

SECTION 51 45 11
CUTTER RESERVOIR BATHYMETRIC REPORT

PART 1 GENERAL

RECLAMATION
Managing Water in the West

Hydraulic Laboratory Technical Memorandum PAP-1039

**Scanning Sonar Survey Report
For Cutter Reservoir, Navajo Indian
Irrigation Project – New Mexico**

Single-Axis Sonar Survey of the River Outlet Works Intake
Structure



U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

September 2011

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Structure**


Prepared: Tracy B. Vermeyen, P.E.

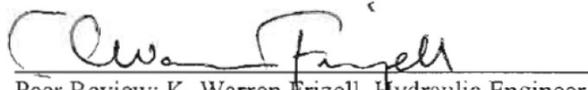
9/2/2011

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9/2/2011

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8/30/2011

Date

Hydraulic Investigations and Laboratory Services Group, 86-68460



U.S. Department of the Interior
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Denver, Colorado

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Introduction

The Technical Service Center's (TSC) Hydraulic Investigations and Laboratory Services Group (86-68460) was requested by TSC designers to perform an underwater sonar inspection of the river outlet works intake structure at Cutter Dam and reservoir and to collect water quality samples for the design of a water treatment plant. A secondary component to the project was a bathymetry survey of Cutter Reservoir.

Equipment

Scanning Sonar

A Kongsberg Mesotech MS1000 scanning sonar system was used for the imaging and bathymetry data collection at the river outlet intake structure, figure 1. The MS1000 system with a 675 kHz scanning sonar was used to collect an accurate two dimensional representation of underwater structural features and detailed bathymetric data. This sonar has a range of 1.5 to 330 ft with a resolution of about 0.06 ft. A detailed specification sheet for the sonar system is included as an appendix to this report.

The scanning sonar was used in two modes for this project:

- 1) Sonar imaging was performed using a fan beam which has a 30° wide beam angle
- 2) Profiling was performed using a cone beam which has a 1.7 ° beam angle



Figure 1. Photograph of the KML MS1000 Scanning Sonar System. (Photo courtesy of KML)

Acoustic Doppler Current Profiler

A Teledyne/RD Instruments acoustic Doppler current profiler (ADCP) was used to collect reservoir bathymetry data for this survey. A 1200 kHz Rio Grande ADCP was selected for this project because it had the necessary profiling range to sample the deepest depths of the reservoir. The ADCP was configured to collect depth readings without regard for the quality of water velocities.



Figure 2. TRDI Rio Grande ADCP (1200 kHz)

Global Positioning Systems

Two global positioning systems (GPS) were used for this project. Two Garmin handheld GPS's were used to provide GPS data to the bathymetry instruments (MS1000 and Rio Grande). The Garmin units were setup with WAAS differential correction to provide horizontal position accuracy of ± 7 to 9 ft. A Trimble R8 base station and rover system was used to survey the boat locations and water surface elevation. The Trimble system uses real time kinetic (RTK) differential correction to provide horizontal position accuracy of ± 0.06 ft. We attempted to connect the Trimble system to the ADCP data collection software, but had RS-232 communication difficulties that could not be overcome on the day of the survey.

Water Quality Profiler

A YSI 650 multi-parameter water quality sonde was used to collect a vertical profile of pH, specific conductance, dissolved oxygen, and temperature. The water quality profile was collected uplake from the dam at a location near the submerged streambed where the water depth was about 65 ft (figure 3).



Figure 3. Photograph of the water quality sampling location on Cutter Reservoir

Kemmerer Water Quality Sampler

A Kemmerer sampler was used for collecting water and plankton at a depth of 40 ft. The open sampler was lowered using a graduated rope and then both ends of the tube were closed by means of a weighted messenger. An undisturbed sample was brought to the surface and samples bottles were filled. This process was repeated until all the samples were collected.

Data Collection

The sonar imaging, bathymetric survey, and water quality sampling at Cutter Reservoir was performed on July 6 and 7, 2011. TSC personnel were assisted by Mr. Justin Gilbert from the Farmington Construction Office. Survey support was provided by Mr. Stan Bauer and Mr. John Mumaw.

Water quality samples were collected about 100 yards uplake from Cutter Dam. A YSI water quality sonde was used to collect a vertical profile of water depth, temperature, pH, specific conductivity, and dissolved oxygen. In about the same

location, a Kemmerer water sampler was used to retrieve water from a 40 ft depth to fill sample bottles for the suite of WQ parameters requested by water treatment plant designers. After filling, the sample bottles were labeled and placed in a cooler with ice. When sampling was complete, Justin Gilbert transported the coolers to the Farmington Office of Green Analytical where they were processed.

All sonar data were collected from a 14-ft-long Jon boat with a 15-HP motor with a jet drive unit.

For sonar imaging, the MS1000 was deployed using a 6-ft-tall tripod that was lowered to the reservoir bottom in the approach channel to the intake structure. The sonar transducer was about 3.5 above the reservoir bottom while scanning. The sonar was gimbal-mounted so that it would remain vertically oriented during scanning. The sonar is equipped with a tilt-pitch-roll sensor which was used to confirm the orientation of the instrument prior to making sonar measurements. A series of scans were made while moving closer and closer to the intake structure. GPS positions were noted at each scan location. Sonar scans were collected from 2:30 to 6:00 p.m. Sonar scan images from distances of 87, 34.4, 9.7, 12.1, 14.2 and 11.1 ft from the intake were processed for this report.

For the bathymetric survey, the ADCP was deployed on the starboard side while the MS1000 was on the port side. Each instrument was submerged about 8 inches below the water surface. The Trimble R8 rover was mounted directly above the ADCP (figure 4). The Garmin GPS units were fastened to their respective instrument mounts so that they supplied position data to the data collection software. Transects across the reservoir were made to collect the bottom depths. Data from both instruments were collected on a single laptop computer. The scanning sonar was used to collect 28,000 profile points (soundings) and the ADCP was used to collect 20,000 depth soundings.



Figure 4. Trimble R8 GPS receiver fastened to the ADCP mount.

Water Quality

The YSI water quality profile data are summarized in table 1. The reservoir was weakly stratified with a surface temperature of 53.1°F and a bottom temperature of 49.7°F. The reservoir has a high concentration of dissolved oxygen and was supersaturated up to 119% at the water surface and 101% near the reservoir bottom. The average specific conductivity was 240 $\mu\text{S}/\text{cm}$ and an average pH of 8.0. Analyses of reservoir water samples for a wide range on constituents was completed by Green Analytical Laboratory (contractor) and the results are included as an appendix to this report.

Table 1. Water quality profile data collected in Cutter Reservoir on July 6, 2011.

Depth (m)	Temp. (°C)	Temp. (°F)	Specific Conductivity (µS/cm)	Dissolved Oxygen (mg/l)	Dissolved Oxygen (%sat)	pH
0.0	11.7	53.1	241	10.4	119.0	8.1
1.0	11.3	52.4	241	10.4	117.4	8.1
2.0	10.9	51.5	240	10.4	114.7	8.1
3.0	10.8	51.4	240	10.4	115.4	8.1
4.0	10.7	51.3	240	10.4	115.1	8.1
5.0	10.5	51.0	240	10.2	113.0	8.0
6.0	10.5	50.9	240	10.2	112.8	8.0
7.0	10.5	50.9	240	10.2	112.2	8.1
8.0	10.5	50.8	240	10.2	112.1	7.9
9.0	10.5	50.8	240	10.2	111.9	8.0
10.0	10.4	50.7	240	10.1	111.5	7.9
12.0	10.3	50.6	240	10.0	110.3	7.9
14.0	10.1	50.2	241	9.9	108.2	7.9
16.0	10.1	50.3	242	9.9	108.2	7.9
18.0	10.1	50.2	242	9.8	107.6	8.1
20.0	9.9	49.7	243	9.3	101.0	8.0

Bathymetry Survey Near River Outlet Works Intake Structure

Bathymetry data collected along two longitudinal transects passing over the intake were analyzed to evaluate the accumulation of sediment in the approach channel to the intake. Table 2 contains elevations for structural features using the original construction datum. A second datum was used for the RTK-Survey and for recent aerial surveys. The RTK-Survey was set up using a panel point located on the dam crest with an elevation of 5983.33 US survey feet. The crest of the dam on the construction drawings (drawing no. 809-D-370, dated May 1, 1970) is at elevation 5980.0 US survey feet. The elevation difference between the two datums is 3.33 ft.

Bathymetry data indicate there is little to no accumulation of sediment on top of the intake structure or in the intake’s approach channel. Measured bed elevations were within ± 0.22 ft of the design elevations.

Table 2. Summary of elevations measured near the Cutter Dam River Outlet Works Structure (for construction datum).

Feature	Design elevation, ft	Bathymetry elevation, ft	Elevation difference, ft*
Top of ROW Intake Structure	5919.50	5919.35	-0.15
Approach channel invert at ROW Intake	5914.50	5914.60	+0.10
Approach channel invert about 75 ft uplake from ROW Intake	5914.50	5914.28	-0.22

*The uncertainty in sonar depth measurements is about ± 0.1 ft

Bathymetric Survey of Cutter Reservoir

Large portions of the ADCP/sonar data were corrupted by delays in logging GPS data because the serial communication buffers were overwhelmed with data. Data from both the MS1000 and ADCP were corrupted to the point of being unusable for sedimentation estimates. Figure 5 illustrates the bathymetric data collected in Cutter reservoir and how poor GPS positions impacts the bottom contours. Attempts to filter out the poor data points resulted in the removal of a large percentage of the data set.

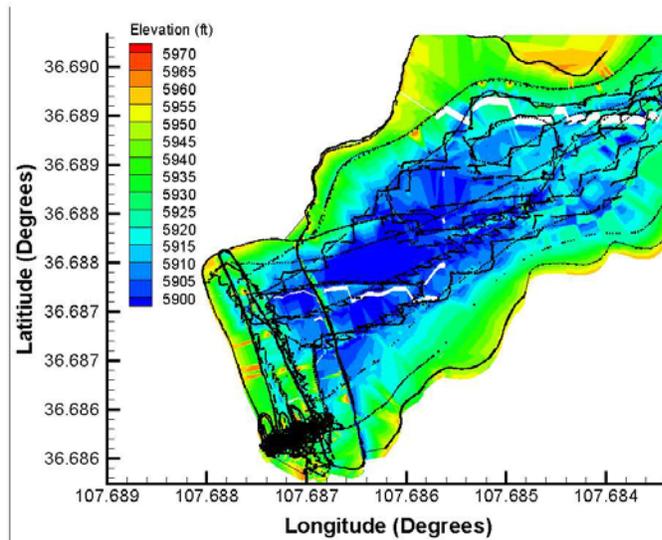


Figure 5. Bathymetric contour plot from raw depth soundings collected in Cutter Reservoir. Delays in processing incoming GPS data resulted in poor contour quality. Black dots are the individual depth measurements from the sonar and ADCP.

Sonar Images of River Outlet Works Intake Structure

Several sonar images of the river outlet works intake structure were collected using the sonar mounted to a tripod. The tripod was positioned at six locations along the intake approach channel. The following figures present the sonar images and brief annotations of the important features. It is important to note that sonar images of the intake features are not photographs and are open to interpretation.

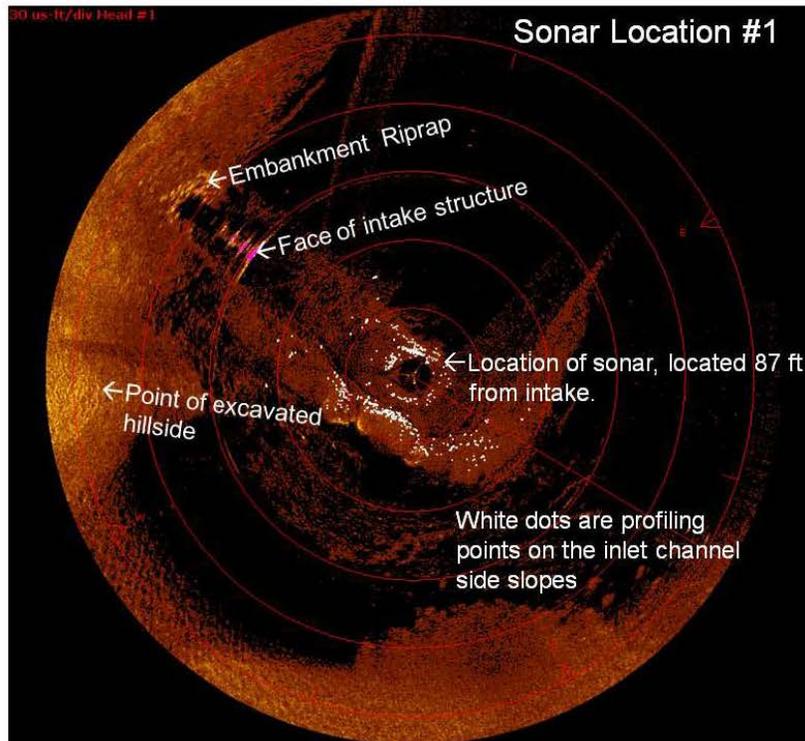


Figure 6. First sonar image was collected at location #1, which was about 87 ft uplake from the intake structure, using a 150 ft scanning range. The distance between concentric circles is 30 ft. This image contains the face of the intake, riprap where the ROW conduit enters the embankment, profile points along the approach channel, and local topography between the ROW and canal outlet works approach channel. Note: equally spaced lines between the intake and the embankment riprap are secondary acoustic reflections from the intake face.

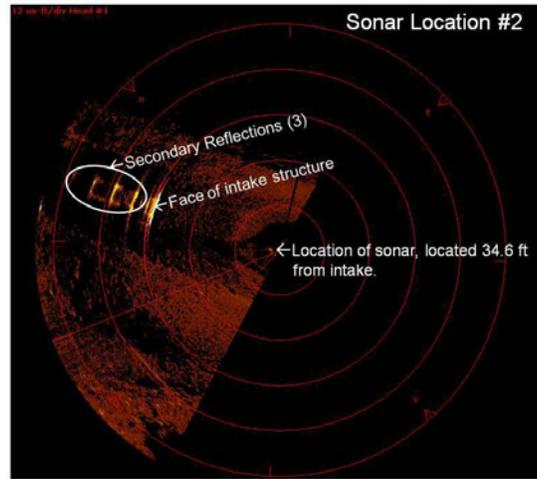


Figure 7. Sonar image was collected at location #2, which was about 34.6 ft uplake from the intake structure, using a 60 ft scanning range. The distance between concentric circles is 12 ft. The image shows the intake face and three secondary reflections. The image resolution is improved as the sonar is moved closer to the intake structure and the scan range is reduced.

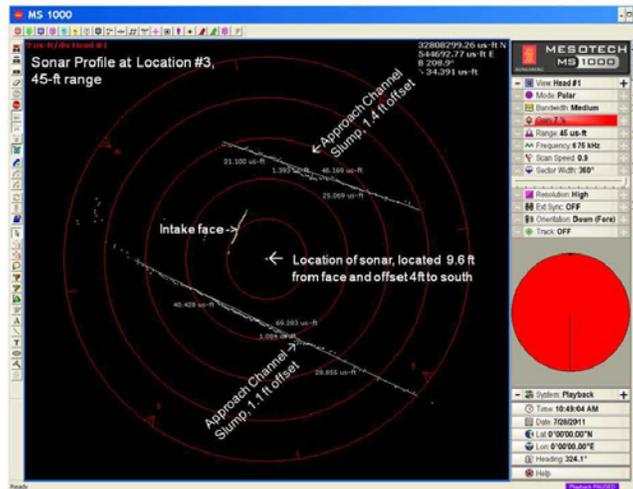


Figure 8. Sonar profile points collected at location #3 which was about 9.6 ft uplake and offset 4 ft to the south. The profiling range was 45 ft and the distance between concentric circles is 9 ft. This image captures the intake and local topography at elevation 5918.0 ft (construction datum). The profile points show some areas along the 2:1 slopes that are no longer parallel, but the changes are small – typically around a 1 ft offset from the original grade.

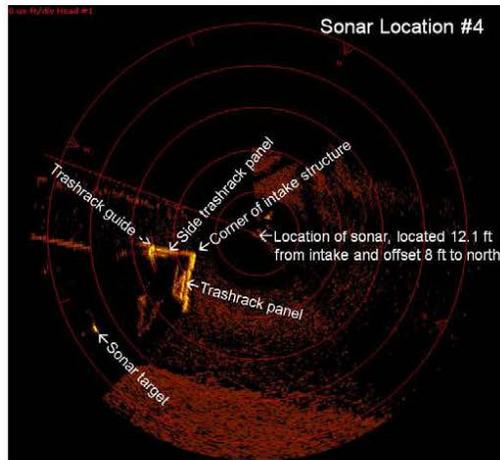


Figure 9. Sonar image collected at location #4 which was about 12.1 ft uplake and offset 8 ft to the north. The scanning range was 30 ft and the distance between concentric circles is 6 ft. This image captures the trashracks on two faces of the intake structure, both of which appear to be free on any large debris. At this resolution, the trash rack members are inset with some darker spots and the concrete surfaces are bright yellow.

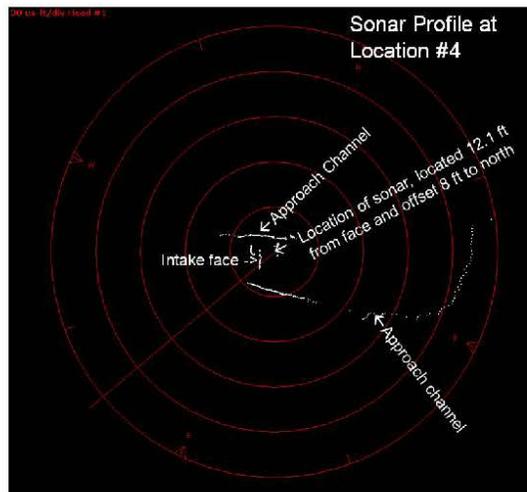


Figure 10. Sonar profile points collected at location #4 which was about 12.1 ft uplake and offset 8 ft to the north. The profiling range was 150 ft and the distance between concentric circles is 30 ft. This image captures the intake and local topography at elevation 5918.0 ft (construction datum) including the curved entrance to the approach channel.

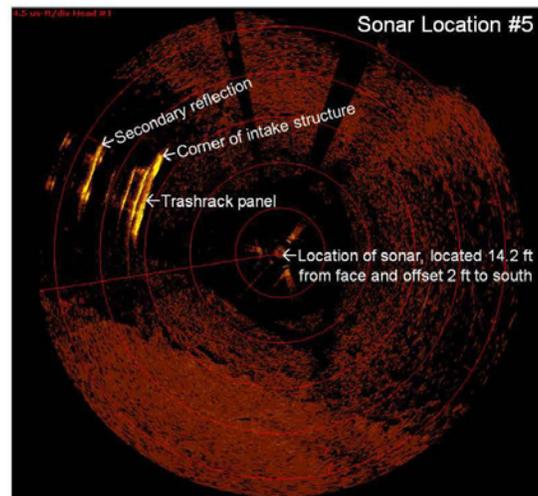


Figure 11. Sonar image collected at location #5 which was about 14.2 ft uplake and offset 2 ft to the south. The scanning range was 22.5 ft and the distance between concentric circles is 4.5 ft. This image captures the trashrack on the face of the intake structure. At this resolution, the trash rack members are visible (darker) and the concrete structure is lighter.

Conclusions

Sonar images of the intake structure and trashracks did not indicate any significant accumulation of sediment or debris. Likewise, images did not reveal any major damage to any of the concrete or trashracks of the outlet works. Note: the trashrack on the south side of the intake structure was not imaged.

The sonar resolution (± 0.06 ft) used for this project did not allow for detailed imaging of trashrack bars. As a result, the small scale damage to the trashrack panels and bars could not be determined.

Sonar profile data measured 3.5 ft above the intake approach channel invert elevation (El. 5918 - construction datum) did not show any major deformation to the approach channel side slopes.

It is important to note that sonar images of the intake features are not photographs and are open to interpretation. However, careful review of the sonar images did not indicate any abnormal features around the intake structure.

The bathymetric survey of Cutter reservoir was compromised by attempting to run two acoustic depth sounders using a single computer. The laptop computer was unable to log the GPS data fast enough to accurately establish the location of each sounding.

Appendix 1

Specification Sheet

1071-Series Sonar – Geared Fan/Cone Sonar Head

3000 m “High Resolution” Geared Fan/Cone Sonar Head Digital Telemetry



P/N 974-23050000

KONGSBERG

This version of the 1071-Series Sonar has been specifically designed to produce the highest resolution scanning sonar images possible with 675 kHz. Its design is targeted at bottom clearance, body recovery, underwater construction, pipeline inspection, cable route survey, bridge/pier inspection and applications where data clarity supercedes any other requirement.

This sonar head should also be considered in conditions where the in-water temperatures are lower than 4° C, or higher than 20° C. Domed, oil-filled heads may acoustically defocus beyond these temperature ranges. This sonar head incorporates the electronic advantages of increased sampling rates, wider receiver bandwidth, increased power output, and a very narrow horizontal beam pattern with the fan transducer. The telemetry is RS 485 and RS 232 compatible, and is automatically sensed and configured. The transducer is of a bare-shaft design, but the motor-end is oil compensated to prevent water ingress into the main electronic stack via the transducer shaft.

The sonar head is compatible with the MS1000 and MS900D Surface Processors. To take full advantage of the advanced features and high resolution this head has to be operated with the MS1000 processor.

Operating Frequency	675 kHz
Beam Width	0.9° X 30° Fan/1.7 X 1.7° Cone (nominal)
Range	0.5 - 100 Metres typical; 150 Metres obtainable
Range Resolution	≥ 19 mm (@ 1500m/sec speed of sound, 25 μs transmit pulse)
Sampling Resolution	≥ 2.5 mm
Scan Angle	360° continuous
Mechanical Step Size	≥ 0.225°
Scan Speed	nom 11 sec/360° @ 10 m and 1.8° step size (@ 230 kbits/sec.) nom 36 sec/360° @ 100m and 1.8° step size (@ 230 kbits/sec.)
Transmit Pulse Lengths	25 - 2500 μs
Transmit Power	OFF, 50 W nom, 500 W nom
Receiver Bandwidth	12/100 kHz
TVG Control	-20 to +100 dB
Telemetry	RS 485/RS 232 auto switching asynchronous serial data
Telemetry Rates	Downlink: 9600 Baud Uplink selectable: 230K, 115K, 57K, 38K, 19K, 9600 bits/sec automatic (to suit cable telemetry)
Power Requirements	33W, 22 - 60VDC
Temperature Ranges	-10 to +40° C operating -30 to +40° storage
Operating Depth	3000 meters
Connector	Seacon RMG-4-BCL (optional connectors; inquire to factory)
Materials	Aluminum 6061-T6, 300-Series SS
Dimensions	Diameter 3.5"/89 mm Length 22.4"/569 mm Transducer width 5.5"/140 mm
Weight	In air 13.5 lbs/6.1 kg, In water 6.5 lbs/2.9 kg
Options:	-7801 Built-in Security Key

Specifications subject to change without notice
P/N 974-23057901 Iss 1.5

KONGSBERG MESOTECH LTD, 1598 Kebet Way, Port Coquitlam B.C. Canada V3C 5M5
Tel: (604) 464 8144 Fax: (604) 941 5423

Appendix 2

Water Quality Sample Analyses for Cutter Reservoir

Prepared by:

Green Analytical Laboratories

75 Suttle Street

Durango, CO 81303



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11 August 2011

Tracy B. Vermeyan
Bureau of Reclamation - Denver
PO Box 25007, MC 86-68460
Denver, CO 80225
RE: Cutter Reservoir Surface

Enclosed are the results of analyses for samples received by the laboratory on 07/06/11 16:17. The data to follow was performed, in whole or in part, by a subcontract laboratory with an additional report attached.

If you any any further assistance, please feel free to contact me.

