State of Utah

GARY R. HERBERT
Governor

SPENCER J. COX
Lieutenant Governor

Department of
Environmental Quality

Amanda Smith
Executive Director

DIVISION OF WATER QUALITY
Walter L. Baker, P.E.
Director

MEMORANDUM

TO: Utah Water Quality Board

THROUGH: Walter L. Baker, Executive Secretary

FROM: Chris Bittner, Standards Coordinator

DATE: 1/7/2014

SUBJECT: Proposed changes to Utah's Water Quality Standards (R317-2): Site-specific total dissolved solids standards for Blue Creek and Blue Creek Reservoir, Box Elder County, Utah

ACTION ITEM: Staff requests Board approval to proceed with rulemaking on the proposed changes to Utah Water Quality Standards

Application of Standards, R317-2-7.1 allows the Board to adopt site-specific standards when natural or irreversible conditions prevent the attainment of the statewide criterion. After a 2-year study, staff has determined that the concentrations of total dissolved solids in Blue Creek Reservoir and Blue Creek are higher than the statewide criterion of 1,200 mg/l due to natural conditions. The total dissolved solids standard is intended to protect the Class 4 agricultural designated use.

Staff proposes a site-specific total dissolved solids (TDS) standard of 2,200 mg/l for Blue Creek Reservoir. For Blue Creek, staff recommends two TDS standards to more accurately characterize natural conditions. Staff recommends 6,300 mg/l as a one-hour maximum and 3,900 mg/l as a 30-day average.

Staff requests Board permission to proceed with rulemaking. If the Board approves the request to proceed with the proposed change to rule, staff will file the changes with the Division of Administrative Rulemaking (DAR). DAR will publish the proposed changes in the Utah bulletin for 30 day public comment period. Staff will address any comments received and return to the Board with recommendations for changes or to adopt the changes.

Supporting Documents

1. Redline/strikeout of R317-2, Table 2.14.1, Numeric Criteria for Domestic, Recreation, and Agriculture Uses
2. Proposed Site-Specific Standard for Total Dissolved Solids, Blue Creek, Box Elder County, Utah, September 4, 2013 Draft

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Attachment 1
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R317-2 Standards of Quality for Waters of the State redline/strikeout mark up of proposed rule changes. Proposed additions are on the 2nd page and are shown with underlining and highlighted in green.

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R317-2-14. Numeric Criteria.

TABLE 2.14.1
NUMERIC CRITERIA FOR DOMESTIC, RECREATION, AND AGRICULTURAL USES

Parameter	Domestic Source	Recreation and Aesthetics		Agri- culture
	1C	2A	2B	4
BACTERIOLOGICAL (30-DAY GEOMETRIC MEAN) (NO.)/100 ML) (7)				
E. coli	206	126	206	
MAXIMUM (NO.)/100 ML) (7)				
E. coli	668	409	668	
PHYSICAL				
pH (RANGE)	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0
Turbidity Increase (NTU)		10	10	
METALS (DISSOLVED, MAXIMUM MG/L) (2)				
Arsenic	0.01			0.1
Barium	1.0			
Beryllium	<0.004			
Cadmium	0.01			0.01
Chromium	0.05			0.10
Copper				0.2
Lead	0.015			0.1
Mercury	0.002			
Selenium	0.05			0.05
Silver	0.05			
INORGANICS (MAXIMUM MG/L)				
Bromate	0.01			
Boron				0.75
Chlorite	<1.0			
Fluoride (3)	1.4-2.4			
Nitrates as N	10			
Total Dissolved Solids (4)				1200
RADIOLOGICAL				
(MAXIMUM pCi/L)				
Gross Alpha	15			15

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Gross Beta	4 mrem/yr	Radium 226, 228		
(Combined)	5			
Strontium 90	8			
Tritium	20000			
Uranium	30			
ORGANICS (MAXIMUM UG/L)				
Chlorophenoxy Herbicides				
2,4-D	70			
2,4,5-TP	10			
Methoxychlor	40			
POLLUTION INDICATORS (5)				
BOD (MG/L)		5	5	5
Nitrate as N (MG/L)		4	4	
Total Phosphorus as P (MG/L)(6)		0.05	0.05	

FOOTNOTES:

(1) Reserved

(2) The dissolved metals method involves filtration of the sample in the field, acidification of the sample in the field, no digestion process in the laboratory, and analysis by approved laboratory methods for the required detection levels.

(3) Maximum concentration varies according to the daily maximum mean air temperature.

