STATE OF COLORADO
OIL & GAS
CONSERVATION COMMISSION

DEPARTMENT OF NATURAL RESOURCES
Bill Ritter, Jr., Governor
1120 Lincoln St. Suite 801
Denver, CO 80203
Phone: (303) 894-2100
FAX: (303) 894-2109
www.colorado.gov/cogcc

September 7, 2010

Mr. Ike King
13141County Road 104
Nunn, CO 80648

RE: Complaint #200262233
Water Quality Analytical Results for Domestic Water Well (Permit #253898)
SWSW Section 17, T-9-N, R-66-W
Weld County, Colorado

Dear Mr. King,

In response to your concerns regarding possible impacts to water quality from oil & gas operations in the area near your home, the Colorado Oil and Gas Conservation Commission (COGCC) conducted a field visit to your property on July 20, 2010. Water samples were collected for general organic and inorganic water quality testing as well as for the analysis of dissolved methane. A summary of the results of the chemical analyses is presented below. The analytical results are also compared to published water quality standards.

FIELD TESTING

The water sample was collected from an exterior faucet on the west side of your house. The water was turned on at approximately 08:50 and allowed to run for approximately 35 minutes at an estimated rate of 5 gallons per minute. The water was clear with no odor or unusual taste. A slight effervescence was noted as the water bubbled when it was allowed to run into a bucket. No sediment accumulated in the bucket and the characteristics of the water did not change during the 35 minutes it ran. The sample was collected at 09:25 and delivered to Test America Laboratories in Arvada, Colorado for general inorganic and organic chemical analyses. A sample for gas composition and isotopic ratio analyses was submitted to Isotech laboratories, Inc. in Champaign, Illinois.

COMPARISON OF INORGANIC ANALYTICAL RESULTS TO CDPHE INORGANIC STANDARDS

The Water Quality Control Commission (WQCC) of the Colorado Department of Public Health and Environment (CDPHE) has established "Domestic Use-Quality" human health standards and drinking water standards. Analytical data for the samples from your water well was compared to these standards. This information is summarized in Table 1, which is located in attachment 1 and discussed in narrative form below. Please keep in mind that these "Domestic Use-Quality Standards" were established for municipal public drinking water supplies and often people use and

consume ground water from private wells that exceed these standards. The data pages of the analytical reports from Test America Laboratories and Isotech Laboratories Inc. are included in Attachments 2 and 3 respectively.

- Total Dissolved Solids (TDS): CDPHE has established a TDS standard for human drinking water of 500 milligrams per liter (mg/l). The standard is called the secondary maximum contaminant level (SMCL) and is based on the aesthetic quality of the water (such as taste and odor) and is intended as a guideline for public water supply systems and is not an enforceable standard. Although CDPHE does not have an agricultural standard for TDS, other agencies recommend concentrations below 1,500 mg/l for irrigation, and below 5,000 mg/l for most livestock watering. TDS concentrations are related to the presence of naturally occurring elements and chemical compounds such as chloride, sodium, potassium, calcium, magnesium, and sulfate.

  TDS was detected in the water sample from your water well at a concentration of 460 mg/L, which is less than the CDPHE SMCL.

- Barium (Ba): The CDPHE human health standard for barium is 2.0 mg/L. Barium is a contaminate metal.

  Barium was detected in the sample collected from your water well at a concentration of 0.02 mg/L, which is below the CDPHE human health standard.

- Fluoride (F): CDPHE has established a fluoride (F) standard for drinking water of 4.0 mg/l. Where fluoride concentrations are in the range of 0.7 mg/l to 1.2 mg/l, health benefits such as reduced dental decay have been observed. Consumption of fluoride at concentrations of greater than 2.0 mg/l can result in mottling of teeth. Consumption of fluoride at concentrations greater than 4.0 mg/l can increase the risk of skeletal fluorosis or other adverse health effects.

  Fluoride was not detected in the water sample from your water well.

- Chloride (Cl): The CDPHE chloride standard for human drinking water is 250 mg/l. Chloride concentrations in excess of 250 mg/l usually produce a noticeable taste in drinking water.

  Chloride was detected in the water sample from your water well at a concentration of 23 mg/l, which is less than the CDPHE drinking water standard.

- Sulfate (SO_4): The CDPHE sulfate standard for human drinking water is 250 mg/l. Although CDPHE does not have an agricultural standard for sulfate, other agencies recommend a concentration below 1,500 mg/l for livestock watering. Waters containing high concentrations of sulfate, typically caused by the leaching of natural deposits of magnesium sulfate (Epsom salts) or sodium sulfate (Glauber's salt), may be undesirable because of their laxative effects. Sulfate occurs naturally in the ground water in many areas in Colorado at concentrations that exceed the drinking water standard.

Sulfate was detected in the water sample from your water well at a concentration of 150 mg/L which is less than the CDPHE drinking water standard.

- Total Nitrate (NO_3) + Nitrite (NO_2) as Nitrogen (N): The CDPHE total nitrate (NO_3) + nitrite (NO_2) as nitrogen (N) standard for human drinking water is 10 mg/l. Nitrate and nitrite are common contaminants in ground water from agricultural sources, such as fertilizer and animal wastes. They are known to cause infant cyanosis or "blue baby disease" in humans and, at concentrations greater than 100 mg/l as nitrogen (N), may be dangerous to livestock. High concentrations of nitrate and nitrite in ground water are known to occur in agricultural areas in Colorado.

  Total nitrate/nitrite, as N was not detected in the water sample from your water well.

- Iron (Fe): The CDPHE iron standard for human drinking water is 0.3 mg/l. Small amounts of iron are common in ground water. Iron may produce a brownish-red color in laundered clothing, can leave reddish stains on fixtures, and impart a metallic taste to beverages and food made with it. After a period of time iron deposits can build up in pressure tanks, water heaters, and pipelines, reducing the effective flow rate and efficiency of the water supply.

  Iron was not detected in the water sample from your water well.

- Manganese (Mn): The CDPHE secondary drinking water standard for manganese is 0.05 mg/l and for agricultural water it is 0.2 mg/l. Manganese produces a brownish color in laundered clothing, may stain fixtures and affect the taste of coffee or tea.

  Manganese was detected in the recent water sample from your well at a concentration of 0.042 mg/l which is within the secondary drinking water standard and within the agricultural standard.

- Lead (Pb): The CDPHE human health standard for lead is 0.05 mg/L. Prolonged exposure to this metal can result in serious health effects.

  Lead was not detected in the sample collected from your water well.

- Chromium (Cr): The CDPHE human health standard for chromium is 0.1 mg/L. Chromium is a contaminate metal.

  Chromium was not detected in the sample collected from your water well.

- Arsenic (As): The CDPHE human health standard for arsenic is 0.01 mg/L. Arsenic is a highly poisonous metal.

  Arsenic was not detected in the sample collected from your water well.

- Selenium (Se): The CDPHE human health standard for selenium is 0.05 mg/L. Selenium is a contaminate metal.

  Selenium was not detected in the sample collected from your water well.

