A Preliminary Investigation into the Water Sources of Iron Fens in Mineral Creek Basin, San Juan County, Colorado

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EXECUTIVE SUMMARY

This project was initiated by the River Protection Workgroup (RPW), a consortium of water entities, conservation groups and governments in Southwest Colorado working to find protections that honor natural values while allowing water development to continue. The RPW wants to better understand the water sources that sustain fens (ground water fed, peat-forming wetlands) and iron fens (low pH fens) and what actions have the potential to adversely affect those sources. Iron fens are a rare and a unique type of fen that are found in the San Juan Mountains of Southwest Colorado. Basin Hydrology (Durango, CO) and Tetra Tech (Fort Collins, CO) completed the first phase, of an anticipated two phased investigation, to identify potential water sources at the Chattanooga fen, a large and well-studied fen-iron fen complex just north of Silverton, Colorado. The investigators conducted a literature review to better understand the fens and the geology of the area. Due to limited access for drilling and subsurface investigations, seismic surveys were initially completed to help identify depths to varying underground features as an aid to identifying limited drilling sites. Several wells and boreholes were completed using a large drill rig, a track-mounted drill rig, and by hand in addition to using several existing shallow wells. Inorganic water chemistry, hydrogen and oxygen isotopes and carbon-14 age dating were performed on new and existing wells and a spring in fall 2016 during baseflow conditions in order to identify, or exclude, potential water sources. Preliminary findings suggest that deep ground water is not a water source for fens due to its age (~ 15,889 years before present) compared with the age of the water in the fen's peat layer (~ 445 years before present). The deep groundwater system appears to be separated from the water in the fen's peat layer by a clay layer that is the perching layer that the fen rests on. The water in the fen's peat layer is likely from lands that lie west to northwest and upslope of the Chattanooga fen where volcanic altered tuffs provide the required pH-reducing reactions to produce the low pH waters required for iron fens. Land disturbing activities that would alter flow paths and quantity from source to discharge areas could impact the fen. In order to provide greater certainty and a more thorough evaluation of potential water sources, the second phase (Phase 2) of this investigation should include a second round of water chemistry sampling during spring high flow to better understand seasonality of the site's hydrology and geochemistry, as well as the spatial distribution of its chemistry and water age.

INTRODUCTION

Fens in the San Juan Mountains of southwest Colorado have been the subject of numerous ecological studies and reclamation efforts but no specific study has been conducted to identify their water source(s). It is important to know whether a fen's hydrology is primarily supported by local recharge and relatively shallow hillslope water migration or by distant recharge areas and local upwelling from deep sources. Knowing the hydrologic source(s) and how a proposed land use would alter the surface and subsurface landscape, one can make informed decisions on how to protect these unique wetland resources.

Numerous fens (but only a few iron fens – fens with a pH less than 4.5 (*Chimner, et al. 2016*) have been mapped in the San Juan Mountains near Silverton. A consortium of water entities, conservation groups and governments in Southwest Colorado formed the *River Protection Workgroup* (RPW). One of the RPW's goals is to identify the hydrology of these fens so that future development proposals can be evaluated for their potential effects to the fens and also to determine if agreement can be found on permanent protection tools.

Peatlands (i.e., lands with peat-accumulating wetlands) are either fens or bogs. Bogs are primarily precipitation driven systems while fens are primarily ground water driven systems (*Chimner, et al. 2006*). Peatlands in the San Juan Mountains are primarily supported by ground water and are therefore fens (*Cooper & Andrus, 1994*). Fens in the San Juan Mountains are 6,000 to 10,000 years old based on carbon dating; they began to form after mountain glaciers melted around 12,000 years ago (*Chimner, et al. 2008*). In order for fens to form and persist, relatively stable conditions are required over thousands of years. Fens are unique wetland ecosystems that are perennially saturated as the result of stable ground water inflow and site conditions. Perpetually saturated soils create anaerobic conditions, slow organic decomposition of hydrophytes, and allow organic matter to accumulate (*Chimner, et al. 2006*). A combination of cold climate, deep snowpack and monsoonal precipitation contribute to the formation of ground water systems that provide perennial discharge to these fens (*Chimner, et al. 2008*).

In order to determine the source(s) of ground water that feed fens in the Animas River Watershed of the San Juan Mountains, as well as to exclude sources, two different fen complexes were considered for investigation; Chattanooga and South Mineral Creek. The Chattanooga complex was ultimately selected as the focal point because it has been the subject of numerous ecological, geologic and shallow water table studies, while little is known about the South Mineral Creek fen. The Chattanooga fen is the largest fen in the San Juan Mountains (*Simon, 2004*) and the most accessible via a State Highway and U.S. Forest Service roads. It is located approximately six miles north of Silverton on the east side of State Highway 550 (Figure 1).

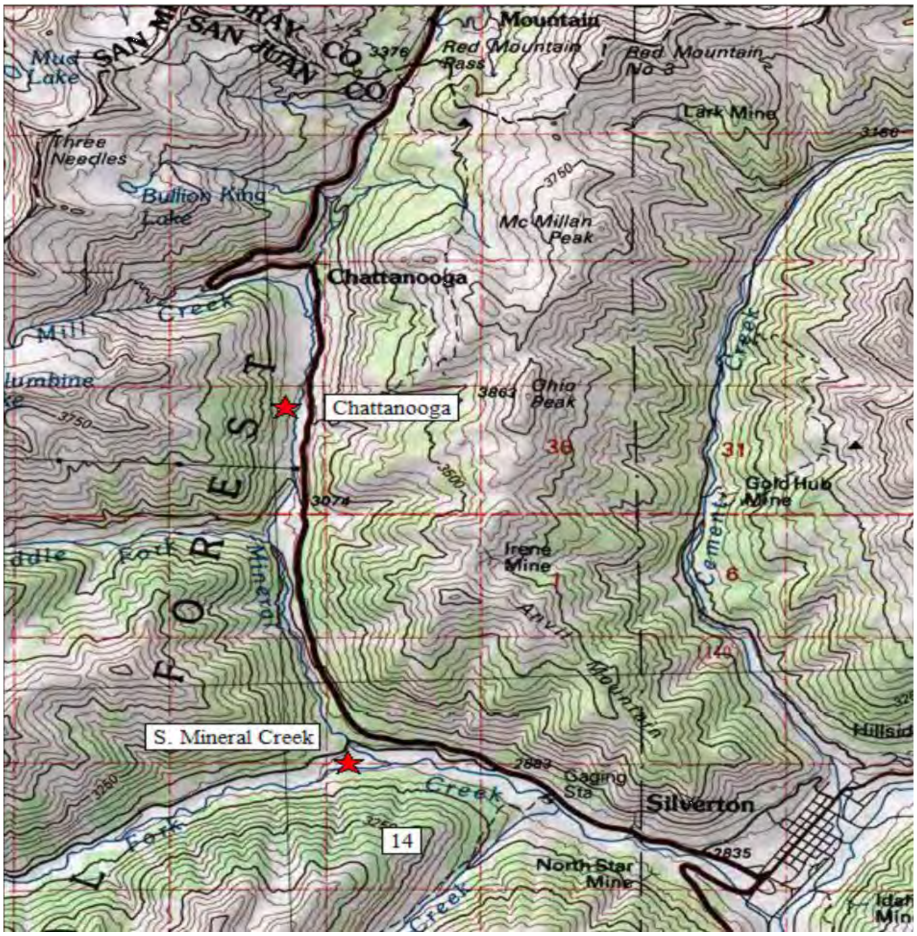


Figure 1. Location Map

<u>Study Area</u>

The Chattanooga Fen complex's elevation lies between 10,150 and 10,250 feet AMSL (above mean sea level, NAVD88). It is located on the east side of State Highway 550 and Mineral Creek. South-flowing Mineral Creek is located near the base of the highway and forms the eastern edge of the fen complex. Forest Service Road 820 (FS820) connects with Highway 550 just south of the site, where it crosses Mineral Creek as it climbs to the west and forms the south edge of this fen complex (Figure 2). On the steep hillside along the west side of the fen complex lies a gated, unnamed Forest Service two-track road (herein called the Gold Finch Road).

Figure 2. Chattanooga fen complex overview.

There are three main areas of the Chattanooga fen (Figure 3); a southern non-forested area (including fen units A-C), a northern forested area (including units E-H), and an eastern beaver pond area (USGS fens unit, *Chimner, et al. 2016*). Table 1 provides pH, fen type, and dominant vegetation characteristics of each fen unit (*Chimner, et al. 2016*).

Table 1. Chattanooga fen characteristics.

Unit	pH	Fen Type	Dominant Vegetation
A	7.18	fen	willow, bog birch, sedges
B/B2	3.44	iron fen	sedges, bog birch, Sphagnum mosses
C/C2	6.62	fen	sedges
D	5.65	iron fen	sedges, Sphagnum mosses
E	3.68	iron fen	sedges, bog birch (E only)
F	4.03-4.36	iron fen	Englemann spruce, sedges, bog birch, willow, Sphagnum mosses
G	3.96	iron fen	Englemann spruce, sedges, bog birch, Sphagnum mosses
H	3.97	iron fen	sedges, bog birch, Sphagnum mosses
I	4.04	iron fen	sedges
USGSfens	*4-6+*[1]	*varies*	*sedges, willow, bog birch*[1]

1 – 2016 observations by Basin Hydrology

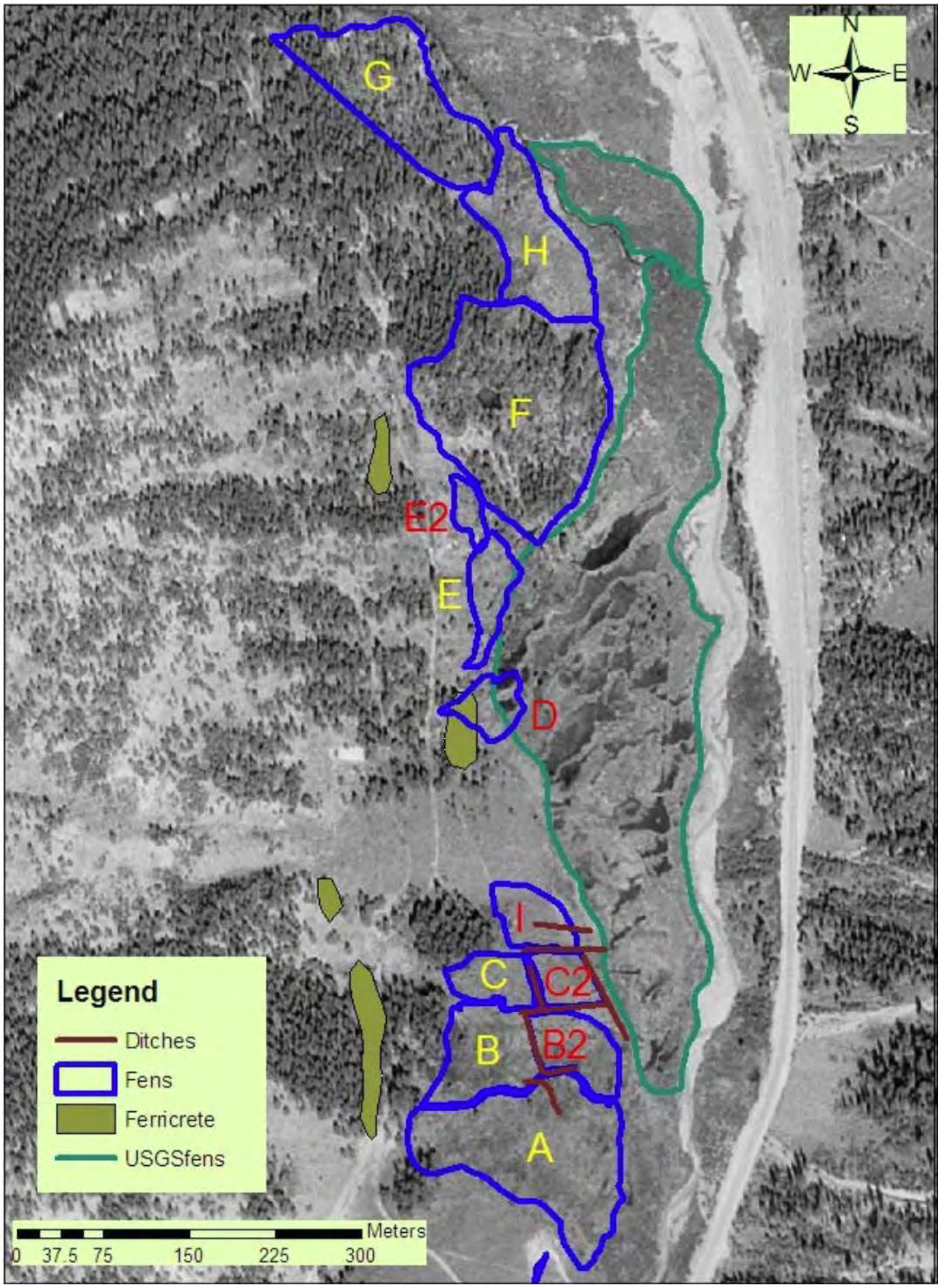


Figure 3. Chattanooga fen features.

Figure 4 identifies the watershed area directly upslope of, and connected to, the Chattanooga fen complex. This steep hillside directly upslope of the fen encompasses approximately 150 acres.

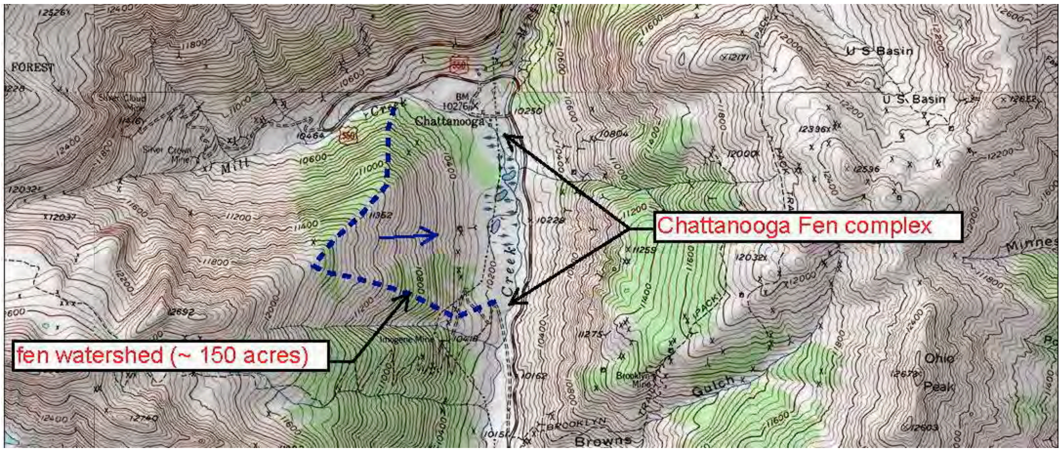


Figure 4. Chattanooga fen watershed.

LITERATURE REVIEW

Various local geologic reports and maps, as well as fen publications were reviewed before any field work began. This information helped form the basis for this investigation.

Fens are wetland systems supported by groundwater flow, while bogs are predominantly supported by precipitation. All peatlands in the Southern Rocky Mountains are hydrologically tied to groundwater that discharges at the base of mountain slopes, alluvial fans, and glacial moraines, making them fens (*Cooper and Andrus 1994*).

The process of fen formation is governed by ground water recharge and storage; aquifer water movement; and the discharge of ground water into the fen. The hydrologic sources of fens can be local or regional ground water systems which mean a fen system can be hydrologically altered from on-site and/or off-site activities (*Patterson and Cooper, 2007*).

Typical fens in the Southern Rocky Mountains have a range of pH values from slightly acidic (~pH 5.5) to slightly basic (pH > 7.5) depending on the type of bedrock that ground water feeding the fen comes in contact with (*Cooper and Andrus 1994, Cooper 1996, Johnson and Steingraeber 2003*). However, there are some very rare and unique fens in the Southern Rocky Mountains that are very acidic (pH = 3.0 - 4.5) due to the weathering of iron pyrite that naturally acidifies the groundwater that supports the fens (Cooper et al. 2002, Simon 2004). These fens are called “iron fens” because they occur in conjunction with thick limonite ($Fe_2O_3.nH_2O$) deposits. Iron fens have very unique plant communities that are often dominated by *Sphagnum* mosses, which are typically associated with acidic bogs in boreal and sub-boreal regions (*Copper et al. 2002*, *Chimner, et al. 2016*).

A 2008 study estimated that there are approximately 6,000 fens in the San Juan Mountains, occupying an estimated 19,000 acres (*Chimner, et al. 2008*). Two dominant hydrogeomorphic fen types were identified in that study: basin and sloping. Basin fens occur in concave features and infill through peat and sediment accumulation. Sloping fens occur where ground water discharges such as at a geologic discontinuity or a change in slope and were the most common hydrogeomorphic type encountered. Fen sizes range from to 0.5 to 50 acres with the average size being 3.0 acres. Peat layer thickness ranged between 1.3 ft. and 13 ft. Chimner et al. (2008) performed limited ground truthing but determined that the vast majority of the inspected fens were in good to excellent condition with a small percentage determined to be in fair or poor condition. Roads, recreation, development, mining, grazing and drainage were the most common sources of fen disturbance.

The 2008 study (*Chimner, et al. 2008*) identified three types of sloping fens: hillside, valley bottom, and toe slope. Hillside fens are those that lie on a hill slope with water flowing from higher to lower elevation through the fen. The valley bottom fen receives ground water from all the adjacent slopes above the fen. Toeslope fens occur at the bottom (toe) of a slope where the gradient transitions from steeper to flatter and where ground water is forced to the surface. The Chattanooga fen is considered to be a toe slope fen (*Chimner, et. al 2008*).

The regional geology, mineralization and hydrothermal alteration of the Animas River watershed within the western San Juan Mountains was mapped by Yager and Bove (2002) and is described in detail by Yager and Bove (2007) and Bove et al. (2007). The western San Juan Mountains has undergone several periods of deformation dating back to the Precambrian, including cycles of deposition, folding, metamorphism, and pluton emplacement (*Yager and Bove, 2007*). Major mountain building episodes that affected the region include the San Luis-Uncompahgre uplifts during the Pennsylvanian and Permian, and the Laramie orogeny, resulting in a dome uplift about 65Ma (million years ago). Mid-Tertiary volcanism in the region started between 35 and 30 Ma, forming thick accumulations of intermediate-to-silicic composition volcanic rocks (*Yager and Bove, 2007*), and burying much of the pre-Oligocine geologic record. From 30 to 23 Ma, eruptions formed multiple calderas depositing lava and pyroclastic material over an area of more than 25,000km^2 in southwest Colorado. Two caldera events occurred in the study area: the San Juan (28.2 Ma) and the nested Silverton caldera (27.6 Ma) (*Yager and Bove, 2007)*.

The Chattanooga fen is situated along the western margin of the Silverton caldera (27.6 Ma, Figure 5). The western margin of the caldera is defined by a series of northward trending caldera-bounding arcuate ring faults and fractures (*Yagar and Bove, 2002*). These ring fractures and tangential radial fractures provided conduits for magmas and hydrothermal fluids, which resulted in regional and localized hydrothermal alteration, mineralization, and ore deposition (*Bove, 2007*).

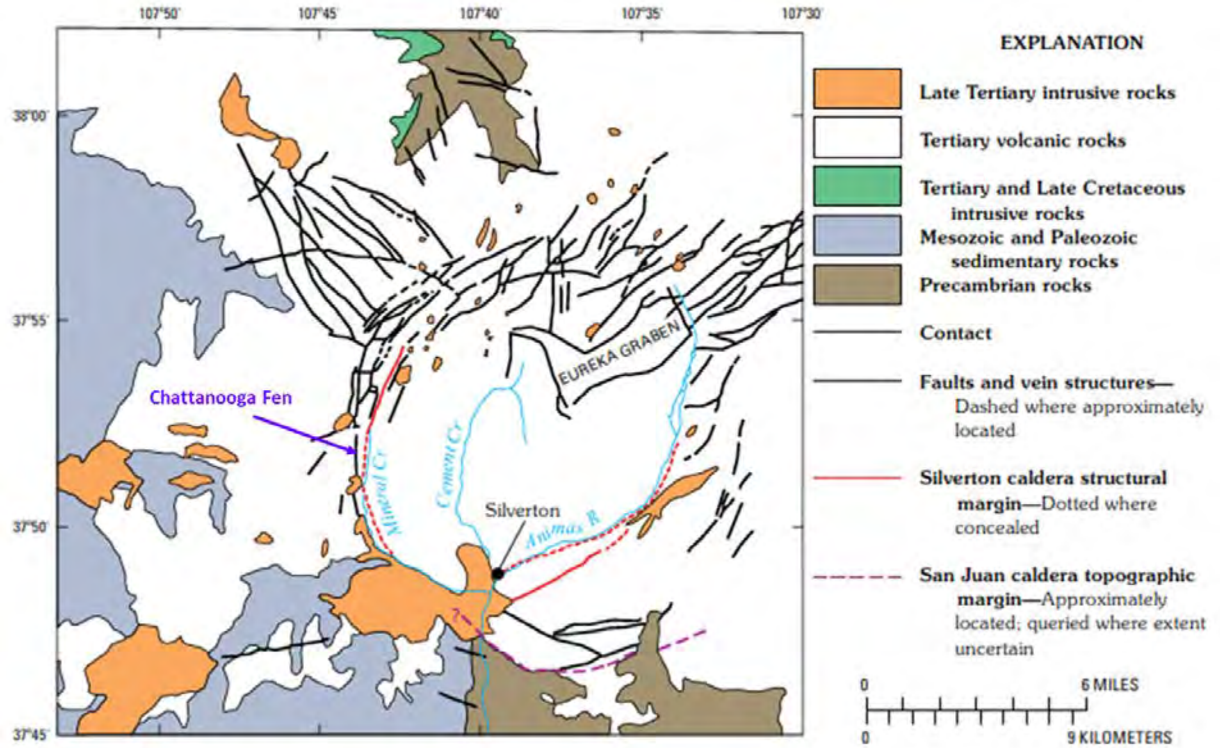


Figure 5. Generalized regional geology of the Animas River watershed.

The Chattanooga site is shown along western Silverton caldera margin (Figure 5 modified from *Yager and Bove 2007*). Also shown are caldera-bounding arcuate faults as well as the Animas River and its tributaries, including Mineral Creek.

Bedrock underlying the Chattanooga fen site and extending regionally westward is mapped as lower Oligocene (35-30Ma) San Juan Formation (Tsj, Figure 6, *Bove and Yager, 2002*), consisting of intermediate-composition lava flow and volcanoclastic deposits. East of the fen site and east of Mineral Creek, bedrock is mapped primarily as upper Oligocene (27.6 Ma) Silverton Volcanics (Tsv, Figure 6), consisting intermediate-to-silicic composition lava flow and volcanoclastic deposits. The bedrock was regionally affected by low-grade propylitization (Figure 7) resulting from thermal events related to the San Juan-nested Silverton calderas (*Bove et al., 2007*). The propylitic mineral assemblage comprise chlorite, epidote, calcite, illite, and freshly to weakly altered feldspar (*Bove et al., 2007*). In addition, north-northeast trending areas of quartz-sericite-pyrite (QSP) alteration assemblages are mapped within the regional propylitic mineral assemblage, both west and east of Mineral Creek (Figure 7). These are mapped by Duggan (2009) as phyillic altered tuff along the slope west of the fen site (Figure 8, *Duggan, 2009*). The QSP assemblage is characterized by complete replacement of the primary igneous plagioclase, potassium feldspar, and groundmass by a pervasive fine-grained quartz, crystalline illite (sericite), and disseminated or fracture-filling pyrite (Bove et al., 2007). The QSP alteration occurred in the Red Mountain area along with acid-sulfate alteration, hydrothermal brecciation, and silver-cooper-arsenic ore deposition related to dacite porphyry magma intrusion at about 23 Ma (Bove et al., 2007).

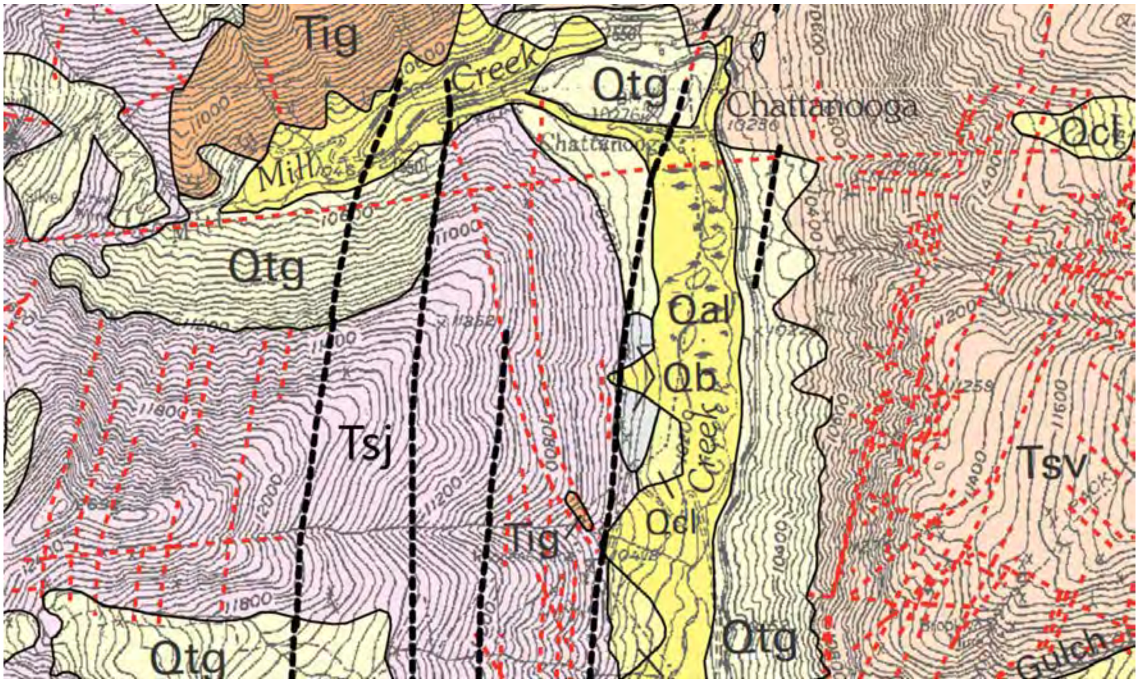


Figure 6. Generalized geologic map of the Chattanooga fen site*.*

Holocene bog deposits (Qb) are located at the toe of east-facing talus slope mapped as San Juan Formation (Tsj, Figure 6). Silverton Volcanics (Tsv) lie east of Mineral Creek. Inferred arcuate-ring faults are depicted as black dashed lines, and inferred mineralized, altered veins and fissure are depicted by red dashed lines (Figure 6).

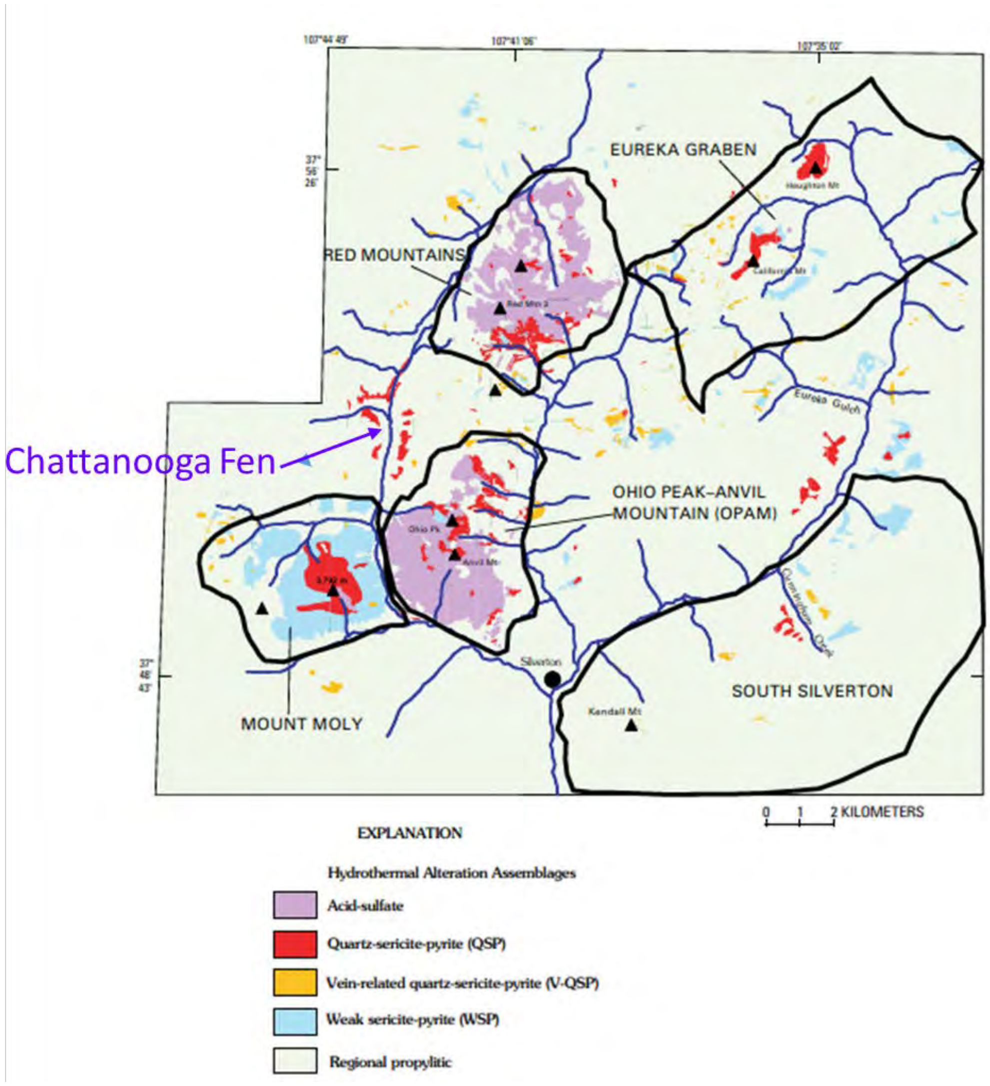


Figure 7. Generalized map of hydrothermal alteration assemblages in the Animas River watershed.

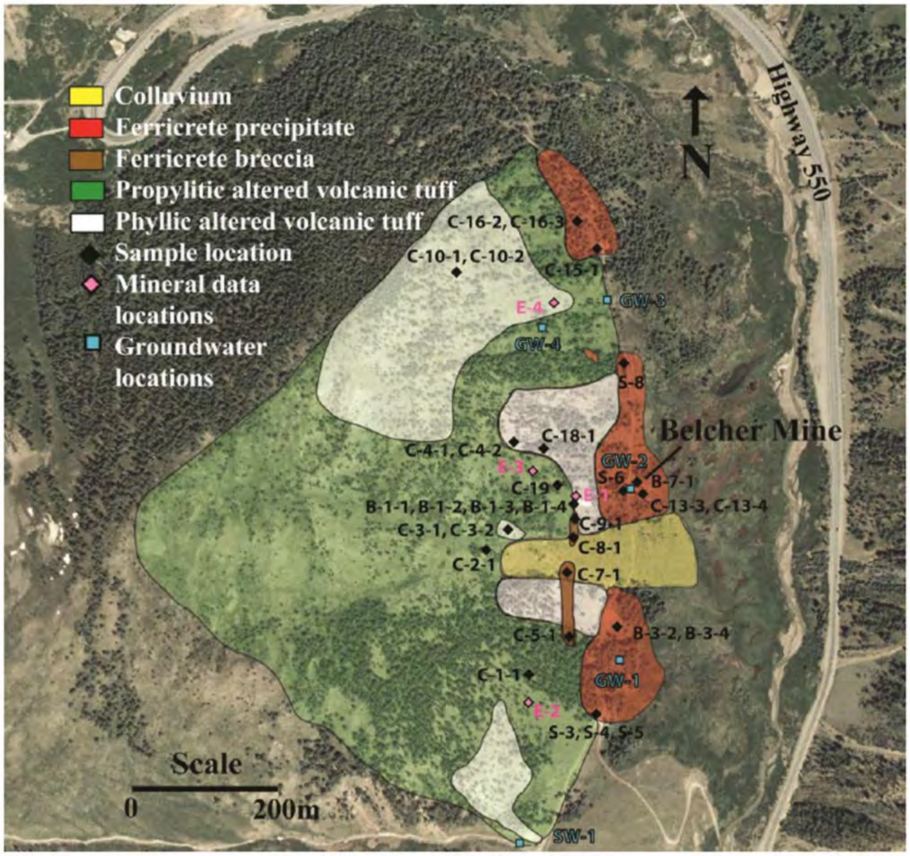


Figure 8. Detailed geology and alteration map of the slope west of the Chattanooga fens.

Sample, mineral data, and groundwater locations identified on the map (Figure 8) from Duggan (2009). Groundwater location GW-3 is identified in this study as the Gold Finch Rd spring, and the Belcher Mine is identified in this study as the Gold Finch adit (Figure 8).

Surficial deposits at the Chattanooga fen site comprise Holocene and Pleistocene colluvium, fan, and glacial deposits largely on the lower slopes west of Mineral Creek (c,f, m, respectively, Figure 9, *Blair and Yager, 2002*) and Holocene bog, terrace, and floodplain deposits (b, t/b, and fp, respectively, Figure 9) below the toe of the slope within the Mineral Creek basin. The colluvium and glacial deposits formed as a result of mass wasting of weathered bedrock, accumulating on the slopes into the creek basins, while alluvial processes have deposited alluvial fans and flood-plain sediments with the Mineral Creek drainage. These surficial deposits provide porous and permeable pathways for surface-water infiltration and groundwater flow (*Yager and Bove, 2007*) and are also the primary precipitation sites for iron-rich water initially derived by the oxidation of pyrite.