TEMP (C)	MG/L
12.0	2.4
12.1-14.6	2.2
14.7-17.6	2.0
17.7-21.4	1.8
21.5-26.2	1.6
26.3-32.5	1.4

(4) SITE SPECIFIC STANDARDS FOR TOTAL DISSOLVED SOLIDS (TDS)

Blue Creek and tributaries, Box Elder County from Gunnison Bay to Blue Creek Reservoir: one-hour maximum 6,300 mg/l, 30-day average 3,900 mg/l;

Blue Creek Reservoir, Box Elder County and tributaries: one hour maximum 2,200 mg/l;

Castle Creek from confluence with the Colorado River to Seventh Day Adventist Diversion: 1,800 mg/l;

Cottonwood Creek from the confluence with Huntington Creek to I-57: 3,500 mg/l;

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Ferron Creek from the confluence with San Rafael River to Highway 10: 3,500 mg/l;

Huntington Creek and tributaries from the confluence with Cottonwood Creek to U-10: 4,800 mg/l;

Ivie Creek and its tributaries from the confluence with Muddy Creek to the confluence with Quitchupah Creek:
3,800 mg/l provided that total sulfate not exceed 2,000 mg/l to protect the livestock watering agricultural existing use;

Ivie Creek and its tributaries from the confluence with Quitchupah Creek to U10: 2,600 mg/l;

Lost Creek from the confluence with Sevier River to U.S. Forest Service Boundary: 4,600 mg/l;

Muddy Creek and tributaries from the confluence with Ivie Creek toU-10: 2,600 mg/l;

Muddy Creek from confluence with Fremont River to confluence with Ivie Creek: 5,800 mg/l;

North Creek from the confluence with Virgin River to headwaters: 2,035 mg/l;

Onion Creek from the confluence with Colorado River to road crossing above Stinking Springs: 3000 mg/l;

Brine Creek-Petersen Creek, from the confluence with the Sevier River to U-119 Crossing: 9,700 mg/l;

Price River and tributaries from confluence with Green River to confluence with Soldier Creek: 3,000 mg/l;

Price River and tributaries from the confluence with Soldier Creek to Carbon Canal Diversion: 1,700 mg/l

Quitchupah Creek from the confluence with Ivie Creek to U-10:
3,800 mg/l provided that total sulfate not exceed
2,000 mg/l to protect the livestock watering agricultural existing use;
Rock Canyon Creek from the confluence with Cottonwood Creek to headwaters: 3,500 mg/l;

San Pitch River from below Gunnison Reservoir to the Sevier River: 2,400 mg/l;

San Rafael River from the confluence with the Green River to Buckhorn Crossing: 4,100 mg/l;

San Rafael River from the Buckhorn Crossing to the confluence with Huntington Creek and Cottonwood Creek: 3,500 mg/l;

Sevier River between Gunnison Bend Reservoir and DMAD Reservoir: 1,725 mg/l;

Sevier River from Gunnison Bend Reservoir to Clear Lake: 3,370 mg/l;

South Fork Spring Creek from confluence with Pelican Pond Slough Stream to US 89	1,450 mg/l (Apr.-Sept.) 1,950 mg/l (Oct.-March)

Virgin River from the Utah/Arizona border to Pah Tempe Springs: 2,360 mg/l

(5) Investigations should be conducted to develop more information where these pollution indicator levels are exceeded.

(6) Total Phosphorus as P (mg/l) indicator for lakes and reservoirs shall be 0.025.

(7) Where the criteria are exceeded and there is a reasonable basis for concluding that the indicator bacteria E. coli are primarily from natural sources (wildlife), e.g., in National Wildlife Refuges and State Waterfowl Management Areas, the criteria may be considered attained provided the density attributable to non-wildlife sources is less than the criteria. Exceedences of E. coli from nonhuman nonpoint sources will generally be addressed through appropriate Federal, State, and local nonpoint source programs.

Measurement of E. coli using the "Quanti-Tray 2000" procedure is approved as a field analysis. Other EPA approved methods may also be used.

For water quality assessment purposes, up to 10% of representative samples may exceed the 668 per 100 ml criterion (for 1C and 2B waters) and 409 per 100 ml (for 2A waters). For small datasets, where exceedences of these criteria are observed, follow-up ambient monitoring should be conducted to better characterize water quality.

