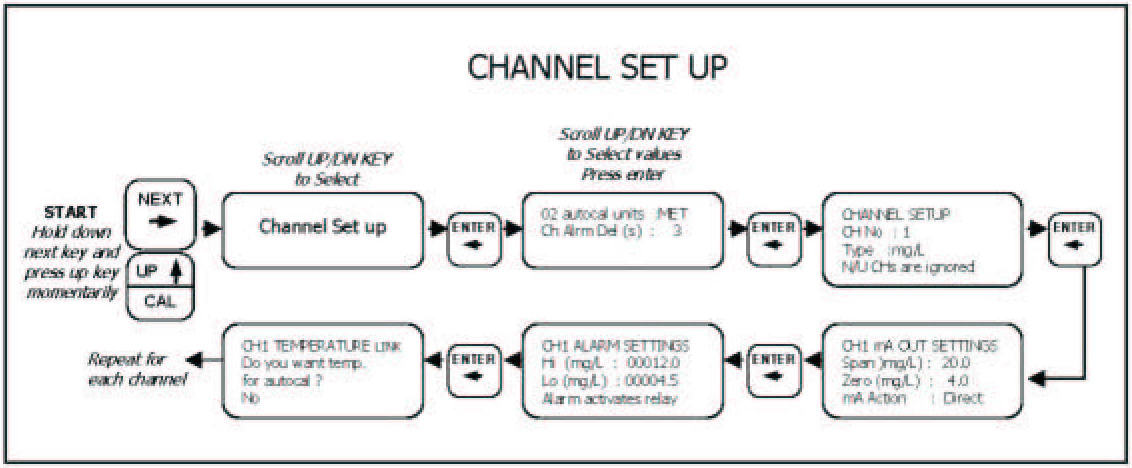
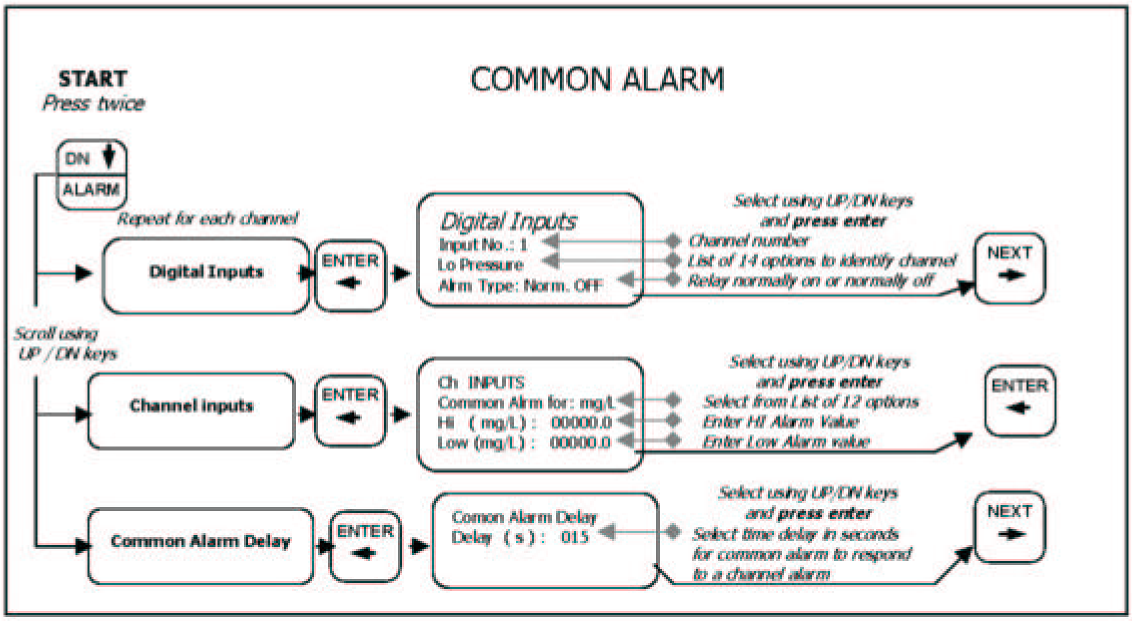
Quick Reference Guide





Point Four Systems Inc.,#100-13720 Mayfield Place, Richmond, British Columbia, Canada V6V 2E4

