1. ACTIVITY SUMMARY

1. The Columbia/Snake River Total Dissolved Gas Monitoring Program is an annual continuing activity started in 1984. The primary program objective is to collect dissolved gas and water temperature data for use in reservoir regulation during the voluntary spill season in an attempt to control total dissolved gas levels to the States' relaxed standards of 115 (forebay) and 120 (tailwater) percents.

2. In 1997, the program operated between September 15, 1996 to September 15, 1997, including spring-summer and winter monitoring. Spring-summer stations operated between April 1 and September 15, 1997 with a total of 39 instruments including 28 instruments provided by the Corps, three by the Bureau of Reclamation, and nine by the mid-Columbia Public Utility Districts (PUDs). Winter monitoring occurred between September 15 and April 1, using 11 stations.

3. Common Sensing tensionometers and HydroLab mini- and datasondes were used for data collection, along with Sutron and Zeno data collection platforms (DCPs). Data collection in the field was at least once every hour, and data transmission to the Corps' Northwestern Division (North Pacific Region) headquarters, once every one to four hours. All data received from the field were compiled and posted on the Columbia River Operational Hydromet Management System (CROHMS) data base and posted on the Division's Water Management homepage. They were ultimately stored in the Division's Water Quality Master File.

4. 1997 was a very high run-off year for the entire basin. The January-July run-off of the Columbia River at The Dalles was 159 million acre-feet of water--the largest since record keeping began. Precipitation for the Columbia Basin above The Dalles was 29.94 inches (129% of normal). On the Snake River, the April-July runoff volume at Lower Granite was the fourth largest observed since 1928. On the mid-Columbia River, the April - July runoff at Grand Coulee was 76.2 million acre-feet, the highest on record.

5. Dissolved gas saturation levels often exceeded the total dissolved gas standards of 115/120% particularly during the months of May and June. All but three stations (Peck, Lewiston and Lower Granite Forebay) reported dissolved gas in excess of 120 percent saturation 46.7 % of the time, while maximum saturation exceeded 140 percent at several locations.

6. Average monthly water temperatures were approximately the same as in 1996 throughout the season, with a season maximum of approximately 24 degrees C recorded in the Bonneville forebay in late August. The average maximum observed temperatures was about 21 degrees C, the same as in 1996, but the lowest since 1984.

7. Starting in 1996, total dissolved gas and water temperature data collection and transmission became the responsibility of each respective District. In 1997, Portland District contracted their fieldwork to the U.S. Geological Survey and continued to use the normal satellite link for data transmission. Walla Walla staff installed and operated their own stations to collect and send data via phone lines. Seattle District contracted with Common Sensing to perform field calibrations of their stations. Reservoir Control Center staff in the Northwestern Division Office con-

tinued to provide program oversight, including some program coordination, data management and in-season applications of operational decision-making.

8. Most stations were operating by the April 1 start date or before. There were special problems at select sites such as flooding of the John Day tailwater site, a broken pipe at Camas/Washougal that impacted readings, and a late start up for Chief Joseph forebay. But overall, the monitoring program went well. Three new stations were installed this season, including the Grand Coulee forebay, Rocky Reach tailrace and Rock Island tailrace stations. A summary of data set completeness for all stations in listed in Table 10 and 11. Of the entire network, the Portland and Walla District stations performed the most reliably over the season. The amount of real-time data transmission appears to have improved, with 94.2% of the data arriving to CROHMS within 24 hours of occurrence. See Table 13.

9. Efforts continue to assess station location representativeness through miscellaneous transect and other monitoring activities. Data continues to be collected to strengthen the relationships between spill and gas dynamics both in the near field, at the TDG monitoring stations and between dams. Appendix D includes the most current TDG production curves.

10. The 1998 TDG Monitoring Plan of Action is outlined in Appendix K. A total of $641,000 dollars were spent during FY 1997 for contract administration, fieldwork, equipment purchase/maintenance and database management. There has been a lot of focus on program cost, and discussions are underway to find ways to cut costs.

11. The Dissolved Gas Team continues to be the regional peer-review group that provided guidelines and technical feedback to the monitoring effort. Cooperation received from the mid-Columbia PUD's and the Bureau of Reclamation throughout the monitoring effort remained excellent.

Marian Valentine, NWS Hydraulic Engineer and Ray Strode, NWS Meteorological Technician install new tailwater station below Chief Joseph. April, 1997.

2. **BACKGROUND**

2.1 Program Objective

The objective of the Columbia and Snake Rivers Dissolved Gas Monitoring Program, which started in 1984, is two-fold:

- to provide the water quality data needed to schedule spill at Columbia and Snake River mainstem dams; and

- to monitor for compliance with state water quality standards.

Total dissolved gas (TDG) saturation (calculated by dividing total dissolved gas pressure by barometric pressure and multiplying by 100), and specifically the nitrogen component of total dissolved gas, can cause physiological conditions harmful to fish. Total dissolved gas is the primary water quality parameter monitored in this program. Oxygen pressure is also measured at several stations. This parameter helps clarify the how much oxygen versus nitrogen gas is present in the water. Water temperature is also measured as it greatly influences the health of fish and other aquatic species. Dissolved gases and water temperature are closely linked to project operations (e.g. spill, total project outflow, forebay and tailwater reservoir pool elevations, etc.). Consequently, the dissolved gas monitoring program is considered an integral part of water management.

2.2 Monitoring Periods

Monitoring routinely occurs during the fish migration season, from April 1 through September 15, for all established stations. See Table 9. Beginning in September 1996, eleven stations operated between September 15 and March 31, to help characterize the impact of involuntary spill on water quality. Involuntary spill is that spill which is considered "uncontrollable," or the amount of spill beyond the hydraulic capacity of a project. Major participants in this annual monitoring program include the Corps of Engineers, U.S. Bureau of Reclamation and the mid-Columbia County PUDs (Chelan, Douglas and Grant).

In the past, the monitoring emphasis was placed on TDG and spill during high flow years and on water temperature and in-stream flows during low flow years. Since 1994, however, because of the Endangered Species Act and attempts to meet the state standards, monitoring became an operational requirement in all years, regardless of the magnitude of the runoff.

Ben Tice, NWW Limnologist and Lisa Patton, NWW Hydrologic Technician. Ben conducted all field calibrations and repairs to NWW network during 1996-7 season. Lisa assumed this responsibility starting in winter, 1997.