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Proposed Site-Specific Standard for Total Dissolved Solids

Blue Creek, Box Elder County, Utah

Utah Division of Water Quality

September 4, 2013 Draft

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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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TABLES

FIGURES

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

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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

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Figures

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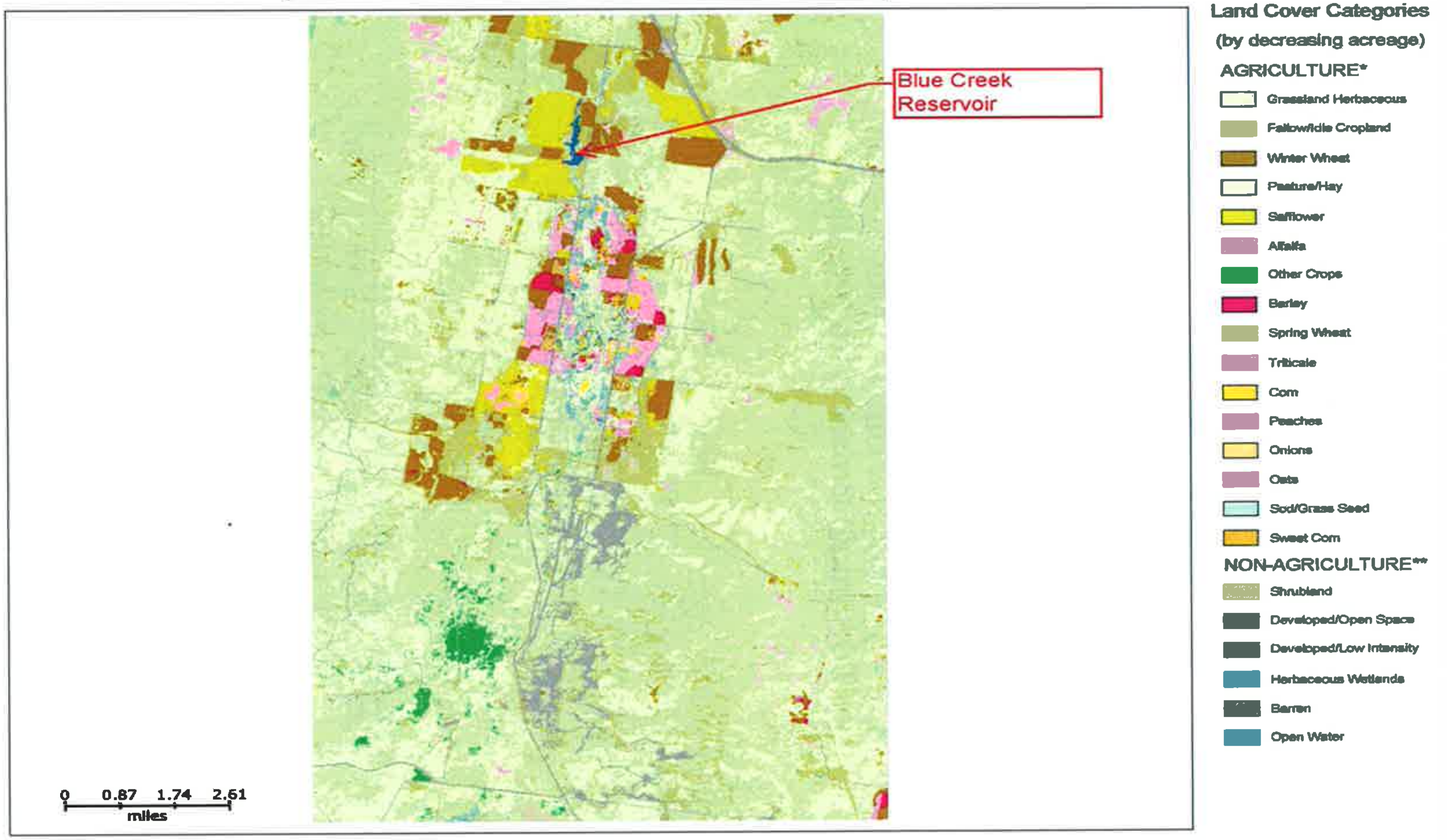
Figure 1
Agricultural Use in the Blue Creek Watershed, 2012