Tel: (604) 273 9939 **Toll Free:** 800 267 9936 **Fax:** (604) 273 9937

E-Mail: sales@pointfour.com **Web Site:** www.pointfour.com

Appendix B

Ridgway Gas Supersaturation: Summary of Fisheries Data for a Section by Section Electrofishing Effort on the Uncompahgre River, 3/31/04

Ridgway Gas Supersaturation Fish Sampling
Date: 3/31/04
Crew: BOR, CDOW
Location: Bypass

Shock Duration(seconds):
622, 810, 811 sec
10.37,13.5,13.52 min

sum of minutes 37.39 minutes

% N2 at bypass= 121.04664

flow was 35 cfs.
Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + location)	Severity	Comment
RBT	341	350	no			
RBT	126	30	no			
RBT	120	15	no			
BRT	95	10	no			
RBT	90	5	no			
RBT	375	535	yes	pectoral fins, unspecified other fins	1	
RBT	457	1005	no			
RBT	412	570	yes	operculum	1	photo
BRT	154	40	no			photo
BRT	393	715	no			
SCU	95	5	yes	head	1	
RBT	132	25	yes	unspecified body		
RBT	112	10	yes	caudal fin	1	
RBT	112	15	no			
SCU	76	5	no			
SCU	75	5	no			
SCU	66	5	no			
SCU	81	5	no			
SCU	64	5	no			
SCU	81	5	no			
BRT	413	675	yes	unspecified fins	1	
BRT	205	65	yes	unspecified fins	3	
BRT	176	45	yes	unspecified body	4	
BRT	205	75	yes	dorsal fin, operculum, buccal	4	
RBT	127	25	yes	caudal fin	3	
RBT	490	364	yes	dorsal fin, unspecified body, buccal	4	gravid male
BRT	160	40	no			
BRT	142	25	yes	anal fin	1	
YEP	84	25	no			
YEP	83	5	yes	dorsal fin	1	
BRT	70	5	yes	dorsal fin, buccal, mouth	2	
RBT	134	20	yes	Caudal fin, pelvic fin	1	
RBT	113	15	no			
SCU	88	5	yes	unspecified body, fins	4	photo
BRT	131	20	no			
BRT	136	20	no			
SCU	88	10	no			
SCU	83	5	no			
	37 samples		42.11	percent with GBT		

Ridgway Gas Supersaturation Fish Sampling
Date: 3/31/04
Crew: BOR, CDOW
Location: [Spillway

Shock Duration(seconds):
626, 662, 700 sec
10.43,11.03,11.67 min 33.13

Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + location)	Severity	Comment
WHS	170	50	no			
RBT	145	25	y	Pectoral fins, caudal fin	2	
YEP	118	15	no			
SCU	99	15	no			
SCU	93	10	no			
SCU	80	5	no			
SCU	86	5	no			
YEP	77	5	no			
SCU	90	5	no			
SCU	91	5	no			
SCU	101	10	no			
SCU	96	5	no			
SCU	77	5	no			
SCU	94	5	no			
SCU	90	5	no			
SCU	94	10	no			
SCU	83	5	no			
SCU	82	5	no			
SCU	41	5	no			
SCU	82	5	y	head	1	
SCU	81	5	no			
SCU	81	5	no			
SCU	66	5	no			
	22 samples		8.70			

Ridgway Gas Supersaturation Fish Sampling
Date: 3/31/04
Crew: BOR, CDOW
Location: USGS Gage
%N2 at USGS= 115.23

Shock Duration(seconds):
682, 701, 793 sec
11.37,11.68,13.22 min 36.27

Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + location)	Severity	Comment
BRT	392	715	no			
SCU	94	5	no			
RBT	372	540	yes	adipose	1	
BRT	471	910	yes	All fins, head, unspecified body	4	
CTT	412	595	yes	gills,buccal cavity, fins, mouth	4	Snake River CTT
BRT	385	585	no			
BRT	444	795	yes	dorsal fins, pelvic fins	3	
SCU	86	5	no			
SCU	94	15	yes	unspecified body	2	
BRT	240	140	yes	caudal fin	1	
BRT	152	35	no			
RBT	125	30	yes	pectoral fin	1	
BRT	90	5	yes	head, dorsal fin	1	
RBT	133	20	no			
SCU	82	10	no			
SCU	87	10	no			
SCU	60	5	no			
SCU	86	5	yes	pectoral fin	2	
SCU	93	10	yes	unspecified body	2	
SCU	93	10	no			
SCU	89	15	no			
SCU	90	10	no			
SCU	82	5	no			
SCU	82	10	no			
SCU	70	5	no			
SCU	44	5	no			
RBT	126	25	yes	caudal fin	1	
SCU	90	10	no			
	27 samples		39.29			