- pH: pH is the measure of the hydrogen ion concentration in water. The pH of water in its natural state is generally from 5.5 to 9.0. The CDPHE standard for domestic and agricultural water is a range of 6.5 to 8.5. Seven (7) represents neutrality, while values less than 7 indicate increasing acidity and values greater than 7 indicate increasing alkalinity.

  pH was measured in the water sample from your well with a value of 8.05, which is within the CDPHE drinking water and agricultural standards.

The following parameters were also measured as part of the laboratory analysis although there are no CDPHE standards.

- Sodium (Na): Although CDPHE does not have a standard for sodium, people on salt restricted diets should be aware of the Na concentration in the water they drink. Drinking water with a concentration of sodium less than 20 mg/l is recommended by some for people on salt restricted diets or for people suffering from hypertension or heart disease. Sodium occurs naturally in the ground water in many areas at concentrations that exceed the recommended level.

  Sodium was detected in the water sample from your water well at a concentration of 110 mg/l, which is greater than the recommended level for people on salt restricted diets.

- Calcium (Ca): The calcium concentration in the sample collected from your well was 44 mg/L.

- Magnesium (Mg): The magnesium concentration in the sample collected from your well was 12 mg/L.

- Potassium (K): The potassium concentration in the sample collected from your well was 9.4 mg/L.

- Bicarbonate (HCO_3): The bicarbonate concentration in the sample collected from your well was 190 mg/L.

- Bromide (Br): The bromide concentration in the sample collected from your well was 0.29 mg/L.

ORGANIC COMPOUNDS ASSOCIATED WITH PETROLEUM HYDROCARBONS

- Benzene: The CDPHE basic ground water standard for benzene is 5 micrograms per liter (µg/l). **Benzene was not detected in the sample from your water well.**

- Toluene: The CDPHE basic ground water standard for toluene is 1,000 µg/l. **Toluene was not detected in the sample from your water well.**

- Ethylbenzene: The CDPHE basic ground water standard for ethylbenzene is 680 µg/l. **Ethylbenzene was not detected in the sample from your water well.**

- Total Xylenes (sum of m,p, and o-xylene): The CDPHE basic ground water standard for total xylenes is 10,000 µg/l. **Total xylenes were not detected in the sample from your water well.**

METHANE GAS CONCENTRATION

Methane gas alone is physiologically inert and non-toxic to humans. Normal breath exhalation contains 1 to 99 parts per million (ppm) of methane. The presence of methane in drinking water does not present a known health hazard to humans or other animals via ingestion. Methane gas dissolved in water "exsolves" when exposed to the atmosphere and dissipates rapidly because it is lighter than air. This is often responsible for the "fizzing" observed in water wells that may contain methane gas. If the methane occurs at a high enough concentration and if it is allowed to accumulate in a confined space, such as a well pit, crawl space, closet, etc., an explosion hazard can be established. In addition, if methane concentrations in well water are high, then pockets of free gas may form within the water that can cause the well pump to cavitate reducing the efficiency of the pump.

Methane gas is common in water wells in Colorado. It occurs naturally and the source of the methane is commonly from one or more of the sources listed below.

1. Methane is commonly found as a gas in coal or black shale seams in the subsurface.
2. Methane is commonly found as a byproduct of the decay of organic matter and the presence of bacteria in water wells can provide the conditions favorable for the production of methane either from the activity or decay of bacteria.

A gas meter was used to field screen for the presence of methane in the headspace of the bucket during purging prior to sample collection. The meter detected methane in the bucket at a concentration of 200-ppm. Because of the field screening and the fact that the water was effervescing it was thought to contain methane as was verbally reported to you during sample collection. However, while the meter used to field screen is generally reliable, it can produce false readings due to improper calibration, sensor failure or other problems. Because dissolved methane was not detected in the sample submitted to Test America Laboratories, it is believed that the field screening was inaccurate.

Based on the effervescing and the field screening, a sample of the water was also sent to Isotech Laboratories for gas composition and isotopic ratio analysis. The sample results were consistent with the results from Test America with only a trace of methane detected in the sample. Isotopic analysis was not possible because the methane concentration was too low. The composition of the gas in the sample was comprised primarily of nitrogen, oxygen, argon and carbon dioxide, which is

consistent with the composition of air. No other components of natural gas such as ethylene, propane, iso-butane, etc. were detected. The Analysis Report from Isotech is provided as Attachment 3.

BACTERIA OCCURENCE

COGCC also collected samples of your well water for the determination of the presence of bacteria using the Biological Activity Reaction Test (**BART™**) for the following: Iron Related Bacteria (IRB), Sulfate Reducing Bacteria (SRB), and Slime Forming Bacteria (SFB).

Iron Related Bacteria: Although not usually harmful, iron related bacteria (IRB) can become a nuisance by plugging the well pump, causing red staining on plumbing fixtures and laundered clothing, building up red, slimy accumulations on any surface the water touches, and causing what may appear to be a oily sheen on standing water. In rare cases, IRB may cause sickness.

- **IRB bacteria were not detected in the water sample from your well.**

Sulfate Reducing Bacteria: Sulfate reducing bacteria (SRB) are serious nuisance organisms in water since they can cause severe taste and odor problems. These bacteria reduce sulfate that occurs naturally in the water and generate hydrogen sulfide (H2S) gas as they grow. In turn, the hydrogen sulfide (H2S) gas is a nuisance because it smells like rotten eggs, it initiates corrosion on metal surfaces, and it reacts with dissolved metals such as iron to generate black sulfide deposits.

- **SRB bacteria were not detected in the water sample from your well.**

Slime Forming Bacteria: Although not usually harmful, Slime Forming Bacteria (SFB) also can become a nuisance by plugging well pumps and causing slimy accumulations on plumbing fixtures and standing water. Slimes often are gelatinous in nature and may range in color from white, to red, to black. As slime bacteria mats grow they create an environment in which complex associations of other strains of bacteria can develop.

- **SFB bacteria were not detected in the water sample from your well.**

SODIUM ADSORPTION RATIO & SPECIFIC CONDUCTANCE

Due to your concerns of possible damage to vegetation and trees on your property, Test America Laboratories also reported the sodium adsorption ratio (SAR) and electrical conductivity (EC) for the water sample collected from your well. The result for SAR was 3.5. SAR is a proportion of sodium to calcium plus magnesium and is used to determine the sodium hazard in irrigation water. Generally, water with SAR values between 1-9 has a low sodium hazard. The result for electrical conductivity (EC) in your water was 0.75 mmhos/cm (millimhos per centimeter). EC is often used to determine the salinity hazard of irrigation water. Water with EC of 0.25 – 0.75 mmhos/cm is considered good.

A copy of a publication titled *Irrigation Water Quality Criteria* has been provided as Attachment 4 for your reference.

CONCLUSIONS

None of the analyzed constituents exceeded the CDPHE primary or secondary drinking water standards. The water sample did not contain the organic compounds benzene, toluene, ethyl benzene or xylenes, which are often associated with contamination from petroleum hydrocarbons. The water sample did not contain detectable concentrations of dissolved methane as analyzed by Test America Laboratories. The composition of the gas in the water sample contained the same primary components found in air. As a result, it is believed that the effervescing observed in the water is a result of air in your water system. The overall quality of the water is similar to water produced from other water wells in northern Weld County.