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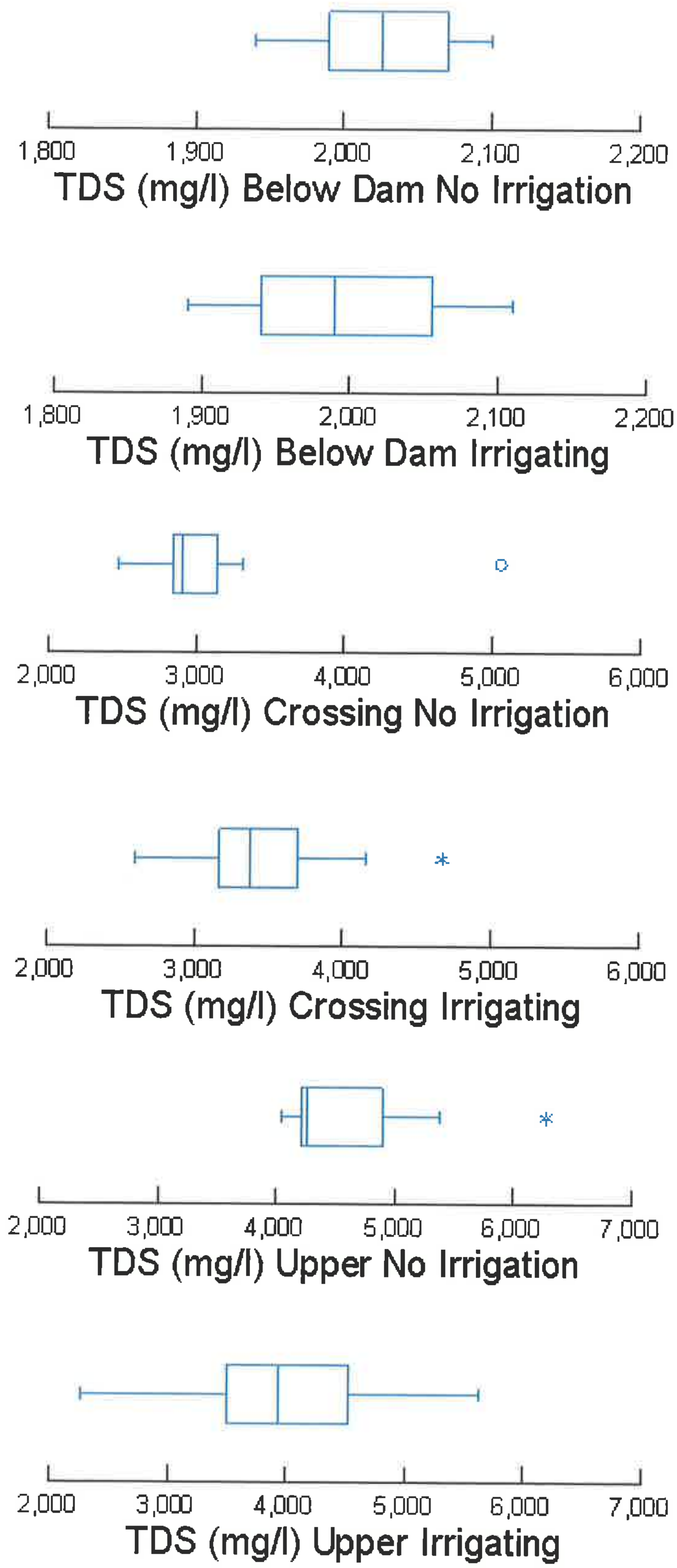