2.3 Data Transmission

Data collection and transmission for the majority of stations is done using fully automated dissolved gas measuring instruments and data collection platforms (DCP). Data for water temperature, barometric pressure, total dissolved gas pressure, (for some stations dissolved oxygen pressure) are collected every one to four hours. These instruments transmit data via satellite to the Corps' Northwestern Division (North Pacific Region) headquarters in Portland, Oregon every four hours. Each DCP first relays the data through the Geosynchronous Operational Environmental Satellite (GOES) which sends the information to the Command and Data Acquisition Station in Wallops, Virginia. After processing, platform messages are retransmitted via a Domestic Communications Satellite (DOMSAT) to a receiving station in Portland, Oregon. The data are then entered in the Columbia River Operational Hydromet Management System (CROHMS) database through its Automated Front End (CAFE).

Walla Walla District utilizes a different data transmission method than the GOES satellite. Data is collected hourly and logged into a Zeno data collection platform. Information collected by the Zeno is transmitted either by modem or radio to a remote PC. The PCs manage data transmission to the NWW server located in CENWW-PL-ER Water Quality Lab. Data is sent hourly to CAFÉ over the Local Area Network (LAN).
Manual transmission of station data was used at some stations in 1997. Douglas PUD sent data to CROHMS every four hours over the Columbia Basin Teletype (CBT) System. (Douglas Co PUD plans to automate this system in 1998). And data from the new tailwater station below Chief Joseph was sent to RCC manually. (Seattle District plans to automate this system in 1998).

A new and very stable tailwater station installation below Rock Island Dam (RIGW), Chelan County PUD.

2.4 Program Coordination

TDG monitoring activities are coordinated by the Corps' Northwestern Division Fish & Water Quality Section (F&WQ), Reservoir Control Center (RCC), Water Management Division. Tasks performed by F&WQ staff include:

- coordinating dates for the start and end of the monitoring season;
- providing oversight of quality assurance and quality control protocols for data measurement, transmission, correction and storage;
- real-time screening of erroneous quality data and filling data gaps as necessary;
- preparing and posting of dissolved gas saturation, water temperature; project spill, pool elevations and flow releases data on the Internet;
- performing statistical analyses and computer modeling to refine or update site- or

The first phase of the study was to evaluate methods for immediately reducing TDG created during voluntary spill for fish passage operations. Information was developed during this study and published in the Phase I Technical Report released in April 1996. Based on the results from Phase I, deflectors were installed on John Day and Ice Harbor dams; actions that have reduced gas considerably.

The Phase II Gas Abatement Study is a feasibility level study to further evaluate the following:

1) Alternatives investigation
2) Prototype structure
3) Numerical model development
4) TDG research
5) Biological research
6) System-wide biological benefit analysis
7) Implementation schedules.

The alternatives being considered at this stage are: spillway deflectors with a raised tailrace, raised stilling basin with a raised tailrace, raised stilling basin, spillway deflectors (extended), raised tailrace, submerged passageway, submerged passageways with flow deflectors, raised stilling basin with deflectors, additional spillbays, new spillway gates, or side channel spillway. This alternative analysis will include cost and schedule details, TDG reduction potential, and biological effects both from physical injury and system-wide gas bubble trauma effects.

This Final Phase II Technical Report, to be completed in September 2001, will provide recommendations on structural and/or operational modifications to specific projects, including a proposed implementation schedule.

2.6 Regional Forum Activities

The Dissolved Gas Team, formed in 1996, served as the regional peer-review forum and provided monitoring guidelines and technical expertise on dissolved gas issues. To date, the team has been trying to complete their initial two tasks. The first task was to complete a regional memorandum of agreement (MOA) between parties that are directly involved with dissolved gas in the Columbia River Basin. The objective of the MOA was to reach consensus between parties on what they can to reduce total dissolved gas (TDG) levels to the state standards. The MOA would replace NMFS' annual waiver application to exceed the state water quality standards during voluntary spill. The Implementation Team gave the second task to DGT. DGT was to summarize the research done to date on total dissolved gas and the effects of TDG on salmonids. Next, they were to prioritize the research still needed.

2.7 Runoff Conditions

1997 was a very high run-off year for the entire basin. The January-July run-off of the Columbia River measured at The Dalles was 159 million acre-feet (Maf) of water, or 50 percent more than during an average year. This year's run-off, at 150% of normal, replaced 1974 by a very narrow margin as the largest since record keeping began. In comparison, 1995 was 98% of normal and 1996 stood at 132% of normal. Precipitation for the Columbia Basin above The Dalles was 29.94 inches (129% of normal), compared to last year's 27.57 inches (118% of normal). On the Snake River, the April-July runoff volume at Lower Granite was the fourth largest observed since 1928. On the mid-Columbia River, the April - July runoff at Grand Coulee was 76.2 million acre-feet, the highest on record. The January runoff itself was very high; reaching close to 220,000 cfs on the lower Snake River compared to a normal discharge this time of the year of 25,000-30,000 cfs. These high flows prompted the governors of five western states to declare portions of their states disaster areas.

Plots of total flows provided in Appendices B and D are reflective of the high runoff conditions experienced basin-wide in 1997.

3. 1997 MONITORING PROGRAM

3.1 General

The 1997 Dissolved Gas Monitoring Program was extended to include the period September 15, 1996 through September 15, 1997. During the spill season, approximately April 1 to September 15, 1997, a total of 39 instruments were assigned to various forebay and tailwater stations. Most of the stations were located on the Columbia and Snake Rivers and included 28 instruments contributed by the Corps, three by the Bureau of Reclamation, and nine by the mid-Columbia PUDs (see Figures and Table 1).

The exact start and end dates for monitoring data transmission varied slightly from station to station (see Table 9). All stations covered, at a minimum, the spring to early summer juvenile out-migration period. As in previous years, tailwater stations were generally located within one mile below the dams as agreed to by the States.

During the fish migration season, real-time dissolved gas monitoring requirements remained as high as they were in 1994 when NMFS first requested spill to achieve an 80 percent fish passage efficiency at Corps mainstem dams. The same type of spill was requested in 1997, subject to state standards.

To serve this operational purpose, the CROHMS database was updated several times per day and data was posted real time for most stations to the Water Management Homepage. Additionally, reports on the CAFÉ system (601, 603, 605) remained available to authorized users, providing real-time data, plus data up to two days old. Based on these TDG data, RCC adjusted spill caps to attempt to control total dissolved gas levels to the State standards, even if this meant not achieving the 80 percent fish passage efficiency targeted by the National Marine Fisheries Service (NMFS).