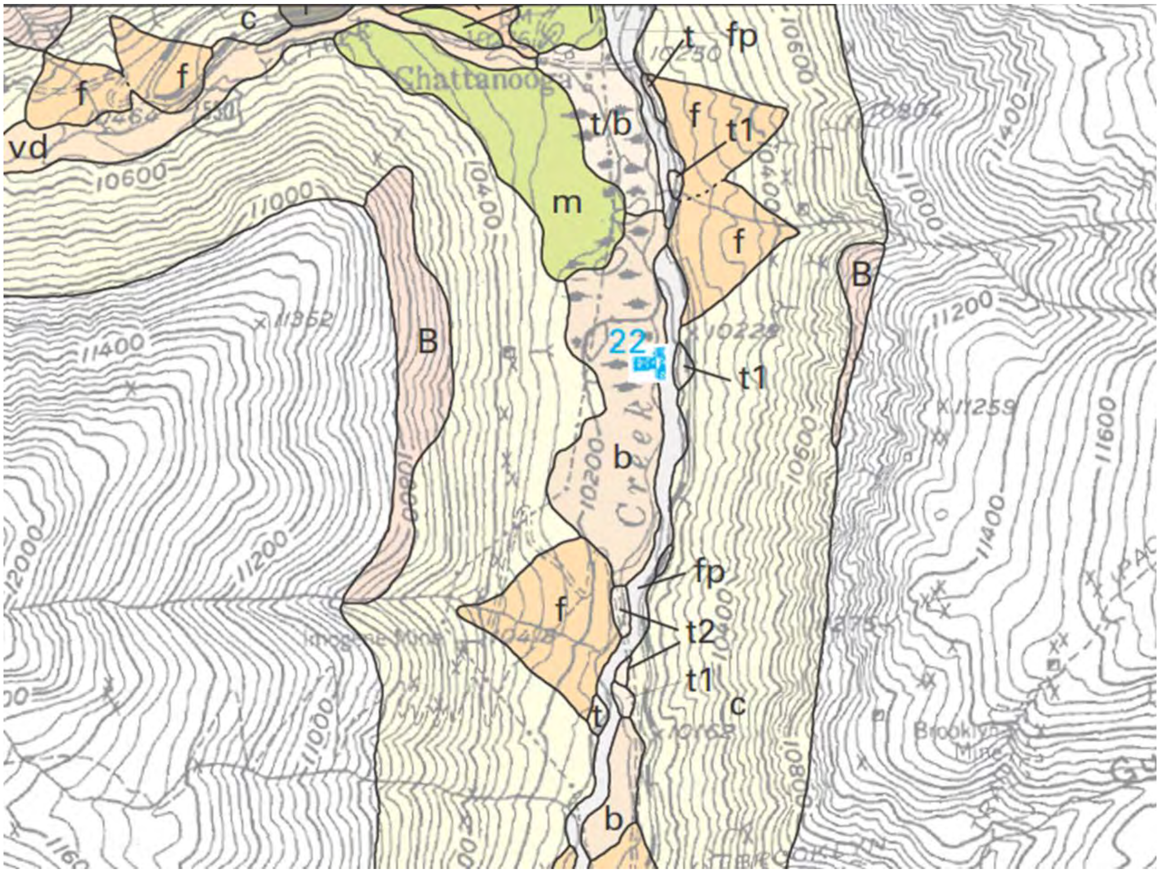


Figure 9. Surficial geology of the Chattanooga fen site.

The Chattanooga fen Holocene bog (b) and terrace bog (t/b) deposits are located west of the floodplain deposits (fp) of Mineral Creek (Figure 9). Colluvium (c), fan (f), and/or glacial deposits (m) overlie San Juan Formation and Silverton volcanic bedrock on both sides of Mineral Creek.

Simon (2004) suggests that fens are perched hydrologic systems. Underlying a fen is an impermeable ferricrete and-or clay layer that isolates the surface/near-surface hydrology from deeper ground water sources. Ferricrete is a hard, impervious layer inches to feet thick that forms when the precipitation of iron oxides occurs. This precipitation process results in the cementing of colluvial, alluvial and organic material to form the hard ferricrete layer. Ferricrete and other iron deposits are found throughout the Animas River watershed, and iron deposition environments can be found not only in fens, but also at springs, seeps, mine adit discharges, and waste-rock drainages (*Stanton et al., 2007*). Ferricrete and iron oxide deposits are found at the Chattanooga site on the lower slope west of the fens (Figure 8).

South of the Chattanooga fen site, iron fens are located along the South Fork Mineral Creek drainage. North of the creek lies a large area of hydrothermal alteration centered on Mount Moly (Figure 7). This area contains a core of acid-sulfate and QSP alteration, grading outward into weak sericite-pyrite and hydrothermal assemblages, and finally into the regional propylitic assemblage (*Bove et al., 2007*).

A geochemical study of iron fens within the Animas River watershed (*Stanton, et al, 2007*) indicates that all the iron fens form in a similar manner. Analysis of geochemical data demonstrates that oxidation of ferrous iron (transported in low-pH, low-dissolved oxygen groundwater) to ferric iron is the primary mechanism of formation of the iron fens. According to the generic model presented by Stanton, et al, (2007), groundwater acquires ferrous iron via dissolution of abundant sulfide minerals (primarily pyrite) as it circulated through the regional rock mass. Upon emergence of groundwater at the surface, usually along structures such as faults or fractures, or where groundwater intersects surface flow, ferrous iron is oxidized to ferric iron by dissolved atmospheric oxygen, biogenic molecular oxygen, or iron-oxidizing microbes, forming fine-grained, crystalline and amorphous iron oxyhydroxide precipitates.

Dissolution of sulfide minerals in groundwater leads to acid weathering of silicate and sulfide minerals and produces high concentrations of a host of aqueous species, including, but not limited to, aluminum, calcium, iron, cooper, and zinc. In the Red Mountain area, water from background springs and streams that interact with QSP-altered rocks tends to have the lowest pH values, and highest dissolved cation and metal concentrations of all water samples collected in the Animas watershed (*Bove et al., 2007*).

Hydraulic conductivity rates in geologic strata are not uniform but can vary widely depending on numerous variables. Ranges of hydraulic conductivity for unconsolidated sediments (Fetter, 1988) include:

Material	**Hydraulic Conductivity (m/day)**
Clay	10^{-6} to 10^{-3}
Silt, sandy silts, clayey sands, till	10^{-3} to 10^{-1}
Silty sand, fine sands	10^{-2} to 1
Well-sorted sands, glacial outwash	1 to 100
Well-sorted gravel	10 to 1000

Colluvium, as found in the Chattanooga study area, can have a mix of grain sized from clay to gravel, and therefore would be expected to have a hydraulic conductivity greater than that of clay but less than that of a well-sorted gravel. Rates within volcanic tuffs can vary from 10^{-5} to 10 meters/day (*Smyth, et al. 2006*) to 10^{-5} to 15 meters/day (*Belcher, et al. 2002*).

Chimner, et al (2010) reviewed distribution, types and restoration priorities for fens in the San Juan Mountains. Of the fens sampled, the majority (66%) are intermediate fens (pH between 5.0 and 6.5), 23% are rich fens (pH greater than 7.0) and 1% are iron fens (pH less than 4.5). Watersheds with calcareous bedrock have the highest Ca^{+2}, Mg^{+2}, and Na^{+} concentrations in groundwater while intrusive igneous watersheds had the highest concentrations of K^{+} and volcanic watersheds had highest groundwater concentrations of Fe^{+3} (Chimner et al 2010).

A San Juan County Biological Assessment completed in 2003 (*Lyon, et al, 2003*) suggests the Chattanooga iron fens are fed by ground water originating on the slopes to the east of Highway 550, which lie within the caldera, and flowing west beneath the highway and Mineral Creek before discharging near the toe of the slope on the west side of the valley. High flows within Mineral Creek are also noted as another water source for the fen.

Iron fens are dependent upon highly acidic water from springs and seeps, although surface water helps maintain high water tables (*Simon 2004*). Simon (2004) states that little hydrothermal alteration occurs on the west side of Mineral Creek (except near Mount Moly) and, as such, west-side ground water springs can be expected to be near neutral, compared with lands on the east side of Mineral Creek that have been subject to a high degree of hydrothermal alteration. Simon (2004) indicates that the low pH water source for the Chattanooga iron fens originates on the east side of Mineral Creek and flows to the west side of Mineral Creek over an impervious clay and-or ferricrete layer.

METHODS

To develop an understanding of the study site's hydrologic source(s), the project team conducted preliminary field assessments, followed by analytical methods including seismic surveys, well drilling and installation, water chemistry and age-dating analyses and discharge measurements into and out of the fen. Field work began in July 2016 with the seismic surveys and concluded in October 2016, with water chemistry sampling and discharge measurements.

Preliminary Field Assessments

A number of field measurements and observations were performed by the project team members to better understand the Chattanooga fen's layout, topography, surficial geology adjacent to the west side of the fen, pH variation, distribution and depth of previously installed water level monitoring wells, surface flow patterns, surface flows into and out of the fen, discharge areas originating from within the fen, and Mineral Creek's interface with the fen.

Field assessments and information obtained from the literature review were used to identify locations where seismic surveys would be performed. The results of the seismic survey, together with the field observations, literature review, locations of existing monitoring wells, and the physical accessibility (including overhead power concerns), were used to propose locations for truck and track-mounted drilling operations to install additional wells. Additional shallow wells were installed to complement existing and project-installed wells.

All project features (e.g., wells, seismic lines, etc.) were surveyed vertically to determine their elevation using a National Geodetic Survey monument (NGS ID: Z 439 located along Highway 550) and surveyed horizontally using a sub-meter GPS unit. Figure 10 identifies the location of these project features, discussed below. A series of elevation benchmarks have been established along Gold Finch Road and FS820should elevation data be needed in the future.

Seismic Surveys

Seismic geophysical surveys were performed during the week of July 18, 2016 to determine subsurface features such as the depth to the water table, depth to bedrock, subsurface stratigraphy, faulting, etc. These surveys were also used to characterize variations in bedrock seismic velocity along the three survey lines (Figure 10) that might provide insight into more permeable zones that were anticipated at shallow depths and which might exhibit enhanced groundwater flow. Details of data acquisition, processing, analysis and interpretation are provided in a report titled Final Report on Seismic Refraction Surveys Chattanooga Fen Site, Silverton, CO August 2016 (Appendix A).

Figure 10. Chattanooga fen project features.

<u>Exploratory and Monitoring Well Installation</u>

Authorizations

Authorizations from the Colorado Division of Water Resources (CDWR) were obtained for all project-installed wells. Prior to drilling wells, a Notice of Intent to Construct Monitoring Hole(s) was submitted to and accepted by the (CDWR) for up to 5 wells (Appendix C). Upon completion of drilling and installation, the required Well Construction and Yield Estimate Report was submitted to the CDWR for wells GF-1S, GF-1D and FB3 (Figure 10, Appendix D). All boreholes (FS820-1, FS820-2 and GF-2, Figure 10) were sealed and did not require any post-drilling submittals to CDWR.

An authorization from the U.S. Army Corps of Engineers (USACE) was obtained for all project-installed wells installed within a wetland (i.e., the fen). Prior to installation, a Pre-Construction Notification for Nationwide Permit 5 (NWP 5, Scientific Measurement Devices) was submitted for two to three wells within the fen complex (Appendix E). Authorization for NWP 5 was issued by the USACE (Appendix F). Upon installation of three wells, the required Compliance Certificate, with pre- and post-installation photographs, was submitted to the USACE (Appendix G).

Wells

Borehole drilling was performed to assess the stratigraphy and subsurface geologic characteristics of the site, to help interpret seismic survey data, and/or to install monitoring wells for collection of water chemistry samples and water level data.

Four boreholes and a pair of nested wells (GF-1D and GF-1S) wells were drilled and installed by McCracken Well Drilling, Inc. (Montrose, CO) on September 13-16, 2016 using a large air rotary drill-rig truck (Table 2). A deep fen well (FB-3) was installed by Scott Drilling, Inc. on September 28, 2016 using a small, track mounted hollow-stem auger rig (Table 2). The wells and boreholes were logged by Tetra Tech and Basin Hydrology. The Gold Finch Road (GF-1 and GF-2) as well as the FS Road 820 (FS820-1 and FS820-2) boreholes were logged via drill cuttings, while the deep fen piezometer was logged via split spoon and continuous samplers. Monitoring wells using 2" (I.D.) PVC pipe was installed at boreholes GF-1 (which includes nested wells GF-1D (deep) and GF-1S (shallow) and FB3.

A 9.5 feet deep well was installed by hand in a sedge-Sphagnum moss community approximately 5 feet west of a visibly upwelling open-water feature that was producing approximately two gallons per minute. This well, FB1, is a 1.25 inch diameter (I.D.) stainless steel drive point with screening in the lowest 3 feet and solid stainless steel pipe above that. The peat depth at this location is approximately 8 feet (based on change in resistance during installation) with a suspected clay layer below the peat (based on change in resistance during installation). A second stainless steel drivepoint well was installed in the same sedge-Sphagnum moss community 5 feet north of FB1, but directly adjacent to the upwelling open-water feature. This well FB2 extends into the peat layer 3 feet and contains full-length screening. FB2 was installed because FB1's water level never matched the upwelling pond's water level and was slow to recharge once dewatered. This slow recharge was likely due to penetration into the underlying clay layer and/or partial clogging of the screen during installation.

Borehole and well/piezometer locations are shown on Figure 10. A summary of borehole and well completion data is provided in Table 2. Graphical borehole and well completion logs are provided in Appendix B.

Table 2. Summary of Borehole and Well Completion Data.

Borehole ID	Well ID-type	Coordinates[1]		Ground Elev.[2]	Install Date	Total Depth	Screen Interval	Filter Pack Interval
		Latitude	Longitude	(ft amsl)		(ft bgs)	(ft bgs)	(ft bgs)
GF-1	Nested deep well (GF-1D)	N 37.870422	W 107.727045	10273.1	9/14/16	100	78-98	77-98
	Nested shallow well (GF-1S)				9/14/16	64	37-57	36-64
FS820-1	borehole	N 37.864324	W 107.725394	10182.1	9/15/16	60	NA	NA
FS820-2	borehole	N 37.863161	W 107.724624	10148.7	9/16/16	60	NA	NA
GF-2	borehole	N 37.867419	W 107.726613	10252.9	9/16/16	100	NA	NA
FB1	hand well	N 37.870547	W 107.726245	10251.0	9/15/16	9.5	6.5-9.5	NA
FB2	hand well	N 37.870558	W 107.726238	10250.9	9/26/16	3	0-3	NA
FB3	hand well	N 34.870528	W 107.726583	10254.7	9/27/16	25	20-25	19-25

Notes:
(1) horizontal datum: NAD83 using a National Geodetic Survey monument
(2) Elevation datum: NAVD88 using a National Geodetic Survey monument
ft amsl= feet above mean sea level
ft bgs = feet below ground surface

The project's Scope of Work (SOW) contemplated installing two pairs of nested wells; one located on the west side of the valley along the Gold Finch Road and the other at the south end of the fen adjacent to FS820. Their purpose was to evaluate upward hydraulic gradients from the underlying bedrock that was suspected to be a fen water source. The western nested wells were installed at GF-1. However, no wells were installed on the south end of the valley because the seismic survey indicated a thick clay layer, with the top of bedrock in excess of 100 feet deep in the southeastern portion of valley bottom. Drilling of borehole FS820-1 encountered clay to a depth of 60 feet before drilling was terminated. Given the thick clay layer and limited budget for drilling, it was decided that obtaining additional subsurface geologic data would be more useful for development of the conceptual site model. Therefore, drilling additional boreholes for geologic logging and seismic survey interpretation was performed in lieu of than drilling the additional set of nested wells on the south end of the fen.

A deep well was installed in the fen (FB3) to determine the peat depth, characterize the underlying geology below the peat and to collect water samples. A low ground pressure, track mounted drill-rig was used because hand augering was limited to a depth of approximately 7 feet. As a result of additional boreholes and the deep fen piezometer at Chattanooga, no drilling or hand-installed wells were possible at the South Mineral Creek site due to budgetary constraints.

Water Chemistry

Surface and groundwater sampling was performed on October 3 and 4, 2016 by Tetra Tech and Basin Hydrology. Sampling was performed at three surface and nine groundwater sites, including six wells, one spring, and one mine portal. A summary of sample location and data collection is provided in Table 3. Sample locations are shown in Figures 10. At each sample site, field parameter data was measured and samples were collected for inorganic chemical, isotopic composition, and age dating analysis. A list of field parameters and chemical and isotopic analytes by site are provided in Table 3.

Table 3. Chattanooga fen water sample location and data collection summary.

		Coordinates[1]			Analysis Performed		
Sample ID	Location Comments	Latitude	Longitude	Sample Date/Time	Inorganic	^{14}C[2]	δD and $\delta^{18}O$[3]
MinCk DS	Mineral Creek downstream of site	N 37.863683	W 107.724716	10/3/16 11:00	x		
MinCk US	Mineral Creek upstream of site	N 37.871753	W 107.724032	10/3/16 12:00	x		
Piezo 32C	Well in Fen Unit B/B2 (Figure 3)	N 37.865286	W 107.725766	10/3/16 13:24	x		
Piezo 30C	Well in Fen Unit B/B2	N 37.865415	W 107.725774	10/3/16 14:25	x	x	x
FeC1	Surface water pooled in ferricrete, Fen Unit B/B2	N 37.865631	W 107.726270	10/3/16 15:00	x		
GF Adit	Adit discharge	N 37.868153	W 107.726828	10/3/16 14:15	x		
GF Adit 2	Adit discharge (duplicate)	N 37.868153	W 107.726828	10/3/16 14:15	x		
GF Rd Spg N	Spring discharge on Gold Finch Rd west of Fen Unit F	N 37.870834	W 107.727126	10/4/16 10:20	x	x	x
GF-1D	Well on Gold Finch Rd west of Fen Unit F	N 37.870422	W 107.727045	10/4/16 11:20	x	x	x
GF-1S	Well on Gold Finch Rd west of Fen Unit F	N 37.870422	W 107.727045	10/4/16 12:46	x	x	x
FB2	Shallow Well in Fen Unit F	N 37.870558	W 107.726238	10/4/16 14:50	x	x	x
FB3	Deep Well in Fen Unit F	N 37.870516	W 107.726576	10/4/16 14:20	x	x	x

Notes:

(1) horizontal datum: NAD83 using a National Geodetic Survey monument

(2) ^{14}C is radiocarbon for age dating
(3) Oxygen ($\delta^{18}O$) and hydrogen (δD) isotopes

Photo 1. FeC1 sample location on top of an exposed ferricrete layer.

Field parameter sampling of surface, spring, and mine discharge water was performed in accordance with accepted industry practices for water quality investigations. Sampling of wells was performed using the micro-purging method modified from the U. S. Environmental Protection Agency guidance titled Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures (*Puls and Barcelona, 1996*). Purging and sample collection was performed using only disposable equipment, including tubing, filters, and collection containers, and sample bottles obtained certified clean from the analytical laboratory. Pumping was through a peristaltic pump using silicon tubing, with the tubing intake placed approximately at mid-screen, or near the bottom in the case of the wells (Piezo 32C and Piezo 30C) and piezometer (FB2). Samples from wells were only collected after stabilization of field parameters (i.e., pH, specific conductance, turbidity, and temperature).

Samples for radiocarbon (^{14}C) and $\delta^{13}C$ (a measure of the ratio of stable isotopes ^{13}C:^{12}C) of dissolved inorganic carbon (DIC) analyses require collection in a CO_2-free atmosphere. To accomplish this, samples for ^{14}C and $\delta^{13}C$ of DIC analyses were collected by first pumping from the intake at the well screen or seep discharge through the silicon tubing to fill the tube, then attaching the discharge end of the tubing into a nitrogen purged (CO_2-free) pre-cleaned double-ended stopcock cylinders (Photo 2). Opening the intake stopcock valve allows filling of the cylinder to begin. When the cylinder is partially filled, the discharge stopcock is partially opened to allow continued filling of the cylinder. To fill the cylinder from the Gold Finch Road spring (Photo 3), the intake of the tubing was placed under water in the location with the greatest discharge (Photo 4) and the filled as described above.

Photo 2. Double ended stopcock cylinder used to collect C14 samples.

Photo 3. Gold Finch Road spring, looking north.

Photo 4. Gold Finch Road spring discharge sampling location.

Analysis of inorganic constituents was performed by Green Analytical Laboratories (Durango, CO). Analysis of stable isotopes of hydrogen and oxygen was performed by the Environmental Isotope Laboratory at University of Arizona, Tucson, Arizona (Appendix H). Radiocarbon and $\delta^{13}C$ of DIC analyses were performed at the AMS laboratory at University of Arizona (Appendix I).

The project's SOW proposed performing tritium age-dating, as well as stable isotope analysis of boron and chloride. Tritium is a non-natural isotope of hydrogen that has been introduced into the natural environment as fallout from above-ground nuclear explosions. Tritium input to ground water has occurred in a series of spikes following periods of atmospheric testing of nuclear devices that began in 1952 and reached a maximum in 1963-1964. While tritium is useful in dating very young groundwater, no tritium is expected in any groundwater greater than about 70 years old. After review of published literature of regional and local geology, the age of most groundwater at the Chattanooga site was anticipated to be centuries if not millennia old, therefore tritium age-dating was not performed to allow for additional radiocarbon dating, which would cover a greater range of water ages (0 to ~50,000 years old). Very low concentrations of boron and chloride precluded stable isotope analysis of the constituents; however samples have been archived for potential future analyses such as strontium and sulfur stable isotopes.

<u>Hydrology and Water Levels</u>
Various water level and discharge measurements were performed from July through October 2016 at the Chattanooga Fen to understand how water levels varied throughout the site, as well where inflows and outflows occurred.

Recording data loggers were installed in four previously installed fen wells (F2, F3, F4 and F5; all in Fen Unit F and 32C; Fen Unit B) and two project-installed wells (FB2, FB3; both in Fen Unit F) on October 4, 2016. The objective of the data loggers is to record one full year of water level data at sites with low pH to document seasonal variations. Each data logger is set to record at 08:00 and 20:00 daily. No data was retrieved from the data loggers prior to the onset of winter. Data logger information will be uploaded once the sites are snow-free and immediately reinstalled to continue data collection until early October 2017 (as part of a Phase 2 program, if funded).

Discharge measurements were conducted in September 2016 to document inflows to and outflows from the fen complex, as well as the discharge of Mineral Creek at the upstream and downstream ends of the fen complex. Discharge measurement methods included the use of a Marsh-McBirney velocity meter, a 90^{o} V-notch weir, and 5-gallon bucket. Visual estimates were made where none of these measurement devices worked without significant site disturbance. Discharge measurements of each GF-1D and GF-1S well (both are artesian) were conducted once the wells were completed. A pressure gauge was used to measure each well's hydraulic pressure.

Surface inflows to the fen consist of the Gold Finch Road spring and the Golf Finch adit. Surface outflows from the fen into Mineral Creek occur at several locations along the east side of the fen. A few seeps originating on the east side of the Mineral Creek below Highway 550 also discharge into the creek. General surface flow patterns within the fen were also mapped within the northern and central portion of the fen. Water level and discharge measurement locations, as well as flow patterns, were located using a sub-meter GPS.

RESULTS

<u>Site Geologic and Hydrogeologic Conceptual Model</u>
Using seismic data and drilling results, a preliminary site geologic and hydrogeologic *conceptual* model has been developed and is illustrated by three cross sections. Figure 11 shows cross section locations. Cross section A-A' (Figure 12) largely parallels the layout of seismic lines 1 and 3 (Figure 10) while the western half of cross section B-B' (Figure 13) parallels the layout of seismic line 2 (Figure 10). Drilling results from the GF-1 and FB3 boreholes (Figure 10) allowed for extrapolation of the conceptual model northward to the area of the Unit F Fen (Figure 3), as illustrated on cross section C-C' (Figure 14).

In general, the geology in the southern and middle portions of the site (sections A-A' and B-B') is characterized by about 60 to 80 feet of glacial till/colluvium overlying fractured propylitic altered volcanic bedrock on the slope west of the valley floor. The drilling and drill sampling method precluded a rigorous evaluation of material, the material identified as glacial till/colluvium may at depth be instead highly weathered volcanic bedrock Eastward towards the valley floor, the top of the volcanic bedrock deepens, and the stratigraphy is characterized by an eastward thinning till/colluvium merging with floodplain alluvium, overlying a thin (5-10 feet thick) fat clay on top of a relatively thick wedge (100 feet) of silty clay with gravel, which overlies the top of the bedrock at more than 120 feet below the ground surface. To the north (section C-C'), the layer of relatively cohesive and compressible (fat) clay extends westward up the slope, and here the stratigraphy is characterized by a near surface layer of colluvium and/or peat, underlain successively by the fat clay, glacial till, and finally volcanic bedrock.

Wells FB2 and FB3 are located within about 97 feet of each other (Figure 10), with FB2 (3 feet total depth and entirely within peat) and FB3 (25 feet total depth) completed below the peat and a confining layer. Water from FB2 was dated at 445 years before present (ybp), whereas the water from FB3 was dated at 15,889ybp. Without the presence of a relatively impervious layer, greater mixing of deeper, older water with younger, near surface water would occur, resulting in a smaller age difference between the two wells. The slightly smaller disparity in ages between the deeper bedrock well GF-1D (9,600ybp) and shallower confined well GF-1S (7,752ybp) and the water from the nearby Gold Finch Road spring (1,545ybp) maybe be due to mixing of waters due to some degree of permeability of the clay on the western slopes. Deeper bedrock water is distinctly older than the water from the unconfined surface aquifer.

The clay layer appears to be relatively impervious throughout the site. The artesian wells along the Gold Finch Adit Road (GF-1D and GF-1S) provide evidence of a confined aquifer at depth, with the clay layer likely forming a relatively impervious aquitard. Likewise, relatively large difference in age between deeper and shallow groundwater suggests the presence of a relativity impervious layer between the deep and shallow aquifers.

The preliminary hydrogeologic conceptual model is illustrated on cross section C-C' (Figure 12). Water upwells through bedrock fractures into the overlying glacial till/colluvium. Age dating of bedrock groundwater indicates a long flow path/residence time, with the source of the bedrock groundwater from higher elevations, but from an unknown source(s). While the illustration on section C-C' suggests a west-to-east deep groundwater flow path, an east-to-west deep groundwater flow path is equally likely but cannot be determined with the data available. Fen-supplying ground water flow through the glacial till/colluvium is downslope on the western valley slope, then, similar to surface flow, toward the southeast and south based on water elevations in a limited number of Fen Unit F wells. While no hydrologic information is available regarding the flow direction within the glacial till/colluvium layers, fen-supplying ground water flow through the glacial till/colluvium is most likely downslope to the east through the western valley slope, then, similar to surface flow, toward the southeast and south in the valley bottom.

Ground water in the unconfined surface aquifer flows downslope and towards the east from meteoric recharge areas upslope and west of the fen area (see Figure 4). Since bedrock groundwater is not the water source for the fen, the fen water source is likely from groundwater flow through the unconfined surface aquifer and/or surface water derived from a source(s) similar to the Gold Finch Road spring.

Since an unconfined shallow aquifer water source to the east cannot physically flow under Mineral Creek and then up-gradient (westward) through the fen complex's unconfined shallow aquifer to discharge near the western edge of the fen, the fen's water source is likely from a connected source upslope of the fen complex. This source area is likely limited to the lands west of Chattanooga fen and/or south of Mill Creek and the Highway 550 "hair pin" just north of the fen. Several bodies of QSP altered rock (phyllic altered volcanic tuff, Figure 8) exist on the slope west of the fens; groundwater that has interacted with the QSP rock there is a probable source of water supplying the iron fens.

Figure 11. Chattanooga fen study area preliminary conceptual site model cross section locations.

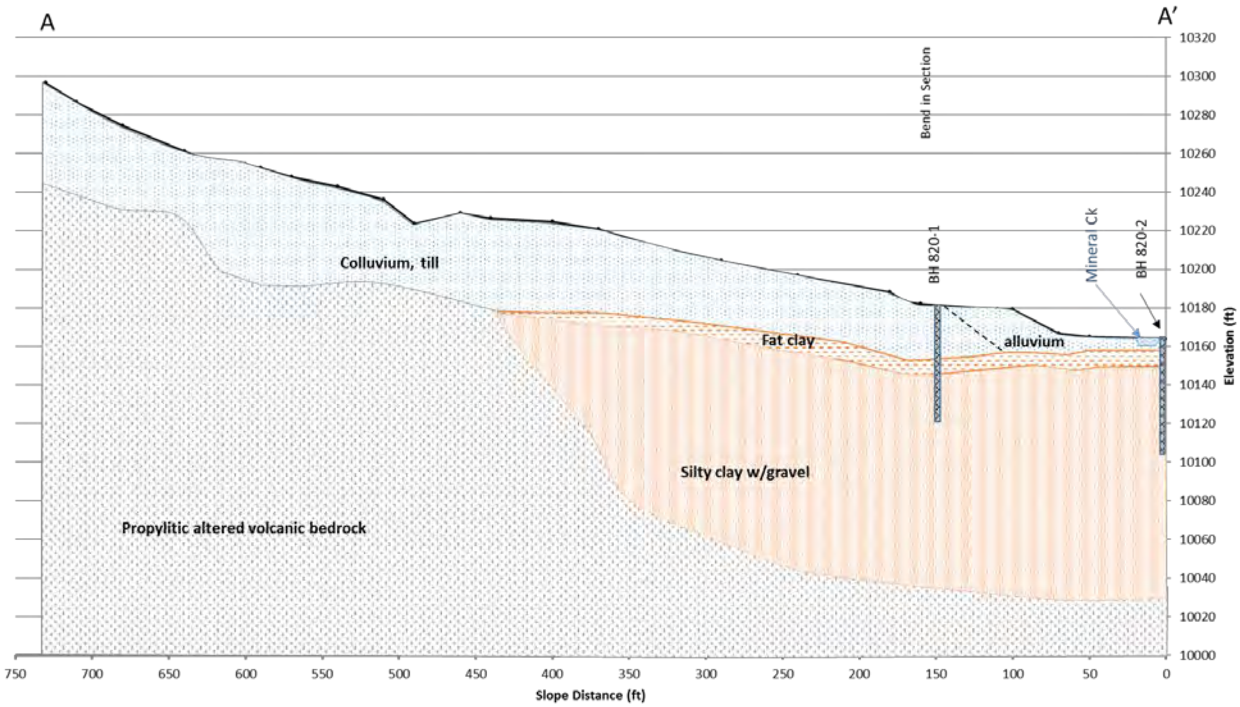


Figure 12. Chattanooga fen preliminary conceptual model cross section A-A'.

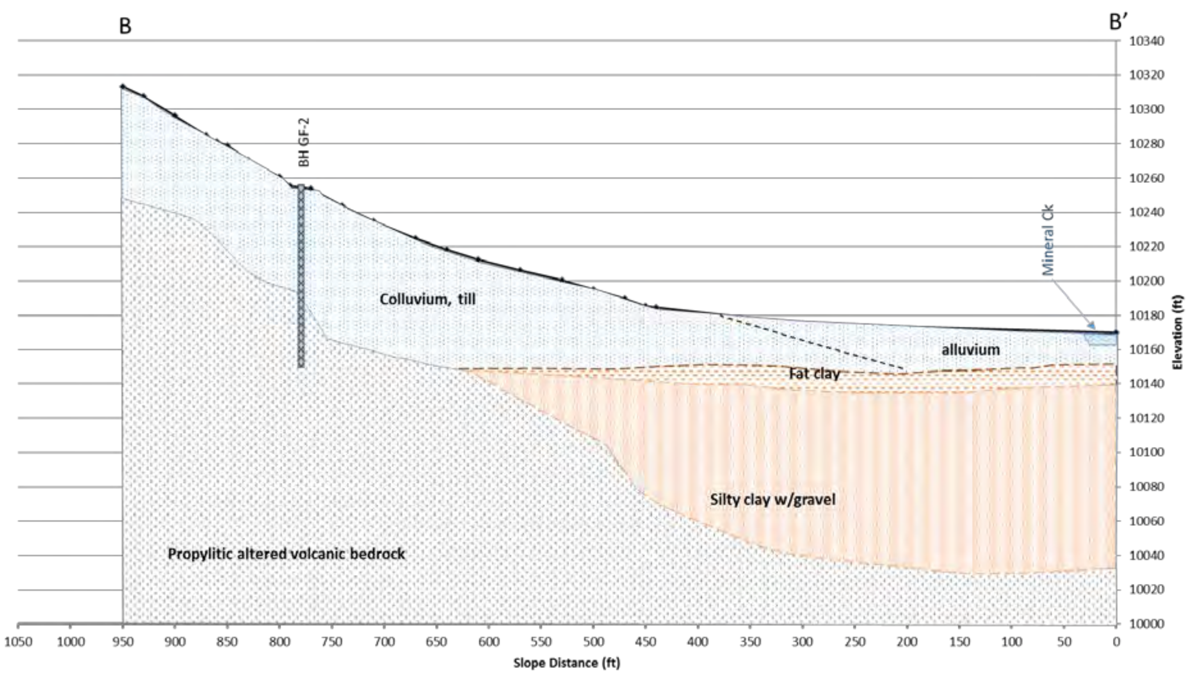


Figure 13. Chattanooga fen preliminary conceptual model cross section B-B'.

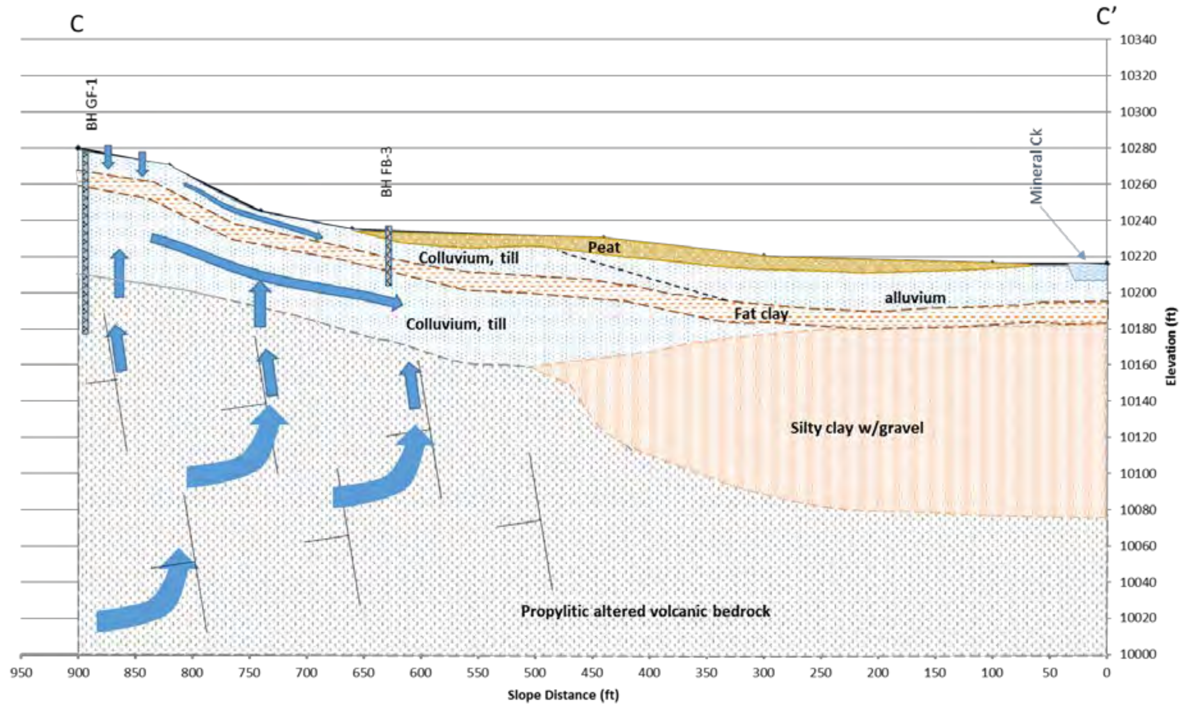


Figure 14. Chattanooga fen preliminary conceptual model cross section C-C'

Figures 12, 13 and 14 are preliminary conceptual model cross sections of the Chattanooga fen study area showing confirmed and interpreted stratigraphy. The cross sections show colluvium and till overlying fractured propylitic altered volcanic bedrock on the slope west of the valley floor. The volcanic bedrock appears to deepen to the east with overlying silty clay, fat clay, and floodplain alluvium strata. At the northern cross section (section C-C', Figure 14), the layer of relatively fat clay extends westward up the slope where the stratigraphy is characterized by a near surface layer of colluvium and/or peat, underlain successively by the fat clay, glacial till, and finally volcanic bedrock. Blue arrows show suspected groundwater flow paths, upwelling through fractures in the volcanic bedrock into overlying colluvium and till. Inferred groundwater flow in the overlying colluvium/till is downslope and eastward, then southward in the floodplain floor.

