Proposed Site-Specific Standard for Total Dissolved Solids

Blue Creek, Box Elder County, Utah

Utah Division of Water Quality

September 4, 2013 Draft

EXECUTIVE SUMMARY

Site-specific total dissolved solids (TDS) criteria that are higher than the statewide criteria of 1,200 mg/l are proposed for Blue Creek Reservoir and Blue Creek in Box Elder County, Utah. For the reservoir, a criterion of 2,200 mg/l TDS with a one-hour averaging period is recommended. For Blue Creek, a criterion of 6,200 mg/l with an one-hour averaging period and a criterion of 3,900 mg/l TDS with a one month averaging period is recommended.

These criteria are primarily based on natural conditions and to the minor extent that the reservoir influences the elevated concentrations of TDS, irreversible conditions.

Proposed Site-specific Total Dissolved Criteria for Blue Creek Reservoir and Blue Creek (mg/l)		
Blue Creek Reservoir	Blue Creek	
Upper Bound	Upper Bound	Average
2,200	6,300	3,900

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1.1 INTRODUCTION

ATK Launch Systems-Promontory (ATK), Promontory, UT, recommended that the Utah Division of Water Quality revise the total dissolved solids (TDS) criterion for Blue Creek in Box Elder County, Utah. This document summarizes the technical and regulatory bases to support this change.

Additional supporting data and analyses for this request are presented in Appendix A and B:

- June 2011 ATK *Work Plan for the Development of a New Site-Specific TDS Criterion for Blue Creek*. (ATK, 2011)
- July 11, 2013 ATK *Blue Creek Site-Specific Standard for Total Dissolved Solids (TDS) Criterion Monitoring Report* (ATK, 2013)

1.1.1 Watershed Summary

Blue Creek Reservoir has no perennial source streams. The majority of water in Blue Creek Reservoir is collected from Blue Springs, a saline warm springs adjacent to the reservoir supplemented by storm runoff. Water control structures allow the reservoir water to be discharged to Blue Creek or to irrigation canals on the east and west side of the valley. The irrigation canals provide water for flood irrigation and stock watering. Direct conveyances for irrigation return flows to Blue Creek are not apparent and unused water likely returns to Blue Creek via sheet flow, shallow groundwater, and roadside ditches.

Downstream of the dam, Blue Creek has flowing water (except when frozen) even absent any intentional releases from the dam. The source of this water appears to be shallow groundwater supplemented by saline springs. As documented in previous studies by USGS, groundwater studies at the ATK facility, and common knowledge amongst locals, most of the groundwater in the area is too salty for agricultural or domestic use.

Blue Creek flows for approximately 8 miles from the dam to the northern boundary of ATK's property. From there, Blue Creeks continues in a defined channel for approximately 9 miles before becoming sheet flow (assuming water is present) on the playa. Bear River Bay Class 5E Transitional Waters/Class 5C Bear River Bay are approximately an additional 9 miles to the south. Based on satellite photos, it appears that water from Blue Creek does not make it to 4208' before infiltrating or evaporating. The photos show a ubiquitous white crust on the playa characteristic of mineralization after water evaporates.

ATK discharges to Blue Creek under UDPES Permit 0024805 and this is the only permitted discharge in the Blue Creek watershed. The majority of agricultural use of the water occurs upstream of the ATK facility.

1.1.2 Uses

UAC R317-2-12 lists the designated uses of Blue Creek as:

- Class 2B, infrequent primary and secondary contact recreation,
- Class 3B warm water aquatic life,
- and Class 4 agriculture.

Only the Class 4 agricultural use has a numeric criterion for TDS,1,200 mg/l. Downstream waters (Bear River Bay, Great Salt Lake), do not have the agricultural designated use.

As shown on Figure 1 and Figures 1 and 2 in ATK (2013), agricultural uses for water from Blue Creek Reservoir include stock watering and crop irrigation. Crops that are irrigated by flooding are: grass pasture, alfalfa, barley, wheat, and less than 40 acres of corn (USDA, 2012).

Agricultural uses of the water downstream of the ATK facility include stock watering, wildlife propagation, and limited irrigation for salt tolerant crops such as wheat grass and salt grass. Non-farming uses included grazing and open range.

The Utah Division of Water Rights water right's database was searched and the results are presented in the Appendix E. Water Rights beneficial uses (different than water quality uses) include stock watering, crop irrigation, and wildlife propagation.

The original dam was constructed in 1904 (ATK, 2011). Blue Creek was an intermittent stream until 1975 when an earthquake changed the creek to perennial (ATK, 2011). The TDS criteria proposed in this document are based primarily on natural conditions. Therefore, existing uses (R317-1-1) will remain protected by the revised criteria.

1.1.3 Regulatory Bases

Site-specific criteria are permitted in the following situations in accordance with UAC R317-2-7.1:

> "Site-specific criterion may be adopted by rulemaking where biomonitoring data, bioassays, or other scientific analyses indicate that the statewide criterion is over or under protective of the designated uses or where natural or un-alterable conditions or

> other factors as defined in 40 CFR 131.10(g) prevent the attainment of the statewide criterion."

Site-specific TDS criteria are appropriate for Blue Creek because based on the analyses presented in this document because of the CFR 131.10 (g) factors of naturally occurring pollutant concentrations and the irreversible conditions created by the dam (CFR 131.10 (g)).

1.2 METHODS

The data was collected by ATK in accordance with the work plan in Appendix A. ATK collected monthly water samples from three locations on Blue Creek for two years. Sample locations are shown on Figure 3 of ATK (2013) in Appendix B. Representatives from ATK and DWQ met periodically to review the results and flow measurements were added for the second year. In addition to TDS concentrations and flow, the irrigation status of the reservoir diversions were recorded on the days that samples were collected. This data supplements monthly samples collected since 1989 from where Blue Creek enters the ATK property (Blue Creek Upper sample site).

To provide data to explain the variation in TDS concentrations between the sites, DWQ and ATK staff investigated the TDS concentrations in surface waters entering Blue Creek from other sources such as springs and drainages upstream of the ATK facility. Potential sources to Blue Creek were initially located using satellite imagery from Google Earth®. The creek was walked and a conductivity meter was used to estimate TDS concentrations with a site-specific calibration (ATK, 2013).

The data was summarized, plotted, and reviewed. The data was then explored for correlations. Based on the results of these analyses and hydrologic factors, the data was combined into two populations, one for the reservoir and one for Blue Creek. Statistical distribution parameters (*e.g.*, 90th percentile) for these two populations were calculated using the USEPA ProUCL software. Excerpts from USEPA guidance describing the parameters calculated and their uses are presented in Appendix F.

1.3 RESULTS

1.3.1 Data Summary

The results for TDS and Flow for each sample site are summarized in Table 1. Box plots of TDS and flow are provided on Figures 2 and 3, respectively. Table 2 summarizes the same data based on whether irrigation was occurring. Box plots based on irrigation status are also included in Figures 2 and 3.

As shown by the flow data on Table 2 and Figure 3, Blue Creek is a gaining stream that increases with volume as it moves down gradient. No tributaries are present which supports that groundwater is a significant source of the water. For the Below Dam site, TDS concentrations were higher when irrigation water is being diverted and a low negative correlation with flow was observed with a Pearson Correlation Coefficient of -0.21. TDS concentrations showed relatively little variance with a range of 1,890 to 2,110 mg/l (Table 1). A poor correlation was expected at this site because flow is controlled by dam releases in response to irrigation demands and not water inputs to the reservoir.

Table 1

Summary Statistics for Total Dissolved Solids and Flow for Blue Creek,

Box Elder County, Utah

	BCBD_TDS (mg/l)	BCCR_TDS (mg/l)	BCU_TDS (mg/l)	BCBD_FLOW (gal/min)	BCCR_FLOW (gal/min)	BCU_FLOW (gal/min)
N of Cases	29	32	32	28	27	24
Minimum	1,890	2,470	2,260	0	0	0
Maximum	2,110	5,060	6,270	11,162	8,079	11,438
Median	1,990	3,180	4,220	374	1,434	2,428
Arithmetic Mean	2,007	3,297	4,261	774	1,847	2,712
Geometric Mean	2,006	3,254	4,184	.	.	.
Standard Deviation	63.6	572.4	802.7	2094	1,776	2,548
Notes BC_BD BCCR BC_U	 Blue Creek below Dam Blue Creek Crossing Blue Creek Upper					

Table 2 Summary Statistics for Total Dissolved Solids During Irrigation and No Irrigation in Blue Creek Box Elder County, Utah						
	Irrigation	Not Irrigating	Irrigation	Not Irrigating	Irrigation	Not Irrigating
	BCBD_TDS (mg/l)		BCCR_TDS (mg/l)		BCU_TDS (mg/l)	
N of Cases	19	10	19	13	19	13
Minimum	1890	1940	2600	2470	2260	4050
Maximum	2110	2100	4670	5060	5630	6270
Arithmetic Mean	1998	2025	3443	3085	4011	4626
Geometric Mean	1997	2024	3410	3039	3928	4589
Standard Deviation	69.6	48.8	492.4	632.9	818.3	645.5
Notes BC_BD BCCR BC_U	 Blue Creek below Dam Blue Creek Crossing Blue Creek Upper					

At the Crossing site, TDS concentrations were higher when irrigation was occurring (Table 1, Figure 2) but mean concentrations were only about 350 mg/l higher. TDS concentrations at this site showed relatively little variation but the variation was higher when irrigation was occurring ranging from 2,470 to 5,060 mg/l (Table 1, Figure 2). Flows were poorly correlated with TDS with a Pearson Correlation Coefficient of 0.09.

At the sample site at the upstream boundary of the ATK property, Blue Creek Upper, a positive correlation between TDS and flow was observed with a Pearson's Correlation Coefficient of 0.29. While a stronger correlation than observed at the other sites, flow only explains less than 10% of the variation in TDS concentrations. TDS concentrations were variable, ranging from 2,260 to 6,270 mg/l at the Blue Creek Upper sample site. TDS concentrations increased when no irrigation was occurring which was the opposite of the trend observed at the Crossing site (Table 1, Figure 2). The mean difference in TDS concentrations between irrigating and not irrigating was a modest 600 mg/l at the Upper site.

TDS concentrations increase moving downstream between the dam and the Blue Creek Upper site as shown by the differences in median concentrations at the dam of 1,990 mg/l, to 3,180 mg/l at the Blue Creek Crossing site, to 4,220 mg/l at the Blue Creek Upper site. These reaches were further investigated to locate and measure specific sources of incoming TDS waters. Several sources of saline inputs that appear to originate from springs were identified (Table 1 in ATK, 2013). The maximum concentration measured in these sources was 31,300 mg/l. The local ranchers report that groundwater in the area was generally unsuitable for irrigation or potable uses.

The impact of the dam on TDS concentrations in Blue Creek is uncertain. Without the dam, the lower TDS water from Blue Springs would flow down Blue Creek instead of being stored. Other inputs to Blue Creek from springs are generally higher in TDS, so the TDS concentrations in Blue Creek could be lower at those times when the dam doesn't currently discharge to Blue Creek or the irrigation canal. However, the changes in TDS concentrations under the different dam operating scenarios (Figure 6, Appendix B) don't appear to support this hypothesis. Additional analyses to normalize for seasonality or a more robust data set and hydrologic modeling might identify a trend but the existing data suggests that the effect of the dam is small.

The data supports that irrigation return flows are not a significant source of TDS. Therefore, additional best management practices for irrigation would not result in the compliance with the statewide TDS standard.

1.3.2 Site-Specific Criteria

Two site-specific TDS criteria are proposed for Blue Creek: one for the reservoir and one for the creek. No additional site-specific criteria are proposed because there are no specific hydrological features (e.g., confluence) or marked changes in TDS to support additional criteria. The reservoir has relatively consistent TDS concentrations that are greater than the statewide

TDS criterion of 1,200 mg/l. Below the dam, TDS concentrations increase rapidly with a larger increase between the dam and the Blue Creek Crossing site than between the Blue Creek Crossing site and the Blue Creek Upper. The distance from ATK's property to the dam is approximately 8 miles. A single site-specific criterion is proposed for this reach, including extending downstream to Great Salt Lake. Although no specific data is available for the reach between ATK and the Great Salt Lake, salinity typically increases as creeks approach the lake and are influenced by saline sediments and future investigations may determine that additional site-specific criteria are appropriate.

These proposed site-specific TDS criteria are based on natural conditions and the goal is to define the range of natural conditions. Therefore, estimates of both an upper percentile and central tendency are appropriate (*e.g.,* maximum and average background concentrations).

ProUCL also provides distributional testing. Histograms of the data were also constructed (Appendix D). Distributional tests were conducted on the data for Blue Creek and for the reservoir.

The dam site concentrations were expected to be normally distributed because the source of the of the water is from saline Blue Springs and any variance in TDS concentrations is dampened by the volume of the reservoir resulting in normally distributed concentrations.

TDS concentrations in the creek were expected to more closely match a lognormal distribution because the additional sources of TDS or dilution water are a multiplicative process (Ott, 1995). However, when the data from the Crossing and Upper sites were combined, the resulting distribution is not significantly different than a normal distribution (Appendix C).

USEPA's ProUCL software was used to provide an estimate of an Upper Prediction Limit (UPL) as a Background Threshold Value. The UPL can be calculated assuming that *k* future samples will be collected and compared to the UPL (see Appendix F for more information on UPLs).

1.3.2.1 Blue Creek Reservoir

Several parameters are potentially appropriate for estimating the high end of TDS concentrations (see Background Threshold Values in the USEPA ProUCL Technical Guidance). Selection of the appropriate descriptor for the upper-bound estimate is a policy decision informed by site-specific characteristics such as variability, strength or study, etc.

For the reservoir, a single upper bound criterion of 2,200 mg/l TDS based on a 95% UPL assuming 10 future samples is recommended. Ten samples is the minimum number of samples DWQ requires to assess a water for the *Integrated Report*. TDS concentrations showed little variation, and the other upper-percentile estimates were similar. For instance, 2,100 mg/l based on the 90th percentile was the lowest upper bound estimate.

1.3.2.2 Blue Creek

TDS concentrations in Blue Creek vary much more temporally and spatially than in the reservoir. This variability causes large variations in the upper-percentile estimate. Figure 4 graphs the upper-bound TDS concentrations that range from 4,900 to 7,500 mg/l. A site-specific criterion of 6,300 mg/l TDS is recommended. Although a higher criterion could be supported by the lack of downstream impacts and the longer-term TDS measurements in Blue Creek at the ATK Upper site, uncertainty remains regarding the representativeness of the dataset for predicting long-term concentrations and the spatial variability of the affected reach.

The upper percentile of 6,300 mg/l is the 95% UPL for the next 5 measurements and coincidentally, converges with the 99% UPL. Utah's current assessment methods require at least 10 samples which potentially could result in a false positive. However, given 6,300 mg/l is also the 99% UPL, a false positive is unlikely and can be addressed with resampling. For UPDES permitting purposes and assessment purposes, an averaging time of one day is recommended.

In conjunction with the one-day upper percentile criterion, a central tendency criterion is also recommended. An average concentration of 3,900 mg/l TDS that is the 90% upper confidence limit of the mean. The averaging time for this criterion is one month.

Table 3 summarizes the proposed site-specific criteria for the reservoir and Blue Creek from the confluence with Class 5 Great Salt to headwaters. An upper bound criterion with a one-hour averaging period is proposed for Blue Creek Reservoir where the low variation observed for TDS concentrations supports a single criterion. Both upper bound and central tendency criteria are proposed for Blue Creek with an averaging period of one hour and one month, respectively. Two criteria are necessary to adequately characterize ambient TDS concentrations because of the variance observed.

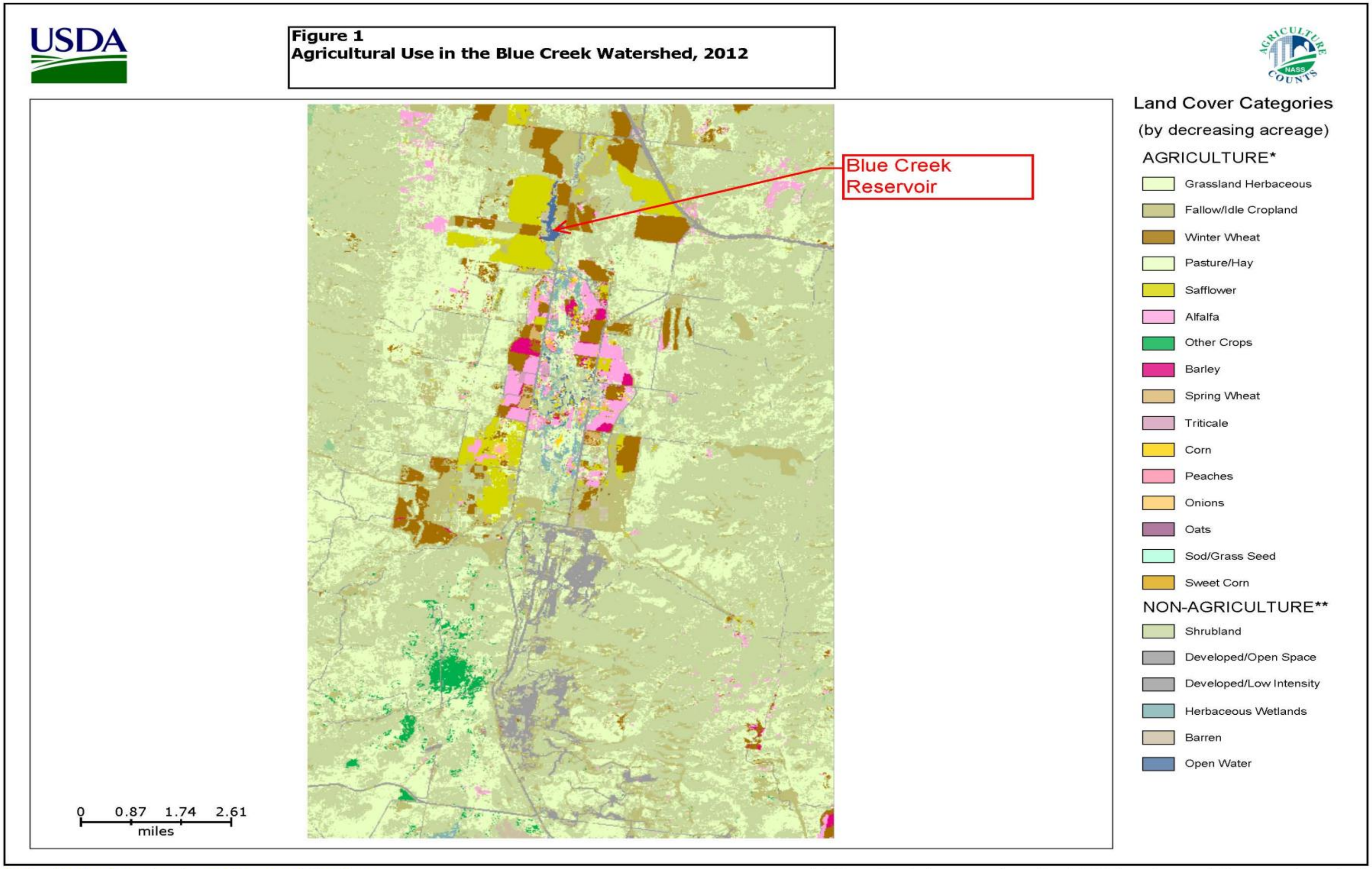
Table 3

Proposed Site-specific Total Dissolved Criteria for Blue Creek Reservoir and Blue Creek (mg/l)

Blue Creek Reservoir	Blue Creek	
Upper Bound	Upper Bound	Average
2,200	6,300	3,900

Figures

Figure 1
Agricultural Use in the Blue Creek Watershed, 2012



Produced by CropScape - http://nassgeodata.gmu.edu/CropScape

* Only top 16 agriculture categroies are listed. ** Only top 6 non-agriculture categroies are listed.

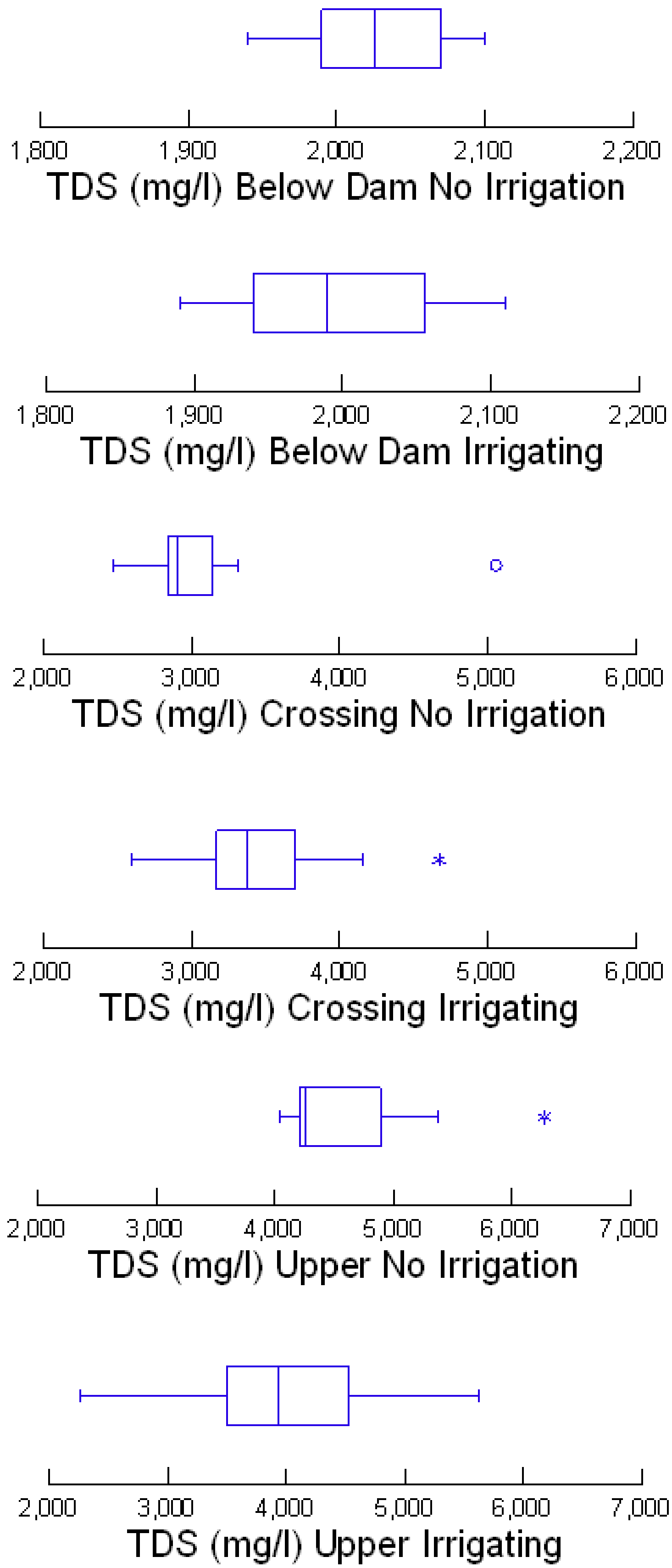


Figure 2

Box Plots for Total Dissolved Solids, Blue Creek, Box Elder County, Utah

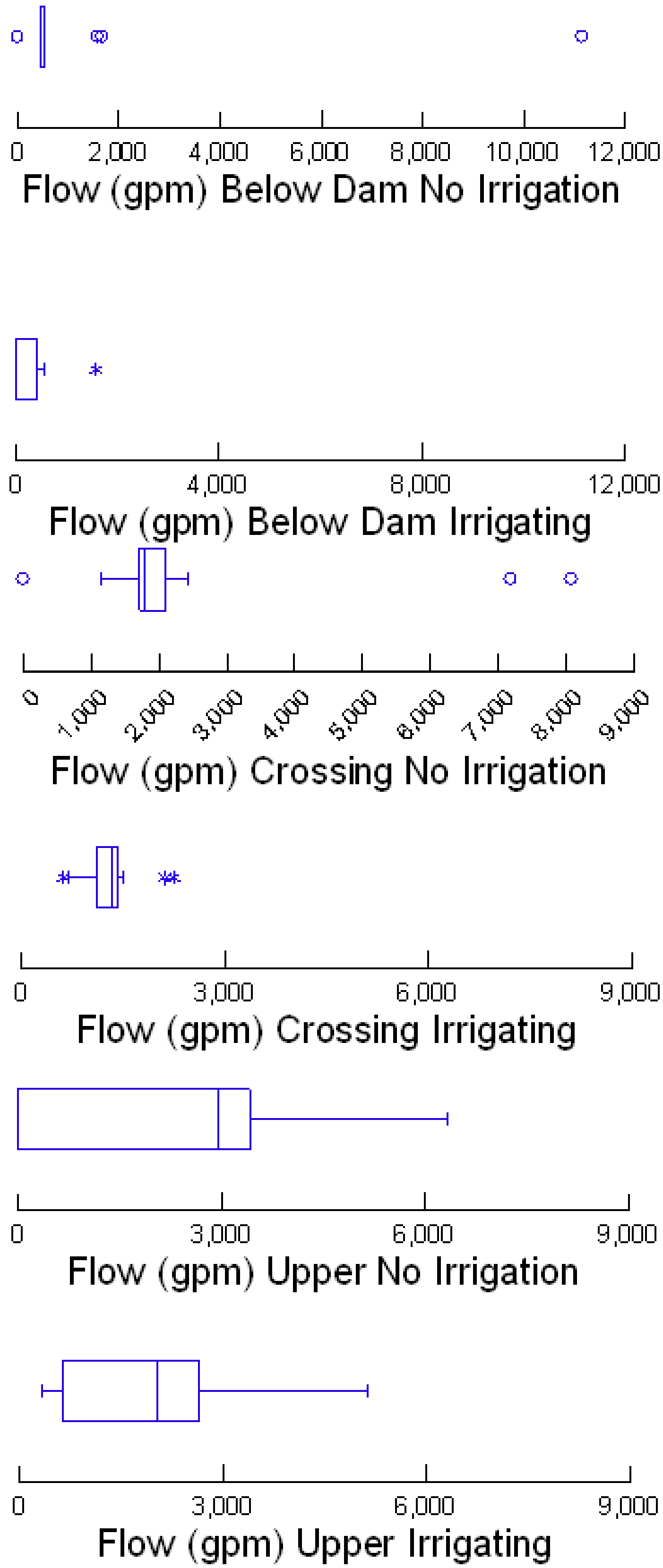


Figure 3

Box Plots for Flow, Blue Creek, Box Elder County, Utah

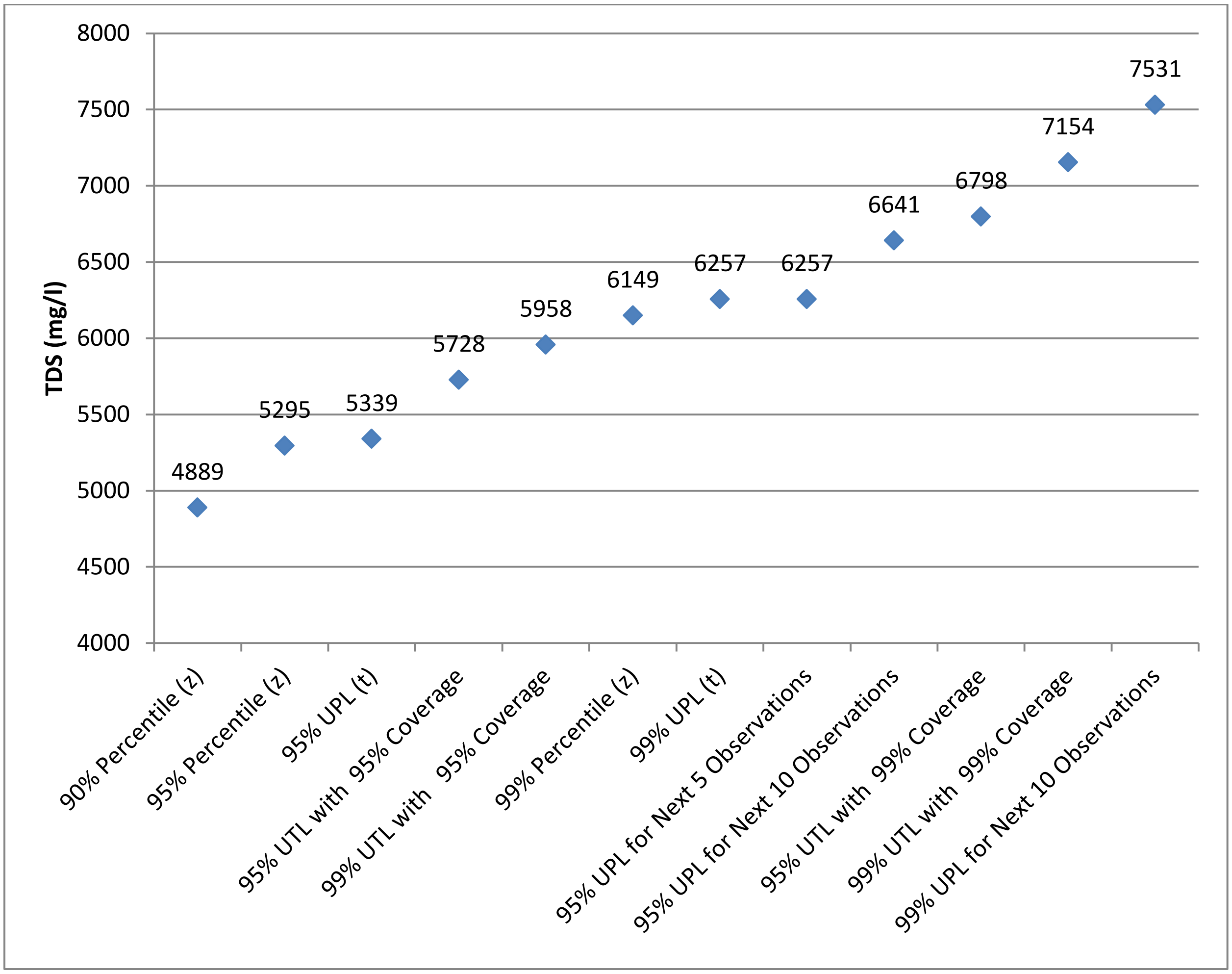


Figure 4

Upper-Bound Estimates for Total Dissolved Solids (TDS), Blue Creek, Box Elder County, Utah See Appendix F for additional information on Upper Tolerance Limits and Upper Prediction Limits.