3.2 Wintertime TDG Monitoring

Monitoring during the winter also occurred at several stations between September 15, 1996 and March 31, 1997. Its objective was to be able to characterize TDG levels during involuntary spill periods over the winter months. Winter monitoring stations included International Boundary, Dworshak tailwater, Lower Granite forebay, Lower Granite tailwater, Ice Harbor forebay, Ice Harbor tailwater, McNary forebay (WA), McNary forebay (OR), McNary tailwater, Bonneville forebay and Warrendale (below Bonneville). Some data was also collected below Grand Coulee Dam during February 5 - 24, 1997, and at Peck, below Dworshak Dam during September 15 - October 18, 1997, Because wintertime data were not crucial to real-time reservoir operation, instrument calibrations were performed only every month or six weeks for most stations. The final data sets are plotted in Appendix C, showing numerous occurrences of TDG above the 110% level, especially at the International Boundary, Dworshak, Ice Harbor and Warrendale.

Rock Island forebay station (RIS). Chelan County PUD biologist, Robert MacDonald and biological technician, Val Koehler. April, 1997.

3.3 Water Temperature Monitoring

Monitoring of water temperature conditions throughout the Columbia and Snake River mainstems was part of the overall dissolved gas monitoring program. Water temperature measurements were taken from temperature sensors located at the same depth (about 15 feet) as the total dissolved gas sensors. In addition to this “surface” water temperature, Corps of Engineers project personnel also recorded water temperatures from powerhouse scroll cases, or comparable sources that reflect deep, well-mixed water. At John Day, fishway temperatures were erroneously recorded as scroll-case temperatures. This problem will be corrected over the winter of 1997-8. See Appendix E.

Scroll case water temperatures are sent to CROHMS through the CBT. TDG station water temperatures were posted on the Water Management homepage, and scroll case water temperatures will be posted on the homepage in 1998.

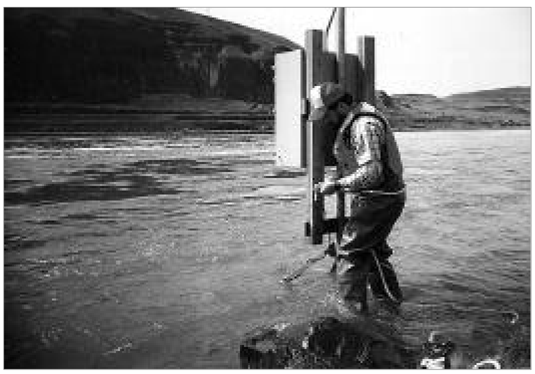
3.4 Station Performance

In this section, the period between April 1 and September 15, 1997 was evaluated although in many cases, stations operated longer than this period. The entire operation period for each station was summarized in Table 9. Performance was evaluated based on completeness of the barometric pressure, total dissolved gas pressure and water temperature parameters for both Corps and non-Corps stations. Further, some stations sent dissolved oxygen pressure data to CROHMS. Although some quality control was performed on the oxygen pressure data, this parameter was not reviewed in detail in this report.

The completeness of the data received from each monitoring station, along with the primary missing parameter and causes, is summarized below. Missing data results from either no data received from the field or data deleted through data screening using the correction protocols. More details are provided in Appendix J.

International Boundary (CIBW): 87%; temperature, late start-up, flooding
Grand Coulee forebay (FDRW): 73.5%, temperature
Grand Coulee tailrace (GCGW): 89.6%, temperature
Libby tailrace station (LIBM). Not operated this year
Chief Joseph forebay (CHJ): 72.9%, late start-up
Chief Joseph tailrace (CHQW): 79.3%
Wells forebay station (WEL): 77.4%, temperature, faulty sensor
Rocky Reach forebay (RRH): 87.2%, temperature, transmission
Rocky Reach tailwater (RRDW): 63.5%, late start-up, broken pipe housing, bad sensor
Rock Island forebay (RIS): 90.5%, transmission
Rock Island tailwater (RIGW): 76.9%, late start-up, transmission, electrical connection
Wanapum forebay (WAN): 89.5%, temperature
Wanapum tailrace (WANW): 98.6%
Priest Rapids forebay (PRD): 97.7%, temperature
Priest Rapids tailrace (PRXW): 89.2%
Dworshak tailrace (DWQI): 96.5% complete
Peck (PEKI): 92.4%, shallow probe, probe jammed
Lewiston (LEWI): 90.3%, TDG and temperature, limited probe depth
Lower Granite forebay (LWG): 96.9%, temperature, probe cable heating
Lower Granite tailrace (LGNW): 88.1%, instrument malfunction, solar panel problems
Little Goose forebay (LGS): 88.9%, temperature and TDG, insufficient depth
Little Goose tailrace (LGSW): 82%, TDG and temperature, damaged membrane
Lower Monumental forebay (LMN): 92.8%, temperature and TDG
Lower Monumental tailrace (LMNW): 95.8%, gas pressure, faulty sensor
Ice Harbor forebay

Dalles forebay (TDA): 91.9%, faulty DCP automatic shut off
Dalles tailrace (TDDO): 99.2%, broken PVC pipe
Bonneville forebay (BON): 98.5%, barometric pressure, temperature
Warrendale (WRNO): 99.6%, temperature
Skamania (SKAW): 97.8%, temperature, DCP problem
Camas-Washougal (CWMW): 90.6%, temperature, broken PVC pipe, debris
Kalama (KLAW): 98.7%, barometric pressure and temperature, faulty probe
Wauna Mills (WANO): 99.7%, temperature



Howard Harrison, USGS, moves the John Day tailwater NEMA box to higher elevation during high flows. June, 1997.

4. 1997 SPILL OPERATION

4.1 Biological Opinion's Spill Requirement

There have been no changes in the BiOp relative to last year's operational requirements. The Biological Opinion prescribed spilling to achieve a fish passage efficiency of 80 % at projects in the lower Snake and Columbia rivers. Spill required to reach this target is listed below in percent of instantaneous outflow. Spill periods are 24 hours a day at Ice Harbor, The Dalles, and Bonneville and 12 hours a day (1800 - 0600 hours) at all other dams.

Spill for Fish Passage in NMFS's Biological Opinion, in percent of Outflow

Projects	Spring Spill	Summer Spill
Lower Granite	80	0
Little Goose	80	0
Lower Monumental	81	0
Ice Harbor	27	70
McNary	50	0
John Day	33	86
The Dalles	64	64
Bonneville	100% nighttime and up to 75 kcfs daytime.	100% nighttime and up to 75 kcfs daytime

The Biological Opinion recognizes that an 80 % FPE level is not obtainable at Bonneville Dam given a day time spill cap of 75 kcfs and the current low fish guidance efficiency levels. This daytime spill cap, which is designed to reduce adult fallback, limits obtainable spring FPE to 74 % and summer FPE to 59% at 100% percent nighttime spill.