Based on the available information gathered to date, there are no indications of oil & gas related impacts to your water well. As a result, your complaint regarding potential impacts to groundwater quality is closed with this letter.

General background information on water wells and methane in water wells was provided to you at the time the sample was collected. If you have any questions or would like to discuss the sample results further, please contact me via e-mail (john.axelson@state.co.us) or by phone at (303) 637-7178.

Respectfully,

John Axelson, P.G.
Environmental Protection Specialist, Northeast Region
Colorado Oil and Gas Conservation Commission

Enclosure(s)

Attachment 1 – Table 1 – Analytical Summary
Attachment 2 – Test America Laboratories Report
Attachment 3 – Isotech Analytical Report
Attachment 4 – Irrigation Water Quality Criteria Publication

cc: David Neslin – COGCC Director
Debbie Baldwin – COGCC Environmental Manager
Steve Lindblom – COGCC Environmental Supervisor

ATTACHMENT 1

Table 1 – Analytical Summary

TABLE 1
ANALYTICAL SUMMARY
Complaint #200262233
King Water Well

Parameter	Water Well Sample		CDPHE Standards		
	Sample Date				
	7-Jul-10				
	Result	Unit	Domestic	Agriculture	Units
Boron	ND	mg/l	NS	0.75	mg/l
Copper	NA	mg/l	1	0.2	mg/l
Arsenic	ND	mg/l	0.05	0.1	mg/l
Barium	0.02	mg/l	2.0		mg/l
Cadmium	NA	mg/l	0.005	0.01	mg/l
Calcium	44	mg/l	NS		
Chromium	ND	mg/l	0.1	0.1	mg/l
Iron	ND	mg/l	0.3	5	mg/l
Lead	ND	mg/l	0.05	0.1	mg/l
Magnesium	12	mg/l	NS		
Manganese	0.042	mg/l	0.05	0.2	mg/l
Potassium	9.4	mg/l	NS		
Selenium	ND	mg/l	0.05	0.02	mg/l
Silver	NA	mg/l	0.05	NS	mg/l
Sodium	110	mg/l	NS		
Chloride	23	mg/l	250	NS	mg/l
Nitrite	ND	mg/l	1.0	10	mg/l
Nitrate	ND	mg/l	10.0	100	mg/l
Total Nitrite/Nitrate	ND	mg/l	10.0	100	mg/l
Fluoride	ND	mg/l	4.0	NS	mg/l
Total Dissolved Solids	460	mg/l	500	*1500	mg/l
pH	8.05	No units	6.5 - 8.5	6.5 - 8.5	No units
Sulfate	150	mg/l	250		mg/l
Sodium Adsorption Ratio	3.5	No units	NS		
Bromide	0.29	mg/l	NS		
Total Alkalinity	190	mg/l	NS		
Bicarbonate	190	mg/l	NS		
Carbonate	ND	mg/l	NS		
Conductivity	0.75	mmhos/cm	NS		
methane	ND	mg/l	NS		

Notes

CDPHE	Colorado Department of Public Health and the Environment.
Domestic	Standards for Domestic Water Supply, Human Health and Drinking Water Standards.
Agriculture	* Standards for agriculture complied from CDPHE and other of sources.
mg/l	Milligrams per liter (equals parts per million).
CDPHE Standards	Water Quality Control Commission 5 CCR 1002-41, Regulation No. 41 - The Basic Standards For Groundwater.
µmhos/cm	**micromhos per centimeer**
NA	Not analyzed.
ND	Not detected.
NS	No Standard.
**	Health Advisory.
	Human health standard.
	Secondardy standard.

ATTACHMENT 2

Test America Laboratory Report

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

ANALYTICAL REPORT

Job Number: 280-5486-1

Job Description: King Complaint #200262233

For:
Colorado Oil&Gas Conservation Commision
1120 Lincoln St.
Suite 801
Denver, CO 80203

Attention: John Axelson

Katie Abbott

Approved for release.
Katie Abbott
Project Mgmt. Assistant
8/5/2010 2:43 PM

Designee for
Lori A Parsons
Project Manager I
lori.parsons@testamericainc.com
08/05/2010

The test results in this report relate only to the samples in this report and meet all requirements of NELAC, with any exceptions noted. Pursuant to NELAP, this report shall not be reproduced except in full, without the written approval of the laboratory. All questions regarding this report should be directed to the TestAmerica Denver Project Manager.

The Lab Certification ID# is E87667.

Reporting limits are adjusted for sample size used, dilutions and moisture content if applicable.

TestAmerica Laboratories, Inc.
TestAmerica Denver 4955 Yarrow Street, Arvada, CO 80002
Tel (303) 736-0100 Fax (303) 431-7171 www.testamericainc.com

ACCREDITED IN ACCORDANCE WITH nelac

Table of Contents

CASE NARRATIVE

Client: Colorado Oil&Gas Conservation Commision

Project: King Complaint #200262233

Report Number: 280-5486-1

With the exceptions noted as flags or footnotes, standard analytical protocols were followed in the analysis of the samples and no problems were encountered or anomalies observed. In addition all laboratory quality control samples were within established control limits, with any exceptions noted below. Each sample was analyzed to achieve the lowest possible reporting limit within the constraints of the method. In some cases, due to interference or analytes present at high concentrations, samples were diluted. For diluted samples, the reporting limits are adjusted relative to the dilution required.

Calculations are performed before rounding to avoid round-off errors in calculated results.

All holding times were met and proper preservation noted for the methods performed on these samples, unless otherwise detailed in the individual sections below.

RECEIPT
The samples were received on 07/20/2010; the samples arrived in good condition, properly preserved and on ice. The temperature of the coolers at receipt was 2.7C.

VOLATILE ORGANIC COMPOUNDS (GC)
Sample KING WATER WELL (280-5486-1) was analyzed for volatile organic compounds (GC) in accordance with EPA SW-846 Method 8021B. The samples were analyzed on 07/26/2010.

TestAmerica Denver's practice for the reporting of dual column data is to report the surrogates from both columns, and the preferred result for any given target analyte from the analyst selected column. The preferred results for target analytes and surrogates are reported as PRIMARY on the Sample Datasheets.

No difficulties were encountered during the VOC analysis.

All quality control parameters were within the acceptance limits.

DISSOLVED GASES
Sample KING WATER WELL (280-5486-1) was analyzed for dissolved gases in accordance with RSK_175. The samples were analyzed on 07/21/2010.

TestAmerica Denver's practice for the reporting of dual column data is to report the surrogates from both columns, and the preferred result for any given target analyte from the analyst selected column. The preferred results for target analytes and surrogates are reported as PRIMARY on the Sample Datasheets.

The Method required MS/MSD could not be performed for analytical batch 280-23858, due to insufficient sample volume submitted. Method precision and accuracy have been verified by the acceptable LCS/LCSD analysis data.

No difficulties were encountered during the dissolved gases analysis.

All quality control parameters were within the acceptance limits.

SODIUM ABSORPTION RATIO
Sample KING WATER WELL (280-5486-1) was analyzed for Sodium Absorption Ratio in accordance with USDA Handbook 60 - 20B. The samples were analyzed on 08/03/2010.

No difficulties were encountered during the SAR analysis.