APPENDIX A WORK PLAN FOR THE DEVELOPMENT OF A NEW SITE-SPECIFIC TDS CRITERION FOR BLUE CREEK, JUNE, 2011

ATK

Launch Systems Group

Work Plan
For the Development of a New Site-Specific TDS Criterion For Blue Creek

June 2011

1.0 Introduction

ATK Launch Systems Inc. is submitting this work plan for use in the development of a site-specific criterion for Total Dissolved Solids (TDS) in a stream segment of Blue Creek. The stream segment of Blue Creek begins at 41°43'20.40" N, 112°26'33.58" W a location on the northern boundary of ATK's facility along Highway 83 that ATK identifies as Blue Creek Upper with the stream segment ending at the Great Salt Lake. ATK currently has two wastewater treatment discharges along this stream segment under UPDES Permit #UT0024805. (See Figure 1 & 2, Goggle Earth image)

2.0 Background

Blue Creek originates approximately 8 miles north of the ATK Facility from Blue Springs. Blue Springs is a warm springs that has a TDS concentration of 2000 mg/L. The water that flows from Blue Springs is then stored in the Blue Creek Reservoir Dam.

The Blue Creek Reservoir Dam was constructed in 1904. The Blue Creek Dam was modified, enlarged and repaired in 1949, 1967 and 1986. The current capacity of the reservoir is about 2,185 acre-feet (UDWR, 2001). Water from Blue Springs is stored in the reservoir during the winter months and used for agricultural irrigation during the spring through fall season. The water in the reservoir is distributed by canals owned by the Blue Creek Irrigation Company. The two main canals, the East Canal and the West Canal, are used to irrigate a portion of the valley north of ATK's facility (Bolke and Price, 1972).

Several saline springs feed the main channel of Blue Creek once it leaves the Blue Creek Reservoir. These springs are the major source of flow in Blue Creek during most of the year as it passes through the ATK facility.

Prior to 1975, the stream segment of Blue Creek from the irrigation dam flowing southward was an intermittent stream only flowing significantly after rainfall events and snow melts. As a result of an earthquake in March 1975, Blue Creek became a perennial stream with year round flow resulting from the springs located below the Blue Creek Reservoir Dam.

In May 2010, four irrigation wells used for pivot irrigation that are located west and south within ½ mile of the Blue Creek Reservoir were sampled, reporting TDS concentrations of 2910 mg/L, 2600 mg/L, 2450 mg/L and 2270 mg/L. Some

- Mercury Method 245.1;
- Total Dissolved Solids (TDS), Method 160.1; and
- Anions, Method 300 IC to include, Fluoride, Chloride, Nitrite-N, Bromide, Nitrate-N, Orthophosphate-P, Sulfate.

During each sampling event, a visual investigation will be conducted to verify if water is flowing from the Blue Creek Reservoir Dam into either the west or east irrigation canal. This will assist in validating when the irrigation season is occurring and allow the opportunity to coincide possible irrigation return flows with changing TDS levels at the two most southern monitoring sites (Blue Creek at crossing 14400 N, and Blue Creek Upper (north boundary of ATK property, Hwy 83).

A second visual investigation will be done each sampling event to verify if water is being released from the Blue Creek Reservoir Dam into the main Blue Creek channel. This will observation will be used to verify when lower TDS water that is being released from the reservoir dam is mixing with the higher TDS water below the dam, and thereby lowering the TDS levels at the two most southern monitoring sites (Blue Creek at crossing 14400 N, and Blue Creek Upper (north boundary of ATK property, Hwy 83).
Sampling these sites and conducting the visual investigations will allow the development of three datasets:

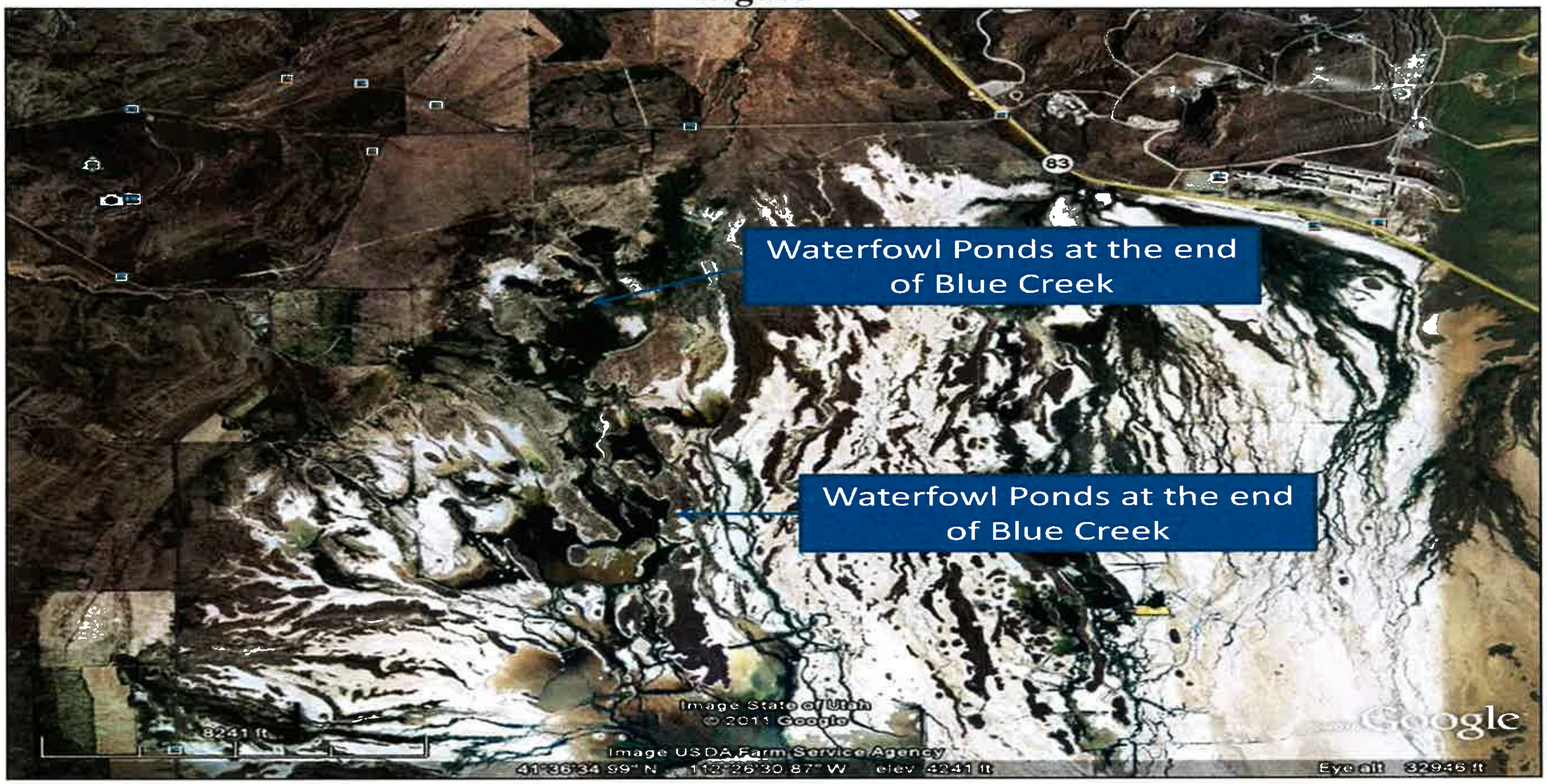
- The existing disturbed conditions, when irrigation is occurring and irrigation return flows are possible;
- When water is being discharged from the Blue Creek Reservoir Dam into the main channel of Blue Creek thereby, lowering the TDS level of Blue Creek by dilution; and
- A dataset for the periods when no irrigation is occurring and no water is being discharged from the Blue Creek Reservoir Dam, which is intended to represent natural conditions that predominate most of the year. This would represent the flow and TDS level in the main channel of Blue Creek that result from springs or seeps that occur below the reservoir dam southward.

The development of these three datasets will help characterize the three different flow conditions, as well as allowing the coordination of the sampling and analytical results with the flow conditions.

Figure 1


Blue Springs, (Source of Blue Creek Reservoir)
Sep 12, 2003
Blue Creek Reservoir
Blue Creek
Highway 83
Point of proposed Site Specific Standard (Highway 83 north boundary of ATK) following Blue Creek south to the Great Salt Lake
84
15
Image USDA Farm Service Agency
© 2009 Tele Atlas
© 2009 Google
Imagery Date Aug 19, 2003
41°43'34.79" N 112°21'43.06" W elev 5182 ft
Eye alt 24.49 mi

Figure 3

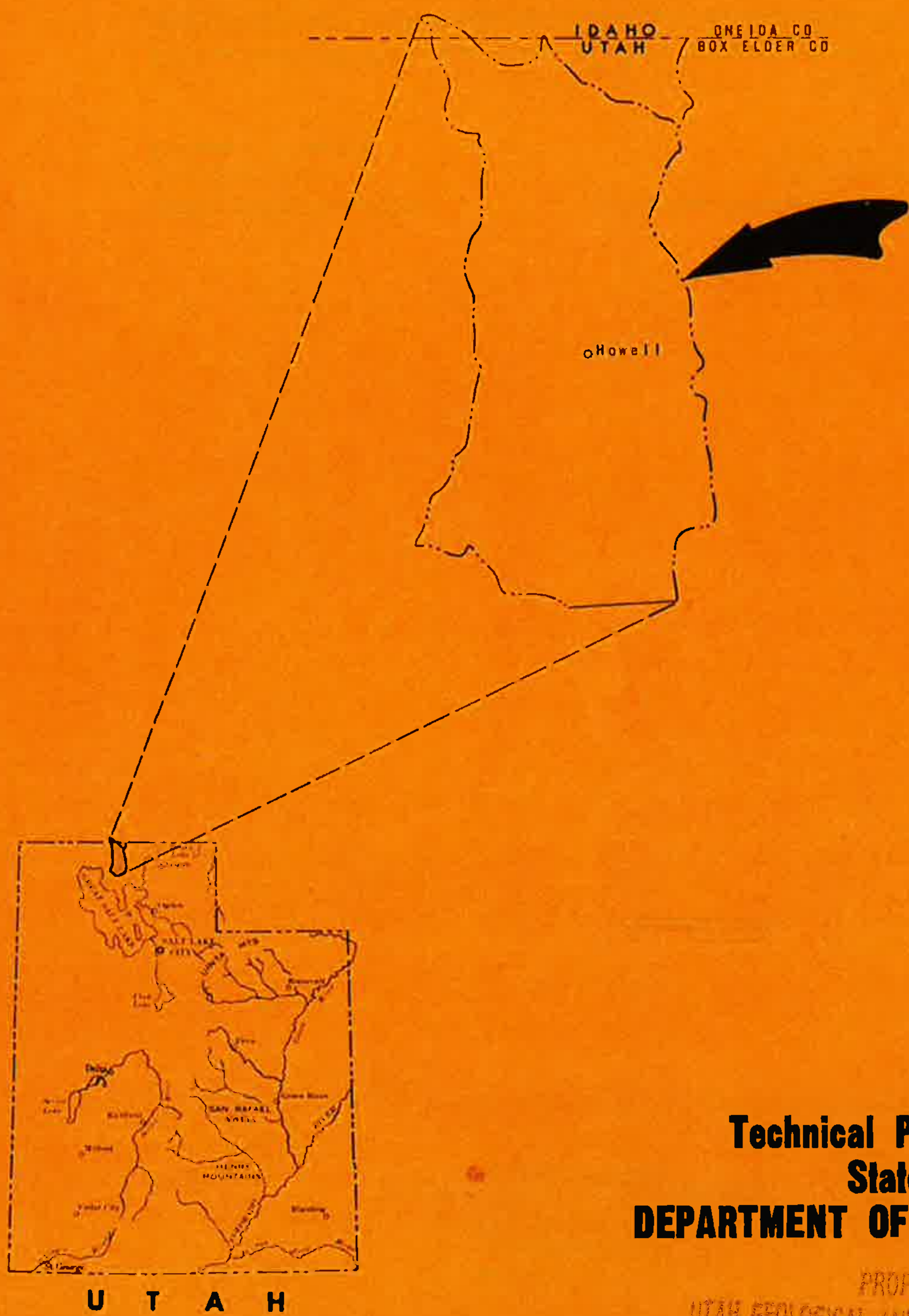

Waterfowl Ponds at the end of Blue Creek
Waterfowl Ponds at the end of Blue Creek
83
8241 ft
Image State of Utah
© 2011 Google
Image USDA Farm Service Agency
41°36'34.99" N 112°26'30.87" W elev 4241 ft
Google
Eye alt 32946 ft

References

Bolke, E.L. and Price D. 1972. Hydrologic Reconnaissance of the Blue Creek Valley Area, Box Elder County, Utah. Utah Department of Natural Resources Technical Publication No. 37.

UDWR (Utah Division of Water Resources). 2001. Utah State Water Plan, West Desert Basin, Salt Lake City, Utah. 3-17p.

HYDROLOGIC RECONNAISSANCE OF THE BLUE CREEK VALLEY AREA, BOX ELDER COUNTY, UTAH



Technical Publication No. 37
State of Utah
DEPARTMENT OF NATURAL RESOURCES
1972

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

Technical Publication No. 37

HYDROLOGIC RECONNAISSANCE OF THE BLUE CREEK VALLEY AREA, BOX ELDER COUNTY, UTAH

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Prepared by the U. S. Geological Survey
in cooperation with the
Utah Department of Natural Resources
Division of Water Rights

1972

ILLUSTRATIONS

TABLES

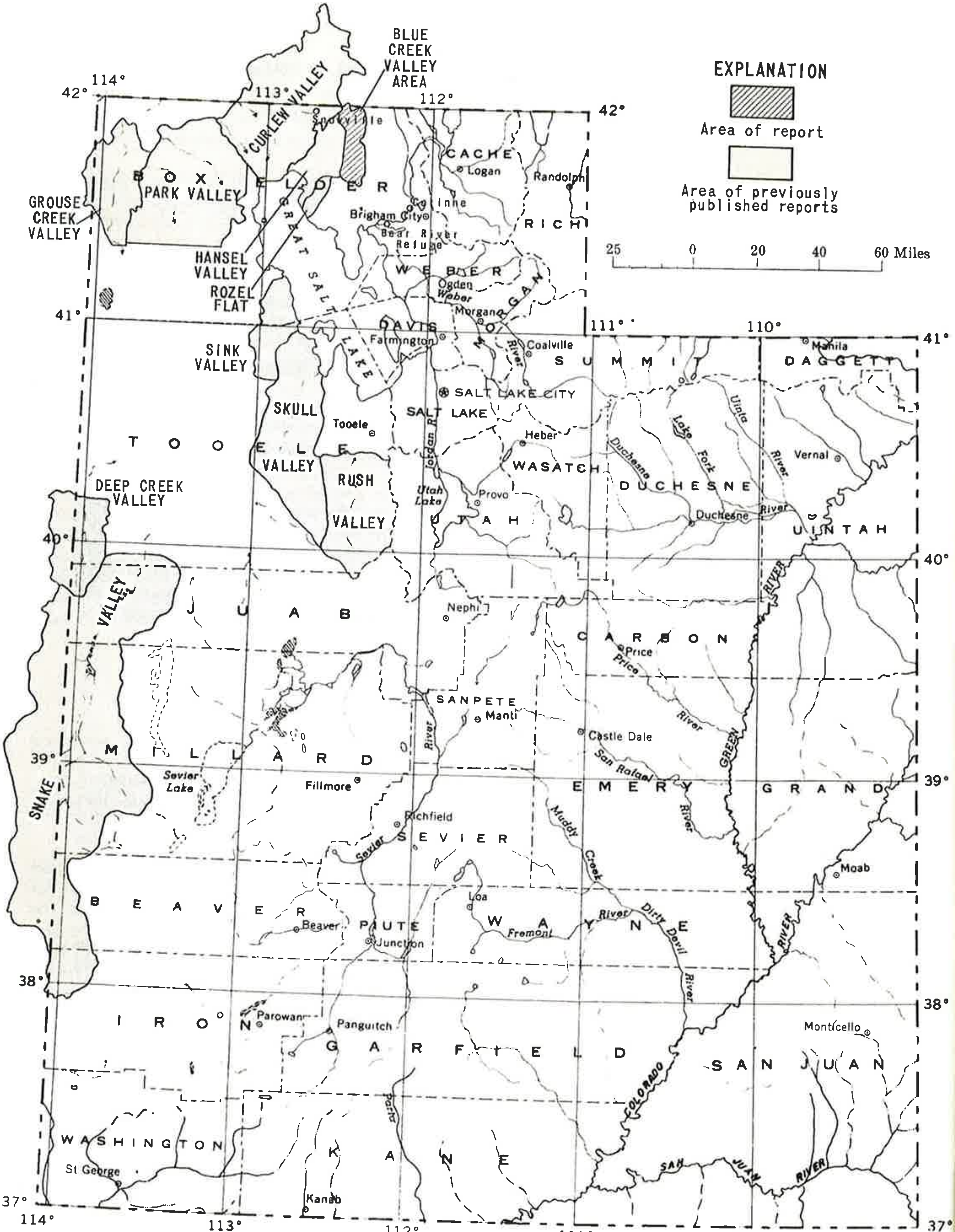

Figure 1.—Location of the Blue Creek Valley area and of other areas described in previously published reports in this reconnaissance series. (See list of technical publications at end of report.)

GEOLOGY

The general geology of the Blue Creek Valley area is shown on plate 1. The age, general lithology, and general hydrologic properties of the principal units are summarized in table 1.

Blue Creek Valley is a structural trough formed by the deformation of rocks of Paleozoic and Tertiary age. The mountain ranges, which consist of rocks of Paleozoic age, were elevated in relation to rocks of the same age that underlie the valley fill by basin- and range-type faulting. Complex folding and faulting accompanied the major structural displacements. The Salt Lake Formation of Tertiary age, which overlies the Paleozoic rocks, was also involved in this structural deformation.

Rocks of Paleozoic and Tertiary age have considerable local relief beneath the valley fill, as indicated by outliers of those rocks (as in Andersons Hill) that protrude above the valley floor. The relief in the consolidated rock is attributed at least in part to faults concealed beneath the valley fill. Such faults are also inferred from (1) the presence of Blue Springs, a thermal spring area that discharges from highly fractured Paleozoic rocks (B. L. Bridges, Geologist, U. S. Soil Conserv. Service, oral commun., 1969) near the north end of Andersons Hill, (2) an apparent "subsurface dam" of upfaulted Paleozoic rocks near the lower end of the valley that impedes drainage from the valley, and (3) local anomalies in the chemical character of the ground water (p. 15). However, subsurface data are not adequate to accurately map any of these inferred faults.

Volcanic activity, which was widespread in adjacent parts of southern Idaho and northern Utah during the Tertiary Epoch, is evidenced in Blue Creek Valley by tuffaceous rocks of the Salt Lake Formation and by layered basaltic lava flows and associated deposits of tuff near the northwest margin of the valley. Lava is reported in logs of several wells drilled in that general area.

The valley fill, which forms the most permeable part of the valley ground-water reservoir, consists largely of detritus eroded from the mountains. Some of the fill was deposited in ancient Lake Bonneville and other pre-existing lakes and reworked by wave action. Shoreline features and deposits of Lake Bonneville are clearly visible at many places along the margins of the valley, especially near the highest level (about 5,200 feet) reached by that lake. Because of the high relief on the underlying rocks, the thickness of the valley fill varies considerably over short distances.

WATER RESOURCES

The quantitative estimates given in this section pertain only to the area within the Blue Creek Valley drainage basin above the narrows in sec. 17, T. 11 N., R. 5 W.

Volume of precipitation

The normal annual (1931-60) precipitation in the Blue Creek Valley drainage basin is shown by isohyets (lines of equal precipitation) on plate 1. The total volume of precipitation was estimated by determining the areas between isohyets, multiplying those areas by the mean value of precipitation between the isohyets and accumulating the total (table 2). The average annual volume of precipitation is about 184,000 acre-feet. Most of this precipitation is returned directly to the atmosphere by evapotranspiration at or near the point of fall; the remaining precipitation becomes runoff or ground-water recharge.

Age	Lithologic unit	General character of material	General hydrologic properties
Mississippian to Permian	Sedimentary and metasedimentary rocks undivided	These rocks form Andersons Hill and the bulk of the mountains that bound Blue Creek Valley. The Oquirrh Formation (Pennsylvanian-Permian age), which consists chiefly of limestone and orthoquartzite with some sandstone, comprises more than 90 percent of the exposures. Manning Canyon Shale (mostly shale and sandstone of Mississippian and Pennsylvanian age) and Great Blue Limestone (mostly massive limestone of Mississippian age) are exposed only locally in Andersons Hill, along the lower slopes of Blue Spring Hills, and in the hills that protrude into the valley from the south. The oldest formation penetrated by oil test (B-11-5)18ddc-1 is reported to be the Laketown Dolomite of Silurian age. All the Paleozoic rocks have undergone considerable deformation and possible local metamorphism. Exposures display intense fracturing, and large solution cavities are evident in several places.	Water-bearing properties are highly variable. The unit as a whole has low permeability, but interconnected fracture zones and solution cavities are capable of transmitting water readily; the possibility of drilling a successful well at any given site is highly unpredictable. The rocks yield less than 10 gpm to most springs in the area; yields to wells range from about 10 to 450 gpm. These rocks probably are the source rocks for most of the flow of Blue Springs and several springs near the south end of Blue Spring Hills.

Table 2.—Estimated average annual volume of precipitation and ground-water recharge from precipitation in the Blue Creek Valley drainage basin

Average annual precipitation: Precipitation zone (inches)	Average annual precipitation: Weighted mean (feet)	Area over which precipitation occurs (acres)	Volume of precipitation (acre-feet)	Precentage of precipitation as recharge	Recharge (acre-feet)
Area where Quaternary and Tertiary sedimentary rocks are exposed					
12-16	1.25	95,770	119,710	5	5,990
16-20	1.50	5,710	8,560	10	860
Subtotals (rounded)		101,500	128,300		6,800
Area where Tertiary igneous rocks and Paleozoic rocks are exposed					
12-16	1.25	21,270	26,590	10	2,660
16-20	1.50	18,950	28,420	15	4,260
More than 20	1.90	440	840	20	170
Subtotals (rounded)		40,700	55,800		7,100
Totals (rounded)		142,000	184,000		14,000

M, Measured by U.S. Geological Survey; F, flowing, but unmeasured (observed by Thiokol Chemical Corp.); E, estimated by U.S. Geological Survey.

Discharge (cfs)	Date
5.0M	Sept. 30, 1959
3.1M	Apr. 19, 1960
4.2M	Oct. 16, 1963
10E	Mar. 19, 1964
11.0M	Apr. 10, 1964
9.0M	Apr. 24, 1964
17.8M	May 7, 1964
2.5M	June 11, 1964
.1E	Sept. 15, 1964
F	Jan. 17, 1969- May 19, 1969
Dry	June 17, 1969
Dry	July 29, 1969
Dry	Aug. 15, 1969
Dry	Sept. 25, 1969
F	Oct. 21, 1969- Dec. 19, 1969
6.8M	Feb. 19, 1970
1.1M	Mar. 18, 1970
1.7M	Apr. 14, 1970
2.4M	May 14, 1970
.5E	July 15, 1970
.3E	Sept. 1, 1970
Dry	Sept. 21, 1970

Ground water

Recharge

The principal source of recharge to the ground-water reservoir in Blue Creek Valley is precipitation that falls on the drainage basin. The volume of recharge was estimated by a method described by Hood and Waddell (1968, p. 22). The estimated recharge is about 14,000 acre-feet annually (table 2) or about 8 percent of the estimated average annual volume of precipitation.

Thiokol Chemical Corp. imports about 150 acre-feet of water per year. About 90 percent of that water is either consumed or percolates into the ground-water reservoir; the remainder is discharged to Blue Creek as treated sewage effluent.

Shallow aquifers in the irrigated segment of the valley below Blue Springs receive some recharge from leaky canals and ditches and from flooded fields; this recharge is regarded as "recycled" ground water and does not add to the total recharge figure. Some additional ground water may enter the Blue Creek Valley area from outside the drainage basin along fault zones and solution cavities. However, data collected for this study were not adequate to confirm this means of recharge or to estimate its magnitude.