There were several special provisions to the spill. During the spring (April 10 through June 20), no spill for fish passage is required at Lower Granite if the weekly flows at that project exceed 100 kcfs. Likewise, when the Lower Granite weekly flows are less than 85 kcfs, the TMT may decide to terminate spill for fish passage at Lower Granite, Little Goose, and Lower Monumental.

4.2 Actual Spill

Despite the high runoff, a formal request to spill water to meet Fish Passage Efficiency (FPE) targets was issued on April 8 for the lower Snake River dams and on April 18 for the lower Columbia River dams. Spill during 1997 was mostly involuntary. In the lower Snake River, a small amount of spring spill and some summer spill was voluntary as called for in the Biological Opinion. See Table 2.

A TDG waiver to 115% was granted by Division of Environmental Quality for the period of April 10 through August 30 for the North Fork Clearwater River below Dworshak Dam and the Clearwater River below the North Fork. Spill occurred at Dworshak for much of the spill season.

In the lower Columbia River, all spill at McNary and Bonneville was involuntary. At John Day and The Dalles some summer spill was voluntary. Whenever voluntary spill occurred in the system, that spill was implemented in compliance with the state standards waivers. By the same token, when involuntary occurred, the TDG level it caused was generally higher than the state standards waivers.

As in previous high flow years, a spill priority list was developed and implemented to the extent physically possible to limit high, localized TDG levels. The list started with projects along the main fish passage corridor (Columbia and Snake Rivers mainstem) proceeding in an upstream direction. It also covered projects on the Willamette River and others that are hydraulically directly connected to the mainstem Columbia and Snake Rivers. Normal unit maintenance at the projects was delayed to make more units available for power generation and thus cutting involuntary spill. In addition, some units were allowed at times to operate outside their 1% peak efficiency flow range. BPA also made significant effort to market as much lack-of-market spill as possible during the fish migration season.

Spring Spill

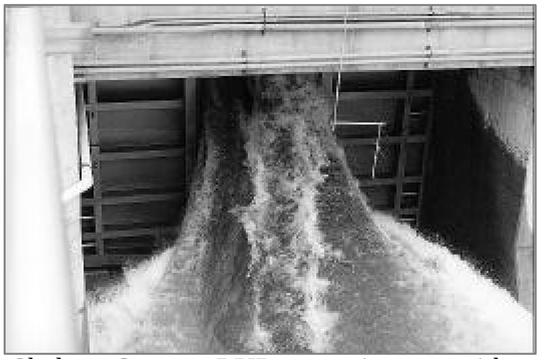
The prospects of high spill and high TDG prompted the fishery agencies to request that flood control reservoirs be refilled at a faster rate than planned to reduce spill. This request was not honored, although the concept of using temporary storage draft and fill at John Day to control spill in the lower Columbia River was contemplated as long as flood control was not jeopardized.

In the spring of 1997, Lower Granite spilled continuously between early April until late June. Because of the high runoff, spill was mostly involuntary. It averaged about 59 kcfs per day (or 36.3 % spill on a daily average basis), which was considerably greater than the 80%, 10-hour nighttime spill called for in the Biological Opinion. The TDG below the project exceeded 130 % for a total of about three weeks in May and June. Waivers from Oregon, Washington and Idaho provided at NMFS's request temporarily raised the state TDG standards from 110% to 120%. The Oregon and Washington waivers applied to the March 23 - August 31 period and the Idaho waivers, to April 15 – June 1, June 18 – July 15 and August 16 – August 31 periods.

To minimize spill and TDG and their impacts on fish the option of running generators outside their 1% peak efficiency range was discussed at the Technical Management Team. This option which would have been applicable to McNary and John Day, was not implemented for lack of consensus and/or conclusive tests results. Redistribution of spill at The Dalles to reduce high TDG during high fish passage hours was also considered but ran up against NMFS's interpretation of the Biological Opinion. NMFS declared that the 64 percent spill for-fish-passage at The Dalles should be calculated on an instantaneous basis, not as a daily average.

Summer Spill

In the middle of July, heavy debris brought in by the high runoff caused the shutdown of the auxiliary water supply system and subsequently forced the fish ladder at Bonneville Second Powerhouse (PH2) out of service. To avoid attracting adults to a nonfunctional ladder the operation of the second powerhouse was severely restricted. As a result of the high runoff and limited PH2 operation, spill limits at Bonneville were increased. Formal state standards waivers were again sought by NMFS to cope with this emergency situation by allowing TDG to go as high as 125% TDG at Warrendale/Skamania and 120% at Camas/Washougal for the month of August 1997. The PH2 operation remained compromised for several weeks; it returned to normal in September.



Chelan County PUD experiments with a "notched" spillway gate at Rock Island Dam. Ideally, modifications to gates can improve both juvenile passage and water quality conditions. April, 1997.

4.3 Spill For Adult Fish Attraction

In accordance with the Fish Passage Plan, John Day, The Dalles and Bonneville spilled to provide attraction flow for migrating adult fish. Bonneville spilled 2.5 kcfs daily from March 1 through November 30; The Dalles, 1.5 kcfs during daylight hours from June 1 through August 15 and John Day, 1.8 kcfs during daylight hours from June 1 through October 31.

4.4 Debris Spill

"Debris spill" operations are special spill operations conducted by projects to pass debris from spillway forebay to spillway tailrace, as quickly and efficiently as possibly. Often, the debris spills are precipitated by reports of debris caught in areas such as bypass system guidance screens, gatewell orifices and dewatering screens. Debris build-up can affect generation by limiting unit loading when unit trash racks are affected.

These operations often entail passing large volumes of spill through only a few spillway gates. A forebay debris removal section has been added to the 1998 Fish Passage Plan addressing this issue. It includes a process for regional coordination to assure integration with other system operations and fish concerns.