Sincerely,

Debbie Zufelt
Reports Manager



dzufelt@greenanalytical.com p: 970.247.4220 f: 970.247.4227 75 Suttle Street Durango, CO 81303

www.GreenAnalytical.com

Bureau of Reclamation - Denver PO Box 25007, MC 86-68460 Denver CO, 80225	Project: Cutter Reservoir Surface Project Name / Number: [none] Project Manager: Tracy B. Vermeyan	Reported: 08/11/11 10:24
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ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
Cutter Reservoir	1107025-01	Water	07/06/11 11:30	07/06/11 16:17

Green Analytical Laboratories

Debbie Zufelt, Reports Manager

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Bureau of Reclamation - Denver PO Box 25007, MC 86-68460 Denver CO, 80225	Project: Cutter Reservoir Surface Project Name / Number: [none] Project Manager: Tracy B. Vermeyan	Reported: 08/11/11 10:24
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Cutter Reservoir

1107025-01 (Water)

Analyte	Result	Reporting Limit	Units	Dilution	Analyzed	Method	Notes	Analyst
*** DEFAULT GENERAL METHOD ***								
Langlier Index	0.0100		[blank]	1	08/01/11	Calc		DJZ
Temperature	20.0		°C	1	08/01/11	Calc		DJZ
Total Metals by ICP								
Iron	ND	0.050	mg/L	1	07/15/11	6010		JGS
Dissolved Metals by ICP								
Aluminum	ND	0.050	mg/L	1	07/18/11	200.7		JGS
Boron	ND	0.300	mg/L	1	07/18/11	200.7		JGS
Calcium	30.6	1.00	mg/L	1	07/18/11	200.7		JGS
Hardness	101	6.62	mg/L	1	07/18/11	Calc		JGS
Iron	ND	0.050	mg/L	1	07/18/11	200.7		JGS
Magnesium	5.94	1.00	mg/L	1	07/18/11	200.7		JGS
Potassium	1.88	1.00	mg/L	1	07/18/11	200.7		JGS
Silica (SiO2)	13.0	1.07	mg/L	1	07/18/11	[CALC]		JGS
Silicon	6.07	0.500	mg/L	1	07/18/11	200.7		JGS
Sodium	13.7	1.00	mg/L	1	07/18/11	200.7		JGS
Strontium	0.296	0.100	mg/L	1	07/18/11	200.7		JGS
Total Metals by ICPMS								
Antimony	ND	0.0005	mg/L	1	07/22/11	6020		JGS
Arsenic	0.0006	0.0005	mg/L	1	07/22/11	6020		JGS
Barium	0.0627	0.0005	mg/L	1	07/22/11	6020		JGS
Beryllium	ND	0.0005	mg/L	1	07/22/11	6020		JGS
Cadmium	ND	0.0001	mg/L	1	07/22/11	6020		JGS
Chromium	ND	0.0010	mg/L	1	07/22/11	6020		JGS
Copper	0.0010	0.0001	mg/L	1	08/03/11	6020		JGS
Lead	ND	0.0005	mg/L	1	07/22/11	6020		JGS
Manganese	0.0023	0.0010	mg/L	1	08/03/11	6020		JGS
Selenium	0.0021	0.0020	mg/L	1	08/03/11	6020		JGS
Thallium	ND	0.0001	mg/L	1	07/22/11	6020		JGS

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Debbie Zufelt, Reports Manager

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Bureau of Reclamation - Denver PO Box 25007, MC 86-68460 Denver CO, 80225	Project: Cutter Reservoir Surface Project Name / Number: [none] Project Manager: Tracy B. Vermeyan	Reported: 08/11/11 10:24
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Cutter Reservoir

1107025-01 (Water)

Analyte	Result	Reporting Limit	Units	Dilution	Analyzed	Method	Notes	Analyst
Dissolved Metals by ICPMS								
Manganese	0.0023	0.0005	mg/L	1	07/14/11	200.8		JGS
Nickel	0.0009	0.0005	mg/L	1	07/14/11	200.8		JGS
Silver	ND	0.0001	mg/L	1	07/19/11	200.8		JGS
Zinc	0.0056	0.0010	mg/L	1	07/14/11	200.8		JGS
Total Mercury								
Mercury	ND	0.0002	mg/L	1	07/12/11	245.1		JGS
General Chemistry								
Alkalinity, Bicarbonate	67.0	10.0	mg/L	1	07/18/11	2320 B		ABP
Alkalinity, Carbonate	12.0	10.0	mg/L	1	07/18/11	2320 B		ABP
Alkalinity, Hydroxide	ND	10.0	mg/L	1	07/18/11	2320 B		ABP
Alkalinity, Total	79.0	10.0	mg/L	1	07/18/11	2320 B		ABP
Ammonia	ND	0.0500	mg/L	1	07/11/11	350.1		KLJ
Bromide	0.188	0.100	mg/L	1	07/27/11	4500 Br		ABP
Chloride	ND	10.0	mg/L	1	07/21/11	4500Cl B		KLJ
Conductivity	246	1.00	uS/cm	1	07/11/11	2510B		KET
Cyanide, Total	ND	0.00500	mg/L	1	07/14/11	335.4		KLJ
Fluoride	ND	0.200	mg/L	1	07/25/11	4500F C		ABP
Nitrate as N	0.060	0.020	mg/L	1	07/15/11	353.2/Calc		KLJ
Nitrate/Nitrite as N	0.060	0.020	mg/L	1	07/15/11	353.2		KLJ
Nitrite as N	ND	0.020	mg/L	1	07/08/11	353.2		KLJ
Total Nitrogen	ND	0.520	mg/L	1	07/27/11	[CALC]		KLJ
Total Kjeldahl Nitrogen	ND	0.500	mg/L	1	07/27/11	EPA 351.2		KLJ
Ortho-Phosphate as P	ND	0.0500	mg/L	1	07/08/11	365.3		KLJ
pH	8.00		pH Units	1	07/07/11	150.1		KET
Phosphorus-Total Dissolved	ND	0.0500	mg/L	1	07/19/11	365.3		KLJ
Phosphorus, Total	ND	0.0500	mg/L	1	07/19/11	365.3		KLJ
TDS	145	10.0	mg/L	1	07/08/11	160.1/2540C		ABP
TSS	ND	2.00	mg/L	1	07/12/11	160.2/2540D		ABP
Sulfate	40.0	10.0	mg/L	1	07/22/11	4500SO4		ABP
Sulfide	ND	0.0500	mg/L	1	07/13/11	4500-S		ABP
Turbidity	1.06	0.0100	NTU	1	07/08/11	180.1		ABP

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Debbie Zufelt, Reports Manager

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Total Metals by ICP - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107110 - EPA 3010										
Blank (B107110-BLK1)										
				Prepared & Analyzed: 07/15/11						
Iron	ND	0.050	mg/L							
LCS (B107110-BS1)										
				Prepared & Analyzed: 07/15/11						
Iron	3.83	0.050	mg/L	4.00		95.8	85-115			
LCS Dup (B107110-BSD1)										
				Prepared & Analyzed: 07/15/11						
Iron	3.72	0.050	mg/L	4.00		93.0	85-115	3.00	20	

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Dissolved Metals by ICP - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
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Batch B107090 - Dissolved Metals

Blank (B107090-BLK1) Prepared: 07/13/11 Analyzed: 07/18/11										
Aluminum	ND	0.050	mg/L							
Boron	ND	0.300	mg/L							
Calcium	ND	1.00	mg/L							
Iron	ND	0.050	mg/L							
Magnesium	ND	1.00	mg/L							
Potassium	ND	1.00	mg/L							
Silicon	ND	0.500	mg/L							
Sodium	ND	1.00	mg/L							
Strontium	ND	0.100	mg/L							

LCS (B107090-BS1) Prepared: 07/13/11 Analyzed: 07/18/11										
Aluminum	4.97	0.050	mg/L	5.00		99.4	85-115			
Boron	4.82	0.300	mg/L	5.00		96.4	85-115			
Calcium	4.99	1.00	mg/L	5.00		99.8	85-115			
Iron	4.77	0.050	mg/L	5.00		95.4	85-115			
Magnesium	25.7	1.00	mg/L	25.0		103	85-115			
Potassium	10.0	1.00	mg/L	10.0		100	85-115			
Silicon	5.28	0.500	mg/L	5.00		106	85-115			
Sodium	8.03	1.00	mg/L	8.10		99.2	85-115			
Strontium	5.06	0.100	mg/L	5.00		101	85-115			

LCS Dup (B107090-BSD1) Prepared: 07/13/11 Analyzed: 07/18/11										
Aluminum	5.06	0.050	mg/L	5.00		101	85-115	1.84	20	
Boron	5.00	0.300	mg/L	5.00		100	85-115	3.75	20	
Calcium	5.05	1.00	mg/L	5.00		101	85-115	1.22	20	
Iron	4.85	0.050	mg/L	5.00		97.0	85-115	1.68	20	
Magnesium	26.0	1.00	mg/L	25.0		104	85-115	1.37	20	
Potassium	9.99	1.00	mg/L	10.0		99.9	85-115	0.108	20	
Silicon	5.41	0.500	mg/L	5.00		108	85-115	2.56	20	
Sodium	8.07	1.00	mg/L	8.10		99.7	85-115	0.514	20	
Strontium	5.12	0.100	mg/L	5.00		102	85-115	1.26	20	

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Total Metals by ICPMS - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107169 - EPA 3010M										
Blank (B107169-BLK1)										
				Prepared: 07/21/11 Analyzed: 07/22/11						
Antimony	ND	0.0005	mg/L							
Arsenic	ND	0.0005	mg/L							
Barium	ND	0.0005	mg/L							
Beryllium	ND	0.0005	mg/L							
Cadmium	ND	0.0001	mg/L							
Chromium	ND	0.0010	mg/L							
Lead	ND	0.0005	mg/L							
Thallium	0.0002	0.0001	mg/L							B1
LCS (B107169-BS1)										
				Prepared: 07/21/11 Analyzed: 07/22/11						
Antimony	0.0499	0.0005	mg/L	0.0500		99.9	85-115			
Arsenic	0.0438	0.0005	mg/L	0.0500		87.7	85-115			
Barium	0.0467	0.0005	mg/L	0.0500		93.5	85-115			
Beryllium	0.0467	0.0005	mg/L	0.0500		93.4	85-115			
Cadmium	0.0464	0.0001	mg/L	0.0500		92.8	85-115			
Chromium	0.0447	0.0010	mg/L	0.0500		89.4	85-115			
Lead	0.0459	0.0005	mg/L	0.0500		91.8	85-115			
Thallium	0.0488	0.0001	mg/L	0.0500		97.6	85-115			
LCS Dup (B107169-BS1)										
				Prepared: 07/21/11 Analyzed: 07/22/11						
Antimony	0.0500	0.0005	mg/L	0.0500		100	85-115	0.193	20	
Arsenic	0.0420	0.0005	mg/L	0.0500		84.1	85-115	4.17	20	
Barium	0.0469	0.0005	mg/L	0.0500		93.7	85-115	0.264	20	
Beryllium	0.0439	0.0005	mg/L	0.0500		87.9	85-115	6.16	20	
Cadmium	0.0479	0.0001	mg/L	0.0500		95.8	85-115	3.21	20	
Chromium	0.0452	0.0010	mg/L	0.0500		90.4	85-115	1.08	20	
Lead	0.0449	0.0005	mg/L	0.0500		89.9	85-115	2.12	20	
Thallium	0.0478	0.0001	mg/L	0.0500		95.5	85-115	2.16	20	

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Total Metals by ICPMS - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B108026 - EPA 3010M										
Blank (B108026-BLK1)										
				Prepared: 08/02/11 Analyzed: 08/03/11						
Copper	ND	0.0010	mg/L							B3
Manganese	ND	0.0010	mg/L							B3
Selenium	ND	0.0020	mg/L							B3
LCS (B108026-BS1)										
				Prepared: 08/02/11 Analyzed: 08/03/11						
Copper	0.0485	0.0010	mg/L	0.0500		97.0	85-115			
Manganese	0.0488	0.0010	mg/L	0.0500		97.6	85-115			
Selenium	0.217	0.0020	mg/L	0.250		86.6	85-115			
LCS Dup (B108026-BSD1)										
				Prepared: 08/02/11 Analyzed: 08/03/11						
Copper	0.0483	0.0010	mg/L	0.0500		96.7	85-115	0.292	20	
Manganese	0.0473	0.0010	mg/L	0.0500		94.6	85-115	3.21	20	
Selenium	0.214	0.0020	mg/L	0.250		85.7	85-115	1.04	20	

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Dissolved Metals by ICPMS - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107096 - Dissolved Metals										
Blank (B107096-BLK1)										
Silver	ND	0.0001	mg/L							Prepared: 07/14/11 Analyzed: 07/19/11
LCS (B107096-BS1)										
Silver	0.0496	0.0001	mg/L	0.0500		99.2	85-115			Prepared: 07/14/11 Analyzed: 07/19/11
LCS Dup (B107096-BS1)										
Silver	0.0487	0.0001	mg/L	0.0500		97.3	85-115	1.85	20	
Batch B107098 - Dissolved Metals										
Blank (B107098-BLK1)										
Manganese	ND	0.0005	mg/L							Prepared & Analyzed: 07/14/11
Nickel	ND	0.0005	mg/L							
Zinc	ND	0.0010	mg/L							
LCS (B107098-BS1)										
Manganese	0.0476	0.0005	mg/L	0.0500		95.2	85-115			Prepared & Analyzed: 07/14/11
Nickel	0.0469	0.0005	mg/L	0.0500		93.8	85-115			
Zinc	0.0451	0.0010	mg/L	0.0500		90.3	85-115			
LCS Dup (B107098-BS1)										
Manganese	0.0457	0.0005	mg/L	0.0500		91.3	85-115	4.18	20	
Nickel	0.0463	0.0005	mg/L	0.0500		92.6	85-115	1.30	20	
Zinc	0.0450	0.0010	mg/L	0.0500		90.1	85-115	0.247	20	

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Total Mercury - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107051 - EPA 245.1/7470										
Blank (B107051-BLK1)										
Mercury	ND	0.0002	mg/L							Prepared: 07/11/11 Analyzed: 07/12/11
LCS (B107051-BS1)										
Mercury	0.0024	0.0002	mg/L	0.00200		120	85-115			BS1
LCS Dup (B107051-BSD1)										
Mercury	0.0025	0.0002	mg/L	0.00200		124	85-115	2.83	20	BS1

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General Chemistry - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107053 - General Prep - Wet Chem										
Blank (B107053-BLK1) Prepared & Analyzed: 07/08/11										
Ortho-Phosphate as P	ND	0.0500	mg/L							
LCS (B107053-BS1) Prepared & Analyzed: 07/08/11										
Ortho-Phosphate as P	0.270	0.0500	mg/L	0.250		108	85-115			
LCS Dup (B107053-BSD1) Prepared & Analyzed: 07/08/11										
Ortho-Phosphate as P	0.275	0.0500	mg/L	0.250		110	85-115	1.83	20	
Batch B107054 - General Prep - Wet Chem										
Blank (B107054-BLK1) Prepared & Analyzed: 07/08/11										
Nitrite as N	ND	0.020	mg/L							
LCS (B107054-BS1) Prepared & Analyzed: 07/08/11										
Nitrite as N	0.110	0.020	mg/L	0.100		110	85-115			
LCS Dup (B107054-BSD1) Prepared & Analyzed: 07/08/11										
Nitrite as N	0.110	0.020	mg/L	0.100		110	85-115	0.00	15	
Batch B107062 - General Prep - Wet Chem										
Reference (B107062-SRMI) Prepared & Analyzed: 07/07/11										
pH	8.70		pH Units	8.80		98.9	90-110			
Batch B107072 - General Prep - Wet Chem										
Blank (B107072-BLK1) Prepared: 07/11/11 Analyzed: 07/15/11										
TDS	ND	10.0	mg/L							

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General Chemistry - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107072 - General Prep - Wet Chem										
Reference (B107072-SRM1)				Prepared: 07/11/11 Analyzed: 07/15/11						
TDS	4080	10.0	mg/L	4030		101	85-115			
Batch B107076 - General Prep - Wet Chem										
Blank (B107076-BLK1)				Prepared & Analyzed: 07/11/11						
Ammonia	ND	0.0500	mg/L							
LCS (B107076-BS1)				Prepared & Analyzed: 07/11/11						
Ammonia	2.57	0.0500	mg/L	2.50		103	80-120			
LCS Dup (B107076-BSD1)				Prepared & Analyzed: 07/11/11						
Ammonia	2.60	0.0500	mg/L	2.50		104	80-120	1.16	20	
Batch B107082 - General Prep - Wet Chem										
Blank (B107082-BLK1)				Prepared & Analyzed: 07/11/11						
Conductivity	ND	1.00	uS/cm							
Reference (B107082-SRM1)				Prepared & Analyzed: 07/11/11						
Conductivity	374	1.00	uS/cm	389		96.1	90-110			
Batch B107100 - General Prep - Wet Chem										
Blank (B107100-BLK1)				Prepared & Analyzed: 07/14/11						
Cyanide, Total	ND	0.00500	mg/L							

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General Chemistry - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107100 - General Prep - Wet Chem										
LCS (B107100-BS1) Prepared & Analyzed: 07/14/11										
Cyanide, Total	0.0540	0.00500	mg/L	0.0500		108	80-120			
LCS Dup (B107100-BSD1) Prepared & Analyzed: 07/14/11										
Cyanide, Total	0.0430	0.00500	mg/L	0.0500		86.0	80-120	22.7	20	
Batch B107102 - *** DEFAULT PREP ***										
Blank (B107102-BLK1) Prepared & Analyzed: 07/13/11										
Sulfide	ND	0.0500	mg/L							
LCS (B107102-BS1) Prepared & Analyzed: 07/13/11										
Sulfide	0.158	0.0500	mg/L	0.144		110	85-115			
LCS Dup (B107102-BSD1) Prepared & Analyzed: 07/13/11										
Sulfide	0.156	0.0500	mg/L	0.144		108	85-115	1.72	20	
Batch B107104 - *** DEFAULT PREP ***										
Blank (B107104-BLK1) Prepared & Analyzed: 07/07/11										
TSS	ND	2.00	mg/L							
Reference (B107104-SRMI) Prepared & Analyzed: 07/07/11										
TSS	126		mg/L	120		105	90-110			
Batch B107122 - General Prep - Wet Chem										
Blank (B107122-BLK1) Prepared & Analyzed: 07/15/11										
Nitrate/Nitrite as N	ND	0.020	mg/L							

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General Chemistry - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107122 - General Prep - Wet Chem										
LCS (B107122-BS1) Prepared & Analyzed: 07/15/11										
Nitrate/Nitrite as N	0.110	0.020	mg/L	0.100		110	85-115			
LCS Dup (B107122-BSD1) Prepared & Analyzed: 07/15/11										
Nitrate/Nitrite as N	0.100	0.020	mg/L	0.100		100	85-115	9.52	20	
Batch B107128 - General Prep - Wet Chem										
Blank (B107128-BLK1) Prepared & Analyzed: 07/08/11										
Turbidity	ND	0.0100	NTU							
Reference (B107128-SRM1) Prepared & Analyzed: 07/08/11										
Turbidity	15.0		NTU	20.0		75.0	75-125			
Batch B107144 - General Prep - Wet Chem										
Blank (B107144-BLK1) Prepared & Analyzed: 07/18/11										
Alkalinity, Total	ND	10.0	mg/L							
LCS (B107144-BS1) Prepared & Analyzed: 07/18/11										
Alkalinity, Total	102	10.0	mg/L	100		102	85-115			
LCS Dup (B107144-BSD1) Prepared & Analyzed: 07/18/11										
Alkalinity, Total	104	10.0	mg/L	100		104	85-115	1.94	20	
Batch B107158 - General Prep - Wet Chem										
Blank (B107158-BLK1) Prepared & Analyzed: 07/19/11										
Phosphorus, Total	ND	0.0500	mg/L							

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General Chemistry - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107158 - General Prep - Wet Chem										
LCS (B107158-BS1) Prepared & Analyzed: 07/19/11										
Phosphorus, Total	0.546	0.0500	mg/L	0.500		109	85-115			
LCS Dup (B107158-BSD1) Prepared & Analyzed: 07/19/11										
Phosphorus, Total	0.544	0.0500	mg/L	0.500		109	85-115	0.367	20	
Batch B107159 - General Prep - Wet Chem										
Blank (B107159-BLK1) Prepared & Analyzed: 07/19/11										
Phosphorus-Total Dissolved	ND	0.0500	mg/L							
LCS (B107159-BS1) Prepared & Analyzed: 07/19/11										
Phosphorus-Total Dissolved	0.546	0.0500	mg/L	0.500		109	0-200			
LCS Dup (B107159-BSD1) Prepared & Analyzed: 07/19/11										
Phosphorus-Total Dissolved	0.544	0.0500	mg/L	0.500		109	0-200	0.367	200	
Batch B107170 - General Prep - Wet Chem										
Blank (B107170-BLK1) Prepared & Analyzed: 07/21/11										
Chloride	ND	10.0	mg/L							
LCS (B107170-BS1) Prepared & Analyzed: 07/21/11										
Chloride	100	10.0	mg/L	100		100	85-115			
LCS Dup (B107170-BSD1) Prepared & Analyzed: 07/21/11										
Chloride	103	10.0	mg/L	100		103	85-115	2.96	20	

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Debbie Zufelt, Reports Manager

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Bureau of Reclamation - Denver PO Box 25007, MC 86-68460 Denver CO, 80225	Project: Cutter Reservoir Surface Project Name / Number: [none] Project Manager: Tracy B. Vermeyan	Reported: 08/11/11 10:24
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General Chemistry - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107189 - General Prep - Wet Chem										
Blank (B107189-BLK1) Prepared & Analyzed: 07/22/11										
Sulfate	ND	10.0	mg/L							
LCS (B107189-BS1) Prepared & Analyzed: 07/22/11										
Sulfate	54.0	10.0	mg/L	50.0		108	80-120			
LCS Dup (B107189-BSD1) Prepared & Analyzed: 07/22/11										
Sulfate	55.0	10.0	mg/L	50.0		110	80-120	1.83	20	
Batch B107204 - General Prep - Wet Chem										
Blank (B107204-BLK1) Prepared & Analyzed: 07/25/11										
Fluoride	ND	0.200	mg/L							
LCS (B107204-BS1) Prepared & Analyzed: 07/25/11										
Fluoride	1.03	0.200	mg/L	1.00		103	80-120			
LCS Dup (B107204-BSD1) Prepared & Analyzed: 07/25/11										
Fluoride	1.08	0.200	mg/L	1.00		108	80-120	4.51	20	
Batch B107223 - General Prep - Wet Chem										
Blank (B107223-BLK1) Prepared: 07/26/11 Analyzed: 07/27/11										
Total Kjeldahl Nitrogen	ND	0.500	mg/L							
LCS (B107223-BS1) Prepared: 07/26/11 Analyzed: 07/27/11										
Total Kjeldahl Nitrogen	0.996	0.500	mg/L	1.00		99.6	85-115			

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Bureau of Reclamation - Denver PO Box 25007, MC 86-68460 Denver CO, 80225	Project: Cutter Reservoir Surface Project Name / Number: [none] Project Manager: Tracy B. Vermeyan	Reported: 08/11/11 10:24
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General Chemistry - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B107223 - General Prep - Wet Chem										
LCS Dup (B107223-BSD1)					Prepared: 07/26/11 Analyzed: 07/27/11					
Total Kjeldahl Nitrogen	0.858	0.500	mg/L	1.00		85.8	85-115	14.9	20	
Batch B107226 - General Prep - Wet Chem										
Blank (B107226-BLKI)					Prepared & Analyzed: 07/27/11					
Bromide	ND	0.100	mg/L							
LCS (B107226-BS1)					Prepared & Analyzed: 07/27/11					
Bromide	0.0907	0.100	mg/L	0.100		90.7	85-115			
LCS Dup (B107226-BSD1)					Prepared & Analyzed: 07/27/11					
Bromide	0.0988	0.100	mg/L	0.100		98.8	85-115	8.55	20	

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Bureau of Reclamation - Denver PO Box 25007, MC 86-68460 Denver CO, 80225	Project: Cutter Reservoir Surface Project Name / Number: [none] Project Manager: Tracy B. Vermejan	Reported: 08/11/11 10:24
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Notes and Definitions

- BS1 Blank spike recovery above laboratory acceptance criteria. Results for analyte potentially biased high. Will reanalyze per client request.
- B3 Target analyte detected in method blank. Reporting limit elevated to account for blank result.
- B1 Target analyte detected in method blank at or above method reporting limit. Sample concentration found to be 10 times above the concentration found in the method blank or less than the reporting limit.
- DET Analyte DETECTED
- ND Analyte NOT DETECTED at or above the reporting limit
- NR Not Reported
- dry Sample results reported on a dry weight basis
*Results reported on as received basis unless designated as dry.
- RPD Relative Percent Difference
- LCS Laboratory Control Sample (Blank Spike)

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Tracy
Mike Hom
303-870-9178
303-548-2783
CHAIN OF CUSTODY RECORD

Page ___ of ___

Client: Bureau of Reclamation
Contact: Tracy B. Vermejan
Address: PO Box 25007, MC 86-684602
Denver, CO 80225
Phone Number: 303-445-2154
FAX Number: 303-445-6324
John (970) 399-8646

NOTES:
1) Ensure proper container packaging.
2) Ship samples promptly following collection.
3) Designate Sample Reject Disposition.