Occurence and movement

Ground water in the Blue Creek Valley area occurs under both confined (artesian) and unconfined (water table) conditions. In most of the ground-water reservoir beneath the valley, artesian conditions apparently exist in permeable water-bearing strata that underlie thick beds of clay or other material of poor permeability. Water-table conditions exist in shallow aquifers beneath the valley flat south of Blue Springs. Perched water-table conditions exist locally, especially near the margins of the valley where permeable lakeshore deposits overlie rocks of relatively low permeability. However, the perched aquifers probably are of limited extent and may not be a reliable perennial source of water.

Artesian conditions also exist in the consolidated rocks. These conditions are indicated by Blue Springs and Engineer Spring, which apparently rise along faults in the Paleozoic rocks; and also by the water level in well (B-11-5)5acd-1 (table 3), which taps Paleozoic rocks. Water-table conditions exist in some deep bedrock aquifers such as those tapped by wells (B-11-5)28bba-1 and (B-12-5)27bac-1.

The general direction of ground-water movement in the ground-water reservoir beneath the valley is shown by water-level contours and arrows on plate 1. Ground water moves generally from principal areas of natural recharge on the sides and upper reaches of the valley toward the axis of the valley; movement is then downvalley through the narrow gap near the south boundary of the project area to Great Salt Lake. The overall gradient along the main axis of the valley is slightly more than 500 feet in 25 miles or about 20 feet per mile. The flattening of the gradient near the center of the valley may be due in part to discharge of ground water by evapotranspiration and in part to a subsurface constriction in T. 11 N., R. 5 W., which impedes ground-water movement.

Movement of ground water in the consolidated rocks is controlled largely by geologic structures, such as fault and fracture zones, bedding planes, and solution cavities. Movement is from areas of natural recharge toward the valley fill or toward springs and seeps near the edge of the valley.

Evapotranspiration

Phreatophytes, chiefly greasewood (*Sarcobatus vermiculatus*), rabbitbrush (*Chrysothamnum greenei (?)*), sedges (*Carex* sp.), other marsh grasses, and alfalfa (*Medicago sativa*) discharge ground water by evapotranspiration. Ground water probably was transpired by native vegetation in most of the area presently cultivated; when the land was cleared of native vegetation, evapotranspiration probably was reduced. Excluding the irrigated alfalfa fields, about 200 acres of land below Blue Creek Reservoir contain various amounts of phreatophytes (plant density about 50 percent). In this area the water table is less than 20 feet below land surface. Adjusting the plant density to 100 percent yields about 100 acres covered by phreatophytes. The rate of evapotranspiration is about 2 acre-feet per acre per year (Mower and Nace, 1957, p. 17-21), hence the total evapotranspiration by native phreatophytes is about 200 acre-feet per year.

There are at least 1,000 acres of well-established alfalfa under irrigation in the valley. This alfalfa probably consumes some ground water to supplement the water applied by irrigation. Assuming a ground-water consumption of 0.5 acre-foot per acre per year (J.W. Hood, U.S. Geol. Survey, oral commun., 1971), the evapotranspiration by alfalfa is about 500 acre-feet per year. Thus the total discharge of ground water by evapotranspiration is about 700 acre-feet per year.

Pumpage

Only two large-diameter (more than 6 inches) irrigation wells exist in Blue Creek Valley. In 1969, 256 acre-feet of water was discharged from well (B-13-6)1dbb-1 (estimated from power-consumption records), and about 50 acre-feet was discharged from well (B-13-5)31daa-1. About 30 small-diameter (6 inches or less) domestic and stock wells (pumped at the rate of 1-10 gpm) discharge about 200 acre-feet annually. The total pumpage is about 500 acre-feet annually.

Ground-water outflow

A direct determination of ground-water outflow was not made. The detailed study of the water-bearing properties of the aquifers needed for such a determination is beyond the scope of this investigation. Therefore, the ground-water outflow was estimated as the difference between the total annual recharge (14,000 acre-feet) and the annual discharge by springs, seeps, wells, and evapotranspiration (8,500 acre-feet). The difference is 5,500 acre-feet, which is assumed to be the ground-water outflow from Blue Creek Valley. Ground-water inflow to Blue Creek, unknown but probably small, is included in that amount.

Water-level fluctuations

Changes in ground-water storage resulting from changes in ground-water recharge and discharge are reflected by changes of water levels in wells. Under natural conditions, ground-water recharge and discharge are equal over the long term, and ground-water levels fluctuate in response to changes in precipitation. (See fig. 3.)

A considerable amount of water is stored in the valley fill and in the consolidated rocks that surround and underlie the valley, but no estimate was made of the total amount. Much of this water is probably saline.

Budget

The estimated annual volumes of ground-water recharge and discharge in the Blue Creek Valley drainage basin are given in the following table:

	Acre-feet
Recharge:	
Precipitation (p. 4)	14,000
Total	14,000
Discharge:	
Springs and seeps (p. 11)	7,300
Withdrawal by wells (p. 12)	500
Evapotranspiration (p. 12)	700
Ground-water outflow (p.12)	5,500
Total	14,000

Of the 8,500 acre-feet of water discharged by wells, springs, and evapotranspiration, about 8,000 acre-feet is used beneficially and about 500 acre-feet is regarded as salvageable.

Perennial yield

The perennial yield of a ground-water system is the maximum amount of water that can be withdrawn from the system each year indefinitely without causing a permanent and continuing depletion of ground water in storage or a deterioration of chemical quality of the ground water. The perennial yield is limited to the amount of natural discharge of water of suitable chemical quality that can economically be salvaged for beneficial use.

Assuming (1) that subsurface outflow is of suitable chemical quality and could be economically intercepted by wells and (2) that the evapotranspiration loss by nonbeneficial phreatophytes could be salvaged, then the perennial yield of the basin would approximate the discharge from the ground-water reservoir or about 14,000 acre-feet.

Chemical quality of water

Chemical analyses of selected water samples from the Blue Creek Valley area are given in table 6. Plate 1 shows diagrams of chemical quality of water. For some analyses, sulfate ion was not determined, and the sulfate values for the diagrams have been estimated by taking the difference (in milliequivalents per liter) of total cations and anions and assuming the difference to be sulfate ion. These estimated values do not appear in table 6.

Most of the water in Blue Creek Valley exceeds these standards in one or more of the categories listed; exceptions are wells (B-13-6)1dbb-1, (B-14-6)3aaa-2, and (B-15-6)35bdb-1 and some mountain springs.

Little information is available concerning the rating of water for stock supplies. The State of Montana (McKee and Wolf, 1963, p. 113) rates water containing less than 2,500 mg/l of dissolved solids as good, 2,500-3,500 mg/l as fair, 3,500-4,000 mg/l as poor, and more than 4,500 mg/l as unfit for stock. Using these criteria, most of the ground-water sampled in Blue Creek Valley is rated as good for stock use.

The principal chemical quality characteristics that affect the usefulness of water for irrigation are: (1) total concentration of soluble salts, (2) relative proportion of sodium to other cations, (3) concentration of boron or other constituents that may be toxic to some plants, and (4) bicarbonate concentration in excess of the concentration of calcium plus magnesium. The U. S. Salinity Laboratory Staff (1954, p. 79-81) has devised a method for classifying water for irrigation use by plotting data on specific conductance (conductivity) versus sodium-absorption ratio (SAR) on a diagram (fig. 4). This method of classification is based on "average conditions" with respect to soil texture, infiltration rate, drainage, quantity of water used, climate, and salt tolerance of crops. Most of the water sampled in Blue Creek Valley has a low- sodium hazard and a high- to very high-salinity hazard (compare table 6 and fig. 4). Well (B-13-6)1dbb-1 (point 7 in fig. 4) is a large-diameter irrigation well; Blue Springs (point 5 in fig. 4) is the largest source of irrigation water in the valley. Crops are raised using water from Blue Springs, which has both a high SAR and a high mineral content.

SUMMARY OF WATER USE

Past and present development

Development of water in the Blue Creek Valley area began prior to 1900 when the first wells were constructed for domestic and stock supplies. The first recorded well in the area was constructed in 1898. However, most of the domestic and stock wells were constructed during the years 1910-20 and 1930-40. Many of those wells are now used only seasonally by the dryland grain farmers.

The water system for the town of Howell began operating in 1947 with the development and diversion of Hillside Spring (table 4). The system was enlarged about 1965 when well (B-12-6)24add-1 was drilled and put into operation. In 1970 the system served about 150 people.

The Thiokol Chemical Corp. plant was constructed about 1957. About that time, Railroad Springs (table 4), which were formerly used for watering of livestock and for wildlife, were developed and diverted to the plant, chiefly for culinary use.

Irrigation in Blue Creek Valley began in 1904 using water from Blue Springs. In 1960 about 2,800 acres of land in the area was irrigated (U. S. Dept. Agriculture, Soil Conserv. Service, 1960, p. 4). Until 1962, Blue Springs was the only major source of irrigation water. An irrigation well was drilled in 1962 and another in 1968; about 300 acres of land is irrigated with water from these two wells.

Future Development

Because most of the land in Blue Creek Valley is cultivated, future development depends chiefly on additional water supplies to provide for increased irrigation. Blue Springs is fully appropriated for irrigation, and surface runoff in the valley is too meager or of too poor quality for irrigation; therefore, any additional irrigation supplies must be obtained from wells. Theoretically, the annual volume of ground water available for additional development is about 6,000 acre-feet—that is, the assumed perennial yield (about 14,000 acre-feet) less the quantity currently used beneficially (about 8,000 acre-feet). However, full development of the 6,000 acre-feet is not feasible because (1) some of the water is chemically unsuitable for irrigation, (2) the valley ground-water reservoir generally has low permeability and in most places yields water too slowly for large-scale irrigation, and (3) pumping may be too costly for irrigation in the upper part of the valley because water levels are several hundred feet below land surface. Therefore, the volume of ground water economically available probably is considerably less than 6,000 acre-feet a year.

PROPOSALS FOR FUTURE STUDIES

As the need for development of ground water in Blue Creek Valley arises, problems resulting from that development will also arise. Problems resulting from increased pumping might be declining water levels, well interference, decrease in flow of Blue Springs, and deterioration of the chemical quality of water. A detailed study of the basin and adjacent areas would help to better understand these problems and bring about a possible solution. Such a study should include:

1. Establishment of streamflow stations, particularly below Blue Springs and on Blue Creek near site (B-10-5)5bab.

2. Test drilling and gravity surveys to determine the subsurface geology and to delineate major aquifers.

3. Inventory of all wells and water sources, expansion of the observation-well network, and monitoring chemical quality of water at selected sites.

4. Aquifer performance tests to determine the water-bearing properties of the aquifers.

5. Collection of climatic records and detailed geologic mapping to more accurately estimate runoff and ground-water recharge.

6. Detailed mapping of phreatophytes.

APPENDIX

TEMPERATURE-CONVERSION TABLE

Temperatures in °C are rounded to nearest 0.5 degree. Underscored temperatures are exact equivalents. To convert from °F to °C where two lines have the same value for °F, use the line marked with an asterisk (*) to obtain equivalent °C.

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-20.0	-4	-10.0	14	0.0	32	10.0	50	20.0	68	30.0	86	40.0	104
-19.5	-3	-9.5	15	+0.5	33	10.5	51	20.5	69	30.5	87	40.5	105
-19.0	-2	-9.0	16	1.0	34	11.0	52	21.0	70	31.0	88	41.0	106
-18.5	-1	-8.5	17	1.5	35	11.5	53	21.5	71	31.5	89	41.5	107
-18.0 *	0	-8.0 *	18	2.0 *	36	12.0 *	54	22.0 *	72	32.0 *	90	42.0 *	108
-17.5	0	-7.5	18	2.5	36	12.5	54	22.5	72	32.5	90	42.5	108
-17.0	1	-7.0	19	3.0	37	13.0	55	23.0	73	33.0	91	43.0	109
-16.5	2	-6.5	20	3.5	38	13.5	56	23.5	74	33.5	92	43.5	110
-16.0	3	-6.0	21	4.0	39	14.0	57	24.0	75	34.0	93	44.0	111
-15.5	4	-5.5	22	4.5	40	14.5	58	24.5	76	34.5	94	44.5	112
-15.0	5	-5.0	23	5.0	41	15.0	59	25.0	77	35.0	95	45.0	113
-14.5	6	-4.5	24	5.5	42	15.5	60	25.5	78	35.5	96	45.5	114
-14.0	7	-4.0	25	6.0	43	16.0	61	26.0	79	36.0	97	46.0	115
-13.5	8	-3.5	26	6.5	44	16.5	62	26.5	80	36.5	98	46.5	116
-13.0	9	-3.0	27	7.0	45	17.0	63	27.0	81	37.0	99	47.0	117
-12.5	10	-2.5	28	7.5	46	17.5	64	27.5	82	37.5	100	47.5	118
-12.0 *	10	-2.0 *	28	8.0 *	46	18.0 *	64	28.0 *	82	38.0 *	100	48.0 *	118
-11.5	11	-1.5	29	8.5	47	18.5	65	28.5	83	38.5	101	48.5	119
-11.0	12	-1.0	30	9.0	48	19.0	66	29.0	84	39.0	102	49.0	120
-10.5	13	-0.5	31	9.5	49	19.5	67	29.5	85	39.5	103	49.5	121

For temperature conversions beyond the limits of the table, use the equations C = 0.5556 (F - 32) and F = 1.8°C + 32. The formulae say, in effect, that from the freezing point of water (0°C, 32°F) the temperature in °C rises (or falls) 5° for every rise (or fall) of 9°F.

BASIC DATA

Table 3.—Records of selected wells—continued

Well number	Owner	Priority date	Well depth (ft)	Casing Diameter (in.)	Casing Depth (ft)	Casing Finish	Altitude of LSD (ft)	Water level (ft)	Date of water-level measurement	Use of water	Log	Other data available
6/(B-13-5)31daa-1	L. D. Nessen	1962C	405	16	20	P	4,610	27A	7-70	I	D	P
33acc-1	Lawrence Hawkes	1900	180	2	-	O	4,780	170G	3-40	H	-	P
(B-13-6)1bdb-1	R. W. Henrie	1904	195	6	-	-	4,870	175G	3-36	S	-	P
1bdb-2	J. E. Deakin	1929	200	4	-	-	4,875	175G	3-40	H	-	-
1cac-1	M. J. Hyde	1929C	200	4	-	-	4,845	150A	10-49	U	-	P
7/1dbb-1	R. W. Henrie	1968C	704	16	482	P	4,835	121A	9-70	I	D	P
2cab-1	D. B. Bradshaw	1941C	275	6	-	-	4,970	237A	7-70	U	-	-
2dab-1	J. E. Deakin	1906	175	6	-	-	4,885	150G	3-36	U	-	-
10dda-1	H. J. Anderson	1926	364	6	-	O	5,075	311A	7-70	U	-	-
12aba-1	R. W. Henrie	1958C	-	8	-	-	4,900	-	-	S	-	P
14bbc-1	O. P. Canfield	1949C	-	-	-	-	5,070	-	-	S	-	-
24add-1	C. H. Miller	1911	250	6	-	-	4,795	-	-	H	-	-
24dcd-1	W. T. Miller	1911	250	6	-	-	4,825	-	-	H	-	P
36acc-1	Alfred Manning	1911	300	6	-	-	4,800	200G	3-36	S	-	P
(B-14-5)4bab-1	Gerald Jessop	1914	185	6	-	O	5,070	160A	7-70	U	-	-
5aaa-1	L. G. Whitney	1922	150	6	-	-	5,065	130G	4-40	H	-	-
5aba-1	Gerald Jessop	1898	430	3	100	-	5,060	125G	8-36	U	-	-
5bab-1	L. G. Whitney	1932	190	4	-	O	5,070	50G	3-40	U	-	-
8dbc-1	Edward Jessop	1917	180	6	-	O	5,160	31A	7-70	S	-	-
8ddd-1	M. S. Jessop	1918	105	6	-	O	5,175	62A	7-70	H	-	P
17aaa-1	Seth Hammond	1915	125	6	113	P	5,175	70A	7-70	U	-	-
19ccc-1	H. M. Schumann	1934	-	-	-	-	4,920	174A	7-70	U	-	-
28cca-1	William Roberts	1935C	610	-	-	X	5,120	Dry	11-35	U	D	-
29abb-1	H. and L. Schumann	1917	340	42	-	W	5,040	297A	7-70	H	-	P
30cbd-1	James Roberts	1924	200	6	191	-	4,960	166G	3-40	U	-	-
31cdd-1	Edward Doutre	1912	160	4	-	-	4,820	96A	7-70	U	-	-
(B-14-6)3aaa-2	W. R. Bishop	1969C	390	6	348	O	5,115	340D	9-69	H	D	P
9aab-1	Deloris Stokes	1967C	409	6	-	-	5,150	390D	8-67	H	D	P
12add-1	W. E. Fridal	1934	462	6	455	O	5,045	287D	-	U	D	-
12caa-1	Coop Security	1933C	480	8	445	P	5,150	406A	7-70	H	-	P
23add-1	Ray Holdaway	1941C	336	4	-	-	5,050	309A	7-70	U	-	-
23ddd-1	Hyer and Turley	1915C	350	6	348	P	5,030	300G	3-40	H	-	K
24cbc-1	R. B. Hyer	1920	330	6	-	-	5,035	304A	7-70	H	-	P
36cba-1	A. H. Rock	1900	200	2	-	O	4,920	149A	7-70	U	-	-
(B-15-5)32cdd-1	L. G. Whitney	1915	200	8	-	-	5,055	50G	8-44	H	-	P
(B-15-6)34ccc-1	R. W. Tolman	1968C	555	6	-	O	5,230	461D	7-68	H	D	P
35bdb-1	Deloris Stokes	1920	-	-	-	-	5,085	-	-	S	-	P

1/ Reported yield and drawdown: 450 gpm and 20 feet, October, 1962.

2/ Reported yield and drawdown: 90 gpm and 32 feet, July, 1956.

3/ Reported yield and drawdown: 80 gpm and 50 feet, June, 1962.

4/ Well destroyed.

5/ Reported yield and drawdown: 290 gpm and 140 feet, April, 1958.

6/ Reported yield and drawdown: 350 gpm and 200 feet, December, 1962.

7/ Reported yield and drawdown: 580 gpm and 192 feet, October, 1968.

Table 5.—Selected drillers' logs of wells.

Altitudes are in feet above sea level for land surface at well, interpolated from U.S. Geological Survey 7.5-minute topographic maps (20-foot contour interval).
Thickness in feet.
Depth in feet below land surface.

Material	Thickness	Depth
(B-11-5)5acd-1. Log by J. Hy Petersen and Sons. Alt. 4,445 ft.		
Topsoil	3	3
Clay, yellow	61	64
Clay, yellow, and gravel	31	95
Clay, sand, and gravel	49	144
Clay, yellow, and streaks of sandstone	20	164
Gravel, sand, and clay	32	196
Clay, sandy, yellow, and gravel	69	265
Gravel, sand, and hard clay	23	288
Gravel, cemented, hard, and sticky and sandy clay	81	369
Clay, yellow, and fine sandy gravel	29	398
Gravel, cemented	7	405
Gravel, hard, and clay	33	438
Gravel, hard, clay, and broken limestone boulders	7	445
Limestone, solid	94	539
Limestone, soft, black	13	552
Limestone, hard, broken	3	555
Limestone, soft, gray	10	565
Limestone, soft, broken	4	569
Limestone, hard, black	41	610
(B-11-5)28bba-1. Log by Melvin Church Drilling Co. Alt. 4,540 ft.		
Soil, rocky	2	2
Clay	3	5
Conglomerate	6	11
Rocks, large, and clay	183	194
Unlogged	1	195
Silt, yellow	5	200
Silt, red, and rocks	10	210
Silt and rocks; water seep	8	218
Limestone, broken	14	232
Shale, black	86	318
Rock; water seepage	6	324
Shale and limestone, lenticular	41	365
(B-11-5)29abb-1. Log by Melvin Church Drilling Co. Alt. 4,410 ft.		
Soil, rocky	4	4
Clay, gumbo	6	10
Conglomerate	26	36
Clay, gumbo	10	46
Conglomerate	37	83
Boulders and clay	4	87
Conglomerate	48	135
Clay, gumbo	6	141
Conglomerate	9	150
Gravel; water bearing	2	152
Clay	7	159
Gravel; water bearing	13	172
Clay	22	194
Gravel	2	196
Clay	4	200
Gravel; water bearing	14	214
Clay	2	216
(B-11-5)29cbd-1. Log by T. J. Burkhart. Alt. 4,340 ft.		
Soil	2	2
Clay, sandy	21	23
Gravel	7	30
Gravel and clay	15	45
Clay, sandy	15	60
Gravel	2	62
Clay, sandy	9	71
Gravel and clay	17	88
Sand, dirty	11	99
Gravel	8	107
Sand	8	115
Gravel	5	120
Clay	6	126
Sand and gravel	20	146
Clay	9	155
Gravel or sand	3	158
Gravel, dirty	26	184
Clay	8	192
Gravel with some clay	40	232
Gravel, loose	19	251
Gravel and boulders, dirty	53	304
Gravel and sand	6	310
(B-11-6)16bcc-1. Log by D. G. Musselman. Alt. 5,040 ft.		
Topsoil	3	3
Sandstone	17	20
Clay, blue	33	53
Clay, white	73	126
Clay, yellow, and gravel	10	136
Sandrock	156	292
(B-12-5)22dbd-1. Log by Robinson Drilling Co. Alt. 4,750 ft.		
Clay, silt, and cobbles	3	3
Sand and gravel	5	8
Clay, yellow, and boulders	7	15
Clay, red	5	20
Clay and boulders	10	30
Boulders	13	43

Material	Thickness	Depth
(B-12-5)22dbd-1 - Continued		
Limestone	18	61
Clay, red and yellow	4	65
Clay and rock	5	70
Limestone	10	80
Clay and rock	7	87
Boulders	6	93
Clay and rock	27	120
Shale, black	26	146
Limestone	53	199
Shale, black	52	251
Limestone, hard	32	283
Limestone, fractured	17	300
Limestone, hard	13	313
Shale, black	20	333
Limestone, hard	9	342
(B-12-6)24add-1. Log by Waymon Yarbrough. Alt. 4,620 ft.		
Clay	6	6
Clay and boulders	17	23
Clay and sand	22	45
Gravel	50	95
Clay and sand	23	118
Limestone	1	119
Limestone and clay	26	145
Clay and sand	10	155
Sand, soft, tight	5	160
Limestone, hard	117	277
Sand, soft	2	279
Sand	12	291
Limestone, hard	2	293
Sand and clay	7	300
(B-12-6)34acd-1. Log by David Musselman. Alt. 5,170 ft.		
Clay, red	10	10
Rocks	4	14
Clay, red	236	250
"Hardpan"	10	260
Clay, red, and gravel	28	288
Clay, white, sandy	10	298
Clay, red, and gravel	54	352
"Hardpan"	10	362
Clay, red, and gravel	10	372
"Hardpan"	12	384
Clay, soft, red	8	392
Sand	46	438
Gravel and clay	20	458
Sand	8	466
Clay	4	470
(B-13-5)5bcb-2. Log by T. J. Burkhart. Alt. 4,820 ft.		
Soil	2	2
Clay, yellow	38	40
Clay, soft, sandy, yellow	12	52
Clay, hard, sandy, light gray	53	105
Clay, yellow, and gravel	82	187
Clay, dense, gray	45	232
Shale, sandy, hard and soft streaks, light gray	28	260
(B-13-5)6aaa-2. Log by R. J. Howell Drilling Co. Alt. 4,840 ft.		
Clay, brown	5	5
Clay, yellow, and sand	30	35
Gravel, dry	2	37
Clay, yellow	33	70
Clay, brown, and conglomerate	12	82
Clay, brown, and lava rock	4	86
Clay, brown, and sand	10	96
Clay, brown, and lava rock	4	100
Clay and gravel	15	115
Clay and boulders	15	130
Sandstone	20	150
Limestone	25	175
Clay, red	10	185
Limestone, hard	3	188
Sand, red, and gravel; water bearing	10	198
Sand and gravel	32	230
Limestone	5	235
(B-13-5)7acc-1. Log by Davis and Davis. Alt. 4,800 ft.		
Sand and shale	±120	±120
Sandstone, sand, and shale	278	398
Sand; water bearing	14	412
(B-13-5)28bab-1. Alt. 4,665 ft.		
Soil, black	1	1
Clay	110	111
Gravel	1	112
(B-13-5)29aaa-1. Log by T. J. Burkhart. Alt. 4,640.		
Soil	2	2
Clay, light gray	21	23
Clay, light brown, and gravel	15	38
Clay, light gray	16	54

Material	Thickness	Depth
(B-13-5)29aaa-1 - Continued		
Gravel and boulders	3	57
Clay, light brown, and gravel	63	120
Clay, sandy, light brown	31	151
Gravel and light brown clay	40	191
Gravel and boulders; some clay	5	196
Gravel and light brown clay	19	215
Boulders, gravel, and light brown clay	88	303
Sand, clay, and gravel	21	324
Gravel and clay	4	328
(B-13-5)31daa-1. Log by Waymon Yarbrough. Alt. 4,610 ft.		
Soil	7	7
Clay	35	42
Unlogged; water bearing	13	55
Clay, gray	23	78
Gravel, coarse, boulders, and sand	12	90
Clay, white	22	112
Shale, hard	3	115
Clay, blue	30	145
Shale, hard	5	150
Clay, white	50	200
Clay, blue green	20	220
Clay, green	50	270
Sandy (sandy streak)	5	275
Shale	5	280
Clay, white	25	305
Clay, soft, blue	10	315
Sandstone, hard	10	325
Sandy (sandy streak)	1	326
Sandstone	4	330
Sandy (sandy streak)	1	331
Shale	4	335
Clay, hard	10	345
Limestone	25	370
Sand, black	10	380
Clay	20	400
Clay, hard	5	405
(B-13-6)1dbb-1. Log by Robinson Drilling Co. Alt. 4,835 ft.		
Soil	9	9
Clay	28	37
Clay and gravel	77	114
Clay	29	143
Clay with lime seams	57	200
Clay	6	206
Clay with limestone seams	6	212
Clay and gravel	69	281
Clay	13	294
Gravel	2	296
Clay	53	349
Gravel	2	351
Clay and sand	23	374
Gravel	11	385
Clay	14	399
Gravel	4	403
Clay and gravel	78	481
Clay	3	484
Gravel	12	496
Clay	16	512
Gravel	7	519
Clay	13	532
Gravel	2	534
Clay and gravel	39	573
Gravel	61	634
Clay and gravel	6	640
Gravel	31	671
Clay	8	679
Gravel	18	697
Clay and gravel	7	704
(B-14-5)28cca-1. Log by Adam Inthurn and F. H. Hughes. Alt. 5,120 ft.		
Conglomerate	140	140
Clay	35	175
Rock	65	240
Conglomerate	80	320
Rock	35	355
Shale	39	394
Rock, black	12	406
Sand and sandstone	77	483
Rock, black	50	533
Conglomerate	10	543
Rock, black	25	568
Conglomerate	15	583
Rock, black	27	610
(B-14-6)3aaa-2. Log by R. H. Howell Drilling Co. (0-320 ft) and R. O. Denton (328-390 ft). Alt. 5,115 ft.		
Lime(stone), white	12	12
Sandstone, red, hard	10	22
Clay, red	28	50
Sandstone, red	18	68
Red rock or hardpan	4	72
Clay, red	15	87
Cobbles	5	92

Table 6.—Chemical analyses of selected water samples.

Sodium and potassium: An entry of C for potassium indicates that sodium and potassium are calculated and reported as sodium.
Agency making analysis: GS, U.S. Geological Survey; IN, Thiokol Chemical Corp.; SU, Utah State University.