Ridgway Gas Supersaturation Fish Sampling
Date: 3/31/04
Crew: BOR, CDOW
Location: Footbridge @ Pa-Co-Chu-Pak
gas level at footbridge= 112.94

Shock Duration(seconds):
404,408,465 sec
6.73,6.8,7.75 min

Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + location)	Severity	Comment
CTT	385	570	no			
RBT	428	790	no			
RBT	362	440	no			
CTT	414	681	no			
CTT	333	225	no			
RBT	360	475	no			
RBT	92	5	no			
CTT	321	345	no			
RBT	372	625	no			
RBT	426	730	yes	dorsal fin	1	
RBT	437	855	no			Spent Female
CTT	436	845	no			
BRT	427	690	yes	dorsal fin, pelvic fin	2	
RBT	225	155	no			
BRT	155	40	no			
RBT	332	345	no			branded
RBT	120	20	no			
CTT	340	360	no			photo: crossjaw
BRT	471	945	yes	dorsal fin, caudal fin, adipose fin	2	
SCU	110	20	no			
SCU	90	5	no			
BRT	440	780	yes	caudal fin	2	
RBT	366	460	no			
RBT	271	225	no			
RBT	155	35	no			
RBT	114	20	no			
RBT	145	30	no			
RBT	135	25	no			
RBT	172	40	no			
BRT	171	60	no			
SCU	110	30	no			
SCU	104	25	no			
SCU	76	5	no			
BRT	89	15	no			
BRT	112	20	no			
SCU	73	5	no			
SCU	65	5	no			
SCU	85	5	no			
SCU	81	5	no			
	38 samples		10.26			

Ridgway Gas Supersaturation Fish Sampling
Date: 3/31/04
Crew: BOR, CDOW
Location: Above Confluence with Cow Creek

Shock Duration(seconds):
TIME MISSING:

Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + location)	Severity	Comment
RBT	432	705	no			
BRT	288	220	no			
BRT	159	35	yes	pectoral fin	1	4 small bubbles
BRT	174	55	no			
SCU	95	10	no			
SCU	72	5	no			
SCU	94	10	no			
RBT	422	755	no			
BRT	136	40	no			
BRT	225	115	no			
RBT	82	5	no			
BRT	94	10	no			
BRT	305	270	no			
BRT	90	5	no			
SCU	106	30	no			
BRT	91	5	no			
RBT	141	40	no			
BRT	275	205	no			
RBT	132	20	no			
BRT	91	5	no			
SCU	90	5	no			
SCU	82	10	no			
RBT	130	25	no			
BRT	98	5	no			
SCU	98	10	no			
RBT	114	20	no			
RBT	88	5	no			
BRT	92	15	no			
BRT	95	5	no			
SCU	95	15	no			
SCU	105	15	no			
SCU	70	5	no			
SCU	80	10	no			
	32 samples		2.56			

Appendix C

Ridgway Gas Supersaturation: Summary of Fisheries Data for a Section by Section Electrofishing Effort on the Uncompahgre River, 9/28/04

Ridgway Gas Supersaturation Fish Sampling
Date: 9/28/04
Crew: BOR, CDOW
Location: Bypass - oultet works was operating - not bypass

Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

% Nitrogen Saturation For Re **115.07**

	Lower	Upper
Site UTM (northing) - NAD 83 Datum	13S 4236050	13S 4235968
Site UTM (easting)	258525	258650

Shock Duration (seconds) - Appx.2680
Temp © - 12

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + L / R side)	Severity	Commment
CRN	279	195	no			
RBT	387	505	yes	Roof of Mouth / L inside operculum	1	Photo taken
RBT	212	115	yes	R inside operculum	1	
RBT	302	285	no			
WHS	241	160	no			
LOC	166	60	no			
LOC	442	790	yes	R inside operculum / L inside operculum	1	2 photos taken
RBT	247	215	yes	Caudal fin L & R	1	
RBT	205	90	yes	top of tongue	1	
RBT	338	410	yes	L inside operculum	1	
CRN	313	305	no			
RBT	243	150	no			
RBT	185	65	no			
RBT	233	135	no			
LOC	151	35	no			
RBT	340	420	yes	L inside operculum	1	
	16 fish total		7 with GBT	43.7		