All quality control parameters were within the acceptance limits.

TOTAL METALS
Sample KING WATER WELL (280-5486-1) was analyzed for total metals in accordance with EPA SW-846 Method 6010B. The samples were prepared on 07/24/2010 and analyzed on 07/27/2010 and 07/29/2010. Sample KING WATER WELL (280-5486-1) was analyzed for total mercury in accordance with EPA SW-846 Methods 7470A. The samples were prepared on 07/21/2010 and analyzed on 07/27/2010.

The MS/MSD was performed on an unrelated sample and was qualified with a '4' for calcium, magnesium and sodium. The analytes present in the original sample were four times greater than the matrix spike concentration; therefore, control limits are no applicable.

No other difficulties were encountered during the metals analysis.

All other quality control parameters were within the acceptance limits.

ANIONS - NO2, NO3, Br, SO4, Cl, F

Sample KING WATER WELL (280-5486-1) was analyzed for anions in accordance with EPA Method 300.0. The samples were analyzed on 07/20/2010.

Sample KING WATER WELL (280-5486-1)[5X] required dilution prior to analysis for Sulfate. The reporting limits have been adjusted accordingly.

No difficulties were encountered during the anions analysis.

All quality control parameters were within the acceptance limits.

CATION ANION BALANCE

Sample KING WATER WELL (280-5486-1) was analyzed for Cation Anion Balance in accordance with Cation Anion Balance. The samples were analyzed on 08/02/2010.

Several analytes were detected in method blank MB 280-25120/1 at levels exceeding the reporting limit. If the associated sample reported a result above the MDL and/or RL, the result has been "B" flagged. Refer to the QC report for details.

No other difficulties were encountered during the Cation Anion Balance analysis.

All other quality control parameters were within the acceptance limits.

ALKALINITY

Sample KING WATER WELL (280-5486-1) was analyzed for Alkalinity in accordance with SM20 2320B. The samples were analyzed on 07/22/2010.

No difficulties were encountered during the alkalinity analysis.

All quality control parameters were within the acceptance limits.

SPECIFIC CONDUCTIVITY

Sample KING WATER WELL (280-5486-1) was analyzed for specific conductivity in accordance with SM20 2510B. The samples were analyzed on 07/22/2010.

No difficulties were encountered during the specific conductivity analysis.

All quality control parameters were within the acceptance limits.

TOTAL DISSOLVED SOLIDS

Sample KING WATER WELL (280-5486-1) was analyzed for total dissolved solids in accordance with SM20 2540C. The samples were analyzed on 07/27/2010.

No difficulties were encountered during the TDS analysis.

All quality control parameters were within the acceptance limits.

CORROSIVITY (PH)

Sample KING WATER WELL (280-5486-1) was analyzed for corrosivity (pH) in accordance with SM20 4500 H+ B. The samples were analyzed on 07/21/2010.

No other difficulties were encountered during the pH analysis.

All other quality control parameters were within the acceptance limits.

GC VOA MANUAL INTEGRATION SUMMARY

Lab Name: TestAmerica Denver Job No.: 280-5486-1

SDG No.:

Instrument ID: GCV_P Analysis Batch Number: 12345

Lab Sample ID: IC 280-12345/1 Client Sample ID:

Date Analyzed: 04/22/10 15:05 Lab File ID: 110F0501.D GC Column: RTX 502.2 ID: 0.45(mm)

COMPOUND NAME	RETENTION TIME	MANUAL INTEGRATION		
		REASON	ANALYST	DATE
Methyl tert-butyl ether	5.55	Analyte not Identified by the Data System	reamb	04/23/10 08:11

SAMPLE SUMMARY

Client: Colorado Oil&Gas Conservation Commision

Job Number: 280-5486-1

Lab Sample ID	Client Sample ID	Client Matrix	Date/Time Sampled	Date/Time Received
280-5486-1	KING WATER WELL	Water	07/20/2010 0925	07/20/2010 1405

EXECUTIVE SUMMARY - Detections

Client: Colorado Oil&Gas Conservation Commision

Job Number: 280-5486-1

Lab Sample ID / Analyte	Client Sample ID	Result / Qualifier		Reporting Limit	Units	Method
280-5486-1	KING WATER WELL					
Sodium Adsorption Ratio		3.5		0.40	No Unit	20B
Barium		20		10	ug/L	6010B
Calcium		44000		200	ug/L	6010B
Magnesium		12000		200	ug/L	6010B
Manganese		42		10	ug/L	6010B
Potassium		9400		3000	ug/L	6010B
Sodium		110000		1000	ug/L	6010B
Bromide		0.29		0.20	mg/L	300.0
Chloride		23		3.0	mg/L	300.0
Sulfate		150		25	mg/L	300.0
Total Anions		7.6			meq/L	SM 1030F
Total Cations		8.2			meq/L	SM 1030F
Percent Difference		4.1			%	SM 1030F
Anion/Cation Balance		4.1			%	SM 1030F
Total Alkalinity		190		5.0	mg/L	SM 2320B
Bicarbonate Alkalinity as CaCO3		190		5.0	mg/L	SM 2320B
Specific Conductance		750		2.0	umhos/cm	SM 2510B
Total Dissolved Solids		460		10	mg/L	SM 2540C
pH		8.05	HF	0.100	SU	SM 4500 H+ B

METHOD SUMMARY

Client: Colorado Oil&Gas Conservation Commision

Job Number: 280-5486-1

Description	Lab Location	Method	Preparation Method
Matrix Water			
Volatile Organic Compounds (GC)	TAL DEN	SW846 8021B	
Purge and Trap	TAL DEN		SW846 5030B
Dissolved Gases (GC)	TAL DEN	RSK RSK-175	
Sodium Adsorption Ratio	TAL DEN	USDA 20B	
Metals (ICP)	TAL DEN	SW846 6010B	
Preparation, Total Metals	TAL DEN		SW846 3010A
Mercury (CVAA)	TAL DEN	SW846 7470A	
Preparation, Mercury	TAL DEN		SW846 7470A
Anions, Ion Chromatography	TAL DEN	MCAWW 300.0	
Anions, Ion Chromatography	TAL DEN	MCAWW 300.0	
Cation Anion Balance	TAL DEN	SM SM 1030F	
Alkalinity	TAL DEN	SM SM 2320B	
Conductivity, Specific Conductance	TAL DEN	SM SM 2510B	
Solids, Total Dissolved (TDS)	TAL DEN	SM SM 2540C	
pH	TAL DEN	SM SM 4500 H+ B	

Lab References:

TAL DEN = TestAmerica Denver

Method References:

MCAWW = "Methods For Chemical Analysis Of Water And Wastes", EPA-600/4-79-020, March 1983 And Subsequent Revisions.

RSK = Sample Prep And Calculations For Dissolved Gas Analysis In Water Samples Using A GC Headspace Equilibration Technique, RSKSOP-175, Rev. 0, 8/11/94, USEPA Research Lab

SM = "Standard Methods For The Examination Of Water And Wastewater",

SW846 = "Test Methods For Evaluating Solid Waste, Physical/Chemical Methods", Third Edition, November 1986 And Its Updates.

USDA = "USDA Agriculture Handbook 60, section 20B".