Location	Date of collection	Temperature (°C)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as $CaCO_3$	Noncarbonate hardness	Dissolved solids		Specific conductance (micromhos/cm at 25°C)	Sodium-adsorption ratio	pH	Agency making analysis
			Milligrams per liter															Determined	Calculated				
Wells																							
(B-11-6)2bdc-1	7-14-70	11.5	-	-	122	28	37	-	171	0	-	240	-	-	-	418	278	765	-	1,080	0.8	8.0	GS
14bbb-1	8-10-70	14.0	-	-	184	54	42	-	143	0	-	218	-	-	-	680	563	-	-	1,460	-	7.9	GS
(B-12-5)5cdb-1	7-14-70	9.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,690	-	-	GS
5d	1913	-	-	-	1/80	-	160	C	310	0	40	155	-	-	-	205	-	570	-	-	4.9	-	GS
7ccc-1	7-13-70	12.0	-	-	131	98	69	-	192	0	-	460	-	-	-	732	575	1,020	-	1,830	1.1	7.8	GS
7ddc-1	7-13-70	9.5	-	-	418	180	1,520	-	539	0	-	2,580	-	-	-	1,780	1,340	6,080	-	9,280	16	7.8	GS
10bca-1	7-14-70	15.5	-	-	66	37	129	-	254	3	-	226	-	-	-	317	104	708	-	1,220	3.2	8.5	GS
19ba	1913	-	-	-	1/80	-	200	C	215	0	40	275	-	-	-	205	-	690	-	-	6.1	-	GS
20bbb-2	7-14-70	9.5	32	-	97	59	1,020	20	525	25	129	1,470	1.2	4.0	0.45	486	14	3,260	3,120	5,270	20	8.7	GS
20bbb-3	7-14-70	10.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,320	-	-	GS
(B-12-6)13ddd-1	7-13-70	12.5	44	-	61	47	38	3.0	179	0	33	173	.9	5.4	.01	347	200	526	493	885	.9	8.2	GS
36ada-1	7-14-70	16.5	42	-	77	49	67	7.7	183	0	54	230	.7	2.9	.05	391	241	644	620	1,100	1.5	8.2	GS
(B-13-5)5bcb-2	7- 8-70	14.5	53	-	98	40	61	6.9	173	0	20	267	.5	4.2	.03	410	268	717	636	1,140	1.3	8.1	GS
6aaa-2	7- 8-70	19.0	-	-	185	70	108	-	144	0	-	591	-	-	-	750	632	1,230	-	2,120	1.7	7.9	GS
8d	1913	-	-	-	1/80	-	180	C	220	0	40	275	-	-	-	205	-	700	-	-	5.5	-	GS
16ccc-1	7- 7-70	18.5	-	-	572	245	547	-	142	0	-	2,380	-	-	-	2,430	2,320	4,860	-	7,190	4.8	7.8	GS
18adb-1	7-13-70	-	-	-	152	226	176	-	224	0	-	520	-	-	-	1,310	1,130	1,980	-	2,980	2.1	8.0	GS
18c	1913	-	-	-	1/80	-	110	C	215	0	100	105	-	-	-	205	-	480	-	-	3.3	-	GS
22ccc-1	7- 8-70	16.5	-	-	65	24	78	-	269	0	-	128	-	-	-	260	40	501	-	860	2.1	8.2	GS
28b	1913	-	-	-	1/95	-	180	C	240	0	30	405	-	-	-	240	-	900	-	-	5.1	-	GS
28bab-1	7- 8-70	13.0	-	-	233	94	146	-	163	0	-	751	-	-	-	968	834	1,600	-	2,660	2.0	7.8	GS
31daa-1	7-13-70	20.5	-	-	89	41	153	-	343	4	-	274	-	-	-	391	103	1,010	-	1,440	3.4	8.4	GS
33acc-1	7-14-70	19.0	-	-	52	23	101	-	274	3	-	136	-	-	-	224	0	509	-	901	2.9	8.6	GS
(B-13-6)1bdb-1	7- 6-70	16.5	-	-	149	32	41	-	144	0	-	331	-	-	-	506	388	818	-	1,340	.8	7.8	GS
1cac-1	10-17-57	-	53	-	204	44	49	C	140	0	102	395	-	20	-	688	573	-	936	1,650	.8	7.5	GS
1dbb-1	7- 6-70	19.0	47	-	71	19	31	10	160	0	16	127	.4	6.1	.04	260	124	405	407	701	.8	8.2	GS
12aba-1	7- 7-70	16.5	-	-	325	77	62	-	150	0	-	551	-	-	-	1,130	1,000	1,700	-	2,470	.8	7.9	GS
24dcd-1	7-13-70	14.5	-	-	113	75	48	-	204	0	-	325	-	-	-	597	430	936	-	1,450	.9	7.9	GS
36acc-1	7-13-70	17.5	-	-	447	153	143	-	162	0	-	1,340	-	-	-	1,740	1,610	3,450	-	4,270	1.5	8.0	GS
(B-14-5)8ddd-1	7- 7-70	10.5	29	-	91	19	72	1.7	321	0	69	55	.2	7.6	.06	304	41	600	474	878	1.8	8.2	GS
29abb-1	7- 6-70	13.0	40	-	216	56	48	7.6	138	0	49	490	.3	3.9	.00	770	657	1,330	979	1,850	.8	8.1	GS
(B-14-6)3aaa-2	7- 7-70	12.0	29	-	56	22	59	4.5	187	0	26	131	.5	1.9	.05	231	78	440	422	739	1.7	7.6	GS
9aab-1	7- 7-70	20.5	-	-	67	25	213	-	2/258	0	-	341	-	-	-	270	58	870	-	1,530	5.6	8.3	GS
12caa-1	7- 7-70	12.0	26	-	87	17	41	10	143	0	44	176	.3	.0	.06	285	168	517	471	823	1.1	8.2	GS
23ddd-1	7- 8-70	10.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,270	-	-	GS
24cbc-1	7- 8-70	10.0	-	-	121	30	33	-	183	-	-	230	-	-	-	428	278	773	-	1,080	.7	7.8	GS
(B-15-5)32cdd-1	7- 7-70	12.5	-	-	199	23	119	-	2/249	0	-	234	-	-	-	340	135	772	-	1,230	2.8	8.4	GS
(B-15-6)34ccc-1	7- 7-70	20.5	41	-	60	25	247	5.7	259	0	40	375	1.0	.3	.06	252	40	938	922	1,610	6.8	7.9	GS
35bdb-1	7- 7-70	18.5	-	-	88	16	16	-	258	0	-	64	-	-	-	284	73	417	-	634	.4	8.2	GS
Springs																							
(B-11-5)3cac-S1	7-14-70	17.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	765	-	-	GS
12cca-S1	7-14-70	17.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	631	-	-	GS
21-23-S3/	10- -62	-	13	-	36	5	47	-	-	-	22	75	-	-	0.06	112	-	382	-	-	1.9	8.1	IN
21-23-S3/	11- -62	-	17	-	53	11	73	-	-	-	42	119	-	-	.19	176	-	526	-	-	2.4	8.3	IN
(B-11-6)24ddb-S1	8-11-70	-	-	-	101	19	71	-	187	0	-	190	-	-	-	330	177	-		1,010	-	8.0	GS
(B-12-5)11cdd-S1	7-14-70	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	858	-	-	GS
14baa-S1	7-14-70	17.0	-	-	79	15	90	-	243	4	-	140	-	-	-	257	51	543	-	909	2.5	8.5	GS
14ccc-S1	7-14-70	18.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	798	-	-	GS
22dac-S1	7-14-70	20.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	889	-	-	GS
(B-12-6)33dba-S1	7-14-70	20.5	-	-	81	12	54	-	250	0	-	100	-	-	-	252	46	477	-	751	1.5	8.2	GS
(B-13-5)29-S	1913	-	-	-	1/75	-	630	C	240	0	40	840	-	-	-	185	-	1,600	-	-	20	-	GS
29-S	9-10-64	26.5	-	-	83	24	540	32	268	-	68	886	-	-	.2	306	-	-	1,923	3,580	13	8.0	SU
29-S	7- 7-70	28.0	19	-	56	24	636	22	329	0	84	895	0.4	1.0	.22	238	0	2,010	1,900	3,410	18	7.9	GS
Blue Creek [at location (B-10-5)5bab]																							
Discharge (cfs)																							
-	6-29-59	17.5	19	-	112	68	1,810	C	538	20	426	2,530	-	10	8.1	560	86	-	5,270	8,640	33	8.4	GS
5.0	9-30-59	12.0	26	0.04	98	36	941	34	350	16	202	1,380	2.0	1.7	.40	392	79	-	2,910	5,130	21	8.5	GS
3.1	4-19-60	12.0	26	.04	128	72	1,430	41	397	24	372	2,150	-	1.7	.55	615	250	-	4,440	7,710	25	8.5	GS
-	4- 6-61	6.0	21	.03	184	126	2,540	65	552	0	716	3,740	-	12	-	978	526	-	7,700	12,400	35	8.0	GS
4.2	10-16-63	15.0	-	-	-	-	-	-	-	-	350	2,200	-	-	-	510	-	4,220	-	7,170	-	-	GS
4/10	3-19-64	-	-	-	-	-	-	-	-	-	434	2,200	-	-	-	595	-	4,670	-	7,430	-	-	GS
11.0	4-10-64	7.0	-	-	-	-	-	-	-	-	354	1,950	-	-	-	510	-	3,850	-	6,400	-	-	GS
9.0	4-24-64	7.0	-	-	-	-	-	-	-	-	400	2,300	-	-	-	600	-	4,670	-	7,550	-	-	GS
17.8	5- 7-64	7.0	-	-	-	-	-	-	-	-	362	1,900	-	-	-	430	-	3,820	-	6,400	-	-	GS
2.5	6-11-64	13.5	26	-	136	96	2,330	-	628	-	612	3,290	-	4.7	-	735	220	6,740	-	10,800	-	8.1	GS
4/.1	9-15-64	-	-	-	-	-	-	-	-	-	395	2,440	-	-	-	454	-	4,920	-	8,140	-	-	GS
6.8	2-19-70	-	22	-	160	107	2,110	C	592	0	570	3,080	-	.6	-	840	355	6,540	6,340	10,100	32	7.8	GS
1.1	3-18-70	2.5	23	-	140	95	2,080	-	579	0	626	3,080	-	.2	-	740	265	6,560	6,330	10,100	33	8.1	GS
1.7	4-14-70	7.0	23	-	124	75	1,640	-	498	0	392	2,480	-	.0	-	620	212	5,140	4,980	8,330	29	8.1	GS
7.0	5-14-70	18.0	-	-	-	-	-	-	-	-	-	3,280	-	-	-	-	-	-	-	10,500	-	-	GS
4/.3	9- 1-70	18.5	-	-	-	-	-	-	-	-	-	2,350	-	-	-	-	-	-	-	7,980	-	-	GS

1/ Calcium plus magnesium. 2/ Some CO_3 included as HCO_3. 3/ Composite sample from 12 springs (Railroad Springs). 4/ Estimated.

PUBLICATIONS OF THE UTAH DEPARTMENT OF NATURAL RESOURCES, DIVISION OF WATER RIGHTS

(*)—Out of Print

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No. 2. The Ogden Valley artesian reservoir, Weber County, Utah, by H. E. Thomas, U. S. Geological Survey, 1945.

*No. 3. Ground water in Pavant Valley, Millard County, Utah, by P. E. Dennis, G. B. Maxey, and H. E. Thomas, U. S. Geological Survey, 1946.

*No. 4. Ground water in Tooele Valley, Tooele County, Utah, by H. E. Thomas, U. S. Geological Survey, in Utah State Eng. 25th Bienn. Rept., p. 91-238, pls. 1-6, 1946.

*No. 5. Ground water in the East Shore area, Utah: Part I, Bountiful District, Davis County, Utah, by H. E. Thomas and W. B. Nelson, U. S. Geological Survey, in Utah State Eng. 26th Bienn. Rept., p. 53-206, pls. 1-2, 1948.

*No. 6. Ground water in the Escalante Valley, Beaver, Iron, and Washington Counties, Utah, by P. F. Fix, W. B. Nelson, B. E. Lofgren, and R. G. Butler, U. S. Geological Survey, in Utah State Eng. 27th Bienn. Rept., p. 107-210, pls. 1-10, 1950.

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*No. 8. Consumptive use of water and irrigation requirements of crops in Utah, by C. O. Roskelly and Wayne D. Criddle, 1952.

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*No. 13. Ground-water resources of selected basins in southwestern Utah, by G. W. Sandberg, U. S. Geological Survey, 1966.

*No. 14. Water-resources appraisal of the Snake Valley area, Utah and Nevada, by J. W. Hood and F. E. Rush, U. S. Geological Survey, 1966.

No. 33. Hydrologic reconnaissance of Hansel Valley and northern Rozel Flat, Box Elder County, Utah, by J.W. Hood, U.S. Geological Survey, 1971.

No. 34. Summary of water resources of Salt Lake County, Utah, by Allen G. Hely, R.W. Mower, and C. Albert Harr, U.S. Geological Survey, 1971.

No. 35. Ground-water conditions in the East Shore area, Box Elder, Davis, and Weber Counties, Utah, 1960-69, by E.L. Bolke and K.M. Waddell, U.S. Geological Survey, 1972.

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No. 2. Ground water in Tooele Valley, Utah, by J. S. Gates and O. A. Keller, U. S. Geological Survey, 1970.

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*No. 1. Records and water-level measurements of selected wells and chemical analyses of ground water, East Shore area, Davis, Weber, and Box Elder Counties, Utah, by R. E. Smith, U. S. Geological Survey, 1961.

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*No. 3. Ground water data, central Sevier Valley, parts of Sanpete, Sevier, and Piute Counties, Utah, by C. H. Carpenter and R. A. Young, U. S. Geological Survey, 1963.

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*No. 6. Work outline and report outline for Sevier River basin survey, (Sec. 6, P.L. 566), U. S. Department of Agriculture, 1961.

No. 7. Relation of the deep and shallow artesian aquifers near Lynndyl, Utah, by R. W. Mower, U. S. Geological Survey, 1961.

*No. 8. Projected 1975 municipal water-use requirements, Davis County, Utah, by Utah State Engineer's Office, 1962.

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No. 11. Amendments to plan of work and work outline for the Sevier River basin (Sec. 6, P.L. 566), U. S. Department of Agriculture, 1964.

*No. 12. Test drilling in the upper Sevier River drainage basin, Garfield and Piute Counties, Utah, by R. D. Feltis and G. B. Robinson, Jr., U. S. Geological Survey, 1963.

*No. 13. Water requirements of lower Jordan River, Utah, by Karl Harris, Irrigation Engineer, Agricultural Research Service, Phoenix, Arizona, prepared under informal cooperation approved by Mr. William W. Donnan, Chief, Southwest Branch (Riverside, California) Soil and Water Conservation Research Division, Agricultural Research Service, U.S.D.A., and by Wayne D. Criddle, State Engineer, State of Utah, Salt Lake City, Utah, 1964.

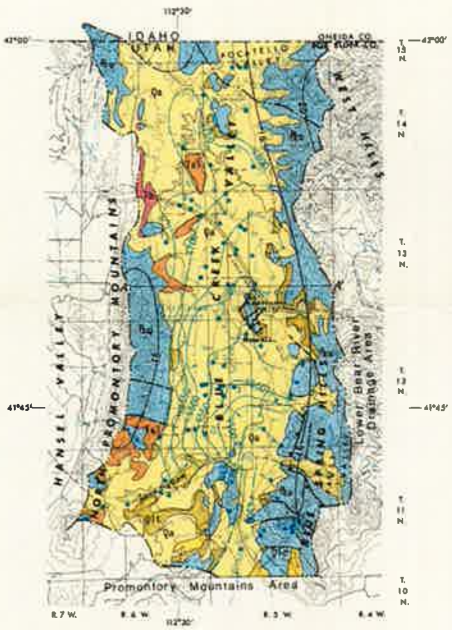
*No. 14. Consumptive use of water by native vegetation and irrigated crops in the Virgin River area of Utah, by Wayne D. Criddle, Jay M. Bagley, R. Keith Higginson, and David W. Hendricks, through cooperation of Utah Agricultural Experiment Station, Agricultural Research Service, Soil and Water Conservation Branch, Western Soil and Water Management Section, Utah Water and Power Board, and Utah State Engineer, Salt Lake City, Utah, 1964.

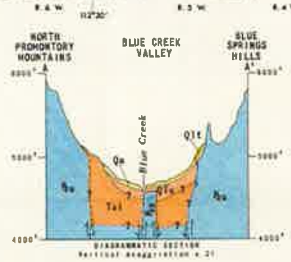
*No. 15. Ground-water conditions and related water-administration problems in Cedar City Valley, Iron County, Utah, February, 1966, by Jack A. Barnett and Francis T. Mayo, Utah State Engineer's Office.

*No. 16. Summary of water well drilling activities in Utah, 1960 through 1965, compiled by Utah State Engineer's Office, 1966.

No. 17. Bibliography of U. S. Geological Survey Water Resources Reports for Utah, compiled by Olive A. Keller, U. S. Geological Survey, 1966.

No. 18. The effect of pumping large-discharge wells on the ground-water reservoir in southern Utah Valley, Utah County, Utah, by R. M. Cordova and R. W. Mower, U. S. Geological Survey 1967.





Generalized hydrogeology

EXPLANATION

GEOLOGY
(See table 1)

Cenozoic

QUATERNARY

Qa — Surficial alluvial deposits
Mostly clay and silt; some gravel and scattered boulders; generally transmit water slowly

Qlb — Lake-bottom deposits
Mostly clay and silt; some very fine sand; transmit water slowly

Qlt — Lakeshore deposits
Sand and gravel in spits, bars, and on terraces; transmit water readily

TERTIARY and QUATERNARY

Valley-fill deposits
Not exposed, but underlie mapped Quaternary units in much of the area. Mostly clay or clay mixed with sand and gravel strata which yield water readily

TERTIARY

Extrusive igneous rocks
Layered basaltic lava flows with some local associated tuff deposits; inter flow zones transmit water readily

Salt Lake Formation
Mostly tuffaceous sandstone; some limestone, conglomerate, and volcanic debris; generally transmits water slowly, but some loosely cemented zones transmit water readily

Paleozoic

MISSISSIPPIAN to PERMIAN

Ps — Sedimentary and metasedimentary rocks undivided
Mostly limestone; some sandstone, quartzite, and shale; generally transmit water slowly, but interconnected fracture zones and solution cavities transmit water readily

Approximate contact
Dashed where inferred

Fault
Dashed where concealed, dotted where inferred

Thrust fault
Barbs on side of thrust sheet

A———A'
Line of diagrammatic section

HYDROLOGY

——20——
Line of equal normal annual precipitation
Interval 4 inches

——4300——
Water-level contour
Shows altitude of water level; dashed where approximately located; contour interval 50 feet; datum is mean sea level; arrows denote direction of ground-water movement

Spring
Number by spring symbol indicates number of springs shown in the same location

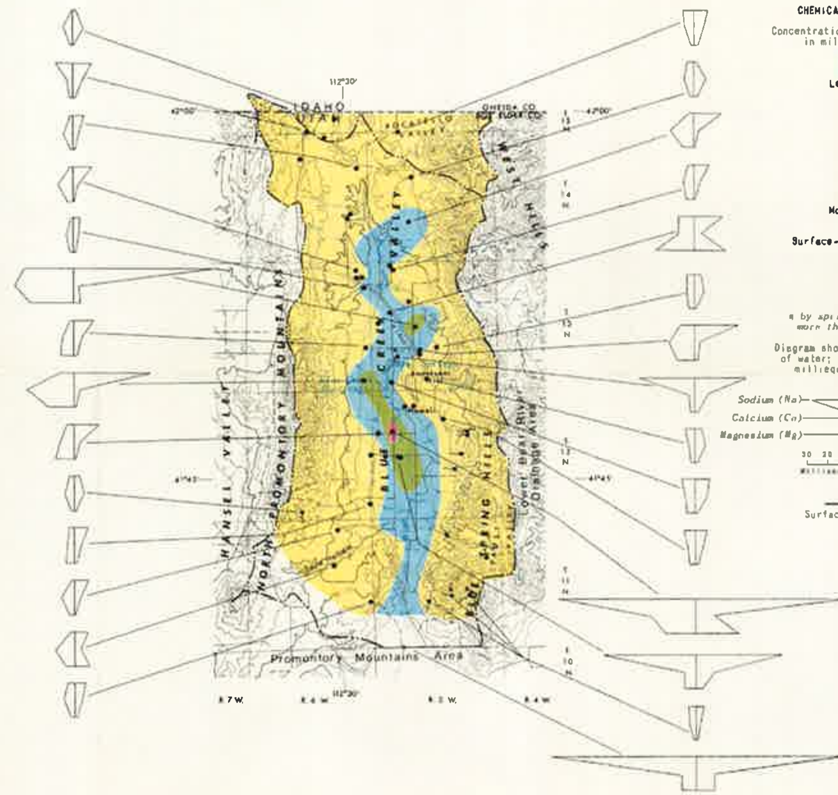
Well
Open circle indicates well used for water-level control; number by symbol indicates number of wells shown in the same location

Miscellaneous stream discharge measuring site

Partial-record gaging station

Surface-drainage divide

Hydrogeology by E. L. Bolke and Don Price, 1970. Geology adapted from Stokes (1964). Climatologic data from U.S. Weather Bureau, 1963



Chemical quality of water and location of sampling sites

EXPLANATION

CHEMICAL QUALITY OF WATER

Concentration of dissolved solids, in milligrams per liter

Less than 1000

1000-3000

3000-6000

More than 6000

Surface-water sampling site

Well

Spring
a by spring symbol indicates more than one spring area

Diagram showing chemical analyses of water; constituents given in milliequivalents per liter

Sodium (Na) — Chloride (Cl)
Calcium (Ca) — Bicarbonate (HCO_3)
Magnesium (Mg) — Sulfate (SO_4)

30 20 10 0 10 20 30
Milliequivalents per liter

Surface drainage divide

Compiled by E. L. Bolke and Don Price 1970

Base from U.S. Geological Survey Pocatello and Brigham City, 1954

0 5 MILES
CONTOUR INTERVAL 200 FEET
DATUM IS MEAN SEA LEVEL

HYDROGEOLOGIC MAPS OF THE BLUE CREEK VALLEY AREA, BOX ELDER COUNTY, UTAH

APPENDIX B

BLUE CREEK SITE-SPECIFIC STANDARD FOR TOTAL DISSOLVED SOLIDS (TDS) CRITERION MONITORING REPORT, ATK LAUNCH SYSTEMS PROMONTORY, JULY 11, 2013

,

ATK

July 11, 2013
8200-FY14-033

Mr. Walter L Baker, Director
Division of Water Quality
Utah Department of Environmental Quality
195 N. 1950 W.
P.O. Box 144870
Salt Lake City, Utah 84114-4870

RECEIVED
JUL 12 2013
PE
Utah Division of Water Quality

Attention: Chris Bittner

Re: ATK Launch Systems-Promontory UPDES Permit #0024805, Blue Creek Site-Specific Standard for Total Dissolved Solids (TDS) Criterion Monitoring Report

Dear Mr. Baker:

In June 2011 ATK Launch Systems Inc. ("ATK") submitted a work plan for the development of a new site-specific TDS standard for Blue Creek. ATK, in cooperation with Chris Bittner of your staff, has completed the monitoring and data collection outlined in the work plan. Enclosed are the monitoring results and data from the sampling that was collected.

ATK appreciates the opportunity to work with the Division in the development of this new stream criterion for Blue Creek.

Please contact me if you have any questions concerning this report. My telephone number is (435)863-2018 or you can contact Blair Palmer at (435)863-2430.

Sincerely

Document Date 7/12/2013 PE
DWQ-2013-004794

George Gooch

George E. Gooch, Manager
Environmental Services

1.0 Introduction

In June 2011 ATK Launch Systems Inc. submitted a work plan for use in the development of a site-specific criterion for Total Dissolved Solids (TDS) on a stream segment of Blue Creek. The stream segment of Blue Creek begins at 41°43'20.40" N, 112°26'33.58" W a location on the northern boundary of ATK's facility along Highway 83 that ATK identifies as Blue Creek Upper with the stream segment ending at the Great Salt Lake. ATK currently has two wastewater treatment discharges along this stream segment under UPDES Permit #UT0024805. (See Figures 1 & 2, Goggle Earth image) The objective of this monitoring report is to assist in the establishment of a site specific standard for the stream segment of Blue Creek from the Blue Creek Reservoir Dam flowing southward to the Great Salt Lake.

2.0 Background

Blue Creek originates approximately 8 miles north of the ATK Facility from Blue Springs. Blue Springs is a warm springs that has a TDS concentration of 2000 mg/L. The primary constituents of the TDS are sodium, chloride, and sulfate which are naturally found in the soils throughout the valley. These soils were generated from localized deposits from the ancient lake Bonneville. It is likely the source feeding the warms springs circulates slowly through these fine-grained sediments allowing these soluble minerals to leach into the groundwater.

The Blue Creek Reservoir Dam was constructed in 1904 and modified, enlarged and repaired in 1949, 1967 and 1986. The current capacity of the reservoir is about 2,185 acre-feet (UDWR, 2001). Water from Blue Springs is stored in the reservoir during the winter months and used for agricultural irrigation during the spring through fall season. The water in the reservoir is distributed by canals owned by the Blue Creek Irrigation Company. The two main canals, the East Canal and the West Canal, are used to irrigate a portion of the valley north of ATK's facility (Bolke and Price, 1972).

Several saline springs feed the main channel of Blue Creek once it leaves the Blue Creek Reservoir. These springs are the major source of flow in Blue Creek during most of the year as it passes through the ATK facility.

Prior to 1975, the stream segment of Blue Creek from the irrigation dam flowing southward was an intermittent stream only flowing significantly after rainfall events and snow melts. As a result of an earthquake in March 1975, Blue Creek became a perennial stream with year round flow resulting from the springs located below the Blue Creek Reservoir Dam.

3.0 Sampling and Investigation

The sampling and investigation was focused on determining the natural and unaltered TDS concentration for the stream segment of Blue Creek beginning at the Blue Creek Reservoir Dam flowing south to Blue Creek Upper (north boundary of ATK property, Hwy 83). This flow is predominantly made up of the springs below the dam.

ATK sampled each site identified below, once a month. During periods of transition, i.e. when conditions changed at the reservoir such as water being discharged or not discharged from the dam to Blue Creek or the irrigation channels, sampling was conducted once a week for a three week period.

- Blue Creek Reservoir below the dam;
- Blue Creek at crossing 14400 N; and
- Blue Creek Upper (north boundary of ATK property, Hwy 83).

These sites are illustrated in Figure 3 (Goggle Earth image), and are all north of the ATK facility.

The samples collected from these sites were analyzed for:

- Metals, Method 200.7 to include, Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Sn, Ti, Tl, V, Zn, Sr;
- Mercury Method 245.1;
- Total Dissolved Solids (TDS), Method 160.1; and
- Anions, Method 300 IC to include, Fluoride, Chloride, Nitrite-N, Bromide, Nitrate-N, Orthophosphate-P, Sulfate.
- Flow (gallons/minute)

During each sampling event, a visual investigation was conducted to verify if water discharged from the Blue Creek Reservoir Dam was flowing into either of the irrigation canals or if it is being discharged directly to Blue Creek.