Ridgway Gas Supersaturation Fish Sampling
Date: 9/28/04
Crew: BOR, CDOW
Location: No Tresspassing sign to irrig.gate

Nitrogen Sa	%N2 @ USGS	**116.07**
	%N2 @ Big Rock	**114.58**
	%N2 @ Kiva	**112.70**

Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

	Lower	Upper
Site UTM (northing) - NAD 83 Datum	13S 4236275	13S 4236157
Site UTM (easting)	258265	258360

Shock Duration (seconds) - Appx.4338
Temp © - 12

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + L / R side)	Severity	Commment
MTS	103	15	yes	R inside operculum	1	
MTS	84	5	no			
CRN	424	850	yes	L inside operculum	1	picture taken
CRN	330	365	no			
LOC	408	800	yes	R inside operculum / L inside operculum	1	
RBT	203	100	no			
RBT	316	350	no			
MTS	110	20	no			
CRN	332	395	no			
LOC	173	50	no			
MTS	92	10	no			
MTS	81	10	no			
MTS	80	10	no			
	13 fish total		3 with GBT	23.1		

Ridgway Gas Supersaturation Fish Sampling
Date: 9/28/04
Crew: BOR, CDOW
Location: Above and Below FootBridge

Nitrogen Saturation For Reach average 109.77

Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

	Lower	Upper
Site UTM (northing) - NAD 83 Datum	13S 4236655	13S 4236528
Site UTM (easting)	258101	258136

Shock Duration (seconds) - Appx.3980
Temp © - 12

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + L / R side)	Severity	Commment
MTS	57	5	no			
LOC	171	55	no			
LOC	410	740	no			
RBT	282	240	no			
RBT	272	240	no			
CRN	312	305	no			
MTS	102	20	no			
MTS	86	10	no			
SRN	388	550	no			
CRN	329	370	no			
RBT	241	165	no			
LOC	130	25	no			
LOC	123	20	no			
MTS	100	10	no			
CRN	303	305	no			
MTS	102	30	no			
MTS	93	30	no			
MTS	102	35	no			
MTS	86	25	no			
MTS	86	25	no			
LOC	340	520	no			
LOC	116	20	no			
RBT	261	210	no			
RBT	176	70	no			
RBT	189	85	no			
LOC	201	110	no			
LOC	185	80	no			
LOC	138	35	no			
LOC	167	55	no			
LOC	321	380	no			
CRN	296	230	no			
CRN	321	325	no			
RBT	340	480	no			
MTS	94	10	no			
LOC	332	390	no			
LOC	140	30	no			
RBT	194	85	no			
MTS	91	15	no			
MTS	104	30	no			
MTS	105	15	no			
MTS	104	15	no			
MTS	85	5	no			
MTS	96	10	no			
MTS	90	5	no			
LOC	424	705	no			
RBT	305	300	no			
RBT	341	385	no			
SRN	360	510	no			
LOC	125	25	no			
RBT	235	185	no			
LOC	120	25	no			
LOC	184	80	no			
LOC	190	65	no			
LOC	228	140	y	L inside operculum		
		54 fish total	1 with GBT	1.85		

Ridgway Gas Supersaturation Fish Sampling
Date: 9/28/04
Crew: BOR, CDOW
Location: Below Campground

Nitrogen Saturation For Reach average 106.74
Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

	Lower	Upper
Site UTM (northing) - NAD 83 Datum	13S 4237137	13S 4237137
Site UTM (easting)	257999	258059

Shock Duration (seconds) - Appx.3148
Temp © - 12.5

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + L / R side)	Severity	Commment
LOC	421	970	no			
LOC	409	830	no			
MTS	84	5	no			
LOC	341	465	no			
LOC	392	645	no			
RBT	176	60	no			
RBT	386	605	no			
RBT	309	315	no			
LOC	242	155	no			
RBT	360	590	no			
LOC	330	440	no			
		11 fish total	none with GBT	0		

Appendix D

Ridgway Gas Supersaturation: Summary of Fisheries Data for a Section by Section Electrofishing Effort on the Uncompahgre River, 3/16/05

NEED TO ADD DATA

Ridgway Gas Supersaturation Fish Sampling

Nitrogen Saturation For Reach
?????