Figure 2

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

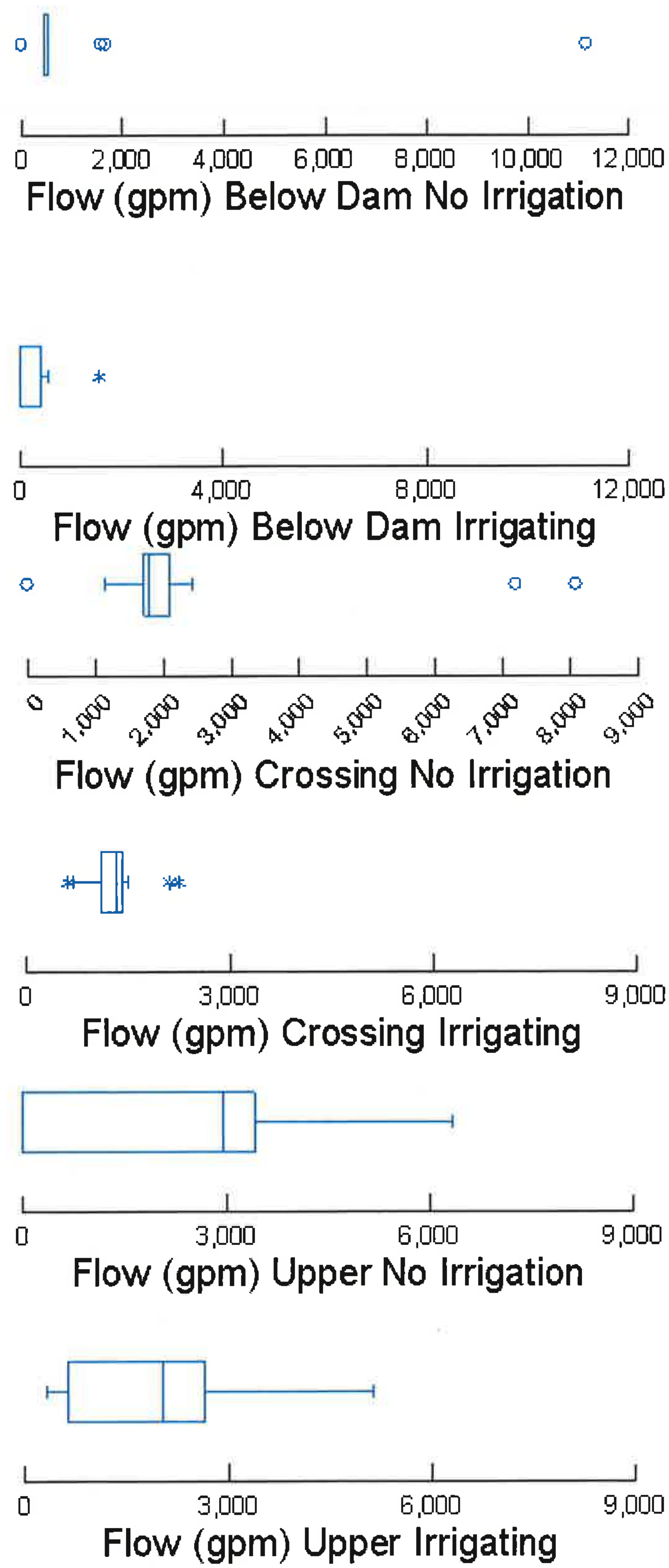

Figure 3

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

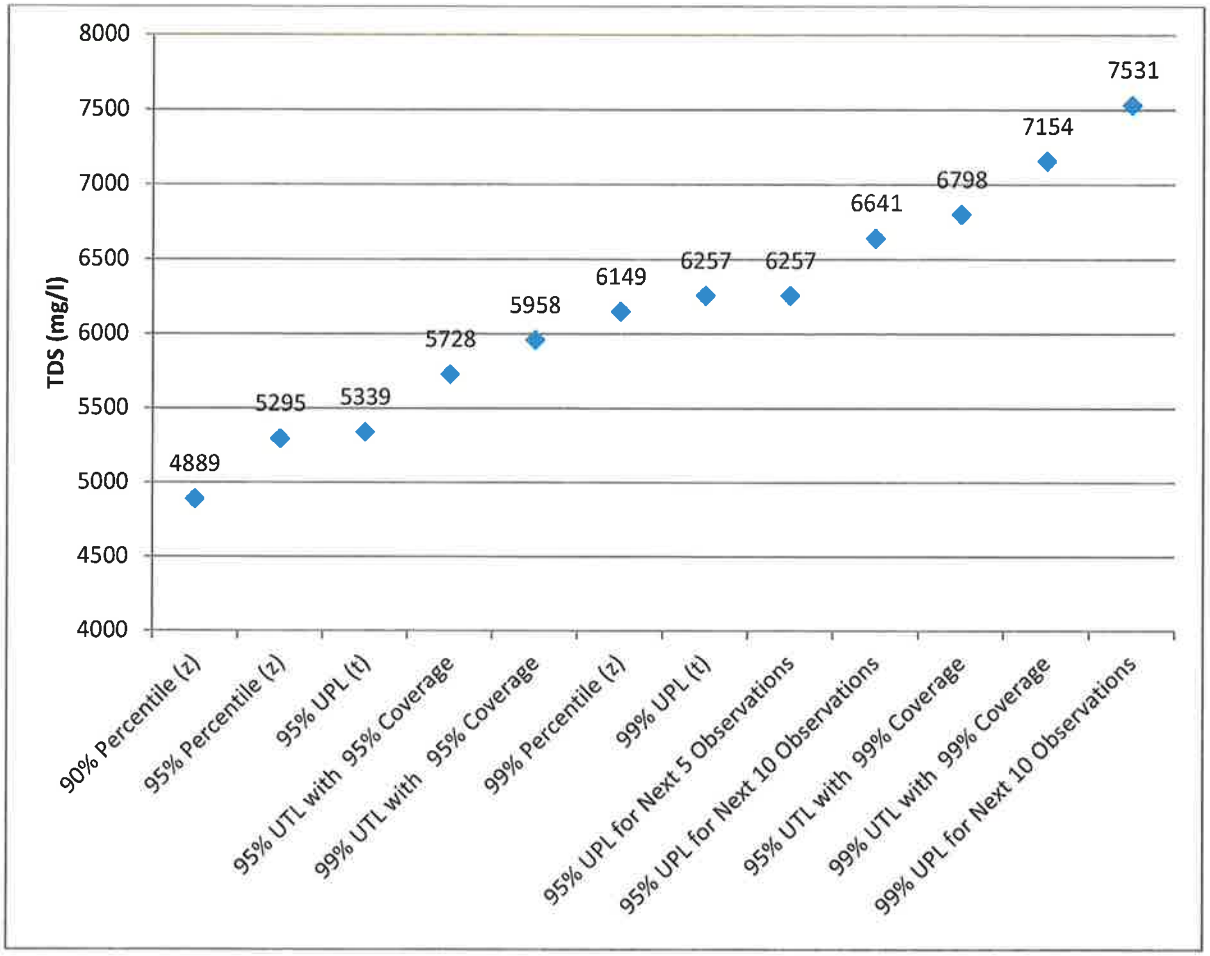

Figure 4

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

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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

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- 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.