Sampling these sites and conducting the visual investigations allowed the development of two datasets:

- When water is being discharged from the Blue Creek Reservoir Dam into the main channel of Blue Creek thereby, lowering the TDS level of Blue Creek by dilution; and
- Periods when water is being discharged from the Blue Creek Reservoir into irrigation canals with no flow going to Blue Creek, which is intended to represent natural conditions that predominate most of the year. This would represent the flow and TDS level in the main channel of Blue Creek that result from springs or seeps that occur below the reservoir dam southward.

The development of these datasets will help characterize different flow conditions, as well as allowing the coordination of the sampling and analytical results with the flow conditions.

In addition to collecting samples, a velocity meter was used to measure the average flow velocity of Blue Creek at each sample site. The water depth was measured and used to determine a cross sectional area of the channel at each site providing an estimate for flow in gallons per minute. The flow measurements were used to determine if TDS concentrations correlated with the changing flows over the course of a year.

Field electrical conductivity measurements were also taken from several sources that flow to Blue Creek during a multi-day sampling event. These sources originate from springs and seeps in the property adjacent to Blue Creek as it flows from the reservoir below the dam to the Blue Creek Upper (north boundary of ATK property, Hwy 83) site (see figures 4 & 5). These electrical conductivity measurements were then correlated to calculate TDS concentrations and can be seen in Table 1.

4.0 Sampling Results

Sampling and visual investigations began April 14, 2011 and have been completed monthly for the past two years. The TDS concentrations of each sampling event have been collected over the course of that time and can be found in Table 2. This data has been plotted in Figure 6 to illustrate seasonal trends in concentrations.

Figure 6 shows the plotted results of the TDS concentrations for each of the sampling sites along with correlating flow measurements. The chart has been color coded to distinguish the two datasets listed on the previous page. The time period where Blue Creek was receiving additional flow from the dam is highlighted in blue. The time period when Blue Creek receives no flow from the dam is highlighted in yellow.

Concentrations have also been color coded to match the measured flow for each site to help decipher which concentration belongs to which flow reading. It can be seen that the flow in Blue Creek does not correlate with the TDS concentrations measured at each site along the stream. TDS concentrations below the dam remain consistent at around 2,000 mg/L while the Upper site and Crossing site show a greater deviation in concentrations and continuously fluctuate over the course of a year, however, they do show TDS levels increase due to the influence of the high TDS springs.

The variation in TDS concentrations and lack of correlation with flow data is most likely the combination of seasonal weather patterns and upstream irrigation practices. Due to the ever changing dynamics of the stream it is difficult to distinguish a specific dataset that would be considered the “natural and unaltered” state for the entire length of Blue Creek. As a result, the focus of the investigation has been directed toward determining the 95% Upper Tolerance Limit (UTL) based on data collected from the Blue Creek Upper site.

ProUCL 4.1 was used to calculate the 95% UTL of 5,918 mg/L for the Blue Creek Upper dataset found in column 4 of Table 2. The same method was used to calculate a second 95% UTL for historical data previously collected each quarter at the Upper site from year 2000 to year 2010. The results from the historical data showed a 95% UTL of 6,123 mg/L. Both levels are much higher than the current standard of 1,200 mg/L set for Blue Creek.

Electrical conductivity measurements taken from several sources that discharge to Blue Creek are identified in Figures 4 and 5 along with Table 1. The conductivity measurements show that those sources have higher levels of TDS than the average concentrations measured at the Upper site. This demonstrates that the high levels of TDS measured in Blue Creek are a result of naturally occurring saline springs that contribute to the TDS loading after the dam and prior to entering ATK property.

The high TDS levels seen in the upstream sources are consistent with concentrations found in groundwater wells and other springs in the area. Historical groundwater monitoring data shows TDS concentrations in wells located in the valley near Blue Creek range from 2,800 mg/L to 8,800 mg/L. Samples taken from nearby springs have TDS concentrations ranging from 4,500 mg/L to 7,170 mg/L. Therefore, it can be seen that the groundwater feeding the springs contributing to the flow of Blue Creek is naturally high in TDS.

5.0 Summary and Conclusions

The objective of this monitoring report is to assist in the establishment of a site specific standard for the stream segment of Blue Creek from the Blue Creek Reservoir Dam flowing southward to the Great Salt Lake. Through the sampling and investigation that was conducted, TDS concentrations, and the concentrations of the individual water constituents that contribute to the Blue Creek TDS have been sampled and monitored along with the different stream flow conditions that occur in Blue Creek. This information will allow a site-specific standard for TDS in Blue Creek to be established that represents the natural and unaltered TDS concentration that is protective of current uses.

ATK believes that the sampling and monitoring that has been completed is sufficient to allow the establishment of a site specific standard for the TDS in Blue Creek. The 95% upper tolerance limits for data from the time period of 2011-2013 and 2000-2010 are 5,918 mg/L and 6,123 mg/L respectively.

Figure 1. Point of Proposed Site Specific Standard for Blue Creek

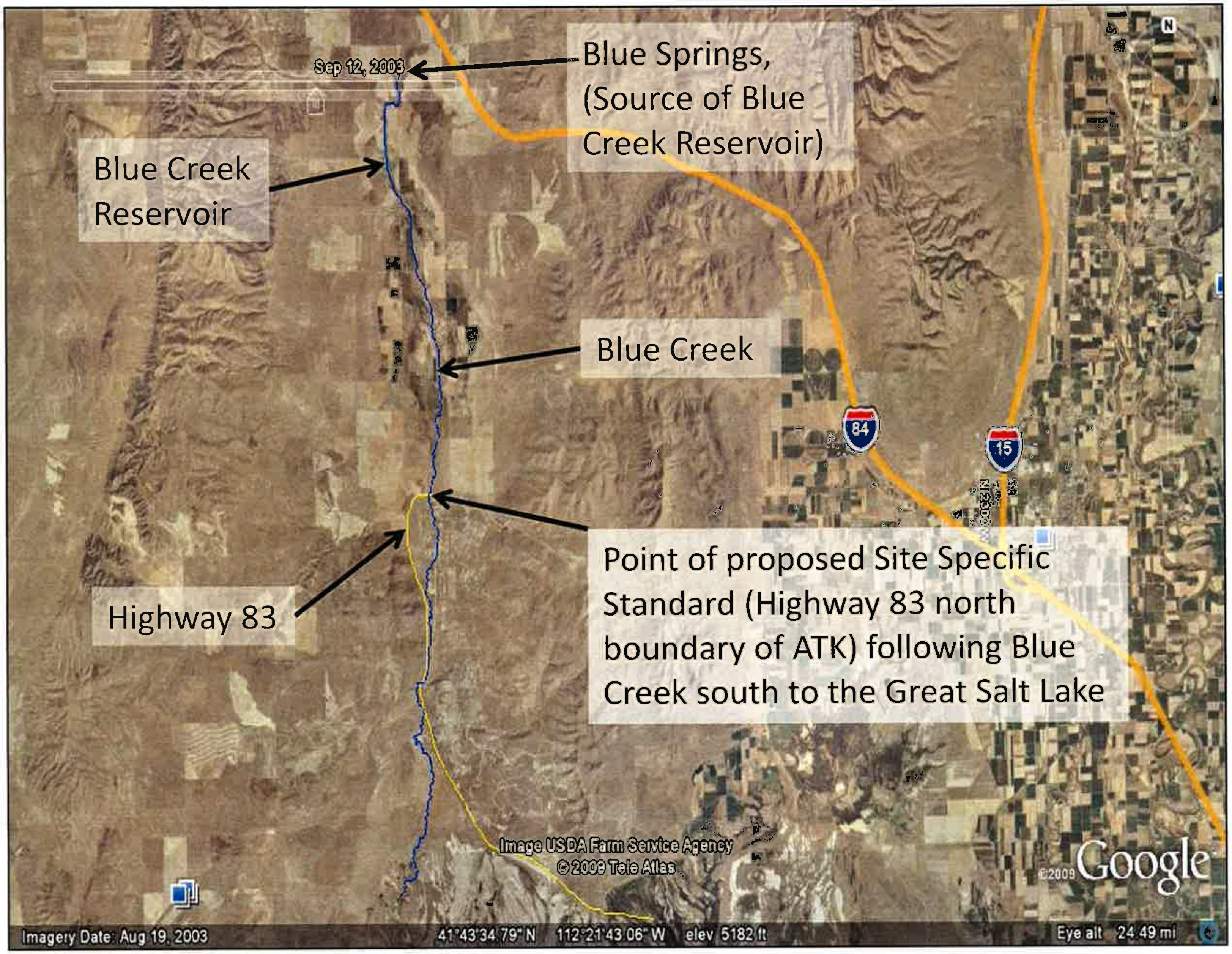


Figure 2. ATK Outfall Locations

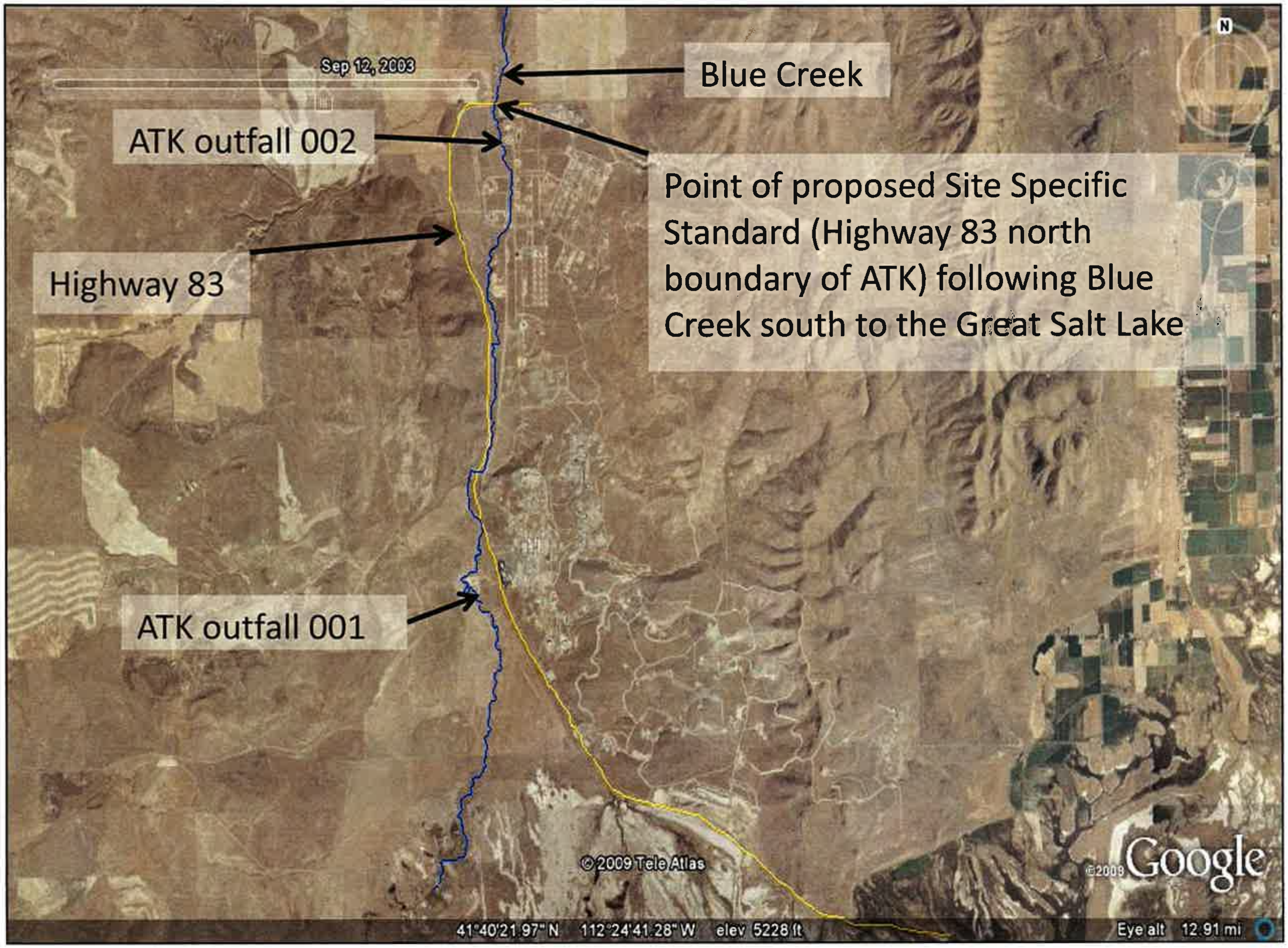


Figure 3. Blue Creek Source and Sample Sites

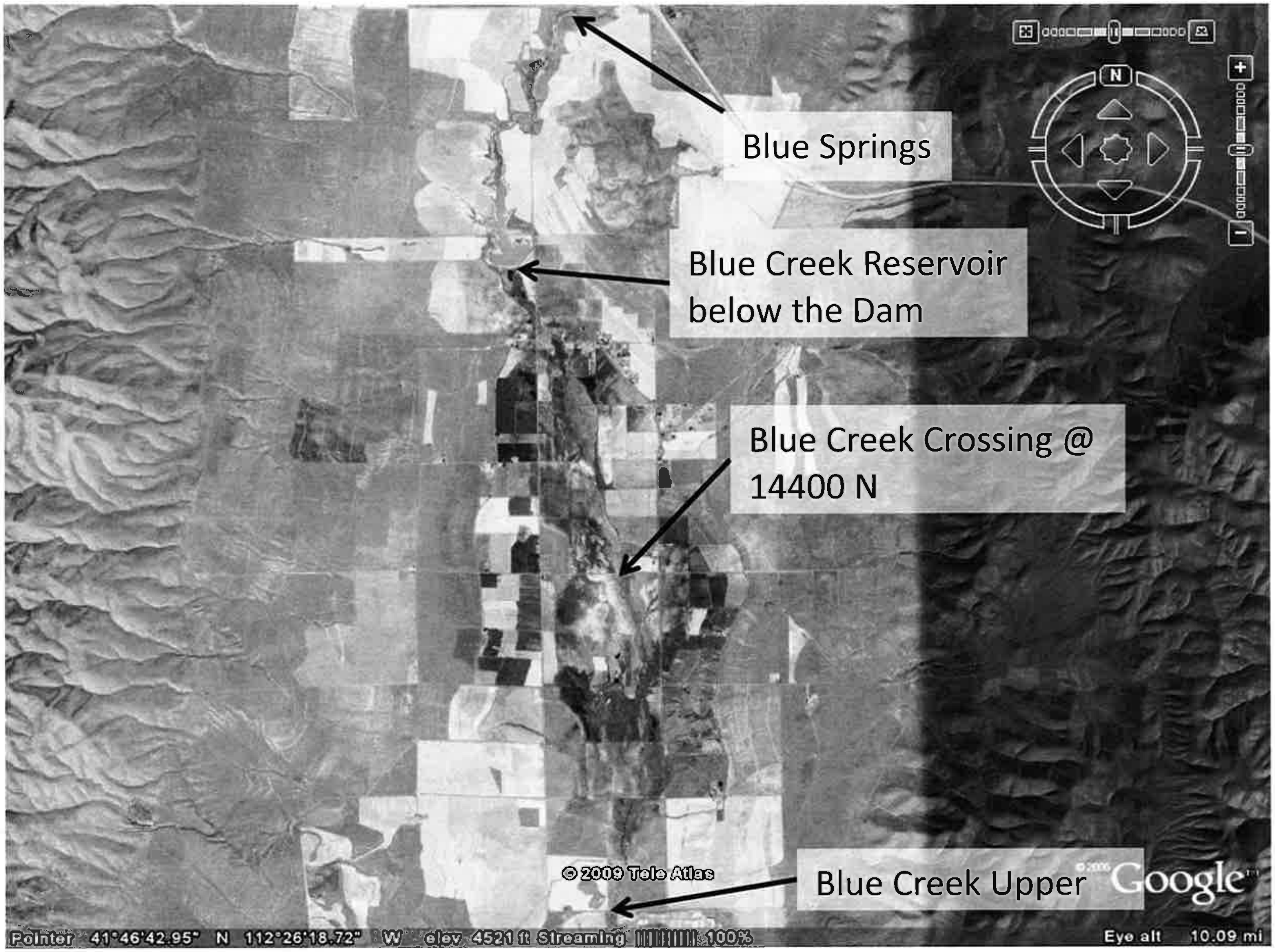


Figure 4. Conductivity Sample Sites of Blue Creek Sources

Figure 5. Conductivity Sample Sites of Blue Creek Sources (Continued)

Table 1. Conductivity Sample Site Descriptions and Concentrations

Sample Point	Site Description	Concentration (mg/L)	Sample Point	Site Description	Concentration (mg/L)
1	Below Dam	2,260	13	Cornwall Blue Creek	4,290
2	Blue Creek at Diversion	2,340	14	Cornwall 4	5,950
3	Sorensen 1	3,170	15	Cornwall 3	4,960
4	Irrigation (no sample)	-	16	Snowmelt	-
5	Sorensen 4	2,900	17	Douglass 2	5,050
6	Sorensen 3	5,690	18	Douglass 3.5	28,200
7	Odel 2	3,770	19	Douglass 3	31,300
8	Odel 1	3,840	20	Douglass 1	9,390
9	Blue Creek Crossing	9,320	21	Cornwall 2	4,930
10	Odel 3	448	22	Cornwall 1	4,800
11	Cornwall Pond	6,320	23	East Culvert	4,350
12	Odell's Discharge	6,330			

Table 2. TDS Concentrations from Blue Creek Study (mg/L)

Sample Date	Below Dam	Crossing	Upper
4-14-2011	1,890	3,350	5,270
5-26-2011	1,920	2,600	2,260
6-8-2011	1,910	3,370	3,930
7-26-2011	2,090	2,820	3,380
8-16-2011	1,990	3,310	3,230
9-29-2011	1,980	3,220	3,780
10-21-2011	1,960	4,020	4,260
11-17-2011	2,030	4,160	3,380
12-20-2011	2,080	3,740	4,850
1-27-2012	2,070	3,140	4,570
2-1-2012	2,020	3,140	4,550
2-9-2012	2,040	2,900	4,210
2-16-2012	2,030	3,310	4,890
3-19-2012	1,940	2,470	4,160
4-16-2012	2,070	5,060	6,270
4-23-2012	1,910	3,490	4,710
4-30-2012	1,990	3,410	4,730
5-7-2012	1,990	3,650	4,350
6-4-2012	1,990	2,930	3,720
7-10-2012	2,060	3,040	4,230
8-8-2012	2,110	3,220	2,980
9-5-2012	2,100	3,780	4,140
10-5-2012	2,050	3,120	3,760
11-5-2012	1,990	3,510	3,620
12-6-2012	1,920	4,670	5,630
1-14-2013	2,020	2,840	4,210
1-22-2013	2,100	2,810	4,050
1-30-2013	2,009	2,870	4,180
2-7-2013	2,009	2,640	5,170
3-4-2013	2,009	2,870	5,370
4-1-2013	1,990	2,980	4,260
5-7-2013	1,970	3,080	4,250
Average	2,009	3,298	4,261
95% UTL	2,115	4,315	5,918

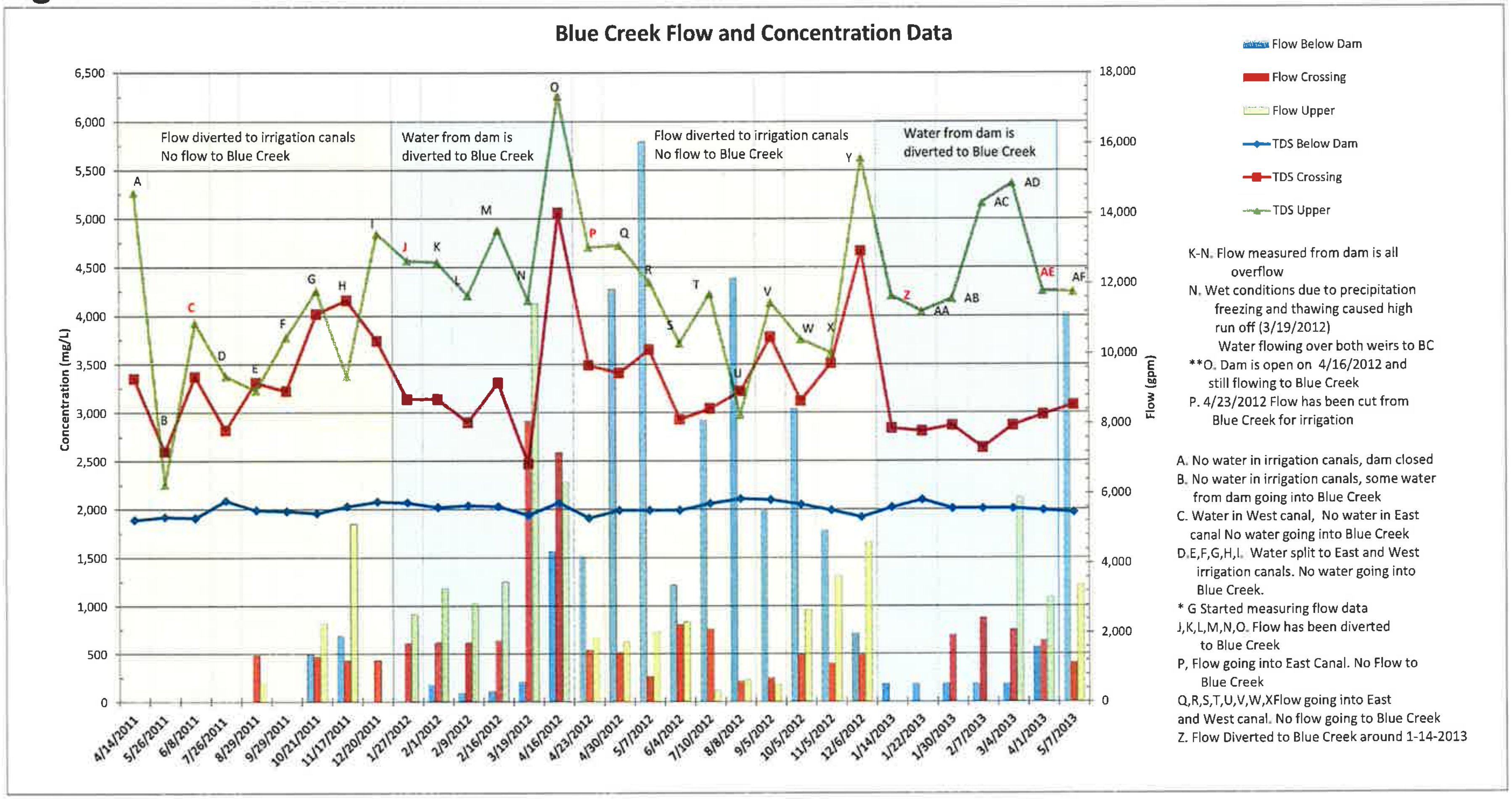
Table 3. ProUCL Results for 2010-2013 Upper Site Concentrations

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Coverage	90%
Different or Future K Values	1
Number of Bootstrap Operations	2,000
Log-Transformed Statistics	
Number of Valid Observations	32
Number of Distinct Observations	29
Minimum	7.723
Maximum	8.744
Second Largest	8.636
Mean	8.339
First Quartile	8.236
Median	8.348
Third Quartile	8.459
SD	0.198
Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.959
5% Shapiro Wilk Critical Value	0.93
Background Statistics Assuming Lognormal Distribution	
90% Percentile (z)	5,395
95% Percentile (z)	5,797
99% Percentile (z)	6,636
95% UPL	5,887
Tolerance Factor K	1.75
95% UTL with 90% Coverage	**5,918**
Some Nonparametric Background Statistics	
95% Chebyshev UPL	7,814
95% Bootstrap BCA UTL with 90% Coverage	5,604
95% Percentile Bootstrap UTL with 90% Coverage	5,604

Table 4. ProUCL Results for 2000-2010 Upper Site Concentrations

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Coverage	90%
Different or Future K Values	1
Number of Bootstrap Operations	2000
Log-Transformed Statistics	
Number of Valid Observations	43
Number of Distinct Observations	40
Minimum	7.99
Maximum	8.753
Second Largest	8.723
Mean	8.341
First Quartile	8.162
Median	8.324
Third Quartile	8.5
SD	0.226
Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.938
5% Shapiro Wilk Critical Value	0.943
Background Statistics Assuming Lognormal Distribution	
90% Percentile (z)	5,604
95% Percentile (z)	6,084
99% Percentile (z)	7,098
95% UPL	6,162
Tolerance Factor K	1.67
95% UTL with 90% Coverage	**6,123**
Some Nonparametric Background Statistics	
95% Chebyshev UPL	8,690
95% Bootstrap BCA UTL with 90% Coverage	5,990
95% Percentile Bootstrap UTL with 90% Coverage	6,050

Figure 6.


Blue Creek Flow and Concentration Data
Concentration (mg/L)
Flow (gpm)
Flow diverted to irrigation canals
No flow to Blue Creek
Water from dam is
diverted to Blue Creek
Flow diverted to irrigation canals
No flow to Blue Creek
Water from dam is
diverted to Blue Creek
Flow Below Dam
Flow Crossing
Flow Upper
TDS Below Dam
TDS Crossing
TDS Upper
K-N. Flow measured from dam is all overflow
N. Wet conditions due to precipitation freezing and thawing caused high run off (3/19/2012)
Water flowing over both weirs to BC
**O. Dam is open on 4/16/2012 and still flowing to Blue Creek
P. 4/23/2012 Flow has been cut from Blue Creek for irrigation
A. No water in irrigation canals, dam closed
B. No water in irrigation canals, some water from dam going into Blue Creek
C. Water in West canal, No water in East canal No water going into Blue Creek
D,E,F,G,H,I. Water split to East and West irrigation canals. No water going into Blue Creek.
* G Started measuring flow data
J,K,L,M,N,O. Flow has been diverted to Blue Creek
P, Flow going into East Canal. No Flow to Blue Creek
Q,R,S,T,U,V,W,XFlow going into East and West canal. No flow going to Blue Creek
Z. Flow Diverted to Blue Creek around 1-14-2013

References

Bolke, E.L. and Price D. 1972. Hydrologic Reconnaissance of the Blue Creek Valley Area, Box Elder County, Utah. Utah Department of Natural Resources Technical Publication No. 37.

UDWR (Utah Division of Water Resources). 2001. Utah State Water Plan, West Desert Basin, Salt Lake City, Utah. 3-17p.