<u>Water Chemistry and Age-Dating</u>
Water chemistry data is provided below in Table 4 (*Note: this table is sized for 11"x17" paper*). Analytical laboratory reports are provided in Appendix H. A brief summary of the analytical data includes:

- Major ion data indicate groundwater throughout the site is predominately a Ca-SO_4 (calcium sulfate) type water (see Piper Diagram Figure 15), with some wells having minor but increased amounts of HCO3 (bicarbonate, at FB3, 30C, and 32C), Na (sodium, at GF-1S), or Mg (magnesium, at FB2, GF-1D, GF-1S).

- In the vicinity of the north fen (Fen Unit F, Figure 3), the shallow groundwater sources (Gold Finch Road spring and FB2) are low pH (4.4) and have relatively low concentrations of dissolved Fe (iron) and dissolved SO4 (sulfate, Figure 16), and relatively high Al (aluminum concentrations, Figure 17) relative to deeper groundwater from GF-1S, GF-1D, and FB-3.

- In the vicinity of the north fen (Fen Unit F, Figure 3), the oldest ground water is from FB3 (15,889ybp, GF-1D (9,600ybp), and GF-1S (7,752ybp) while the youngest groundwater is from FB2 (445ybp) and the Gold Finch Rd spring (1,545ybp).

- Groundwater pH is lowest in the Gold Finch Road spring and FB2 (3.83 and 4.40, respectively). GF-1D and GF-1S have slightly higher pH's (4.93 and 5.26, respectively) while the Gold Finch adit discharge is pH 5.88 and FB3 has a pH of 6.22. Southern fen wells pH values for 30C and 32C are 6.43 and 6.83, respectively, which are similar to those of FB3 (Table 4).

- Dissolved oxygen levels, which can aid in distinguishing between ground water (lower DO) from surface sources (higher DO), are the highest in the Gold Finch Road spring (8.2 mg/l) and FB3 (7.7 mg/l) and GF1S (4.5 mg/l). The lowest levels occur in GF1D (0.4 mg/l), FB2 (0.7 mg/l), Gold Finch adit (2.2 mg/l), 30C (2.60 mg/l) and 32C (3.60 mg/l).

- Table 5 presents' low-high/young-old categories for pH, DO and ^{14}C values by site. This table suggests that FB2 and FB3 may be different water sources.

- Water from the southern fen well (30C and 32C, Fen Unit B) and the Gold Finch adit discharge have relatively high concentrations of Fe and SO4 similar to values seen in FB3 (Figure 16).

- Dissolved Al concentrations from wells 30C and 32C and from FB3 are significantly lower compared to other ground waters sampled (Figure 17). These sites also have the highest pH and alkalinity of all groundwater sampled at the site (Table 4).

- Magnesium is lowest in the south fen wells and highest in the deep bedrock (GF-1D and GF-1S) groundwater and adit discharge (Figure 17).

- Oxygen (δD) and hydrogen ($\delta^{18}O$) isotopic values are similar for the northern fen-area groundwater but are depleted relative to well 30C and Mineral Creek values (Figure 18). All samples are depleted in oxygen isotope relative to the modern global meteoric water line (GMWL, Figure 18).

- In comparison to groundwater chemistry, both upstream and downstream Mineral Creek samples are very dilute with overall lower concentration of ions. Also, the concentrations of major and minor ions in both Mineral Creek samples are similar, suggesting no significant constituent loading is occurring along the reach between the two samples locations.

- FeC1 is a sample of pooled surface water on top of ferricrete in the southern fen area. The sample has very low pH (3.61) and relatively high concentrations of Fe and SO4 (Table 4). Calculation of ion charge balance of this sample results in a relatively large (23%) difference between the total cation charges to the total anion charge, indicating an unreliable result for the inorganic constituents. While the pool was fed by runoff from shallow, upslope ground water seepage, evaporation may have affected the overall water composition of the pooled water, which may be reflected the large charge imbalance.

Table 4. Chattanooga 2016 water chemistry data.

	Well Name		MinCk DS		MinCk US		Piezo 32C		Piezo 30C		FeC 1		GF Adit	
	Sample Date		10/3/16 11:00		10/3/16 12:00		10/3/16 13:24		10/3/16 14:25		10/3/16 15:00		10/3/16 14:15	
	Constituent	Units	Value	Q	Value	Q	Value	Q	Value	Q	Value	Q	Value	Q
Field Parameters	pH (field)	std units	7.76		7.74		6.83		6.43		3.61		5.88	
	DO	mg/L	NM		NM		3.6		2.60		6.1		2.2	
	Tubidity	NTU	NM		NM		NM		NM		NM		NM	
	Ferrous Iron	mg/L	NM		NM		1.92		1.95		0.95		1.93	
	Total Iron	mg/L	NM		NM		OL		2.06		OL		OL	
	Temperature (field)	Celsius	6.2		3.9		6.3		5.7		5.1		5.5	
General and Inorganic	Bicarbonate as $CaCO_3$	mg/L	15.0		17.0		55.0		22.0		10.0	U	10.0	U
	Carbonate as $CaCO_3$	mg/L	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U
	Hydroxide as $CaCO_3$		10.0	U	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U
	Total Alkalinity as $CaCO_3$	mg/L	15.0		17.0		55.0		22.0		10.0	U	10.0	U
	Bromide, dissolved	mg/L	0.0313	U	0.0313	U	0.0313	U	0.0313	U	0.0313	U	0.0313	U
	Chloride, dissolved	mg/L	1.34		1.50		1.48		1.16		1.49		0.219	U
	Specific Conductance @25C (lab)	µS/cm	317		289		555		451		629		450	
	Fluoride, dissolved	mg/L	0.196		0.167		1.03		0.993		0.437		0.941	
	pH (lab)	std units	7.54		7.50		6.73		6.52		2.95		5.97	
	Residue, Filterable (TDS)	mg/L	245		220		480		370		305		350	
	Residue, Non-Filterable (TSS)	mg/L	2.00	U	2.00	U	33.5		20.80		8.40		2.40	
	Sulfate, dissolved	mg/L	135		115		256		216		218		223	
	Aluminum, dissolved	mg/L	0.020	U	0.020	U	0.020	U	0.020	U	0.945		0.605	
	Barium, dissolved	mg/L	0.003	U	0.003	U	0.003	U	0.003	U	0.003	U	0.003	U
	Boron, dissolved	mg/L	0.053	U	0.053	U	0.053	U	0.053	U	0.053	U	0.053	U
	Calcium, dissolved	mg/L	50.0		43.9		109		81.9		35.3		64.3	
	Iron, dissolved	mg/L	0.003	U	0.003	U	9.23		2.45		15.0		10.7	
	Lithium, dissolved	mg/L	0.006	U	0.006	U	0.006	U	0.006	U	0.006	U	0.006	U
	Magnesium, dissolved	mg/L	2.89		3.00		3.74		3.83		3.63		6.41	
	Manganese, dissolved	mg/L	0.142		0.163		4.01		0.860		0.586		2.30	
	Potassium, dissolved	mg/L	0.335	U	0.335	U	0.335	U	0.335	U	2.29		0.335	U
	Silica, dissolved	mg/L	7.28		5.85		26.8		24.3		31.5		32.5	
	Sodium, dissolved	mg/L	3.58		3.30		5.92		5.78		4.83		5.88	
	Strontium, dissolved	mg/L	0.761		0.720		1.12		0.779		0.195		0.542	
	Dissolved Inorganic Carbon (DIC)[(1)]	mg/L	NM		NM		NM		4.2		NM		NM	
Isotopes	$\delta^{18}O$ of H_2O	‰	NM		NM		NM		-14.8		NM		NM	
	δD of H_2O	‰	NM		NM		NM		-105.5		NM		NM	
	d13C of DIC	‰	NM		NM		NM		-16.8		NM		NM	
	14C	pMC	NM		NM		NM		1.0253		NM		NM	
	14C age BP	yr	NM		NM		NM		post-bomb		NM		NM	

	Well Name		GF Adit 2		GF Rd Sp N		GF-1D		GF-1S		FB-2		FB-3	
	Sample Date		10/3/16 14:15		10/4/16 10:20		10/4/16 11:20		10/4/16 12:46		10/4/16 14:50		10/4/16 14:20	
	Constituent	Units	Value	Q	Value	Q	Value	Q	Value	Q	Value	Q	Value	Q
Field Parameters	pH (field)	std units	--		3.83		4.93		5.26		4.40		6.22	
	DO	mg/L	--		8.2		0.4		4.5		0.7		7.7	
	Tubidity	NTU	--		NM		3.32		424		2.13		NM	
	Ferrous Iron	mg/L	--		0.11		2.04		2.53		0.01		OL	
	Total Iron	mg/L	--		OL		OL		OL		0.00		OL	
	Temperature (field)	Celsius	--		5.4		6.8		5.8		6.5		6.8	
General and Inorganic	Bicarbonate as $CaCO_3$	mg/L	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U	78.0	
	Carbonate as $CaCO_3$	mg/L	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U
	Hydroxide as $CaCO_3$		10.0	U	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U
	Total Alkalinity as $CaCO_3$	mg/L	10.0	U	10.0	U	10.0	U	10.0	U	10.0	U	78.0	
	Bromide, dissolved	mg/L	0.0313	U	0.0313	U	0.0313	U	0.0313	U	0.0313	U	0.0313	U
	Chloride, dissolved	mg/L	0.219	U	0.219	U	0.219	U	0.219	U	0.219	U	1.15	
	Specific Conductance @25C (lab)	µS/cm	437		287		337		375		246		457	
	Fluoride, dissolved	mg/L	0.936		0.665		0.810		0.503		0.635		0.290	
	pH (lab)	std units	6.00		4.01		4.88		5.50		4.54		6.96	
	Residue, Filterable (TDS)	mg/L	360		235		280		310		235		350	
	Residue, Non-Filterable (TSS)	mg/L	2.40		2.00	U	2.10		92.6		2.40		874	
	Sulfate, dissolved	mg/L	221		125		162		165		119		165	
	Aluminum, dissolved	mg/L	0.593		3.86		0.670		1.69		2.69		0.020	U
	Barium, dissolved	mg/L	0.003	U	0.003	U	0.003	U	0.010		0.003	U	0.003	U
	Boron, dissolved	mg/L	0.053	U	0.053	U	0.053	U	0.053	U	0.053	U	0.053	U
	Calcium, dissolved	mg/L	62.9		22.4		34.3		26.8		22.3		66.9	
	Iron, dissolved	mg/L	10.5		0.003	U	8.42		9.87		0.091		0.897	
	Lithium, dissolved	mg/L	0.006	U	0.006	U	0.006	U	0.006	U	0.006	U	0.006	U
	Magnesium, dissolved	mg/L	6.26		5.63		8.15		7.42		5.64		5.16	
	Manganese, dissolved	mg/L	2.26		0.687		1.50		1.41		0.717		0.793	
	Potassium, dissolved	mg/L	0.335	U	0.335	U	1.18		2.45		0.335	U	1.59	
	Silica, dissolved	mg/L	31.9		48.7		48.8		63.6		47.0		21.7	
	Sodium, dissolved	mg/L	5.80		6.34		8.15		21.3		6.22		17.7	
	Strontium, dissolved	mg/L	0.533		0.128		0.112		0.142		0.126		0.275	
	Dissolved Inorganic Carbon (DIC)[(1)]	mg/L	NM		0.52		3.0		1.6		2.1		5.2	
Isotopes	$\delta^{18}O$ of H_2O	‰	NM		-16.6		-16.8		-16.8		-16.5		-16.8	
	δD of H_2O	‰	NM		-119.0		-121.1		-121.5		-119.0		-122.7	
	d13C of DIC	‰	NM		-19.2		-10.1		-11.4		-23.0		-7.8	
	14C	pMC	NM		0.8250		0.3027		0.3810		0.9461		0.1384	
	14C age BP	yr	NM		1,545		9,600		7,752		445		15,889	

NOTES

Q	Analytical Qualifier
U	Not detected, value reported equals MDL
pMC	Percent modern carbon
BP	Before present
NM	Not measured
OL	Over limit
--	No duplicate filed measurement
(1)	Calcualted from reported mass, assuming 250ml liquid volume

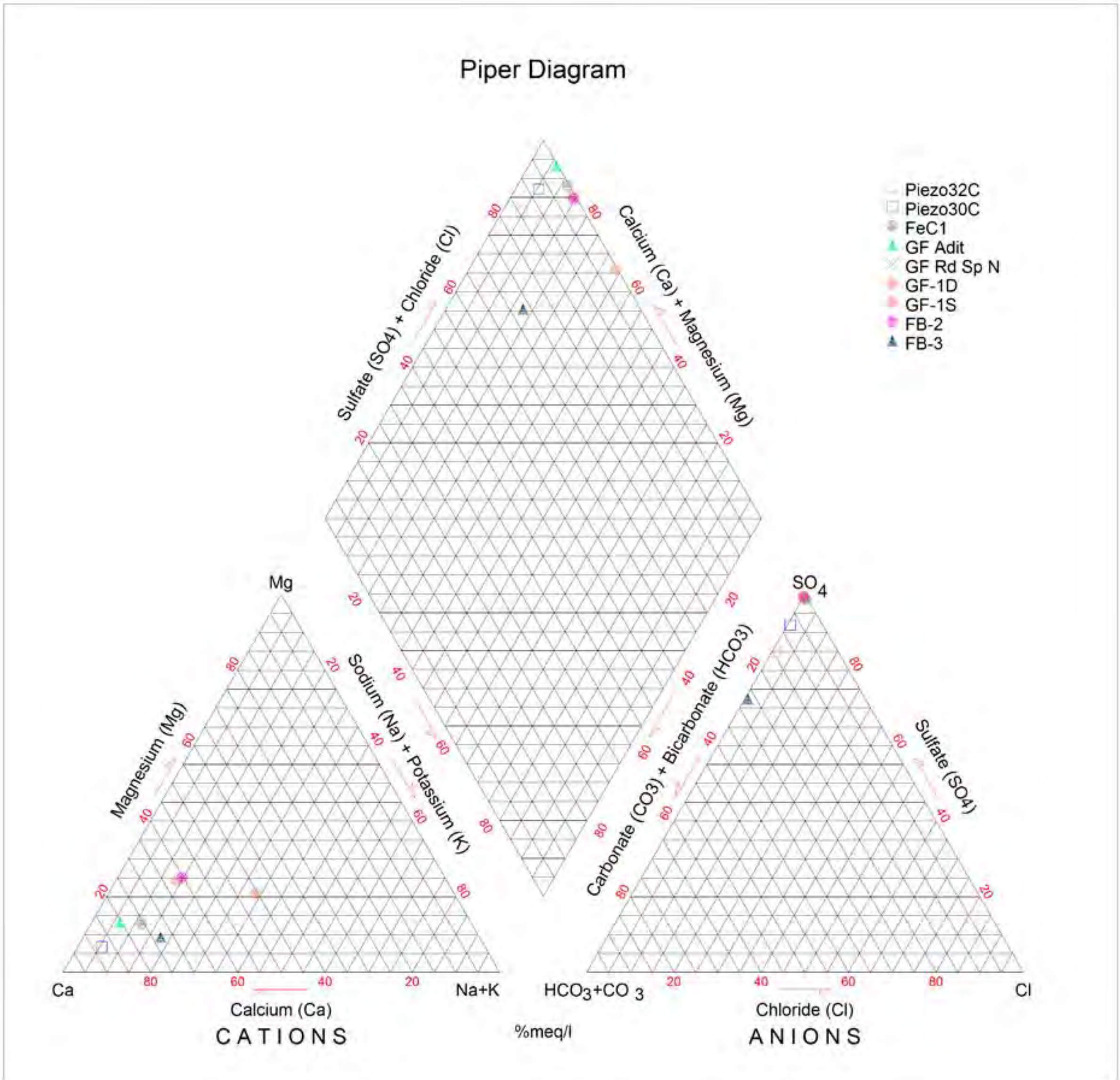
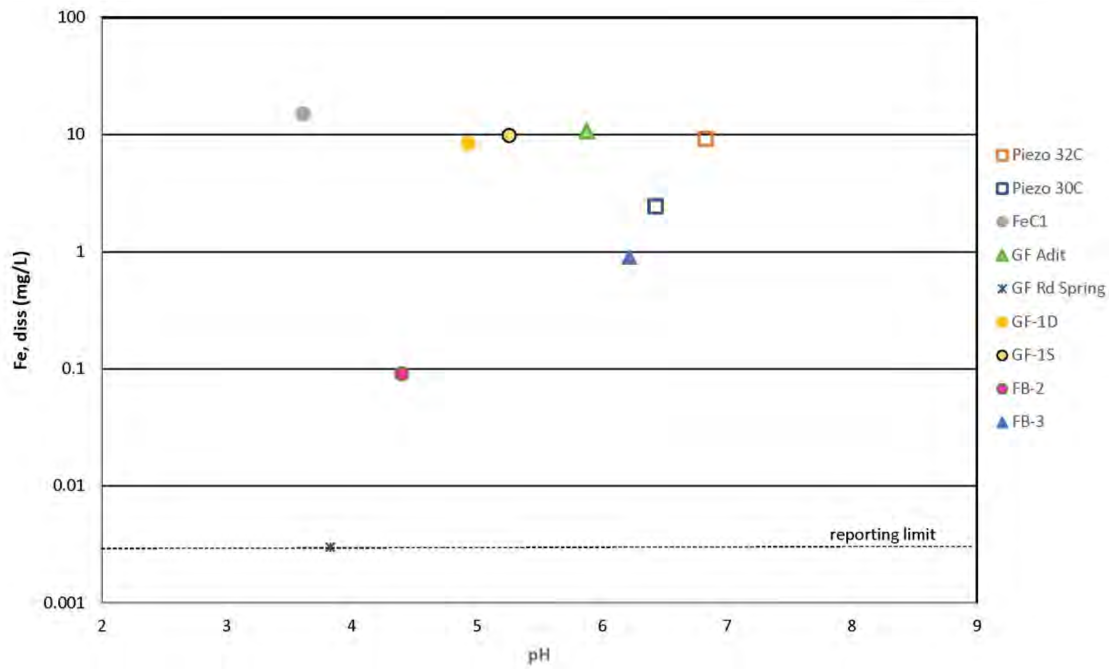


Figure 15. Piper diagram showing relative concentrations of major cations and anions of Chattanooga fen study area waters.



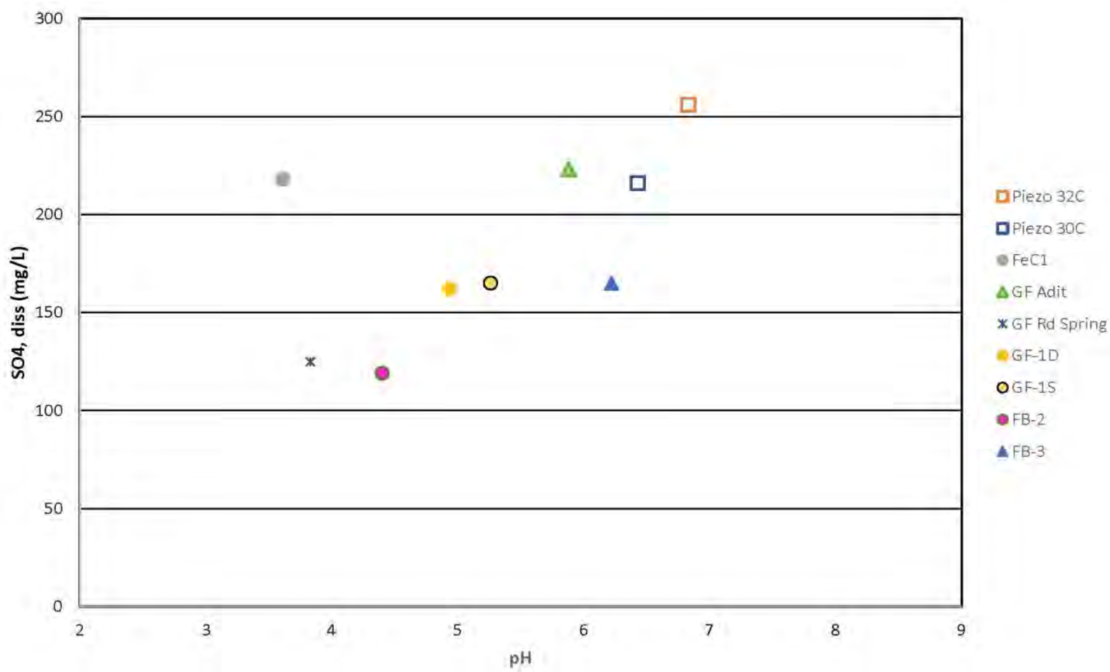
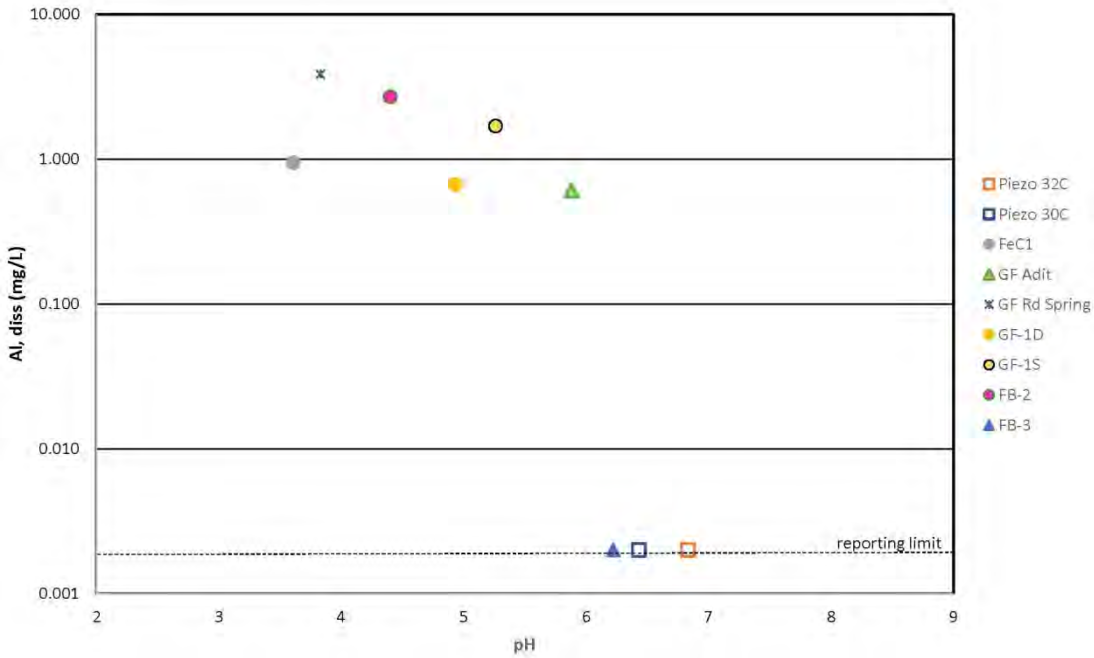


Figure 16. Dissolved iron (Fe) and sulfate (SO4) concentrations as a funciton of pH.



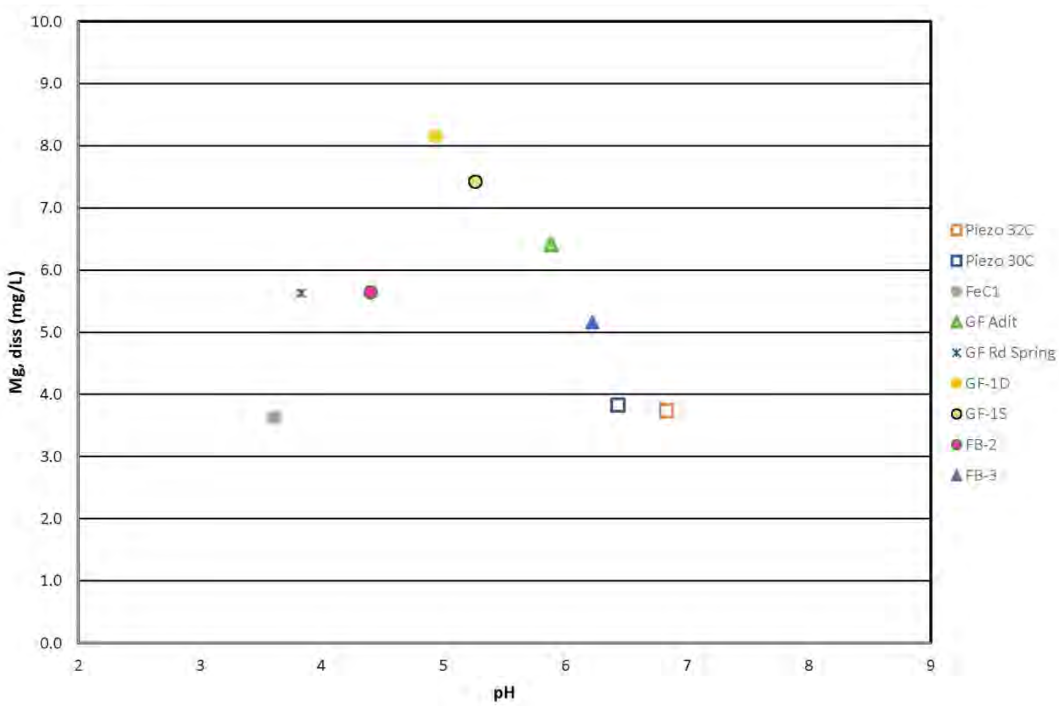


Figure 17. Dissolved aluminum (Al) and magnesium (Mg) concentrations as a function of pH.

Table 5. Comparison of DO, pH and C14 values by site .

Parameter	Matching Sites	Parameter	Matching Sites
Low DO (< 3 mg/l)	30C, GF Adit, GF-1D, FB2	*High DO (>3 mg/l)*	32C, GF Rd Spring, GF-1S, FB3
Low pH (<4.5)	GF Rd Spring, FB2	*High pH (>4.5)*	30C, 32C, GF Adit, GF-1D, GF-1S, FB3
Young Age (<2000 ybp)	30C, FB2, GF Rd Spring	*Older Age (>7000ybp)*	GF-1D, GF-1S, FB3

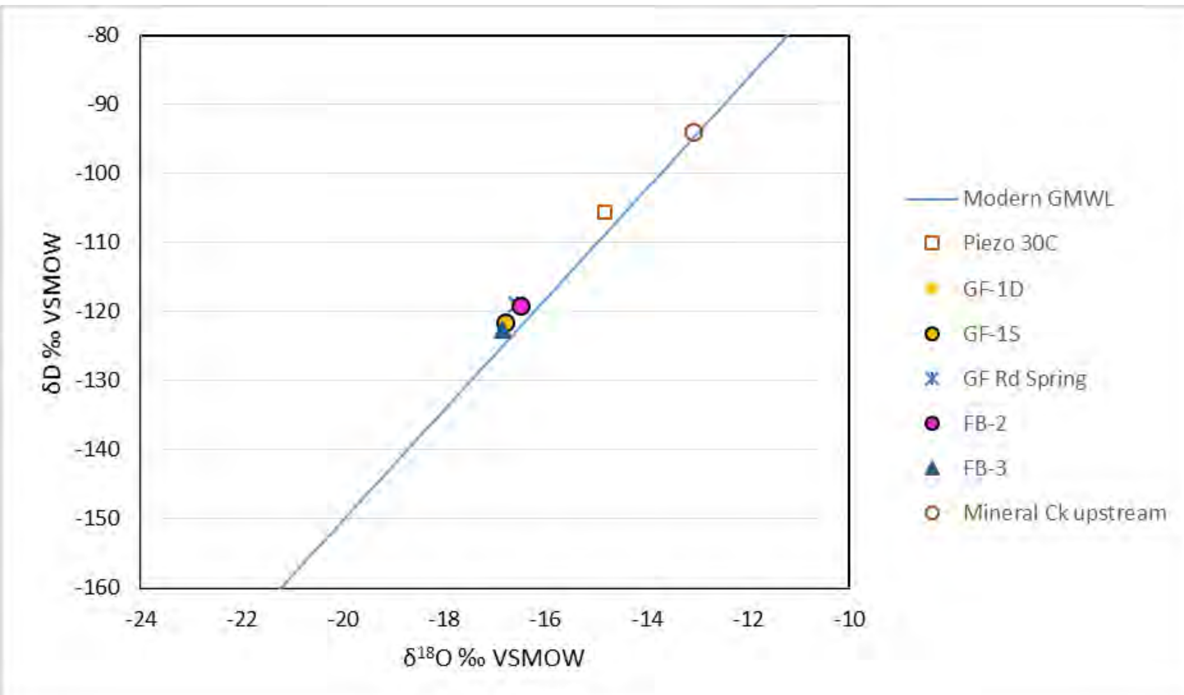


Figure 18. Oxygen and hydrogen isotopic compostion of surface and groundwater at Chattanooga fen study area.

<u>Water Levels</u>

Water level measurements were performed within the Chattanooga fen at select previously installed wells and project-installed wells to determine the depth-to-water below the ground surface and the actual water elevations. Table 6 provides ground and water elevations for Chattanooga fen wells and the spring, for project-installed wells, and existing wells located near project-installed wells (Figure 10).

Table 6. 2016 Chattanooga fen well and water elevation data.

			Water Elevation Observation Date							
Well ID	Top Pipe Elev. (ft)	Ground Elev. (ft)	9/13/2016	9/15/2017	9/19/2016	9/26/2016	9/27/2016	10/3/2016	10/4/2016	10/7/2016
F2	10,259.5	10,259.1	10,258.7	10,258.7						
F3	10,257.8	10,256.6	10,254.5	10253.7	10,253.5	10,254.0			10,253.2	10,253.4
F4	10,254.4	10,254.0	10,254.1	10,253.9		10,253.9			10,253.8	10,253.8
F5	10,253.9	10,252.8	10,252.7	10,251.9	10,251.5	10,251.9			10,251.5	10,251.4
FB2	10,251.3	10,250.9				10,250.5			10,250.4	10,250.5
FB3	10,255.5	10,254.7					*10,246.2*		10,251.3	10,251.2
GF1S	10,272.8	10,273.1							10,288.9	
GF1D	10,272.8	10,273.1							10,277.3	
GF Road Spring	-	10,282								
30C	10,197.4	10,196.4						10,196.4		
32C	10,197.7	10,196.8						10,196.6	10,196.6	
FEC1	-	10,212.0								

Notes:
(1) Shaded wells represent those present prior to this study.
(2) FB3's 9/27/2016 water elevation was the day of well installation.
(3) GF1S & GF1D are artesian wells.
(4) GF Road Spring and FEC1 are spring/seep features only.

Measurements of surface water flow rates was completed during low flow (baseflow) conditions to help understand how much water flows into and out of the Chattanooga fen and how Mineral Creek responds as it flows through the Chattanooga reach. Surface flow measurements into Mineral Creek from the east (QinE, Figure 19) and west (QinW) were taken on September 19, 2016, while the Mineral Creek channel discharges and surface inputs to the fen complex were measured on October 3, 2016. General surface flow patterns were also field-mapped (Figure 19).

The Mineral Creek SNOTEL station (approximately 0.5 miles south of the site near Highway 550) recorded 5.4 inches of precipitation in August 2016 (3.0 inches above 1981-2010 mean) and 2.7 inches in September 2016 (0.2 inches below the 1981-2010 mean) of which 1.6 inches fell from the 19th to the 30th. No precipitation was recorded through October 3rd. While the August and September precipitation amounts may have elevated some of the sites' discharge values slightly, the measured discharge values are considered to be a close approximation of baseflow conditions.

A summary of surface water discharge data is provided below in Tables 7 and 8.

Table 7. Surface inflows to Mineral Creek at the Chattanooga fen.

Discharge Coordinates		Source:	Measurement	Discharge Rate	
Lat.	Long.	East or West	Method	gpm	cfs
37.8641142	-107.7242283	east	bucket	8.7	0.019
37.8644316	-107.7243230	west	90° notch	5.4	0.012
37.8653916	-107.7240200	east	est.	3	0.007
37.8656789	-107.7241375	west	bucket	1.3	0.003
37.8657279	-107.7239326	east	90° notch	15.3	0.034
37.8660264	-107.7239749	west	bucket	17	0.0379
37.8663438	-107.7235756	east	90° notch	97	0.209
37.8665351	-107.7238061	west	90° notch	28.7	0.064
37.8668980	-107.7239701	west	90° notch	25.6	0.057
37.8683070	-107.7240399	west	est.	1	0.002
37.8708440	-107.7239210	west	est.	2	0.004

	gpm	cfs
East Inflows	**124**	**0.27**
West Inflows	**81**	**0.18**
TOTALS	***205***	***0.45***

Table 8. Mineral Creek and Chattanooga fen discharge summary.

Mineral Creek Summary	cfs
Mineral Creek Upstream	11.27
East & West Inflows	0.45
Total Reach Inputs	***11.72***
Mineral Creek Downstream	11.89
Unaccounted for Inputs (seepage)	***0.18***

Surface Inputs to Fen Complex	cfs
Gold Finch Adit	0.38
Gold Finch Road Springs	0.04
Total Surface Inputs	***0.43***

Storage/Discharge of Fen	cfs
Total Surface Inputs to Fen	0.43
Outflows from Fen to Mineral Ck.	0.18
Fen Storage/Subsurface to Mineral Ck.	***-0.25***

The nested Gold Finch Road wells (GF1) are artesian; the deeper well (GF-1D) has a discharge of 1.7 gpm, while the shallower well (GF-1S) has a discharge of 0.1 gpm. Both wells are capped to prevent continuous discharge, except during water chemistry sampling and pressure measurements.

Figure 19. Surface flow directions and measurement locations.

This discharge data indicates that:

- Mineral Creek is a gaining reach along the Chattanooga fen.
- There is more surface inflow into than there is outflow from the Chattanooga fen.

- Approximately 90% of the point source surface inflows to the Chattanooga fen originate from the Gold Finch adit, with only 10% originating from the Gold Finch Road springs.

- Numerous small, dispersed seeps that produce several gallons per minute exist throughout the west side of the northern and southern portions of the fen. These were not measured due to their number, size and often surface-to-subsurface nature. These seeps contribute an additional, unknown but likely significant, amount of surface water to the fen complex.

- Surface inflows to Mineral Creek from the east side of the creek (i.e., from seeps between the highway and Mineral Creek) are greater than the inflows on the west side of Mineral Creek (i.e., from Chattanooga fen).