4.5 Special Spill Operations

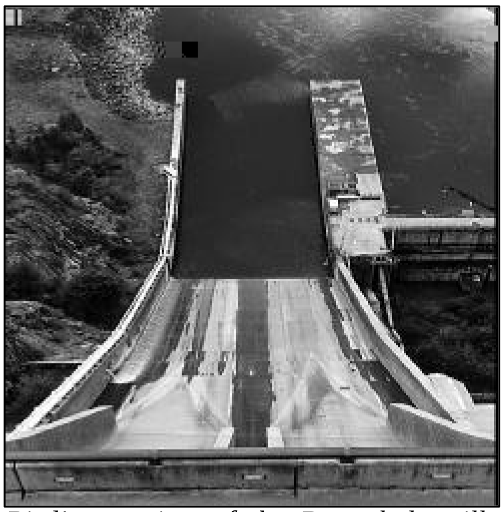
Bonneville Spring Creek Hatchery Release Operation. From March 13 to March 21 additional spill was released at Bonneville to help the sub-yearling chinook released from Spring Creek National Fish Hatchery travel to the estuary as timely as possible. There was some controversy about the length of the spill because monitoring equipment was not in place to determine when the majority of fish had passed. The Corps wanted to limit the spill to seven days because in the past the majority of fish had passed by that time. The fish agencies wanted the spill to last for 10 days because of the lack of monitoring equipment. Voluntary spill continued through 2000 on March 21, however flows were high enough to require involuntary spill through the beginning of the voluntary spill season. TDG levels did not exceed the 120% level at Warrendale and Skamania. Spill was managed at or below 115% for the average of the 12 highest hours in one calendar day at Camas/Washougal.

John Day Unit 1 Operation. BPA requested that they be allowed to run John Day Unit 1 at 150 MW, rather than at 100 MW, during the day, in order to reduce spill at the project. Unit 1 is normally operated at 100 MW output during the day to help adult fish passage. A test of this went on during the fish passage season, but led to inconclusive results.

IHR spill pattern test for navigation impacts. Tests were done determine the effects of different spill patterns on navigation. Based on the results of these tests changes were made to the spill patterns to ease the problems.

Little Goose and Lower Monumental Spill Pattern versus Adult Passage Tests. Walla Walla District conducted an adult passage study in May and June. The objective of the test was to evaluate adult fish passage given a nighttime spill pattern applied during the day versus the normal daytime pattern. To conduct the study, the nighttime spill pattern was applied during the daytime until at least five radio-tagged adult fish passed the project.

Every five fish, the pattern during the day switched between normal daytime pattern and nighttime pattern. This test did not result in a net increase in gas production because the nighttime patterns at both projects produce less gas per volume spill than the daytime patterns. Because of favorable passage results using the nighttime pattern during the day, a "nighttime" pattern may be applied during the 1998 passage season both during the day and night.



Bird's-eye view of the Dworshak spillway. September, 1997.

5. DISSOLVED GAS AND WATER TEMPERATURE CONDITIONS

5.1 Total Dissolved Gas

As a result of the voluntary and involuntary spill that occurred throughout the system, total dissolved gas exceeded 130% below several dams for extended periods during April through June, a situation similar to that of 1996. Tailrace areas most seriously affected were located below Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, and Bonneville (down to Kalama, WA).

In 1997, the number of days with total dissolved levels above 120% ranged from 60 (Lower Granite) to 135 days (Ice Harbor) below lower Snake River dams, and from 42 (Wauna Mills, OR) to 84 days (McNary) below lower Columbia River dams. In the summer, the above-120% conditions persisted for a few days in July below McNary and Bonneville (Skamania, WA). In the headwater areas, Dworshak released close to the maximum downstream channel capacity of 25 kcfs (including a spill of up to about 13 kcfs) during late April-early May and during July-August, creating 120% TDG especially between mid-April and mid-May.

Average monthly and maximum instantaneous forebay dissolved gas levels were generally higher than those recorded in 1996 because of the higher runoff, and also stayed at those high levels for longer periods. Most of the levels exceeding 130 percent saturation generally occurred at the same locations as last year. The monthly average for the system during May was 123.1% and for June, 124.6%. (See Table 3).

All of the monitoring stations exceeded the 115/120% total dissolved gas standards except for three (Peck, Lewiston and Lower Granite Forebay) on the average of 46.7% of the time. (See Table 14)

Maximum instantaneous dissolved gas levels were an average of about 2% higher, 133.5% in 1997 than during 1996 at 131.1%. (See Table 4). All but three stations reported dissolved gas in excess of 120 percent saturation at some point during the season, while maximum saturation exceeded 140 percent at several locations.

5.2 Water Temperature

Average monthly water temperatures were approximately the same in 1997 as in 1996 throughout the season. Temperatures for April – August in 1996 and 1997 varied by no more than 0.6 degrees C. The 1997 maximum temperature, 23.9 degrees C was measured at Bonneville forebay in late August.

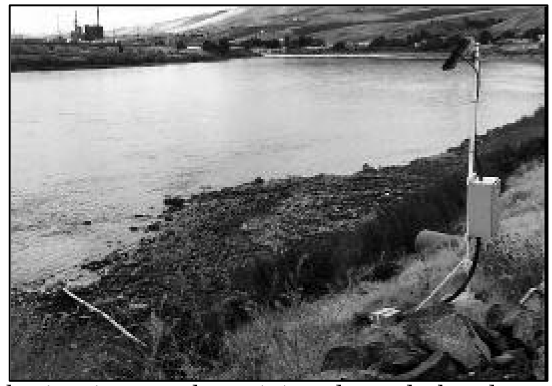
The average maximum temperature in 1997, at about 21 degrees C, was the same as in 1996 and the lowest observed since 1984. The next higher average maximum temperature, at about 22 degrees C, applied to 1989 and 1986. The highest average maximum temperature since 1984 occurred in 1992, 1991, and 1990 (at approximately 23 degrees C (see Tables 6 - 8).

Appendix I contains the results of a preliminary test performed by Bureau of Reclamation at Grand Coulee forebay. Differences in temperature and total dissolved gas were observed primarily at various depths in the forebay. The Bureau will be conducting additional profiles in 1998 to determine how project operations can be linked to downstream temperatures and TDG, and how the monitor can best be positioned to measure meaningful information.

6. MONITORING EQUIPMENT AND CALIBRATION

6.1 Equipment Used

Table 1 lists the station locations and corresponding equipment used in 1997. The Figures section contains geographical locations of the monitoring sites with respect to each



The Lewiston station(LEWI) during low flow, 2,000-5,000 cfs, in the Clearwater River. September, 1997.

project. Approximately the same number of HydroLab and Common Sensing monitoring instruments were used this monitoring year. The HydroLab (HL) instruments come in two basic sizes – the minisonde and the datasonde. The minisonde is small enough to fit in the PVC pipes used at many of the stations. The HL instruments can be outfitted with accessory sensors such as gas pressure, water temperature and depth. They also have a mechanized "water stirrer" that helps circulate water past the oxygen membrane for better oxygen measurements. The barometric pressure reading does not come with the HL and for many stations, an accessory Honeywell barometer was used.