APPENDIX C

GOODNESS OF FIT STATISTICS

- Blue Creek Below Dam
- Blue Creek Crossing
- Blue Creek Upper
- Blue Creek Crossing and Blue Creek Upper Combined

Goodness-of-Fit Test Statistics for Full Data Sets without Non-Detects

From File	F:\Permits\ATK Blue Creek\WriteUp\Blue Creek ProUCL.xls.wst
Full Precision	OFF
Confidence Coefficient	0.95

Blue Creek Below Dam TDS (mg/l)

Raw Statistics	
Number of Valid Observations	29
Number of Missing Values	3
Number of Distinct Observations	18
Minimum	1890
Maximum	2110
Mean of Raw Data	2007
Standard Deviation of Raw Data	63.63
Kstar	920.8
Mean of Log Transformed Data	7.604
Standard Deviation of Log Transformed Data	0.0318

Normal Distribution Test Results

Correlation Coefficient R	0.985
Shapiro Wilk Test Statistic	0.954
Shapiro Wilk Critical (0.95) Value	0.926
Approximate Shapiro Wilk P Value	0.258
Lilliefors Test Statistic	0.124
Lilliefors Critical (0.95) Value	0.165

Data appear Normal at (0.05) Significance Level

Gamma Distribution Test Results

Correlation Coefficient R	0.982
A-D Test Statistic	0.406
A-D Critical (0.95) Value	0.742
K-S Test Statistic	0.122
K-S Critical(0.95) Value	0.162

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal Distribution Test Results

Correlation Coefficient R	0.984
Shapiro Wilk Test Statistic	0.953
Shapiro Wilk Critical (0.95) Value	0.926
Approximate Shapiro Wilk P Value	0.243
Lilliefors Test Statistic	0.118
Lilliefors Critical (0.95) Value	0.165

Data appear Lognormal at (0.05) Significance Level

Blue Creek Crossing TDS (mg/L)

Raw Statistics	
Number of Valid Observations	32
Number of Distinct Observations	28
Minimum	2470
Maximum	5060
Mean of Raw Data	3298
Standard Deviation of Raw Data	572.4
Kstar	34.52
Mean of Log Transformed Data	8.088
Standard Deviation of Log Transformed Data	0.161
Normal Distribution Test Results	
Correlation Coefficient R	0.944
Shapiro Wilk Test Statistic	0.898
Shapiro Wilk Critical (0.95) Value	0.93
Approximate Shapiro Wilk P Value	0.00543
Lilliefors Test Statistic	0.141
Lilliefors Critical (0.95) Value	0.157
Data not Normal at (0.05) Significance Level	
Gamma Distribution Test Results	
Correlation Coefficient R	0.964
A-D Test Statistic	0.628
A-D Critical (0.95) Value	0.745
K-S Test Statistic	0.115
K-S Critical(0.95) Value	0.155
Data appear Gamma Distributed at (0.05) Significance Level	
Lognormal Distribution Test Results	
Correlation Coefficient R	0.974
Shapiro Wilk Test Statistic	0.95
Shapiro Wilk Critical (0.95) Value	0.93
Approximate Shapiro Wilk P Value	0.175
Lilliefors Test Statistic	0.105
Lilliefors Critical (0.95) Value	0.157
Data appear Lognormal at (0.05) Significance Level	

Blue Creek Upper TDS (mg/L)

Raw Statistics	
Number of Valid Observations	32
Number of Distinct Observations	29
Minimum	2260
Maximum	6270
Mean of Raw Data	4261
Standard Deviation of Raw Data	802.7
Kstar	25.04
Mean of Log Transformed Data	8.339
Standard Deviation of Log Transformed Data	0.198
Normal Distribution Test Results	
Correlation Coefficient R	0.986
Shapiro Wilk Test Statistic	0.984
Shapiro Wilk Critical (0.95) Value	0.93
Approximate Shapiro Wilk P Value	0.917
Lilliefors Test Statistic	0.125
Lilliefors Critical (0.95) Value	0.157
Data appear Normal at (0.05) Significance Level	
Gamma Distribution Test Results	
Correlation Coefficient R	0.986
A-D Test Statistic	0.381
A-D Critical (0.95) Value	0.745
K-S Test Statistic	0.122
K-S Critical(0.95) Value	0.155
Data appear Gamma Distributed at (0.05) Significance Level	
Lognormal Distribution Test Results	
Correlation Coefficient R	0.971
Shapiro Wilk Test Statistic	0.959
Shapiro Wilk Critical (0.95) Value	0.93
Approximate Shapiro Wilk P Value	0.307
Lilliefors Test Statistic	0.135
Lilliefors Critical (0.95) Value	0.157
Data appear Lognormal at (0.05) Significance Level	

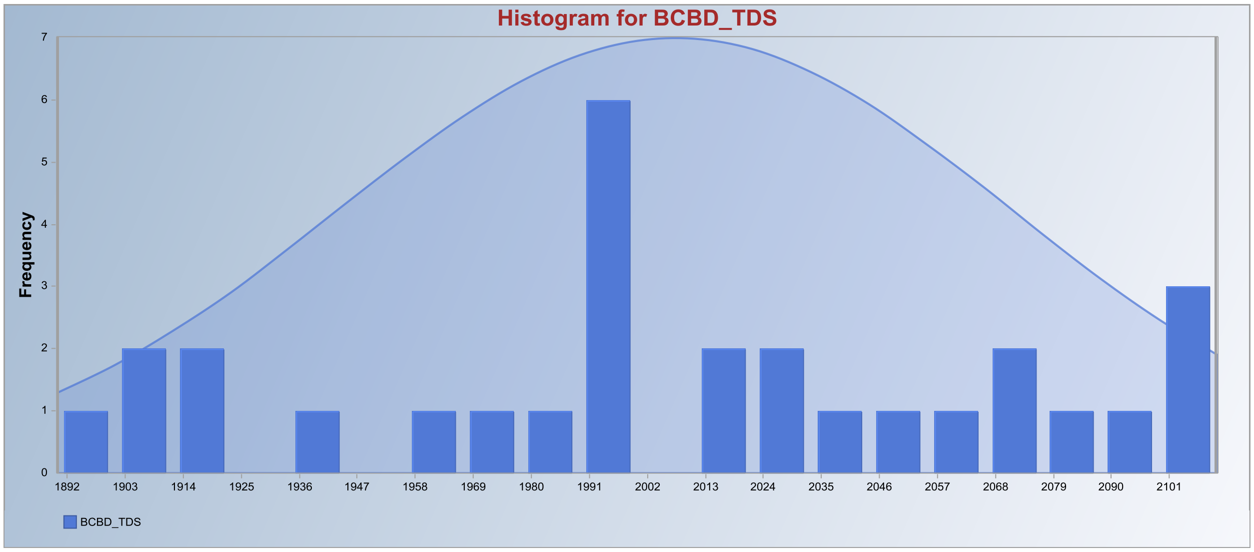
Blue Creek Crossing and Blue Creek Upper TDS (mg/l)

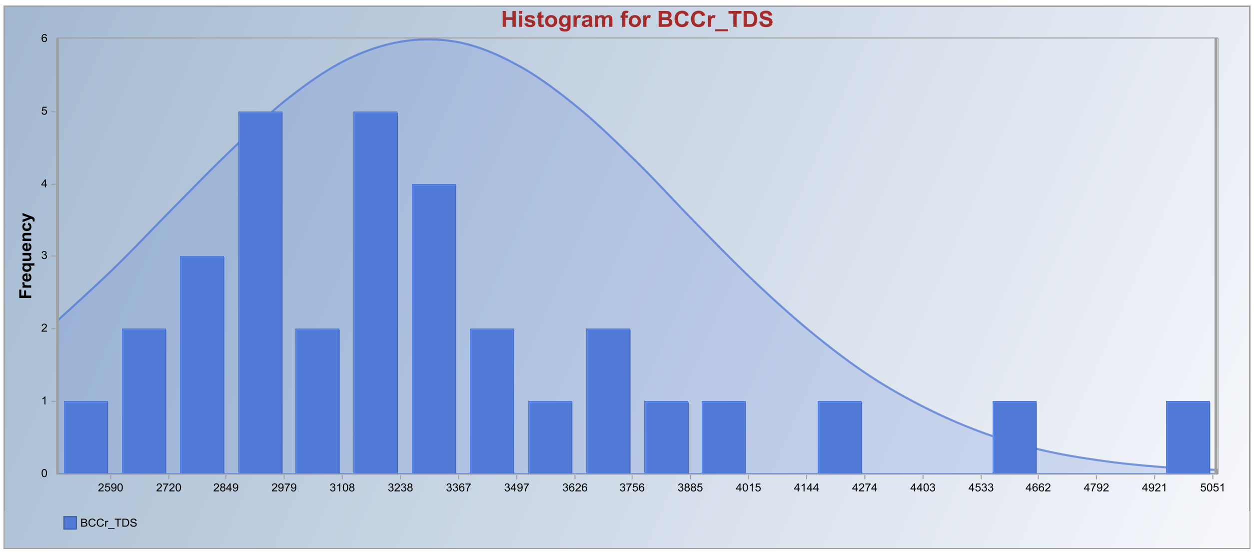
Raw Statistics	
Number of Valid Observations	64
Number of Distinct Observations	54
Minimum	2260
Maximum	6270
Mean of Raw Data	3779
Standard Deviation of Raw Data	845
Kstar	20.11
Mean of Log Transformed Data	8.213
Standard Deviation of Log Transformed Data	0.22
Normal Distribution Test Results	
Correlation Coefficient R	0.983
Approximate Shapiro Wilk Test Statistic	0.961
Approximate Shapiro Wilk P Value	0.0979
Lilliefors Test Statistic	0.106
Lilliefors Critical (0.95) Value	0.111
Data appear Normal at (0.05) Significance Level	
Gamma Distribution Test Results	
Correlation Coefficient R	0.994
A-D Test Statistic	0.402
A-D Critical (0.95) Value	0.749
K-S Test Statistic	0.0896
K-S Critical(0.95) Value	0.111
Data appear Gamma Distributed at (0.05) Significance Level	
Lognormal Distribution Test Results	
Correlation Coefficient R	0.995
Approximate Shapiro Wilk Test Statistic	0.982
Approximate Shapiro Wilk P Value	0.737
Lilliefors Test Statistic	0.0779
Lilliefors Critical (0.95) Value	0.111
Data appear Lognormal at (0.05) Significance Level	

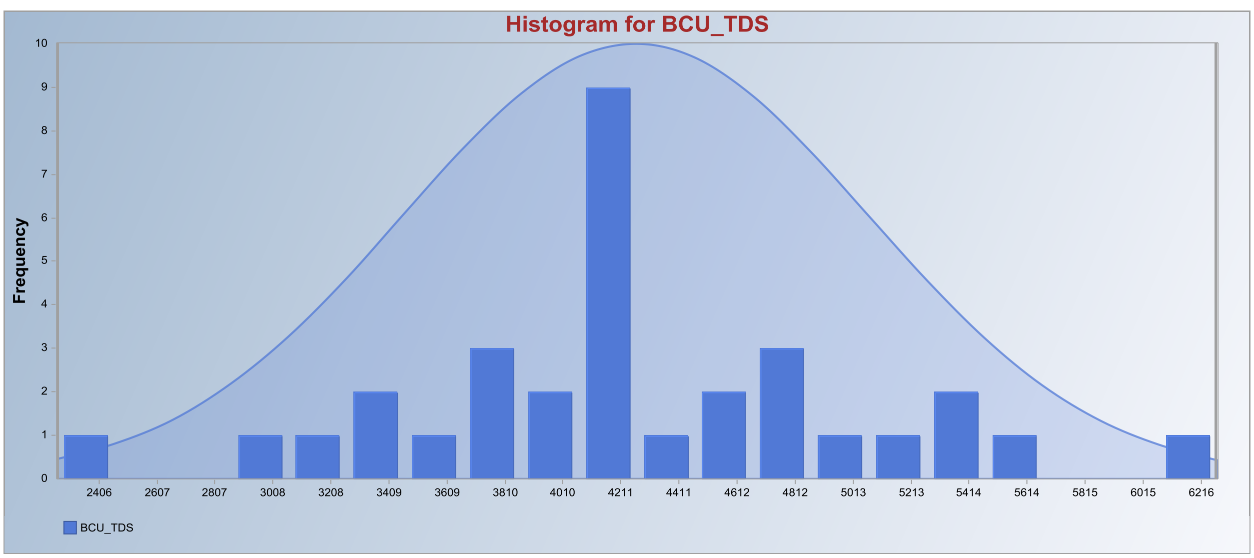
APPENDIX D

HISTOGRAMS

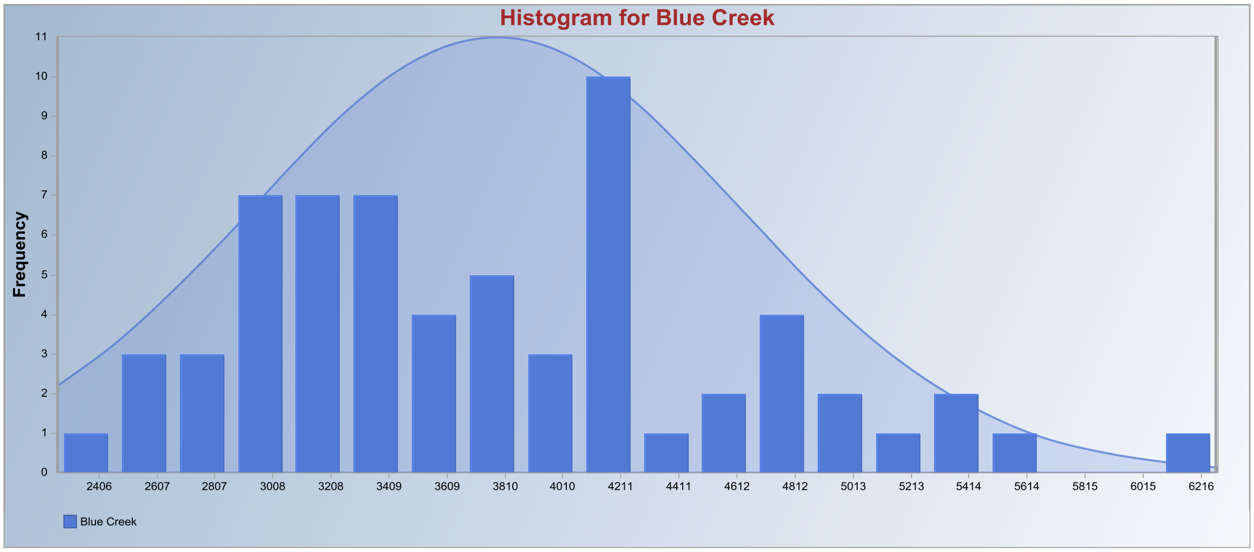
- Blue Creek Below Dam
- Blue Creek Crossing
- Blue Creek Upper
- Blue Creek Crossing and Blue Creek Upper Combined







TDS (mg/l) Histograms for Blue Creek-Below Dam, - Crossing, and - Upper Samples



TDS Histogram for Blue Creek-Crossing and -Upper Sites Combined

APPENDIX E

UTAH WATER RIGHTS DATABASE FOR BLUE CREEK

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-196** APPLICATION/CLAIM NO.: **A29767** CERT. NO.: 7733

==

OWNERSHIP

==

NAME: Merlin H. Larsen
ADDR: Promontory Route
      Corinne UT 84307

==

DATES, ETC.

==

LAND OWNED BY APPLICANT? COUNTY TAX ID#:
FILED: |PRIORITY: 03/11/1958|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [Approved]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: |LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-3]|MAP: [123a]|PUB DATE:

TYPE -- DOCUMENT -- STATUS---*

Type of Right: Application to Appropriate Source of Info: Proposed Determination Status: Certificate

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*****************

==

FLOW: 2.39 cfs SOURCE: Blue Creek
COUNTY: Box Elder COMMON DESCRIPTION:

POINTS OF DIVERSION -- SURFACE:
(1) S 2030 ft W 2310 ft from NE cor, Sec 07, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(2) S 3250 ft W 2530 ft from NE cor, Sec 07, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(3) S 4010 ft W 1040 ft from NE cor, Sec 07, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(4) S 5240 ft W 1700 ft from NE cor, Sec 07, T 10N, R 5W, SLBM

Diverting Works:
Source:
(5) N 30 ft W 700 ft from SE cor, Sec 18, T 10N, R 5W, SLBM
Diverting Works:
Source:
(6) S 1460 ft W 1650 ft from NE cor, Sec 18, T 10N, R 5W, SLBM
Diverting Works:
Source:

Stream Alt Required?: No
===

USES OF WATER RIGHT******** ***ELU -- Equivalent Livestock Unit (cow, horse, etc.)*** ******** ***EDU -- Equivalent Domestic Unit or 1 Family***
===

SUPPLEMENTAL GROUP NO.: 6272.

....
IRRIGATION: 349.0 acres
Div Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
....
###PLACE OF USE: *-------NORTH WEST QUARTER------*-------NORTH EAST QUARTER------*-------SOUTH WEST QUARTER------*-------SOUTH EAST QUARTER------* Section
* NW | NE | SW | SE * NW | NE | SW | SE * NW | NE | SW | SE * NW | NE | SW | SE * Totals
Sec 07 T 10N R 5W SLBM
*_______|_______|_______|_______*_______|_______|23.5000|11.0000*_______|_______|_______|_______*30.8000|12.1000|30.0000|26.8000* 134.2000
Sec 08 T 10N R 5W SLBM
*_______|_______|_______|_______*_______|_______|_______|_______*9.5000|_______|30.4000|_______*_______|_______|_______|_______* 39.9000
Sec 18 T 10N R 5W SLBM *_______|_______|_______|_______*6.3000|18.4000| 8.3000|21.8000*_______|_______|_______|13.6000*22.6000|31.3000|31.5000|21.1000* 174.9000

GROUP ACREAGE TOTAL: 349.0000
E N D O F D A T A*

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-2043** APPLICATION/CLAIM NO.: CERT. NO.:

===

OWNERSHIP*

===

NAME: Salt Wells Cattle Company, LLC
ADDR: 192 North Highland Blvd
Brigham UT 84302
INTEREST: 100% REMARKS:

===

DATES, ETC.*

===

LAND OWNED BY APPLICANT? COUNTY TAX ID#:
FILED: |PRIORITY: 00/00/1869|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 08/28/1967|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-3]|MAP: [108]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS---*'**

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

===

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*****************

===

FLOW: SOURCE: Blue Creek
COUNTY: Box Elder COMMON DESCRIPTION: Howell Valley

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point at S 660 ft. E 660 ft. from W4 corner, Sec 20, T11N, R5W, SLBM,
to a point at N 660 ft. W 660 ft. from S4 corner, Sec 32, T11N, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

===

USES OF WATER RIGHT****** *ELU -- Equivalent Livestock Unit (cow, horse, etc.)* ******** *EDU -- Equivalent Domestic Unit or 1 Family***

==
===
SUPPLEMENTAL GROUP NO.: 6183. Water Rights Appurtenant to the following use(s):
13-1796(WUC),2043(DIL),2634(DIL)

....
....
STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 1000.0000
Div Limit: 28.0 acft.   PERIOD OF USE: 01/01 TO 12/31
==
===
PLACE OF USE for STOCKWATERING
==
===

```
                               NORTH-WEST¼      NORTH-EAST¼
SOUTH-WEST¼      SOUTH-EAST¼
                               NW NE SW SE      NW NE SW SE      NW
NE SW SE      NW NE SW SE
Sec 20 T 11N R  5W SLBM       *  :  :  :  *     *  :  :  :  *     * X:
:  :  *     *  :  :  :  *
Sec 32 T 11N R  5W SLBM       *  :  :  :  *     *  :  :  :  *     *  :
:  : X*     *  :  :  :  *
```

****
E N D   O F   D A T A
****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-2044** APPLICATION/CLAIM NO.: CERT. NO.:

==

OWNERSHIP

==

NAME: Conner Cattle Company
ADDR: c/o Parley Holmgren
Bear River City UT 84301

==

DATES, ETC.*

==

LAND OWNED BY APPLICANT? COUNTY TAX ID#:
FILED: |PRIORITY: 00/00/1869|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 08/23/1967|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-3]|MAP: [123a]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS**---*

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)*********MAP VIEWER*****************

==

FLOW: SOURCE: Blue Creek
COUNTY: Box Elder COMMON DESCRIPTION: Howell Valley

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point at S 660 ft. W 660 ft. from N4 corner, Sec 05, T10N, R5W, SLBM,
to a point at N 660 ft. E 660 ft. from SW corner, Sec 05, T10N, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

==

USES OF WATER RIGHT******* *ELU -- Equivalent Livestock Unit (cow, horse, etc.) ******** EDU -- Equivalent Domestic Unit or 1 Family***

===
===
SUPPLEMENTAL GROUP NO.: 5791. Water Rights Appurtenant to the following use(s):
13-1104(DIL),1105(DIL),2044(DIL),2047(DIL),2050(DIL)
2201(DIL),2202(DIL),2203(DIL)

....
....
STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 400.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31
*===
===
========================*
SUPPLEMENTAL GROUP NO.: 7097. Water Rights Appurtenant to the following use(s):
13-1104(DIL),1105(DIL),2044(DIL),2047(DIL),2050(DIL)
2201(DIL),2202(DIL),2203(DIL),3407(WUC)

....
....
STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 500.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31
===
===

PLACE OF USE for STOCKWATERING

===
===

	NORTH-WEST¼	NORTH-EAST¼	SOUTH-WEST¼	SOUTH-EAST¼
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 05 T 10N R 5W SLBM	* : X: : *	* : : : *	* : : X: *	* : : : *

****
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****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-2045** APPLICATION/CLAIM NO.: CERT. NO.:

==

OWNERSHIP*

==

NAME: Merlin H. Larsen
ADDR: Promontory Route
Corrine UT 84307

==

DATES, ETC.

==

LAND OWNED BY APPLICANT? COUNTY TAX ID#:
FILED: |PRIORITY: 00/00/1869|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 08/22/1967|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-3]|MAP: [123a]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS**---*

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*****************

==

FLOW: SOURCE: Blue creek
COUNTY: Box Elder COMMON DESCRIPTION: Lampo Junction

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point at N 660 ft. W 660 ft. from SE corner, Sec 06, T10N, R5W, SLBM,
to a point at N 660 ft. W 660 ft. from SE corner, Sec 18, T10N, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

==

USES OF WATER RIGHT****** *ELU -- Equivalent Livestock Unit (cow, horse, etc.)* ******** *EDU -- Equivalent Domestic Unit or 1 Family***

==
==
SUPPLEMENTAL GROUP NO.: 6267. Water Rights Appurtenant to the following use(s):
13-284(UGWC),1955(DIL),1956(DIL),1957(UGWC),1958(UGWC)
1959(UGWC),1960(UGWC),1961(UGWC),1962(UGWC),1963(UGWC)
1964(UGWC),1965(UGWC),1966(UGWC),1967(UGWC),2045(DIL)

....
....
STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 210.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31
==
==
PLACE OF USE for STOCKWATERING
****
==
==

	NORTH-WEST¼				NORTH-EAST¼				SOUTH-WEST¼				SOUTH-EAST¼			
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE
Sec 06 T 10N R 5W SLBM	* :	:	:	*	* :	:	:	*	* :	:	:	*	* :	:	:	X*
Sec 18 T 10N R 5W SLBM	* :	:	:	*	* :	:	:	*	* :	:	:	*	* :	:	:	X*

****
****
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****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-2046** APPLICATION/CLAIM NO.: CERT. NO.:

==

OWNERSHIP*

==

NAME: Security Title Company
ADDR: 330 East 4th South
Salt Lake City UT 84111

==

DATES, ETC.*

==

LAND OWNED BY APPLICANT? COUNTY TAX ID#:
FILED: |PRIORITY: 00/00/1869|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 11/01/1967|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-3]|MAP: [123d]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS**---*

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*****************

==

FLOW: SOURCE: Blue Creek
COUNTY: Box Elder COMMON DESCRIPTION: Lampo Junction

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point at S 660 ft. W 660 ft. from NE corner, Sec 19, T10N, R5W, SLBM,
to a point at N 660 ft. W 660 ft. from SE corner, Sec 19, T10N, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

==

USES OF WATER RIGHT****** *ELU -- Equivalent Livestock Unit (cow, horse, etc.)* ******** *EDU -- Equivalent Domestic Unit or 1 Family***

==
==
SUPPLEMENTAL GROUP NO.: 5903. Water Rights Appurtenant to the following use(s):
13-481(DIL),1248(DIL),1250(DIL),1347(DIL),1413(DIL)
1415(DIL),1467(DIL),1860(DIL),1873(DIL),2046(DIL)
2051(DIL)

....
....
STOCKWATER: Sole Supply: UNEVALUATED ELUs Group Total: 100.0000
Div Limit: 2.8 acft. PERIOD OF USE: 01/01 TO 12/31
*===
==
========================*
SUPPLEMENTAL GROUP NO.: 6332. Water Rights Appurtenant to the following use(s):
13-2046(DIL),2048(DIL),2051(DIL)

....
....
STOCKWATER: Sole Supply: UNEVALUATED ELUs Group Total: 300.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31
==
==

PLACE OF USE for STOCKWATERING

==
==

```
                               NORTH-WEST¼        NORTH-EAST¼
SOUTH-WEST¼       SOUTH-EAST¼
                               NW NE SW SE        NW NE SW SE        NW
NE SW SE       NW NE SW SE
Sec 19 T 10N R  5W SLBM       *  :  :  :  *      *  : X:  :  *      *  :
:  :  *      *  :  :  : X*
```

****
**E N D   O F   D
A T A**
****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-2873** APPLICATION/CLAIM NO.: **A42932** CERT. NO.:
CHANGES: a13790 Water User's Claim (Issued: 05/05/1987)

==

OWNERSHIP

==

NAME: Stangl B-21 Associates Inc.
ADDR: 90 East 7200 South, Suite 200
Midvale UT 84047
INTEREST: 100% REMARKS:

==

DATES, ETC.

==

LAND OWNED BY APPLICANT? Yes COUNTY TAX ID#:
FILED: 09/26/1973|PRIORITY: 09/26/1973|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate:12/14/1974|PROOF DUE: 01/04/1988
EXTENSION: |ELEC/PROOF:[Election]|ELEC/PROOF:12/04/1985|CERT/WUC: 05/05/1987|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-]|MAP: [123d,c]|PUB DATE:

TYPE -- DOCUMENT -- STATUS---

Type of Right: Application to Appropriate Source of Info: Water User's Claim Status: Water User's Claim

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*****************

==

FLOW: 3300.0 acre-feet SOURCE: Unnamed Stream (Blue Creek)
COUNTY: Box Elder COMMON DESCRIPTION: 4 1/2 miles SW of Lampo Jnct.

POINTS OF DIVERSION -- SURFACE:
(1) N 1900 ft E 2650 ft from NW cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(2) S 1900 ft W 730 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:

(3) S 2050 ft W 1250 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(4) S 2200 ft W 2450 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(5) S 2700 ft W 2600 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(6) S 2800 ft W 1400 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(7) S 1850 ft E 2350 ft from NW cor, Sec 20, T 10N, R 5W, SLBM
Diverting Works:
Source:
(8) S 2100 ft E 1520 ft from NW cor, Sec 20, T 10N, R 5W, SLBM
Diverting Works:
Source:
(9) S 1700 ft W 500 ft from NE cor, Sec 29, T 10N, R 5W, SLBM
Diverting Works:
Source:
(10)S 1750 ft E 100 ft from NW cor, Sec 29, T 10N, R 5W, SLBM
Diverting Works:
Source:
(11)S 2150 ft W 500 ft from NE cor, Sec 30, T 10N, R 5W, SLBM
Diverting Works:
Source:
(12)S 2800 ft W 480 ft from NE cor, Sec 30, T 10N, R 5W, SLBM
Diverting Works:
Source:
(13)N 50 ft E 800 ft from SW cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(14)S 800 ft E 450 ft from NW cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(15)S 1000 ft E 2100 ft from NW cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(16)S 1100 ft W 1950 ft from NE cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(17)S 1250 ft W 2250 ft from NE cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(18)S 1600 ft W 1000 ft from NE cor, Sec 36, T 10N, R 6W, SLBM
Diverting Works:
Source:

Stream Alt Required?: No

==
==

USES OF WATER RIGHT ******** ***ELU -- Equivalent Livestock Unit (cow, horse, etc.)*** ******** ***EDU -- Equivalent Domestic Unit or 1 Family***

==
==

SUPPLEMENTAL GROUP NO.: 6642.