- The gain in Mineral Creek's upstream-to-downstream discharge (0.18 cfs) is likely due to subsurface seepage and/or release of bank storage waters.

- The difference in the measured and observed surface inputs to the fen (0.43 cfs+) compared with the measured discharges into Mineral Creek (0.18 cfs) suggests:
    - The fen is storing water which should be reflected in an increase in fen water levels,
    - There is subsurface seepage from the fen to Mineral Creek and-or its underlying alluvium, or
    - A combination of both.

- Both Gold Finch Road wells (GF-1S and GF-1D) are artesian. The deeper well has a potentiometric surface[1] of 16.1 ft. above the ground surface (6.95 psi <lbs/in^2>) while the shallower well has a hydraulic head of 4.5 ft. above the ground surface (1.95 psi) based on October 2016 readings.

- The Gold Finch Road well GF-1S and well FB3 have overlapping well screen elevations (10,216 ft.-10,236 ft. and 10,230 ft.-10,235 ft., respectively) but have significantly different water elevations. GF-1S (artesian) hydraulic head is 10,289 ft. while FB3's (not artesian) water elevation is 10,251 ft., suggesting there is an unknown boundary or geologic feature separating these two wells that are 138 feet apart.

DISCUSSION

The initial findings and preliminary interpretation of the investigation include:

Geology

- In general, the geology in the Chattanooga fen valley comprises a surface peat and colluvium layer underlain by a lower permeability clay, which in turn is underlain by colluvium/glacial till (and/or highly weathered igneous bedrock) and igneous bedrock.

- The lower permeability clay forms a confining layer, separating the unconfined surface aquifer from the underlying confined aquifer(s).

- The underlying confined aquifer comprises glacial till/colluvium overlying igneous bedrock. The confined till/colluvium aquifer is artesian on the western slope along the Gold Finch Road. The nested wells on the Gold Finch Road (GF-1S and GF-1D) are both artesian.

- Igneous bedrock is relatively deep, ranging from about 80 feet deep along the Gold Finch Road to over 100 feet deep near Mineral Creek. Igneous bedrock is fractured, and groundwater systems associated with the igneous bedrock are artesian. The artesian wells indicate their water source(s) originate at higher elevations from unknown locations.

- The low permeability clay layer beneath the fen extends eastward beyond Mineral Creek based on borehole FS820-2, where it was encountered at five feet below the ground surface (which was approximately three feet above the channel bed). This suggests the alluvial stratum associated with Mineral Creek is relatively thin.

Water Chemistry and Age-Dating

- Carbon-14 dating of groundwater indicates water in the shallow fen well (FB2) is distinctly younger (<450ybp) than water in the Gold Finch road artesian wells (>7750+ ybp). In the north fen, FB2 (2.6 ft. deep, Fen Unit F) and FB3 (25 ft. deep, Fen Unit F) are separated horizontally by 97 feet and vertically by 3.8 feet, yet the age of the waters in these wells are 450ybp and 15,889ybp, respectively.

[1] Potentiometric surface - elevation that water can rise to above the ground surface.

- At an age of 1,545ybp, the water from the spring along the Gold Finch Road may represent a mix of older and younger water. If so, the clay aquitard in this area may be somewhat permeable.

- Well FB3 is the farthest east and the shallowest of the study wells, yet it contains the youngest water. This finding suggests that there is more than one water source, or that the fen's water source is not directly upslope, but potentially further north.

- Carbon-14 dating from an existing shallow well (30C, Fen Unit B) in the south end of the fen complex indicates the water is less than 71ybp suggesting a shallow and localized water source.

- The age disparity between waters from the unconfined surface aquifer (FB2) and the deeper confined aquifer(s) (FB3, GF-1S, GF-1D) suggests that the deeper bedrock ground water is not the water source for the fen.

- A more thorough evaluation and interpretation of water geochemistry data is required to understand additional differences in water sources and potential mixing of sources.

- Additional sampling and monitoring is required to determine if seasonal variations may exist in both water chemistry and water levels, which may provide additional data to identify, and exclude, fen source waters.

<u>Water Sources & Hydrology</u>

- If bedrock groundwater is not the water source for the iron fens, their water source would appear to be from shallow groundwater flow through the unconfined surface aquifer that lies above the low permeability clay layer.

- Since an unconfined shallow water source to the east cannot physically flow under Mineral Creek and continue to flow up-gradient (westward) through the fen complex above the underlying clay layer, possible sources of fen water include, but are not limited to: groundwater flow from upslope and west of the fen complex; groundwater flow from upslope and northwest of the fen complex and; groundwater flow from south of Mill Creek within the river basin floodplain.

- Mineral Creek is not a likely water source for the fen, primarily due to its significantly lower elevation than the western edge of the iron fens just east of the Gold Finch Road and Mill Creek acts as boundary between the fen and Mineral Creek's higher elevations.

- Surface flows within the fen complex are generally towards the east and south.

- Based on September and October 2016 surface discharge measurements and observations, there are greater inputs of surface water to the Chattanooga fen than what is visually discharging from the fen into Mineral Creek.

- Lands further north of the Gold Finch spring and wells could be another source of low pH waters supplying the fen; whether from the east-facing hillside (where appropriate geology exists) OR from east flowing Mill Creek's subsurface waters comingling with hillslope water.

RECOMMENDATIONS FOR FURTHER STUDY

In order to validate 2016 findings, to acquire additional supporting water source data and to determine if Chattanooga-identified fen water sources apply to other iron fens, the following measures are proposed.

- In order to confirm age-date differences between shallow and deeper aquifers, resample wells FB-2, FB-3, and the Gold Finch Adit Road spring

- To aid in evaluating the hydrologic properties of geologic materials, including the suspected aquitard material, in-situ samples collected by coring is preferable to collection of drill cuttings during rotary drilling. Therefore, drill one borehole adjacent to GF-1 using a hole-stem auger setup to approximately 40 feet deep to obtain core samples.

- In order to evaluate all potential groundwater sources to the fen, collect inorganic chemical and carbon-14 samples from existing wells (and-or springs) north of the Gold Finch Road springs and south of Mill Creek.

- Sample at least one seep located on the east side of Mineral Creek and analyze for inorganic chemistry and carbon-14.

- To evaluate potential groundwater sources to the South Fork Mineral Creek, install a hand-installed well (3 to 6 feet deep) within the peat layer in the S. Mineral Creek fen. Collect water samples for inorganic chemical and carbon-14 analysis.

- To evaluate potential groundwater sources to the South Fork Mineral Creek, drill a borehole immediately north of the S. Mineral Creek fen to bedrock (if possible). If groundwater is encountered, install a well(s) into bedrock and into the overlying sediment, if applicable. Collect water samples for inorganic chemical and carbon-14 analysis.

- To evaluate potential seasonal variations (baseflow to high flow) from wells, springs and adit sampled in fall 2016, collect water samples in late spring/early summer 2017 for inorganic chemical analysis.

- To evaluate potential seasonal variations (baseflow to high flow) in discharge measured in 2016, measure discharge at the 2016 sites in late spring/early summer 2017 (except Mineral Creek due to potentially unsafe wading conditions).

- Monitor the hydraulic head of both Gold Finch wells (GF-1S and GF-1D) from late spring-early summer through fall 2017 to document seasonal variations.

- To evaluate potential seasonal variations in fen water elevations, leave data loggers in wells through September 2017. Document and evaluate water level variations for a complete water year, including inputs from summer precipitation.

FEN WATER RESOURCE PROTECTION MEASURES

Based on this preliminary study that has not positively identified potential water source(s), the following information responds to the principle question identified in the RPW's December 15, 2015 Request for Proposals: what land uses or activities could adversely affect these water sources and the fen. The potential adverse impacts listed below, based on the current level of understanding of water source(s), do not pertain to land uses that would have a <u>direct</u> adverse effect such as placing fill (soil, roads, etc.) or excavating within or directly adjacent to the fen, grazing, dewatering, altering vegetation, discharging additional waters into the fen, and soil deposition from anthropogenic erosion.

1. Water sources.
   i. The primary water source for the Chattanooga iron fens <u>*appears*</u> to be from lands lying upslope and west of the fen, and north of Mill Creek.
   ii. It <u>*appears*</u> that water from the watershed travels downslope through relatively shallow strata comprised of colluvium- glacial till-weathered bedrock and altered volcanic tuffs before it encounters a shallow perching clay layer near the west edge of the valley floor.
   iii. Upward leakage from the underlying confined aquifers <u>*appears*</u> to be an insignificant water source, if it's a water source at all.

2. Based on the current level of understanding, potential adverse activities include:
   i. Excavating into the hillside above (i.e., west and north) the fen to a depth that encounters or disturbs the colluvium-glacial till-weathered bedrock layer conveying water from the fen's watershed.
   ii. Converting subsurface colluvium- glacial till-weathered bedrock transported water to surface water.
   iii. Diverting encountered colluvium- glacial till-weathered bedrock waters away from the fen.
   iv. Concentrating encountered colluvium- glacial till-weathered bedrock waters and discharging it into the fen.

PROJECT SUPPORTERS

The River Protection Workgroup (RPW) was formed as an outgrowth of discussions among various regional water planning and resource protection organizations where a need became apparent for a collaborative process to select long-term, reliable, federal, state, local and/or other measures to protect the identified values of regional streams while allowing water development to continue.

Funding for this project was obtained through a grant from the Colorado Water Conservation Board with additional funding from the Southwestern Water Conservation District and the Five Rivers Chapter of Trout Unlimited. Without their funding and support, including the support by RPW Steering Committee, local U.S. Forest Service staff, and Mountain Studies Institute, this study would not be possible.

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APPENDICES

A. Final Report on Seismic Refraction Surveys Chattanooga Fen Site, Silverton, CO

B. Graphical Borehole and Well Completion Logs

C. DWR Notice of Intent to Construct Monitoring Hole(s)

D. DWR Well Construction and Yield Estimate Report

E. Army Corps of Engineers Pre-Construction Notification

F. Army Corps of Engineers Authorization

G. Compliance Certificate for Army Corps of Engineers

H. University of Arizona Analysis of Hydrogen and Oxygen Isotopes

I. University of Arizona Radiocarbon Analytical Report

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APPENDIX A

Final Report on Seismic Refraction Surveys Chattanooga Fen Site, Silverton, CO

Final Report

on

Seismic Refraction Surveys

Chattanooga Fen Site, Silverton, CO

August 2016

Version 1.0

August 2016

Prepared by:

TETRA TECH EC, INC.

Seismic refraction data were acquired along three profile lines during the week of July 18, 2016 at the Chattanooga Fen site, approximately 6 miles north of Silverton Colorado. The purpose of the study was to acquire information regarding the depth to the water table, depth to bedrock, and to characterize variations in bedrock seismic velocity along the profile lines that might provide insight into more permeable zones that were anticipated at shallow depths and which could exhibit enhanced groundwater flow. These might serve as a source of water to feed the fens that are found at the bottom of the slope. It was anticipated that bedrock would be encountered at shallow depths, perhaps 10-20 ft beneath the profile lines. The fractured or weathered zones would be exhibited in the seismic data as low velocity zones, relative to adjacent portions of the subsurface.

Lines 1 and 2 were oriented in a predominantly E-W direction, were designed to cross anticipated permeable zones, and were 710 ft. and 470 ft. in length respectively. Line 3, 380 ft. in length and oriented NW-SE, was designed to characterize properties in proximity to the stream and would likely cross fracture zones at an angle.

Figure 1. Seismic lines at the Chattanooga Fen Site

Data Acquisition

Seismic data were acquired with a 48-channel Geometrics Geode system using an 18-lb sledge hammer as the seismic energy source and 4.5 Hz geophones as receivers at 10-ft. spacing. The sledge hammer shots were located at 5 ft. off the ends of each line (except for the north end of Line 3, where only a 3 ft. offset was possible due to vegetation), and at 30 ft intervals within each line, always halfway between two geophones. Line 1 acquisition required that one of the two geophone cables be moved downline after data were acquired along the first 24-channel cable. This allowed a 720-ft line to be covered with a 48-channel cable. Eight hammer blows were executed at each shot point, with the nearest geophone channels “frozen” after the first shot to avoid saturating the amplitudes of data from those geophones. We chose to acquire data beginning at the higher altitude end of each line so that we could always move downhill between shotpoints. The field crew consisted of William Doll and Ed Muller of TetraTech and

Mark Oliver of Basin Hydrology, Inc. Elevations were provided by Basin Hydrology and are based on NAVD88 using a National Geodetic Survey monument.

Data Processing and Analysis

Seismic Refraction Tomography

Data were processed using the Rayfract software package, from Intelligent Resources, Inc. This software allows analysis of seismic refraction data using conventional wavefront and plus-minus methods as well as tomographic inversion based on the Waveform Eikonal Tomography (WET) method. The conventional methods can provide estimates of depths to sharp contacts, such as the water table or depth to bedrock, while the tomographic method is best suited to finding variations in velocity *within* a geologic unit. The seismic refraction tomography (SRT) methods tend to smear sharp boundaries where they exist, so that users often choose a particular velocity contour as representing the approximate depth of such a contact.

For sites with igneous bedrock, such as the Chattanooga Fen site, the important features in the seismic refraction data are 1) the water table (typically the shallowest depth where p-wave velocities first reach 5000 ft/s), 2) saturated alluvium (typical velocities of 5000 ft/s – 8000 ft/s) which may be similar to velocities of weathered bedrock, 3) weathered bedrock which should have p-wave velocities between the velocity of water and that of unweathered bedrock (5000-15000 ft/s), and unweathered igneous bedrock, which will have p-wave velocities of 15000 ft/s (5000 m/s) or higher. The bedrock velocity can be higher than this value, while the water table velocity is universally less variable. At the Chattanooga site, all three lines exhibited transitions in seismic velocity associated with the water table. Because the WET solutions tend to smear abrupt boundaries, the wavefont solutions provide a more reliable estimate of the depth to bedrock. From the p-wave data alone, it was difficult to determine whether the material beneath the water table, with velocities in the range of 5000-10000 ft/s, represented alluvium or weathered bedrock. The former would seem more likely from a geophysical perspective. However, information available before the survey indicated that bedrock was likely shallow, on the order of 10-20 ft. None of the lines exhibited velocities typical of unweathered igneous bedrock within the top 30-40 ft. Depth of penetration exceeded 100 ft (30m) along portions of each of the lines, but with lower sensitivity at that depth than in the top 40-50 ft (10-15m).

Seismic refraction analysis is based on identifying the travel time for seismic waves from the shotpoint to each geophone, and then, through forward modeling or inversion, finding a structural model that can cohesively explain these measurements for all shotpoints along a line. Figure 2 shows a representative shot from Line 3. The top panel shows the seismic measurements from 39 geophones with time increasing from 0 to 100 milliseconds (ms) in the top panel. Red x's represent the picked travel times for this shotpoint and blue x's represent the travel times for the model that has been determined from the data. The modeling procedure always aims to minimize the differences between these two sets of traveltimes. The shotpoint in this example is between Station Numbers (geophones) 21 and 22, and that there are transitions from steeper to gentler slopes in traveltime at about Station Numbers 17 and 25. The near geophones provide velocities for the shallow layer above the water table. There is some variation in travel time moving out from the shotpoint that is related to the topographic variation along the line. When data are acquired on a planar surface, and when the velocities beneath the water table are gradational as at the Chattanooga site, the travel time lines will tend to flatten out as the geophones get further from the source, indicating progressively higher velocities. This is difficult to envision in the unprocessed Chattanooga data because of the overprint of topographic effects. The lower panel in Figure 2 shows traveltimes for all shot points on the line in a single plot. The “tomograms” in Figures 5, 9, and 12 include headers that show the starting model (e.g. “GRADIENT.GRD”, wavepath width (e.g. “4.5%”), number of inversion iterations (e.g. “100 ITER”), and final RMS accuracy (e.g. “2.7%”). These are all parameters that validate the result and are retained to document the modeling, but are only included for thoroughness should any questions arise.

Wavefront Analysis of Seismic Refraction Data

We present wavefront analysis results for each of the three lines as a secondary, more conventional type of processing of the first arriving or refracted waves (vis a vis seismic refraction tomography, the primary method discussed above). This type of analysis is best where velocity changes are abrupt rather than gradational, as is the case for the water table. Therefore, we show estimates of depth to the water table along the lines that are based on the wavefront analysis. At the south end of Line 3, there was a shotpoint adjacent to the streambed, which provides a good check of the reliability of the water table depth. At this point, the water table is shown to be at the surface on the wavefront solution, as expected. The wavefront results also show a color-coded estimate of velocities immediately beneath the water table along each line.

The wavefront results can be used as a starting model for the tomographic inversions. We compared results from a wavefront starting model as well as velocity gradient models to evaluate the reliability of the tomographic inversion. Both starting models produced similar results, which affirms the reliability of the tomographic analysis.

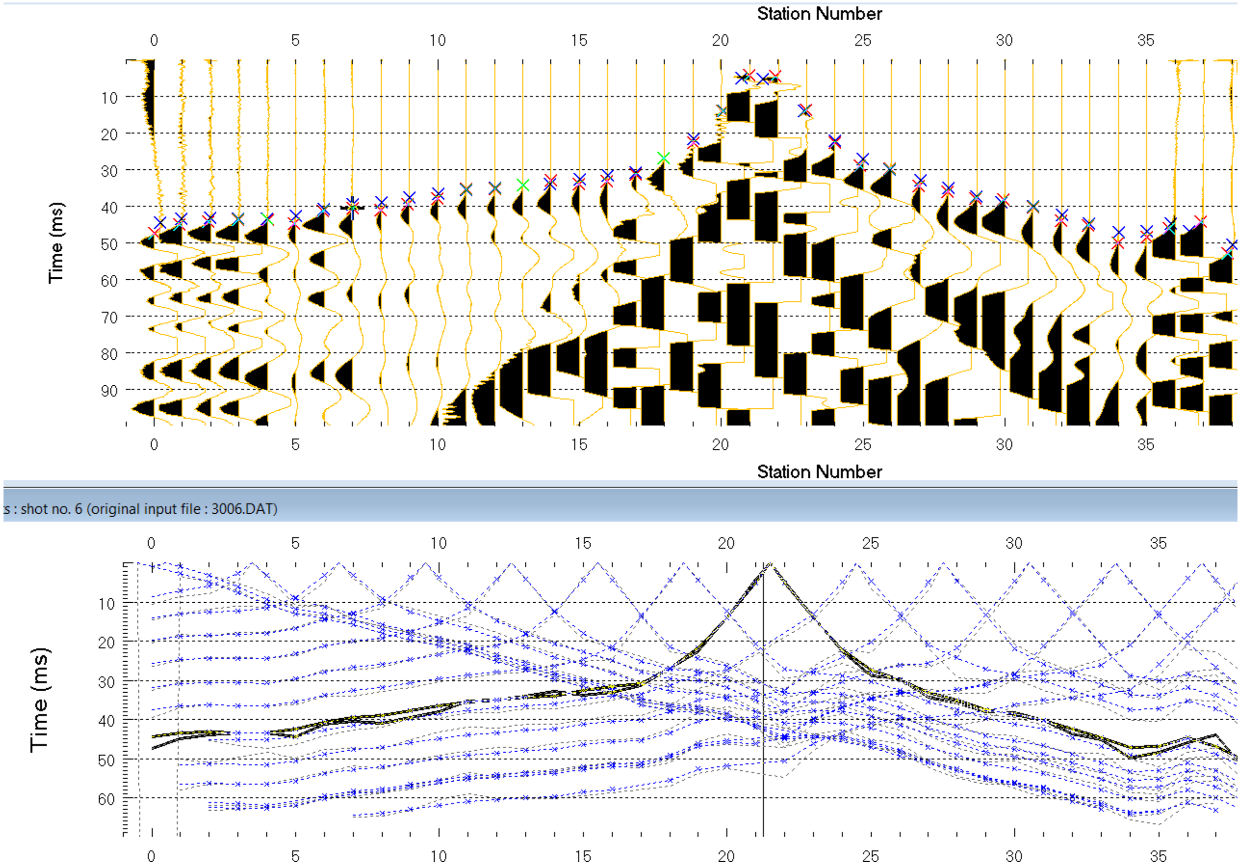


Figure 2. Travel time picks for a shotpoint on Line 3 at the Chattanooga Fen Site.

MASW Processing

As a byproduct of the seismic refraction analysis of first arriving waves, the surface wave data from Line 1 were processed to provide a second perspective on the near surface structure. Surface waves are low-frequency waves that are produced by the sledge hammer blows and which travel more slowly than the P-waves used for refraction analysis (Figure 3). Surface waves are not the same as shear waves but shear wave velocities can be derived from surface wave analysis. Surface waves exhibit a behavior known as dispersion, where their different frequency components can travel at different velocities. The long-wavelength (low frequency) components of the surface wave penetrate deeper than the short wavelength (high frequency) components. Dispersion causes the surface waves to form a long wavetrain that is several milliseconds in duration. Processing of the surface waves using SurfSeis software for multichannel analysis of surface waves (MASW) produces a map of the shear wave velocity along the same transect where the refraction tomography analysis produced a p-wave velocity section. This analysis proved beneficial in understanding the nature of material between the water table and the interpreted bedrock at the Chattanooga fen site.

When surface wave analysis is the primary purpose of a field deployment, a different data acquisition procedure would normally be used with smaller geophone separation and a “roll-along” process where the energy source is operated from the end of the geophone spread and the group of geophones that are recorded is advanced as the energy source moves along the profile. When MASW analysis is performed on a seismic refraction data set which uses a fixed geophone spread, groups of geophones must be selected that are behind the source, ahead of the source, or both, and each group must be processed separately to produce a partial image of the structure along the line. Sparser geophones of the refraction configuration can result in poorer isolation of high frequency surface wave components, which typically causes reduced detail or confidence in the shallow portions of the transect. Despite these features, it is generally beneficial to conduct surface wave analysis as a means of confirming the SRT results or providing insight into questions that have not been resolved by the SRT analysis.

There are fundamental differences between p-waves and shear waves that can provide useful insights regarding the subsurface. First, because shear waves will not pass through liquids, they are largely insensitive to the presence of fluids in the rocks/ sediments and therefore to the water table. Despite this, MASW sections will often have a subtle response, much weaker than that in p-wave sections, associated with the water table, due to the more complicated properties of surface waves, as compared to shear waves. Secondly, the shear waves will always travel more slowly than P-waves, with the ratio of the two depending on the elastic moduli (e.g. compressibility, shear strength) of the medium. Where both P-wave and shear wave cross sections are reliable, they can be used to produce Poisson's Ratio cross sections*. This was not appropriate for the dataset from the Chattanooga Fen site.

* When a material is stretched in one direction it tends to get thinner in the other two perpendicular directions. Poisson's ratio is the ratio of the relative contraction strain (or transverse strain) normal to the applied load - to the relative extension strain (or axial strain) in the direction of the applied load. To put it simply, it is a measure of the material's response to contraction or extension in one direction that can be indicative of the type of material, and can help differentiate between one type of rock/sediment and another.

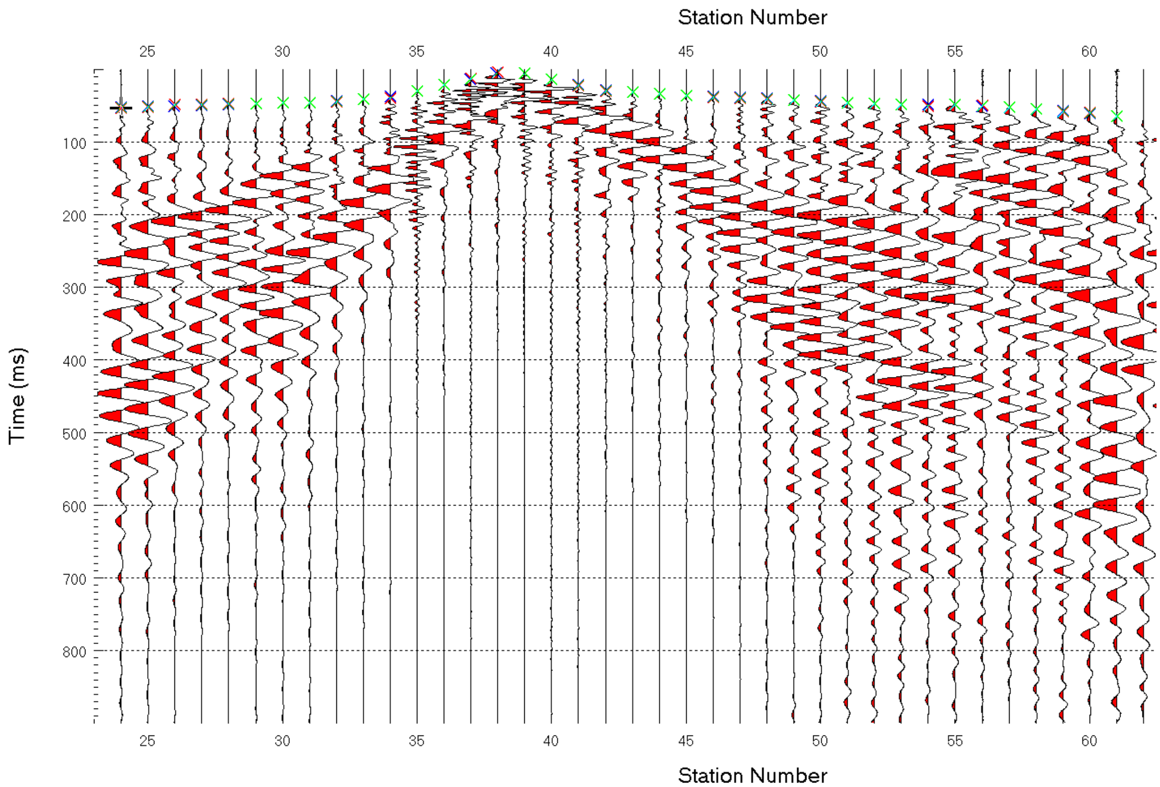


Figure 3. Surface waves, predominant between about 200-800ms, from the Line 1 data.

The ratio of P-wave velocity to shear-wave velocity, Vp/Vs, should be in the range of 1.5- 2 for saturated well-consolidated rocks (e.g. weathered igneous rocks), and when the ratio exceeds 2 it typically is indicative of saturated unconsolidated rocks (M.W. Lee, Velocity Ratio and its Application to Predicting Velocities, USGS Bulletin 2197, 2003), where both velocities are well-resolved. This turned out to provide important information when MASW analysis was performed on the Line 1 data. Unfortunately, the data from Lines 2 and 3 were not suitable for MASW analysis. In Line 2, this was largely due to some settings that were used for data recording which didn't affect SRT analysis, but made the data unsuitable for MASW analysis. Line 3 was too short to perform reliable MASW analysis. Fortunately, the MASW results from Line 1 can reasonably be extended to the interpretation of Lines 2 and 3.

Results

Line 1

Line 1 had a total length of about 720 ft (220m) with about 125 ft. change in elevation from the west end to the east end. It crossed a toe road at about 100 ft. from the west end, a saturated zone between about 160-200 ft. from the west end, a parking pad between about 550-600 ft., and terminated at the east end in a low wet zone between 670-720 ft.. Although station flags extended from -10 ft. at the east end to 730 ft at the west end, the profiles shown here have the opposite numbering scheme due to the order in which data were acquired and idiosyncrasies of the processing software. Hereafter, we refer to locations shown on the profiles in this report, rather than the survey flag numbers. The 0.0 ft point on the cross sections here corresponds to flag 720, the uphill end, in the database, and the 720 ft / 219.5m point here corresponds to the 0 flag, the downhill end, in the database. There were no geophones at flags 3 (690 ft), 4 (680 ft), 52 (200 ft), 53 (190 ft), 54 (180 ft), and 55 (170 ft) due to saturated soil or surface water. Likewise, no shotpoints were located at flags 3.5 (685 ft) and 54.5 (185 ft.) due to saturation.

The wavefront solution for Line 1 is shown in Figure 4, and the WET tomographic solution is shown in Figure 5. Figure 6 is a "raypath" figure that is included to assist in interpretation. Generally speaking, high raypath coverage indicates a high degree of reliability. Low velocity zones always have low raypath coverage, but this does not mean that those features are unlikely to be real; rather it is important to have good raypath coverage on all sides of a low velocity feature, but raypaths, which represent the path traveled by first arriving waves from a source to a geophone, would not be expected to pass through a low velocity zone because it would cause delays – the fastest arrival will always go around a low velocity zone. The actual velocity of a low velocity feature is not well constrained by tomographic refraction analysis.

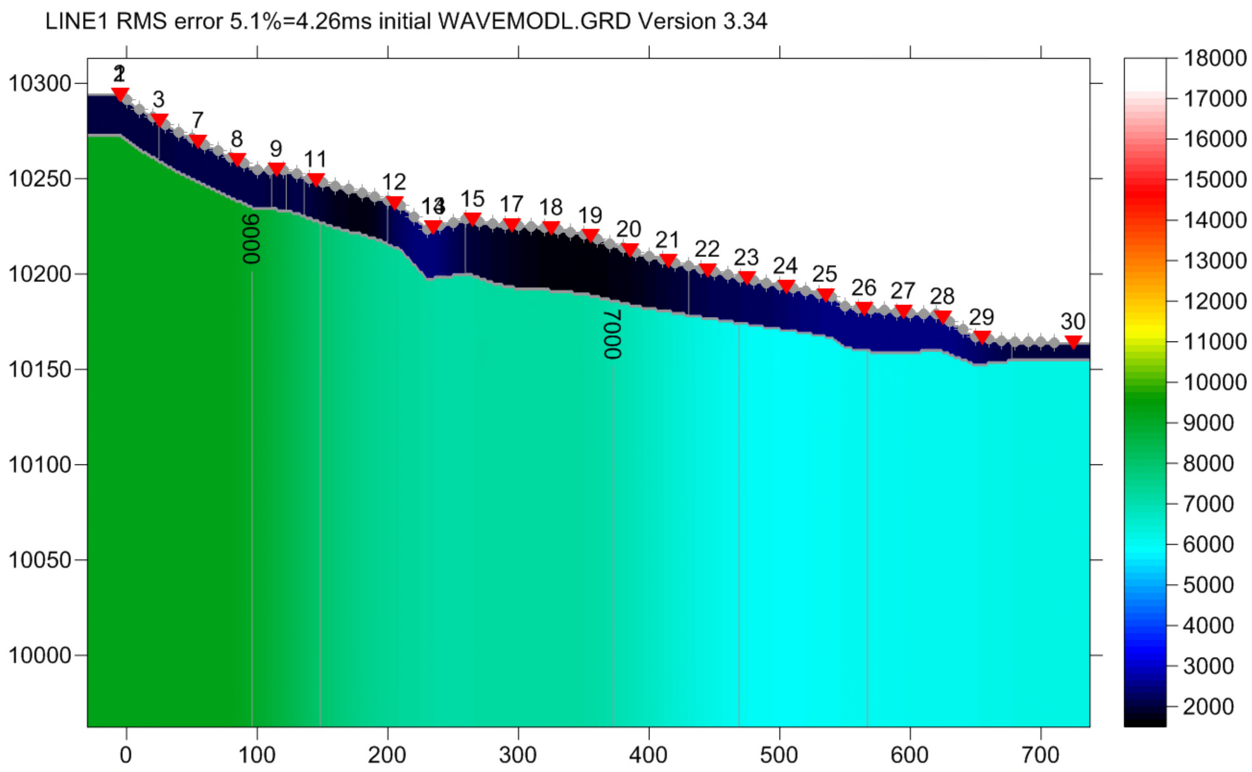


Figure 4, Wavefront solution showing depth to water table for LIne 1. The interface between the dark blue/black and the lighter colors represents the top of the water table.

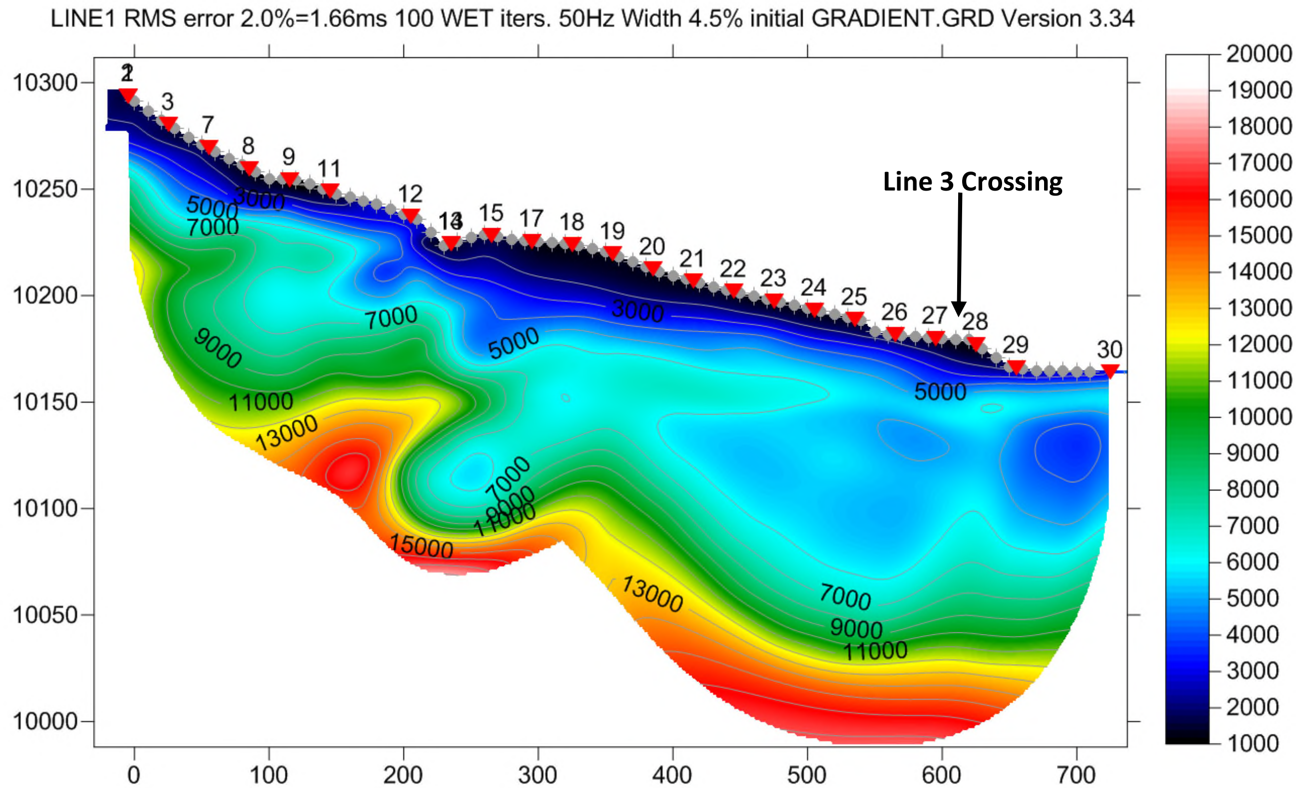


Figure 5. Seismic velocity cross section from SRT for Line 1.