METHOD / ANALYST SUMMARY

Client: Colorado Oil&Gas Conservation Commision

Job Number: 280-5486-1

Method	Analyst	Analyst ID
SW846 8021B	Ream, Brian E	BER
RSK RSK-175	Moore, Tegan E	TEM
USDA 20B	Wells, David	DW
SW846 6010B	Harre, John K	JKH
SW846 7470A	Stoltz, Katie	KS
MCAWW 300.0	Kudla, Ewa	EK
SM SM 1030F	Sullivan, Roxanne	RS
SM SM 2320B	Kudla, Ewa	EK
SM SM 2510B	Plumb, Paul M	PMP
SM SM 2540C	Domnick, Brandon J	BJD
SM SM 4500 H+ B	Kilker, Lorelei M	LMK

Client: Colorado Oil&Gas Conservation Commision

Job Number: 280-5486-1

Client Sample ID: **KING WATER WELL**

Lab Sample ID: 280-5486-1
Client Matrix: Water

Date Sampled: 07/20/2010 0925
Date Received: 07/20/2010 1405

8021B Volatile Organic Compounds (GC)

Method:	8021B	Analysis Batch: 280-24296		Instrument ID:	GCV_P
Preparation:	5030B			Initial Weight/Volume:	5 mL
Dilution:	1.0			Final Weight/Volume:	5 mL
Date Analyzed:	07/26/2010 1301			Injection Volume:	5 mL
Date Prepared:	07/26/2010 1301			Result Type:	PRIMARY

Analyte	Result (ug/L)	Qualifier	RL
Benzene	ND		0.50
Ethylbenzene	ND		0.50
Toluene	ND		0.50
m-Xylene & p-Xylene	ND		0.50
o-Xylene	ND		0.50

Surrogate	%Rec	Qualifier	Acceptance Limits
a,a,a-Trifluorotoluene	100		85 - 115

Client: Colorado Oil&Gas Conservation Commision

Job Number: 280-5486-1

Client Sample ID: **KING WATER WELL**

Lab Sample ID: 280-5486-1
Client Matrix: Water

Date Sampled: 07/20/2010 0925
Date Received: 07/20/2010 1405

8021B Volatile Organic Compounds (GC)

Method:	8021B	Analysis Batch: 280-24296		Instrument ID:	GCV_P
Preparation:	5030B			Initial Weight/Volume:	5 mL
Dilution:	1.0			Final Weight/Volume:	5 mL
Date Analyzed:	07/26/2010 1301			Injection Volume:	5 mL
Date Prepared:	07/26/2010 1301			Result Type:	SECONDARY

Surrogate	%Rec	Qualifier	Acceptance Limits
a,a,a-Trifluorotoluene	97		85 - 115

Client: Colorado Oil&Gas Conservation Commision

Job Number: 280-5486-1

Client Sample ID: **KING WATER WELL**

Lab Sample ID: 280-5486-1
Client Matrix: Water

Date Sampled: 07/20/2010 0925
Date Received: 07/20/2010 1405

RSK-175 Dissolved Gases (GC)

Method:	RSK-175	Analysis Batch: 280-23858		Instrument ID:	GCV_J
Preparation:	N/A			Initial Weight/Volume:	18 mL
Dilution:	1.0			Final Weight/Volume:	18 mL
Date Analyzed:	07/21/2010 1554			Injection Volume:	
Date Prepared:				Result Type:	PRIMARY

Analyte	Result (ug/L)	Qualifier	RL
Methane	ND		5.0

Client: Colorado Oil&Gas Conservation Commision

Job Number: 280-5486-1

Client Sample ID: **KING WATER WELL**

Lab Sample ID: 280-5486-1
Client Matrix: Water

Date Sampled: 07/20/2010 0925
Date Received: 07/20/2010 1405

RSK-175 Dissolved Gases (GC)

Method:	RSK-175	Analysis Batch: 280-23858		Instrument ID:	GCV_J
Preparation:	N/A			Initial Weight/Volume:	18 mL
Dilution:	1.0			Final Weight/Volume:	18 mL
Date Analyzed:	07/21/2010 1554			Injection Volume:	
Date Prepared:				Result Type:	SECONDARY

Analyte	Result (ug/L)	Qualifier	RL
Methane	ND		5.0

Client: Colorado Oil&Gas Conservation Commision

Job Number: 280-5486-1

Client Sample ID: **KING WATER WELL**

Lab Sample ID: 280-5486-1
Client Matrix: Water

Date Sampled: 07/20/2010 0925
Date Received: 07/20/2010 1405

20B Sodium Adsorption Ratio

Method:	20B	Analysis Batch: 280-25253		Instrument ID:	NOEQUIP
Preparation:	N/A			Lab File ID:	N/A
Dilution:	1.0			Initial Weight/Volume:	
Date Analyzed:	08/03/2010 1039			Final Weight/Volume:	1.0 mL
Date Prepared:					

Analyte	Result (No Unit)	Qualifier	RL
Sodium Adsorption Ratio	3.5		0.40

6010B Metals (ICP)

Method:	6010B	Analysis Batch: 280-24293		Instrument ID:	MT_025
Preparation:	3010A	Prep Batch: 280-23631		Lab File ID:	25A8072610.txt
Dilution:	1.0			Initial Weight/Volume:	50 mL
Date Analyzed:	07/27/2010 0431			Final Weight/Volume:	50 mL
Date Prepared:	07/24/2010 1030				

Analyte	Result (ug/L)	Qualifier	RL
Arsenic	ND		15
Barium	20		10
Calcium	44000		200
Chromium	ND		10
Lead	ND		9.0
Magnesium	12000		200
Manganese	42		10
Potassium	9400		3000
Selenium	ND		15
Sodium	110000		1000

Method:	6010B	Analysis Batch: 280-24875		Instrument ID:	MT_025
Preparation:	3010A	Prep Batch: 280-23631		Lab File ID:	25A4072910.txt
Dilution:	1.0			Initial Weight/Volume:	50 mL
Date Analyzed:	07/29/2010 1856			Final Weight/Volume:	50 mL
Date Prepared:	07/24/2010 1030				

Analyte	Result (ug/L)	Qualifier	RL
Iron	ND		100

7470A Mercury (CVAA)

Method:	7470A	Analysis Batch: 280-24567		Instrument ID:	MT_033
Preparation:	7470A	Prep Batch: 280-23663		Lab File ID:	100727AA2.txt
Dilution:	1.0			Initial Weight/Volume:	10 mL
Date Analyzed:	07/27/2010 1505			Final Weight/Volume:	10 mL
Date Prepared:	07/21/2010 1555				