13-2873(WUC)

....
....
STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 50.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31
....
....
WILDLIFE: Waterfowl propogation in marshes and ponds
PERIOD OF USE: 01/01 TO 12/31
Acre Feet Contributed by this Right for this Use:
Unevaluated
A network of earth dikes are used to impound water for wildlife
propagation.
*==
===
========================*
SUPPLEMENTAL GROUP NO.: 7337. Water Rights Appurtenant to the
following use(s):
13-2873(WUC),3632(APP)

....
....
IRRIGATION: Sole Supply: UNEVALUATED acres   Group Total: 2900.0
Div Limit: 0.0 acft.   PERIOD OF USE: 04/01 TO 10/31
....
....
STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 399.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31
....
....
###PLACE OF USE: *-------NORTH WEST QUARTER------*-------NORTH
EAST QUARTER------*-------SOUTH WEST QUARTER------*-------SOUTH EAST
QUARTER------*   Section
* NW | NE | SW | SE * NW | NE
| SW | SE * NW | NE | SW | SE * NW | NE | SW
| SE * Totals
Sec 05 T 9N R 5W SLBM *X |X |X |X *X |X
|X |X *X |X |X |X *X |X |X
|X * 0.0000
Sec 19 T 10N R 5W SLBM *X |X |X |X *X |X
|X |X *X |X |X |X *X |X |X
|X * 0.0000
Sec 29 T 10N R 5W SLBM *X |X |X |X *X |X
|X |X *X |X |X |X *X |X |X
|X * 0.0000
Sec 31 T 10N R 5W SLBM *X |X |X |X *X |X
|X |X *X |X |X |X *X |X |X
|X * 0.0000

GROUP ACREAGE TOTAL: 0.0000
===
===
PLACE OF USE for
STOCKWATERING*
****

==
==
                                NORTH-WEST¼   NORTH-EAST¼
SOUTH-WEST¼   SOUTH-EAST¼
                                NW NE SW SE   NW NE SW SE   NW
NE SW SE   NW NE SW SE
Sec 05 T 9N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * :
X: : X*   * X: X: X: X*
Sec 19 T 10N R 5W SLBM   * : X: : X*   * X: X: X: X*   * :
X: : *   * X: X: X: X*
Sec 20 T 10N R 5W SLBM   * X: X: X: X*   * : : : *   * X:
X: X: X*   * : : : *
Sec 29 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 30 T 10N R 5W SLBM   * : : : *   * X: X: X: X*   * :
: : *   * X: X: X: X*
Sec 31 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 32 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 36 T 10N R 5W SLBM   * : : : *   * : X: : X*   * :
: : *   * : X: : X*
==
==
Storage from 01/01 to 12/31, inclusive, in Earthen Dikes and Ditches
with a maximum capacity of 3300.000 acre-feet, located in:
   Height of Dam: 4   NORTH-WEST¼   NORTH-EAST¼
SOUTH-WEST¼   SOUTH-EAST¼
   Area Inundated: 2200.00   NW NE SW SE   NW NE SW SE   NW
NE SW SE   NW NE SW SE

Small Dam Required?: No

****
****
***E N D   O F   D
A T A***
****
****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-3642** APPLICATION/CLAIM NO.: **A69440** CERT. NO.:

===

OWNERSHIP*

===

NAME: Randy Marriott
ADDR: 5238 West 2150 North
Plain City UT 84404

===

DATES, ETC.*

===

LAND OWNED BY APPLICANT? Yes COUNTY TAX ID#:
FILED: 11/02/1995|PRIORITY: 11/02/1995|PUB BEGAN: 11/22/1995|PUB ENDED: 11/29/1995|NEWSPAPER: The Leader
ProtestEnd:12/19/1995|PROTESTED: [HearHeld]|HEARNG HLD: |SE ACTION: [Approved]|ActionDate:06/25/1997|PROOF DUE: 08/31/2002
EXTENSION: |ELEC/PROOF:[Proof]|ELEC/PROOF:09/03/2002|CERT/WUC: |LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-]|MAP: [123d,c]|PUB DATE:

TYPE -- DOCUMENT -- STATUS--

Type of Right: Application to Appropriate Source of Info: Application to Appropriate Status: Approved

===

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*******************

===

FLOW: 20000.0 acre-feet SOURCE: Unnamed Stream (Blue Creek)
COUNTY: Box Elder COMMON DESCRIPTION: 4 1/2 miles SW of Lampo Jnct.

POINTS OF DIVERSION -- SURFACE:
(1) N 1900 ft E 2650 ft from NW cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(2) S 1900 ft W 730 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(3) S 2050 ft W 1250 ft from NE cor, Sec 19, T 10N, R 5W, SLBM

      Diverting Works:
Source:
(4) S 2200 ft W 2450 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(5) S 2700 ft W 2600 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(6) S 2800 ft W 1400 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(7) S 1850 ft E 2350 ft from NW cor, Sec 20, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(8) S 2100 ft E 1520 ft from NW cor, Sec 20, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(9) S 1700 ft W 500 ft from NE cor, Sec 29, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(10)S 1750 ft E 100 ft from NW cor, Sec 29, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(11)S 2150 ft W 500 ft from NE cor, Sec 30, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(12)S 2800 ft W 480 ft from NE cor, Sec 30, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(13)N   50 ft E 800 ft from SW cor, Sec 31, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(14)S 800 ft E 450 ft from NW cor, Sec 31, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(15)S 1000 ft E 2100 ft from NW cor, Sec 31, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(16)S 1100 ft W 1950 ft from NE cor, Sec 31, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(17)S 1250 ft W 2250 ft from NE cor, Sec 31, T 10N, R 5W, SLBM
      Diverting Works:
Source:
(18)S 1600 ft W 1000 ft from NE cor, Sec 36, T 10N, R 6W, SLBM
      Diverting Works:
Source:

Stream Alt Required?: No

==

USES OF WATER RIGHT ******** ***ELU -- Equivalent Livestock Unit (cow, horse, etc.)*** ******** ***EDU -- Equivalent Domestic Unit or 1 Family***

==

SUPPLEMENTAL GROUP NO.: 7345.

....
IRRIGATION: 3000.0 acres
Div Limit: 0.0 acft.   PERIOD OF USE: 04/01 TO 10/31
....
STOCKWATER: 300.0000 Stock Units
Div Limit: PERIOD OF USE: 01/01 TO 12/31
....
WILDLIFE: Waterfowl propogation in marshes and ponds
PERIOD OF USE: 01/01 TO 12/31
Acre Feet Contributed by this Right for this Use: 10991.6
A network of earth dikes are used to impound water for wildlife propagation.
....
###PLACE OF USE: *-------NORTH WEST QUARTER------*-------NORTH EAST QUARTER------*-------SOUTH WEST QUARTER------*-------SOUTH EAST QUARTER------*   Section

	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	Totals
Sec 05 T 9N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 19 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 20 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 29 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 30 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 31 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 32 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 36 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000

GROUP ACREAGE TOTAL: 0.0000

==

PLACE OF USE for STOCKWATERING

==

NORTH-WEST¼ NORTH-EAST¼
SOUTH-WEST¼ SOUTH-EAST¼
NW NE SW SE NW NE SW SE NW
NE SW SE NW NE SW SE
Sec 05 T 9N R 5W SLBM * X: X: X: X* * X: X: X: X* * X:
X: X: X* * X: X: X: X*
Sec 19 T 10N R 5W SLBM * X: X: X: X* * X: X: X: X* * X:
X: X: X* * X: X: X: X*
Sec 20 T 10N R 5W SLBM * X: X: X: X* * X: X: X: X* * X:
X: X: X* * X: X: X: X*
Sec 29 T 10N R 5W SLBM * X: X: X: X* * X: X: X: X* * X:
X: X: X* * X: X: X: X*
Sec 30 T 10N R 5W SLBM * X: X: X: X* * X: X: X: X* * X:
X: X: X* * X: X: X: X*
Sec 31 T 10N R 5W SLBM * X: X: X: X* * X: X: X: X* * X:
X: X: X* * X: X: X: X*
Sec 32 T 10N R 5W SLBM * X: X: X: X* * X: X: X: X* * X:
X: X: X* * X: X: X: X*
Sec 36 T 10N R 5W SLBM * X: X: X: X* * X: X: X: X* * X:
X: X: X* * X: X: X: X*
==
==
Storage from 01/01 to 12/31, inclusive, in Earthen Dikes and Ditches
with a maximum capacity of 3300.000 acre-feet, located in:
Height of Dam: 4 NORTH-WEST¼ NORTH-EAST¼
SOUTH-WEST¼ SOUTH-EAST¼
Area Inundated: 2200.00 NW NE SW SE NW NE SW SE NW
NE SW SE NW NE SW SE

Small Dam Required?: No
==
==
OTHER
COMMENTS*
****
==
==

The applicant has a prior application 13-2873 to fill marsh habitat. This
water right is being filed to create year-round waterfowl habitat and will be
diverted as needed to keep water levels constant in existing ponds through
each year.
==
==
PROTESTANTS*
****
==
==

NAME: Blue Creek Irrigation Company
NAME: Stangl B-21 Inc.
ADDR: c/o Ray D. Sorensen, President
ADDR: c/o F.C. Stangl III, President
Box 67
1515 West 2200 South, Suite B-2

      Howell UT 84316
Salt Lake City UT 84119
===
===
****
****
***E N D   O F   D
A T A**
****
****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-3810** APPLICATION/CLAIM NO.: **A75052** CERT. NO.:

==

OWNERSHIP*

==

NAME: Stangl B-21 Associates Inc.
ADDR: 90 East 7200 South, Suite 200
Salt Lake City UT 84047

==

DATES, ETC.*

==

LAND OWNED BY APPLICANT? Yes COUNTY TAX ID#:
FILED: 08/04/2003|PRIORITY: 08/04/2003|PUB BEGAN: 08/20/2003|PUB ENDED: 08/27/2003|NEWSPAPER: The Leader
ProtestEnd:09/16/2003|PROTESTED: [No Hear]|HEARNG HLD: |SE ACTION: [Approved]|ActionDate:03/17/2004|PROOF DUE: 03/31/2013
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: |LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-]|MAP: [ ]|PUB DATE:

TYPE -- DOCUMENT -- STATUS--

Type of Right: Application to Appropriate Source of Info: Application to Appropriate Status: Approved

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*****************

==

FLOW: 2.5 cfs SOURCE: Shotgun Springs & Blue Creek
COUNTY: Box Elder COMMON DESCRIPTION: Lampo Junction

POINT OF DIVERSION -- SURFACE:
(1) N 634 ft W 1050 ft from SE cor, Sec 07, T 10N, R 5W, SLBM
Diverting Works:
Source: Blue Creek

Stream Alt Required?: No

POINT OF SPRING:
(1) N 2307 ft W 312 ft from S4 cor, Sec 09, T 10N, R 5W, SLBM

Diverting Works:
Source: Shotgun Springs
==
USES OF WATER RIGHT****** *ELU -- Equivalent Livestock Unit (cow, horse, etc.) ******** EDU -- Equivalent Domestic Unit or 1 Family***
==
SUPPLEMENTAL GROUP NO.: 7526.

....
WILDLIFE:
PERIOD OF USE: 09/01 TO 10/30
Acre Feet Contributed by this Right for this Use: 1809.94995
....
OTHER:
PERIOD OF USE: 03/01 TO 04/30
Acre Feet Contributed by this Right for this Use: 1809.94995
Wetland
==
PLACE OF USE for STOCKWATERING
==

	NORTH-WEST¼	NORTH-EAST¼	SOUTH-WEST¼	SOUTH-EAST¼
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 09 T 10N R 5W SLBM	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*
Sec 16 T 10N R 5W SLBM	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*
Sec 20 T 10N R 5W SLBM	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*
Sec 21 T 10N R 5W SLBM	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*

==
OTHER COMMENTS
==
The applicant proposes to construct 35 small retention ponds to enhance vegetative growth.
==
PROTESTANTS*

==
==

NAME: Connor Cattle Company
NAME:
ADDR: c/o Clair Holmgren
ADDR:
      13599 West Hwy 102
      Tremonton UT 84337
==
==
==
==
APPLICATIONS FOR EXTENSIONS OF TIME WITHIN WHICH TO SUBMIT PROOF*
==
==
FILED: 03/15/2007|PUB BEGAN: |PUB ENDED:
|NEWSPAPER: No Adv Required
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE
ACTION: [Approved]|ActionDate:03/26/2007|PROOF DUE: 03/31/2010
==
==
FILED: 03/31/2010|PUB BEGAN: |PUB ENDED:
|NEWSPAPER: No Adv Required
ProtestEnd: |PROTESTED: [ ]|HEARNG HLD: |SE
ACTION: [Approved]|ActionDate:04/29/2010|PROOF DUE: 03/31/2013
==
==
****
****
E N D O F D A T A
****
****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010 Page 1

CHANGE: **a13790** WATER RIGHT: 13-2873 CERT. NO.:
COUNTY TAX ID#: AMENDATORY? Yes
BASE WATER RIGHTS: 13-2873
RIGHT EVIDENCED BY: A42932
CHANGES: Point of Diversion [X], Place of Use [X], Nature of Use [X], Reservoir Storage [X].

--

NAME: Stangle B-21 Associates Inc.
ADDR: 90 East 7200 South, Suite 200
Midvale UT 84047
INTEREST: 100% REMARKS:

--

FILED: 12/26/1986|PRIORITY: 12/26/1986|ADV BEGAN: 01/14/1987|ADV ENDED: |NEWSPAPER: The Leader
ProtestEnd:02/27/1987|PROTESTED: [Yes]|HEARNG HLD: |SE ACTION: [Approved]|ActionDate:04/17/1987|PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 05/05/1987|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
Status: Water User's Claim

****

****

***********************H E R E T O F O R E***********************

***********************H E R E A F T E R***********************

****

****

|FLOW: 76.0 cfs
||FLOW: 3300.0 acre-feet |

|---||---|

|SOURCE: Unnamed Springs & Streams (Blue Cr.)
||SOURCE: Unnamed Streams (Blue Creek) |

|---||---|

|COUNTY: Box Elder
||COUNTY: Box Elder COM DESC: 4-1/2 mi SW Lampo Junction |

|---||---|

| ||
A network of earth dikes is used to |
| ||
impound water for wildlife propagation. |

|---||---|

|POINT(S) OF DIVERSION ------> MAP VIEWER
||CHANGED AS FOLLOWS: (Click Location link for WRPLAT) |

```
|-----------------------------------------------------------------||----
------------------------------------------------------------|
|Point Surface:
||Point Surface:                                                  |
|(1)  N 2400 ft E    5 ft from SW cor, Sec 05, T  9N, R  5W, SLBM||(1)
S 1900 ft W  730 ft from NE cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                   ||
Dvrting Wks:                                                   |
| Source:                                                        ||
Source:                                                        |
|(2)  N 1850 ft E    5 ft from SW cor, Sec 05, T  9N, R  5W, SLBM||(2)
S 2050 ft W 1250 ft from NE cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                   ||
Dvrting Wks:                                                   |
| Source:                                                        ||
Source:                                                        |
|(3)  N  200 ft E 4500 ft from SW cor, Sec 17, T 10N, R  5W, SLBM||(3)
S 2800 ft W 1400 ft from NE cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                   ||
Dvrting Wks:                                                   |
| Source:                                                        ||
Source:                                                        |
|(4)  N  300 ft E 5050 ft from SW cor, Sec 17, T 10N, R  5W, SLBM||(4)
S 2200 ft W 2450 ft from NE cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                   ||
Dvrting Wks:                                                   |
| Source:                                                        ||
Source:                                                        |
|(5)  S  100 ft E    5 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(5)
S 2700 ft W 2600 ft from NE cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                   ||
Dvrting Wks:                                                   |
| Source:                                                        ||
Source:                                                        |
|(6)  S 3150 ft E    5 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(6)
N 1900 ft E 2650 ft from SW cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                   ||
Dvrting Wks:                                                   |
| Source:                                                        ||
Source:                                                        |
|(7)  S 4830 ft E    5 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(7)
S 1850 ft E 2350 ft from NW cor, Sec 20, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                   ||
Dvrting Wks:                                                   |
| Source:                                                        ||
Source:                                                        |
|(8)  S    5 ft E 1450 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(8)
S 2100 ft E 1520 ft from NW cor, Sec 20, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                   ||
Dvrting Wks:                                                   |
| Source:                                                        ||
Source:                                                        |
|(9)  S    5 ft E  300 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(9)
S 1750 ft E  100 ft from NW cor, Sec 29, T 10N, R  5W, SLBM|
```

```
| Dvrting Wks:                                                    ||
Dvrting Wks:                                                    |
| Source:                                                         ||
Source:                                                         |
|(10) S    5 ft E 4125 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(10)
S 1700 ft W  500 ft from NE cor, Sec 29, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                    ||
Dvrting Wks:                                                    |
| Source:                                                         ||
Source:                                                         |
|(11) S    5 ft E 4810 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(11)
S 2150 ft W  500 ft from NE cor, Sec 30, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                    ||
Dvrting Wks:                                                    |
| Source:                                                         ||
Source:                                                         |
|(12) S    5 ft E 2250 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(12)
S 2800 ft W  480 ft from NE cor, Sec 30, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                    ||
Dvrting Wks:                                                    |
| Source:                                                         ||
Source:                                                         |
|(13) S    5 ft E 1180 ft from NW cor, Sec 20, T 10N, R  5W, SLBM||(13)
S 1100 ft W 1950 ft from NE cor, Sec 31, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                    ||
Dvrting Wks:                                                    |
| Source:                                                         ||
Source:                                                         |
|(14) S    5 ft E 1725 ft from NW cor, Sec 20, T 10N, R  5W, SLBM||(14)
S 1250 ft W 2250 ft from NE cor, Sec 31, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                    ||
Dvrting Wks:                                                    |
| Source:                                                         ||
Source:                                                         |
|(15) S    5 ft E 1700 ft from NW cor, Sec 20, T 10N, R  5W, SLBM||(15)
S 1000 ft E 2100 ft from NW cor, Sec 31, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                    ||
Dvrting Wks:                                                    |
| Source:                                                         ||
Source:                                                         |
|(16) S    5 ft E 3050 ft from NW cor, Sec 20, T 10N, R  5W, SLBM||(16)
S  800 ft E  450 ft from NW cor, Sec 31, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                    ||
Dvrting Wks:                                                    |
| Source:                                                         ||
Source:                                                         |
|(17) N 2080 ft E    5 ft from SW cor, Sec 29, T 10N, R  5W, SLBM||(17)
N   50 ft E  800 ft from SW cor, Sec 31, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                    ||
Dvrting Wks:                                                    |
| Source:                                                         ||
Source:                                                         |
|(18) N 2780 ft E    5 ft from SW cor, Sec 29, T 10N, R  5W, SLBM||(18)
S 1600 ft W 1000 ft from NE cor, Sec 36, T 10N, R  6W, SLBM|
| Dvrting Wks:                                                    ||
Dvrting Wks:                                                    |
```

| Source: ||
Source: |
|(19) N 3300 ft E 5 ft from SW cor, Sec 29, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(20) N 3700 ft E 5 ft from SW cor, Sec 29, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(21) N 4550 ft E 2325 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(22) N 5 ft E 100 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(23) N 4180 ft E 350 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(24) N 1880 ft E 5 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(25) N 3490 ft E 5 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(26) N 4750 ft E 3300 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
| ||
|
|
||Stream Alt?: No |
|---||----
--|

|PLACE OF USE ------>
||CHANGED as follows: |
|---||----
--|

| --NW¼--   --NE¼--   --SW¼--   --SE¼-- ||
--NW¼--   --NE¼--   --SW¼--   --SE¼-- |
	N N S S		N N S S		N N S S		N N S S		
N N S S		N N S S		N N S S		N N S S	
	W E W E		W E W E		W E W E		W E W E		
W E W E		W E W E		W E W E		W E W E	
Sec 05 T 9N R 5W SLBM *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*		Sec
05 T 9N R 5W SLBM   *X:X:X:X**X:X:X:X**X:X: :X**X:X:X:X*|
Sec 19 T 10N R 5W SLBM *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*		Sec
19 T 10N R 5W SLBM   * :X: :X**X:X:X:X** :X: :X**X:X:X:X*|
Sec 20 T 10N R 5W SLBM *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*		Sec
20 T 10N R 5W SLBM   *X:X:X:X** : : : **X:X:X:X** : : : *|
Sec 29 T 10N R 5W SLBM *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*		Sec
29 T 10N R 5W SLBM   *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
Sec 31 T 10N R 5W SLBM *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*		Sec
30 T 10N R 5W SLBM   * : : : **X:X:X:X** : : : **X:X:X:X*|
		Sec
31 T 10N R 5W SLBM   *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
		Sec
32 T 10N R 5W SLBM   *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
		Sec
36 T 10N R 6W SLBM   * : : : ** :X: :X** : : : ** :X: :X*|

|NATURE OF USE ------>
||CHANGED as follows: |
|--||----
---|
|IRR = values are in acres. ||
|
|STK = values are in ELUs meaning Cattle or Equivalent. ||
|
|DOM = values are in EDUs meaning Equivalent Domestic Units (F ||
|
|--||----
---|
|SUPPLEMENTAL to Other Water Rights: No
||SUPPLEMENTAL to Other Water Rights: No |
|--||----
---|
|IRR: 3184.0000 acres.   USED 04/01 - 10/31||
|
|..||....
....|
|..||....
....|
|STK: 1000.0000 Cattle or Equivalent   USED 01/01 - 12/31||STK:
50.0000 Cattle or Equivalent   USED 01/01 - 12/31|
|..||....
....|
|..||....
....|
|OTH: WILDLIFE: Waterfowl propogation USED 01/01 - 12/31||OTH:
OTHER: Waterfowl Propagation USED 01/01 - 12/31|

```
|     in marshes and ponds                                        ||
|
|----------------------------------------------------------------||----
------------------------------------------------------------|
 ________________________________________________________________
________________________________________________________________
 ________________________________________________________________
________________________________________________________________
```