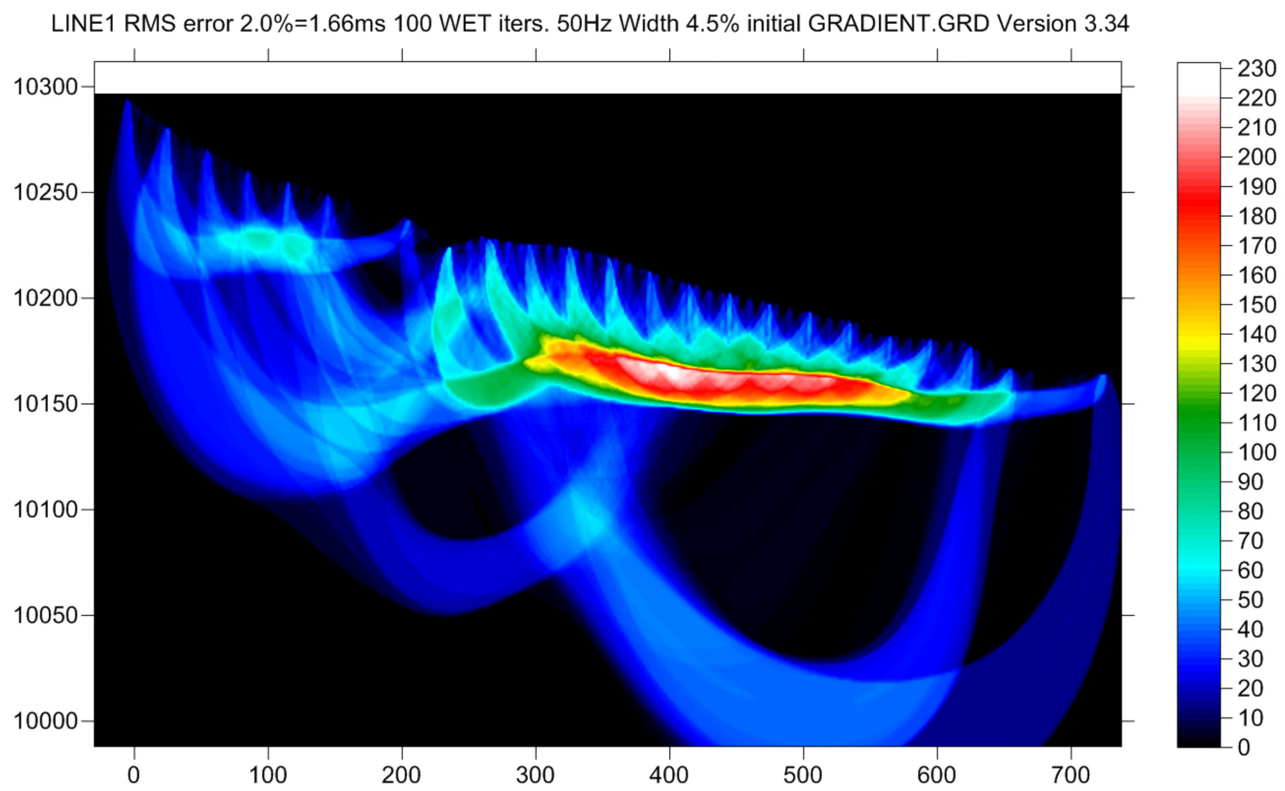


Figure 6. Raypath coverage diagram for Line 1 seismic refraction tomography.

MASW processing was applied to three segments of data from Line 1. On the lower portion of the line, two subsets of the data were suitable for MASW processing: one where the source was uphill from geophones, and another where the source was downhill from the geophones. On the upper portion of the line we were able to process a subset of the data where the source was downhill from geophones. Within each of these segments, geophones that were between 20 and 260 feet from the source were used to perform MASW analysis. The results of the shear wave analysis are overlain on the SRT image for Line 1 in Figure 4. In this figure we have overlain SRT velocity contours on top of the MASW sections to make visual comparison between the two results easier. The shear velocity color bars are scaled from 800-8000 ft/s whereas the p-wave velocities on the SRT sections typically range from 1000-20000 ft/s.

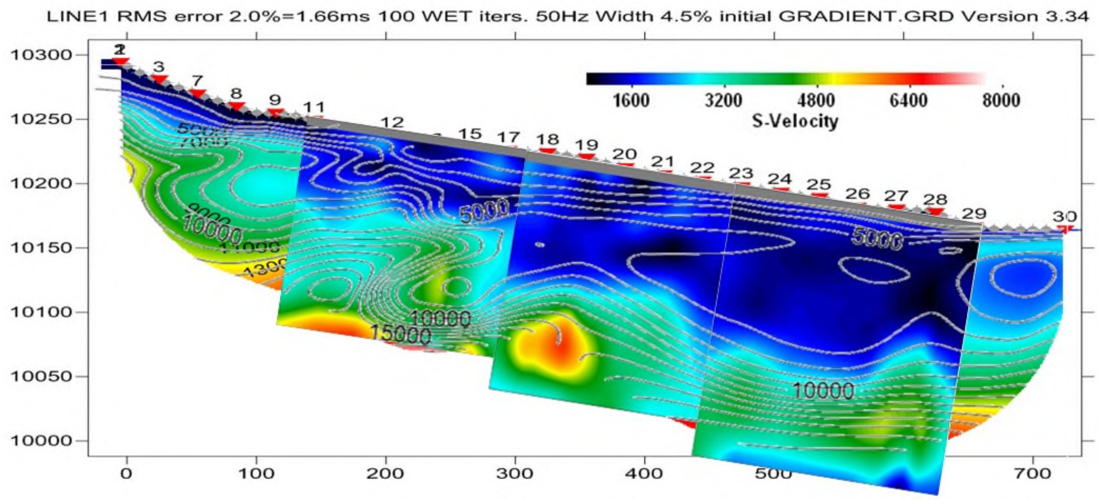


Figure 7. MASW shear velocity overlain on the P-wave map for Line 1. A 1:1 vertical to horizontal scale was used to simplify overlays of the MASW sections and SRT contours. Shot point file numbers are indicated with numbers and inverted red triangles on the surface.

Line 2

Line 2 had a total length of about 470 ft. (143m) with more than100 ft. change in elevation from the west end to the east end. It passed under a high voltage power line at about 100 ft. from the west end and crosses a toe road at about 125 ft. from the west end. Although station flags extended from -10 ft. at the east end to 470 ft. at the west end, the profiles shown here have the opposite sense as with Line 1. The 0.0 ft. point on the cross sections here corresponds to flag 470 in the database, and the 470 ft. point here corresponds to the 0 flag in the database.

The wavefront solution for Line 2 is shown in Figure 8, and the WET tomographic solution is shown in Figure 9. Figure 10 is the corresponding "raypath" figure.

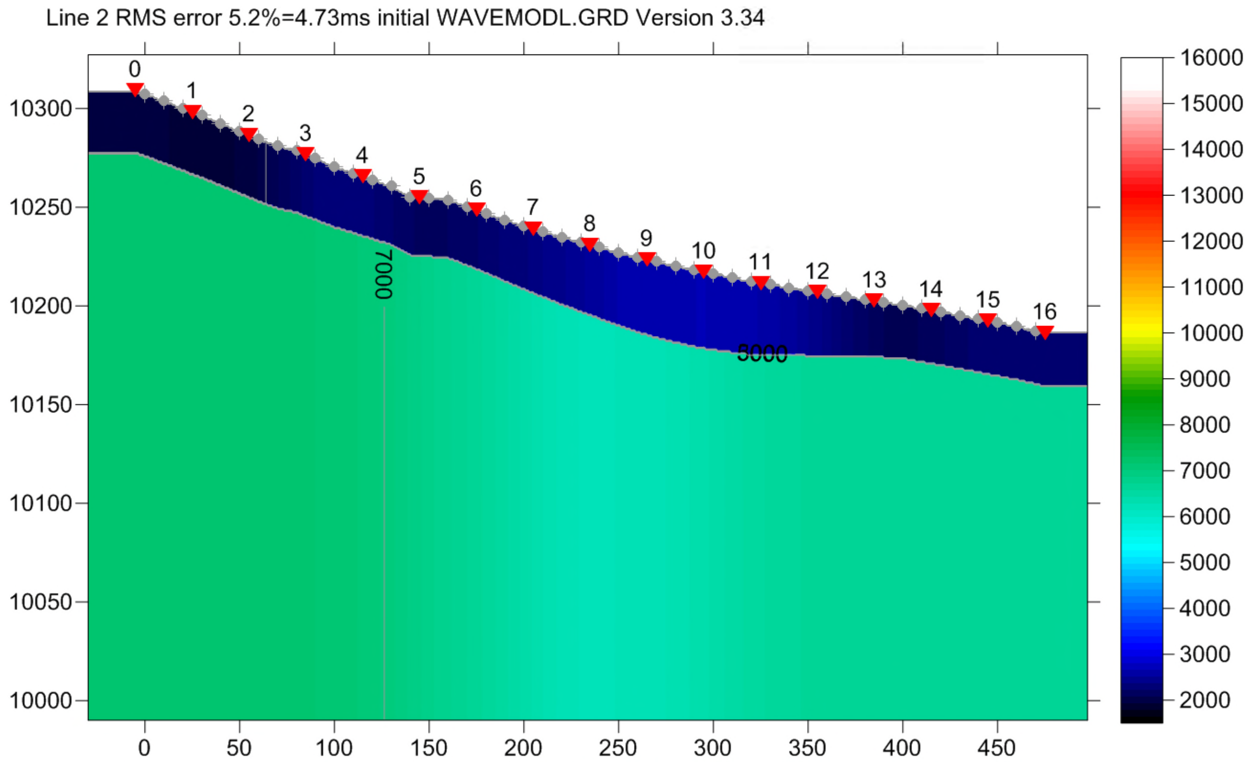


Figure 8. Wavefront solution for Line 2, showing depth to water table.

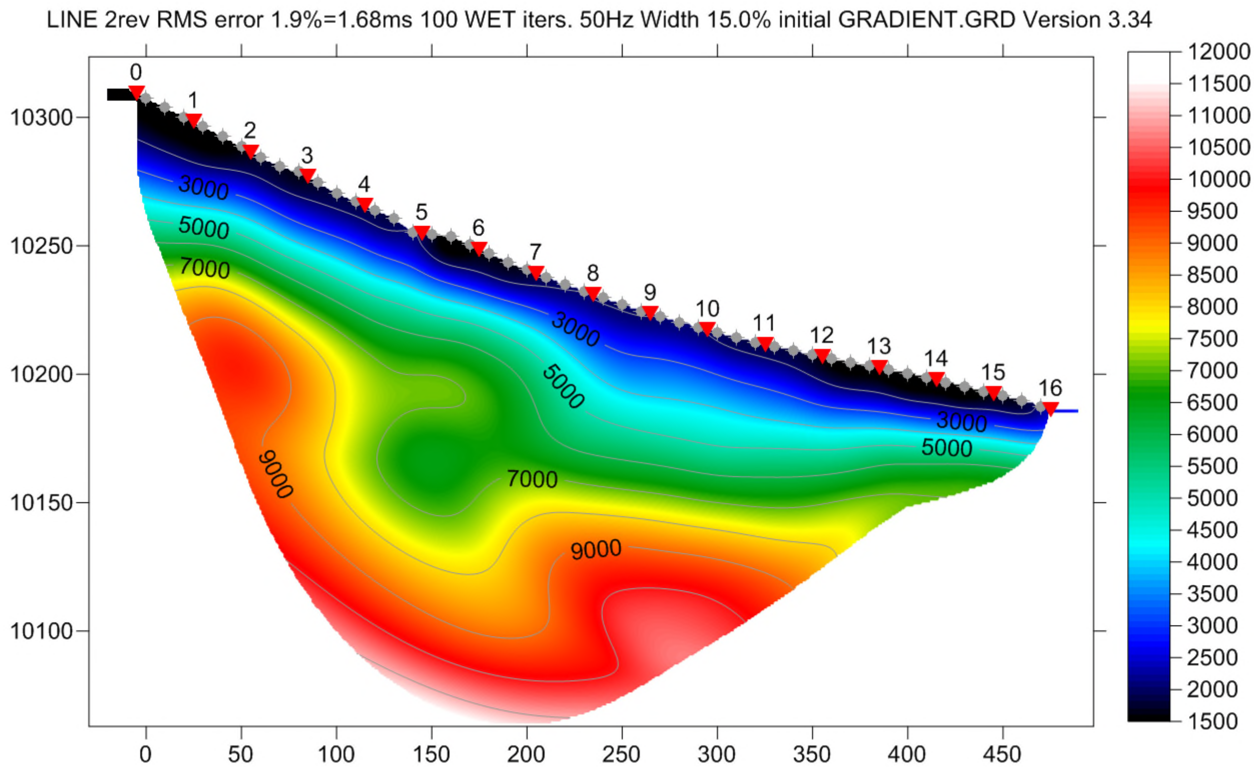


Figure 9. SRT velocity profile for Line 2.

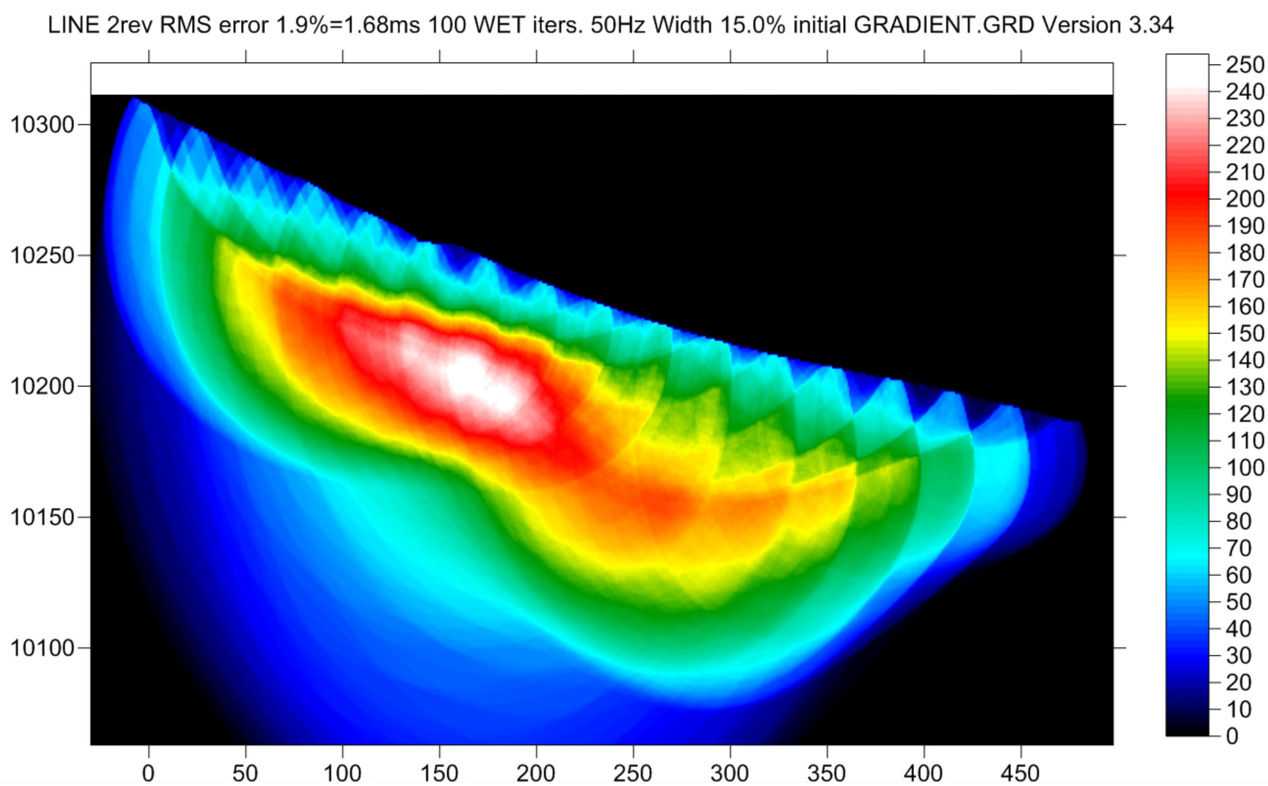


Figure 10.. Raypath diagram for SRT profile of LIne 2.

Line 3

Line 3 had a total length of about 380 ft (116m) with only about 30 ft change in elevation from the northwest end to the southeast end. It passed along a dirt road, with some stations located on the edge of the road and some off the edge of the ditch along the side of the road. Station 314.5 of line 3 crosses Line 1 at its station 611. Station 0 of Line 3 is located a few inches above the water level in the streambed and is positioned a few meters away from the edge of the stream. The wavefront solution for Line 3 is shown in Figure 11, and the WET tomographic solution is shown in Figure 12. Figure 13 is the corresponding “raypath” figure.

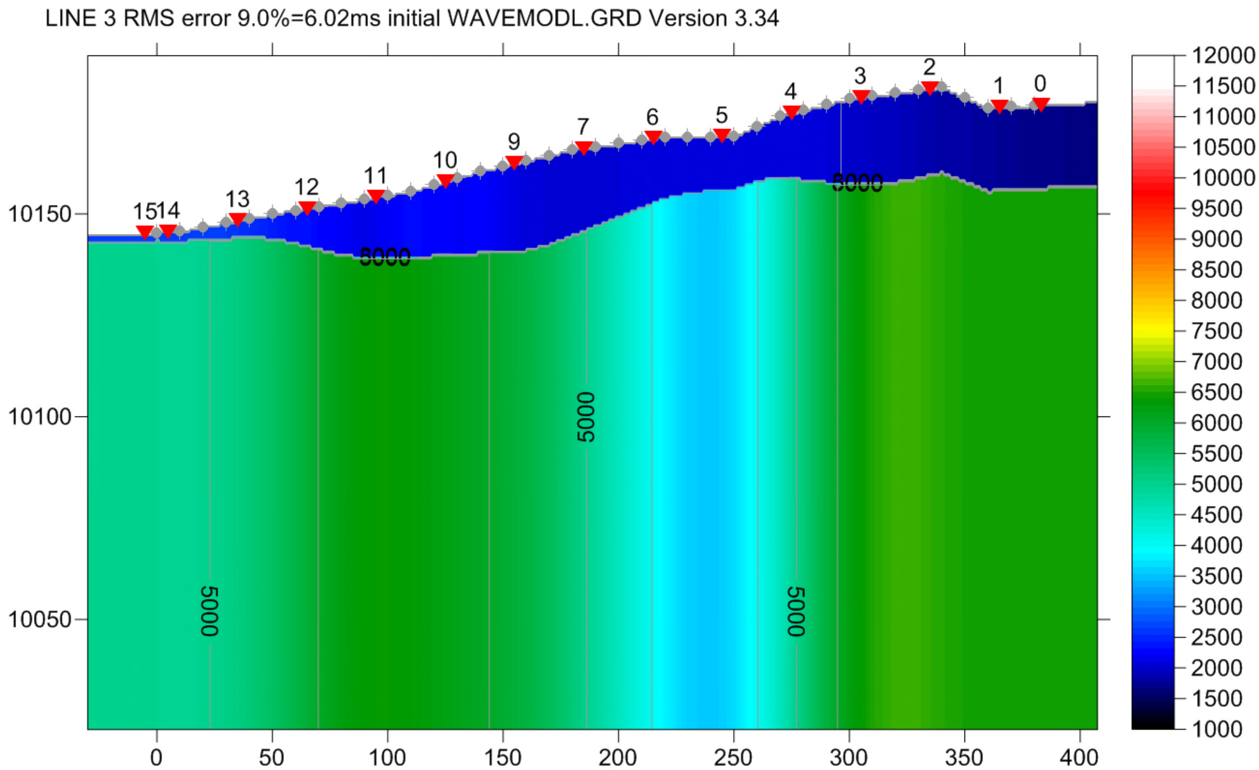


Figure 11. Wavefront solution for Line 3, showing depth to water table.

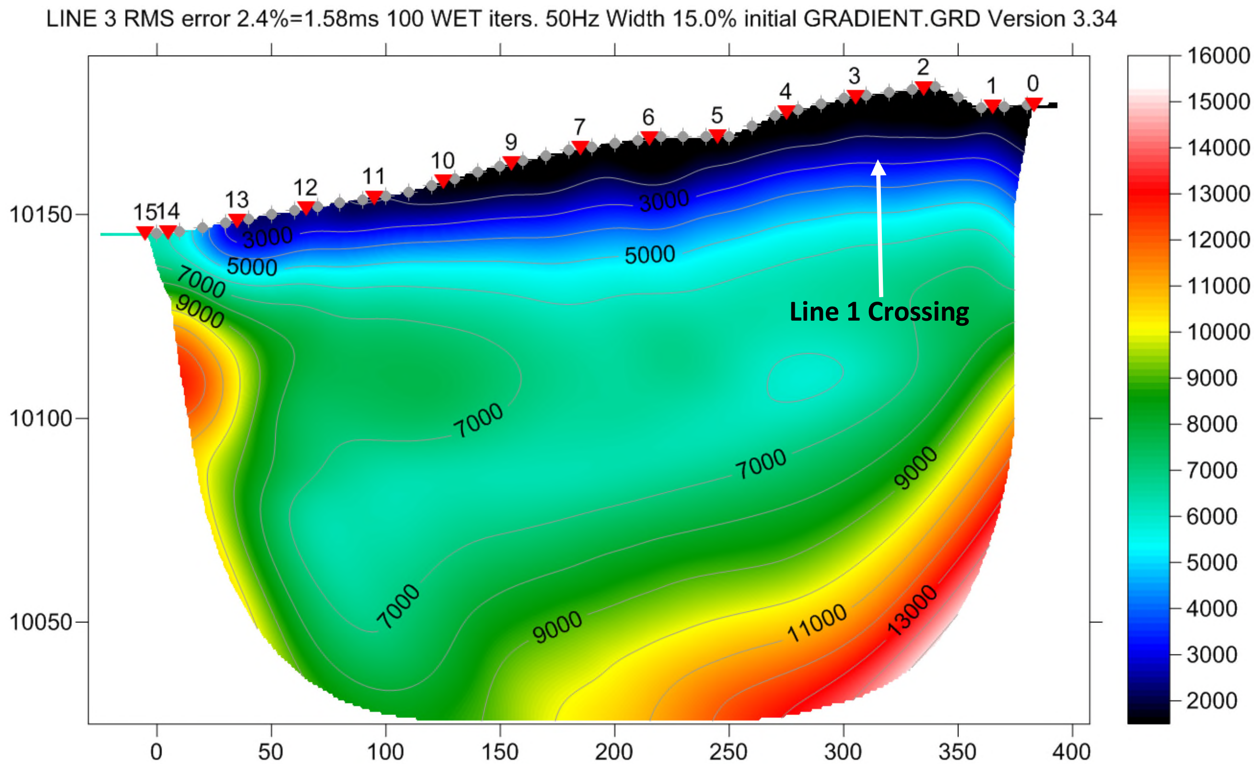


Figure 12. SRT seismic velocity profile for Line 3.

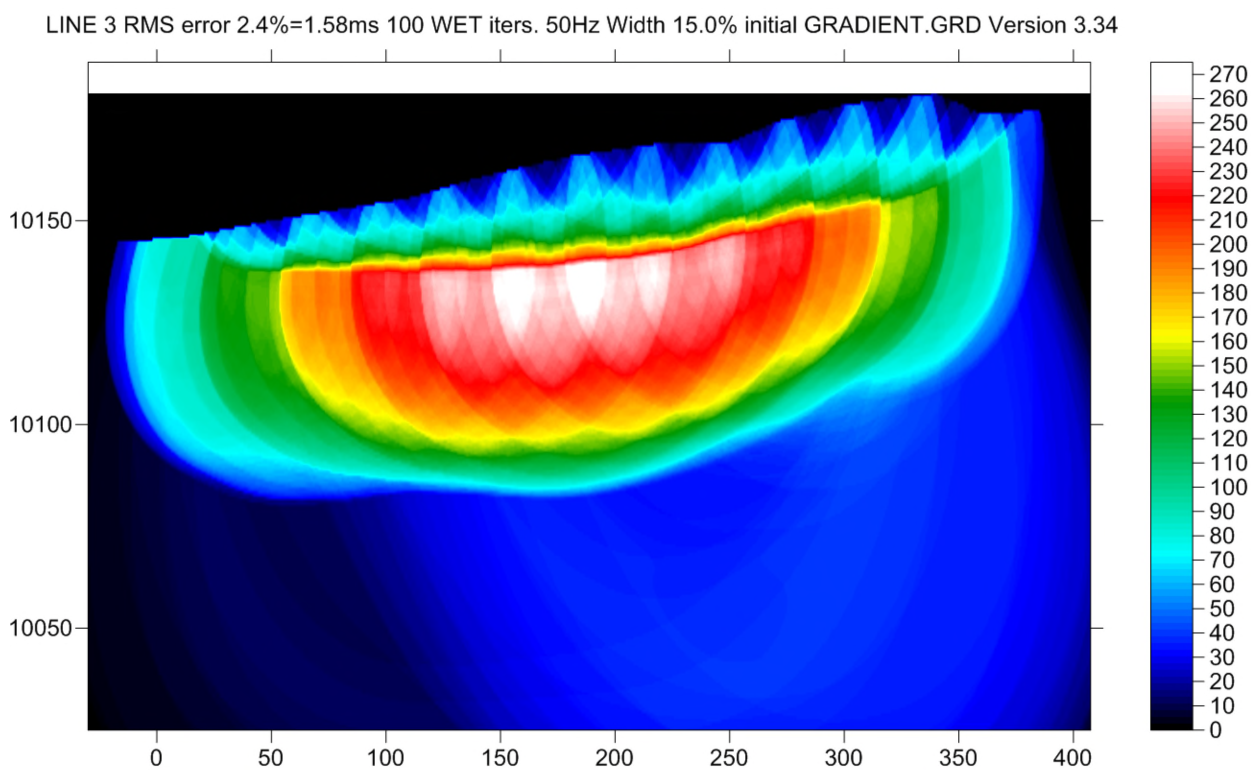


Figure 13. Raypath diagram for SRT profile of Line 3.

Interpretation

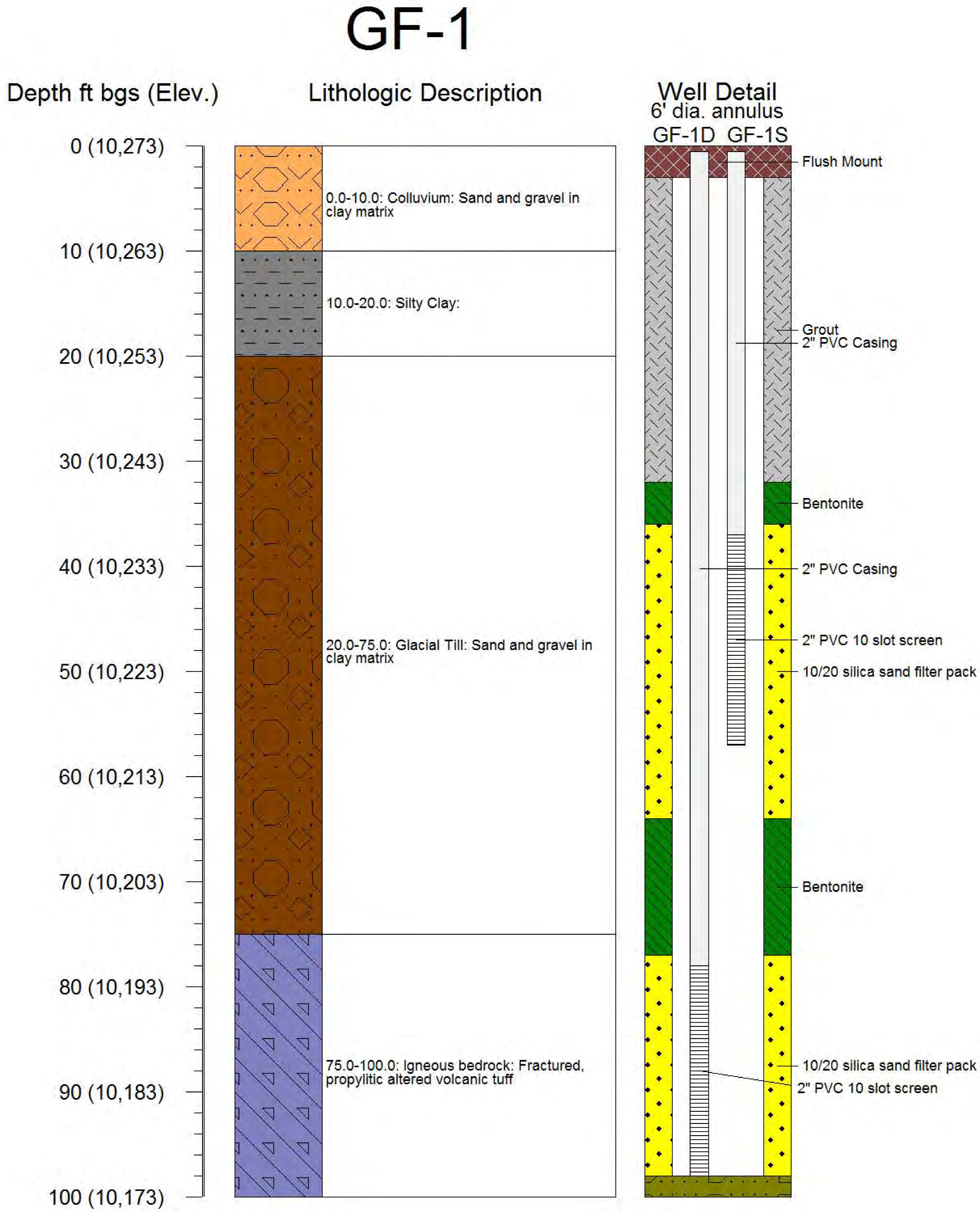
1. The water table, as indicated by the base of the upper layer in Figures 4, 8, and 11 and approximated by the 5000 ft/s contours on Figures 5, 9, and 12 are consistent with the observed features along the three lines, specifically: 1) the stream level at 0-10ft. on Line 3; 2) the saturated area between 175-200 ft on Line 1, and 3) the low soft area between 680-720 ft. on Line 1. The depth of the water table interface and contours at the northwest end of Line 3 are unexpectedly deep (about 20 ft). The water table value at the east end of Line 2 (about 15 ft) seems reasonable, given that the line terminated well above the observed surface water. The interface and contours tend to be subparallel to the ground surface, as would be expected for a water table. The water table on Line 2 appears to be a few feet deeper on average than along Line 1.
2. The seismic data indicate that the top of bedrock is much deeper than originally believed. The top of bedrock is not apparent on profiles for any of the lines. None of the velocities measured on any of the lines at any depth are as high as we would expect to see for unweathered igneous bedrock. The MASW results on Line 1 provide shear velocities that are generally less than half of the p-wave velocities on the corresponding SRT cross section in the portion of the section between the water table and the 8000 ft/s p-wave velocity contour (roughly the blue and black portions of the MASW overlays of Line 1). The resulting Vp/Vs ratio is typical of saturated unconsolidated sediments, as opposed to weathered bedrock. An alternative explanation, based on the SRT analysis alone, would be that the region between the water table and the 8000 ft/s contour represents a transitional zone from highly-weathered bedrock to predominantly unweathered bedrock at depth. This second explanation seems untenable, in light of the MASW results.
3. The gradients in seismic velocities are steeper on average when velocities on the SRT profiles exceed 8000 ft/s. SRT tends to smooth out abrupt changes in velocity and make them appear as steep gradients. On this basis, we believe that the top of bedrock is likely to be found near the 8000 ft velocity contours on the SRT images.
4. SRT processing was performed with a suite of different control parameters, and each of these produces a slightly different model of the velocity structure for the profile. The SRT results for Line 1 were compared to the MASW results for that line, and the SRT model that best matched the MASW was selected as the basis for interpretation. The primary difference between this SRT model and others is the more enhanced low velocity feature at x=250, y=10100, which appears to be supported by the MASW data.
5. Both Line 1 and Line 2 have high velocity tongues that extend from the uphill side over a lower velocity zone beneath them. These occur at two depths on Line 1 (x=180, y=10225 and x=500, y=10150), and one of those occurs at about the same depth and with the same velocities as the one on Line 2. Note that in Figure 1, Line 2 appears to cover an area that may correspond to the upper portion of Line 1, but the distance from the top of the line to the saturated area adjacent to the stream appears shorter on Line 2. It is possible that the feature on Line 2 corresponds to one of the features on Line 1. One interpretation is that these high velocity layers might correspond to iron-cemented zones related to development of the fens.
6. All three lines indicate some areas of low velocity zones within the top 50-100 ft and underlying the high velocity tongues described above. Low velocity zones infer material that is less consolidated, perhaps more permeable, and/or having a different character

than the sediments above them and to their sides. On Lines 1 and 2, these features might appear to dip to the west at roughly 45 degrees on some images. Two such features are indicated on Line 1, the largest centered at about x=500 ft., y=10125 ft. The minimum velocity of this feature (5000 ft/s and less) has some uncertainty, as the velocities within low velocity zones are poorly constrained by the tomographic inversion as previously indicated. A second feature on Line 1 extends from about shot point 13 (x=60m) to about x=100 ft., y=10200 ft. A third low velocity area occurs at about x=250, y=10125 on Line 1. This zone is not as obvious on some of the SRT solutions that were developed for Line 1, but correlates well with MASW solutions. On Line 2, a similar low velocity feature occurs at about x=150, y=10160. The higher velocity tongue overlying this feature is only present in some of the solutions that were tested during processing of Line 2 data. A more subtle low velocity feature on Line 3 occurs at similar depths and has a trajectory that is at a lower angle to the horizontal, as would be expected for a feature oriented perpendicular to Lines 1 and 2 (roughly parallel to slope).