Table 1. - Matrix Type
1 = Surface Water, 2 = Ground Water
3 = Soil/Sediment, 4 = Rinse, 5 = Oil
6 = Waste, 7 = Other (Specify) _____

FOR GAL USE ONLY
GAL JOB #
1107-029

Lab Name: Green Analytical Laboratories (970) 247-4220 FAX (970) 247-4227

Address: 75 Suttle Street, Durango, CO 81303

Project Name: Cutter Reservoir Surface

Samplers Signature: _____

Sample ID	Collection		Collected by: (Init.)	Miscellaneous			Preservative(s)					Analyses Required	Comments
	Date	Time		Matrix Type From Table 1	No. of Containers	Sample Filtered? Y/N	Unpreserved (Ice Only)	HNO3	HCL	H2SO4	NAOH		
1. <u>Conductivity</u>	7/6	1130	MS SW	1	N	X							9.2°C
2. <u>Algalic Growth</u>	7/6	1155	MS SW	1	N	X							
3. <u>Algalic Growth</u>	7/6	1120	MS SW	1	N	X							
4. <u>Fecal Coliforms</u>	7/6	1115	MS	2	N	X							
5. <u>Total Virus</u>	7/6	1115	MS	1	N	X							
6. <u>Baby T & TRS</u>	7/6	1115	MS	1	N	X							
7. <u>Legionella</u>	7/6	1115	MS	1	N	X							
8. <u>TDC</u>	7/6	1120	MS	3	N	X							
9. <u>DOC/Sur</u>	7/6	1120	MS	3	N	X							
10. <u>UV ABS</u>	7/6	1115	MS	1	N	X							

Retained by: _____ Date: 7/6/11 Time: 1617

Received by: Shirley Paul Date: 7/6/11 Time: 1617

For GAL USE ONLY
Date: 7/6/11 Time: 1617

* Sample/Reject: Return Dispose Store (30 Days)



PHONE (575) 393-2326 ° 101 E. MARLAND ° HOBBS, NM 88240

July 20, 2011

Debbie Zufelt
Green Analytical Laboratories
75 Suttle Street
Durango, CO 81303

RE: B O R

Enclosed are the results of analyses for samples received by the laboratory on 07/07/11 10:50.

Cardinal Laboratories is accredited through Texas NELAP for:

Method SW-846 8021	Benzene, Toluene, Ethyl Benzene, and Total Xylenes
Method SW-846 8260	Benzene, Toluene, Ethyl Benzene, and Total Xylenes
Method TX 1005	Total Petroleum Hydrocarbons

Certificate number T104704398-08-TX. Accreditation applies to solid and chemical materials and non-potable water matrices.

Cardinal Laboratories is accredited through the State of Colorado Department of Public Health and Environment for:

Method EPA 552.2	Haloacetic Acids (HAA-5)
Method EPA 524.2	Total Trihalomethanes (TTHM)
Method EPA 524.4	Regulated VOCs (V2, V3)

Accreditation applies to public drinking water matrices.

This report meets NELAP requirements and is made up of a cover page, analytical results, and a copy of the original chain-of-custody. If you have any questions concerning this report, please feel free to contact me.

Sincerely,

A handwritten signature in cursive script that reads "Celey D. Keene".

Celey D. Keene
Lab Director/Quality Manager



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Analytical Results For:

Green Analytical Laboratories
 Debbie Zufelt
 75 Suttle Street
 Durango CO, 81303
 Fax To: (970) 247-4227

Received:	07/07/2011	Sampling Date:	07/06/2011
Reported:	07/20/2011	Sampling Type:	Water
Project Name:	B O R	Sampling Condition:	Cool & Intact
Project Number:	1107-025-01	Sample Received By:	Celey D. Keene
Project Location:	NOT GIVEN		

Sample ID: CUTTER RESERVOIR SURFACE (H101398-01)

Semi-volatile 8270C	mg/L	Analyzed By: CK								
Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier	
Pyridine	<0.005	0.005	07/19/2011	ND	0.010	102	0.0100	9.80		
N-Nitrosodimethylamine	<0.005	0.005	07/19/2011	ND	0.010	103	0.0100	10.7		
2-Picoline	<0.005	0.005	07/19/2011	ND	0.010	101	0.0100	10.6		
Methyl methanesulfonate	<0.005	0.005	07/19/2011	ND	0.010	98.7	0.0100	9.78		
Ethyl methanesulfonate	<0.005	0.005	07/19/2011	ND	0.010	102	0.0100	10.2		
Pentachloroethane	<0.005	0.005	07/19/2011	ND	0.010	99.8	0.0100	13.0		
Aniline	<0.005	0.005	07/19/2011	ND	0.010	102	0.0100	9.95		
Phenol	<0.005	0.005	07/19/2011	ND	0.011	106	0.0100	7.31		
2-Chlorophenol	<0.005	0.005	07/19/2011	ND	0.010	102	0.0100	9.95		
bis(2-Chloroethyl)ether	<0.005	0.005	07/19/2011	ND	0.011	107	0.0100	12.9		
1,4-Dichlorobenzene	<0.005	0.005	07/19/2011	ND	0.010	102	0.0100	10.5		
1,3-Dichlorobenzene	<0.005	0.005	07/19/2011	ND	0.012	116	0.0100	2.63		
Benzyl alcohol	<0.001	0.001	07/19/2011	ND	0.011	111	0.0100	2.47		
1,2-Dichlorobenzene	<0.001	0.001	07/19/2011	ND	0.011	108	0.0100	1.69		
bis(2-Chloroisopropyl)ether	<0.001	0.001	07/19/2011	ND	0.011	108	0.0100	3.00		
Acetophenone	<0.001	0.001	07/19/2011	ND	0.011	110	0.0100	2.20		
2-Methylphenol	<0.001	0.001	07/19/2011	ND	0.010	105	0.0100	1.14		
4-Methylphenol	<0.001	0.001	07/19/2011	ND	0.010	100	0.0100	0.895		
Hexachloroethane	<0.001	0.001	07/19/2011	ND	0.011	106	0.0100	2.88		
N-Nitrosodi-n-propylamine	<0.001	0.001	07/19/2011	ND	0.014	135	0.0100	1.42		
Nitrobenzene	<0.001	0.001	07/19/2011	ND	0.011	106	0.0100	0.853		
N-Nitrosopiperidine	<0.001	0.001	07/19/2011	ND	0.010	103	0.0100	1.07		

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Celey D. Keene, Lab Director/Quality Manager



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Analytical Results For:

Green Analytical Laboratories
 Debbie Zufelt
 75 Suttle Street
 Durango CO, 81303
 Fax To: (970) 247-4227

Received:	07/07/2011	Sampling Date:	07/06/2011
Reported:	07/20/2011	Sampling Type:	Water
Project Name:	B O R	Sampling Condition:	Cool & Intact
Project Number:	1107-025-01	Sample Received By:	Celey D. Keene
Project Location:	NOT GIVEN		

Sample ID: CUTTER RESERVOIR SURFACE (H101398-01)

Semi-volatile 8270C	mg/L	Analyzed By: CK								
Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier	
Isophorone	<0.001	0.001	07/19/2011	ND	0.011	111	0.0100	1.54		
2-Nitrophenol	<0.001	0.001	07/19/2011	ND	0.011	109	0.0100	1.94		
2,4-Dimethylphenol	<0.005	0.005	07/19/2011	ND	0.011	111	0.0100	3.95		
bis(2-Chloroethoxy)methane	<0.001	0.001	07/19/2011	ND	0.011	109	0.0100	2.70		
2,6-Dichlorophenol	<0.001	0.001	07/19/2011	ND	0.010	100	0.0100	4.39		
1,2,4-Trichlorobenzene	<0.005	0.005	07/19/2011	ND	0.010	105	0.0100	1.42		
Naphthalene	<0.001	0.001	07/19/2011	ND	0.011	110	0.0100	0.272		
2,4-Dichlorophenol	<0.001	0.001	07/19/2011	ND	0.011	108	0.0100	1.92		
4-Chloroaniline	<0.001	0.001	07/19/2011	ND	0.011	113	0.0100	1.79		
Hexachloropropene	<0.001	0.001	07/19/2011	ND	0.011	110	0.0100	0.818		
Hexachlorobutadiene	<0.001	0.001	07/19/2011	ND	0.010	104	0.0100	1.06		
N-Nitroso-di-n-butylamine	<0.001	0.001	07/19/2011	ND	0.011	109	0.0100	2.79		
4-Chloro-3-methylphenol	<0.001	0.001	07/19/2011	ND	0.011	108	0.0100	6.42		
Safrole	<0.001	0.001	07/19/2011	ND	0.011	108	0.0100	0.463		
2-Methylnaphthalene	<0.001	0.001	07/19/2011	ND	0.011	106	0.0100	1.61		
1,2,4,5-Tetrachlorobenzene	<0.001	0.001	07/19/2011	ND	0.010	104	0.0100	1.25		
Hexachlorocyclopentadiene	<0.001	0.001	07/19/2011	ND	0.011	106	0.0100	9.11		
2,4,6-Trichlorophenol	<0.001	0.001	07/19/2011	ND	0.011	105	0.0100	0.955		
2,4,5-Trichlorophenol	<0.001	0.001	07/19/2011	ND	0.011	106	0.0100	3.55		
Isosafrole	<0.001	0.001	07/19/2011	ND	0.011	109	0.0100	8.18		
2-Chloronaphthalene	<0.001	0.001	07/19/2011	ND	0.011	109	0.0100	6.84		
2-Nitroaniline	<0.001	0.001	07/19/2011	ND	0.011	113	0.0100	4.81		

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Celey D. Keene, Lab Director/Quality Manager



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Analytical Results For:

Green Analytical Laboratories
 Debbie Zufelt
 75 Suttle Street
 Durango CO, 81303
 Fax To: (970) 247-4227

Received:	07/07/2011	Sampling Date:	07/06/2011
Reported:	07/20/2011	Sampling Type:	Water
Project Name:	B O R	Sampling Condition:	Cool & Intact
Project Number:	1107-025-01	Sample Received By:	Celey D. Keene
Project Location:	NOT GIVEN		

Sample ID: CUTTER RESERVOIR SURFACE (H101398-01)

Semi-volatile 8270C	mg/L	Analyzed By: CK								
Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier	
Dimethylphthalate	<0.001	0.001	07/19/2011	ND	0.011	114	0.0100	6.52		
Acenaphthylene	<0.001	0.001	07/19/2011	ND	0.011	111	0.0100	7.55		
2,6-Dinitrotoluene	<0.001	0.001	07/19/2011	ND	0.011	106	0.0100	8.45		
3-Nitroaniline	<0.001	0.001	07/19/2011	ND	0.011	109	0.0100	2.22		
Acenaphthene	<0.001	0.001	07/19/2011	ND	0.011	107	0.0100	2.59		
2,4-Dinitrophenol*	<0.001	0.001	07/19/2011	ND	0.008	81.6	0.0100	10.0		
Dibenzofuran	<0.001	0.001	07/19/2011	ND	0.011	109	0.0100	0.642		
4-Nitrophenol	<0.001	0.001	07/19/2011	ND	0.009	93.2	0.0100	5.74		
Pentachlorobenzene	<0.001	0.001	07/19/2011	ND	0.010	103	0.0100	0.580		
2,4-Dinitrotoluene	<0.001	0.001	07/19/2011	ND	0.012	119	0.0100	4.21		
2-Naphthylamine	<0.001	0.001	07/19/2011	ND	0.009	91.2	0.0100	1.52		
1-Naphthylamine	<0.001	0.001	07/19/2011	ND	0.007	67.6	0.0100	8.32		
2,3,4,6-Tetrachlorophenol	<0.001	0.001	07/19/2011	ND	0.009	90.2	0.0100	11.2		
Fluorene	<0.001	0.001	07/19/2011	ND	0.011	106	0.0100	0.752		
Diethylphthalate	<0.001	0.001	07/19/2011	ND	0.011	113	0.0100	0.709		
4-Chlorophenyl-phenyl ether	<0.001	0.001	07/19/2011	ND	0.010	105	0.0100	0.381		
5-Nitro-o-toluidine	<0.001	0.001	07/19/2011	ND	0.012	118	0.0100	1.43		
4-Nitroaniline	<0.001	0.001	07/19/2011	ND	0.012	121	0.0100	2.60		
4,6-Dinitro-2-methylphenol	<0.001	0.001	07/19/2011	ND	0.010	96.4	0.0100	10.6		
Diphenylamine	<0.001	0.001	07/19/2011	ND	0.011	108	0.0100	1.74		
Azobenzene	<0.001	0.001	07/19/2011	ND	0.011	113	0.0100	0.0884		
1,3,5-Trinitrobenzene	<0.001	0.001	07/19/2011	ND	0.011	114	0.0100	7.28		

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Celey D. Keene, Lab Director/Quality Manager



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Analytical Results For:

Green Analytical Laboratories
 Debbie Zufelt
 75 Suttle Street
 Durango CO, 81303
 Fax To: (970) 247-4227

Received:	07/07/2011	Sampling Date:	07/06/2011
Reported:	07/20/2011	Sampling Type:	Water
Project Name:	B O R	Sampling Condition:	Cool & Intact
Project Number:	1107-025-01	Sample Received By:	Celey D. Keene
Project Location:	NOT GIVEN		

Sample ID: CUTTER RESERVOIR SURFACE (H101398-01)

Semi-volatile 8270C	mg/L	Analyzed By: CK								
Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier	
4-Bromophenyl-phenyl ether	<0.005	0.005	07/19/2011	ND	0.010	104	0.0100	2.66		
Phenacetin	<0.001	0.001	07/19/2011	ND	0.013	130	0.0100	4.06		
Diallate	<0.005	0.005	07/19/2011	ND	0.011	114	0.0100	0.614		
Hexachlorobenzene	<0.005	0.005	07/19/2011	ND	0.011	109	0.0100	1.20		
4-Aminobiphenyl	<0.001	0.001	07/19/2011	ND	0.013	130	0.0100	1.94		
Pentachlorophenol	<0.001	0.001	07/19/2011	ND	0.012	120	0.0100	17.8		
Pentachloronitrobenzene	<0.001	0.001	07/19/2011	ND	0.012	122	0.0100	6.79		
Pronamide	<0.001	0.001	07/19/2011	ND	0.011	114	0.0100	0.793		
Phenanthrene	<0.001	0.001	07/19/2011	ND	0.011	108	0.0100	0.918		
Anthracene	<0.001	0.001	07/19/2011	ND	0.011	110	0.0100	1.71		
Dinoseb	<0.005	0.005	07/19/2011	ND	0.009	92.2	0.0100	11.0		
Carbazole	<0.001	0.001	07/19/2011	ND	0.011	115	0.0100	2.07		
Di-n-butylphthalate	<0.005	0.005	07/19/2011	ND	0.012	124	0.0100	5.19		
Isodrin	<0.001	0.001	07/19/2011	ND	0.012	118	0.0100	3.02		
Fluoranthene	<0.001	0.001	07/19/2011	ND	0.011	115	0.0100	4.02		
Benzidine	<0.005	0.005	07/19/2011	ND	0.010	100	0.0100	5.53		
Pyrene	<0.001	0.001	07/19/2011	ND	0.011	111	0.0100	8.63		
Dimethylaminoazobenzene	<0.001	0.001	07/19/2011	ND	0.011	108	0.0100	19.1		
Chlorobenzilate	<0.001	0.001	07/19/2011	ND	0.011	108	0.0100	21.6		
Butylbenzylphthalate	<0.001	0.001	07/19/2011	ND	0.010	103	0.0100	20.5		
Benzo[a]anthracene	<0.001	0.001	07/19/2011	ND	0.010	101	0.0100	21.0		
3,3'-Dichlorobenzidine	<0.005	0.005	07/19/2011	ND	0.012	117	0.0100	2.59		

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Celey D. Keene, Lab Director/Quality Manager



PHONE (575) 393-2326 • 101 E. MARLAND • HOBBS, NM 88240

Analytical Results For:

Green Analytical Laboratories
Debbie Zufelt
75 Suttle Street
Durango CO, 81303
Fax To: (970) 247-4227

Received:	07/07/2011	Sampling Date:	07/06/2011
Reported:	07/20/2011	Sampling Type:	Water
Project Name:	B O R	Sampling Condition:	Cool & Intact
Project Number:	1107-025-01	Sample Received By:	Celey D. Keene
Project Location:	NOT GIVEN		

Sample ID: CUTTER RESERVOIR SURFACE (H101398-01)

Semi-volatile 8270C		mg/L		Analyzed By: CK						
Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier	
Chrysene	<0.001	0.001	07/19/2011	ND	0.011	107	0.0100	2.32		
bis(2-Ethylhexyl)phthalate	<0.005	0.005	07/19/2011	ND	0.012	115	0.0100	0.0868		
Di-n-octylphthalate	<0.005	0.005	07/19/2011	ND	0.011	109	0.0100	7.82		
Benzo[b]flouranthene	<0.001	0.001	07/19/2011	ND	0.011	108	0.0100	9.06		
Benzo[k]flouranthene	<0.001	0.001	07/19/2011	ND	0.010	96.7	0.0100	6.12		
Benzo[a]pyrene	<0.0002	0.0002	07/19/2011	ND	0.010	105	0.0100	4.19		
3-Methylcholanthrene	<0.001	0.001	07/19/2011	ND	0.015	154	0.0100	10.6		
Indeno[1,2,3-cd]pyrene	<0.001	0.001	07/19/2011	ND	0.013	125	0.0100	7.15		
Dibenz[a,h]anthracene	<0.001	0.001	07/19/2011	ND	0.013	128	0.0100	0.472		
Benzo[g,h,i]perylene	<0.001	0.001	07/19/2011	ND	0.012	116	0.0100	3.04		

Surrogate: 2-Fluorophenol 38.9 % 21-100
 Surrogate: Phenol-d5 25.6 % 10-94
 Surrogate: Nitrobenzene-d5 89.2 % 35-114
 Surrogate: 2-Fluorobiphenyl 95.8 % 43-116
 Surrogate: 2,4,6-Tribromophenol 126 % 10-123
 Surrogate: Terphenyl-d4 104 % 33-141

Volatile 8260		mg/L		Analyzed By: CDK						
Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier	
Dichlorodifluoromethane	<0.001	0.001	07/08/2011	ND	0.017	86.0	0.0200	3.79		
Chloromethane	<0.001	0.001	07/08/2011	ND	0.019	93.0	0.0200	4.06		
Vinyl chloride	<0.001	0.001	07/08/2011	ND	0.020	97.5	0.0200	5.32		

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Analytical Results For:

Green Analytical Laboratories
 Debbie Zufelt
 75 Suttle Street
 Durango CO, 81303
 Fax To: (970) 247-4227

Received:	07/07/2011	Sampling Date:	07/06/2011
Reported:	07/20/2011	Sampling Type:	Water
Project Name:	B O R	Sampling Condition:	Cool & Intact
Project Number:	1107-025-01	Sample Received By:	Celey D. Keene
Project Location:	NOT GIVEN		

Sample ID: CUTTER RESERVOIR SURFACE (H101398-01)

Volatile 8260		mg/L		Analyzed By: CDK						
Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier	
Bromomethane	<0.001	0.001	07/08/2011	ND	0.021	103	0.0200	7.38		
Chloroethane	<0.001	0.001	07/08/2011	ND	0.020	101	0.0200	4.79		
Trichlorofluoromethane	<0.001	0.001	07/08/2011	ND	0.021	104	0.0200	1.10		
1,1-Dichloroethene	<0.001	0.001	07/08/2011	ND	0.020	101	0.0200	1.25		
Carbon disulfide	<0.001	0.001	07/08/2011	ND	0.023	116	0.0200	4.55		
Iodomethane	<0.001	0.001	07/08/2011	ND	0.022	112	0.0200	2.08		
Acrolein	<0.005	0.005	07/08/2011	ND	0.149	149	0.100	23.7		
Methylene chloride	<0.001	0.001	07/08/2011	ND	0.016	78.5	0.0200	19.4		
Acetone	<0.005	0.005	07/08/2011	ND	0.100	99.8	0.100	2.69		
trans-1,2-Dichloroethene	<0.001	0.001	07/08/2011	ND	0.019	97.1	0.0200	4.80		
Methyl t-Butyl Ether	<0.001	0.001	07/08/2011	ND	0.021	105	0.0200	3.92		
1,1-Dichloroethane	<0.001	0.001	07/08/2011	ND	0.020	99.1	0.0200	5.18		
Acrylonitrile	<0.001	0.001	07/08/2011	ND	0.020			1.33		
Vinyl acetate	<0.005	0.005	07/08/2011	ND	0.024	118	0.0200	6.08		
cis-1,2-Dichloroethene	<0.001	0.001	07/08/2011	ND	0.020	98.1	0.0200	3.74		
2,2-Dichloropropane	<0.001	0.001	07/08/2011	ND	0.023	115	0.0200	7.38		
Bromochloromethane	<0.001	0.001	07/08/2011	ND	0.021	103	0.0200	3.36		
Chloroform	<0.001	0.001	07/08/2011	ND	0.019	97.0	0.0200	2.35		
Carbon tetrachloride	<0.001	0.001	07/08/2011	ND	0.020	102	0.0200	5.07		
1,1,1-Trichloroethane	<0.001	0.001	07/08/2011	ND	0.021	104	0.0200	5.56		
1,1-Dichloropropene	<0.001	0.001	07/08/2011	ND	0.019	95.9	0.0200	2.48		
2-Butanone	<0.005	0.005	07/08/2011	ND	0.096	96.0	0.100	2.34		

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Celey D. Keene, Lab Director/Quality Manager



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Analytical Results For:

Green Analytical Laboratories
 Debbie Zufelt
 75 Suttle Street
 Durango CO, 81303
 Fax To: (970) 247-4227

Received:	07/07/2011	Sampling Date:	07/06/2011
Reported:	07/20/2011	Sampling Type:	Water
Project Name:	B O R	Sampling Condition:	Cool & Intact
Project Number:	1107-025-01	Sample Received By:	Celey D. Keene
Project Location:	NOT GIVEN		

Sample ID: CUTTER RESERVOIR SURFACE (H101398-01)

Volatiles 8260	mg/L		Analyzed By: CDK							
Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier	
Benzene	<0.001	0.001	07/08/2011	ND	0.019	95.8	0.0200	2.91		
1,2-Dichloroethane	<0.001	0.001	07/08/2011	ND	0.019	96.8	0.0200	0.103		
Trichloroethene	<0.001	0.001	07/08/2011	ND	0.019	92.6	0.0200	2.52		
Dibromomethane	<0.001	0.001	07/08/2011	ND	0.020	102	0.0200	1.94		
1,2-Dichloropropane	<0.001	0.001	07/08/2011	ND	0.020	98.6	0.0200	0.406		
Bromodichloromethane	<0.001	0.001	07/08/2011	ND	0.021	104	0.0200	2.23		
cis-1,3-Dichloropropene	<0.001	0.001	07/08/2011	ND	0.019	92.9	0.0200	1.74		
Toluene	<0.001	0.001	07/08/2011	ND	0.019	96.9	0.0200	2.77		
4-Methyl-2-pentanone	<0.005	0.005	07/08/2011	ND	0.090	90.1	0.100	0.702		
Tetrachloroethene	<0.001	0.001	07/08/2011	ND	0.018	91.0	0.0200	3.40		
trans-1,3-Dichloropropene	<0.001	0.001	07/08/2011	ND	0.018	89.2	0.0200	0.168		
1,1,2-Trichloroethane	<0.001	0.001	07/08/2011	ND	0.019	97.4	0.0200	0.00		
Dibromochloromethane	<0.001	0.001	07/08/2011	ND	0.019	94.0	0.0200	0.480		
1,3-Dichloropropane	<0.001	0.001	07/08/2011	ND	0.019	95.8	0.0200	1.25		
1,2-Dibromoethane	<0.001	0.001	07/08/2011	ND	0.020	99.0	0.0200	1.26		
2-Hexanone	<0.005	0.005	07/08/2011	ND	0.097	97.3	0.100	1.82		
Chlorobenzene	<0.001	0.001	07/08/2011	ND	0.019	96.2	0.0200	1.99		
Ethylbenzene	<0.001	0.001	07/08/2011	ND	0.020	97.8	0.0200	3.01		
1,1,1,2-Tetrachloroethane	<0.001	0.001	07/08/2011	ND	0.022	109	0.0200	2.37		
m+p - Xylene	<0.002	0.002	07/08/2011	ND	0.041	102	0.0400	2.71		
o-Xylene	<0.001	0.001	07/08/2011	ND	0.021	105	0.0200	3.55		
Total Xylenes	<0.003	0.003	07/08/2011	ND	0.062	103	0.0600	2.99		