|RESERVOIR STORAGE -->
||CHANGED as follows: |

```
|----------------------------------------------------------------||----
------------------------------------------------------------|
|
||Storage 01/01 to 12/31, in Earthen Dikes and Ditches            |
|                                                                 ||
with a maximum capacity of 3300.000 acre-feet, located in:     |
|                                                                 ||
--NW¼--  --NE¼--  --SW¼--  --SE¼-- |
|                                                                 ||
Height of Dam:       4 ft |N N S S||N N S S||N N S S||N N S S||
|                                                                 ||
Area Inundat  2200.000 acs|W E W E||W E W E||W E W E||W E W E||
|                                                                 ||Sec
05 T  9N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X: :X**X:X:X:X*|
|                                                                 ||Sec
19 T 10N R  5W SLBM     * :X: :X**X:X:X:X** :X: :X**X:X:X:X*|
|                                                                 ||Sec
20 T 10N R  5W SLBM     *X:X:X:X** : : : **X:X:X:X** : : : *|
|                                                                 ||Sec
29 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
|                                                                 ||Sec
30 T 10N R  5W SLBM     * : : : **X:X:X:X** : : : **X:X:X:X*|
|                                                                 ||Sec
31 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
|                                                                 ||Sec
32 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
|                                                                 ||Sec
36 T 10N R  6W SLBM     * : : : ** :X: :X** : : : ** :X: :X*|
|----------------------------------------------------------------||----
------------------------------------------------------------|
|----------------------------------------------------------------||----
------------------------------------------------------------|
|
||Small Dam Permit Required?: No                                  |
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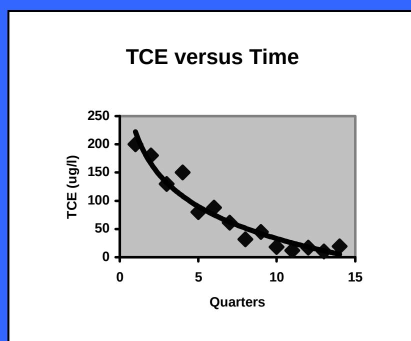
APPENDIX F

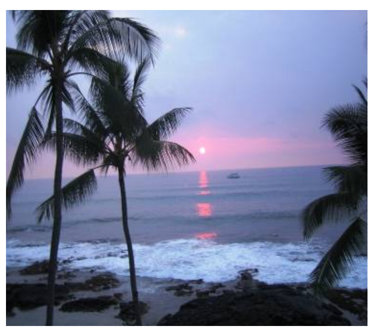
SUPPLEMENTARY INFORMATION ON UPPER TOLERANCE LIMITS AND UPPER PREDICTION LIMITS

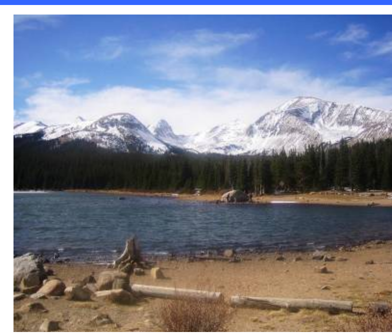
STATISTICAL ANALYSIS OF GROUNDWATER MONITORING DATA AT RCRA FACILITIES

UNIFIED GUIDANCE MARCH 2009

EPA 530/R-09-007







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Also compute the adjustment for ties with equation [17.10]. There is only one group of distinct tied observations — the non-detects — containing 12 samples. Thus, the adjusted Kruskal-Wallis statistic is given by:

$$H^* = 10.56 \Bigg/ \left[1 - \left(\frac{12^3 - 12}{25^3 - 25}\right)\right] = 11.87$$

Step 4. Determine the critical point of the Kruskal-Wallis test: with α = .05, the upper 95th percentage point of the chi-square distribution with (k–1) = 4–1 = 3 degrees of freedom [*df*] is needed. **Table 17-2** of **Appendix D** gives $\chi^2_{cp} = \chi^2_{.95,3} = 7.81$.

Step 5. Since the observed Kruskal-Wallis statistic of 11.87 is greater than the chi-square critical point, there is evidence of significant differences between the well groups. Therefore, post-hoc pairwise comparisons are necessary.

Step 6. To determine the significance level appropriate for post-hoc comparisons, note there are three compliance wells that need to be tested against background. Therefore, each of these contrasts should be run at the α* = 0.05/3 = 0.0167 significance level.

Step 7. Calculate the standard error of the difference for the three contrasts using equation [17.14]. Since the sample size at each compliance well is five, the *SE* will be identical for each comparison, namely,

$$SE_i = \sqrt{\frac{25 \cdot 26}{12}\left(\frac{1}{10} + \frac{1}{5}\right)} = 4.031$$

Step 8. Form the post-hoc Z-statistic for each contrast using equation [17.15]:

$$\text{Well 3: } Z_2 = (12.2 - 7.9)/4.031 = 1.07$$
$$\text{Well 4: } Z_3 = (17.7 - 7.9)/4.031 = 2.43$$
$$\text{Well 5: } Z_4 = (19.3 - 7.9)/4.031 = 2.83$$

Step 9. Find the upper (1–α*) × 100th percentage point from the standard normal distribution in **Table 10-1** in **Appendix D**. With α* = .0167, this gives a critical point (by linear interpolation) of $z_{cp} = z_{.9833} = 2.127$.

Step 10. Since the *Z*-statistics at wells 4 and 5 exceed the critical point, there is significant evidence of increased concentration levels at wells 4 and 5, but not at well 3. ◄

17.2 TOLERANCE LIMITS

A *tolerance interval* is a concentration range designed to contain a pre-specified proportion of the underlying population from which the statistical sample is drawn (*e.g.*, 95 percent of all possible population measurements). Since the interval is constructed from random sample data, a tolerance interval is expected to contain the specified population proportion only with a certain level of statistical confidence. Two coefficients are thus associated with any tolerance interval. One is the population proportion that the interval is supposed to contain, called the coverage (γ). The second is the degree of confidence with which the interval reaches the specified coverage. This is sometimes known as the tolerance coefficient or more simply, the confidence level ($1–\alpha$). A tolerance interval with 95% coverage and a tolerance coefficient of 90 percent is constructed to contain, on average, 95% of the distribution of all possible population measurements with a confidence probability of 90%.

A *tolerance limit* is a one-sided tolerance interval. The upper limit is typically of most interest in groundwater monitoring. Tolerance limits are a standard statistical method that can be useful in groundwater data analysis, especially as an alternative to *t*-tests or ANOVA for interwell testing. The RCRA regulations allow greater flexibility in the choice of α when using tolerance and prediction limits and control charts, so a larger variety of data configurations may be amenable to one of these approaches. The Unified Guidance still recommends prediction limits or control charts over tolerance limits for formal compliance testing in detection monitoring, and confidence intervals over tolerance limits in compliance/assessment monitoring when a background standard is needed.

An interwell tolerance limit constructed on background data is designed to cover all but a small percentage of the background population measurements. Hence background observations should rarely exceed the upper tolerance limit. By the same token, when testing a null hypothesis (H_0) that the compliance point population is identical to background, *compliance point* measurements also should rarely exceed the upper tolerance limit, unless H_0 is false. The upper tolerance limit thus gauges whether or not concentration measurements sampled from compliance point wells are too extreme relative to background.

17.2.1 PARAMETRIC TOLERANCE LIMITS

BACKGROUND AND PURPOSE

To test the null hypothesis (H_0) that a compliance point population is identical to that of background, an upper tolerance limit with high coverage (γ) can be constructed on the sample background data. Coverage of 95% is usually recommended. In this case, random observations from a distribution identical to background should exceed the upper tolerance limit less than 5% of the time. Similarly, a tolerance coefficient or confidence level of at least 95% is recommended. This gives 95% confidence that the (upper) tolerance limit will contain at least 95% of the distribution of observations in background or in any distribution similar to background. Note that a tolerance coefficient of 95% corresponds to choosing a significance level (α) equal to 5%. Hence, as with a one-way ANOVA, the overall false positive rate for a tolerance interval is set to approximately 5%.

Once the limit is constructed on background, each compliance point observation (perhaps from several different wells) is compared to the upper tolerance limit. This is different from the comparison of sample means in an ANOVA test. If any compliance point measurement exceeds the limit, the well from which it was drawn is flagged as showing a significant increase over background. Note that the factors κ used to adjust the width of the tolerance interval (**Table 17-3** in **Appendix D**) are designed to provide *at least* 95% coverage of the parent population. Applied over many data sets, the *average* coverage of these intervals will often be close to 98% or more (see Guttman, 1970). Therefore, it would be unusual to find more than 2 or 3 samples out of every 100 exceeding the tolerance limit under the null hypothesis. This fits with the purpose behind the use of a tolerance interval, which is to establish an upper limit on background that will rarely be exceeded, unless some change in the groundwater causes concentration levels to rise significantly at one or more compliance points.

Testing a large number of compliance point samples against such a background tolerance limit even under conditions of no releases practically ensures a few measurements will occasionally exceed the limit. The Unified Guidance therefore recommends that tolerance limits be used in conjunction with verification resampling of those wells suspected of possible contamination, in order to either verify or disconfirm the initial round of sampling and to avoid false positive results.

REQUIREMENTS AND ASSUMPTIONS

Standard parametric tolerance limits assume normality of the sample background data used to construct the limit. This assumption is critical to the statistical validity of the method, since a tolerance limit with high coverage can be viewed as an estimate of a *quantile* or *percentile* associated with the *tail probability* of the underlying distribution. If the background sample is non-normal, a normalizing transformation should be sought. If a suitable transformation is found, the limit should be constructed on the transformed measurements and can then be *back-transformed* to the raw concentration scale prior to comparison against individual compliance point values.

If no transformation will work, a non-parametric tolerance limit should be considered instead. Unfortunately, non-parametric tolerance limits generally require a much larger number of observations to provide the same levels of coverage and confidence as a parametric limit. It is recommended that a parametric model be fit to the data if at all possible.

A tolerance limit can be computed with as few as three observations from background. However, doing so results in a high upper tolerance limit with limited statistical power for detecting increases over background. Usually, a background sample size of at least eight measurements will be needed to generate an adequate tolerance limit. If multiple background wells are screened in equivalent hydrostratigraphic positions and the data can reasonably be combined (**Chapter 5**), one should consider using pooled background data from multiple wells to increase the background sample size.

Like many tests described in the Unified Guidance, tolerance limits as applied to groundwater monitoring assume *stationarity* of the well field populations both temporally (*i.e.*, over time) and spatially. The data also needs to be statistically *independent*. Since an adequately-sized background sample will have to be amassed over time (in part to maintain enough temporal spacing between observations so that independence can be assumed), the background data should be checked for apparent *trends* or *seasonal effects*. As long the background mean is stable over time, the amassed data from a longer span of sampling will provide a better statistical description of the underlying background population.

As a primarily interwell technique, tolerance limits should only be utilized when there is minimal *spatial variability*. Explicit checks for spatial variation should be conducted using box plots and/or ANOVA.

In the usual test setting, one new compliance point observation from each distinct well is compared against the tolerance limit during each statistical evaluation. Under the null hypothesis of identical populations, the compliance point measurements are assumed to follow the same distribution as background. Further, the compliance data are assumed to be mutually statistically independent. Such assumptions are almost impossible to check with only one new value per compliance well. However, periodic checks of the key assumptions are recommended after accumulating several sampling rounds of compliance data.

PROCEDURE

Step 1. Calculate the mean $\bar{x}$, and the standard deviation s, from the background sample.

Step 2. Construct the one-sided upper tolerance limit as

$$TL = \bar{x} + \kappa\left(n, \gamma, 1-\alpha\right) \cdot s \qquad [17.16]$$

where $\kappa(n, \gamma, 1-\alpha)$ is the one-sided normal tolerance factor found in **Table 17-3** of **Appendix D** associated with a sample size of n, coverage coefficient of γ, and confidence level of $(1-\alpha)$.

Equation [17.16] applies to normal data. If a transformation is needed to normalize the sample, the tolerance limit needs to be constructed on the transformed measurements and the limit back-transformed to the original concentration scale. If the limit was constructed, for example, on the logarithms of the original observations, where $\bar{y}$ and s_y are the log-mean and log-standard deviation, the tolerance limit can be back-transformed to the concentration scale by exponentiating the limit. The tolerance limit is computed as:

$$TL = \exp\left[\bar{y} + \kappa(n, \gamma, 1-\alpha) \cdot s_y\right] \qquad [17.17]$$

Step 3. Compare each observation from the compliance well(s) to the upper tolerance limit found in Step 2. If any observation exceeds the tolerance limit, there is statistically significant evidence that the compliance well concentrations are elevated above background. Verification resampling should be conducted to verify or disconfirm the initial result.

►EXAMPLE 17-3

The table below consists of chrysene concentration data (ppb) found in water samples obtained from two background wells (Wells 1 and 2) and three compliance wells (Wells 3, 4, and 5). Compute the upper tolerance limit on background for coverage of 95% with 95% confidence and determine whether there is evidence of possible contamination at any of the compliance wells.

	Chrysene Concentration (ppb)				
Month	Well 1	Well 2	Well 3	Well 4	Well 5
1	19.7	10.2	68.0	26.8	47.0
2	39.2	7.2	48.9	17.7	30.5
3	7.8	16.1	30.1	31.9	15.0
4	12.8	5.7	38.1	22.2	23.4
Mean	19.88	9.80	46.28	24.65	28.98
SD	13.78	4.60	16.40	6.10	13.58

CHAPTER 18. PREDICTION LIMIT PRIMER

This chapter introduces the concept of statistical intervals and focuses on several types of prediction limits useful for detection monitoring. The requirements and common assumptions of such limits are explained, as well as specific descriptions of:

- Prediction limits for *m* future values (**Section 18.2.1**)
- Prediction limits for future means (**Section 18.2.2**)
- Non-parametric prediction limits for *m* future values (**Section 18.3.1**)
- Non-parametric prediction limits for a future median (**Section 18.3.2**)

18.1 INTRODUCTION TO PREDICTION LIMITS

First discussed in **Chapter 6,** *prediction limits* belong to a class of methods known as *statistical intervals*. Statistical intervals represent concentration or measurement ranges computed from a sample that are designed to estimate one or more characteristics of the parent population. In groundwater monitoring, statistical intervals offer a convenient and statistically valid way to test for significant differences between background versus compliance point groundwater measurements.

The statistical interval accounts for variability inherent not only in future measurements, but also additional uncertainty in the prediction limit itself. The latter is derived from a relatively small background sample with an associated level of variability in estimating the true characteristics of the underlying groundwater population.

Prediction limits are generally easy to construct and have a straightforward interpretation. Background data are used to construct a concentration limit *PL*, which is then compared to one or more observations from a compliance point population. The acceptable range of concentrations includes all values no greater than the prediction limit. The appropriate *prediction interval* will generally have the form [0, *PL*], with the upper limit *PL* as the comparison of importance. Unless pH or a similar parameter is being monitored, a one-sided upper prediction limit is used in detection monitoring.

A significant advantage to prediction limits is their *flexibility*, which can accommodate a wide variety of groundwater monitoring networks. Prediction limits can be constructed so that as few as *one* new measurement per compliance well may suffice for a test. Prediction limits may be based on a comparison of means, medians, or individual compliance point measurements, depending on the characteristics of the monitoring network and the constituents being tested.

Prediction limits can also be designed to accommodate a wide range of *multiple statistical comparisons* or *tests*. Each periodic statistical evaluation (*e.g.*, semi-annually) under RCRA and other regulations involves separate tests at all compliance well locations for each monitoring constituent. Often, the number of separate statistical tests can be quite sizeable. Prediction limits can be constructed to precisely account for the number of tests to be conducted, so as to limit the *site-wide false positive rate* [SWFPR] and ensure an adequate level of *statistical power* (see discussion in **Chapter 6**).

This and the following chapter present basic concepts and procedures for using prediction limits as detection monitoring tests. The intent is to provide a relatively simple framework for using prediction limits in RCRA or CERCLA groundwater monitoring. **Chapter 18** describes the construction of prediction limits for tests involving a single constituent at one well. It describes the basic mechanics of each type of prediction limit and how they differ from one another.

Chapter 19 expands this discussion to cover multiple *simultaneous* prediction limit tests (*i.e.*, all occurring during a single statistical evaluation or during a single year of monitoring). Cumulative SWFPRs and statistical power are considered, including how these criteria impact the expected performance of a given prediction limit strategy. Examples are provided to illustrate these procedures, as well as explanations of associated tables and software.

Specific strategies in **Chapter 19** apply the concept of *retesting*. Generally speaking, ***almost any prediction limit procedure in detection monitoring should be combined with an appropriate retesting strategy***. The reason is that when testing a large number of compliance point samples, it is almost guaranteed that one or more measurements will exceed an upper prediction limit. *Resampling* of those wells where an exceedance has occurred can either verify the initial evidence of a release or disconfirm it, while avoiding unnecessary false positives.

Chapter 6 introduced a number of key terms used in the Unified Guidance, especially for prediction limit and control chart tests. The guidance applies the term *comparison* to <u>individual</u> future measurements or sample statistics evaluated against a prediction limit (or *control chart limit*), and the term *test* to represent a series of future data comparisons that ultimately result in a statistical decision. A 1-of-m retesting procedure (described below), for instance, might involve comparison of up to m distinct sample measurements against the prediction limit. Each of these individual samples involves a *comparison*, but only after all the necessary individual comparisons have been made is the *test* complete. This distinction becomes particularly important when properly determining SWFPRs, a subject discussed both in **Chapter 6** and **Chapter 19**.

One or more *future* observations are collected for purposes of testing compliance well data, as distinct from the *background* sample from which the prediction limit is constructed. Background data can be obtained from upgradient wells or in combination with historical, uncontaminated compliance well data. In intrawell testing, data from an individual compliance well constitute both the background and future samples. The two data sets need to be distinct and may not overlap, even if the historical background data is periodically updated with previously evaluated future samples. The key idea is that at any given point in time, background and future data sets are clearly distinguished.

Formally, prediction limits are constructed to contain one or more future observations or sample statistics generated from the background population with a specified probability equal to (1–α). The probability (1–α) is known as the confidence level of the limit. It represents the chance — over repeated applications of the limit to many similar data sets — that the prediction limit will contain future observations or statistics drawn from its background population.

A sample of *n* background measurements is used to construct the prediction limit. Under the null hypothesis that the compliance point population is identical to background, a set of *m* independent compliance point observations or a statistic like the mean based on those observations (*i.e.*, the future data) is then compared against the prediction limit. For the prediction limit to serve as a valid statistical test, the future observations are initially presumed to follow the same distribution as background.

Only background values are used to construct the prediction limit. But the probability that the limit contains all *m* future observations or sample statistics derived from those future data does not depend solely on the observed background. It is also based on the number of future measurements or sample statistics used in the comparison and *how* the individual comparisons are conducted. To underscore this point, consider the general equation for a prediction limit based on normal or transformably normal populations, given by

$$PL = \bar{x} + \kappa s \tag{18.1}$$

where $\bar{x}$ is the sample mean in background, s is the background standard deviation, and κ is a multiplier depending on the type of prediction limit under construction. The simplest type of prediction limit test compares a specific number of individual future observations to the limit (*PL*). For example, do all three compliance measurements collected during a 6-month period fall within the prediction interval? The multiplier κ and hence the prediction limit itself, changes depending on whether one, two or three compliance observations will be compared against *PL*. More generally, the κ-multiplier is selected to account not only for the number of future comparisons, but also for the *rules of the comparison strategy* and the number of simultaneous tests to be conducted (*e.g.*, the number of monitoring constituents times the number of compliance wells).

In the simplest case of a successive comparison of *m* individual future measurements against *PL*, the test is labeled as an *m*-of-*m* prediction limit. All *m* of the future observations need to fall within the prediction interval for the test to 'pass' — that is, be no greater than *PL*. If any one or more of the future values exceed the PL, the test fails and the well is deemed to have a *statistically significant increase* [SSI] or constitute an exceedance.

The κ-multiplier appropriate for an *m*-of-*m* prediction limit test is different from the multipliers that would be computed for other kinds of comparison rules. Another simple type is a comparison of a single future *mean of order p*. Here, *p* future measurements are collected and *averaged* before comparing against *PL*. If the order-*p* mean is no greater than *PL*, the test passes; otherwise, it fails. A test following this rule is labeled a *1-of-1 prediction limit on a future mean*. The important thing to remember is that the κ-multiplier and thus the prediction limit will differ depending on whether or not the *p* future values are first averaged or simply compared against *PL* one-by-one. The choice to use one rule versus the other impacts the magnitude of the prediction limit and ultimately its expected statistical power and false positive rate.

Other comparison rules of substantial benefit in groundwater monitoring are 1-of-*m* prediction limit on future observations or a statistic like the mean or median. This test requires at least one of *m* successive observations or statistic to fall within the prediction interval in order to pass. Operationally this means that if an initial compliance well measurement is no greater than *PL*, the test is complete and no further sampling need be done. If the initial value exceeds *PL,* one or more of (*m*–1) *resamples* need to be obtained. Since these additional measurements are collected sequentially over sufficiently long time periods to maintain approximate statistical independence (**Chapter 3**), the first resample to fall within the prediction interval also ends the test as 'inbounds' or passing, frequently obviating the need to gather all *m* measurements.

Another comparison rule of some use is known as the California strategy, first developed for the State of California RCRA program. The California strategy can be construed as a *conditional* rule: if an initial future observation is no greater than *PL*, further comparisons are not needed and the test passes. However, if the initial observation exceeds the *PL*, 2-of-2 or 3-of-3 resamples *all need to not exceed the PL* in order for the well to remain in compliance. A slight modification to this rule termed the *modified California* approach has better statistical power and false positive rate characteristics than the original California strategies, and is therefore included as a potential prediction limit test.

18.1.1 BASIC REQUIREMENTS FOR PREDICTION LIMITS

All prediction limits share certain basic assumptions when applied as tests of groundwater. Further, *parametric* prediction limits as presented in the Unified Guidance require the sample data to be either normally-distributed or normalized via a transformation. The key points can be summarized as follows:

1. background and future sample measurements need to be identically and independently distributed (the *i.i.d.* presumption; see **Chapter 3**);
2. sample data do not exhibit temporal non-stationarity in the form of trends, autocorrelation, or other seasonal or cyclic variation;
3. for interwell tests (*e.g.*, upgradient-to-downgradient comparisons), sample data do not exhibit non-stationary distributions in the form of significant natural spatial variability;
4. background data do not include statistical outliers (a form of non-identical distributions);
5. for parametric prediction limits, background data are normal or can be normalized using a transformation; and
6. a minimum of 8 background measurements is available; more for non-parametric limits or when accounting for multiple, simultaneous prediction limit tests.

The first assumption implies that background data are randomly drawn from a single common parent population, especially if aggregated from more than one source well. As discussed in **Chapter 5**, analysis of variance [ANOVA] can be used to determine the appropriateness of pooling data from different background wells. There is also a presumption that the compliance point measurements follow the same distribution as background in the absence of a release.

The second assumption is corollary to the first, and requires that the background data are *stationary over time* (**Chapter 3**). This can be evaluated with one or more techniques described in **Chapter 14** on temporal variability. These account for trends, autocorrelation, or other variation, perhaps by utilizing *data residuals* instead of the raw measurements. If the background residuals meet the basic points above, they can be used to construct an adjusted prediction limit. Residuals of the future observations would also need to be computed and compared against the adjusted prediction limit to ensure a valid and consistent test.

The second assumption also requires that there be only a single source of variation in the data, when using the usual sample standard deviation (s) to compute the prediction limit. If there are other sources of variation such as seasonal patterns or temporal variation in lab analytical performance, these should be included in the estimate of variability. Otherwise s is likely to be *biased*. One method to accomplish this is by use of an appropriate ANOVA model to include temporal factors affecting the variability (**Chapter 14**). Determination of the components of variance in more complicated models is beyond the scope of this guidance and may require consultation with a professional statistician.

The third assumption requires that background and compliance point populations be identical in distribution, absent a release, for interwell tests. Spatial variation violates this assumption since the well population means (μ) will be different, making it impossible to know whether an apparent upgradient-to-downgradient difference is attributable to a release or simply variations in natural groundwater concentration levels. The assumption also requires that each population share a common variance (σ^2). Tests of equal variance (*i.e.*, homoscedasticity) when using prediction limits may be possible either by examining groups of historical background and compliance point data or by performing periodic tests when enough compliance point measurements have been accumulated to make a diagnostic test possible.

The fourth assumption implies that background data should be screened for outliers using the techniques in **Chapter 12**. Statistical outliers can potentially inflate a prediction limit and severely limit its statistical power and accuracy by over-inflating both the sample background mean ($\bar{x}$) and especially the background standard deviation (s). The Unified Guidance discourages automated removal of outliers from background samples, but all possible outliers should be examined to determine whether a cause can be identified (see discussion in **Chapter 6**). In some cases, an apparent outlier may represent a valid portion of the underlying background population that has not yet been sampled or observed. It also could represent evidence that conditions in background have changed or are changing.

The fifth assumption of normality for parametric prediction limits can be evaluated using the diagnostic techniques described in **Part II** of the guidance. If skewed background data can be normalized via a transformation (*e.g.*, the natural logarithm), the prediction limit should be constructed on the transformed background values. The resulting limit should either be: 1) back-transformed to the concentration domain (*e.g.*, by exponentiation) when comparing future individual compliance observations; or 2) left in the transformed scale when compared to future mean compliance data also based on *the same transformation*. In the latter case, use of a logarithmic transformation results in evaluating population medians or geometric means and *not* the arithmetic means.

When normality cannot be justified, a non-parametric prediction limit should be considered instead. A non-parametric limit assumes only that all the data come from the same, usually unknown, continuous population. Non-parametric prediction limits generally require a much larger number of background observations in order to provide the same level of confidence (1–α) as a comparable parametric limit. Consequently, the Unified Guidance recommends that a parametric model be fit to the data if at all possible.

The last assumption concerns sufficient background sample sizes. A prediction interval can be computed with as few as three observations from background. However, this can result in an unacceptably large upper prediction limit and a test with very limited statistical power. A sample size of eight or more is generally needed to derive an adequate parametric prediction limit, especially if a retesting strategy is not employed. The exact requirements depend on the number of simultaneous tests (*i.e.*, number of wells times number of constituents per well) to be made against the prediction limit and the type of retesting strategy adopted (see **Chapter 19** for more discussion of retesting strategies).

If a minimum schedule of quarterly sampling is being followed and there is only one background well, at least two years of data will be needed before constructing the prediction limit.[1] If data from multiple background wells screened in comparable hydrologic conditions can reasonably be combined (see **Chapter 5**), pooling background data to increase background sample sizes is encouraged.

18.1.2 PREDICTION LIMITS WITH CENSORED DATA

When a sample contains a substantial fraction of non-detects or left-censored measurements, it may be impossible to even approximately normalize the data A sample data set may originate from a normal or transformable-to-normal population, but the uncertainty surrounding both the censored values and the consequent shape of the lower tail of the distribution prevents a clear identification. If the apparent underlying distribution is not normal or transformable to normality, a non-parametric prediction limit (**Section 18.3**) should be used.

Given that non-parametric prediction limits typically have much steeper background data requirements than their parametric counterparts, one remedy is to attempt a fit to normality by using censored probability plots (**Chapter 15**) in conjunction with either the *Kaplan-Meier* or *robust regression on order statistics* [ROS] techniques (**Chapter 15**) for left-censored data. Censored observations prevent a full and complete ordering of the sample, making it difficult to assess normality with standard probability plots (**Chapter 9**). Censored probability plots, on the other hand, only graph the detected values, but do so based on a *partial ordering and ranking* of the sample. Data that appear distinctly non-normal on a standard probability plot (where non-detects are perhaps replaced by half their reporting limits [RLs] to allow plotting) can sometimes appear reasonably normal on a censored probability plot. Transformations can also be applied and the censored probability plot reconstructed to see if the data can be normalized in that fashion.

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[1] The Unified Guidance does not recommend that only one background well be used in any kind of interwell or upgradient-to-downgradient comparison. Multiple background wells are always preferred so that tests for spatial variability may be made and the exact nature of background better understood.

If the censored probability plot is close to linear and the sample approximately normalized, an estimated mean and standard deviation should be computed. These estimates will not be the same if each non-detect were replaced by half its RL, and the sample mean calculated from the resulting imputed sample. To properly account for the censoring, the estimated mean (denoted as $\hat{\mu}$) and the estimated standard deviation ($\hat{\sigma}$) needs to be derived as parameters from the normal distribution providing the closest fit to a partial ordering of the sample (as on a censored probability plot). The Unified Guidance describes two slightly different techniques for accomplishing this task.

Once $\hat{\mu}$ and $\hat{\sigma}$ estimates have been computed, an adjusted parametric prediction limit is constructed by substituting $\hat{\mu}$ for $\bar{x}$ and $\hat{\sigma}$ for s in the equations of **Section 18.2** or **Chapter 19**. For example, the adjusted equation for a general parametric prediction limit would become:

$$PL = \hat{\mu} + \kappa \cdot \hat{\sigma} \qquad [18.2]$$

Another potential difference between the adjusted prediction limit in equation [18.2] and the unadjusted prediction limit in equation [18.1] is the number of *degrees of freedom* [*df*] used in selecting the κ-multiplier. Absent any censored measurements, a background sample of size n would normally have (n–1) *df*. With censoring, there is greater statistical uncertainty surrounding each non-detect than surrounding the detected values. Because of this, the actual degrees of freedom is somewhere between d (the number of detects) and (n–1) (the total sample minus one). Unfortunately, there is no straightforward, general method to determine the true *df.* To be conservative, the *df* should be set equal to d, since the value of each detect is known with reasonable certainty. Setting a lower *df* tends to raise the κ-multiplier and thus the prediction limit over what would be selected with an uncensored sample of the same size. This is consistent with the greater uncertainty associated with non-detect measurements. However, it is at best an approximate remedy. Further consultation with a professional statistician may be warranted to arrive at a better choice of the degrees of freedom.

18.2 PARAMETRIC PREDICTION LIMITS

18.2.1 PREDICTION LIMIT FOR M FUTURE VALUES

BACKGROUND AND PURPOSE

A prediction limit test for m future values is constructed so that m compliance point observations are evaluated by determining whether or not they fall within a prediction interval derived from background. As mentioned in **Chapter 2**, some State programs may require up to 4 successive sampling events per evaluation period for testing, which can be addressed by the prediction limit approach described below.

If the distributions of background and compliance point data are identical as assumed under the null hypothesis H_0, *all m of the compliance point observations* should be no greater than the upper prediction limit [*PL*]. If any of the future observations exceeds *PL*, there is statistical evidence that the compliance data do not come from the same distribution as background, but instead are elevated above background.[2]

With intrawell comparisons, a prediction limit can be computed on historical data or intrawell background to contain a specified number (m) of future (*i.e.*, more recent) observations from the same well. If any of the future values exceeds the upper prediction limit, there is evidence of recent contamination at the well.

REQUIREMENTS AND ASSUMPTIONS

As noted in **Section 18.1**, the prediction limit test on m future values is designated as an m-of-m test. *Each* of the m individual future observations need to be compared to the prediction limit [*PL*]. All should be no greater than *PL* for the test to pass. The number of future observations to be collected (m) need to be specified *in advance* in order to correctly compute the κ-multiplier from equation [18.1]. Consequently, if compliance data are collected on a regular schedule, the prediction interval can be constructed to cover a specified *time period* of future sampling. Usually this period will coincide with the time between statistical evaluations specified in the site permit (*e.g.*, on a semi-annual or annual basis). Keep in mind also that m denotes the number of consecutive sampling events being compared to the prediction limit at a given well for a given constituent.

As discussed in more detail in **Chapter 6**, a new prediction limit should be constructed prior to each statistical evaluation for *interwell* tests, when additional background data have been collected along with the new compliance point measurements. Unless there is evidence of characteristic changes within background groundwater quality (*e.g.*, as demonstrated by observable trends in background), background data should be amassed or accumulated over time. Earlier background measurements need not be discarded, both to maintain an adequate background sample size and also because a larger span of sampling results will provide a better statistical description of the underlying background population. The revised prediction limit will then reflect a larger background sample size, n, but possibly the same number, m, of future values to be predicted at the next statistical evaluation.

For *intrawell* tests, the prediction limits should be revised only after intrawell background has been updated (**Chapter 5**). Such updating may not coincide with the regular schedule of statistical evaluations if done, for instance, every two years or so. In that case, the same intrawell prediction limit might be used for multiple evaluations before being revised.

PROCEDURE

Step 1. Calculate the sample mean $\bar{x}$, and standard deviation s, from the set of n background measurements.

Step 2. Specify the number of individual future observations (m) from the compliance well to be included in the prediction interval for an m-of-m test. For an upper prediction limit with an overall $(1-\alpha)$ confidence test level for the m comparisons, use the equation:

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[2] In the context of the Unified Guidance, m represents the number of consecutive samples being compared in the prediction limit test for a given well and constituent.