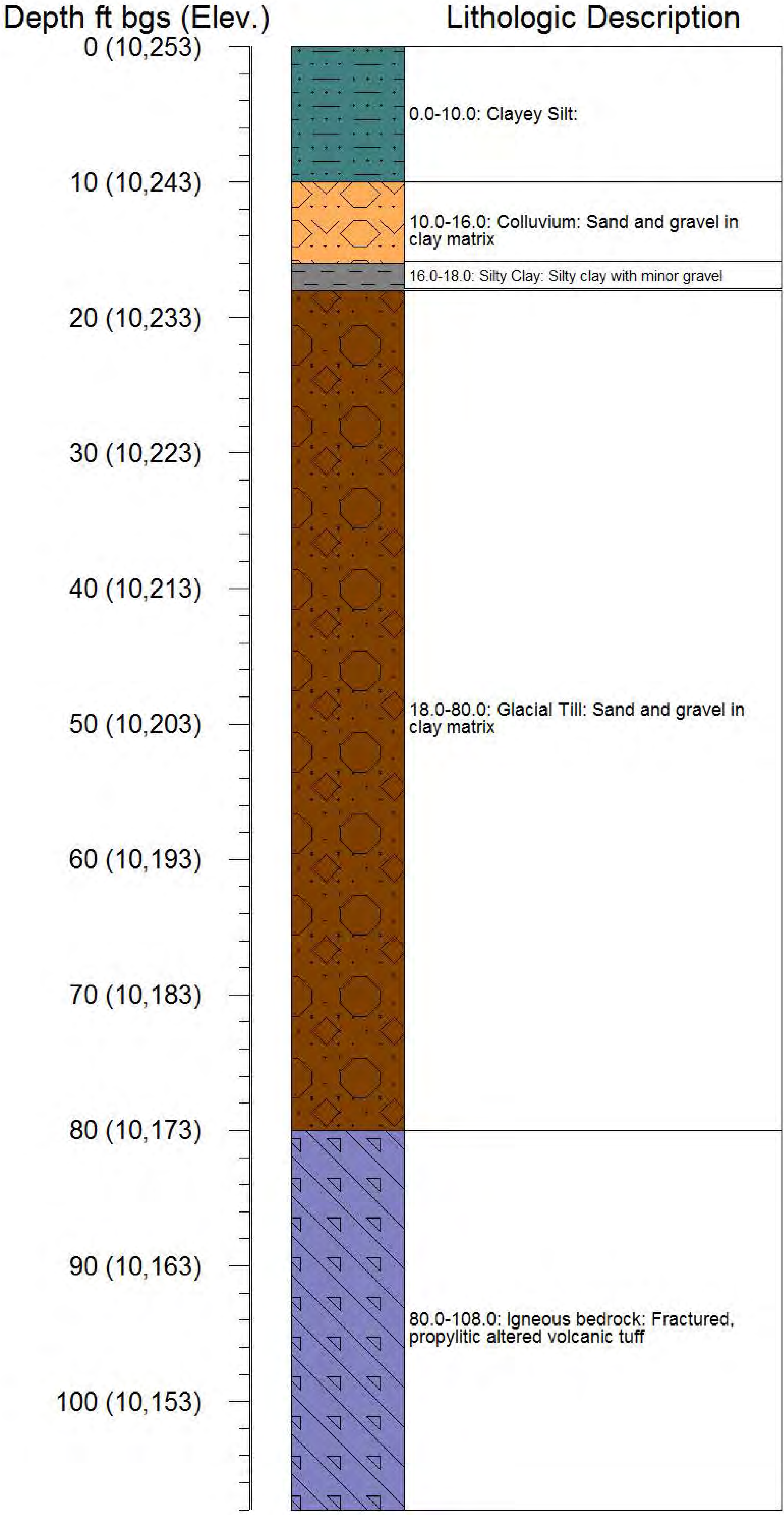
7. Where Lines 1 and 3 intersect, the contours seem to be consistent: The water table is at roughly 20 ft depth on both, and the low velocity feature is at z=10100 on both. The 8000 ft. contour, which might represent unweathered bedrock, is at about 100060 on Line 1 and about 20 feet shallower on Line 3. This apparent discrepancy is understood as a byproduct of the poorly-constrained character of deep features at the ends of both of these lines.

APPENDIX B

Graphical Borehole and Well Completion Logs


GF-1
Depth ft bgs (Elev.)
Lithologic Description
Well Detail
6' dia. annulus
GF-1D GF-1S
0 (10,273)
10 (10,263)
20 (10,253)
30 (10,243)
40 (10,233)
50 (10,223)
60 (10,213)
70 (10,203)
80 (10,193)
90 (10,183)
100 (10,173)
0.0-10.0: Colluvium: Sand and gravel in clay matrix
10.0-20.0: Silty Clay:
20.0-75.0: Glacial Till: Sand and gravel in clay matrix
75.0-100.0: Igneous bedrock: Fractured, propylitic altered volcanic tuff
Flush Mount
Grout
2" PVC Casing
Bentonite
2" PVC Casing
2" PVC 10 slot screen
10/20 silica sand filter pack
Bentonite
10/20 silica sand filter pack
2" PVC 10 slot screen

GF-2


Depth ft bgs (Elev.)
Lithologic Description
0 (10,253)
10 (10,243)
20 (10,233)
30 (10,223)
40 (10,213)
50 (10,203)
60 (10,193)
70 (10,183)
80 (10,173)
90 (10,163)
100 (10,153)
0.0-10.0: Clayey Silt:
10.0-16.0: Colluvium: Sand and gravel in clay matrix
16.0-18.0: Silty Clay: Silty clay with minor gravel
18.0-80.0: Glacial Till: Sand and gravel in clay matrix
80.0-108.0: Igneous bedrock: Fractured, propylitic altered volcanic tuff

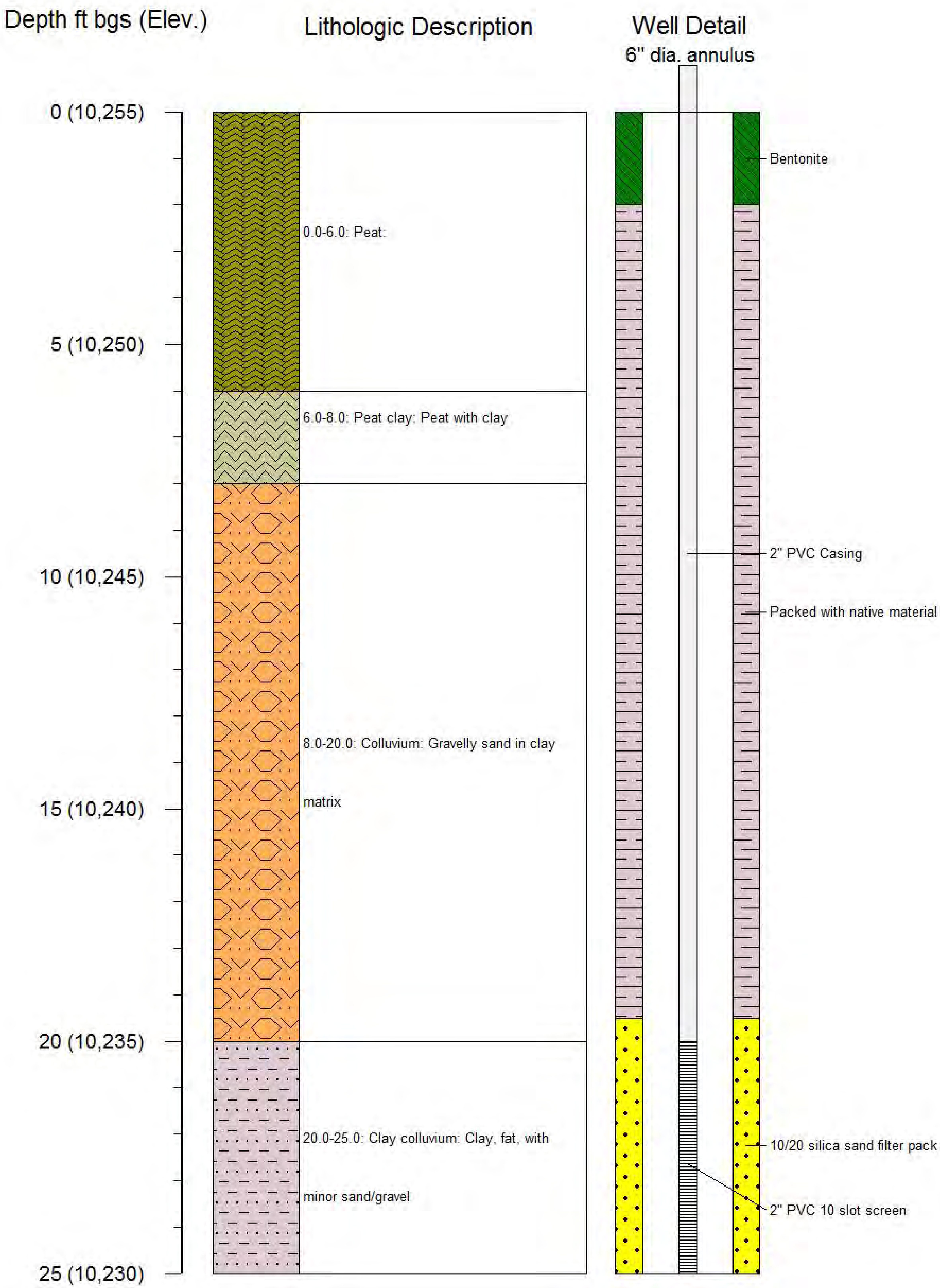
820-1

Depth (ft. bgs)
Lithologic Description
0 (10,182)
10 (10,172)
20 (10,162)
30 (10,152)
40 (10,142)
50 (10,132)
60 (10,122)
0.0-13.0: Gravel: Gravel with minor silt
13.0-18.0: Colluvium: Gravel and sand in clay matirx
18.0-35.0: Clay: Clay, fat
35.0-60.0: Silty Clay: Silty clay with minor gravel

820-2


Depth ft bgs (Elev.)
Lithologic Description
0 (10,149)
10 (10,139)
20 (10,129)
30 (10,119)
40 (10,109)
50 (10,099)
60 (10,089)
0.0-5.0: Gravel: Stream bed cobbles
5.0-16.0: Clay: Clay, fat
16.0-18.0: Colluvium: Sand and gravel in clay matrix
18.0-28.0: Clay: Clay, fat
28.0-60.0: Colluvium: Sand and gravel in clay matrix

FB-3


Depth ft bgs (Elev.)
Lithologic Description
Well Detail
6" dia. annulus
0 (10,255)
5 (10,250)
10 (10,245)
15 (10,240)
20 (10,235)
25 (10,230)
0.0-6.0: Peat:
6.0-8.0: Peat clay: Peat with clay
8.0-20.0: Colluvium: Gravelly sand in clay matrix
20.0-25.0: Clay colluvium: Clay, fat, with minor sand/gravel
Bentonite
2" PVC Casing
Packed with native material
10/20 silica sand filter pack
2" PVC 10 slot screen

APPENDIX C

DWR Notice of Intent to Construct Monitoring Hole(s)

RECEIVED
SEP 07 2016
WATER RESOURCES
STATE ENGINEER
COLO

GWS-51
3/2008

NOTICE OF INTENT TO CONSTRUCT MONITORING HOLE(S)

Please type or print legibly in black or blue ink or file online @ dwrpermitsonline@state.co.us
COLORADO DIVISION OF WATER RESOURCES-1313 SHERMAN ST-STE 821-DENVER-CO-80203
PHONE 303-866-3581 WEB www.water.state.co.us

Well Owner Name(s): Basin Hydrology, Inc.
Address : 2340 CR 203, Durango, CO 81301
Phone (area code & no.): 970-903-0366
Landowner's Name: San Juan National Forest, Columbine R D

Please check one and complete as indicated including contact info:

- ☐ Water Well Driller Licensed in Colorado – Lic. No. ______
- ☐ Professional Engineer Registered in Colorado – Reg. No ______
- ☒ Professional Geologist per CRS 34-1-201(3)
- ☐ Other -anyone directly employed by or under the supervision of a licensed driller, registered professional engineer or professional geologist

Contact / Company Ed Muller, Tetra Tech
Address 3801 Automation Way, Suite 100
City, State & Zip Ft. Collins, CO 80525
Phone 971-206-4218 **Fax** ______

Print Name: Ed Muller
Sign or enter full name here: Edward Muller CN = Edward Muller C = AD 2016.08.30 07:31:58 -07'00'

Location: SE ¼ SE ¼, Section 27
Township 42 ☒N ☐S, Range 8 ☐E ☒W, NM PM
County San Juan
Subdivision n/a
Lot: ______ Block ______ Filing Unit ______
Site/Property Address n/a

GPS Location in UTM format (optional):
Set GPS unit to true north, datum NAD83, and use meters for the distance units, ☐ Zone 12 or ☐ Zone 13
Easting ______ Northing ______

# of Monitoring Hole(s) to be constructed: up to 3
Estimated Depth 60 **Ft., Aquifer** surface
Purpose of Monitoring Hole(s) sample water chemistry & observe water depth

Anticipated Date of Construction (mm/dd/yyyy) 09/12/2016

Date Notice Submitted (mm/dd/yyyy): 08/30/2016
(Must be at least 3 days prior to construction)

ACKNOWLEDGEMENT FROM STATE ENGINEER'S OFFICE

FOR OFFICE USE ONLY

55853 - MH PROCESSED BY W

DIV 7 WD 30 BAS ______ MD ______ DATE ACKNOWLEDGED 9-7-16

CONDITIONS OF MONITORING HOLE ACKNOWLEDGEMENT

A COPY OF THE WRITTEN NOTICE OR ACKNOWLEDGEMENT SHALL BE AVAILABLE AT THE DRILLING SITE.

1) **Notice was provided to the State Engineer at least 3 days prior to construction of monitoring & observation hole(s).**
2) **Construction of the hole(s) must be completed within 90 days of the date notice was given to the State Engineer.** Testing and/or pumping shall not exceed a total of 200 hours unless prior written approval is obtained from the State Engineer. Water diverted during testing shall not be used for beneficial purposes. The owner of the hole(s) is responsible for obtaining permit(s) and complying with all rules and regulations pertaining to the discharge of fluids produced during testing.
3) **All work must comply with the Water Well Construction Rules, 2 CCR 402-2.** Minimum construction standards must be met or a variance obtained. Standard permit application and work report forms, including online filing instructions, are found on the DWR website at http://www.water.state.co.us. **Well Construction and Test Reports (GWS-31)** must be completed for each hole drilled. The licensed contractor or authorized individual must submit the completed forms to this office within 60 days of monitoring hole completion.
4) **Unless a well permit is obtained, or variance approved, the hole(s) must be plugged and sealed within one (1) year after construction. An Abandonment Report (form GWS-9) must be submitted within 60 days of plugging & sealing.** The above MH acknowledgement number, owner's structure name, and owner's name and address must be provided on all well permit application(s), well construction and abandonment reports.
5) **The owner of the hole(s) shall maintain records of water quality testing and submit this data to the State Engineer upon request.**
6) **A MONITORING HOLE CANNOT BE CONVERTED TO A PRODUCTION WATER WELL, except for purposes of remediation (recovery) or as a permanent dewatering system, if constructed in accordance with the Water Well Construction Rules and policies of the State Engineer.**
7) IF HOLES WILL NOT BE CONSTRUCTED UNDER THIS NOTICE WITHIN 90 DAYS, PLEASE WRITE, "NO HOLES CONSTRUCTED" ON A COPY OF THE ACKNOWLEDGED NOTICE WITH THE FILE NUMBER AND FAX THE COPY TO THE DIVISION OF WATER RESOURCES.

THIS ACKNOWLEDGEMENT OF NOTICE DOES NOT INDICATE THAT WELL PERMIT(S) CAN BE APPROVED.

(Use above space for labels or additional conditions as needed)

RECEIVED
SEP 07 2016
WATER RESOURCES
STATE ENGINEER
COLO

GWS-61
3/2015

NOTICE OF INTENT TO CONSTRUCT MONITORING HOLE(S)

Please type or print legibly in black or blue ink or file online @ dwrpermitsonline@state.co.us

COLORADO DIVISION OF WATER RESOURCES-1313 SHERMAN ST-STE 821-DENVER-CO-80203

PHONE 303-866-3581 WEB www.water.state.co.us

Well Owner Name(s): Basin Hydrology, Inc.

Address : 2340 CR 203, Durango, CO 81301

Phone (area code & no.): 970-903-0366

Landowner's Name: San Juan National Forest, Columbine R D

Please check one and complete as indicated including contact info:

- ☐ Water Well Driller Licensed in Colorado – Lic. No ________
- ☐ Professional Engineer Registered in Colorado – Reg. No. ________
- ☒ Professional Geologist per CRS 34-1-201(3)
- ☐ Other -anyone directly employed by or under the supervision of a licensed driller, registered professional engineer or professional geologist

Contact / Company Ed Muller, Tetra Tech

Address 3801 Automation Way, Suite 100

City, State & Zip Ft. Collins, CO 80525

Phone 971-206-4218 Fax ________

Print Name: Ed Muller

Sign or enter full name here: Edward Muller CN = Edward Muller C = AD 2016.08.30 07:31:58 -07'00'

Location: NE ¼ SE ¼, Section 27

Township 42 ☒N ☐S, Range 8 ☐E ☒W, NM PM

County San Juan

Subdivision n/a

Lot ________ Block ________ Filing Unit ________

Site/Property Address n/a

GPS Location in UTM format (optional):

Set GPS unit to true north, datum NAD83, and use meters for the distance units, ☐ Zone 12 or ☐ Zone 13

Easting ________ Northing ________

# of Monitoring Hole(s) to be constructed: up to 2

Estimated Depth 60 **Ft., Aquifer** surface

Purpose of Monitoring Hole(s) sample water chemistry & observe water depth

Anticipated Date of Construction (mm/dd/yyyy) 09/12/2016

Date Notice Submitted (mm/dd/yyyy): 08/30/2016

(Must be at least 3 days prior to construction)

ACKNOWLEDGEMENT FROM STATE ENGINEER'S OFFICE

FOR OFFICE USE ONLY

55854 - MH PROCESSED BY MJ

DIV. 7 WD 30 BAS ________ MD ________ DATE ACKNOWLEDGED ~~9-8~~ 9-7-16

CONDITIONS OF MONITORING HOLE ACKNOWLEDGEMENT

A COPY OF THE WRITTEN NOTICE OR ACKNOWLEDGEMENT SHALL BE AVAILABLE AT THE DRILLING SITE.

1) **Notice was provided to the State Engineer at least 3 days prior to construction of monitoring & observation hole(s).**
2) **Construction of the hole(s) must be completed within 90 days of the date notice was given to the State Engineer.** Testing and/or pumping shall not exceed a total of 200 hours unless prior written approval is obtained from the State Engineer. Water diverted during testing shall not be used for beneficial purposes. The owner of the hole(s) is responsible for obtaining permit(s) and complying with all rules and regulations pertaining to the discharge of fluids produced during testing.
3) **All work must comply with the Water Well Construction Rules, 2 CCR 402-2.** Minimum construction standards must be met or a variance obtained. Standard permit application and work report forms, including online filing instructions, are found on the DWR website at http://www.water.state.co.us. Well Construction and Test Reports (GWS-31) must be completed for each hole drilled. The licensed contractor or authorized individual must submit the completed forms to this office within 60 days of monitoring hole completion.
4) **Unless a well permit is obtained, or variance approved, the hole(s) must be plugged and sealed within one (1) year after construction. An Abandonment Report (form GWS-9) must be submitted within 60 days of plugging & sealing.** The above MH acknowledgement number, owner's structure name, and owner's name and address must be provided on all well permit application(s), well construction and abandonment reports.
5) **The owner of the hole(s) shall maintain records of water quality testing and submit this data to the State Engineer upon request.**
6) **A MONITORING HOLE CANNOT BE CONVERTED TO A PRODUCTION WATER WELL, except for purposes of remediation (recovery) or as a permanent dewatering system, if constructed in accordance with the Water Well Construction Rules and policies of the State Engineer.**
7) IF HOLES WILL NOT BE CONSTRUCTED UNDER THIS NOTICE WITHIN 90 DAYS, PLEASE WRITE, "NO HOLES CONSTRUCTED" ON A COPY OF THE ACKNOWLEDGED NOTICE WITH THE FILE NUMBER AND FAX THE COPY TO THE DIVISION OF WATER RESOURCES.

THIS ACKNOWLEDGEMENT OF NOTICE DOES NOT INDICATE THAT WELL PERMIT(S) CAN BE APPROVED.

(Use above space for labels or additional conditions as needed)

APPENDIX D

DWR Well Construction and Yield Estimate Report

Form No. GWS-31 9/2016	WELL CONSTRUCTION AND YIELD ESTIMATE REPORT State of Colorado, Office of the State Engineer 1313 Sherman St., Room 821, Denver, CO 80203 303.866.3581 www.water.state.co.us and dwrpermitsonline@state.co.us	For Office Use Only

1. Well Permit Number: Receipt Number:

2. Owner's Well Designation: GF- 1S

3. Well Owner Name: Basin Hydrology, Inc.

4. Well Location Street Address: TBD Rd 820 Silverton, CO 81433

5. GPS Well Location: ☐ Zone 12 ☒ Zone 13 Easting: 260125.0 Northing: 4194963 County: San Juan

6. Legal Well Location: Se 1/4, NE 1/4, Sec., 27 Twp. 42 ☒ N or S ☐, Range 8 ☐ E or W ☒, N.M. P.M.
Distances from Section Lines: 1875 ft. from ☒ N or S ☐ section line, and 820 ft. from ☒ E or W ☐ section line
Subdivision: n/a, Lot ____, Block ____, Filing (Unit) ____

7. Ground Surface Elevation: 10314 feet Date Completed: 09/13/2016 Drilling Method: air rotary ODEX

8. Completed Aquifer Name: n/a Total Depth: 100 feet Depth Completed: 57 feet

9. Advance Notification: Was Notification Required Prior to Construction? ☐ Yes ☒ No, Date Notification Given: ____

10. Aquifer Type: (Check one)
☐ Type I (One Confining Layer) ☐ Type I (Multiple Confining Layers) ☐ Laramie-Fox Hills
☐ Type II (Not overlain by Type III) ☒ Type II (Overlain by Type III) ☐ Type III (alluvial/colluvial)

11. Geologic Log:

Depth	Type	Grain Size	Color	Water Loc.
0-10	colluvium	grvl, silt, cly	brown	
10-20	colluvium	silt, cly	brown	
20-75	colluvium	grvl, silt, cly	brown	
75-100	frac igneous	xtalline	gray	75

12. Hole Diameter (in.)

Hole Diameter (in.)	From (ft)	To (ft)
6 gal H20	0	100

13. Plain Casing

OD (in)	Kind	Wall Size (in)	From (ft)	To (ft)
2.375	PVC	0.218	1	37

Perforated Casing

OD (in)	Kind	Wall Size (in)	From (ft)	To (ft)
2.375	PVC	0.218	57	37

14. Filter Pack: Material sand; Size 10-20; Interval 36-57

15. Packer Placement: Type bentonite; Depth 32-36

16. Grouting Record

Material	Amount	Density	Interval	Placement
cement	2 sk	6 gal/sk	0-32	positive

Remarks: Monitoring well. GF-1S is the shallower of 2 nested wells. GF-1D is deeper nested well, with packer placed to 64 ft bgs, and sand above that to 57 ft bgs. GF-1S completed above sand at 57 ft bgs.

17. Disinfection: Type n/a Amt. Used

18. Well Yield Estimate Data: ☐ Check box if Test Data is submitted on Form Number GWS-39, Well Yield Test Report
Well Yield Estimate Method: air lift
Static Level: artesian Estimated Production Rate 1 gpm.
Date/Time measured: 09/14/2016 12:00 Estimate Length (hrs) 0.5

Remarks:

19. I have read the statements made herein and know the contents thereof, and they are true to my knowledge. This document is signed (or name entered if filing online) and certified in accordance with Rule 17.4 of the Water Well Construction Rules, 2 CCR 402 2. The filing of a document that contains false statements is a violation of section 37 91 108(1)(e), C.R.S., and is punishable by fines up to $1,000 and/or revocation of the contracting license. If filing online the State Engineer considers the entry of the licensed contractor's name to be compliance with Rule 17.4.

Company Name:	Email:	Phone w/area code:	License Number:
McCracken Well Drilling	mccrackenwelldrilling@gmail.com	9703236332	1398

Mailing Address:

Sign (or enter name if filing online)	Print Name and Title	Date:
[signature]	Alan McCracken, Driller	9/26/16

Form No. GWS-31 9/2016	**WELL CONSTRUCTION AND YIELD ESTIMATE REPORT** State of Colorado, Office of the State Engineer 1313 Sherman St., Room 821, Denver, CO 80203 303.866.3581 www.water.state.co.us and dwrpermitsonline@state.co.us	For Office Use Only

1. Well Permit Number: **Receipt Number:**

2. Owner's Well Designation: GF- 1D

3. Well Owner Name: Basin Hydrology, Inc.

4. Well Location Street Address: TBD Rd 820 Silverton, CO 81433

5. GPS Well Location: ☐ Zone 12 ☒ Zone 13 Easting: 260125.0 Northing: 4194963 **County:** San Juan

6. Legal Well Location: Se 1/4, NE 1/4, Sec., 27 Twp. 42 ☒ N or S ☐, Range 8 ☐ E or W ☒, N.M. P.M.

Distances from Section Lines: 1875 ft. from ☒ N or S ☐ section line, and 820 ft. from ☒ E or W ☐ section line

Subdivision: n/a, Lot ____, Block ____, Filing (Unit) ____

7. Ground Surface Elevation: 10314 feet **Date Completed:** 09/13/2016 **Drilling Method:** air rotary ODEX

8. Completed Aquifer Name : n/a **Total Depth:** 100 feet **Depth Completed:** 98 feet

9. Advance Notification: Was Notification Required Prior to Construction? ☐ Yes ☒ No, Date Notification Given: ____

10. Aquifer Type: (Check one) ☐ Type I (One Confining Layer) ☐ Type I (Multiple Confining Layers) ☐ Laramie-Fox Hills ☐ Type II (Not overlain by Type III) ☒ Type II (Overlain by Type III) ☐ Type III (alluvial/colluvial)

11. Geologic Log:

Depth	Type	Grain Size	Color	Water Loc.
0-10	colluvium	grvl, silt, cly	brown	
10-20	colluvium	silt, cly	brown	
20-75	colluvium	grvl, silt, cly	brown	
75-100	frac igneous	xtalline	gray	75

Remarks: Monitoring Well. GF-1D is deeper of 2 nested wells. Shallow well GF-1S is completed in sand from 64-32 feet bgs.

12. Hole Diameter (in.)

Hole Diameter (in.)	From (ft)	To (ft)
6 gal H20	0	100

13. Plain Casing

OD (in)	Kind	Wall Size (in)	From (ft)	To (ft)
2.375	PVC	0.218	1	78

Perforated Casing

OD (in)	Kind	Wall Size (in)	From (ft)	To (ft)
2.375	PVC	0.218	78	98

14. Filter Pack: Material: sand; Size: 10-20; Interval: 79-98

15. Packer Placement: Type: bentonite; Depth: 64-79

16. Grouting Record

Material	Amount	Density	Interval	Placement
cement	4 sk	6 gal/sk	0-32	positive

17. Disinfection: Type n/a Amt. Used

18. Well Yield Estimate Data: ☐ Check box if Test Data is submitted on Form Number GWS-39, Well Yield Test Report

Well Yield Estimate Method: air lift

Static Level: artesian Estimated Production Rate 2 gpm.

Date/Time measured: 09/14/2016 11:00 Estimate Length (hrs) 0.5

Remarks:

19. I have read the statements made herein and know the contents thereof, and they are true to my knowledge. This document is signed (or name entered if filing online) and certified in accordance with Rule 17.4 of the Water Well Construction Rules, 2 CCR 402 2. The filing of a document that contains false statements is a violation of section 37 91 108(1)(e), C.R.S., and is punishable by fines up to $1,000 and/or revocation of the contracting license. If filing online the State Engineer considers the entry of the licensed contractor's name to be compliance with Rule 17.4.

Company Name: McCracken Well Drilling	Email: mccrackenwelldrilling@gmail.com	Phone w/area code: 9703236332	License Number: 1398
Mailing Address:			
Sign (or enter name if filing online) [signature]	Print Name and Title: Alan McCracken, Driller		Date: 9/26/16

Form No. GWS-31 9/2016	**WELL CONSTRUCTION AND YIELD ESTIMATE REPORT** State of Colorado, Office of the State Engineer 1313 Sherman St., Room 821, Denver, CO 80203 303.866.3581 www.water.state.co.us and dwrpermitsonline@state.co.us	For Office Use Only

1. Well Permit Number: **Receipt Number:**

2. Owner's Well Designation: FB3

3. Well Owner Name: Basin Hydrology, Inc.

4. Well Location Street Address: TBD FS Rd 820 Silverton, CO 81433

5. GPS Well Location: ☐ Zone 12 ☒ Zone 13 Easting: 260170.5 Northing: 4194954.6 **County:** San Juan

6. Legal Well Location: SE 1/4, NE 1/4, Sec., 27 Twp. 42 ☒ N or S ☐, Range 8 ☐ E or W ☒, NM P.M.
Distances from Section Lines: 1840 ft. from ☒ N or S ☐ section line, and 685 ft. from ☒ E or W ☐ section line
Subdivision: n/a, Lot ___, Block ___, Filing (Unit) ___

7. Ground Surface Elevation: 10255 feet **Date Completed:** 09/27/2016 **Drilling Method:** hole stem auger

8. Completed Aquifer Name : n/a **Total Depth:** 25 feet **Depth Completed:** 25 feet

9. Advance Notification: Was Notification Required Prior to Construction? ☐ Yes ☒ No, Date Notification Given:

10. Aquifer Type: (Check one) ☐ Type I (One Confining Layer) ☐ Type I (Multiple Confining Layers) ☐ Laramie-Fox Hills ☐ Type II (Not overlain by Type III) ☐ Type II (Overlain by Type III) ☒ Type III (alluvial/colluvial)

11. Geologic Log:

Depth	Type	Grain Size	Color	Water Loc.
0-6 ft	organic peat	n/a	brown	24"
6-8 ft	peat clay	peat clay	light brown	
8-20 ft	colluvium-clay	grv sand clay	grey	
20-25 ft	clay-colluvium	clay sand grv	grey	

Remarks:

12. Hole Diameter (in.)

Hole Diameter (in.)	From (ft)	To (ft)
6	0	25

13. Plain Casing

OD (in)	Kind	Wall Size (in)	From (ft)	To (ft)
2.375	PVC	0.218	0	20

Perforated Casing

OD (in)	Kind	Wall Size (in)	From (ft)	To (ft)
2.375	PVC	0.218	20	25

14. Filter Pack:
Material: sand
Size: 10-20
Interval: 19-25

15. Packer Placement:
Type: native 8'-25' mat.
Depth: 2'-19'

16. Grouting Record

Material	Amount	Density	Interval	Placement
bentonite	1 sk	6 gal/sk	0-2'	positive

17. Disinfection: Type n/a Amt. Used

18. Well Yield Estimate Data: ☐ Check box if Test Data is submitted on Form Number GWS-39, Well Yield Test Report
Well Yield Estimate Method: n/a
Static Level: 112" below grd surface Estimated Production Rate <1 gpm.
Date/Time measured: 9/27/2016; 4:45 pm Estimate Length (hrs)

Remarks:

19. I have read the statements made herein and know the contents thereof, and they are true to my knowledge. This document is signed (or name entered if filing online) and certified in accordance with Rule 17.4 of the Water Well Construction Rules, 2 CCR 402 2. The filing of a document that contains false statements is a violation of section 37 91 108(1)(e), C.R.S., and is punishable by fines up to $1,000 and/or revocation of the contracting license. If filing online the State Engineer considers the entry of the licensed contractor's name to be compliance with Rule 17.4.

Company Name:	Email:	Phone w/area code:	License Number:
McCrackenWell Drilling Inc	mccrackenwelldrilling@gmail.com	9703236332	1398

Mailing Address:

Sign (or enter name if filing online)	Print Name and Title	Date:
Al McC[illegible]	Alan McCracken Owner	10-13-16

APPENDIX E

Army Corps of Engineers Pre-Construction Notification

BASIN HYDROLOGY, INC
river, watershed & wetland studies
2340 County Road 203
Durango, CO 81301

September 7, 2016

Ms. Kara Hellige
Army Corps of Engineers
Regulatory Division
1970 E. 3rd Avenue, Suite 109
Durango, CO 81301-5025
Kara.A.Hellige@usace.army.mil

RE: Chattanooga Fen Piezometers, NWP 5 PCN

Kara,

Attached is a Pre-Construction Notification package requesting Nationwide Permit 5 (Scientific Measurement Devices) for the installation of two or three shallow piezometers with the Chattanooga Fen complex located north of Silverton.

Location
The Chattanooga fen complex is located approximately 5.5 miles north of Silverton. It is bounded to the east by Mineral Creek and Highway 550, to the south by County Road 820 and to the west by an unnamed Forest Service two-track and overhead powerline road. A Location Map is attached.

Project Purpose
The River Protection Workgroup is interested in determining the water source(s) of fens (and iron fens) so that protection measures can be discussed should land uses be proposed that may adversely affect their hydrology. Basin Hydrology is completing this study which involves the collection of geophysical data; chemical analysis of surface (natural and mine adits), near-surface and bedrock waters during the fall and spring; and continuous water level monitoring. The installation of piezometers in the two mapped fen areas is necessary to sample water from beneath the peat layer and to monitor seasonal water level changes.

Nature of Activity
Two or three shallow piezometers will be installed near existing piezometers (which do not extend below the peat layer) to collect water samples below the peat layer, or deeper if possible. The proposed piezometers will provide information about water chemistry and water level fluctuations relative to the bedrock-overlying colluvium wells, mine adits, springs and Mineral Creek.
A truck-mounted drill rig will install 4 to 5 deep (30 to 60 feet) wells to bedrock at upland locations on or adjacent to County Road 820 and the Forest Service two-track on the west side of the fen complex. These wells will allow sampling of the fractured bedrock and overlying colluvium since one theory is that the low pH waters are originating from the fractured rock on the west side of the Chattanooga complex.

The 1¼" diameter shallow piezometers will be driven into the ground with a T-post pounder or sledge hammer. The bottom 3 ft. of the piezometer system contains a sharp point and is stainless steel and screened. Three to 4 ft. segments of 1¼" unslotted pipe will be screwed onto the 3 ft. drivepoint and driven into the ground until refusal or until a depth of ~ 10 ft. is reached. No excavation or filling is required other than driving the pipe into the ground. Each piezometer will contain a water level logger and be capped. It is expected that the piezometers will remain in place for years to complement the existing network of Mountain Studies Institutes' (MSI)piezometers.

Jurisdictional Boundaries

No formal wetland determination was completed for this study or for this PCN. Wetland mapping for the PCN relies on mapping (See Figure 1) obtained from a draft report prepared by Dr. David Cooper and Dr. Rod Chimner (*A report on the restoration potential of Chattanooga Fen, San Juan's Colorado, 2006*). The piezometers will be placed with fen area F (potentially 2 piezometers) and fen area A (1 piezometer). Both areas have excellent vegetation and hydrologic indicators but no soil/peat pits have been dug.

Landowner

All well and piezometers will be placed on National Forest Lands administered by the San Juan National Forest, Columbine Ranger District and within the Right-of-Way of San Juan County Road 820. ON August 30, 2016 Matt Janowiak, District Ranger, provided email confirmation that they have modified MSI's Research Agreement to accommodate these proposed wells and piezometers.

Cultural and Biological Surveys

No cultural or biological surveys have been completed for this project or PCN. Any disturbance will be limited to about 2 hours at each site with a surface disturbance of ~ 9 ft^2 due to staging of materials and standing. No surface or vegetative disturbances are required.

Schedule

Well drilling is to occur the week of September 12. Once the wells are completed, the piezometer locations will be determined followed by their installation. Piezometer installation would ideally occur by September 15 or 16.

Once you have reviewed this PCN, please contact me should you have any questions.