5.62

Figure 1

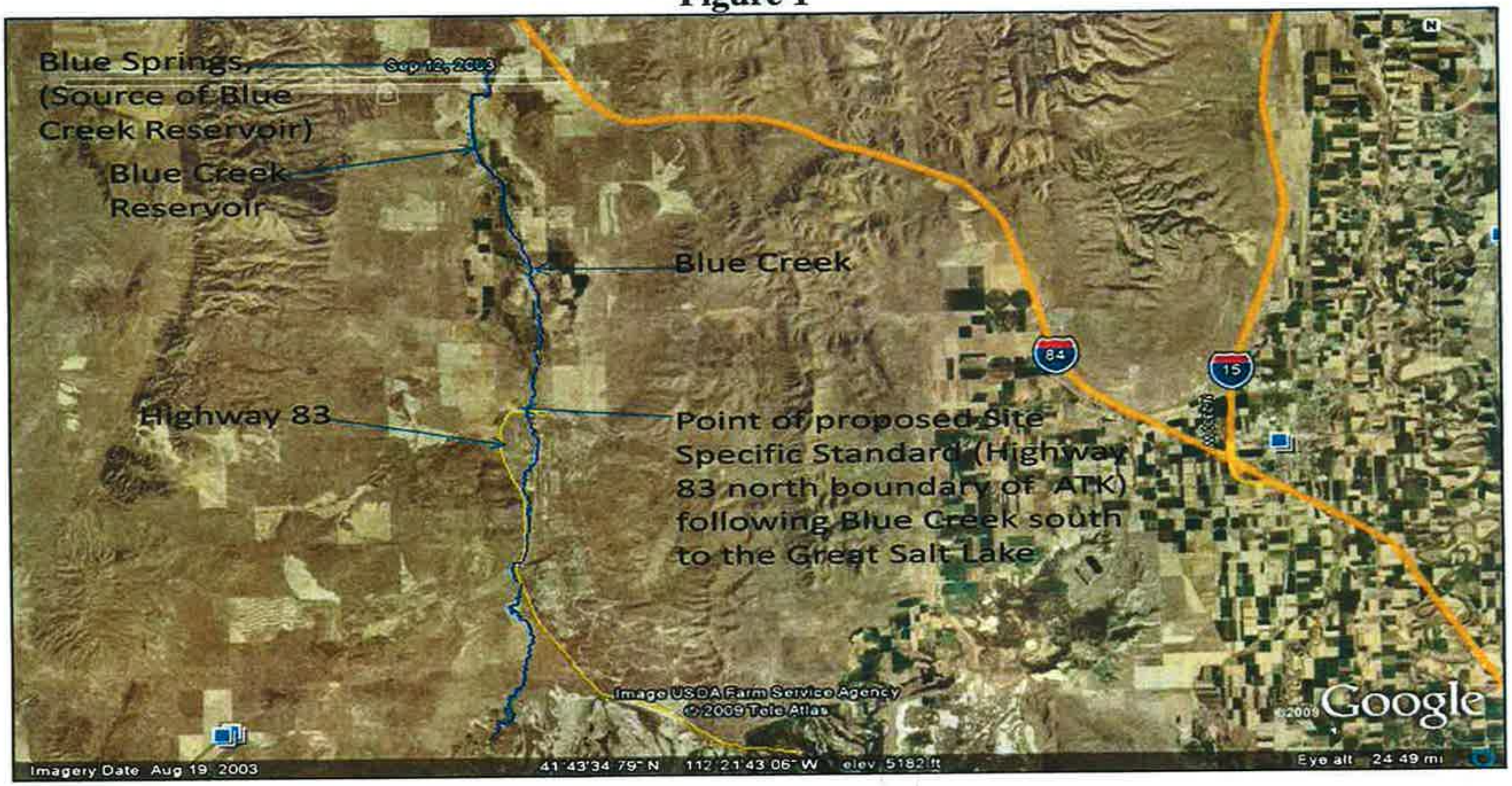
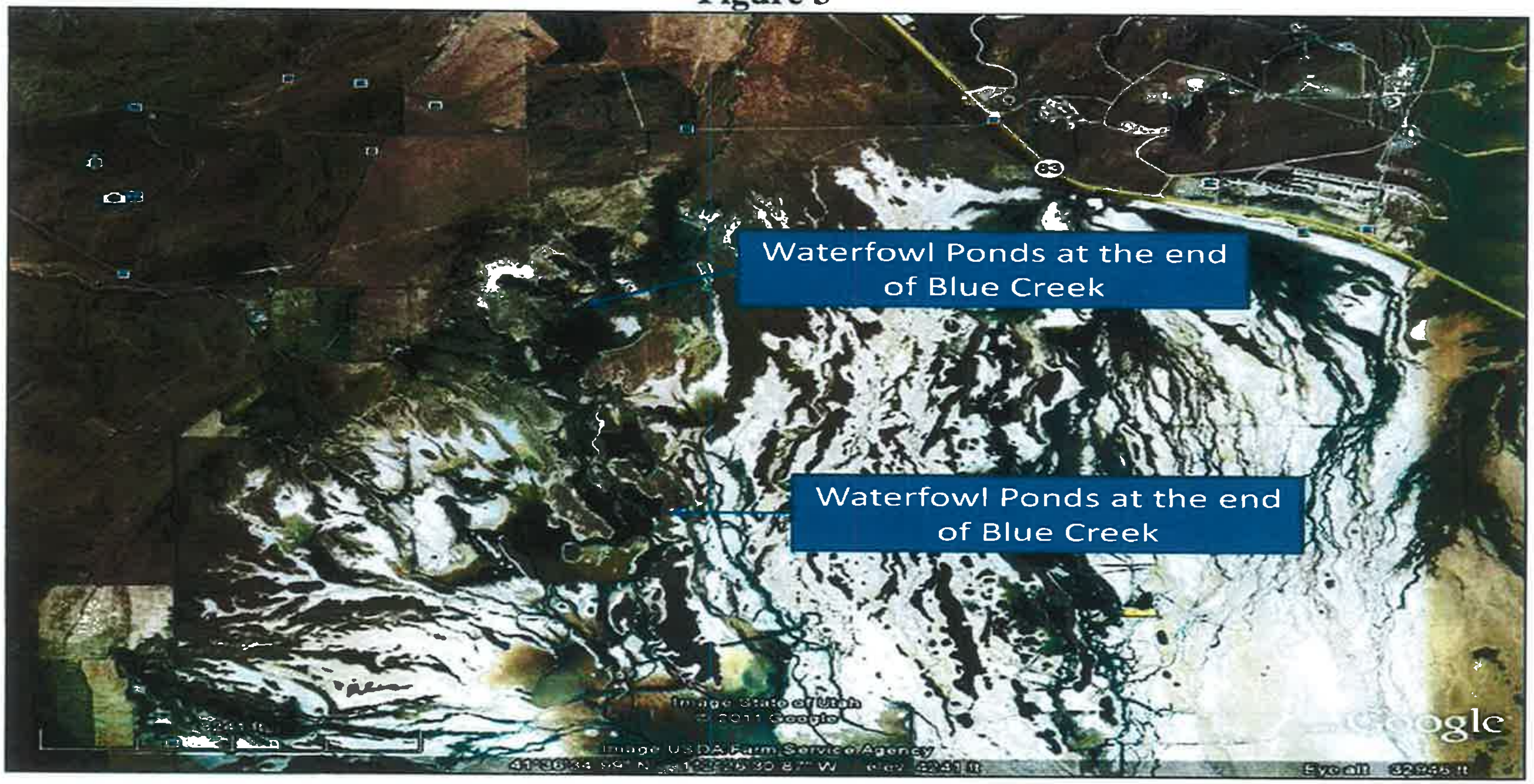

Blue Springs, (Source of Blue Creek Reservoir)
Sep 12, 2003
Blue Creek Reservoir
Blue Creek
Highway 83
Point of proposed Site Specific Standard (Highway 83 north boundary of ATK) following Blue Creek south to the Great Salt Lake
84
15
Image USDA Farm Service Agency
© 2009 Tele Atlas
©2009 Google
Imagery 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
Image State of Utah
© 2011 Google
Image USDA Farm Service Agency
Google

5.63

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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