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Celey D. Keene, Lab Director/Quality Manager



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Analytical Results For:

Green Analytical Laboratories
 Debbie Zufelt
 75 Suttle Street
 Durango CO, 81303
 Fax To: (970) 247-4227

Received:	07/07/2011	Sampling Date:	07/06/2011
Reported:	07/20/2011	Sampling Type:	Water
Project Name:	B O R	Sampling Condition:	Cool & Intact
Project Number:	1107-025-01	Sample Received By:	Celey D. Keene
Project Location:	NOT GIVEN		

Sample ID: CUTTER RESERVOIR SURFACE (H101398-01)

Volatile 8260		mg/L		Analyzed By: CDK						
Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier	
Bromoform	<0.001	0.001	07/08/2011	ND	0.019	93.4	0.0200	0.698		
Styrene	<0.001	0.001	07/08/2011	ND	0.021	105	0.0200	1.39		
Isopropylbenzene	<0.001	0.001	07/08/2011	ND	0.021	104	0.0200	4.26		
Bromobenzene	<0.001	0.001	07/08/2011	ND	0.020	99.6	0.0200	0.605		
n-Propylbenzene	<0.001	0.001	07/08/2011	ND	0.021	103	0.0200	3.86		
1,1,2,2-Tetrachloroethane	<0.001	0.001	07/08/2011	ND	0.021	107	0.0200	0.942		
2-Chlorotoluene	<0.001	0.001	07/08/2011	ND	0.020	101	0.0200	2.77		
1,2,3-trichloropropane	<0.001	0.001	07/08/2011	ND	0.021	104	0.0200	0.816		
1,3,5-Trimethylbenzene	<0.001	0.001	07/08/2011	ND	0.021	105	0.0200	2.51		
trans-1,4-Dichloro-2-butene	<0.001	0.001	07/08/2011	ND	0.020	101	0.0200	2.70		
4-Chlorotoluene	<0.001	0.001	07/08/2011	ND	0.019	96.9	0.0200	1.56		
tert-Butylbenzene	<0.001	0.001	07/08/2011	ND	0.020	102	0.0200	4.34		
1,2,4-Trimethylbenzene	<0.001	0.001	07/08/2011	ND	0.021	104	0.0200	2.49		
sec-Butylbenzene	<0.001	0.001	07/08/2011	ND	0.020	102	0.0200	2.99		
p-Isopropyltoluene	<0.001	0.001	07/08/2011	ND	0.021	103	0.0200	2.41		
1,3-Dichlorobenzene	<0.001	0.001	07/08/2011	ND	0.019	96.6	0.0200	0.988		
1,4 Dichlorobenzene	<0.001	0.001	07/08/2011	ND	0.020	97.8	0.0200	1.34		
n-Butylbenzene	<0.001	0.001	07/08/2011	ND	0.020	101	0.0200	3.16		
1,2-Dichlorobenzene	<0.001	0.001	07/08/2011	ND	0.020	100	0.0200	1.81		
1,2-Dibromo-3-chloropropane	<0.001	0.001	07/08/2011	ND	0.019	95.6	0.0200	0.574		
Hexachlorobutadiene	<0.001	0.001	07/08/2011	ND	0.022	108	0.0200	0.740		
1,2,4-Trichlorobenzene	<0.001	0.001	07/08/2011	ND	0.022	109	0.0200	0.692		

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Celey D. Keene, Lab Director/Quality Manager



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Analytical Results For:

Green Analytical Laboratories
 Debbie Zufelt
 75 Suttle Street
 Durango CO, 81303
 Fax To: (970) 247-4227

Received:	07/07/2011	Sampling Date:	07/06/2011
Reported:	07/20/2011	Sampling Type:	Water
Project Name:	B O R	Sampling Condition:	Cool & Intact
Project Number:	1107-025-01	Sample Received By:	Celey D. Keene
Project Location:	NOT GIVEN		

Sample ID: CUTTER RESERVOIR SURFACE (H101398-01)

Volatile 8260		mg/L		Analyzed By: CDK						
Analyte	Result	Reporting Limit	Analyzed	Method Blank	BS	% Recovery	True Value QC	RPD	Qualifier	
Naphthalene	<0.001	0.001	07/08/2011	ND	0.022	110	0.0200	0.825		
1,2,3-Trichlorobenzene	<0.001	0.001	07/08/2011	ND	0.021	105	0.0200	1.35		
<i>Surrogate: Dibromofluoromethane</i>	<i>91.4 %</i>	<i>80-120</i>								
<i>Surrogate: Toluene-d8</i>	<i>85.6 %</i>	<i>80-120</i>								
<i>Surrogate: 4-Bromofluorobenzene</i>	<i>91.5 %</i>	<i>80-120</i>								

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Notes and Definitions

- S-AC Acid surrogate recovery outside of control limits. The data was accepted based on valid recovery of remaining two acid surrogates.
- ND Analyte NOT DETECTED at or above the reporting limit
- RPD Relative Percent Difference
- ** Samples not received at proper temperature of 6°C or below.
- *** Insufficient time to reach temperature.
- Chloride by SM4500Cl-B does not require samples be received at or below 6°C
Samples reported on an as received basis (wet) unless otherwise noted on report

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A handwritten signature in cursive script, appearing to read "Celey D. Keene", is written over a horizontal line.

Celey D. Keene, Lab Director/Quality Manager



Cardinal
CHAIN OF CUSTODY RECORD

Page _____ of _____

Client: GREEN ANALYTICAL
Contact: DEBBIE ZUFELT
Address: 75 SUTTLE ST
DURANGO, CO 81303
Phone Number: 970-247-4220
FAX Number: 970-247-4227

NOTES:
1) Ensure proper container packaging.
2) Ship samples promptly following collection.
3) Designate Sample Reject Disposition.
PO# G A 11 - 152
Project Name: BOR

Table 1. – Matrix Type	
1 = Surface Water, 2 = Ground Water	
3 = Soil/Sediment, 4 = Rinsate, 5 = Oil	
6 = Waste, 7 = Other (Specify) _____	

FOR GAL USE ONLY
GAL JOB #

Samplers Signature: _____

PLEASE CALL WITH ANY QUESTIONS

Lab Name: Green Analytical Laboratories (970) 247-4220 FAX (970) 247-4227		Analyses Required										Comments					
Address: 75 Suttle Street, Durango, CO 81303																	
Sample ID	Collection		Miscellaneous				Preservative(s)										
	Date	Time	Collected by: (Init.)	Matrix Type From Table 1	No. of Containers	Sample Filtered ? Y/N	Unpreserved (Ice Only)	HNO3	HCL	H2SO4	NAOH	Other (Specify)					
H101398-																	
01 A-E 1. Cutter	7-6-11	1140	DJ	1	5	N	X	X						X	X		1107-025-01
2. Reservoir																	
3. Surface																	
4.																	
5.																	
6.																	
7.																	
8.																	
9.																	
10.																	
Relinquished by: <u>Debbie Zufelt</u>	Date: <u>7-6-11</u>	Time: <u>1600</u>	Received by: <u>Ally Keene</u>	Date: <u>7/7/11</u>	Time: <u>10:50</u>												
Relinquished by:	Date:	Time:	Received by:	Date:	Time:												

* Sample Reject: [] Return [] Dispose [] Store (30 Days)

1.5°C #26

Page 31 of 44

Page 12 of 12



One Government Gulch - PO Box 929

Kellogg ID 83837-0929

(208) 784-1258

Fax (208) 783-0891

Green Analytical Laboratories
75 Suttle Street
Durango, CO 81303

Work Order: W1G0121
Reported: 12-Jul-11 12:10

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Sampled By	Date Received
CUTTER RESERVOIR SURFACE	W1G0121-01	Surface Water	06-Jul-11 11:40	MJ	07-Jul-2011

Solid samples are analyzed on an as-received, wet-weight basis, unless otherwise requested.

Sample preparation is defined by the client as per their Data Quality Objectives.

This report supercedes any previous reports for this Work Order. The complete report includes pages for each sample, a full QC report, and a notes section.

The results presented in this report relate only to the samples, and meet all requirements of the NELAC Standards unless otherwise noted.

Case Narrative

07/12/2011mab: Report reissued. Sample name changed to Cutter per client.

SVL holds the following certifications: AZ:0538, CA:2080, CO:ID00019, FL(NELAC):E87993, ID:ID00019 & ID00965 (Microbiology), NV:ID000192007A, WA:1268, WY:ID00019

Work Order: **Page 32 of 44**



One Government Gulch - PO Box 929 Kellogg ID 83837-0929 (208) 784-1258 Fax (208) 783-0891

Green Analytical Laboratories 75 Suttle Street Durango, CO 81303	Work Order: W1G0121 Reported: 12-Jul-11 12:10
--	---

Client Sample ID: **CUTTER RESERVOIR SURFACE** Sampled: 06-Jul-11 11:40
 SVL Sample ID: **W1G0121-01 (Surface Water)** Sample Report Page 1 of 1 Received: 07-Jul-11
 Sampled By: MJ

Method	Analyte	Result	Units	RL	MDL	Dilution	Batch	Analyst	Analyzed	Notes
Classical Chemistry Parameters										
SM 2120B	Color @pH 6.0	10.0	Color Units	5.00	5.00		W128252	NCS	07/07/11 14:15	
SM 2150 B	Threshold Odor Number	< 1.00	T.O.N.	1.00			W128251	NCS	07/07/11 16:10	H3
SM 5540C	MBAS as LAS, mw 334	< 0.025	mg/L	0.025	0.004		W128246	SM	07/07/11 12:32	

This data has been reviewed for accuracy and has been authorized for release by the Laboratory Director or designee.

John Kern
 Laboratory Director

SVL holds the following certifications: AZ:0538, CA:2080, CO:ID00019, FL(NELAC):E87993, ID:ID00019 & ID00965 (Microbiology),
 NV:ID000192007A, WA:1268, WY:ID00019



One Government Gulch - PO Box 929 Kellogg ID 83837-0929 (208) 784-1258 Fax (208) 783-0891

Green Analytical Laboratories
 75 Suttle Street
 Durango, CO 81303
 Work Order: W1G0121
 Reported: 12-Jul-11 12:10

Quality Control - BLANK Data

Method	Analyte	Units	Result	MDL	MRL	Batch ID	Analyzed	Notes
Classical Chemistry Parameters								
SM 2120B	Color	Color Units	<5.00	5.00	5.00	W128252	07-Jul-11	
SM 2150 B	Threshold Odor Number	T.O.N.	<1.00		1.00	W128251	07-Jul-11	
SM 5540C	MBAS as LAS, mw 334	mg/L	<0.025	0.004	0.025	W128246	07-Jul-11	

Quality Control - LABORATORY CONTROL SAMPLE Data

Method	Analyte	Units	LCS Result	LCS True	% Rec.	Acceptance Limits	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
SM 2120B	Color	Color Units	25.0	25.0	100	60 - 140	W128252	07-Jul-11	
SM 5540C	MBAS as LAS, mw 334	mg/L	0.115	0.109	106	75 - 125	W128246	07-Jul-11	

Quality Control - DUPLICATE Data

Method	Analyte	Units	Duplicate Result	Sample Result	RPD	RPD Limit	Batch ID	Analyzed	Notes
Classical Chemistry Parameters									
SM 2120B	Color	Color Units	10.0	10.0	0.0	20	W128252	07-Jul-11	
SM 2150 B	Threshold Odor Number	T.O.N.	1.60	<1.00	<RL	20	W128251	07-Jul-11	
SM 5540C	MBAS as LAS, mw 334	mg/L	<0.025	<0.025	<RL	20	W128246	07-Jul-11	

Notes and Definitions

- H3 Sample was received and analyzed past holding time.
- LCS Laboratory Control Sample (Blank Spike)
- RPD Relative Percent Difference
- UDL A result is less than the detection limit
- R > 4S % recovery not applicable, sample concentration more than four times greater than spike level
- <RL A result is less than the reporting limit
- MRL Method Reporting Limit
- MDL Method Detection Limit
- N/A Not Applicable

SVL holds the following certifications: AZ:0538, CA:2080, CO:ID00019, FL(NELAC):E87993, ID:ID00019 & ID00965 (Microbiology), NV:ID000192007A, WA:1268, WY:ID00019



Asbestos • Lead • Environmental • Materials & Indoor Air Analysis

EMSL Analytical, Inc.

7330 S. Alton Way Building 12 Suite A Centennial, CO

Phone: (303) 740-5700 Fax: (303) 741-1400 Web: <http://www.emsl.com> Email: denverlab@emsl.com

Attn: **Debbie Zufelt**
Green Analytical
75 Suttle Street
Durango, CO 81303

EMSL Order: 221101995
 Customer ID: GRNA25
 Customer PO:
 EMSL Project ID:
 Received: 7/07/2011
 Analyzed: 7/13/2011

Fax: Phone: (970) 247-4220

Project: BOR

Test Report: Determination of Asbestos Structures >10µm in Drinking Water
Performed by the 100.2 Method (EPA 600/R-94/134)

Sample ID Client / EMSL	Sample Filtration Date/Time	Original Sample Vol. Filtered (ml)	Effective Filter Area (mm ²)	Area Analyzed (mm ²)	ASBESTOS				
					Asbestos Types	Fibers Detected	Analytical Sensitivity	Concentration MFL (million fibers per liter)	Confidence Limits
221101995-0001	7/7/2011 01:30 PM	100	1257	0.0680	None Detected	ND	0.19	<0.19	0.00 - 0.70

Sampled 7/6/11

Initial report from: 07/13/2011 18:13:17

Analyst(s)
 Erin Orthun (1)

Erin Orthun, Laboratory Manager
 or other Approved Signatory

Any questions please contact Erin Orthun.

Sample collection and containers provided by the client. acceptable bottle blank level is defined as ≤0.01MFL-10µm. ND=None Detected. This report may not be reproduced, except in full, without written permission by EMSL Analytical, Inc. The test results contained within this report meet the requirements of NELAC unless otherwise noted. This report relates only to the samples reported above. Samples received in good condition unless otherwise noted.

Samples analyzed by EMSL Analytical, Inc. Centennial, CO



AQUATIC CONSULTING & TESTING, INC.

1525 W. University Drive, Suite 106
P.O. Box 1510
Tempe, Arizona 85281
Phone: (480) 921-8044 • Fax: (480) 921-0049

Lic. No. AZ0003

LABORATORY REPORT

Client: Green Analytical Labs
75 Suttle Street
Durango, Co 81303

Date Submitted: 07/07/11
Date Reported: 07/25/11

Attn: Debbie Zufelt

Project: BOR 1107-025-01

RESULTS

Client ID: Cutter Reservoir Surface
ACT Lab No.: BT06260

Sample Type: Surface Water
Sample Time: 07/06/11 11:35

<u>Parameter</u>	<u>Analysis Date</u>		<u>Method No.</u>	<u>Result</u>	<u>Unit</u>
	<u>Start</u>	<u>End</u>			
Chlorophyll a	07/18/11	07/19/11	SM10200 H	0.90	ug/L

Reviewed by:

Frederick A. Amalfi, Ph.D.
Laboratory Director



Underwriters
Laboratories

LABORATORY REPORT

This report contains 8 pages.
(including the cover page)

If you have any questions concerning this report, please do not hesitate to call us at
(800) 332-4345 or (574) 233-4777.

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Underwriters Laboratories Inc. (UL).*

Underwriters Laboratories Inc.
110 S. Hill Street, South Bend, IN 46817-2702 USA
T-800-332-4345/F-574-233-4777/W ul.com

UL-SBN-REP-F-007-01

Effective Date: October 6, 2008

(cover) Page 1 of 1

Page 37 of 44



Underwriters
 Laboratories

Laboratory Report

Client: Green Analytical Laboratories
 Attn: Debbie Zufelt
 75 Suttle Street
 Durango, CO 81303

Report: 264556
 Priority: Standard Written
 Status: Final
 PWS ID: Not Supplied

Copies
 to: None

Sample Information					
UL ID #	Client ID	Method	Collected Date / Time	Collected By:	Received Date / Time
2475713	Cutter Reservoir Surface	5310 C	07/06/11 11:15	Client	07/07/11 10:15
2475713	Cutter Reservoir Surface	Fed. Reg.	07/06/11 11:15	Client	07/07/11 10:15
2475714	Cutter Reservoir Surface	1623	07/06/11 11:15	Client	07/07/11 10:15
2475715	Cutter Reservoir Surface	9223 B	07/06/11 11:15	Client	07/07/11 10:15
2475715	Cutter Reservoir Surface	SimPlate	07/06/11 11:15	Client	07/07/11 10:15
2475716	Cutter Reservoir Surface	9222 D	07/06/11 11:15	Client	07/07/11 10:15
2475717	Cutter Reservoir Surface	7500-Ra B	07/06/11 11:15	Client	07/07/11 10:15
2475717	Cutter Reservoir Surface	7500-Ra D	07/06/11 11:15	Client	07/07/11 10:15
2475718	Cutter Reservoir Surface	200.8	07/06/11 11:15	Client	07/07/11 10:15
2475718	Cutter Reservoir Surface	7110 B	07/06/11 11:15	Client	07/07/11 10:15
2475719	Cutter Reservoir Surface	5310 C	07/06/11 11:15	Client	07/07/11 10:15
2475720	Cutter Reservoir Surface	5910 B	07/06/11 11:15	Client	07/07/11 10:15
2475721	Cutter Reservoir Surface	521	07/06/11 11:15	Client	07/07/11 10:15
2475722	Cutter Reservoir Surface	10200	07/06/11 11:20	Client	07/07/11 10:15

Report Summary

Project: 1107-025-01 / BOR

Note: The sample submitted for Algae Enumeration and Identification analysis was concentrated and preserved by Analytical Services, Inc., Williston, VT and microscopic examination was performed by CH Diagnostics and Consulting Services, Berthoud, CO.

Note: The samples submitted for Methods 9222 D, 9223 B and SimPlate analyses were received beyond the twenty-four hour holding time. The client was notified of the situation, and analysis was authorized by Debbie Zufelt of Green Analytical Laboratories.

Detailed quantitative results are presented on the following pages. The results presented relate only to the samples provided for analysis.

We appreciate the opportunity to provide you with this analysis. If you have any questions concerning this report, please do not hesitate to call Kelly Trott at (574) 233-4777.

Note: This report may not be reproduced, except in full, without written approval from Underwriters Laboratories (UL).

Client Name: Green Analytical Laboratories

Report #: 264556

Kelly Goto

Authorized Signature

Project Manager

Title

8/9/2011

Date

Client Name: Green Analytical Laboratories
Report #: 264556

Client Name: Green Analytical Laboratories

Report #: 264556

Sampling Point: Cutter Reservoir Surface

PWS ID: Not Supplied

General Chemistry									
Analyte ID #	Analyte	Method	Reg Limit	MRL†	Result	Units	Preparation Date	Analyzed Date	UL ID #
---	Dissolved Organic Carbon	5310 C	---	0.500	2.36	mg/L	07/07/11 17:01	07/08/11 18:42	2475713
---	Total Organic Carbon (TOC)	5310 C	---	0.500	2.31	mg/L	---	07/08/11 15:05	2475719
---	UV absorbance at 254nm	5910 B	---	0.009	0.074	cm-1	---	07/07/11 13:04	2475720
---	SUVA	Federal Register	---	0.1	3.1	L/mg*m	---	07/19/11 07:41	2475713

Microbiology									
Analyte ID #	Analyte	Method	Reg Limit	MRL†	Result	Units	Preparation Date	Analyzed Date	UL ID #
---	Giardia	1623	---	0.093	< 0.093	cysts/L	---	07/08/11 08:50	2475714
---	Cryptosporidium	1623	---	0.093	< 0.093	oocysts/L	---	07/08/11 08:50	2475714
---	Heterotrophic Plate Count	SimPlate	---	2.0	100	MPN/ml	---	07/07/11 12:20	2475715
---	Fecal Coliform	9222 D	1 *	1	1	cfu/100 ml	---	07/07/11 11:55	2475716
---	Total Coliform	9223 B	---	N/A	Present	in 100 ml	---	07/07/11 12:32	2475715
---	Escherichia coli	9223 B	---	N/A	Present	in 100 ml	---	07/07/11 12:32	2475715

For method 1623: The calculated MRL value is dependant on the volume filtered and the volume analyzed for each sample.

Radionuclides									
Analyte ID #	Analyte	Method	Reg Limit	DL**	Result	Units	Preparation Date	Analyzed	UL ID #
7440-61-1	Uranium	200.8	20.1 *	0.67	0.26 ± 0.02	pCi/L	07/14/11 18:00	07/15/11 00:47	2475718
---	Gross Alpha	7110 B	15 *	3.0	0.00 ± 0.66	pCi/L	07/13/11 13:10	07/14/11 12:50	2475718
---	Gross Beta	7110 B	---	4.0	5.2 ± 1.2	pCi/L	07/13/11 13:10	07/14/11 12:50	2475718
13982-63-3	Radium-226	7500-Ra B	---	1.00	0.31 ± 0.32	pCi/L	07/11/11 09:49	07/19/11 07:25	2475717
15262-20-1	Radium-228	7500-Ra D	---	1.00	0.68 ± 0.47	pCi/L	07/11/11 09:49	07/18/11 09:35	2475717
---	Combined Radium	calc.	5 *	1.00	0.99 ± 0.56	pCi/L	07/11/11 09:49	07/19/11 07:25	2475717

** Detection Limit (DL) shall be that concentration which can be counted with a precision of plus or minus 100% at the 95 % confidence level.

Semi-volatile Organic Chemicals									
Analyte ID #	Analyte	Method	Reg Limit	MRL†	Result	Units	Preparation Date	Analyzed	UL ID #
930-55-2	N-Nitrosopyrrolidine (NPYR)	521	---	2.0	< 2.0	ng/L	07/14/11 07:50	07/20/11 10:52	2475721
924-16-3	N-Nitrosodi-N-butylamine (NDBA)	521	---	4.0	< 4.0	ng/L	07/14/11 07:50	07/20/11 10:52	2475721
55-18-5	N-Nitrosodiethylamine (NDEA)	521	---	5.0	< 5.0	ng/L	07/14/11 07:50	07/20/11 10:52	2475721
62-75-9	N-Nitrosodimethylamine (NDMA)	521	---	2.0	< 2.0	ng/L	07/14/11 07:50	07/20/11 10:52	2475721
621-64-7	N-Nitrosodi-N-propylamine (NDPA)	521	---	7.0	< 7.0	ng/L	07/14/11 07:50	07/20/11 10:52	2475721
10595-95-6	N-Nitrosomethylethylamine (NMEA)	521	---	3.0	< 3.0	ng/L	07/14/11 07:50	07/20/11 10:52	2475721
100-75-4	N-Nitrosopiperidine (NPIP)	521	---	2.0	< 2.0	ng/L	07/14/11 07:50	07/20/11 10:52	2475721

Reference Lab Tests									
Analyte ID #	Analyte	Method	Reg Limit	MRL†	Result	Units	Preparation Date	Analyzed	UL ID #
---	Algae, Total	10200	---	1	22	algal cells/ml	---	07/15/11 00:00	2475722

Client Name: Green Analytical Laboratories

Report #: 264556

† UL has demonstrated it can achieve these report limits in reagent water, but can not document them in all sample matrices.