The Common Sensing instruments are comprised of a monitor and accessory sensor. The 3-channel units measure (water temperature, atmospheric barometric and total dissolved gas pressures) and the 5-channel units (water temperature, atmospheric barometric, total dissolved, dissolved oxygen and nitrogen + argon gas pressures).

In 1997, the 8200-A Sutron Model DCPs continued to be used throughout most of the basin. The DCP logged each water quality parameter electronically every hour, on the hour, and stored the information in the DCP memory. Every four hours, the DCP transmitted the most recent 12 hours of logged data to the GOES satellite. Consequently, each piece of data was transmitted three times to protect against data loss. If transmission problems occurred between calibration visits, data could often be downloaded directly from the DCPs into a personal computer, and this data was forwarded to CROHMS.

In the Walla Walla District (NWW), all stations transmitted data through Zeno data collection platforms. DCPs contained a 900 MHz spread spectrum radio that transmitted data either directly or via standard modem or phone line to one of eight remote PCs. NWW solved many of their maintenance and programming challenges they faced in 1996 and the monitoring season went well. There were still some problems with modem communication to phone lines, project PCs off line and occasional transmission glitches between NWW and Division. NWW transmitted approximately 72 hours worth of hourly data to CROHMS on the hour.

6.2 Instrument Calibration

Monitors were calibrated throughout the COE network once every two to three weeks. All of the parameters, except for dissolved oxygen, tracked well between calibration visits. In the Portland District, adjustments to the total dissolved gas parameter were less than 8 mm Mercury for 91.7% of the calibrations, resulting in a maximum difference of 1% total dissolved gas saturation. Of the remaining 8.2% of adjustments, a maximum adjustment of 16 millimeters Mercury was made, resulting in a 3% maximum difference in total dissolved gas saturation

In the Walla Walla District, a maximum difference observed between the total dissolved gas pressure parameter and the field calibration instrument was six millimeters of Mercury, or less than a total change of 1% total dissolved gas saturation. More detailed field calibration information and basic equipment performance summaries are included in Appendix F. These results suggest that the instruments performed reliably and that there is no need to improve equipment performance through more frequent visits.

Obvious anomalies in the CROHMS water quality data set were removed within one to five days by RCC. The F&WQ staff, RCC completed final corrections to the data set, at the end of the 1996-97 season. Table 9 summarizes the period of record for all stations.

Faith Ruffing, NWP Biologist, calibrating Camas/Washougal TDG station. July, 1997.

7. EXPENDITURES

7.1 Actual 1997 Expenditures

Total direct Corps expenditures for equipment installation, service and maintenance, and related contracts in 1997 amounted to about $641,000 (compared to $679,000 in 1996). A summary of major expenses is provided below.

	Cost ($)
Division	
1. Contracts ($)	0
2. Contract Admin.($)	0
3. Coordination ($)	36,000
4. Database ($)	35,000
Division Total	**71,000**
Seattle	
1. Contract Admin.	2,000
2. Contract	18,000
NWS Total	**20,000**
Walla Walla	
1. Contracts/maintenance	0
2. Contract/Install+O&M	0
3. Software/hardware/IM	88,000
4. In-house Labor	122,000
5. Phone/car/boat/communication.	10,000
NWW Total	**220,000**
Portland	
1. Contract Admin/Mgt.	56,000
2. Contracts USGS, etc.	264,000

3. In-house O&M	10,000
NWP Total	**330,000**
1997 Total Program Cost	**$641,000**

7.2 Potential Cost Cutting Measures

During the past two years, more time, more energy and more money have been placed onto the TDG monitoring effort. As a result, the completeness and timeliness of the data has improved, with the percent of "good and complete" TDG data received at the RCC increasing from 87.1 percent in 1995 to 88.6 percent in 1996 and 93.4 percent in 1997. At the same time, the cost of the program has also gone up from about $420,000 to close to $680,000 in FY96 and close to $640,000 in FY97. This cost increase prompted the Corps to discuss how to manage the program and strike a happy medium between cost and real need.

One of the options under consideration is to move the TDG monitoring program back to the RCC once again. Currently the database and real-time operational response to the data already reside at RCC, and the division office and TMT use the TDG data regularly. A program with centralized administration and uniform protocols and equipment, minimum duplication of efforts in data screening and analysis, more efficient coordination, and more directly tailored to real-time operational needs should result in cost savings under most circumstances.

Another possible alternative is to centralize the monitoring function within one district --a decision that would transcend traditional district boundaries.

The pros and cons of each possible centralization concept will continue to be discussed for some time in the context of Corps-wide centralization of reservoir regulation functions.

8. TOTAL DISSOLVED GAS ISSUES

8.1 General

During high flow years, it is difficult to effectively control spill and the resulting high TDG levels in the Columbia River Basin. Because of limited plant capacity, spill is required at most lower Snake River dams as soon as flows exceed 100 kcfs. At these and other projects in the system, decreasing spill through upstream storage or passing more water through the powerhouse is not always feasible. The need to operate all turbine units at flows within 1 percent of their peak efficiency flow to avoid more extensive damages to fish contributes to a de facto decrease in powerhouse capacities. Spilling for-fish-passage also increases TDG levels in the main stem Columbia and Snake Rivers. The often already supersaturated waters from Canada and the upper Snake River basin that enter Corps reservoirs tend to make matters even worse.

In 1997, the Corps continued making progress on the multi-year Dissolved Gas Abatement Study on structural and operational means for reducing dissolved gas saturation. Construction of eight spillway deflectors was completed at Ice Harbor in the fall of 1997, and 18 spillway deflectors were completed at John Day in the fall of 1997. These improvements have resulted in quick TDG relief for relatively low spill and low flows. The spill caps for the 120 percent TDG level will increase from 25 kcfs to about 50 kcfs at Ice Harbor, and from 12 kcfs to around 100 kcfs at John Day.

8.2 Need for Waivers

TDG and its spill component continued to be an issue in 1997. Waivers from Oregon, Washington and Idaho were provided at NMFS's request (or USFWS for the Spring Creek Hatchery Release) to temporarily raise the state TDG standards from 110% to 120% below the projects (see Table 14). DEQ and DOE signed waivers allowing exceedance of the standard between April 10 and August 31.

DOE and DEQ signed waivers allowing exceedance of the waiver during the Spring Creek Fish Hatchery release between March 13-23.

Both DOE and DEQ sent documentation allowing for a deviation from the waiver standards to 125% at Warrendale and to 120% at Camas/Washougal between the period August 1 through August 31. This deviation was created when the Bonneville powerhouse two adult fish collection system was only partially operating because of debris plugging and blown floor gratings in the collection system.