BLUE CREEK VALLEY AREA

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

by

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U. S. Geological Survey

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

1972

ILLUSTRATIONS

TABLES

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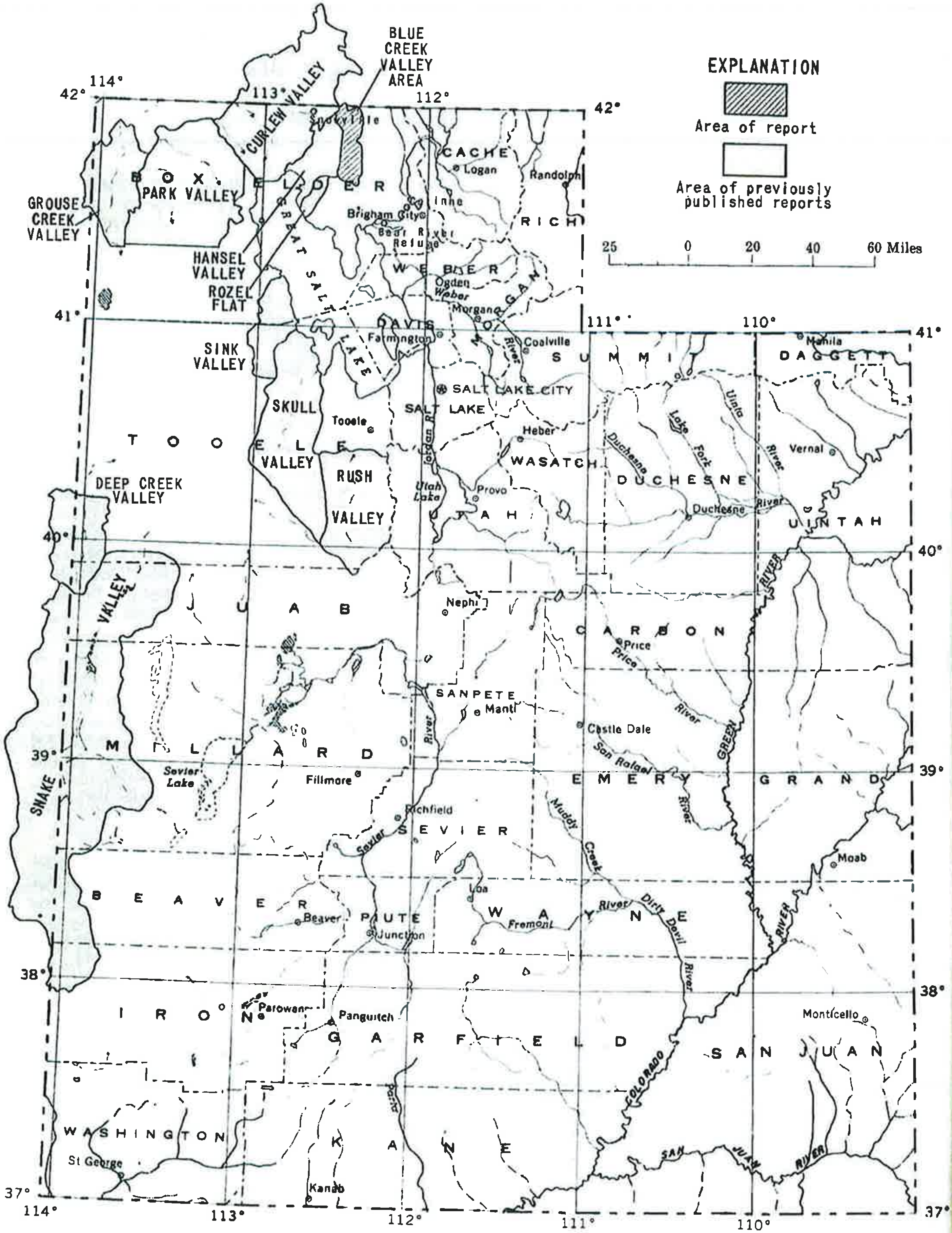

Figure 1.—Location of the Blue Creek Valley area and of other areas described in previously published reports in this reconnaissance series. (See list of technical publications at end of report.)

2 5.68

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

5.70

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
2.6M	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

5.71
8

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

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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.

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BASIC DATA

5.79

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.

5.80

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
(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 grey	16	54
(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

5.81

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: Determined	Dissolved solids: Calculated	Specific conductance (micromhos/cm at 25°C)	Sodium-adsorption ratio	pH	Agency making analysis
			Milligrams per liter																				
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	175	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 CO3 included as HCO3. 3/ Composite sample from 12 springs (Railroad Springs). 4/ Estimated.

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