Date: 3/16/05
Crew: BOR, CDOW **Flow at shocking????** **Flow 3/15 = 45 cfs: flow 3/17 = 30 cfs**
Location: Bypass to USGS gage

	Lower	Upper
Site UTM (northing) - NAD 83 Datum	13S 4235989	13S 4236101
Site UTM (easting)	258545	258424

Shock Duration (seconds) - Appx.2128 (3 shockers) 35.46666667 min
Temp © - 4

Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + L / R side)	Severity	Commment
LOC	487	1020	y	anal fin	1	
RBT	240	150	y	caudal fin, l. pectoral fin	2,1	
LOC	208	105	n			
			2 of 3 fish: 66% GBT occurrence			

Ridgway Gas Supersaturation Fish Sampling

Nitrogen Saturation For Reach
?????

Date: 3/16/05
Crew: BOR, CDOW
Location: Beginning below headgate to spawning channel, to just upstream of headgate

	Lower	Upper
Site UTM (northing) - NAD 83 Datum	13S 4236327	13S 4236244
Site UTM (easting)	258265	258274

Shock Duration (seconds) - Appx.2137 (3 shockers) 35.61666667 min
Temp © - 5

Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + L / R side)	Severity	Commment
LOC	317	250	y	dorsal fin	1	
LOC	367	470	n			
RBT	360	415	n			
CRN	313	300	n			
LOC	195	80	n			
RBT	212	110	y	caudal and dorsal fin, l. opercle	2,2,2	
SRN	495	1120	y	r.&. Opercle, r.&l. pectoral fins, r.&l. dorsal fins		several photos this fish
				adipose fin, r.&l. caudal peduncle (bleeding)	4 for all areas	
LOC	327	335	y	caudal fin	1	
RBT	114	35	n			
LOC	145	45	n			
LOC	375	470	y	dorsal fin,l. pectoral, caudal fin	2,3,3	
LOC	265	190	n			
RBT	330	355	n			
LOC	263	160	n			
LOC	293	220	n			
LOC	195	85	y	dorsal fin,caudal fin, r.&l. pelvic fins,r. pectoral fin	2,2,1,1	
LOC	176	60	n			
LOC	317	295	y	caudal fin, l. inner opercle	2,2	
LOC	359	465	n			
LOC	267	205	y	dorsal fin, caudal fin, r.&l. caudal peduncle	2,1,1	
LOC	195	95	y	dorsal fin, r. pectoral fin	2, 3	
MTS	11 Sculpins Tallied, not measured		n			
	9 of 32 fish: 28% GBT occurrence					

Ridgway Gas Supersaturation Fish Sampling
Date: 3/16/05
Crew: BOR, CDOW
Location: Above and below footbridge

Nitrogen Saturation For Reach
?????

	PASS 1 Lower	Upper
Site UTM (northing) - NAD 83 Datum	13S 4236467	13S 4236620
Site UTM (easting)	258103	258109

Shock Duration (seconds) - Bank shocker used for Pop. Estimate, no time recorded
Temp © - 6

Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + L / R side)	Severity	Commment
MTS	98	10	n			
MTS	95	5	n			
MTS	96	15	n			
MTS	92	5	n			
MTS	96	15	n			
MTS	96	15	n			
MTS	91	10	n			
MTS	94	10	n			
MTS	86	10	n			
MTS	78	5	n			
MTS	71	5	n			
LOC	341	360	n			
LOC	154	35	n			
LOC	246	140	n			
LOC	198	75	y	r. opercle	1	
LOC	152	40	n			
LOC	166	40	n			
LOC	148	35	n			
LOC	192	70	n			
LOC	146	35	n			
MTS	132	35	y	r. pectoral fin	1	
LOC	152	30	n			
LOC	161	30	n			
LOC	153	25	n			
LOC	155	40	n			
LOC	173	45	n			
MTS	96	20	n			
LOC	85	n/a	n			
MTS	95	10	n			
RBT	244	140	n			gravid male
RBT	300	300	n			hook scar, gravid male
RBT	200	85	n			
RBT	199	70	n			
LOC	185	65	n			
LOC	161	45	n			
LOC	178	55	n			
LOC	175	55	n			
LOC	134	20	n			
LOC	184	60	n			
LOC	175	60	n			
MTS	104	15	n			
MTS	112	20	n			
MTS	100	15	n			
LOC	92	5	n			
MTS	105	15	n			
MTS	93	15	n			
LOC	413	575	n			hook scar
CRN	385	530	n			hook scar
RBT	320	305	n			
LOC	258	185	n			
LOC	225	110	n			
LOC	381	480	n			
LOC	255	150	y	dorsal fin	1	
LOC	282	215	n			hook scar
LOC	281	205	n			