8.3 Actual TDG Incidences

In the mid-Columbia, local fish farmers questioned data quality at the station below Grand Coulee several times in the May-July time frame, especially on June 27-8, and again on June 30 and July 1. Attention to the station coincided with reports of fish kills in the net pens of a downstream fish farm between April 29 and May 10. Columbia River Fish Farms reported that mortality of pen fish was caused by "gas bubble disease." Reports of resident fish kills were also received after May 1.

The TDG and spill relationship at Grand Coulee is difficult to predict. BOR is addressing this issue by drafting a gas abatement plan to look at structural and operational alternatives to try and minimize gas production as possible.

There has been much speculation as to the cause of elevated GBT symptoms in juvenile fish at Rock Island Dam. Since little GBT monitoring has occurred upstream of Rock Island, it is difficult to determine the source or reason for the high incidence of symptoms.

8.4 Misleadingly High FPE Values

Fish passage efficiency (FPE) was higher as a result of the higher spill. According to an analysis performed by NMFS in their report to OR-DEQ in December 1997, McNary achieved an FPE of about 0.9 from April through the end of June, and greater than 0.6 thereafter until the end of August. Equivalent FPE values were as follows for the other lower Columbia River dams:

- The Dalles: greater than 0.8 between mid-April through end of August
- John Day: 0.7 during mid-April through end of June; greater than 0.4 thereafter
- Bonneville: about 0.7 during mid-April through end of June; and greater than 0.5 thereafter.

NMFS cautioned that these relatively high FPE values did not necessarily equate to high smolt survival because of the high spill level. Under normal spill conditions, spillway mortality has been measured at 0-2 percent. In 1997, survival tests at The Dalles indicated approximately 7-14% mortality under the extremely high spill flows prevalent during much of the spring and summer migration. It is suspected that the high mortality was, at least in part, due to physical injuries. It is unknown whether all fish passing this spillway or the spillways at other lower Snake and lower Columbia Rivers dams suffered the same mortality level. Based on the foregoing, a high value of fish passage efficiency brought about by high spill is not necessarily a good indication of high, safe fish passage rates over mainstem dams.

Given the sensitivity of the spill and the related TDG issue, TDG data continued to be closely scrutinized by various agencies and interest groups. As a result, the demands on the monitoring program continued to be high. More than ever, users expect high instrument performances, accurate and reliable information, and easy access to the data.


Pipe repair at Snake River tailwater station, 1997.

9. DATA ANALYSIS SUMMARIES

9.1 Maximum and Minimum Water Temperatures and Total Dissolved Gas

These plots show the maximum and minimum water temperatures (in degrees C) and Total Dissolved Gas values at all of the fixed monitoring sites for the April through September time frame. The 1997 data is plotted separately from the historic maximums and minimums. The data are grouped into six-hour averages.

Many of the 1997 TDG plots are higher than the historic maximums and minimums. And many of the 1997 water temperature plots are on the low side of the historic maximums and minimums. (See Appendix A).

9.2 Spill, Total Flow and TDG Plots

These plots show the 1997 total flow, spill and percentage of total dissolved gas saturation for Corps of Engineers, Bureau of Reclamation and Mid-Columbia PUD hydropower and storage projects and their respective downstream fixed monitoring sites. The data in these plots are six-hour averages and cover the period of April 1 through September 15. See Appendix B).

Appendix C shows similar plots for the period September 15, 1996 through March 31, 1997. However, plots were only presented where winter monitoring occurred.

9.3 TDG Rating Curves for Dworshak

Appendix H includes individual TDG rating curves for Dworshak. These plots show the expected gas levels given total flow and its spill portion. It appears that under low loading conditions (e.g.: one unit loaded lightly), gas saturation is as much as 6% higher than when all three units are operating at maximum loading. Likely, the activation of vacuum breakers in the unit scroll case under low loading injects air into the draft tube and subsequently into the river

9.4 Spill vs. TDG Regression Equations

The regression analyses are the foundation of this report (See Appendix D). These analyses are intended to help managers operate projects to reach respective TDG gas saturation levels.

There is a section in this appendix outlining the new gas production equations that University of Washington CRiSP modelers are using in their gas production-forecasting model. Most of their equations come from the Gas Abatement Study results.

Regression equations used by the Reservoir Control Center staff are also provided. These equations reflect gas production equations expected as gathered from the fixed monitoring sites. These two sets of WES and RCC equations do not differ empirically.

The plots show the expected gas production levels at the tailrace fixed monitors. Travel time of the water parcel was included when comparing the forebay gas value and the corresponding tailwater value. The correlation coefficients for all stations averaged 0.88, a higher value than in earlier reports, indicating that the equations are getting stronger as more data is screened out systematically. These data were grouped into six-hour averages.

This report contains a plot comparing gas production before and after the construction of four flip lips at Ice Harbor Dam. There is a notable decrease in gas production per volume spill after flip lip construction.

Also, for projects that have a different dayriety of regulating outlet configurations. They noted that the lowest TDG levels resulted when spill went through both the upper and lower level outlets operating in an over/under combination. "The increase in TDG caused by this flow rate was 26.3% with no power plant flow. The TDG reading was about 10% less than measured with either the upper or lower outlets operating separately with no power plant flow." (From, "Progress Report for the Outlet Works Testing Performed below the Grand Coulee Dam, March 1997, Frizell, BOR.")

A second test, scheduled in June, to test TDG levels given spillway versus regulating outlet spill was cancelled due to very high TDG and flow during 1997. Though this test was not performed, there is some analysis provided in Appendix D, showing how TDG levels measured during in-season spillway versus regulating outlets operation. Basically, it appears that TDG levels are lower when spill occurs over the spillway, versus the regulating outlets. However, the spillway can only be used when the forebay is above 1260 feet.

10.3 Mid-Columbia PUD's

Douglas County conducted weekly transects approximately 1.5 miles below Wells Dam to evaluate TDG conditions in the tailrace. Results of this work can be referenced in the following report: "Dissolved Gas Monitoring at Wells Dam, 1997," Klinge, 1998. The following plot provided by Douglas County is preliminary look at the difference between forebay and tailwater TDG as a function of spill. It is based on data from the fixed monitoring station in the Wells forebay and from limited tailwater samples collected weekly by boat between April – July 1997. Douglas County will be installing a fixed tailwater station in 1998 , 2.3 miles below Wells Dam.

Difference in forebay and tailwater TDG as a function of spill, Wells Dam, 1997.