Sincerely,

T. Mark Oliver

T. Mark Oliver
Basin Hydrology, Inc.
970.903.0366
www.basinhydrology.com

attachments

U.S. Army Corps of Engineers
South Pacific Division

Nationwide Permit Pre-Construction Notification (PCN) Form

This form integrates requirements of the U.S. Army Corps of Engineers Nationwide Permit Program within the South Pacific Division (SPD), including General and Regional Conditions. You MUST fill out all boxes related to the work being done. Fillable boxes in this form expand if additional space is needed.

Box 1 Project Name Chattanooga Fen Piezometers			
Applicant Name Mark Oliver		**Applicant Title**	
Applicant Company, Agency, etc. Basin Hydrology, Inc.		Applicant's internal tracking number (if any)	
Mailing Address 2340 County Road 203, Durango, CO 81301			
Work Phone with area code 970-903-0366	Mobile Phone with area code	Home Phone with area code	Fax # with area code
E-mail Address mark@basinhydrology.com	Relationship of applicant to property: ☐ Owner ☐ Purchaser ☐ Lessee ☒ Other:		
Application is hereby made for verification that subject regulated activities associated with subject project qualify for authorization under a U.S. Army Corps of Engineers Nationwide Permit or Permits as described herein. I certify that I am familiar with the information contained in this application and, that to the best of my knowledge and belief, such information is true, complete, and accurate. I further certify that I possess the authority to undertake the proposed activities. I hereby grant to the agency to which this application is made the right to enter the above-described location to inspect the proposed, in-progress or completed work. I agree to start work <u>only</u> after all necessary permits have been received and to comply with all terms and conditions of the authorization.			
Signature of applicant T. Mark Oliver			Date (mm/dd/yyyy) 9/7/2016

If anyone other than the person named as the Applicant will be in contact with the U.S. Army Corps of Engineers representing the Applicant regarding this project during the permit process, Box 2 MUST be filled out.

Box 2 Authorized Agent/Operator Name		**Agent/Operator Title**	
Agent/Operator Company, Agency, etc.		E-mail Address	
Mailing Address			
Work Phone with area code	Mobile Phone with area code	Home Phone with area code	Fax # with area code
I hereby authorize the above named authorized agent to act in my behalf as my agent in the processing of this application and to furnish, upon request, supplemental information in support of this permit application. I understand that I am bound by the actions of my agent and I understand that if a federal or state permit is issued, I, or my agent, must sign the permit.			
Signature of applicant			Date (mm/dd/yyyy)
I certify that I am familiar with the information contained in this application, and that to the best of my knowledge and belief, such information is true, complete, and accurate.			
Signature of authorized agent			Date (mm/dd/yyyy)

Revised March 21, 2012. For the most recent version of this form, visit your Corps District's Regulatory website.

Box 3 Name of Property Owner(s), if other than Applicant: Matt Janowiak		
Owner Title District Ranger	**Owner Company, Agency, etc.** San Juan National Forest, Columbine Ranger District	
Mailing Address 367 Pearl Street, P.O. Box 439, Bayfield, CO 81122		
Work Phone with area code 970-884-2512	Mobile Phone with area code	Home Phone with area code

Box 4 Name of Contractor(s) (if known): Mark Oliver		
Contractor Title	**Contractor Company, Agency, etc.** Basin Hydrology, Inc.	
Mailing Address 2340 County Road 203, Durango, CO 81301		
Work Phone with area code 970-903-0366	Mobile Phone with area code	Home Phone with area code

Box 5 Site Number 1 of 1. Project location(s), including street address, city, county, state, zip code where proposed activity will occur:	
Waterbody (if known, otherwise enter "an unnamed tributary to"): Mineral Creek Tributary to what known, downstream waterbody:	
Latitude & Longitude (D/M/S, DD, or UTM with Zone): 37.8649N, 107.7257W	Section, Township, Range: S27, T42N, R8W, NMPM
County Assessor Parcel Number (Include County name): n/a	USGS Quadrangle map name: Silverton, CO
Watershed (HUC and watershed name[1]): 14080104 [1]http://water.usgs.gov/GIS/regions.html	Size of permit area or project boundary: ~ 60 acres linear feet
Directions to the project location and other location descriptions, if known: North on Hwy 550 ~ 5.5 miles north of Silverton, west & north onto County Road 820, cross Mineral Creek and continue NW to 1st switchback. Fen area is the large wetland complex directly north.	
Nature of Activity (Description of the project, include all features): Install 2 or perhaps 3 shallow piezometers up to 8 ft. in depth. Piezometers will be 1 1/4" diamter stainless steel, screened Drive Points with galvanized pipe attached to reach maximum depth. Drive Points are driven into the ground using a T-post driver or sledge hammer. No excavation required.	
Project Purpose (Description of the reason or purpose of the project): To sample ground water chemistry below the fen's peat layer and monitor ground water levels over time.	

Box 6 Reason(s) for discharge into Waters of the United States (Description of why dredged and/or fill material needs to be placed in Waters of the United States):

The piezometers will compliment a series of ground water wells to be drilled into bedrock to monitor water chemistry, age dating and water level data to help identify (or eliminate) probably sources of fen hydrology.

Proposed discharge of dredge and/or fill material. Indicate total surface area in **acres** and **linear feet** (where appropriate) of the proposed impacts to Waters of the United States, indicate water body type (tidal wetland, non-tidal wetland, riparian wetland, ephemeral stream/river, intermittent stream/river, perennial stream/river, pond/lake, vegetated shallows, bay/harbor, lagoon, ocean, etc.), and identify the impact(s) as permanent and/or temporary for each requested Nationwide Permit[1]:

[1] Enter the intended permit number(s). See Nationwide Permit regulations for permit numbers and qualification information: http://www.usace.army.mil/Missions/CivilWorks/RegulatoryProgramandPermits/NationwidePermits.aspx

Water Body Type	Requested NWP Number: 5				Requested NWP Number:				Requested NWP Number:			
	Permanent		Temporary		Permanent		Temporary		Permanent		Temporary	
	Area	Length	Area	Length	Area	Length	Area	Length	Area	Length	Area	Length
Non-tidal Wetland	<0.001											
Pick One												
Pick One												
Pick One												
Non-tidal Wetland												
Total:	<0.001											

Total volume (in cubic yards) and type(s) of material proposed to be dredged from or discharged into Waters of the United States:

Material Type	Total Volume Dredged	Total Volume Discharged
Rock Slope Protection (RSP)		
Clean spawning gravel		
River rock		
Soil/Dirt/Silt/Sand/Mud		
Concrete		
Structure		
Stumps/Root wads		
Other: Stainless steel pipe	0	up to 0.3 Cubic Feet
Total:	0	up to 0.3 Cubic Feet

Activity requires a written waiver to exceed specified limits of the Nationwide Permit? ☐ Yes ☒ No
If yes, provide Nationwide Permit number and name, limit to be exceeded, and rationale for each requested waiver:

Activity will result in the loss of greater than ½-acre of Waters of the United States? ☐ Yes ☒ No
If yes, provide an electronic copy (compact disc) or multiple hard copies (7) of the complete PCN for appropriate Federal and State Pre-discharge Notification (See General Condition #31, Pre-construction Notification, Agency Coordination, Section 2 and 4).

Describe direct and indirect effects caused by the activity and how the activity has been designed (or modified) to have minimal adverse effects on the aquatic environment (See General Condition #31, Pre-construction Notification, District Engineer's Decision, Section 1):

Access to each piezometer site across the fen will be by foot. Installation will be by hand.

Potential cumulative impacts of proposed activity(if any):
none

Required drawings and figures (see each U.S. Army Corps of Engineers District's Minimum Standards Guidance):
Vicinity map: ☒ Attached (or mail copy separately if applying electronically)
To-scale Plan view drawing(s): ☒ Attached (or mail copy separately if applying electronically)
To-scale elevation and/or Cross Section drawing(s): ☒ Attached (or mail copy separately if applying electronically)
Numbered and dated pre-project color photographs: ☒ Attached (or mail copy separately if applying electronically)
Sketch drawing(s) or map(s): ☐ Attached (or mail copy separately if applying electronically)

Has a wetlands/waters of the U.S. delineation been completed?
☐ Yes, Attached[2] (or mail copy separately if applying electronically) ☒ No
If a delineation has been completed, has it been verified in writing by the Corps?
☐ Yes, Date of preliminary or approved jurisdictional determination (mm/dd/yyyy): Corps file number: ☐ No
[2]If available, provide ESRI shapefiles (NAD83) for delineated waters

For proposed discharges of dredged material resulting from navigation dredging into inland or near-shore waters of the U.S. (including beach nourishment), please attach[3] a proposed Sampling and Analysis Plan (SAP) prepared according to Inland Testing Manual (ITM) guidelines (including Tier I information, if available), or if disposed offshore, a proposed SAP prepared according to the Ocean Disposal Manual. ☐ Attached (or mail copy separately if applying electronically)
[3]Or mail copy separately if applying electronically

Is any portion of the work already complete? ☐ YES ☒ NO
If yes, describe the work:

Box 7 Authority:
Is Section 10 of the Rivers and Harbors Act applicable?: ☐ YES ☒ NO
Is Section 404 of the Clean Water Act applicable?: ☒ YES ☐ NO

Is the project located on U.S. Army Corps of Engineers property or easement?: ☐ YES ☒ NO
If yes, has Section 408 process been initiated?: ☐ YES ☒ NO
Would the project affect a U.S. Army Corps of Engineers structure?: ☐ YES ☒ NO
If yes, has Section 408 process been initiated?: ☐ YES ☒ NO

Is the project located on other Federal Lands (USFS, BLM, etc.)?: ☒ YES ☐ NO
Is the project located on Tribal Lands?: ☐ YES ☒ NO

Box 8 Is the discharge of fill or dredged material for which Section 10/404 authorization is sought part of a larger plan of development?: ☐ YES ☒ NO

If discharge of fill or dredged material is part of development, name and proposed schedule for that larger development (start-up, duration, and completion dates):

Location of larger development (if discharge of fill or dredged material is part of a plan of development, a map of suitable quality and detail of the entire project site should be included):

Box 9 Measures taken to avoid and minimize impacts to waters of the United States:

installation by hand and pedestrian access

Box 10 Proposed Compensatory Mitigation related to fill/excavation and dredge activities. Indicate in **acres** and **linear feet** (where appropriate) the total quantity of Waters of the United States proposed to be created, restored, enhanced and/or preserved for purposes of providing compensatory mitigation. Indicate water body type (tidal wetland, non-tidal wetland, riparian wetland, ephemeral stream/river, intermittent stream/river, perennial stream/river, pond/lake, vegetated shallows, bay/harbor, lagoon, ocean, etc.) or non-jurisdictional (uplands[1]). Indicate mitigation type (permittee-responsible on-site/off-site, mitigation bank, or in-lieu fee program). If the mitigation is purchase of credits from a mitigation bank, indicate the bank to be used, if known:

[1] For uplands, please indicate if designed as an upland buffer.

Site Number	Water Body Type	Created		Restored		Enhanced		Preserved		Mitigation Type
		Area	Length	Area	Length	Area	Length	Area	Length	
	Pick One									Pick One
	Pick One									Pick One
	Pick One									Pick One
	Pick One									Pick One
	Pick One									Pick One
Total:										Pick One

If no mitigation is proposed, provide detailed explanation of why no mitigation would be necessary:

No measurable impact

If permittee-responsible mitigation is proposed, provide justification for not utilizing a Corps-approved mitigation bank or in-lieu fee program:

Has a draft/conceptual mitigation plan been prepared in accordance with the April 10, 2008, Final Mitigation Rule[2] and District Guidelines?

[2]http://www.usace.army.mil/Missions/CivilWorks/RegulatoryProgramandPermits/mitig_info.aspx

[3]**Sacramento and San Francisco Districts**-http://www.spk.usace.army.mil/organizations/cespk-co/regulatory/pdf/Mitigation_Monitoring_Guidelines.pdf

[4]**Los Angeles District**-http://www.spl.usace.army.mil/regulatory/mmg_2004.pdf

[5]**Albuquerque District**-http://www.spa.usace.army.mil/reg/mitigation/SPA%20Final%20Mitigation%20Guidelines_OLD.pdf

☐ Yes, Attached (or mail copy separately if applying electronically) ☒ No

If no, a mitigation plan must be prepared and submitted, if applicable.

Mitigation site(s) Latitude & Longitude (D/M/S, DD, or UTM with Zone):	USGS Quadrangle map name(s):
Assessor Parcel Number(s):	Section(s), Township(s), Range(s):

Other location descriptions, if known:
Directions to the mitigation location(s):

Box 11 Threatened or Endangered Species

Please list any federally-listed (or proposed) threatened or endangered species or critical habitat (or proposed critical habitat) within the project area (include scientific names (e.g., Genus species), if known):

a. b.
c. d.
e. f.

Have surveys, using U.S. Fish and Wildlife Service/NOAA Fisheries protocols, been conducted?
☐ Yes, Report attached (or mail copy separately if applying electronically) ☒ No

If a federally-listed species would be impacted, please provide a description of the impactand a biological evaluation, if available.
☐ Yes, Report attached (or mail copy separately if applying electronically) ☐ Not attached

Has Section 7 consultation been initiated by another federal agency?
☐ Yes, Initiation letter attached (or mail copy separately if applying electronically) ☒ No

Has Section 10 consultation been initiated for the proposed project?
☐ Yes, Initiation letter attached (or mail copy separately if applying electronically) ☒ No

Has the USFWS/NOAA Fisheries issued a Biological Opinion?
☐ Yes, Attached (or mail copy separately if applying electronically) ☒ No
If yes, list date Opinion was issued (m/d/yyyy):

Box 12 Historic properties and cultural resources:

Are any cultural resources of any type known to exist on-site? ☒ Yes ☐ No

Please list any known historic properties listed, or eligible for listing, on the National Register of Historic Places:

a. not at the identified piezometer sites b.
c. d.
e. f.

Has a cultural resource records search been conducted?
☐ Yes, Report attached (or mail copy separately if applying electronically) ☒ No

Has a cultural resource pedestrian survey been conducted for the site?
☐ Yes, Report attached (or mail copy separately if applying electronically) ☒ No

Has another federal agency been designated the lead federal agency for Section 106 consultation?
☐ Yes, Designation letter/email attached (or mail copy separately if applying electronically) ☒ No

Has Section 106 consultation been initiated by another federal agency?
☐ Yes, Initiation letter attached (or mail copy separately if applying electronically) ☒ No

Has a Section 106 MOA or PA been signed by another federal agency and the SHPO?
☐ Yes, Attached (or mail copy separately if applying electronically) ☒ No
If yes, list date MOA or PA was signed (m/d/yyyy):

Box 13 Section 401 Water Quality Certification:
Applying for certification? ☐ Yes, Attached (or mail copy separately if applying electronically) ☒ No

Certification issued? ☐ Yes, Attached (or mail copy separately if applying electronically) ☒ No
Certification waived? ☐ Yes, Attached (or mail copy separately if applying electronically) ☒ No
Certification denied? ☐ Yes, Attached (or mail copy separately if applying electronically) ☒ No

Exempted activity? ☒ Yes ☐ No
Agency concurrence? ☐ Yes, Attached ☒ No
If exempt, state why:

Box 14 Coastal Zone Management Act:
Is the project located within the Coastal Zone? ☐ Yes ☒ No

If yes, applying for a coastal commission-approved Coastal Development Permit?
☐ Yes, Attached (or mail copy separately if applying electronically) ☐ No

If no, applying for separate CZMA-consistency certification?
☐ Yes, Attached (or mail copy separately if applying electronically) ☒ No

Permit/Consistency issued? ☐ Yes, Attached (or mail copy separately if applying electronically) ☒ No

Exempt? ☒ Yes ☐ No
Agency concurrence? ☐ Yes, Attached ☒ No
If exempt, state why:

Box 15 List of other certifications or approvals/denials received from other federal, state, or local agencies for work described in this application:

Agency	Type of Approval[4]	Identification Number	Date Applied	Date Approved	Date Denied
US Forest Service	well installations	email		8/30/2016	

[4] Would include but is not restricted to zoning, building, and flood plain permits

Nationwide Permit General Conditions (GC) checklist:

(http://www.gpo.gov/fdsys/pkg/FR-2012-02-21/pdf/2012-3687.pdf)

Check	General Condition	Rationale for compliance with General Condition
☒	1. Navigation	n/a
☒	2. Aquatic Life Movements	n/a
☒	3. Spawning Areas	n/a
☒	4. Migratory Bird Breeding Areas	no affect
☒	5. Shellfish Beds	n/a
☒	6. Suitable Material	yes
☒	7. Water Supply Intakes	n/a
☒	8. Adverse Effects from Impoundments	n/a
☒	9. Management of Water Flows	n/a
☒	10. Fills Within 100-Year Floodplains	n/a
☒	11. Equipment	no mechanized equipment required
☒	12. Soil Erosion and Sediment Controls	no soil disturbance required
☒	13. Removal of Temporary Fills	n/a
☒	14. Proper Maintenance	none required

☒	15. Single and Complete Project	yes
☒	16. Wild and Scenic Rivers	n/a
☒	17. Tribal Rights	n/a
☒	18. Endangered Species	See Box 11 above.
☒	19. Migratory Bird and Bald and Golden Eagle Permits	n/a
☒	20. Historic Properties	See Box 12 above.
☒	21. Discovery of Previously Unknown Remains and Artifacts	agreed
☒	22. Designated Critical Resource Waters	project site within DCRW watershed (Animas River)
☒	23. Mitigation	See Box 10 above.
☒	24. Safety of Impoundment Structures	n/a
☒	25. Water Quality	See Box 13 above.
☒	26. Coastal Zone Management	See Box 14 above.
☒	27. Regional and Case-by-Case Conditions	agreed
☒	28. Use of Multiple Nationwide Permits	n/a
☒	29. Transfer of Nationwide Permit Verifications	agreed
☒	30. Compliance Certification	agreed
☒	31. Pre-Construction Notification	this document is part of the submitted PCN package

Sacramento District
Nationwide Permit Program
Regional Conditions Checklist for Colorado

U.S. ARMY CORPS OF ENGINEERS **BUILDING STRONG ®**

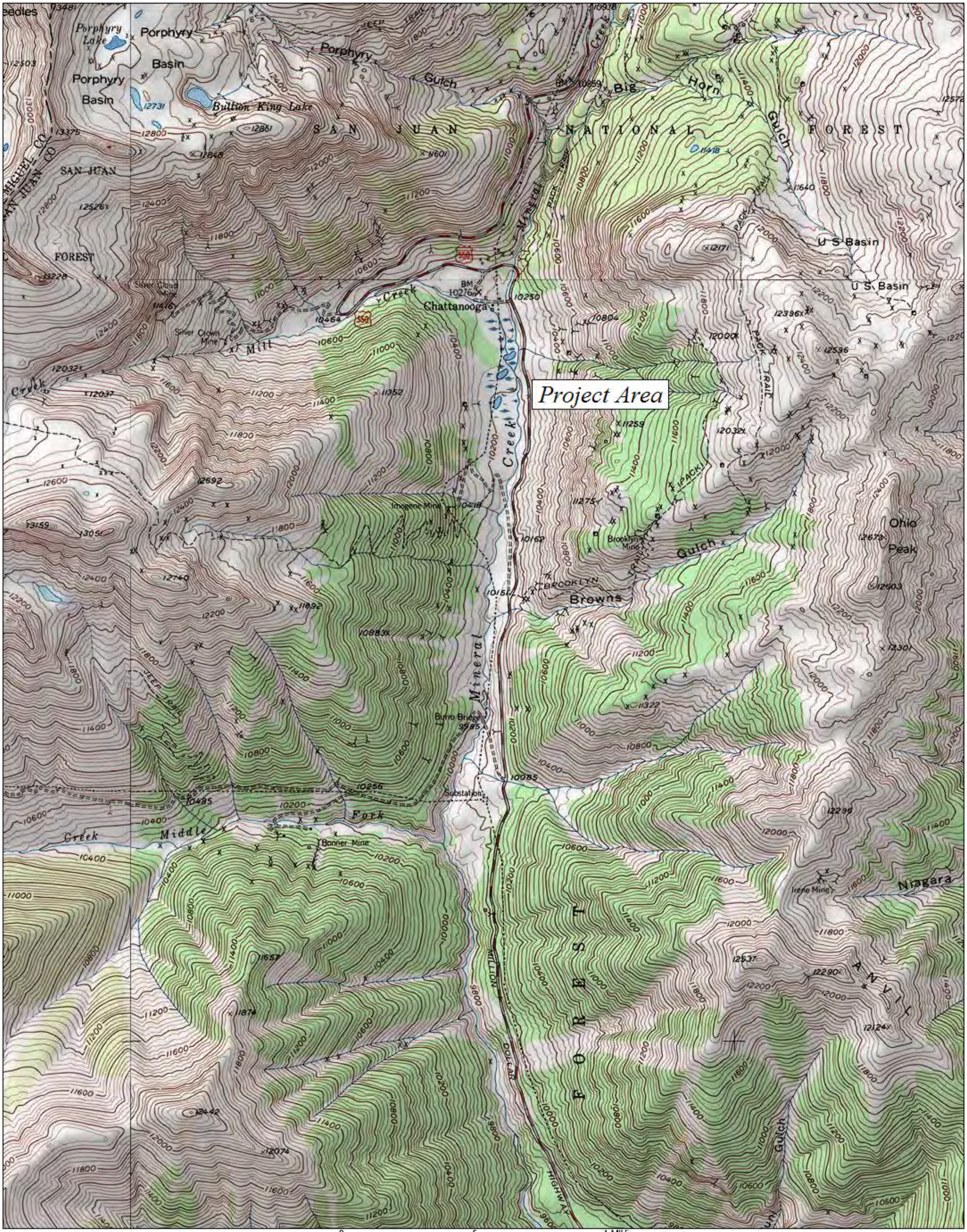
On March 18, 2012, the U.S. Army Corps of Engineers' South Pacific Division approved 26 regional conditions for the 2012 Nationwide Permits (NWP) in Colorado, within the Sacramento District. This checklist is intended to assist applicants with completing the South Pacific Division Pre-Construction Notification Checklist and to ensure compliance with the regional conditions. This checklist does not include the full text of each regional condition.

Please refer to the *2012 Regional Conditions in Colorado* when completing this checklist (http://www.spk.usace.army.mil/Portals/12/documents/regulatory/nwp/2012_nwps/2012-NWP-RC-CO.pdf).

Please check the box to indicate you have read and have/will comply with the regional condition and provide a rationale on how you have/will comply with the condition**.**

Check	Regional Condition	Compliance Rationale
☒	**1. Nationwide Permit 12.** PCN must be submitted for open trenching in perennial waters or if the utility line is for the purpose of water transmission	The activity does not involve open trenching and is not for the purpose of water transmission. OR The PCN has been submitted with this checklist, and if the project will result in a withdrawal of water from a waterway, includes an evaluation of the effects of the withdrawal.
☒	**2. Nationwide Permits 12 and 14.** PCN must be submitted for projects in the Colorado River Basin.	The activity does not involve utility lines or transportation activities in perennial waters or special aquatic sites in the Colorado River Basin. OR The PCN has been submitted with this checklist.
☒	**3. Nationwide Permit 13.** PCN must be submitted for bank stabilization exceeding 250 feet or in streams with an average width of less than 20 feet. ☐ For streams with a width less than 20 feet, activities are limited to no more than ¼ cubic yard per linear foot.	The activity does not involve bank stabilization activities. OR The activity involves bank stabilization but under the thresholds of the regional condition 3. OR The PCN has been submitted with this checklist. (also address the requirement for no more than ¼ CY in streams < 20 feet wide, if applicable)
☒	**4. Nationwide Permit 23.** PCN must be submitted.	The activity does not involve the use of NWP 23. OR The PCN has been submitted with this checklist.
☒	**5. Nationwide Permit 27.** ☐ Fishery enhancement in perennial streams not authorized. ☐ Channel realignment not authorized. ☐ Structures must allow passage of aquatic organisms. ☐ Structures must not impede navigation. ☐ Concrete/grout not authorized. ☐ Construction of water parks and flood control projects not authorized.	I agree that the activity meets all requirements of regional condition number 5.

Check	Regional Condition	Compliance Rationale
☒	**6. <u>Nationwide Permits 29 and 39.</u>** Floodplain map must be submitted with the PCN.	The activity does not involve the use of NWPs 29 or39 OR A copy of the floodplain map has been submitted with the PCN.
☒	**7. <u>Important Spawning Areas.</u>** ☒ Will not destroy spawning areas or be conducted during trout and Kokanee spawning seasons. ☐ Bio-engineering required for bank protection activities over 50 feet. ☐ PCN required for activities in important spawning areas.	The activity will not be located in identified important spawning areas. OR The PCN has been submitted with this checklist (also explain how the activity will comply with the remaining requirements of this condition).
☒	**8. <u>Removal of Temporary Fills.</u>** Horizontal marker must be used in wetlands.	I agree to use a horizontal marker to delineate the existing ground elevation of wetlands that will be temporarily impacted. OR The activity does not involve temporary fill.
☒	**9. <u>Fens</u>**. NWPS, with the exception of 3, 5, 6, 20, 27, 32, 37 and 38, are revoked in fens and wetlands adjacent to fens. PCN required for these other NWPs.	The activity would not occur in a fen or wetland adjacent to a fen. OR The activity does not involve use of a revoked NWP. OR The PCN has been submitted with this checklist.
☒	**10. <u>Springs.</u>** PCN must be submitted within 100 feet of discharge of a spring.	The activity would not occur within 100 feet of the discharge point of a spring. OR The PCN has been submitted with this checklist.
☒	**11. <u>Suitable Fill.</u>** ☐ PCN must be submitted for the use of broken concrete. ☐ Must demonstrate that soft engineering methods are not practicable. ☐ Concrete with exposed rebar not authorized.	The proposed project would not involve the use of broken concrete or concrete with exposed rebar. OR The PCN has been submitted with this checklist (also explain why soft engineering methods are not practicable, if applicable).



TN MN 10½°

0 .5 1 MILE

0 1000 FEET

0 500 1000 METERS

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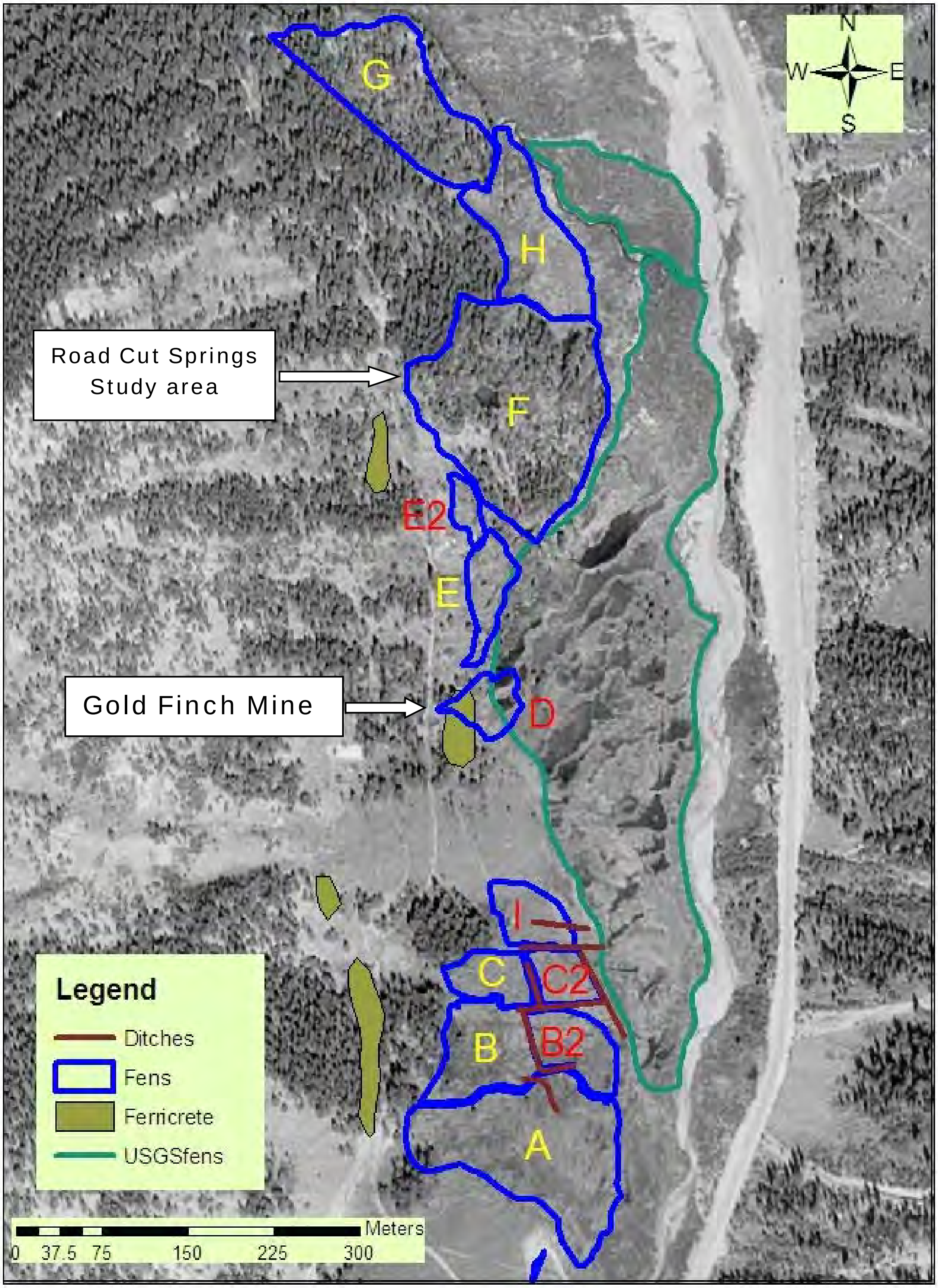


Figure 1. Site map of Chattanooga fen. Letters denote mapped units with red letters indicating areas that are classified as disturbed.

Figure 2. Chattanooga Fen proposed piezometer and well locations.

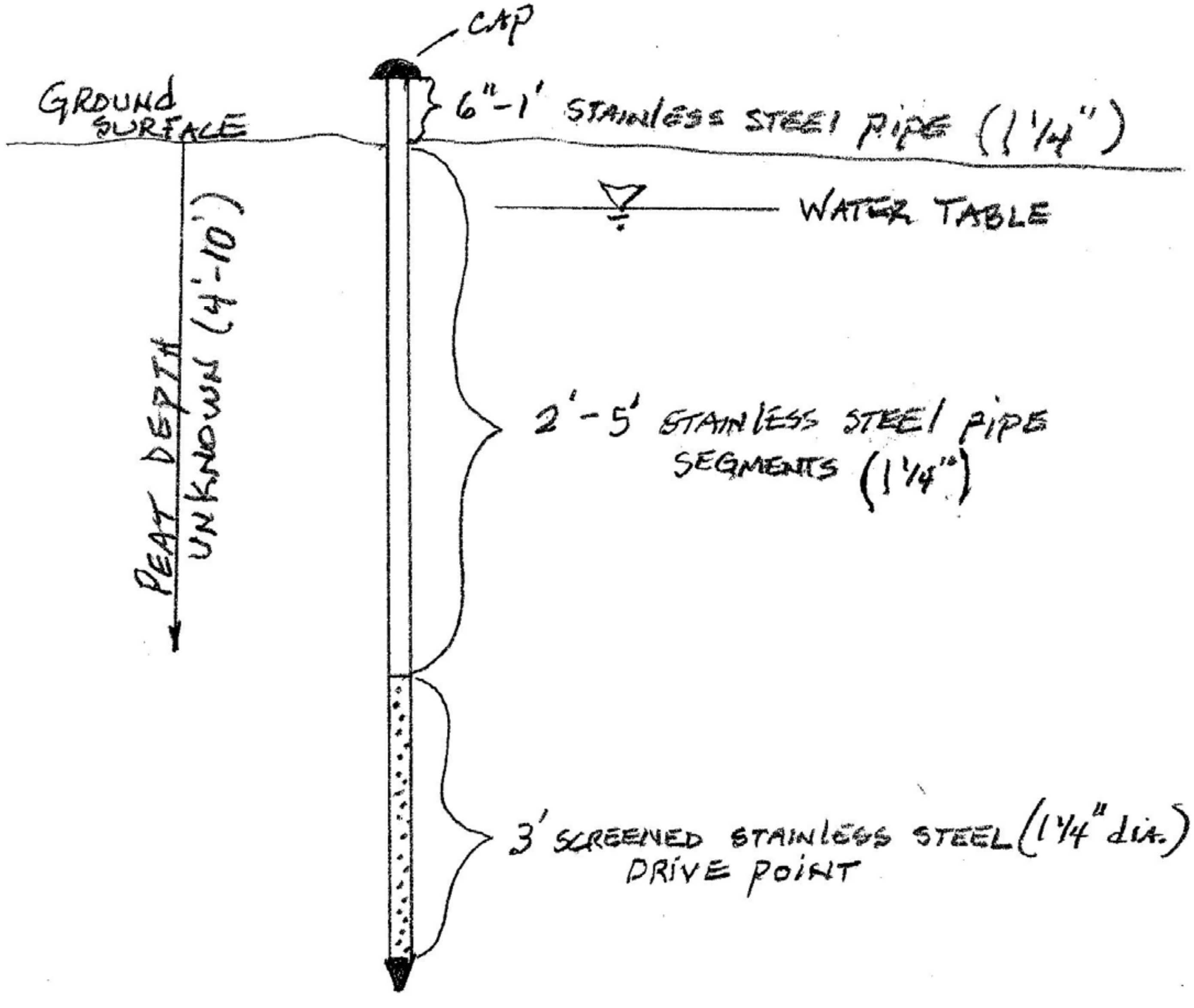
Chattanooga Fen Piezometers

Pre-Construction Photographs

Typical fen character at northern end of Chattanooga site where Drive Point piezometers will be installed (with existing piezometers installed by others).

Typical fen character at southern end of Chattanooga site where Drive Point piezometers will be installed.

CHATTANOOGA FEN PIEZOMETER



SECTION

NTS

APPENDIX F

Army Corps of Engineers Authorization

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS, SACRAMENTO DISTRICT
1325 J STREET
SACRAMENTO CA 95814-2922

September 16, 2016

Regulatory Division (SPK-2016-00722)

Basin Hydrology, Inc.
Attn: Mr. Mark Oliver
2340 County Road 203
Durango, Colorado 81301

Dear Mr. Oliver:

We are responding to your request for a Department of the Army permit for the Chattanooga Fen Piezometers project. The project site is located near the Chattanooga fen complex, ~ 5.5 miles northwest of the Town of Silverthorne, within the SE ¼ SE ¼ of Section 27, Township 42 North, Range 8 West, New Mexico Principal Meridian, Latitude 37.8649°, Longitude -107.7257°, San Juan County, Colorado.