Reg Limit Type:	MCL	SMCL	AL
Symbol:	*	^	!

Client Name: Green Analytical Laboratories

Report #: 264556

Lab Definitions

Continuing Calibration Check Standard (CCC) / Continuing Calibration Verification (CCV) / Initial Calibration Verification Standard (ICV) / Initial Performance Check (IPC) - is a standard containing one or more of the target analytes that is prepared from the same standards used to calibrate the instrument. This standard is used to verify the calibration curve at the beginning of each analytical sequence, and may also be analyzed throughout and at the end of the sequence. The concentration of continuing standards may be varied, when prescribed by the reference method, so that the range of the calibration curve is verified on a regular basis.

Internal Standards (IS) - are pure compounds with properties similar to the analytes of interest, which are added to field samples or extracts, calibration standards, and quality control standards at a known concentration. They are used to measure the relative responses of the analytes of interest and surrogates in the sample, calibration standard or quality control standard.

Laboratory Duplicate (LD) - is a field sample aliquot taken from the same sample container in the laboratory and analyzed separately using identical procedures. Analysis of laboratory duplicates provides a measure of the precision of the laboratory procedures.

Laboratory Fortified Blank (LFB) / Laboratory Control Sample (LCS) - is an aliquot of reagent water to which known concentrations of the analytes of interest are added. The LFB is analyzed exactly the same as the field samples. LFBs are used to determine whether the method is in control.

Laboratory Method Blank (LMB) / Laboratory Reagent Blank (LRB) - is a sample of reagent water included in the sample batch analyzed in the same way as the associated field samples. The LMB is used to determine if method analytes or other background contamination have been introduced during the preparation or analytical procedure. The LMB is analyzed exactly the same as the field samples.

Laboratory Trip Blank (LTB) - is a sample of laboratory reagent water placed in a sample container in the laboratory and treated as a field sample, including storage, preservation, and all analytical procedures. The LTB container follows the collection bottles to and from the collection site, but the LTB is not opened at any time during the trip. LTB is not exposed to site conditions or pumping and collection equipment. The LTB is primarily a travel blank used to verify that the samples were not contaminated during shipment.

Matrix Spike Duplicate Sample (MSD) / Laboratory Fortified Matrix Duplicate (LFD) - is a sample aliquot taken from the same field sample source as the Matrix Spike Sample to which known quantities of the analytes of interest are added in the laboratory. The MSD is analyzed exactly the same as the field samples. Analysis of the MSD provides a measure of the precision of the laboratory procedures in a specific matrix.

Matrix Spike Sample (MS) / Laboratory Fortified Matrix (LFM) - is a sample aliquot taken from field sample source to which known quantities of the analytes of interest are added in the laboratory. The MS is analyzed exactly the same as the field samples. The purpose is to demonstrate recovery of the analytes from a sample matrix to determine if the specific matrix contributes bias to the analytical results.

Quality Control Standard (QCS) / Second Source Calibration Verification (SSCV) - is a solution containing known concentrations of the analytes of interest prepared from a source different from the source of the calibration standards. The solution is obtained from a second manufacturer or lot if the lot can be demonstrated by the manufacturer as prepared independently from other lots. The QCS sample is analyzed using the same procedures as field samples. The QCS is used as a check on the calibration standards used in the method on a routine basis.

Reporting Limit Check (RLC) / Initial Calibration Check Standard (ICCS) - is a procedural standard that is analyzed each day to evaluate instrument performance at or below the minimum reporting limit (MRL).

Surrogate Standard (SS) / Surrogate Analyte (SUR) - is a pure compound with properties similar to the analytes of interest, which is highly unlikely to be found in any field sample, that is added to the field samples, calibration standards, blanks and quality control standards before sample preparation. The SS is used to evaluate the efficiency of the sample preparation process.



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South Bend, IN 46617
E: 1.800.332.4345
F: 574.233.3207
Order # 198844
Batch #

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Shaded area for UL use only

CHAIN OF CUSTODY RECORD

Page 1 of 1

REPORT TO: **UL**

SAMPLER (Signature): **MJ**

COMPLIANCE MONITORING: Yes No

STATE (of sample origin): **NM**

POPULATION SERVED: **NA**

SOURCE WATER: **NA**

PROJECT NAME: **BOR**

POB: _____

CHLORINATED: YES NO

OF CONTAINERS: **1**

MATRIX CODE: **SW SW**

TURNAROUND TIME: _____

LAB Number	COLLECTION		SAMPLING SITE	TEST NAME	SAMPLE REMARKS	CHLORINATED	# OF CONTAINERS	MATRIX CODE	TURNAROUND TIME
	DATE	TIME							
1	7-6-14	1120 X	Cutter Reservoir Surface	Algal Inhibition & Enumeration	1107-025-01	X	1	SW SW	
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									

RELINQUISHED BY (Signature): *Daniel E. Smith* DATE: 7/6/14 TIME: 1600 RECEIVED BY (Signature): *Daniel Brown* DATE: 7/11 TIME: 1055

RELINQUISHED BY (Signature): _____ DATE: _____ TIME: _____ RECEIVED BY (Signature): _____ DATE: _____ TIME: _____

RELINQUISHED BY (Signature): _____ DATE: _____ TIME: _____ RECEIVED BY (Signature): _____ DATE: _____ TIME: _____

RELINQUISHED BY (Signature): _____ DATE: _____ TIME: _____ RECEIVED BY (Signature): _____ DATE: _____ TIME: _____

LAB RESERVES THE RIGHT TO RETURN UNUSED PORTIONS OF NON-AQUEOUS SAMPLES TO CLIENT

MATRIX CODES:
 DW-DRINKING WATER
 RW-REAGENT WATER
 GW-GROUND WATER
 EW-EXPOSURE WATER
 SW-SURFACE WATER
 PW-POOL WATER
 WW-WASTE WATER

TURNAROUND TIME (TAT) - SURCHARGES
 TV* = Immediate Verbal: (3 working days) 100%
 IW* = Immediate Written: (3 working days) 125%
 SP* = Weekend, Holiday CALL
 STAT* = Less than 48 hours Effective Date: 05/08/2009

SW - Standard Written: (15 working days) 0%
RV* = Rush Verbal: (5 working days) 50%
RW* = Rush Written: (5 working days) 75%

CONVERTION: (water) _____ (gas) _____ (solid) _____

Special Handling: _____

Chlorine Residue: _____

Notes: _____

Sample analysis will be provided according to the standard UL GSA Water Services Terms, which are available upon request. Any other terms proposed by Customer are deemed material alterations and are rejected unless expressly agree to in writing by UL.

PART 2 PRODUCTS

Not Used

PART 3 EXECUTION

Not Used

END OF SECTION

SECTION 51 45 13
COAGULATION AND DBF FORMATION

PART 1 GENERAL

Analysis Results for
Coagulation Jar Testing and
Disinfection By-Product Formation for the
USBR Navajo/Gallup Water Supply Project
(September 2011 – Cutter Reservoir)

Testing Completed for:
United States Bureau of Reclamation
c/o Ronald LeBlanc
Mail Code 86-68120
Denver Federal Center
PO Box 25007
Denver, CO 80225

Analyses Performed at:
UNM Environmental Engineering Laboratories
Civil Engineering Department
Centennial Engineering Center, Room 3020
University of New Mexico
Albuquerque, NM 87131

Analyst: Jesse Dickson, Graduate Student

Supervisor: Dr. Kerry Howe
Associate Professor
Phone: 505-277-2702
Email: howe@unm.edu

Water sample collected: September 27, 2011
Final report date: January 5, 2012



Coagulation Jar Testing and Disinfection By-Product Formation Potential for the USBR Navajo/Gallup Water Supply Project

The United States Bureau of Reclamation is conducting studies to evaluate the treatability of the Cutter Reservoir in San Juan County in northwest New Mexico as a potential water supply for the Navajo/Gallup Water Supply Project. As part of that effort, the University of New Mexico (UNM) Environmental Engineering Laboratory conducted a series of jar tests to test the effectiveness of several coagulants for the removal of turbidity and natural organic matter. The coagulants included alum, polyaluminum chloride (PACl), and ferric chloride. In addition, UNM performed the incubation portion of disinfection by-product formation potential (DBFP) tests. Trihalomethane (THM) and haloacetic acid (HAA) analyses were performed by the Scientific Laboratory Division of the New Mexico Department of Health. This report provides the results of that testing.

Experimental Methods and Materials

Source water

Raw water was collected from the Cutter Reservoir by USBR personnel on September 27, 2011 and received at UNM the following day. The shipment consisted of 20 gallons of raw water, which was shipped in two plastic coolers that each contained two 5-gallon cubitainers. The temperature of the water when it arrived was 20.2 °C. The water was immediately stored in a walk-in 4 °C cold room when it was received at UNM. On the evening before each group of jar tests, water was taken out of the cold room and placed in a dark box in the laboratory so that it could come to room temperature for the tests. During the jar tests, the water was at room temperature (about 20 to 22 °C). Before each set of jar tests, the cubitainer was rolled on a countertop until the water inside was thoroughly homogenized to provide a consistent starting condition.

Coagulant chemicals

Alum, PACl, and ferric chloride were used for the tests. No polymers were used. All three coagulants were manufactured by Kemira and were received directly from the manufacturer. The concentration and density of the stock coagulants was provided on a specification sheet that arrived with the coagulant samples from Kemira; these are described in Table 1. A fresh 0.1-M stock solution of each coagulant was made for dosing during the jar testing.

Jar Test Procedures

The tests followed generally accepted jar test procedures, as described in references such as *Integrated Design and Operation of Water Treatment Facilities, 2nd Ed.* (Kawamura, 2000) and *AWWA Manual M37 - Operational Control of Coagulation and Filtration Processes* (AWWA, 2007). The tests were conducted using a 6-position jar tester (Phipps and Bird Model PB-700) and plastic 2-liter square jars (Phipps and Bird B-KER²). One set of jar tests was completed with each coagulant. Coagulant doses were calculated on a molar metal ion (Al^{3+} or Fe^{3+}) basis to

Navajo/Gallup Water Quality Treatability Study

Table 1 – Coagulant Chemicals Used for Jar Testing

	Alum	PACl	Ferric chloride
Concentration	8.15 % as Al ₂ O ₃	22.75 % as Al ₂ O ₃	40.87 % as FeCl ₃
Specific gravity	1.324	1.336	1.424
Conc. of metal ion (Al or Fe)	2.12 M	5.96 M	3.59 M

allow comparison between coagulants. Rapid mix was conducted at the maximum speed of the mixer (300 rpm) for about 1 minute. Flocculation mixing time was 30 minutes, using tapered flocculation that reduced the velocity gradient (G) every 10 minutes. The velocity gradient was 60 s⁻¹ for the first 10 minutes, 40 s⁻¹ for the second 10 minutes, and 20 s⁻¹ for the final 10 minutes. These velocity gradients were achieved using mixing speeds of 60, 45, and 28 rpm, respectively, using the calibration curve given in AWWA (2007). After the flocculation time was complete, the mixer was turned off and the solution was allowed to settle for 30 minutes. After settling, approximately 1 L of supernatant was drawn off through a sample tap located 10 cm above the bottom of the jar.

Analytical Procedures

The analytical procedures used for each water quality parameter are shown in Table 2.

DBPFP Incubation

After the coagulation jar tests were completed, water was decanted and stored in 1 L containers. Each water sample that was to be used for the DBPFP tests was filtered through a 0.45 µm filter (Pall Supor 450 polyethersulfone). The samples were placed in cleaned and acid-washed 250 mL amber glass bottles with tapered caps that excluded all air when the bottle was capped. Bottles were dosed with 5 mL of a phosphate buffer solution as described in Standard Methods to control the pH during the incubation period. DBPFP tests with chlorine were dosed with sodium hypochlorite at a dose of 8 mg/L as Cl₂. DBPFP tests with chloramines were dosed with ammonium chloride at a dose 2.4 mg/L as NH₃, followed by sodium hypochlorite at a dose of 8 mg/L as Cl₂ (corresponding to a molar ratio of Cl₂:NH₃ of 0.8). The jars were incubated for 7 days at 25 °C in a constant-temperature water bath.

Results

Coagulation Jar Tests

The turbidity, pH, alkalinity, dissolved organic carbon (DOC), and UV₂₅₄ absorbance of the settled water from each jar test are summarized in Table 3. To permit comparison between coagulants, the doses are reported in molar metal ion (Al³⁺ or Fe³⁺) concentrations in the first column (millimole/L, or mM) and the corresponding dose in mg/L is provided in the second column.

Navajo/Gallup Water Quality Treatability Study

Table 2 – Summary of Analytical Procedures

Parameter	Method	Description/Comments
pH	Standard Method 4500-H ⁺	Mettler-Toledo Model MP225 pH meter.
Alkalinity	Standard Method 2320	Titration with 0.02 M H ₂ SO ₄ .
Temperature	Standard Method 2550	ERTCO glass organic filled thermometer, 0.1 °C gradations.
Turbidity	Standard Method 2130	Hach Model 2100AN Laboratory Turbidimeter.
UV ₂₅₄ Absorbance	Standard Method 5910	Varian Cary 50 UV/vis spectrophotometer, 1 cm path-length cell.
Dissolved organic carbon	Standard Method 5310-C	Persulfate/UV oxidation method using a Tekmar-Dohrmann Phoenix 8000 TOC Analyzer.
Free chlorine residual	Hach DPD Method 8021	Hach DR-890 Colorimeter.
Total chlorine residual	Hach DPD Method 8167	Hach DR-890 Colorimeter.
DBP formation potential	Standard Method 5710	THM and HAA Analyses by the NM Scientific Lab Division.

The turbidity is shown in Figure 1. The turbidity of the raw water was about 15 NTU, which is significantly lower than the turbidity of San Juan River water tested during earlier jar tests. The data indicates that significant reductions in turbidity could be achieved with coagulant doses of about 0.1 mM or less for each coagulant. The lowest settled water turbidity occurred at a coagulant dose of 0.05 mM for alum and 0.1 mM for ferric chloride and PACl (corresponding to doses of 15, 16, and 22 mg/L, respectively). Alum and ferric chloride achieved the best turbidity removal with turbidity less than 0.8 NTU at the optimal dose, compared to turbidity of 3.0 NTU for PACl at the optimal dose.

The DOC is shown in Figure 2 and the UV₂₅₄ absorbance is shown in Figure 3. The raw water DOC was 3.25 mg/L, which is lower than the DOC of San Juan River water tested during earlier jar tests. Ferric chloride had the best effectiveness for DOC removal, achieving about 50 percent DOC removal at a coagulant dose of 0.2 mM. The alum and PACl achieved maximum DOC removal of 40 and 32 percent DOC at the coagulant dose of 0.2 mM. The reduction in UV₂₅₄ absorbance was more similar for the three coagulants.

The pH and alkalinity followed expected trends as the coagulant dose increased, as shown in Figures 4 and 5. Alum and ferric chloride both behave as strong acids and reduce the pH and alkalinity as the dose is increased, whereas PACl is partially neutralized and has a minimal effect on the pH and alkalinity. Alum and ferric chloride reduced the pH by similar amounts, with a final pH around 6.6 at a coagulant dose of 0.2 mM. The pH of the PACl at the same dose was 7.6. The lack of pH reduction for PACl may be the reason it achieves less DOC removal, since optimal DOC removal (e.g., enhanced coagulation) occurs at a lower pH, in the range of about pH = 6.0.

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Table 3 – Results of Coagulation Jar Tests

Alum

Al Dose (mM)	Dose ¹ (mg/L alum)	Turbidity (NTU)	pH	Alkalinity (mg/L as CaCO ₃)	DOC (mg/L)	UV ₂₅₄ (filtered)	DOC Removal (%)
0.000	0	15.3	7.76	88.0	3.25	0.0734	
0.025	7	7.08	7.49	88.0	3.23	0.0656	0.6
0.050	15	0.79	7.16	85.8	2.69	0.0521	17.2
0.075	22	1.23	7.23	79.2	2.48	0.0456	23.7
0.100	30	1.55	7.02	77.0	2.26	0.0407	30.5
0.150	45	2.28	6.71	68.2	1.99	0.0347	38.8
0.200	59	1.88	6.56	61.6	1.93	0.0300	40.6

Polyaluminum Chloride (PACl)

Al Dose (mM)	Dose ¹ (mg/L PACl)	Turbidity (NTU)	pH	Alkalinity (mg/L as CaCO ₃)	DOC (mg/L)	UV ₂₅₄ (filtered)	DOC Removal (%)
0.000	0	12.9	7.62	81.4	3.25	0.0734	
0.025	5.6	6.96	7.68	83.6	3.02	0.0616	7.1
0.050	11	5.08	7.63	79.2	2.64	0.0467	18.8
0.075	17	4.53	7.77	81.4	2.47	0.0403	24.0
0.100	22	3.02	7.63	83.6	2.36	0.0360	27.4
0.150	34	3.47	7.66	83.6	2.14	0.0312	34.2
0.200	45	2.55	7.64	81.4	2.21	0.0277	32.0

Ferric Chloride

Fe Dose (mM)	Dose ¹ (mg/L FeCl ₃)	Turbidity (NTU)	pH	Alkalinity (mg/L as CaCO ₃)	DOC (mg/L)	UV ₂₅₄ (filtered)	DOC Removal (%)
0.000	0	17.3	7.66	85.8	3.25	0.0734	
0.025	4	8.73	7.33	81.4	3.09	0.0720	4.9
0.050	8	2.14	7.35	74.8	2.65	0.0560	18.5
0.075	12	1.02	7.26	74.8	2.45	0.0459	24.6
0.100	16	0.47	6.99	66.0	2.14	0.0403	34.2
0.150	24	3.30	6.77	61.6	1.79	0.0309	44.9
0.200	32	0.47	6.63	50.6	1.60	0.0280	50.8

1. Dose of alum is reported in mg/L as Al₂(SO₄)₃·14H₂O; MW = 594 g/mol
 Dose of PACl is reported as mg of PAX-XL19 stock solution per liter
 Dose of ferric chloride is reported in mg/L as FeCl₃; MW = 162.2 g/mol

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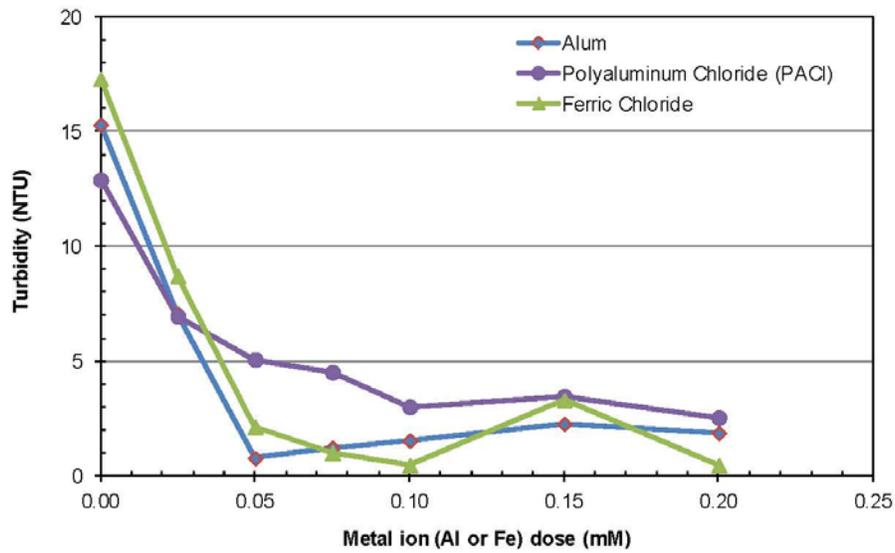


Figure 1 – Settled Water Turbidity as a Function of Coagulant Dose.

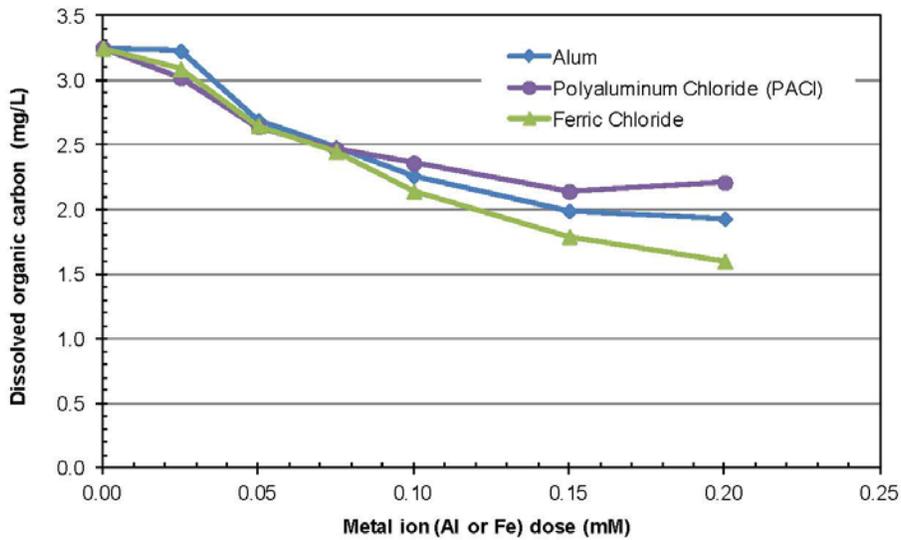


Figure 2 – Dissolved Organic Carbon as a Function of Coagulant Dose.

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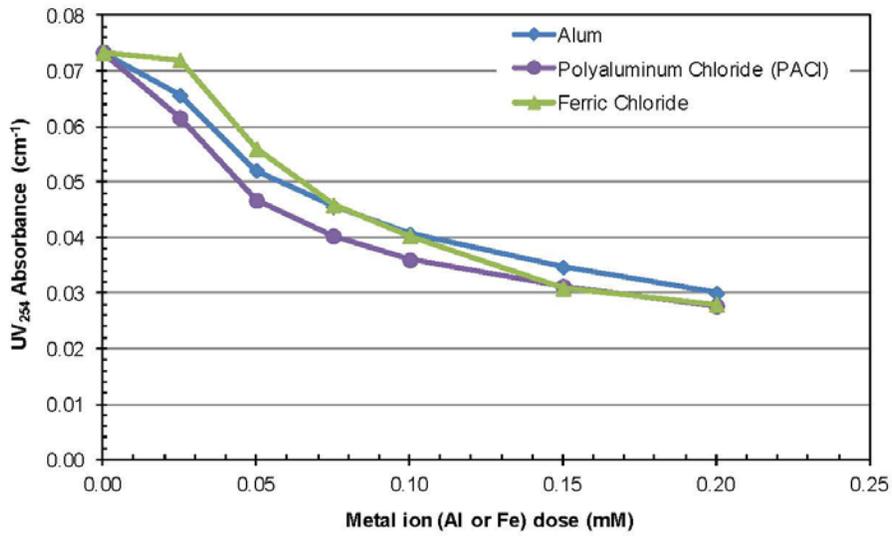


Figure 3 – Filtered UV₂₅₄ Absorbance as a Function of Coagulant Dose.

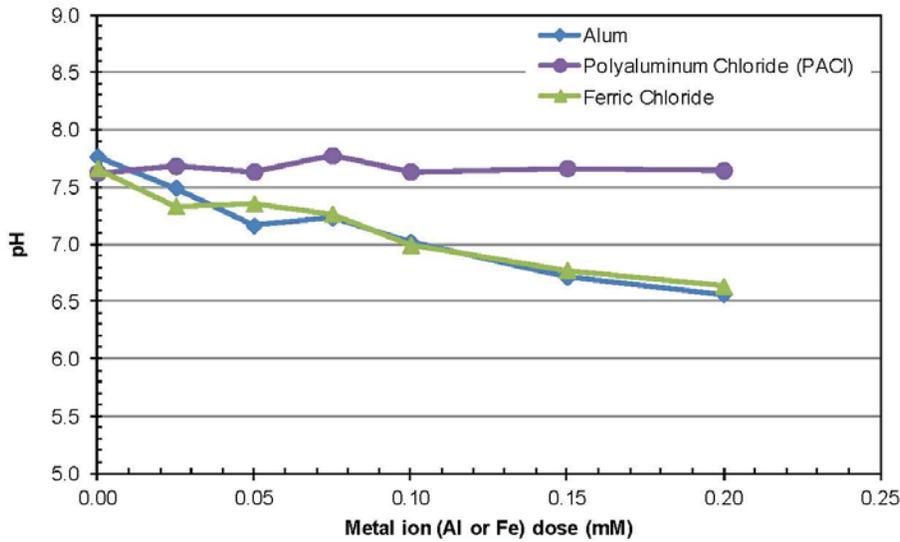


Figure 4 – pH as a Function of Coagulant Dose.