Grant County PUD also conducted weekly transect measurements from shore to shore near the station below Wanapum Dam. There appears to be some uneven mixing occurring below Wanapum, possibly due to the numerous shallow areas and islands below the dam. The station, located mid-channel, appears to usually reflect approximately an average value of measurements.

Weekly transects along the width of the Priest Rapids Dam forebay were also taken, generally confirming that the station now in place appears to measure a median value relative to the other measurements. Similar weekly transect measurements from shore to shore near the station below Priest Rapids Dam reflected adequate mixing at this station. There appears to be considerable dissipation of gases occurring between the dam and this tailwater station.

10.4 Walla Walla District

NWW also conducted an adult fish passage test by applying a nighttime spill pattern for several days instead of the normal daytime pattern and observing trends in adult passage. (The nighttime pattern results in less gas per volume spill but is not used during the day because it may not be as effective for passing adults). Overall, the relationship between gas and spill is stronger during the nighttime spill pattern (the opposite of Little Goose). This station appears to be representing gas versus spill relatively well, with an r-squared during the day of 0.86 and during the evening of 0.92.

11. STAFF ACTIVITIES AND COORDINATION

The list of contact persons at the various monitoring sites is provided in Table 15. Coordination efforts have continued cooperatively between Division and District staff, contractors, procurement staff, project personnel, and outside agency representatives.

Dr. Bolyvong Tanovan, Chief of the Fish & Water Quality Section, served as Division TDG program coordinator. Ms. Cindy Henriksen, Chief of the Reservoir Control Center, and Mr. Bill Branch, Chief of the Water

Management Division, provided general guidance and supervision for the Corps monitoring activities.

Ms. Mary Todd Uhlir, hydrologic technician, continued to work with agencies, COE districts and PUDs in managing the TDG monitoring program data quality.

Mr. Aaron Brown, Cooperative Education Program student trainee, contributed greatly to the analysis provided in this report. He contributes throughout the season in screening data and making the needed corrections to the hourly data received from the field.

Ms. Nancy Yun, hydraulic engineer, continued to refine the necessary procedures for quickly and easily extracting data from the HEC-DSS Data Storage System. She also ran model scenarios using GASSPILL, COLTEMP AND HEC-5Q.

Other Division staff involved in data collection, retrieval and dissemination include Rick Delaney, Doris Spaulding, Scott Boyd and Jim Versteeg.

Several District staff members were instrumental in supporting the Corps TDG monitoring effort. In the Walla Walla District, Ben Tice and Rick Jones (Team Leader) spent considerable time operating and maintaining a relatively extensive monitoring network. Tom Miller, on a 2-year assignment to work with the WES team of DGAS, was back to the Walla Walla District in September 1997.

In the Portland District, Faith Ruffing, Jim Britton and Dick Cassidy (Section Chief), continued to work closely with their USGS contractors to gather timely and quality data in the Portland District. USGS was responsible for most of the station set-up, instrument calibration, data collection and transmission at the Lower Columbia stations.

In the Seattle District, Marian Valentine, Hydraulic Engineer, continued to oversee the monitoring efforts at Chief Joseph and below Libby.

Common Sensing Inc. (CSI) was under contract to the Bureau of Reclamation to provide biweekly maintenance service to tensionometers and DCPs. CSI manufactures TDG measuring instruments and is continually involved in upgrading and refining them for increased accuracy and reliability.

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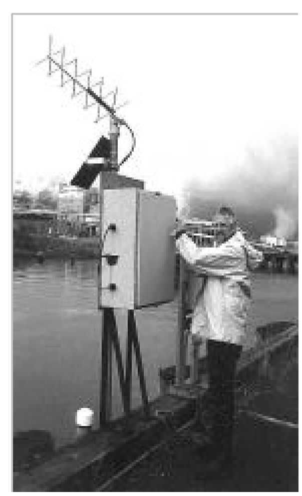
12. PLAN OF OPERATION FOR 1998

Appendix K contains a copy of the 1998 Corps of Engineers Plan of Action for Dissolved Gas Monitoring. Included in this document is a detailed overview of the monitoring program approach, responsibilities and implementation phases. This year, the plan of actions provided by the Mid-Columbia PUDs is also included.

The COE has agreed to install two new stations in the system. One, at the Clearwater and Snake River confluence on the Snake and the other on the Columbia and Snake River confluence on the Columbia.

Two new sites will be installed in 1998 by other agencies. Hungry Horse tailwater will be installed by BOR. Douglas has upgraded their monitoring equipment for 1998 to avoid lost data and will be adding a tailwater station below Wells Dam to better monitor dissolved gas and temperature changes between forebay and tailrace. The tailwater station



will be established on the Douglas County side of the river approximately 2.3 miles downstream of Wells. Data collection frequency will change to hourly for both the forebay and tailrace.

Other TDG related activities that the Dissolved Gas Team supports include:

- monitoring TDG in the Hell's Canyon reach by Idaho Power Company as part of their Federal Energy Regulatory Commission (FERC) re-licensing requirement
- extension of calibration schedule from once every two weeks to once every three weeks.

Seattle District plans to continue contracting with Common Sensing for station calibration and general maintenance. They will be automating their new tailwater station below Chief Joseph.

Walla Walla District plans to continue to refine their monitoring network by working out the remaining trouble spots, such as instrument placement, phone line and timer problems on the project PCs. NWW's system has the unique feature of being partially operable from the office. The Zeno DCP's are programmed for bi-directional communication between instrument and NWW server; the NWW server can interrogate the monitors directly to manipulate data collection frequency, view DCP settings, and turn on and off data transmission. Ultimately, Division will have the access to view the station platforms directly to help diagnose the source of data flow problems. All NWW sites are capable of data collection as often as every five minute.

Portland District will continue to contract with USGS, though the contract is smaller this year than last. Data will continue to be collected hourly and transmitted every four hours, and USGS will regularly inform Division of station status and data correction or deletion recommendations

Dwight Tanner, USGS, checking condition of TDG data platform at Wauna Mills. October, 1997.

13. CONCLUSIONS

As summarized in the tables and text, 1997 was a very high flow year. Much of the spill during the spill season and just prior to the season was involuntary. Gas levels reached levels higher than during previous monitoring periods and persisted for several weeks. Most of the data gathered this year from the participants in the monitoring effort was of high quality. Real-time receipt of data was exceptional, at 94.2%. The completeness of most of the data sets was exceptional as well, with a season average of 90.5% for the total network. Information was gathered by researchers during this high flow year will contribute greatly to the modeling efforts and understanding of gas dynamics in the Basin.