continued

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + L / R side)
RBT	225	100	n	
RBT	268	210	n	
LOC	476	890	n	
RBT	305	300	n	
RBT	322	345	n	
LOC	332	395	n	
RBT	342	390	n	
RBT	110	5	n	
MTS	122	25	n	
MTS	101	5	n	
LOC	412	590	y	l. pectoral fin
RBT	290	225	n	
LOC	215	85	n	
RBT	219	80	n	
LOC	161	40	n	
LOC	138	25	n	
LOC	144	25	n	
MTS	100	15	n	
MTS	83	5	n	
LOC	439	730	n	
RBT	307	275	n	
LOC	344	380	n	
LOC	308	295	n	
LOC	174	45	n	
LOC	142	30	n	
MTS	85	5	n	
LOC	346	755	y	r. pectoral fin
LOC	297	225	n	
RBT	305	295	n	
RBT	246	165	n	
LOC	87	5	n	
LOC	204	70	n	
RBT	198	75	n	
LOC	103	5	n	
MTS	94	10	n	
LOC	356	400	n	
LOC	412	610	n	
LOC	250	135	n	
RBT	342	420	n	
MTS	117	35	n	
MTS	103	5	n	
SRN	411	535	n	
LOC	435	595	n	
LOC	422	665	y	dorsal fin, caudal fin
LOC	177	60	n	
LOC	165	40	n	
LOC	122	25	n	
LOC	98	10	n	
LOC	100	5	n	
LOC	105	10	n	
LOC	130	5	n	
MTS	107	15	n	
LOC	100	5	n	
MTS	98	15	n	
LOC	91	5	n	

Ridgway Gas Supersaturation Fish Sampling   Nitrogen Saturation For Reach
Date: 3/16/05   ?????
Crew: BOR, CDOW
Location: Above and below footbridge   **PASS 2**

	Lower	Upper
Site UTM (northing) - NAD 83 Datum	13S 4236467	13S 4236620
Site UTM (easting)	258103	258109

Shock Duration (seconds) - Bank shocker used for Pop. Estimate, no time recorded
Gas Bubble Trauma:
Trauma Location: Buccal, Opercula, Fins, Body, Gill Lamellae
Severity: 1=1-25%, 2=26-50%, 3=51-75%, 4 = >76%

Temp © - 6

Species	TL Length (MM)	Weight (g)	GBT Present?	Location (body part + L / R side)	Severity	Commment
LOC	331	295	n			hook scar
CRN	312	215	n			hook scar
RBT	225	105	n			
RBT	242	130	n			
LOC	170	40	n			
LOC	112	15	n			
LOC	115	15	n			
MTS	115	25	n			
MTS	108	10	n			
MTS	96	15	n			
MTS	97	10	n			
MTS	75	5	n			
LOC	311	250	n			
LOC	431	700	n			hook scar
RBT	282	215	n			
LOC	221	105	y	dorsal fin	1	
BHS	281	210	n			
RBT	229	120	n			
LOC	254	140	n			
LOC	286	205	n			hook scar
LOC	216	105	y	anal fin	1	
RBT	255	160	y	dorsal fin	1	
LOC	185	55	n			
LOC	140	20	n			
MTS	115	25	n			
LOC	124	15	n			
LOC	141	30	n			
RBT	196	65	n			
RBT	126	20	n			
LOC	155	35	n			
LOC	100	10	n			
LOC	80	5	n			
LOC	110	10	n			
LOC	105	10	n			
LOC	140	25	n			
LOC	75	5	n			
LOC	91	5	n			
LOC	120	115	n			
LOC	125	20	n			
LOC	144	30	n			
MTS	102	15	n			
LOC	91	5	n			
LOC	96	15	n			
MTS	110	10	n			
LOC	110	5	n			
LOC	72	5	n			
LOC	89	5	n			
LOC	90	10	n			
LOC	1023	10	n			
LOC	98	10	n			
LOC	92	5	n			
LOC	85	5	n			
Remaining Mottled Sculpins Tallied: 53, no GBT						
	3 of 105 fish: 3% GBT occurrence					
Total GBT incidence from both passes: 12 of 245 = 5%						