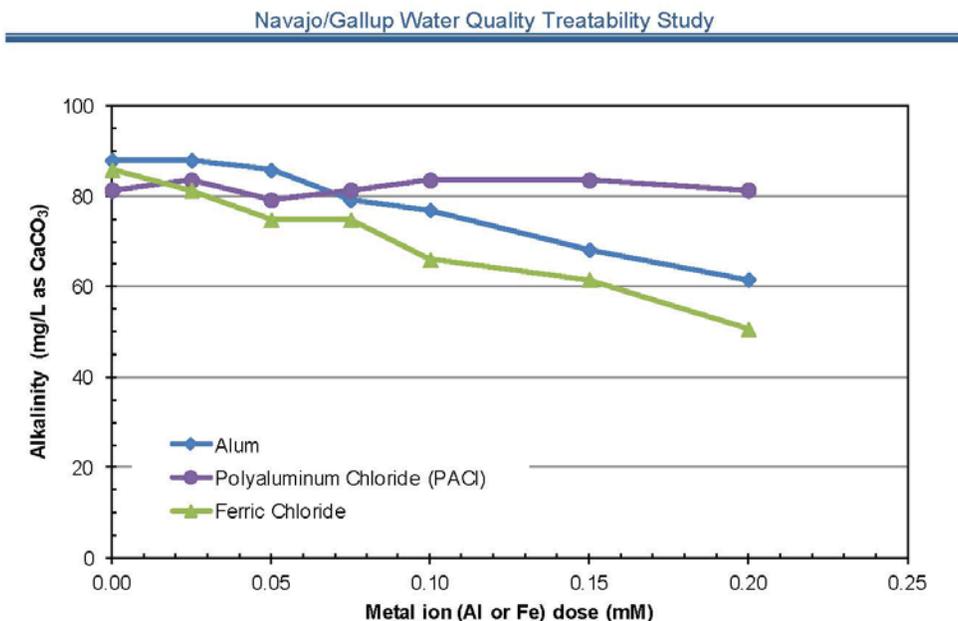


Figure 5 – Alkalinity as a Function of Coagulant Dose.

Disinfectant By-Product Formation Potential Tests

THM, HAA, pH, and chlorine residual data for the DBPFP tests are summarized in Table 4. At these test conditions, the THM formation potential (THMFP) of the raw water was 194 µg/L and the HAA formation potential (HAAFP) was 169 µg/L. These values are significantly lower than the values from the San Juan River, where the THMFP reached 411 µg/L and the HAAFP was 239 µg/L during the August 2010 sampling. Despite the lower formation potential in the raw water, coagulation was not able to reduce the THMFP or HAAFP to below the THM and HAA regulations (80 and 60 µg/L, respectively). The best overall formation potential with free chlorine as the disinfectant was achieved with 0.2 mM of ferric chloride, which had THMFP of 101 µg/L and HAAFP of 79 µg/L. As expected, the formation potential with chloramines as the disinfectant was lower, with formation potentials in the range of 13 to 23 µg/L with all disinfectants.

It should be noted that formation potential tests generally represent a worst-case condition for DBP formation. The tests are done with a relatively warm temperature, 7-day holding time, and a high chlorine dose (the chlorine residual at the end of the 7-day incubation period ranged from 4.5 to 5.6 mg/L for the free chlorine tests with coagulants). DBP formation would likely be lower during actual operation. On the other hand, the tests only represent a single snapshot in time, which may not represent worst-case conditions from a water quality perspective (DOC, etc). Nonetheless, these tests give a general indication of DBP formation and indicate that treatment facilities designed to treat this water source will likely have to employ treatment strategies to limit DBP formation in order to meet regulations.

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Table 4 – Results of Disinfection By-Product Formation Potential Tests

Solution	Disinfectant	Final pH	Cl ₂ Residual (mg/L)	THMs (µg/L)	HAA5 (µg/L)
Raw water	Chlorine	6.97	2.76	194	169
0.1 mM alum	Chlorine	6.98	4.53	139	107
0.2 mM alum	Chlorine	6.98	5.61	131	90
0.1 mMPACl	Chlorine	7.00	4.77	129	97
0.2 mMPACl	Chlorine	7.00	4.68	106	77
0.1 mM FeCl ₃	Chlorine	6.99	4.50	135	103
0.2 mM FeCl ₃	Chlorine	6.97	5.46	101	79
0.1 mM alum	Chloramine	6.98	2.82	15	23
0.1 mMPACl	Chloramine	6.97	2.16	13	19
0.1 mM FeCl ₃	Chloramine	6.99	2.61	15	20

PART 2 PRODUCTS

Not Used

PART 3 EXECUTION

Not Used

END OF SECTION

SECTION 51 45 14
BENCH SCALE RESULTS REPORT

PART 1 GENERAL

BUREAU OF RECLAMATION
TECHNICAL SERVICE CENTER



CONTRACT: R12PC80235
TASK ORDER: R13PD80243

CUTTER RESERVOIR WATER TREATMENT
BENCH-SCALE TESTING

FINAL

BENCH-SCALE TEST RESULTS
REPORT

Revision 1

January 2014

HDR-CDM Joint Venture

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Appendix

Appendix A Test Plan and Reclamation Review Comments-JV Responses

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List of Acronyms

AOC	assimilable organic carbon
APHA	American Public Health Association
BAF	biologically active filtration
BCAA	bromochloroacetic acid
BDCM	bromodichloromethane
BDM	bromodichloromethan
°C	degrees Celsius
CaCO ₃	calcium carbonate
DBAA	dibromoacetic acid
DBCM	dibromochloromethane
DBM	dibromomethane
DBP	disinfection byproduct
DCAA	dichloroacetic acid
DCM	tribromomethane
DI	deionized
DOC	dissolved organic carbon
EBCT	empty-bed contact time
GAC	granular activated carbon
g/hr	grams/hour
H ₂ SO ₄	sulfuric acid
HAA	haloacetic acid
HAA5	haloacetic acids 5
HAA6	haloacetic acids 6
JV	joint venture
MBAA	monobromoacetic acid
MCAA	monochloroacetic acid
MCL	maximum contaminant level
mgd	million gallon per day
mg/L	milligrams per litre
mL	milliliters
mL/min	milliliters per minute
mm	millimeters
Na ₂ S ₂ O ₃	sodium thiosulfate
NH ₄ Cl	ammonium chloride
NOM	natural organic matter
NTU	nephelometric turbidity units
PAC	powdered activated carbon
PCU	platinum-cobalt units
PTFE	polytetrafluoroethylene
Reclamation	Bureau of Reclamation
SM	standard methods
SU	specific units
SUVA	specific UV absorbance

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TBM	tribromomethane
TCCA	trichloroacetic acid
TCM	trichloromethane
TOC	total organic carbon
TTHM	total trihalomethanes
µg/L	microgram per liter
UV	ultraviolet
WTP	water treatment plant

Introduction

The Cutter Lateral, when completed, will consist of a 100-mile network of pipelines and pump stations along the eastern portion of the Navajo/Gallup Water Supply Project and will include a new 5.4 million gallon per day (mgd) water treatment plant (WTP) that will provide treated water from the Cutter Reservoir. The treated water may experience water age as long as 14 to 21 days. The Bureau of Reclamation (Reclamation) wants to verify the performance of the currently preferred WTP process of enhanced coagulation-flocculation sedimentation, ozonation, biologically active filtration (BAF), and ultraviolet (UV) disinfection for primary disinfection. The treatment objectives include meeting turbidity, disinfection, and disinfection byproduct (DBP) goals of the U.S. Environmental Protection Agency, Navajo Nation EPA, and applicable regulations such as the Surface Water Treatment Rule and Disinfection and Disinfection Byproducts Rule. Bench-scale testing was requested by Reclamation as a proof-of-concept to determine if the ozone/BAF process would remove sufficient natural organic matter (NOM) to reduce DBP formation with the potential use of free chlorine as the secondary disinfectant. The HDR-CDM Joint Venture (JV) team conducted bench-scale testing to evaluate the feasibility of ozone/BAF as a potential treatment process to reduce the NOM levels in Cutter Reservoir water. All testing was conducted at the HDR-CDM JV's laboratories in Bellevue, Washington and Redmond, Washington.

Methodology

The goals of the bench-scale testing were to determine whether the ozone/BAF treatment process could reduce the DBP formation potential of the Cutter Reservoir water to meet drinking water regulations. The testing was performed to evaluate whether the proposed treatment process could meet the treatment criteria summarized in Table 1. This bench-scale testing consisted of two phases to evaluate achieving these goals. Phase 1 involved collection of Cutter Reservoir water, Lake Washington (Bellevue, Washington) water, and anthracite media from an existing full-scale BAF. Phase 2 consisted of bench-scale treatability experiments involving pretreatment followed BAF.

The following sections summarize the methodology followed for testing Phases 1 and 2. A copy of the original proposed Work Plan, Reclamation comments, and the JV team responses are attached in Appendix A.

Table 1. Cutter Reservoir Bench-scale Testing Finished Water Treatment Criteria

Parameters	Criteria
Dissolved Organic Carbon (DOC)	≤ 1.5 mg/L
Assimilable Organic Carbon (AOC)	≤ 100 µg/L
Total Trihalomethanes (TTHM) formation potential	≤80% of the maximum contaminant level (MCL) (≤ 64 µg/L)
Haloacetic Acids 5 (HAA5) formation potential	≤80% of the MCL (≤ 48 µg/L)

Phase 1 - Sample Collection

Water Samples

Eighty gallons of Lake Washington water (lake water) was collected in 5-gallon plastic containers and transported to the JV laboratories where it was maintained in the dark at 4°C. Solids were then removed from the lake water using a high flow rate 5-micron filtration system with no further treatment prior to use in the anthracite acclimation process.

A total of 100 gallons of Cutter Reservoir water (source water) was collected by Reclamation in 5-gallon polyethylene cubitainers. Source water samples were shipped on ice via overnight delivery to the JV laboratories. Cutter reservoir water samples were inspected upon receipt to confirm sample integrity and acceptability for testing. The received source water was stored in the dark at 4°C. The source water was not prefiltered prior to subsequent coagulation and flocculation.

Prior to use, both lake and source waters were taken out of the cold room and placed in a dark area to allow equilibration with room temperature. After warming, the source water samples were slowly physically agitated by rolling them on the countertop to resuspend any settled particulates and homogenize the samples.

Media Acquisition and Acclimation

One liter of biomass-established anthracite BAF media was acquired from the Rolling Hills WTP in Fort Worth, Texas. This plant was selected for media acquisition because of the media's high adenosine triphosphate content, an indicator of biological activity (Evans et al. 2013). Table 2 lists the media characteristics.

Table 2. Characteristics of Anthracite Media Used for Testing

Characteristic	Value
Material	Anthracite
Uniformity coefficient	1.40
Effective size	1.29 mm
Specific gravity	1.62
Moh's hardness	3.0

The process of media collection consisted of scraping and discarding the top 0.5-inch of media layer in the biofilter, as this may contain undesirable captured solids. Media below the scraping was then collected from the next six inches of the BAF, where the most extensive biological activity is expected. Media was collected in a one-liter polyethylene bottle, unchlorinated biofilter influent water was added to the bottle to keep the biofilm moist, and then shipped on ice via overnight delivery to the JV laboratories.

Biological Active Filtration (BAF) Column

The shipped media was loaded into a one-inch diameter BAF column with a bed depth of 24 inches. A schematic of the BAF column setup is shown in Figure 1. A plastic perforated disk

with approximately one-inch of glass wool was placed on each end of the column to support and restrain the BAF media. Lake water was recirculated through the column at a flow rate of 30 mL/min to start the media acclimation process (Figure 1 does not show the recirculation loop). This flowrate provided 10 minutes empty-bed contact time (EBCT) for the test column diameter and bed depth. The 10 minute EBCT was selected based on the JV team’s experience in achieving appropriate filter column hydraulics and optimal BAF performance given the limited quantity of source water provided.

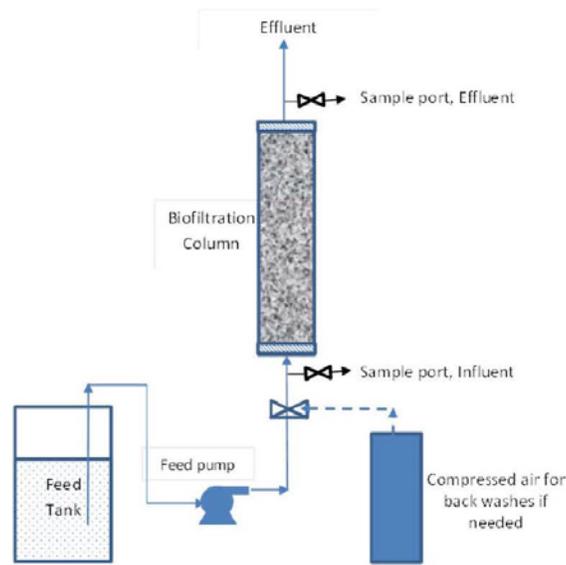


Figure 1. BAF Column Schematic

Lake water was pumped into the BAF column in an up-flow configuration (i.e. water enters the bottom of the column and exits the top). The up-flow configuration differs from most full-scale municipal BAF treatment facilities, whose configuration is principally down-flow during filtration and only up-flow in backwashing. This configuration was specifically chosen to overcome experimental errors unique to testing with small-diameter laboratory columns (such as dewatering the column during sample collection, accumulating air in a head space, and siphoning). The resultant data and trends presented in this report are generally representative of a full-scale treatment system operated in down-flow configuration with similar chemical pretreatment, filtration EBCT, and post-treatment disinfection.

The recirculated lake water was replaced twice a week for two weeks. The recirculation maintained the biofilm on the BAF media and kept the media active while the Cutter Reservoir source water was being collected and shipped.

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Phase 2 - Bench-Scale Testing

The BAF pretreatment process consisted of coagulation, flocculation, sedimentation and ozonation. This section provides a detailed description for each step of this process along with a description of the BAF and the analytical methods used.

Coagulation/Flocculation

The 100-gallon source water sample was divided and treated in four batches due to physical limitations in mixing vessel volumes. Approximately 25 gallons of source water was transferred from the cubitainers into one of four clean 30-gallon polyethylene drums. Each batch of source water was dosed with the Reclamation-specified 20 mg/L ferric chloride (as coagulant) and then mixed with an impeller to provide rapid mixing at a velocity gradient (G value) of approximately 950 sec^{-1} for 30 seconds and then slow mixed (flocculated) with a G value of approximately 30 sec^{-1} for 20 minutes. The flocculated source water settled for 60 minutes before the supernatant was decanted by siphoning into clean 5-gallon polyethylene jugs. The settled source water was then stored in the dark at 4°C prior to use. Approximately 90 gallons of settled source water was recovered while the remaining 10 gallons was laden with settled coagulant and discharged.

Ozonation

Three 5-gallon polypropylene jugs containing a combined approximate total of 13 gallons of settled source water were removed from cold storage and allowed to adjust to ambient room temperature every evening. The following morning, the 5-gallon jugs were poured into a polyethylene barrel and mixed briefly to homogenize the warmed settled source water. Water from the barrel was then transferred to a 6-foot tall, 6-inch diameter (25-L) clear PVC ozone contact column. Each daily volume of settled source water was ozonated in two separate batches given the size of the ozone contact column.

Ozone was introduced into the water at the ozone contact column base via a stainless steel fine-bubble diffuser. A Clearwater Tech CD 12 ozonator with a maximum capacity of 8 g/hr ozone generation (using ultra-high purity oxygen) generated the ozone in the ozone contact column. The settled source water was ozonated for 20 minutes. This duration was established in calibration testing in which the ozone contact column was filled with deionized (DI) water and ozonated at identical ozonator settings. Samples of the ozonated DI water were collected and analyzed on a regular basis to develop a relationship between ozonation time and dissolved ozone residual concentrations inside the column. The settled source water was determined to have 2.3 mg/L total organic carbon (TOC) and ozonation was to be conducted at an ozone:TOC ratio of 1.5:1. The resultant required ozone dosage was 3.4 mg/L, which the calibration testing determined to occur at 20 minutes of ozonation.

The two batches of ozonated water were then mixed together in an open barrel and allowed to off-gas under a fume hood for 30 minutes. The water was checked after this time to verify that the water fully off-gassed and contained no ozone residual.

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Bench-Scale BAF Column Testing

The BAF column tests consisted of transferring the ozonated water to the column at a flow rate of 30 mL/min to achieve 10 minute EBCT. Whereas Phase 1 was conducted with lake water recirculating through the BAF column, the Phase 2 testing was conducted by transferring the ozonated source water to the BAF column using a peristaltic pump in a single-pass configuration. The flow path was maintained as up-flow. The BAF-treated source water was sampled per the requirements listed in Table 3 and then discharged to the drain. Column testing occurred continuously for four calendar days.

Disinfection By-Product Formation Potential Testing

TTHM and HAA6 formation potential testing was performed on the BAF-treated source water at the conclusion of BAF testing. Free chlorine was used to obtain potential worst-case DBP concentrations in the future Cutter Lateral. A preliminary 24-hour chlorine demand test was conducted to determine an adequate starting chlorine dose. First, 5 mg/L of sodium hypochlorite was added to 100 mL of phosphate buffered source water and left to react for 24 hours in the dark at 25 °C. The residual free chlorine in the chlorinated sample after 24 hours was determined. The 24-hour chlorine demand value was calculated by subtracting the residual free chlorine dose from the initial applied free chlorine dose. Adequate chlorine was added as the initial dose in order to have a residual of 3 to 5 mg/L free chlorine after 7-day hold time at 25 °C per Standard Methods 5710 B.

Monitoring, Sampling, and Analytical Testing

Water samples were collected and analyzed for different water quality parameters for each of the four waters generated during bench testing (raw, settled, ozonated, BAF-treated). Table 3 lists the analytical methods and equipment used to analyze the water. TOC, DOC, and pH were measured at each stage. Raw source water was characterized for all the analytes mentioned in the table except AOC and ozone residuals. BAF column influent and effluent was sampled every calendar day. AOC analysis on the post-BAF water was conducted at the end of BAF testing.

Total and free chlorine content was only measured during TTHM and HAA6 formation potential testing. TTHM analysis consisted of measurement of trichloromethane (TCM, also known as chloroform), tribromomethane (TBM), dibromochloromethane (DBCM), and bromodichloromethane (BDCM). HAA6 analysis consisted of trichloroacetic acid (TCAA), dichloroacetic acid (DCAA), monochloroacetic acid (MCAA), dibromoacetic acid (DBAA), and monobromoacetic acid (MBAA) (the five regulated HAAs) in conjunction with unregulated bromochloroacetic acid (BCAA).

Table 3. Testing Analytical Parameters

Parameter	Sampling Frequency at:					Analytical Method	Method Detection Limit	Bottle Type	Preservative	Holding Time	JV Lab Equipment
	Raw Water	Settled Water	Ozonated Water	Post Biofiltration (Column experiment)	Post Biofiltration (DBP analysis)						
pH	Daily	Daily	Daily	Daily	Daily	SM 4500-H B	±0.1 SU	15 mL polypropylene centrifuge tube	None	Analyze immediately	Multiple calibrated digital pH meters
Free chlorine	Once	Once	-	-	Once	Hach Method 10069	0.1 mg/L	15 mL polypropylene centrifuge tube	None	Analyze immediately	Hach test kit
Total chlorine	Once	Once	-	-	Once	Hach Method 10070	0.1 mg/L	15 mL polypropylene centrifuge tube	None	Analyze immediately	Hach test kit
Ozone residual	-	-	Daily	-	-	SM 4500-O3	0.1 mg/L	100 mL glass serum bottle	None	Analyze immediately	Hach DR 6000 and Hach DR 4000 UVspectrophotometers
Total organic carbon	Daily	Daily	Daily	Daily	-	SM 5310 B	0.1 mg/L	40 mL pre-cleaned glass TOC vial	H ₂ SO ₄ (sample pH<2)	28 days	Shimadzu TOC analyzer
Dissolved organic carbon	Daily	Daily	Daily	Daily	-	SM 5310 B	0.1 mg/L	40 mL pre-cleaned glass TOC vial	H ₂ SO ₄ (sample pH<2)	28 days	Shimadzu TOC analyzer
TTHM	Once	Once	-	-	Once	SM 5710B	0.5 µg/L	40 mL volatile organic analysis vials	4°C	14 days	Gas chromatograph-mass spectrometer with purge & trap
HAA6	Once	Once	-	-	Once	SM 5710D	1.0 µg/L	3 x60 mL vials with PTFE lined cap	100 mg/L NH ₄ Cl	14 days	Eurofins Eaton Laboratories
Assimilable organic carbon	-	Once	-	Once	-	Weinrich et al., 2009	1 µg/L	250 mL amber glass	4°C and Na ₂ S ₂ O ₃	3 days	Eurofins Eaton Laboratories

H₂SO₄ = Sulfuric Acid
 PTFE = Polytetrafluoroethylene
 NH₄Cl = Ammonium Chloride
 Na₂S₂O₃ = Sodium Thiosulfate
 SM: Standard Methods

Results

Table 4 is a summary of the water quality parameters analyzed during this bench-scale testing effort. The Cutter Reservoir source water was found to contain considerable amounts of organic carbon, predominantly in the dissolved form, and is quite reactive to chlorine in forming DBPs. Coagulation with the specified 20 mg/L ferric chloride (as coagulant) dose resulted in the removal of approximately one-third of the TOC and DOC. TTHM formation was correspondingly reduced by a third, while HAA5 and HAA6 formations were reduced by approximately 50 percent. The coagulated, settled source water still exhibited considerable chlorine demand as the demand only decreased from 6.1 to 5.0 mg/L, a reduction of 18 percent. The Cutter Reservoir source water is well-buffered as the heavy acidic ferric chloride dose only reduced the water pH from 7.9 to 7.0. The minor difference between TOC and DOC is attributable to particulate organic carbon.

Table 4. Bench-Scale Testing Result Summary

Sample water	TOC (mg/L) ¹	DOC (mg/L) ¹	AOC (Note 2)	SUVA (L/mg-m)	pH (SU) ¹	Chlorine demand (mg/L) ¹	TTHM (µg/L) ¹	HAA5 (µg/L) ³	HAA6 (µg/L) ³
Raw	3.1	3.0	-	4.0	7.9	6.1	178	240 (240)	247 (247)
Settled	2.3	2.1	1.5	2.2	7.0	5.0	122	120 (124)	130 (130)
Post-ozonation ⁴	2.3	2.1	-	0.6	7.7	-	-	-	-
Post-biofiltration ⁴	1.5	1.5	0.3	1.0	7.9	3.1	82	65 (65)	69 (69)

Notes:

- Value shown is average of two analyses.
- As mg acetate-C/L.
- First values are as reported by laboratory. Second value in parentheses is the sum of the reported individual HAA5 concentrations.
- Average of all daily sampling.

The post-ozonation and post-biofiltration data in Table 4 reflects the average of all the daily samples during the BAF column testing. The addition of 3.4 mg/L ozone subsequently raised the source water pH to 7.7. No changes occurred to TOC and DOC concentrations as ozonation alone does not affect these parameters. DOC and AOC were further reduced through contact with the BAF. TOC matches DOC as the single-pass BAF is also physically trapping particulate organic carbon.

The single analysis of settled source water AOC indicated 1.5 mg acetate-C/L, or 71 percent of the DOC. This value is unexpected as the JV Team's experience has found that AOC for unozonated surface waters is generally less than 30 percent of DOC. Further analysis would be warranted to determine if this single analysis is anomalous to the water sample, result of the experimental or analytical procedures, or if the Cutter Reservoir source water contains a different

type of NOM. The AOC in the post-biofiltration water was 20 percent of the DOC, which is an expected result as BAF readily degrades AOC.