Analyte	Result (ug/L)	Qualifier	RL
Mercury	ND		0.20

General Chemistry

Client Sample ID: **KING WATER WELL**

Lab Sample ID: 280-5486-1
Client Matrix: Water

Date Sampled: 07/20/2010 0925
Date Received: 07/20/2010 1405

Analyte	Result	Qual	Units	RL	Dil	Method
Bromide	0.29		mg/L	0.20	1.0	300.0
Analysis Batch: 280-24803	Date Analyzed: 07/20/2010 1737					
Nitrate as N	ND		mg/L	0.50	1.0	300.0
Analysis Batch: 280-24802	Date Analyzed: 07/20/2010 1737					
Chloride	23		mg/L	3.0	1.0	300.0
Analysis Batch: 280-24803	Date Analyzed: 07/20/2010 1737					
Nitrite as N	ND		mg/L	0.50	1.0	300.0
Analysis Batch: 280-24802	Date Analyzed: 07/20/2010 1737					
Fluoride	ND		mg/L	0.50	1.0	300.0
Analysis Batch: 280-24803	Date Analyzed: 07/20/2010 1737					
Nitrate Nitrite as N	ND		mg/L	0.50	1.0	300.0
Analysis Batch: 280-24802	Date Analyzed: 07/20/2010 1737					
Sulfate	150		mg/L	25	5.0	300.0
Analysis Batch: 280-24803	Date Analyzed: 07/20/2010 1901					
Total Alkalinity	190		mg/L	5.0	1.0	SM 2320B
Analysis Batch: 280-24018	Date Analyzed: 07/22/2010 2101					
Bicarbonate Alkalinity as CaCO3	190		mg/L	5.0	1.0	SM 2320B
Analysis Batch: 280-24018	Date Analyzed: 07/22/2010 2101					
Carbonate Alkalinity as CaCO3	ND		mg/L	5.0	1.0	SM 2320B
Analysis Batch: 280-24018	Date Analyzed: 07/22/2010 2101					
Hydroxide Alkalinity	ND		mg/L	5.0	1.0	SM 2320B
Analysis Batch: 280-24018	Date Analyzed: 07/22/2010 2101					
Total Dissolved Solids	460		mg/L	10	1.0	SM 2540C
Analysis Batch: 280-24407	Date Analyzed: 07/27/2010 1450					

Analyte	Result	Qual	Units	Dil	Method
Total Anions	7.6		meq/L	1.0	SM 1030F
Analysis Batch: 280-25120	Date Analyzed: 08/02/2010 0932				
Total Cations	8.2		meq/L	1.0	SM 1030F
Analysis Batch: 280-25120	Date Analyzed: 08/02/2010 0932				
Percent Difference	4.1		%	1.0	SM 1030F
Analysis Batch: 280-25120	Date Analyzed: 08/02/2010 0932				
Anion/Cation Balance	4.1		%	1.0	SM 1030F
Analysis Batch: 280-25120	Date Analyzed: 08/02/2010 0932				

Analyte	Result	Qual	Units	RL	Dil	Method
Specific Conductance	750		umhos/cm	2.0	1.0	SM 2510B
Analysis Batch: 280-23905	Date Analyzed: 07/22/2010 1519					
pH	8.05	HF	SU	0.100	1.0	SM 4500 H+ B
Analysis Batch: 280-23757	Date Analyzed: 07/21/2010 0923					

Denver
4955 Yarrow Street

Arvada, CO 80002
phone 303.736.0100 fax 303.431.7171

2.7°C IR2
DAB 7/20/10

Chain of Custody Record

TestAmerica
THE LEADER IN ENVIRONMENTAL TESTING

TestAmerica Laboratories, Inc.

Client Contact	Project Manager: John Axelson	Site Contact: John Axelson	Date: 7/20/10	COC No:
Colorado Oil & Gas Conservation Commission	Tel/Fax: 303-637-7178	Lab Contact: Lori Parsons	Carrier: NA	1 of 1 COCs
9203 E. 155th Drive	Analysis Turnaround Time			Job No.
Brighton, CO 80602	Calendar (C) or Work Days (W)			
303-637-7178	TAT if different from Below ___Standard___			SDG No.
303-637-7179	☐ 2 weeks			
Project Name: King Complaint #200262233	☐ 1 week			
13141 WCR 104, Nunn, CO	☐ 2 days			
PO#	☐ 1 day			

Sample Identification	Sample Date	Sample Time	Sample Type	Matrix	# of Cont.	Filtered Sample	BTEX 8021	TEPH 8015-M	Total Metals - see list below	Major Anions/Cations - see list below	Dissolved Methane	Alkaline Group	TDS	Conductivity	pH	SAR	Sample Specific Notes:
King Water Well	~~7/8/2010~~ 7/20/10	09:25	GW	H2O	9		X		X	X	X	X	X	X	X	X	

Page 15 of 46

Preservation Used: 1= Ice, 2= HCl; 3= H2SO4; 4=HNO3; 5=NaOH; 6= Other _____

Possible Hazard Identification
☒ Non-Hazard ☐ Flammable ☐ Skin Irritant Poison B ☐ Unknown ☐

Sample Disposal (A fee may be assessed if samples are retained longer than 1 month)
☐ Return To Client ☒ Disposal By Lab ☐ Archive For _____ Months

Special Instructions/QC Requirements & Comments: Remit pdf of lab report and invoice to John Axelson @ John.Axelson@state.co.us. Analyze for the following metals/anions/cations: ~~Ca~~, ~~Fe~~, ~~Mn~~, ~~K~~, ~~Mg~~, ~~Na~~, Cl, ~~NO2~~, ~~NO3~~, Br, ~~SO4~~, ~~CO3~~, ~~HCO3~~, ~~F~~, ~~Sr~~, ~~Pb~~, ~~Ba~~, ~~Ge~~ & ~~As~~. Provide anion/cation balance report.

Relinquished by: John Axelson	Company: COGCC 7/20/10	Date/Time: 14:05	Received by:	Company: PA	Date/Time: 7/20/10 1405
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:
Relinquished by:	Company:	Date/Time:	Received by:	Company:	Date/Time:

08/05/2010

Login Sample Receipt Check List

Client: Colorado Oil&Gas Conservation Commision

Job Number: 280-5486-1

Login Number: 5486
Creator: Bindel, Aaron M
List Number: 1

List Source: TestAmerica Denver

Question	T / F/ NA	Comment
Radioactivity either was not measured or, if measured, is at or below background	True	
The cooler's custody seal, if present, is intact.	True	
The cooler or samples do not appear to have been compromised or tampered with.	True	
Samples were received on ice.	True	
Cooler Temperature is acceptable.	True	
Cooler Temperature is recorded.	True	
COC is present.	True	
COC is filled out in ink and legible.	True	
COC is filled out with all pertinent information.	True	
Is the Field Sampler's name present on COC?	True	
There are no discrepancies between the sample IDs on the containers and the COC.	True	
Samples are received within Holding Time.	True	
Sample containers have legible labels.	True	
Containers are not broken or leaking.	True	
Sample collection date/times are provided.	True	
Appropriate sample containers are used.	True	
Sample bottles are completely filled.	True	
Sample Preservation Verified	True	
There is sufficient vol. for all requested analyses, incl. any requested MS/MSDs	True	
VOA sample vials do not have headspace or bubble is <6mm (1/4") in diameter.	True	
If necessary, staff have been informed of any short hold time or quick TAT needs	True	
Multiphasic samples are not present.	True	
Samples do not require splitting or compositing.	True	

ATTACHMENT 3

ISOTECH ANALYTICAL REPORT

ISOTECH
ISOTECH LABORATORIES INC

ANALYSIS REPORT

Lab #: 191470 Job #: 13424
Sample Name: King WW Co. Lab#:
Company: Colorado Oil & Gas Conservation
Date Sampled: 7/20/2010
Container: Dissolved Gas Bottle
Field/Site Name: King Complaint #200262233
Location: Weld County, CO
Formation/Depth:
Sampling Point:
Date Received: 7/21/2010 Date Reported: 8/26/2010

Component	Chemical mol. %	$\delta^{13}C$ ‰	δD ‰	$\delta^{15}N$ ‰
Carbon Monoxide	0.008			
Hydrogen Sulfide	nd			
Helium	nd			
Hydrogen	nd			
Argon	1.49			
Oxygen	4.75			
Nitrogen	92.69			
Carbon Dioxide	1.04			
Methane	0.0189			
Ethane	nd			
Ethylene	nd			
Propane	nd			
Iso-butane	nd			
N-butane	nd			
Iso-pentane	nd			
N-pentane	nd			
Hexanes +	nd			

Total BTU/cu.ft. dry @ 60deg F & 14.7psia, calculated: 0
Specific gravity, calculated: 0.986

Remarks: Analysis is of gas extracted from water by headspace equilibration. Analysis has been corrected for helium added to create headspace. Helium dilution factor = 0.67
*Addition of helium negates the ability to detect native helium or hydrogen.

nd = not detected. na = not analyzed. Isotopic composition of carbon is relative to VPDB. Isotopic composition of hydrogen is relative to VSMOW. Calculations for BTU and specific gravity per ASTM D3588. Chemical compositions are normalized to 100%. Mol. % is approximately equal to vol. %.

ATTACHMENT 4

Irrigation Water Quality Criteria Publication

IRRIGATION

Irrigation Water Quality Criteria no. 0.506

by T.A. Bauder, R.M. Waskom and J. G. Davis[1] (3/07)

Quick Facts...

Knowledge of irrigation water quality is critical to understanding management for long-term productivity.

Water with electrical conductivity (EC_w) of only 1.15 dS/m contains approximately 2,000 pounds of salt for every acre foot of water.

In many areas of Colorado, irrigation water quality can influence crop productivity more than soil fertility, hybrid, weed control and other factors.

Salt-affected soils develop from a wide range of factors including: soil type, field slope and drainage, irrigation system type and management, fertilizer and manuring practices, and other soil and water management practices. In Colorado, perhaps the most critical factor in predicting, managing, and reducing salt-affected soils is the quality of irrigation water being used. Besides affecting crop yield and soil physical conditions, irrigation water quality can affect fertility needs, irrigation system performance and longevity, and how the water can be applied. Therefore, knowledge of irrigation water quality is critical to understanding what management changes are necessary for long-term productivity.

Corn plant damaged by saline sprinkler water.

Irrigation Water Quality Criteria

Soil scientists use the following categories to describe irrigation water effects on crop production and soil quality:

- Salinity hazard - total soluble salt content
- Sodium hazard - relative proportion of sodium (Na^+) to calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions
- pH
- Alkalinity - carbonate and bicarbonate
- Specific ions: chloride (Cl), sulfate (SO_4^{2-}), boron (B), and nitrate-nitrogen (NO_3-N).

Other potential irrigation water contaminants that may affect suitability for agricultural use include heavy metals and microbial contaminants.

Salinity Hazard

The most influential water quality guideline on crop productivity is the water salinity hazard as measured by electrical conductivity (EC_w). The primary effect of high EC_w water on crop productivity is the inability of the plant to compete with ions in the soil solution for water (physiological drought). The higher the EC, the less water is available to plants, even though the soil may appear wet. Because plants can only transpire "pure" water, usable plant water in the soil solution decreases dramatically as EC increases.

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Table 1. Suggested criteria for irrigation water use based upon conductivity.

Classes of water	Electrical Conductivity
	(dS/m)*
Class 1, Excellent	≤ 0.25
Class 2, Good	0.25 - 0.75
Class 3, Permissible[1]	0.76 - 2.00
Class 4, Doubtful[2]	2.01 - 3.00
Class 5, Unsuitable[2]	≥3.00

*dS/m at 25° C = mmhos/cm

[1]Leaching needed if used.

[2]Good drainage needed and sensitive plants will have difficulty obtaining stands.

The amount of water transpired through a crop is directly related to yield; therefore, irrigation water with high EC_w reduces yield potential (Table 2). Beyond effects on the immediate crop is the long term impact of salt loading through the irrigation water. Water with an EC_w of only 1.15 dS/m contains approximately 2,000 pounds of salt for every acre foot of water. You can use conversion factors in Table 3 to make this calculation for other water EC levels.

Table 2. Potential yield reduction from saline water for selected irrigated crops.[1]

Crop	% yield reduction 0%	10%	25%	50%
	EC_w[2]			
Barley	5.3	6.7	8.7	12
Wheat	4.0	4.9	6.4	8.7
Sugarbeet[3]	4.7	5.8	7.5	10
Alfalfa	1.3	2.2	3.6	5.9
Potato	1.1	1.7	2.5	3.9
Corn (grain)	1.1	1.7	2.5	3.9
Corn (silage)	1.2	2.1	3.5	5.7
Onion	0.8	1.2	1.8	2.9
Beans	0.7	1.0	1.5	2.4

[1]Adapted from "Quality of Water for Irrigation." R.S. Ayers. Jour. of the Irrig. and Drain. Div., ASCE. Vol 103, No. IR2, June 1977, p. 140.

[2]EC_w = electrical conductivity of the irrigation water in dS/m at 25°C.

[3]Sensitive during germination. EC_w should not exceed 3 dS/m for garden beets and sugarbeets.

Other terms that laboratories and literature sources use to report salinity hazard are: salts, salinity, electrical conductivity (EC_w), or total dissolved solids (TDS). These terms are all comparable and all quantify the amount of dissolved "salts" (or ions, charged particles) in a water sample. However, TDS is a direct measurement of dissolved ions and EC is an indirect measurement of ions by an electrode.

Definitions

Abbrev.	*Meaning*
mg/L	*milligrams per liter*
meq/L	*milliequivalents per liter*
ppm	*parts per million*
dS/m	*deciSiemens per meter*
µS/cm	*microSiemens per centimeter*
mmho/cm	*millimhos per centimeter*
TDS	*total dissolved solids*

Although people frequently confuse the term "salinity" with common table salt or sodium chloride (NaCl), EC measures salinity from all the ions dissolved in a sample. This includes negatively charged ions (e.g., Cl^-, NO_3^-) and positively charged ions (e.g., Ca^{++}, Na^+). Another common source of confusion is the variety of unit systems used with EC_w. The preferred unit is deciSiemens per meter (dS/m), however millimhos per centimeter (mmho/cm) and micromhos per centimeter (µmho/cm) are still frequently used. Conversions to help you change between unit systems are provided in Table 3.

Table 3. Conversion factors for irrigation water quality laboratory reports.