The raw water specific UV absorbance (SUVA) measurement was 4.0 L/mg-m. The Cutter source water used in this testing was determined to have a higher humic acid content compared to the water quality analysis conducted by Westerhoff and Chiu (2012) though the DOC concentrations were roughly equal. The settled water had a lower SUVA, indicating that the larger, very humic fraction of DOC was preferentially co-precipitated by the ferric coagulation step. In addition, the combination of lower SUVA and high AOC content (if confirmed) would indicate that the remaining DOC is most likely short-chained molecules instead of larger, non-humic molecules. The further reduction in SUVA in the post-ozonation sampling is representative of the ozone destroying available carbon-carbon bonds in the remaining organic molecules. The slight increase in the post-biofiltration water is simply a reflection of reduced DOC as the UV-254 measurements were generally the same as the post-ozonation measurements. In general, these results would indicate that the sample of Cutter Reservoir water used for this testing was more amenable to both coagulation/precipitation and biofiltration treatment than the water sample analyzed by Westerhoff and Chiu.

If additional and frequent sampling and analysis finds that the high AOC:DOC ratio persists for several months and seasons, then the results would indicate that the raw water TOC could be treated primarily through biofiltration. The required ozone dose could also be decreased, as the purpose for the high ozone dose was to convert TOC to AOC, which would be irrelevant if most of the TOC is already AOC. The implications for a full-scale design is that either an overall smaller ozone system can be installed and used, or a larger ozone system can be installed to meet a higher dosage but used at a lower optimized dose in day-to-day operations.

It is also important to note that AOC might not represent biological instability of a given source as variations between natural/indigenous bacteria communities in the water and those used in the AOC test does result in some analytical error. Additional AOC sampling would also further refine the test’s specific sensitivity and accuracy to the Cutter Reservoir.

The post-biofiltration data indicates that chlorine demand and corresponding TTHM formation is approximately half of the raw source water while HAA formation reduced even further, with the detected HAA formation being only 27 percent of the raw source water HAA. The end result is that although TTHM and HAA5 concentrations still exceed drinking water MCLs and this project’s finished water treatment criteria (see Table 5), considerable reduction has occurred and even further reduction can most likely be achieved with process optimization. The conclusion section of this document describes these potential optimizations.

Table 5. Comparison of Total Trihalomethane and Haloacetic Acid Criteria and Results

Finished Water Quality Parameters	Max. Contaminant Level	Test Criteria	Testing Results
Total Trihalomethanes (TTHM) (µg/L)	80	≤64	82 µg/L
Haloacetic Acids 5 (HAA5) (µg/L)	60	≤48	65 µg/L

The following sections provide additional detail on the TOC, DOC, pH and DBPs detected during the course of this bench-scale testing.

TOC/DOC Results over Time

Figure 2 shows the results from the single-pass BAF column experiment for post-ozonation and post-biofiltration TOC and DOC concentrations measured with respect to time. The relatively constant concentrations indicate that the pre-testing acclimation with lake water succeeded in maintaining the Rolling Hills WTP BAF media biological culture while the Cutter Reservoir water was being collected and shipped, and that the BAF reached steady-state operation (i.e. filter performance has stabilized and there is little subsequent variability in measurements over time) with respect to the source water by the first day of column testing.

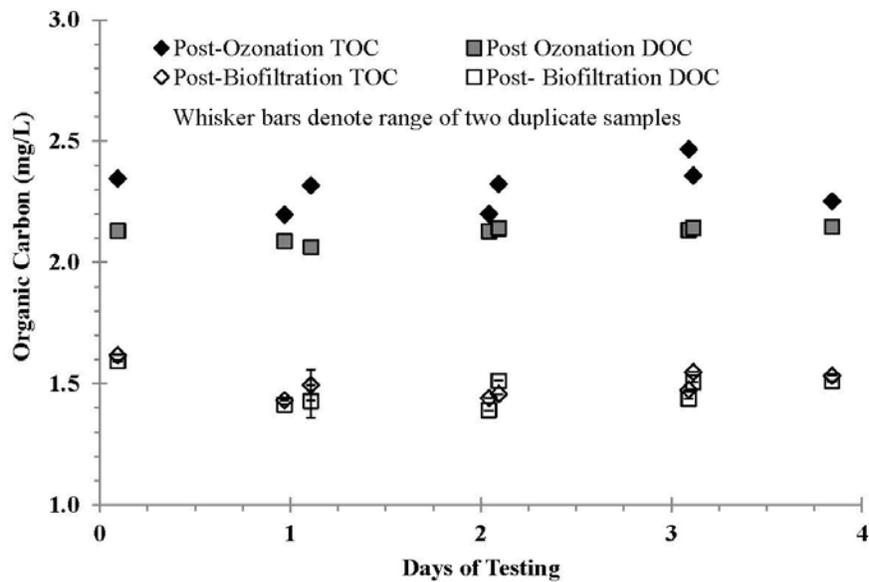


Figure 2. Organic Carbon during BAF Column Testing

pH Results over Time

Figure 3 shows the pH for post-ozonation and post-biofiltration waters. As with the TOC and DOC results, the relatively stable post-biofiltration water pH is another indicator that the steady state removals were achieved very quickly once ozonated source water was introduced to the BAF column. In addition, the relatively stable post-ozonated source water pH is an indirect indicator that the ozonation process was repeated with little variability between daily batches of

room temperature settled source water. In other words, the pH results indicate that the JV team precisely repeated the ozonation process every day and minimized experimental variability.

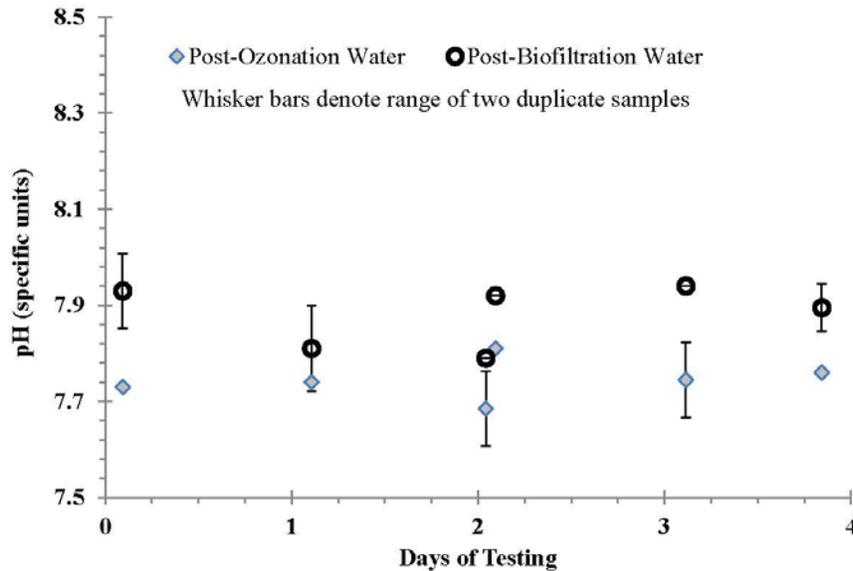


Figure 3. pH during BAF Column Testing

Disinfection Byproducts

Figure 4 illustrates the measured TTHM concentrations formed after chlorination of the raw source water, settled source water, and the source water after BAF filtration. TCM is the principal TTHM formed during chlorination, and is the compound whose formation is reduced in the settled and post-filtration source waters.

The concentrations of the remaining regulated TTHMs: TBM, DBCM, and BDCM, are low to non-detectable (<0.1 µg/L) relative to TCM. The hypothesis for the low bromo-compound formation is that formation is likely limited by the lack of significant bromine/bromide in the raw source water. Reclamation analyzed for bromide in the Cutter Reservoir twice between 2011 to 2013, with results of non-detect (no detection limit was provided) and 188 µg/L. The results of this bench-scale testing would indicate that the particular batch of Cutter Reservoir water provided had bromide concentrations closer to non-detect.

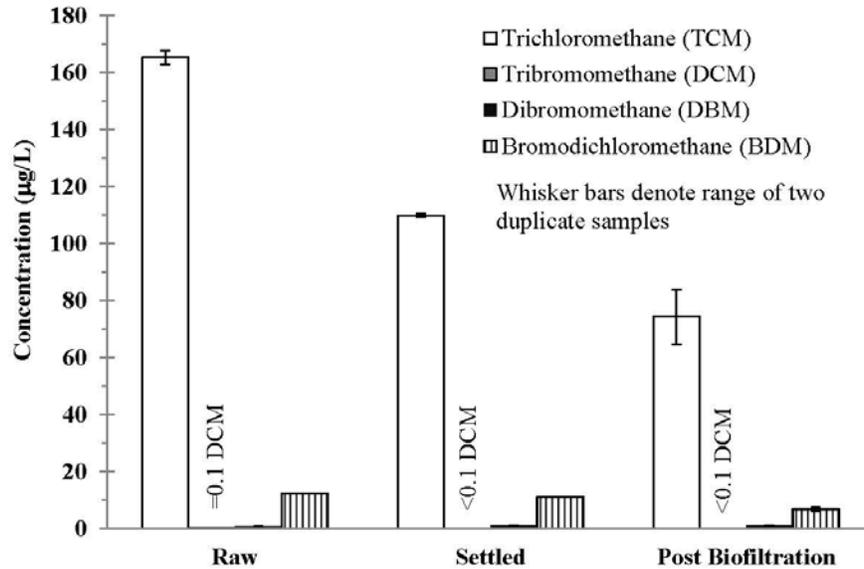


Figure 4. Trihalomethane Concentrations

Despite the low bromide levels, the relatively constant concentration of BDCM between the aforementioned three water samples indicates that Cutter Reservoir NOM preferentially forms bromo-compounds when chlorinated over TCM formation. The result is that further NOM removal will inhibit TCM formation but that between 5 to 15 µg/L of bromo-compounds will still contribute to TTHM compliance when raw source water bromide concentrations are low. More bromo-compounds would be formed if raw source water bromide concentrations are higher and bromated, which could limit the applied ozone dosage.

Measured haloacetic acids are shown in Figure 5. As with TTHMs, the chloro-compounds have the highest concentrations and contribute the most to DBP compliance, with TCAA predominant followed by DCAA at two-thirds that of TCAA formation in the raw source water. Both chloro-compounds decrease but TCAA formation is inhibited more than DCAA as the water is treated. As a result, TCAA and DCAA are essentially equal after BAF filtration. Regulated bromo-compounds were essentially non-detect while the unregulated BCAA was detected at very low concentrations.

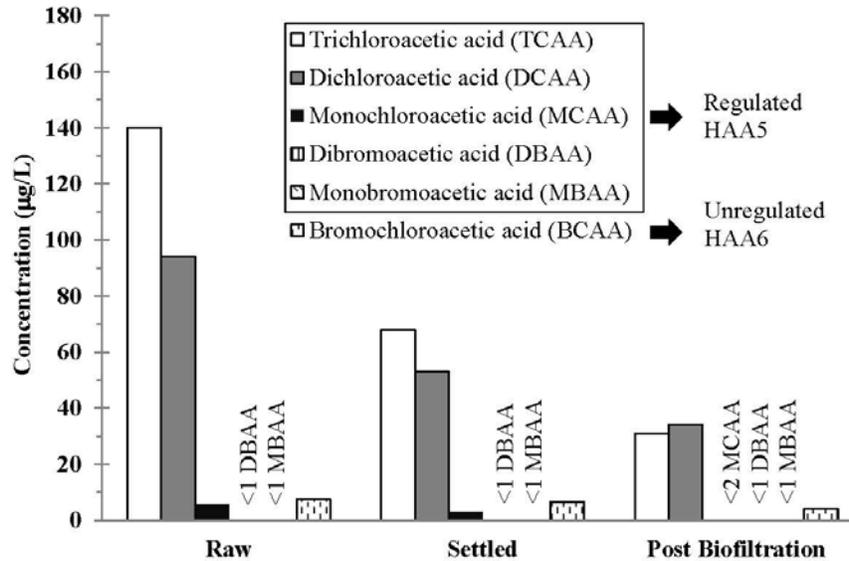


Figure 5. Haloacetic Acid Concentrations

Other Parameters

The JV team analyzed other water parameters in addition to those listed Table 3 using JV laboratory equipment. These parameters were collected principally to help set-up and troubleshoot the testing setup. This section provides information on some of the ancillary data that would be worthwhile for further design.

Raw and Settled Water Supernatant Turbidity

The supplied raw source water had a turbidity of 9.0 NTU. After coagulation, the settled source water supernatant turbidity decreased as the ferric chloride formed sweep flocs co-precipitating or entraining suspended particles and then removing them from solution as they sank to the bottom of the mixing barrels. The water turbidity had decreased to 2.3 NTU after three hours. Further reduction greatly slowed down, with water turbidity falling to only 1.2 NTU after 22 hours of quiescent settling.

Settled Water Supernatant Color and Iron

The settled water supernatant after 22 hours settling contained an apparent color of 27 PCU and 1.05 mg/L total iron. Passing a small grab sample of the settled source water supernatant through a 1.0-µm filter resulted in the color and iron reducing to 4 PCU and 0.02 mg/L iron respectively. No other color or iron measurements were obtained.

Raw and Settled Water Alkalinity

The one analysis of the raw source water determined that the alkalinity is 90 mg/L as CaCO₃ which then decreased to 73 mg/L as CaCO₃ after 20 mg/L ferric chloride (as coagulant) addition. This decrease is expected as coagulation consumes alkalinity. Inadequate alkalinity inhibits floc formation and results in dissolved coagulant iron remaining in the settled water supernatant, which is then loaded onto the BAF. The remaining alkalinity still indicates that the water can support additional ferric chloride coagulation for enhanced NOM removal.

As noted earlier, ferric chloride is acidic and will depress the water pH. NOM adsorption/co-precipitation with ferric chloride is best between pH 5.5 to 6.5, though removal will improve with further pH depression below the pH 7.9 of the raw water and pH 7.0 of the settled water.

Conclusion

The testing found that ferric coagulation/flocculation was an effective pretreatment technique to remove a significant portion of the NOM and the subsequent BAF removed much of the remaining NOM. This removal translated into reduced concentrations of DOC and AOC in the finished water, and lower DBP formation potential, and generally far superior water quality compared to the raw water. Table 6 compares the testing results discussed herein with the Scope of Work water quality criteria previously listed in Table 1. The testing was able to meet the DOC criterion but did not meet the AOC criterion and slightly exceeded the TTHM and HAA5 criteria following a particular set of simulated treatment processes (20 mg/L ferric chloride addition, no pH adjustment, ozonation, BAF, and free chlorination). The JV team is confident that the treatment parameters can be optimized to provide even greater DOC/AOC removal and further suppress DBP formation so that all finished water criteria can be consistently met.

Table 6. Bench-Scale Criteria Comparison

Finished Water Parameters	Criteria	Was Criteria Met in this Testing?	Will Criteria be Met with Optimization?
Dissolved Organic Carbon (DOC)	≤1.5 mg/L	Yes, 1.5 mg/L	Yes
Assimilable Organic Carbon (AOC)	≤100 µg/L	No, 300 µg/L	Yes
Total Trihalomethanes (TTHM) formation potential	≤64 µg/L	No, 82 µg/L	Yes
Haloacetic Acids 5 (HAA5) formation potential	≤48 µg/L	No, 65 µg/L	Yes

Example optimization options to further improve the finished water quality can include:

1. Increasing the ferric chloride dosage – The testing was conducted with the ferric chloride dosage of 20 mg/L. Higher ferric coagulant dosages would generate more sweep flocs for NOM to co-precipitate out of solution.
2. Depressing the raw water pH prior to coagulation – NOM removal by co-precipitation improves as the water pH lowers since ferric flocs are able to adsorb less humic NOM molecules. Decreasing in the water pH via acid addition prior to coagulation will make a

- given coagulant dosage more effective. Increasing the ferric chloride dosage will also further reduce the pH as ferric chloride coagulant contains a considerable amount of hydrochloric acid.
3. Switching from anthracite media to granular activated carbon (GAC) media in the BAF – GAC is more porous than anthracite and can support more biological activity for improved NOM adsorption.
 4. Powdered activated carbon (PAC) addition – PAC readily adsorbs a broad range of NOM and its use would help remove the fraction of NOM not readily amenable to ferric co-precipitation.
 5. Post-filtration GAC adsorption – GAC adsorption would remove most of the remaining NOM from the water prior to secondary disinfection and thereby reducing TTHM and HAA5 formation.
 6. Utilize more representative chlorination conditions, such as simulated distribution system tests in conjunction with the DBP formation potential test to bracket a range of average to worst-case results.
 7. Switching from free chlorination to chloramination as the pipeline secondary disinfectant – Chloramination generates less TTHMs and HAAs than free chlorination.

All of these options will improve the Cutter water quality but options 1, 2, and 3 are the most amenable for the proposed Cutter WTP as treatment benefits can be readily obtained without the cost of additional treatment systems. Option 4 will work but using PAC will involve the cost of an additional chemical handling and feed system. Option 5 most likely provides the greatest NOM removal but at the disadvantage of highest capital and operational costs. Option 6 (chloramination) has a low increased cost with an additional ammonia feed system but further study is required to determine chloramine stability and potential biological regrowth in the long finished water pipelines.

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Appendix A

Test Plan and Reclamation Review Comments-JV Responses

**US BUREAU OF RECLAMATION
TECHNICAL SERVICE CENTER**



**CONTRACT: R12PC80235
TASK ORDER: R13PD80243**

**CUTTER RESERVOIR WATER TREATMENT
BENCH SCALE TESTING**

**BENCH SCALE STUDY
TEST PLAN**

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ACRONYMS

AOC	Assimilable Organic Carbon
APHA	American Public Health Association
ATP	Adenosine Triphosphate
BAF	Biologically Active Filtration
BDOC	biodegradable dissolved organic carbon
CFU/g	colony forming units per gram
DBP	Disinfection Byproduct
DBPFP	Disinfection Byproduct Formation Potential
DI	de-ionized
DOC	Dissolved Organic Carbon
EBCT	Empty Bed Contact Time
g/hr	grams per hour
GC-MS	Gas Chromatograph - Mass Spectrometer
H ₂ SO ₄	Sulfuric Acid
HAA6	Haloacetic Acids 6
HASP	Health and Safety Plan
HCl	Hydrochloric Acid
JV	Joint Venture
MCL	Maximum Contaminant Level
mg/L	milligrams per liter
mgd	million gallons per day
mL	milliliter
mL/min	milliliters per minute
Na ₂ S ₂ O ₃	Sodium Thiosulfate
NaOH	Sodium Hydroxide
NGWSP	Navajo/Gallup Water Supply Project
NH ₄ Cl	Ammonium Chloride
NOM	Natural Organic Matter
PBRWS	Pojoaque Basin Regional Water System
pg/g	picograms per gram
PWS	Project Work Statement
QA/QC	Quality Assurance/Quality Control
scfh	standard cubic feet per hour
SDS	Simulated Distribution System
SDWA	Safe Drinking Water Act
DBPSDS	Disinfection Byproduct Simulated Distribution System
SWTR	Surface Water Treatment Rule
TOC	Total Organic Carbon
TSC	Technical Service Center
TTHM	Total Trihalomethanes
US EPA	United States Environmental Protection Agency
UV	Ultra-Violet
Water RF	Water Research Foundation
WTP	Water Treatment Plant
°C	degrees Centigrade
µg/L	micrograms per liter

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Cutter Reservoir Water Treatment Bench Scale Testing
Bench Scale Study Test Plan

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1.0 INTRODUCTION

Cutter Lateral is a 100-mile network of pipelines and pump stations at the eastern portion of the Navajo/Gallup Water Supply Project (NGWSP) and will include a new 5.4 million gallons per day (mgd) water treatment plant (WTP) that will treat water from the Cutter Reservoir. The new Cutter WTP will supply treated water to the Cutter Lateral and deliver water to the eastern Navajo Nation and Jicarilla Apache Nation. The United States Bureau of Reclamation (Reclamation) is conducting studies to evaluate the treatability of the Cutter Reservoir water in San Juan County in northwest New Mexico to meet Federal and state drinking water standards.

2.0 PROBLEM STATEMENT

Based on the Project Work Statement (PWS), Reclamation has been investigating several water treatment processes for the Cutter WTP. Reclamation wants to verify the acceptability of the currently preferred WTP process of enhanced coagulation-flocculation sedimentation, ozone coupled with biologically active filtration (BAF), followed by disinfection with ultraviolet (UV) and free chlorine to meet turbidity, disinfection and disinfection byproduct (DBP) goals of the U.S. Environmental Protection Agency (U.S. EPA), Navajo Nation EPA, and applicable regulations such as the Safe Drinking Water Act (SDWA) and Surface Water Treatment Rule (SWTR). Bench scale testing has been requested by Reclamation to determine if the ozone/BAF process will remove sufficient natural organic matter (NOM) to reduce DBP formation with the use of free chlorine.

The CDM Smith and HDR joint venture (JV) team will conduct a bench scale study to evaluate the feasibility of ozone/BAF as a potential treatment process to reduce the NOM levels in Cutter reservoir water. This test plan describes proposed bench scale testing to be conducted at the JV Laboratory in Bellevue Washington. The JV team will systematically apply our laboratory bench scale expertise with the goal of determining if the proposed treatment scheme can meet the water quality goals.

The primary objective of the bench scale study is to evaluate the feasibility of ozone/BAF for reducing disinfection byproduct formation potential (DBPFP), assimilable organic carbon (AOC), and dissolved organic carbon (DOC). The study will evaluate if these constituents can be reduced to levels that meet the treatment goals summarized in Table 1 without process optimization.

Table 1: Treatment goals for the finished water

	Regulatory requirement
Dissolved Organic Carbon (DOC)	≤ 1.5 mg/L
Assimilable Organic Carbon (AOC)	≤ 100 µg/L
Disinfection Byproduct Formation Potential (DBPFP)	
Total Trihalomethanes (TTHM)	80% of the maximum contaminant level (MCL) (≤ 64 µg/L)
Haloacetic Acids 6 (HAA6)	80% of the MCL (≤ 48 µg/L)

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3.0 GENERAL APPROACH - OZONE/BIOLOGICALLY ACTIVE FILTRATION

Previous bench and pilot studies conducted by our team recognize the key to minimizing DBP formation is maximizing natural organic matter (NOM) removal. Therefore, our approach is based on removal or conversion of NOM to a form that can be more easily removed by biological filtration. Coagulation followed by oxidation with ozone and biofiltration is an effective process (Evans 2010). Coagulation removes the bulk of the NOM and ozonation converts a sufficient amount of the residual NOM to a form that can be removed in a biological filter. Pre-oxidation increases the biodegradability of complex NOM that is present in surface water and typically results in generation of biodegradable dissolved organic carbon (BDOC) and smaller organic compounds including carboxylic acids and aldehydes. BAF downstream of oxidation is capable of oxidizing these biodegradable compounds to carbon dioxide leading to decreased DBP formation potential upon chlorination and increased water stability in the distribution system.

4.0 DETERMINING ACCEPTABILITY OF OZONE/BAF PROCESS

The primary goal of this bench scale study is to determine if the ozone/BAF treatment process can reduce Cutter Reservoir water (source water) NOM to acceptable levels and reduce DBP formation potential. The study will also evaluate if the proposed treatment process can meet the treatment goals summarized in Table 1. For this purpose, bench scale testing is divided into two phases. Phase 1 will involve collection of source water, Lake Washington water (Lake water), and anthracite media (media) from a bioactive filter. Phase 2 will consist of conducting bench scale treatability testing involving pretreatment followed BAF. Details of these activities are provided in the following sections.

4.1 Phase 1 - Sample Collection

Lake Washington water samples - Grab water samples from Lake Washington (lake water) will be collected in sixteen 5-gallon plastic containers. A total of 80 gallons of lake water will be collected and transported to the JV laboratory where this water will be stored at 4°C for preservation. Lake water will be filtered by using a high flow rate filtration system to remove solids before using in the anthracite acclimation process. This activity is an in-kind contribution from the JV team and is currently in progress.