Component	To Convert	Multiply By	To Obtain
Water nutrient or TDS	mg/L	1.0	ppm
Water salinity hazard	1 dS/m	1.0	1 mmho/cm
Water salinity hazard	1 mmho/cm	1,000	1 µmho/cm
Water salinity hazard	EC_w (dS/m) for EC <5 dS/m	640	TDS (mg/L)
Water salinity hazard	EC_w (dS/m) for EC >5 dS/m	800	TDS (mg/L)
Water NO_3N, SO_4-S, B applied	ppm	0.23	lb per acre inch of water
Irrigation water	acre inch	27,150	gallons of water

Sodium Hazard

While EC_w is an assessment of all soluble salts in a sample, sodium hazard is defined separately because of sodium's specific detrimental effects on soil physical properties. The sodium hazard is typically expressed as the

Table 4. General classification of water sodium hazard based on SAR values.

SAR values	Sodium hazard of water	Comments
1-9	Low	Use on sodium sensitive crops must be cautioned.
10-17	Medium	Amendments (such as gypsum) and leaching needed.
18-25	High	Generally unsuitable for continuous use.
≥26	Very high	Generally unsuitable for use.

$$SAR = \frac{Na^{+}\ \text{meq/L}}{\sqrt{\frac{(Ca^{++}\ \text{meq/L}) + (Mg^{++}\ \text{meq/L})}{2}}}$$

meq/L = mg/L divided by atomic weight of ion divided by ionic charge (Na^{+}=23.0 mg/meq, Ca^{++}=20.0 mg/meq, Mg^{++}=12.15 mg/meq)

sodium adsorption ratio (SAR). This index quantifies the proportion of sodium (Na^{+}) to calcium (Ca^{++}) and magnesium (Mg^{++}) ions in a sample. Calcium will flocculate (hold together), while sodium disperses (pushes apart) soil particles. This dispersed soil will readily crust and have water infiltration and permeability problems. General classifications of irrigation water based upon SAR values are presented in Table 4.

However, many factors including soil texture, organic matter, crop type, climate, irrigation system and management impact how sodium in irrigation water affects soils. Additionally, at the same SAR, water with low EC_w (salinity) has a greater dispersion potential than water with high EC_w. Sodium in irrigation water can also cause toxicity problems for some crops, especially when sprinkler applied. Crops vary in their susceptibility to this type of damage as shown in Table 5.

Table 5. Susceptibility ranges for crops to foliar injury from saline sprinkler water.

	Na or Cl concentration (mg/L) causing foliar injury			
Na concentration	<46	46-230	231-460	>460
Cl concentration	<175	175-350	351-700	>700
	Apricot	Pepper	Alfalfa	Sugarbeet
	Plum	Potato	Barley	Sunflower
	Tomato	Corn	Sorghum	

Foliar injury is influenced by cultural and environmental conditions. These data are presented only as general guidelines for daytime irrigation. Source: Mass (1990) Crop salt tolerance. In: Agricultural Assessment and Management Manual. K.K. Tanji (ed.). ASCE, New York. pp. 262-304.

pH and Alkalinity

The acidity or basicity of irrigation water is expressed as pH (< 7.0 acidic; > 7.0 basic). The normal pH range for irrigation water is from 6.5 to 8.4. Abnormally low pH's are not common in Colorado, but may cause accelerated irrigation system corrosion where they occur. High pH's above 8.5 are often caused by high bicarbonate (HCO_3^{-}) and carbonate (CO_3^{2-}) concentrations, known as alkalinity. High carbonates cause calcium and magnesium ions to form insoluble minerals leaving sodium as the dominant ion in solution. This alkaline water could intensify sodic soil conditions. In these cases, a lab will calculate an adjusted SAR (SAR_{ADJ}) to reflect the increased sodium hazard.

Table 6. Chloride classification of irrigation water.

Chloride (ppm)	Effect on Crops
Below 70	Generally safe for all plants.
70-140	Sensitive plants show injury.
141-350	Moderately tolerant plants show injury.
Above 350	Can cause severe problems.

Chloride tolerance of selected crops. Listing in order of increasing tolerance: (low tolerance) dry bean, onion, carrot, lettuce, pepper, corn, potato, alfalfa, sudangrass, zucchini squash, wheat, sorghum, sugar beet, barley (high tolerance). Source: Mass (1990) Crop Salt Tolerance. *Agricultural Salinity Assessment and Management Manual.* K.K. Tanji (ed.). ASCE, New York. pp 262-304.

Chloride

Chloride is a common ion in Colorado irrigation waters. Although chloride is essential to plants in very low amounts, it can cause toxicity to sensitive crops at high concentrations (Table 6). Like sodium, high chloride concentrations cause more problems when applied with sprinkler irrigation (Table 6). Leaf burn under sprinkler from both sodium and chloride can be reduced by night time irrigation or application on cool, cloudy days. Drop nozzles and drag hoses are also recommended when applying any saline irrigation water through a sprinkler system to avoid direct contact with leaf surfaces.

Boron

Boron is another element that is essential in low amounts, but toxic at higher concentrations (Table 7). In fact, toxicity can occur on sensitive crops at concentrations less than 1.0 ppm. Colorado soils and irrigation waters contain enough B that additional B fertilizer is not required in most situations. Because B toxicity can occur at such low concentrations, an irrigation water analysis is advised for ground water before applying additional B to crops.

Table 7. Boron sensitivity of selected Colorado plants (B concentration, mg/ L*)

Sensitive		Moderately Sensitive	Moderately Tolerant	Tolerant
0.5-0.75	0.76-1.0	1.1-2.0	2.1-4.0	4.1-6.0
Peach	Wheat	Carrot	Lettuce	Alfalfa
Onion	Barley	Potato	Cabbage	Sugar beet
	Sunflower	Cucumber	Corn	Tomato
	Dry Bean		Oats	

Source: Mass (1987) Salt tolerance of plants. *CRC Handbook of Plant Science in Agriculture*. B.R. Cristie (ed.). CRC Press Inc.

*Maximum concentrations tolerated in soil water or saturation extract without yield or vegetative growth reductions. Maximum concentrations in the irrigation water are approximately equal to these values or slightly less.

Sulfate

The sulfate ion is a major contributor to salinity in many of Colorado irrigation waters. However, toxicity is rarely a problem, except at very high concentrations where high sulfate may interfere with uptake of other nutrients. As with boron, sulfate in irrigation water has fertility benefits, and irrigation water in Colorado often has enough sulfate for maximum production for most crops. Exceptions are sandy fields with <1 percent organic matter and <10 ppm SO_4-S in irrigation water.

Nitrogen

Nitrogen in irrigation water (N) is largely a fertility issue, and nitrate-nitrogen (NO_3-N) can be a significant N source in the South Platte, San Luis Valley, and parts of the Arkansas River basins. The nitrate ion often occurs at higher concentrations than ammonium in irrigation water. Waters high in N can cause quality problems in crops such as barley and sugar beets and excessive vegetative growth in some vegetables. However, these problems can usually be overcome by good fertilizer and irrigation management. Regardless of the crop, nitrate should be credited toward the fertilizer rate especially when the concentration exceeds 10 ppm NO_3-N (45 ppm NO^-_3). Table 3 provides conversions from ppm to pounds per acre inch.

[1]*T.A. Bauder, Colorado State University Extension water quality specialist; R.M. Waskom, Extension water resource specialist; and J.G. Davis, Extension soils specialist and professor, soil and crop sciences.*

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