Cutter reservoir water samples - Reclamation will collect 100 gallons of source water from Cutter Reservoir and ship to the JV laboratory at the following address:

CDM Smith
Attn: Tony Singh
14432 SE Eastgate Way
Suite #100
Bellevue, WA 98007

For easy handling during transportation and storage, five-gallon plastic cubitainers are preferred for sample collection. Source water samples will be shipped on ice via overnight delivery to the JV laboratory. The JV laboratory will send a sample shipment memo to the Reclamation prior to source water sample shipment. This memo is used to identify any

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hazards associated with the samples. For test planning purposes, the source water sample is anticipated to be received on October 1, 2013. Cutter reservoir water samples will be inspected upon arrival in the laboratory to confirm the integrity of the sample and that the sample is acceptable for analysis. Samples leaked during transportation will be discarded.

Upon receipt at the JV laboratory, the source water will be pre-treated as discussed in Section 5.0 and stored at 4°C. Prior to any testing, water will be taken out of the cold room and placed in a dark area in the laboratory to allow equilibration with room temperature. Before any testing, the source water samples will be homogenized by rolling the cubitainer on the countertop.

Media Acquisition and Acclimation - The JV team is in the process of acquiring 1000 milliliters (mL) of biomass-established anthracite BAF media from the Rolling Hills Water Treatment Plant in Fort Worth, Texas. This plant was selected for media collection because of the high adenosine triphosphate (ATP) (5.04×10^4 picograms per gram (pg/g) media dry weight and heterotrophic plate counts (3.15×10^8 colony forming units per gram (CFU/g) media dry weight) observed during a previous WaterRF 4231 project (Evans et al. 2013). For media collection, the top 0.5-inch of media layer in the biofilter will be scraped and discarded as this may contain solids. Media will then be collected from the top six inches of the BAF, where the most extensive biological activity is expected. Media will be collected in a one-liter polyethylene bottle. To keep the biofilm moist during shipping/transportation, biofilter influent water (unchlorinated) will be added to the polyethylene bottle containing media. Media will be shipped on ice via overnight delivery to the JV laboratory.

The media will be loaded into a one-inch diameter, 24-inch (bed height) long BAF column at the JV laboratory. A plastic perforated disk with approximately one-inch of glass wool on each end of the column will be used for supporting anthracite media. Lake water will be recirculated through the column at a flow rate of 30 milliliters per minute (mL/min) (10 minutes empty-bed contact time [EBCT]) to start the media acclimation process. Lake water will be changed twice a week for two weeks. The goal is to have the BAF system ready when the shipment of source water arrives. Use of Lake water for acclimation will acclimate the BAF media column prior to operation with Cutter Reservoir water.

4.2 Phase 2 – Bench Scale Testing

Pretreatment Process Train – In accordance with the PWS the pretreatment process train will consist of coagulation/flocculation/sedimentation and ozonation. Ferric chloride will be used as coagulant at dose of 20 milligrams per liter (mg/L), as indicated by Reclamation in the PWS, followed by flocculation and sedimentation. An additional pretreatment process step of filtering the water after sedimentation will be employed to remove solids or floc. Filtered source water will be ozonated in separate batches of 13 gallons each day and this will be used as the feed water to the BAF column. Detailed test procedures on the pretreatment testing are given in Section 5.0.

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Bench Scale BAF Column testing - Biofiltration column tests will be conducted on the ozonated source water that have been pre-treated using coagulation/flocculation/sedimentation and filtration. The objective of the column testing is to evaluate the feasibility of BAF in combination with pre-oxidation for reducing NOM, and thus DBPFP. A one-inch diameter 24-inch bed height column containing acclimated anthracite media will be operated in single pass flow through mode. Ozonated source water will be introduced to the column using a peristaltic pump at a flow rate of 30 mL/minute to achieve an EBCT of 10 minutes.

5.0 SPECIFIC TESTING METHODS

Coagulation/Flocculation - The 100-gallon source water sample will be divided and treated in three batches at the JV laboratory upon arrival. Each batch will be coagulated, settled, and filtered prior to storage at 4°C in a cold room. Approximately 34 gallons of sample will be transferred to a clean unused 55-gallon drum. 20 mg/L of ferric chloride (NSF certified) will be added to the sample followed by a rapid mixing with a velocity gradient (G value) between 700 – 1,000 sec⁻¹ for 30 seconds and then a slow mixing (flocculation) with a G value between 25 and 50 sec⁻¹ for 20 minutes. A variable speed mixer will be used in conjunction with a mixing paddle to provide appropriate mixing energy for coagulation and flocculation. The flocculated water will be settled for 60 minutes before the supernatant is carefully decanted and filtered through a high flow rate filtration system using a pump. Filtered water pH will be measured and recorded. If the pH is considered too low for optimal biological filtration (6.5 – 8.5), pH will be adjusted using diluted NaOH or HCl.

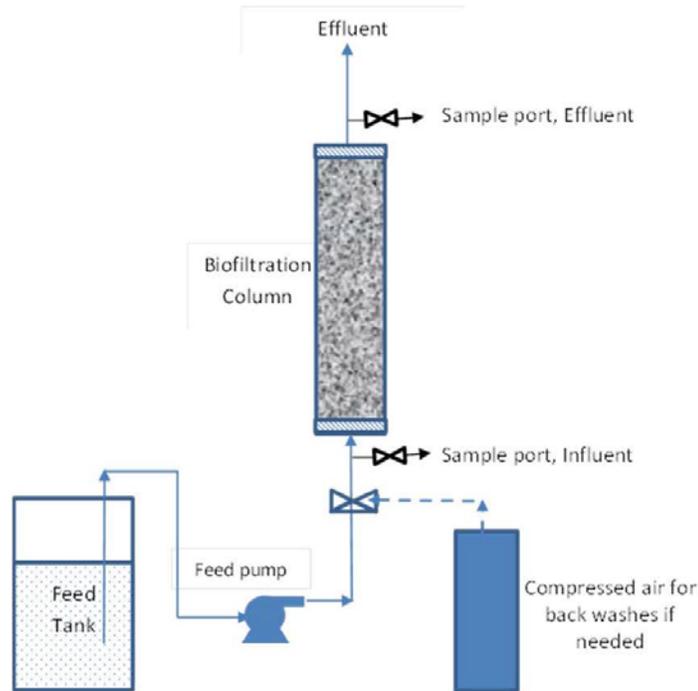
Ozonation - A 1.5 ozone/total organic carbon (TOC) dose ratio will be used in this study to provide adequate pre-oxidation for BAF. The TOC of the pretreated water sample will be analyzed using an in-house TOC analyzer. An ozone generator (Clearwater Tech CD 12) that has a capacity of 8 grams/hour (8 standard cubic feet per hour ((scfh)) with oxygen source (3 grams per hour [g/hr] with air) will be used to generate ozone needed. Thirteen gallons of pretreated water sample (the quantity needed for one day of BAF operation is approximately 12 gallons) will be ozonated in a vertical ozone reactor (equipped with a ceramic fine bubble diffuser) in semi batch mode. At 8 scfh oxygen and full power setting, ozone will be generated and passed through one gallon of deionized (DI) water in a semi batch mode (continuous gas flow through a batch of water). Aqueous samples will be withdrawn at different time intervals (5, 10, 15, 30, 45, and 60 minutes) and analyzed for residual aqueous phase ozone content using standard method 4500 O₃ B (APHA, 2005). An ozone dose calibration graph of aqueous ozone content versus time will be developed. Assuming the same ozone mass transfer efficiency in source water, this calibrated ozone dose curve will be used as the operation guidance for appropriate ozone dosing throughout the study.

Biological active filtration (BAF) Column Testing – A schematic of the BAF column setup is shown in Figure 1. An EBCT of 10 minutes is selected based on the JV team's experience in achieving appropriate filter column hydraulics, optimal BAF performance, and the quantity of water sample available (100 gallons). Ozonated source water will be pumped to the BAF column through a peristaltic pump at 30 mL/min flow rate that corresponds to a

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column run of 8 days (using 100 gallons of water). Influent and effluent samples will be taken at a minimum of once per day and measured for analytes listed in Table 2. Exact sampling frequency will be determined based on the DOC reduction observed at each sampling point. Sample analysis is described in Section 7.0.

Figure 1: Schematic of single pass flow through BAF column setup



DBPSDS Testing using Chlorine – Standard 5-day Simulated Distribution System (SDS) testing will be performed using the standard method 5710 (APHA, 2005). SDS testing will be conducted with chlorine. Free chlorine, TTHM, and HAA6 will be analyzed during SDS testing. To determine an appropriate chlorine dose for the SDS testing, a preliminary 24-hour chlorine demand test will be conducted. For this, 5 mg/L of sodium hypochlorite will be added to a water sample (100 mL), and left to react for 24 hours in the dark at room temperature. Phosphate buffer will be added for pH adjustment. An initial water sample will be collected and analyzed for free chlorine dose (Initial). After 24 hours, residual free chlorine of the sample will be determined. The 24-hour chlorine demand value will be calculated by subtracting the final chlorine dose from the initial applied chlorine dose. Chlorine dose for the actual SDS testing will be calculated by adding 1 mg/L to the 24-hour chlorine demand value.

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6.0 DESCRIPTION OF THE EXPECTED RESULTS

NOM is a key surface water quality parameter that affects the disinfection process and formation of DBPFP. Coagulation/flocculation is an effective technique to remove NOM. With an optimized oxidation step (ozonation), it is expected that NOM will be converted to smaller and more easily biodegradable organic compounds (carboxylic acids and aldehydes). These smaller organic compounds can be effectively removed by the BAF process. This removal is anticipated to translate into reduced DOC, AOC, and DBPSDS. The actual reductions will be determined by the testing.

7.0 MONITORING, SAMPLING, AND ANALYTICAL TESTING

Water samples will be collected and analyzed for different water quality parameters at four stages during bench testing (Table 2). Sample pH, TOC and DOC will be measured in all four stages. Table 2 lists the analytical methods and equipment necessary to evaluate the treatment options.

Raw source water will be characterized for all the analytes mentioned in Table 2 except AOC and ozone residuals. Total and free chlorine content will be measured during DBPSDS testing only. Current BAF column influent and effluent will be sampled every day but this sampling frequency may be altered during column testing based on effluent DOC, and TOC reduction observed. AOC and DBPSDS analysis on the post biofiltration will be conducted for the sample at the end of the column run. The BAF column will be operated for a maximum of 8 days based on the 100 gallons source water.

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Table 2: Analytical methods and instrumentation for bench testing

Parameter	Sampling Points					Analytical Method	Method Detection Limit	Bottle type	Preservative	Holding Time	JV Lab Equipment
	Raw Water	Post Sedimentation	Post Ozonation	Post Biofiltration (Column study)	Post Biofiltration (SDS testing)						
pH	1X	1X	Daily	Daily	Daily	SM 4500-H B	±0.1 SU	15 ml polypropylene centrifuge tube	4°C	Analyze immediately	Multiple calibrated digital pH meters
Free chlorine	1X	1X	-	-	Daily	Hach Method 10069	0.1 mg/L	15 ml polypropylene centrifuge tube	none	Analyze immediately	Hach test kit
Total chlorine	1X	1X	-	-	Daily	Hach Method 10070	0.1 mg/L	15 ml polypropylene centrifuge tube	none	Analyze immediately	Hach test kit
Ozone residual	-	-	Daily	-	-	SM 4500-O ₃	0.01 mg/L	15 ml polypropylene centrifuge tube	none	Analyze immediately	Hach DR 6000 and Hach DR 4000 UV-spectrophotometers
TOC	1X	1X	Daily	Daily	-	SM 5310 B	0.1 mg/L	40 ml pre-cleaned glass TOC vial	H ₂ SO ₄ (sample pH<2)	28 days	Shimadzu TOC analyzer
DOC	1X	1X	Daily	Daily	-	SM 5310 B	0.1 mg/L	40 ml pre-cleaned glass TOC vial	H ₂ SO ₄ (sample pH<2)	28 days	Shimadzu TOC analyzer
DBP/SDS – TTHM	1X	1X	-	-	1x	EPA Method 501.1	0.5µg/L	40 ml VOA vials	4°C	14 days	Gas chromatograph-mass spectrometer (GC-MS) with purge & trap
DBP/SDS – HAA6	1X	1X	-	-	1x	EPA Method 552.2	1.0µg/L	3 x 60mL vials with PTFE lined cap	100 mg/L NH ₄ Cl	14 days	Eurofins Eaton Laboratories
AOC	1X	1X	-	1X	-	SM 9217 B	10 µg/L	40 ml pre-cleaned glass TOC vials (10 per sample)	4°C and Na ₂ S ₂ O ₃	3 days	Eurofins Eaton Laboratories
SDS Testing	1X	1X	-	-	1X	SM 5710	N/A	N/A	4°C	N/A	JV Laboratory

1X: One time per day
H₂SO₄ = Sulfuric Acid
PTFE = Polytetrafluoroethylene
NH₄Cl = Ammonium Chloride
Na₂S₂O₃ = Sodium Thiosulfate
N/A: Not applicable

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8.0 DESCRIPTION OF TESTING EQUIPMENT

Table 3: Description of testing equipment for bench testing

	Quantity	Make and Model
Water Storage and Preparation		
▪ Water heaters and chillers	1	Sheldon Manufacturing, Inc. 1213
▪ Walk-in coolers (cold room) and refrigerators	2	Piedmont Air PR12-1AS, Marvel Scientific
Experimental equipment		
▪ Fume hoods	1	Jamestown Metal Products MHC0
▪ Bench-scale ozone generators	1	Clearwater Tech CD12
▪ Vacuum filtration systems	1	Gast Aerojet Vacuum Pump, AO3
▪ Biofiltration columns	1	Plastic column with end caps
▪ Pumps, piping and tubing for bench-scale columns	1	Cole-Parmer Tygon Tubing
Analytical Equipment		
▪ UV visible spectrophotometers	1	HACH DR6000
▪ Imhoff sludge settling columns	1	Wheaton W990800
▪ TOC analyzer	1	Shimadzu TOC-V CSH
▪ Ion chromatograph with auto sampler	1	Dionex LC 20
▪ GC-MS	2	Agilent 6890 w/ 5973N
▪ pH/DO meters	1	Orion

9.0 KEY PERSONNEL PERFORMING THE BENCH WORK WITH QUALIFICATIONS

The following paragraphs provide more detail about the key project team members’ roles and responsibilities as well as the benefits they provide to Reclamation on the Cutter Bench Scale testing.

Task Order Manager | Chris Rodriguez, PE. The task order contract administration for Cutter Bench Scale testing project will be led by Chris Rodriguez. Mr. Rodriguez has over 19 years of experience with a variety of water and wastewater related projects and will oversee and manage all day-to-day project activities and will coordinate communication between team members to keep the project on schedule and within budget. Mr. Rodriguez has been regularly attending the NGWSP Pre-Construction Committee meetings, which has allowed him and the team to gain first-hand knowledge regarding some of the challenges and issues associated with the NGWSP as well as establish positive relationships with the Navajo Nation, City of Gallup, Indian Health Service and Reclamation staff in the Four Corners Construction Office. His previous project experience including on-going work for the Reclamation Pojoaque Basin Regional Water System (PBRWS) water treatment pilot study project in Northern New Mexico will enable him to work effectively on this project.

Technical Lead | Dr. Pat Evans, PhD. Dr. Evans will serve as the Technical Lead for the project and will oversee the development of the bench-scale testing program including protocols and procedures as well as analysis and interpretation of the testing results. Dr. Evans is considered an industry expert in water treatment and ozone/BAF treatment and has

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completed several recent studies for the Water Research Foundation (WaterRF) that included bench-scale testing. Dr. Evans's knowledge and experience will be valuable for developing and implementing the testing program as well as assessing the overall technical feasibility of the treatment processes, specifically BAF.

Technical Advisor | Scott Summers, PhD. As Technical Advisor to the JV team, Dr. Summers will provide guidance for the overall program and insight regarding the most current research and development pertaining to BAF. Scott also participated in previous bench-scale testing for the NGWSP San Juan WTP which included evaluation of ozone/BAF unit treatment processes and source water with similarities to this project.

Test Planning and Analysis | YuJung Chang, PhD. Dr. Chang is a nationally recognized expert in the water treatment industry and will primarily be responsible for the pre-treatment testing prior to the BAF testing. He will work closely and collaboratively with Dr. Evans to provide guidance on the overall planning and implementation of the testing program and assist with the analysis of the testing results of the pre-treatment and BAF processes.

Test Planning, Analysis and Reporting | Jennifer Smith, PE. Ms. Smith will be Responsible for preparation of the bench scale test plan, data analysis, and final bench scale testing report. Ms. Smith has worked closely with Dr. Evans on many of the BAF research projects and will be responsible for the BAF column testing elements.

Bench Scale Laboratory Process and Analytical Testing | Tony Singh, PhD and Al Vetrovs. Dr. Singh and Mr. Vetrovs have a combined experience of more than 40 years with water treatability studies at both the bench and pilot-scale. Dr. Singh and Mr. Vetrovs will be responsible for the day-to-day process and analytical testing required to complete the bench-scale testing program. Dr. Singh will be primarily responsible for the BAF testing and analytical testing, with Mr. Vetrovs primarily responsible for the pre-treatment bench-scale testing.

Quality Assurance/ Quality Control | Michael Zafer, PE. Mr. Zafer has extensive experience with the completion of bench-scale and pilot-scale studies for numerous water treatment plants across the U.S. Mr. Zafer will be responsible for the QA/QC for the bench-scale testing program and will provide independent review of both the bench-scale test plan and report documentation.

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10.0 QUALITY ASSURANCE/QUALITY CONTROL

Quality assurance/quality control (QA/QC) for the water quality testing will include chain-of-custody procedures, instrument calibration requirements, bench testing protocols, data recording and data collections spreadsheets. All sample collection, preservation and analysis will be performed in accordance with the appropriate EPA or Standard Methods requirements. Sample collection and analysis will be performed by laboratory staff that has been trained in the appropriate laboratory methods including sample collection, preservation, analysis, data entry and the appropriate QA/QC procedures.

Detection limits have been or will be determined for each of the analytical parameters and the use of blanks, replicate samples, spiked samples, and method recovery samples will be employed as per the applicable analytical method. Replicate samples will be collected at a frequency of 10% to assess the precision of laboratory results. Applicable precision and accuracy goals for the bench scale testing are provided in Table 4.

Table 4: Project data precision and accuracy goals

Parameter	Accuracy	Precision
pH	92-102%	-
Free chlorine	± 1 mg/L	-
Total chlorine	± 1 mg/L	-
Ozone residual	-	-
TOC	85%-115%	70%-130% RPD
DOC	85%-115%	70%-130% RPD
DBPFP – TTHM	60-140%	60-140% RPD
DBPFP – HAA6	60-140%	60-140% RPD
AOC	60-140%	60-140% RPD

RPD: Relative Percent Difference

Chain of custody forms will be generated and accompany all samples that are sent to outside laboratories for analysis (HAA6 and AOC). Copies of the chain of custody forms will be received from the outside laboratories once analyses are completed. Upon receipt of the results, sample quality control will be reviewed and, if acceptable, the sample data will be added to the project database. All data and submittals performed by outside analytical laboratories will be reviewed and approved by the JV team prior to their submittal to Reclamation. If requested, data will be made available to the project participants and/or the Navajo Nation regulatory agents.

Data Storage, Reporting, and Statistics - The data management system used for the bench scale testing program will involve the use of computer spreadsheets and/or a project database. As much as possible, data collection will be done electronically with data entry to the project spreadsheet or database after validation. All data will be stored electronically with backup copies made routinely. If appropriate, original data will be included as a part of the appendices for the final report.

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11.0 HEALTH AND SAFETY

Laboratory health and safety plan (HASP) will be developed and implemented prior to starting any testing. An addendum to the plan will be written to address additional hazards posed by the use of oxidants including ozone, and sodium hypochlorite. This addendum will address storage and signage requirements for these oxidants to protect laboratory personnel from associated hazards.

12.0 DATA REVIEW AND REPORTING

Throughout the bench-scale testing period, the Project Team will review and interpret all of the laboratory performance and water quality data and extract useful information through data analysis techniques. A draft report will be prepared after the completion of bench scale testing for Reclamation review/comments. Reclamation comments will be incorporated and a final project report will be prepared and submitted to Reclamation. The final report will summarize the results of the testing and will also discuss recommendations for future optimization testing of the pre-treatment and BAF processes if needed.

13.0 PROJECT SCHEDULE

Table 5: Deliverables/reviews for bench scale testing project

Deliverable	Due date
Bench Scale Test Plan	09/26/2013
TSC Comments to Contractor	10/03/2013
Start of Bench Tests	10/04/2013
Bench Scale Test Report – Draft	10/18/2013
TSC Comments to contractor and conference call	10/30/2013
Bench Scale Test Report – Final	11/19/2013

14.0 REFERENCES

- American Public Health Association (APHA). 2005. *Standard Methods of Water and Wastewater*. 21st ed. American Public Health Association, American Water Works Association, Water Environment Federation publication. APHA, Washington D.C.
- Evans, P.J. 2010. "Nature works: Biological treatment methods yield high quality water." *Opflow* July: 12-15.
- Evans, P.J., J.L. Smith, M.W. LeChevallier, O.D. Schneider, L.A. Weinrich, and P.K. Jjemba. 2013. "Monitoring and Control Tool Box for Assessing and Enhancing Biological Filtration." *Water Research Foundation Project 4231 Report* Water Research Foundation.

Rodriguez, Chris

From: Jurenka, Robert <rjurenka@usbr.gov>
Sent: Monday, November 04, 2013 2:58 PM
To: Rodriguez, Chris
Cc: Judith Chamberlin; Ronald LeBlanc
Subject: Comments on Ozone/BAF Test Plan, Cutter Reservoir, T.O. R13PD80423
Attachments: Cutter Bench Test Plan - BOR Review Comments 11.4.13.pdf

Thank you for the subject Test Plan.

Ron and I are ready to discuss these comments with you and your team as soon as possible. We found out today that sample coolers are in and reservoir water samples will be collected and shipped this week.

Please share these comments with your team and let me know when we can discuss these comments. A re-submittal of the Test Plan is not required.

Thanks again!

Robert Jurenka, P.E.
Environmental Engineer
Bureau of Reclamation
Technical Services Center
Water Treatment Group
303 445-2254 work
303 947-8013 cell

Contract # R12PC80235, Task Order R13PD80243
Cutter Reservoir Water Treatment Bench Scale Testing
Reclamation Review Comments on Bench Scale Study Test Plan
November 4, 2013

Conference call requested to discuss our comments. A resubmittal of the Test Plan is NOT necessary.

JV responses in RED.

1. Re: Page 5: Has the memo described at the bottom of the page been sent? If not, let's discuss.

The memo was submitted.

2. Re: Page 6:

- a. The date of October 1 for sample receipt has slipped. Samples are to be shipped the week of November 4th. Can a new schedule (not a new Test Plan) be provided?

A new schedule has been submitted.

- b. 3^d paragraph, describes water being added to the media to keep it moist. What is the source of this "bio-filter influent water" and how was it selected?

The biofilter influent water is the water from the Rolling Hills WTP, the same source water fed to the media..

- c. Section 4.2 and 5.0 discusses using a high rate filter after sedimentation. Our preference was to ozonate clarifier effluent with the only filter in the process being the biofilter. What are the details of your clarifier? What is the justification or rationale of using a pre-ozone filter (POF)?

The clarifier is a new 30-gallon polypropylene drum. Per the subsequent conference call, the pre-ozonation filter was deleted from the test plan.

- d. We question the need, description and type of filter requested. We are concerned that using a filter will not accurately simulate the full-scale treatment process proposed by Reclamation. Also, it may remove some potential food source for biomass on the BAF.

See the response to Comment 2.c.

3. Page 7:

- a. A description of specification for the material of the 55-gallon drums proposed for sample holding is requested.

Per the subsequent conference call, the sample water is stored in the supplied cubitainer and then transferred to a new 30-gallon polypropylene drum.

- b. For ozone, confirm the ozone: TOC ratio is 1.5:1

The ratio is 1.5:1.

4. Page 8: Our PWS called for Disinfectant Formation Potential Tests, not SDS tests.

The test plan was changed to DBP Formation Potential Test.

5. Page 9: What kind of graphical results will be used in the Results Report to show the expected performance of the BAF over the 8 day test?

See the report figures.

6. Page 10:

- a. Is Column 1's "Raw Water" collected before or after coagulation?

Before coagulation.

- b. Is "Holding Time, column 11, a maximum that is not to be exceeded?

Not be exceeded.

PART 2 PRODUCTS

Not Used

PART 3 EXECUTION

Not Used

END OF SECTION

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