Based on the information you provided to this office, the Chattanooga fen project involves the installation of three piezometers into the Chattanooga fen to sample water from beneath the peat layer. These activities will result in the permanent impacts to approximately 0.001 acre of the Chattanooga fen complex. We have determined activities in waters of the U.S. associated with the project are authorized by Nationwide Permit Number (NWP) 5 - Scientific Measuring Devices. You must comply with all terms and conditions of the NWP, applicable regional conditions, and project-specific special conditions. Information about the NWP and regional conditions are available on our website at *www.spk.usace.army.mil/Missions/Regulatory/Permitting/NationwidePermits.aspx*. In addition, your work must comply with the following **special condition**:

1. **Within 30 days following construction activities, you shall submit to the Corps post-construction photographs of the project site showing the completed work, along with a signed copy of the enclosed Compliance Certification. The camera positions and view angles of post-construction photographs shall be identified on a map of the project area.**

This verification is valid until March 18, 2017, when the existing NWPs are scheduled to be modified, reissued, or revoked. Furthermore, if you commence or are under contract to commence this activity before the date the NWP is modified, reissued, or revoked, you will have 12 months from the date of the modification, reissuance or revocation to complete the activity under the present terms and conditions. Failure to comply with the general and regional conditions of this NWP, or the project-specific special conditions of this authorization, may result in the suspension or revocation of your authorization.

Please refer to identification number SPK-2016-00722 in any correspondence concerning this project. If you have any questions, please contact Tyler Adams at the Colorado West Regulatory Branch, 400 Rood Avenue, Room 224, Grand Junction, Colorado 81501, by email at *Tyler.R.Adams@usace.army.mil*, or telephone at 970-243-1199, extension 1013. We would appreciate your feedback on this permit action including your interaction with our staff. At your earliest convenience, please tell us how we are doing by completing the Corps' Regulatory Program national customer service survey found on our website at www.spk.usace.army.mil/Missions/Regulatory.aspx.

Sincerely,

PP Susan Bachini Nall
Chief, Colorado West Branch
Regulatory Division

Enclosure
1. Compliance Certification

cc: (w/o encl)
Mr. Matt Janowiak, District Ranger, San Juan National Forest, Columbine Ranger District, Post Office Box 439, Bayfield, Colorado 81122

COMPLIANCE CERTIFICATION

Permit File Name: Chattanooga Fen Piezometers

Action ID: SPK-2016-00722

Nationwide Permit Number: 5

Permittee: Basin Hydrology, Inc.
Attn: Mr. Mark Oliver
2340 County Road 203
Durango, Colorado 81301

County: San Juan

Date of Verification: September 16, 2016

Within 30 days after completion of the activity authorized by this permit, sign this certification and return it to the following address:

U.S. Army Corps of Engineers
Sacramento District
Colorado West Regulatory Branch
400 Rood Avenue, Room 224
Grand Junction, Colorado 81501
FAX (970) 241-2358
DLL-CESPK-RD-Compliance@usace.army.mil

Please note that your permitted activity is subject to a compliance inspection by a U.S. Army Corps of Engineers representative. If you fail to comply with the terms and conditions of the permit your authorization may be suspended, modified, or revoked. If you have any questions about this certification, please contact the U.S. Army Corps of Engineers.

* * * * * * * * *

I hereby certify that the work authorized by the above-referenced permit, including all the required mitigation, was completed in accordance with the terms and conditions of the permit verification.

______________________________ ______________

Permittee Signature Date

"Enclosure 1"

APPENDIX G

Compliance Certificate for Army Corps of Engineers

COMPLIANCE CERTIFICATION

Permit File Name: Chattanooga Fen Piezometers

Action ID: SPK-2016-00722

Nationwide Permit Number: 5

Permittee: Basin Hydrology, Inc.
Attn: Mr. Mark Oliver
2340 County Road 203
Durango, Colorado 81301

County: San Juan

Date of Verification: September 16, 2016

Within 30 days after completion of the activity authorized by this permit, sign this certification and return it to the following address:

U.S. Army Corps of Engineers
Sacramento District
Colorado West Regulatory Branch
400 Rood Avenue, Room 224
Grand Junction, Colorado 81501
FAX (970) 241-2358
DLL-CESPK-RD-Compliance@usace.army.mil

Please note that your permitted activity is subject to a compliance inspection by a U.S. Army Corps of Engineers representative. If you fail to comply with the terms and conditions of the permit your authorization may be suspended, modified, or revoked. If you have any questions about this certification, please contact the U.S. Army Corps of Engineers.

* * * * * * * * *

I hereby certify that the work authorized by the above-referenced permit, including all the required mitigation, was completed in accordance with the terms and conditions of the permit verification.

J. Mark Oliver 9/29/16

Permittee Signature Date

"Enclosure 1"

BASIN HYDROLOGY, INC
river, watershed & wetland studies
2340 County Road 203
Durango, CO 81301

Chattanooga Fen Piezometers

Pre & Post Installation Photographs

SPK-2016-722

Well FB3 pre-installation looking north.

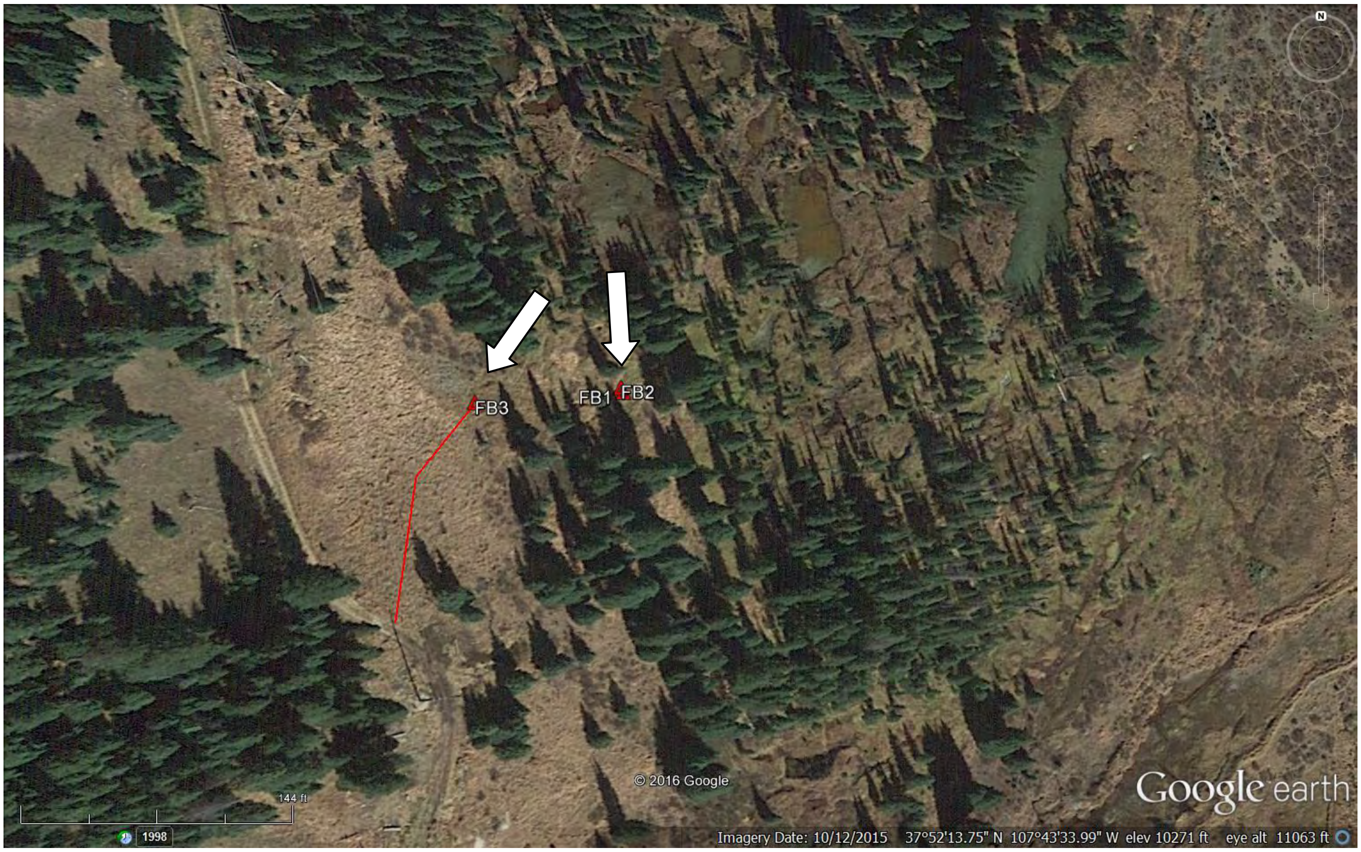
Well FB3 post-installation, looking north.


Well FB3 pre-installation of well site (foreground) and ingress/egress route, looking southwest.


Well FB3 post-installation of well and ingress/egress route, looking southwest.

Well FB2 pre-installation (only the point, ~ 3'', is in the ground) and post-installation of well FB1 (short well) looking southeast (no pre-installation of FB1).

Well FB2 (foreground) and FB1 (background) post installation looking south.



Map showing camera view (arrows) and track rig ingress-egress route (red line).

APPENDIX H

University of Arizona Analysis of Hydrogen and Oxygen Isotopes

Environmental Isotope Laboratory
Geosciences Department
University of Arizona

Room 208 Gould-Simpson Building
+1-520-621-4618
dettman@email.arizona.edu

Data report for:

Ed Muller
Tetra Tech Inc.
3801 Automation Way
Fort Collins CO 80525

18 October 2016

Project # 114-021834

REPORT OF ANALYSES
6 samples for H and O isotopes in water

W	Sample	Date	Time	δ18O ‰ VSMOW	δD ‰ VSMOW
W65422	PIEZO 30C	10/3/2016		-14.8	-105.5
W65423	GF RD SPN	10/4/2016		-16.6	-119.0
W65424	GF-1D	10/4/2016		-16.8	-121.1
W65425	GF-1S	10/4/2016		-16.8	-121.5
W65426	FB-3	10/4/2016		-16.8	-122.7
W65427	FB-2	10/4/2016		-16.5	-119.0

Analytical precision (1σ) 0.10 0.9

David Dettman
Research Scientist

Environmental Isotope Laboratory
Geosciences Department
University of Arizona

Room 208 Gould-Simpson Building
+1-520-621-4618
dettman@email.arizona.edu

Data report for:

Ed Muller
Tetra Tech Inc.
3801 Automation Way
Fort Collins CO 80525

2 December 2016

Project # no COC delivered

REPORT OF ANALYSES
1 sample for H and O isotopes in water

W	Sample	Date	Time	δ18O ‰ VSMOW	δD ‰ VSMOW
W65866	MIN CK US			-13.1	-93.9
Analytical precision (1σ)				0.10	0.9

David Dettman
Research Scientist

APPENDIX I

University of Arizona Radiocarbon Analytical Report

THE UNIVERSITY OF ARIZONA

UNIVERSITY OF ARIZONA AMS LABORATORY

RADIOCARBON ANALYTICAL REPORT

Muller, E. (AA108831 – AA108836)

Summary Page

The following analytical report contains 14C analysis from the University of Arizona for six samples listed on the next page. This report contains:

1. Summary page, includes data qualifiers and non-conformances (page 1)
2. Data summary - DIC (page 2)

Data Qualifiers: Fraction Modern Carbon and Radiocarbon Age were calculated as weighted averages of combined machine runs to reduce overall error. A small sample correction is applied to samples with a carbon mass less than 0.50 mg.

Non-Conformances: 14C results are calculated without a d13C correction (i.e. d13C = -25 permil) for DIC samples.

Report generated by: Richard Cruz

Report Generation Date: 11/15/2016

Reviewer: Greg Hodgins

Date: 11/15/2016

Signature:

Data Summary (DIC)

AA	lab #	Contact 1	sample ID	MASS	d13C value	F (-25)	dF (-25)	14C age BP	d14C age
AA108831	B10527	Muller, E.	Piezo 30C	1.04	-16.8	1.0253	0.0031	post-bomb	
AA108832	B10528	Muller, E.	GF-1D	0.76	-10.1	0.3027	0.0014	9,600	38
AA108833	B10529	Muller, E.	GF-1S	0.40	-11.4	0.3810	0.0025	7,752	53
AA108834	B10530	Muller, E.	GF Rd SpN	0.13	-19.2	0.8250	0.0080	1,545	78
AA108835	B10531	Muller, E.	FB-2	0.53	-23.0	0.9461	0.0035	445	30
AA108836	B10532A	Muller, E.	FB-3	1.30	-7.8	0.1384	0.0010	15,889	59

APPENDIX J

Green Analytical Labs Water Chemistry Report

75 Suttle Street
Durango, CO 81303
970.247.4220 Phone
970.247.4227 Fax
www.greenanalytical.com

18 October 2016

Ed Muller
Tetra Tech
350 Indiana Street, Suite 500
Golden, CO 80401

RE: SW & GW

Enclosed are the results of analyses for samples received by the laboratory on 10/05/16 09:06.
If you need any further assistance, please feel free to contact me.

Sincerely,

Debbie Zufelt

Debbie Zufelt
Reports Manager

All accredited analytes contained in this report are denoted by an asterisk (*). For a complete list of accredited analytes please do not hesitate to contact us via any of the contact information contained in this report. All of our certifications can be viewed at http://greenanalytical.com/certifications/

Green Analytical Laboratories is NELAP accredited through the Texas Commission on Environmental Quality. Accreditation applies to drinking water and non-potable water matrices for trace metals and a variety of inorganic parameters. Green Analytical Laboratories is also accredited through the Colorado Department of Public Health and Environment and EPA region 8 for trace metals, Cyanide, Fluoride, Nitrate, and Nitrite in drinking water.

Our affiliate laboratory, Cardinal Laboratories, is also NELAP accredited through the Texas Commission on Environmental Quality for a variety of organic constituents in drinking water, non-potable water and solid matrices. Cardinal is also accredited for regulated VOCs, TTHM, and HAA-5 in drinking water through the Colorado Department of Public Health and Environment and EPA region 8.

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Tetra Tech	Project:	SW & GW	
350 Indiana Street, Suite 500	Project Name / Number:	[none]	**Reported:**
Golden CO, 80401	Project Manager:	Ed Muller	10/18/16 11:45

ANALYTICAL REPORT FOR SAMPLES

Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
Min Ck DS	1610021-01	Water	10/03/16 11:00	10/05/16 09:06
Min Ck US	1610021-02	Water	10/03/16 12:00	10/05/16 09:06
Piezo 32C	1610021-03	Water	10/03/16 13:24	10/05/16 09:06
Piezo 30C	1610021-04	Water	10/03/16 14:25	10/05/16 09:06
FeC 1	1610021-05	Water	10/03/16 15:00	10/05/16 09:06
GF Adit	1610021-06	Water	10/03/16 14:15	10/05/16 09:06
GF Adit 2	1610021-07	Water	10/03/16 14:15	10/05/16 09:06
GF Rd Sp N	1610021-08	Water	10/04/16 10:20	10/05/16 09:06
GF -1D	1610021-09	Water	10/04/16 11:20	10/05/16 09:06
GF -1S	1610021-10	Water	10/04/16 12:46	10/05/16 09:06
FB-2	1610021-11	Water	10/04/16 14:50	10/05/16 09:06
FB-3	1610021-12	Water	10/04/16 14:20	10/05/16 09:06

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

Min Ck DS

1610021-01 (Water)

Analyte	**Result**	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	**15.0**	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	**15.0**	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	**1.34**	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**317**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.196**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**7.54**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**245**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	<2.00	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**135**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	<0.050	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**50.0**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	<0.050	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**2.89**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**0.142**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	<1.00	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**7.28**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**3.40**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**3.58**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.761**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

Min Ck US

1610021-02 (Water)

Analyte	**Result**	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	**17.0**	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	**17.0**	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	**1.50**	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**289**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.167**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**7.50**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**220**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	<2.00	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**115**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	<0.050	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**43.9**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	<0.050	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**3.00**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**0.163**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	<1.00	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**5.85**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**2.74**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**3.30**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.720**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

Piezo 32C

1610021-03 (Water)

Analyte	Result	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	**55.0**	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	**55.0**	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	**1.48**	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**555**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**1.03**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**6.73**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**480**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	**33.5**	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**256**	10.0	1.99	mg/L	10	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	<0.050	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**109**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	**9.23**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**3.74**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**4.01**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	<1.00	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**26.8**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**12.5**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**5.92**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**1.12**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

Piezo 30C

1610021-04 (Water)

Analyte	**Result**	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	**22.0**	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	**22.0**	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	**1.16**	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**451**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.993**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**6.52**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**370**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	**20.8**	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**216**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	<0.050	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**81.9**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	**2.45**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**3.83**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**0.860**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	<1.00	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**24.3**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**11.4**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**5.78**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.779**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project:	SW & GW	
350 Indiana Street, Suite 500	Project Name / Number:	[none]	**Reported:**
Golden CO, 80401	Project Manager:	Ed Muller	10/18/16 11:45

FeC 1

1610021-05 (Water)

Analyte	**Result**	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	**1.49**	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**629**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.437**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**2.95**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**305**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	**8.40**	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**218**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	**0.945**	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**35.3**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	**15.0**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**3.63**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**0.586**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	**2.29**	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**31.5**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**14.7**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**4.83**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.195**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	Reported:
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

GF Adit

1610021-06 (Water)

Analyte	Result	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	<1.00	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**450**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.941**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**5.97**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**350**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	**2.40**	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**223**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	**0.605**	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**64.3**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	**10.7**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**6.41**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**2.30**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	<1.00	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**32.5**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**15.2**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**5.88**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.542**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

GF Adit 2

1610021-07 (Water)

Analyte	Result	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	<1.00	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**437**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.936**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**6.00**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**360**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	**2.40**	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**221**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	**0.593**	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**62.9**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	**10.5**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**6.26**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**2.26**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	<1.00	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**31.9**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**14.9**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**5.80**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.533**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

GF Rd Sp N

1610021-08 (Water)

Analyte	Result	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	<1.00	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**287**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.665**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**4.01**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**235**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	<2.00	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**125**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	**3.86**	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**22.4**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	<0.050	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**5.63**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**0.687**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	<1.00	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**48.7**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**22.8**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**6.34**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.128**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

GF -1D

1610021-09 (Water)

Analyte	**Result**	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	<1.00	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**337**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.810**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**4.88**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**280**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	**2.10**	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**162**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	**0.670**	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**34.3**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	**8.42**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**8.15**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**1.50**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	**1.18**	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**48.8**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**22.8**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**8.15**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.112**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

GF -1S

1610021-10 (Water)

Analyte	**Result**	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	<1.00	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**375**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.503**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**5.50**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**310**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	**92.6**	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**165**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	**1.69**	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	**0.010**	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**26.8**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	**9.87**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**7.42**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**1.41**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	**2.45**	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**63.6**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**29.7**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**21.3**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.142**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

FB-2

1610021-11 (Water)

Analyte	**Result**	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	<1.00	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**246**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.635**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**4.54**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**235**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	**2.40**	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**119**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	**2.69**	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**22.3**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	**0.091**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**5.64**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**0.717**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	<1.00	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**47.0**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**22.0**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**6.22**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.126**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

FB-3

1610021-12 (Water)

Analyte	Result	RL	MDL	Units	Dilution	Analyzed	Method	Notes	Analyst
General Chemistry									
Alkalinity, Bicarbonate*	**78.0**	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Carbonate*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Hydroxide*	<10.0	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Alkalinity, Total*	**78.0**	10.0		mgCaCO3/L	1	10/17/16	2320 B		KDG
Bromide	<0.100	0.100	0.0313	mg/L	1	10/14/16	EPA300.0		JDA
Chloride	**1.15**	1.00	0.219	mg/L	1	10/06/16	EPA300.0		JDA
Conductivity*	**457**	10.0		uS/cm	1	10/05/16	2510 B		KDG
Fluoride*	**0.290**	0.100	0.0171	mg/L	1	10/06/16	EPA300.0		JDA
pH*	**6.96**			pH Units	1	10/05/16	EPA150.1		KDG
Total Dissolved Solids	**350**	10.0		mg/L	1	10/06/16	EPA160.1		KDG
Total Suspended Solids*	**874**	2.00		mg/L	1	10/05/16	EPA160.2		KDG
Sulfate	**165**	5.00	0.994	mg/L	5	10/07/16	EPA300.0		JDA
Dissolved Metals by ICP									
Aluminum*	<0.050	0.050	0.020	mg/L	1	10/13/16	EPA200.7		LLG
Barium*	<0.010	0.010	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Boron	<0.300	0.300	0.053	mg/L	1	10/13/16	EPA200.7		LLG
Calcium*	**66.9**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Iron*	**0.897**	0.050	0.003	mg/L	1	10/13/16	EPA200.7		LLG
Lithium	<0.100	0.100	0.006	mg/L	1	10/13/16	EPA200.7		LLG
Magnesium*	**5.16**	0.100	0.032	mg/L	1	10/13/16	EPA200.7		LLG
Manganese*	**0.793**	0.005	0.0007	mg/L	1	10/13/16	EPA200.7		LLG
Potassium*	**1.59**	1.00	0.335	mg/L	1	10/13/16	EPA200.7		LLG
Silica (Si02)	**21.7**	1.07	0.534	mg/L	1	10/13/16	Calculation		LLG
Silicon	**10.2**	0.500	0.250	mg/L	1	10/13/16	EPA200.7		LLG
Sodium*	**17.7**	1.00	0.305	mg/L	1	10/13/16	EPA200.7		LLG
Strontium*	**0.275**	0.100	0.0004	mg/L	1	10/13/16	EPA200.7		LLG

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

General Chemistry - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B610034 - General Prep - Wet Chem										
Blank (B610034-BLK1)				Prepared & Analyzed: 10/06/16						
Chloride	ND	1.00	mg/L							
Fluoride	ND	0.100	mg/L							
Sulfate	ND	1.00	mg/L							
LCS (B610034-BS1)				Prepared & Analyzed: 10/06/16						
Chloride	23.7	1.00	mg/L	25.0		95.0	90-110			
Fluoride	2.42	0.100	mg/L	2.50		97.0	90-110			
Sulfate	24.0	1.00	mg/L	25.0		95.8	90-110			
LCS Dup (B610034-BSD1)				Prepared & Analyzed: 10/06/16						
Chloride	23.7	1.00	mg/L	25.0		94.7	90-110	0.270	20	
Fluoride	2.42	0.100	mg/L	2.50		96.7	90-110	0.248	20	
Sulfate	24.0	1.00	mg/L	25.0		95.9	90-110	0.0167	20	
Batch B610035 - General Prep - Wet Chem										
Blank (B610035-BLK1)				Prepared & Analyzed: 10/05/16						
Total Suspended Solids	ND	2.00	mg/L							
Duplicate (B610035-DUP1)		**Source: 1609290-01**		Prepared & Analyzed: 10/05/16						
Total Suspended Solids	20.0	2.00	mg/L		18.9			5.66	20	
Reference (B610035-SRM1)				Prepared & Analyzed: 10/05/16						
Total Suspended Solids	102	2.00	mg/L	100		102	85-115			
Batch B610036 - General Prep - Wet Chem										
Blank (B610036-BLK1)				Prepared & Analyzed: 10/06/16						
Total Dissolved Solids	ND	10.0	mg/L							
Duplicate (B610036-DUP1)		**Source: 1610003-02**		Prepared & Analyzed: 10/06/16						
Total Dissolved Solids	250	10.0	mg/L		250			0.00	20	
Reference (B610036-SRM1)				Prepared & Analyzed: 10/06/16						
Total Dissolved Solids	425	10.0	mg/L	400		106	85-115			
Batch B610038 - General Prep - Wet Chem										
Duplicate (B610038-DUP2)		**Source: 1610021-04**		Prepared & Analyzed: 10/05/16						
pH	6.53		pH Units		6.52			0.153	20	
Reference (B610038-SRM1)				Prepared & Analyzed: 10/05/16						
pH	9.14		pH Units	9.18		99.6	7.807-102.19			

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Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

General Chemistry - Quality Control
(Continued)

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B610040 - General Prep - Wet Chem										
Duplicate (B610040-DUP2)	**Source: 1610021-05**		Prepared & Analyzed: 10/05/16							
Conductivity	644	10.0	uS/cm		629			2.36	20	
Reference (B610040-SRM1)			Prepared & Analyzed: 10/05/16							
Conductivity	509		uS/cm	496		103	90-110			
Batch B610104 - General Prep - Wet Chem										
Blank (B610104-BLK1)			Prepared & Analyzed: 10/14/16							
Bromide	ND	0.100	mg/L							
LCS (B610104-BS1)			Prepared & Analyzed: 10/14/16							
Bromide	2.43	0.100	mg/L	2.50		97.3	90-110			
LCS Dup (B610104-BSD1)			Prepared & Analyzed: 10/14/16							
Bromide	2.45	0.100	mg/L	2.50		97.9	90-110	0.615	20	
Batch B610129 - General Prep - Wet Chem										
Blank (B610129-BLK1)			Prepared & Analyzed: 10/17/16							
Alkalinity, Total	ND	10.0	mgCaCO3/L							
LCS (B610129-BS1)			Prepared & Analyzed: 10/17/16							
Alkalinity, Total	103	10.0	mgCaCO3/L	100		103	85-115			
LCS Dup (B610129-BSD1)			Prepared & Analyzed: 10/17/16							
Alkalinity, Total	103	10.0	mgCaCO3/L	100		103	85-115	0.00	20	

Green Analytical Laboratories

Debbie Zufelt

Debbie Zufelt, Reports Manager

Green Analytical Laboratories
dzufelt@greenanalytical.com p: 970.247.4220 f: 970.247.4227 75 Suttle Street Durango, CO 81303
www.GreenAnalytical.com

Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

Dissolved Metals by ICP - Quality Control

Analyte	Result	Reporting Limit	Units	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit	Notes
Batch B610100 - Dissolved Metals, E200.7/E200.8										
Blank (B610100-BLK1)			Prepared & Analyzed: 10/13/16							
Aluminum	ND	0.050	mg/L							
Barium	ND	0.010	mg/L							
Boron	ND	0.300	mg/L							
Calcium	ND	0.050	mg/L							
Iron	ND	0.050	mg/L							
Lithium	ND	0.100	mg/L							
Magnesium	ND	0.100	mg/L							
Manganese	ND	0.005	mg/L							
Potassium	ND	1.00	mg/L							
Silicon	ND	0.500	mg/L							
Sodium	ND	1.00	mg/L							
Strontium	ND	0.100	mg/L							
LCS (B610100-BS1)			Prepared & Analyzed: 10/13/16							
Aluminum	4.67	0.050	mg/L	5.00		93.3	85-115			
Barium	2.47	0.010	mg/L	2.50		98.9	85-115			
Boron	4.51	0.300	mg/L	5.00		90.2	85-115			
Calcium	4.69	0.050	mg/L	5.00		93.8	85-115			
Iron	4.81	0.050	mg/L	5.00		96.3	85-115			
Lithium	4.61	0.100	mg/L	5.00		92.1	85-115			
Magnesium	23.8	0.100	mg/L	25.0		95.1	85-115			
Manganese	2.30	0.005	mg/L	2.50		92.2	85-115			
Potassium	9.25	1.00	mg/L	10.0		92.5	85-115			
Silicon	4.68	0.500	mg/L	5.00		93.6	85-115			
Sodium	7.61	1.00	mg/L	8.10		94.0	85-115			
Strontium	4.59	0.100	mg/L	5.00		91.9	85-115			
LCS Dup (B610100-BSD1)			Prepared & Analyzed: 10/13/16							
Aluminum	4.63	0.050	mg/L	5.00		92.7	85-115	0.696	20	
Barium	2.43	0.010	mg/L	2.50		97.4	85-115	1.55	20	
Boron	4.61	0.300	mg/L	5.00		92.2	85-115	2.18	20	
Calcium	4.76	0.050	mg/L	5.00		95.1	85-115	1.34	20	
Iron	4.78	0.050	mg/L	5.00		95.7	85-115	0.620	20	
Lithium	4.57	0.100	mg/L	5.00		91.4	85-115	0.809	20	
Magnesium	23.9	0.100	mg/L	25.0		95.8	85-115	0.746	20	
Manganese	2.33	0.005	mg/L	2.50		93.4	85-115	1.30	20	
Potassium	9.30	1.00	mg/L	10.0		93.0	85-115	0.576	20	
Silicon	4.63	0.500	mg/L	5.00		92.7	85-115	0.948	20	
Sodium	7.64	1.00	mg/L	8.10		94.3	85-115	0.364	20	
Strontium	4.55	0.100	mg/L	5.00		91.1	85-115	0.865	20	

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Debbie Zufelt

Debbie Zufelt, Reports Manager

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www.GreenAnalytical.com

Tetra Tech	Project: SW & GW	
350 Indiana Street, Suite 500	Project Name / Number: [none]	**Reported:**
Golden CO, 80401	Project Manager: Ed Muller	10/18/16 11:45

Notes and Definitions

DET	Analyte DETECTED
ND	Analyte NOT DETECTED at or above the reporting limit
NR	Not Reported
dry	Sample results reported on a dry weight basis *Results reported on as received basis unless designated as dry.
RPD	Relative Percent Difference
LCS	Laboratory Control Sample (Blank Spike)
RL	Report Limit
MDL	Method Detection Limit

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

Green Analytical Laboratories
(970) 247-4220
Fax: (970) 247-4227
service@greenanalytical.com or dzufelt@greenanalytical.com
75 Suttle St Durango, CO 81303

Company Name(If Applicable): Tetra Tech
Contact Person: Ed Muller
Address: 3801 Automation Way Ste 100
City: Fort Collins **State:** Co **Zip:** 80525
Phone #: 970-443-7065
Email: ed.muller@tetratech.com
Project Name(optional):
Project Number(optional):
Sampler Name (Print): Ed Muller

Bill to (if different):
P.O. #:
Company: Basin Hydrolgy
Attn: Mark Oliver
Address: 2430 Cnty Rd 203
City: Durango
State: Co Zip: 81301
Phone #:
Email:

For Lab Use	Sample Name or Location	Collected: Date	Collected: Time	Matrix: GROUNDWATER	SURFACEWATER	WASTEWATER	PRODUCEDWATER	SOIL	DRINKING WATER	OTHER:	# of containers: No preservation (general)	HNO_3	HCl	H_2SO_4	Other: Filtered	Other:	Analysis Request: Alk, ph, Cond, TSS	Anions, TDS (dissolved)	Metals (dissolved)	See Attached
1610-021																				
-1	Minck DS	10/3/16	1100		X						1	1			1		X	X	X	
-2	Minck US	10/8/16	1200		X															
-3	Piezo 32C	10/3/16	1324	X																
-4	Piezo 30C	10/3/16	1425	X																
-5	FeC 4	10/3/16	1500		X															
-6	GF Adit	10/3/16	1415		X															
-7	GF Adit 2	10/3/16	1415		X															

Relinquished By: [signature]	Date: 10/5/16 Time: 9:06	Received By: Michael Valentine	
Relinquished By:	Date: Time:	Received By:	
Relinquished By:	Date: Time:	Received By:	
Delivered By: (Circle One) Sampler - UPS - FedEx - Kangaroo - Other:		† Temperature at reciept: 4.4°C on ice	CHECKED BY: Dz

ADDITIONAL REMARKS: Report to State? (Circle) Yes No

250mL filtered unpreserved bottle for anions and TDS

All metals by ICP

Analysis as per GW & SW Tetra Tech quote

† GAL cannot always accept verbal changes. Please fax or email written change requests.
* Chain of Custody must be signed in "Reliquished By:" as an acceptance of services and all applicable charges.

CHAIN-OF-CUSTODY AND ANALYSIS REQUEST

GREEN GAL Analytical Laboratories
(970) 247-4220
Fax: (970) 247-4227
service@greenanalytical.com or dzufelt@greenanalytical.com
75 Suttle St Durango, CO 81303

Company Name(If Applicable): Tetra Tech
Contact Person: Ed Muller
Address: 3801 Automation Way Ste 100 **State:** Co **Zip:** 80525
City: Fort Collins
Phone #: 970-443-7065
Email: ed.muller@tetratech.com
Project Name(optional):
Project Number(optional):
Sampler Name (Print): Ed Muller

Bill to (if different):
P.O. #:
Company: Basin Hydrology
Attn: Mark Olivir
Address: 2430 Cnty Rd 203
City:
State: Zip: 81301
Phone #:
Email:

For Lab Use	Sample Name or Location	Collected Date	Collected Time	GROUNDWATER	SURFACEWATER	WASTEWATER	PRODUCEDWATER	SOIL	DRINKING WATER	OTHER:	No preservation (general)	HNO_3	HCl	H_2SO_4	Other: filtered	Other:	Alk, pH, Cond, TSS	Anions, TDS (dissolved)	Metals, dissolved	See Attached
1610-021-8	GF Rd Sp N	10/4/16	1020		X						1	1			1		X	X	X	
-9	GF-1D		1120	X																
-10	GF-15		1246	X																
-11	FB-2		1450	X																
-12	FB-3		1420	X																

PLEASE NOTE: GAL's liability and client's exclusive remedy for any claim arising whether based in contract or tort, shall be limited to the amount paid by the client for the analyses. All claims including those for negligence and any other cause whatsoever shall be deemed waived unless made in writing and received by GAL within 30 days after completion. In no event shall GAL be liable for incidental or consequential damages, including without limitation, business interruptions, loss of use, or loss of profits incurred by client, its subsidiaries, affiliates or successors arising out of or related to the performance of services hereunder by GAL, regardless of whether such claim is based upon any of the above stated reasons or otherwise.

Relinquished By:	Date/Time	Received By:
[signature]	Date: 10/5/16 Time: 9:06	Michael Valentine
Relinquished By:	Date: Time:	Received By:
Relinquished By:	Date: Time:	Received By:

Delivered By: (Circle One)
Sampler - UPS - FedEx - Kangaroo - Other:

Temperature at reciept: #1 4.4°C on ice
CHECKED BY: DZ

ADDITIONAL REMARKS:
Report to State? (Circle) Yes No

- 250ml filtered unpreserved bottle for anions and TDS
- All metals by ICP
- Analyses as per GW SW Tetra Tech quote

† GAL cannot always accept verbal changes. Please fax or email written change requests.
* Chain of Custody must be signed in "Reliquished By:" as an acceptance of services and all applicable charges.

Project Information

Tetra Tech
350 Indiana Street, Suite 500
Golden, CO 80401
Phone:(303) 217-5700
Fax:(303) 217-5705

10/5/2016

Laboratory PM: **Debbie Zufelt**

Project Name:	SW & GW	**Invoice To:**	Tetra Tech
Project Number:	SW & GW	**Invoice Bid:**	SW & GW
Client PM:	Doc Richardson	**Invoice Manager:**	Doc Richardson
Comments:			

Analysis	Comment
Alkalinity, Bicarbonate	
Alkalinity, Carbonate	
Alkalinity, Hydroxide	
Alkalinity, Total	
Aluminum Dissolved by ICP	
Barium Dissolved by ICP	
Boron Dissolved by ICP	
Bromide by IC	
Calcium Dissolved by ICP	
Chloride by IC	
Conductivity	
Fluoride by IC	
Iron Dissolved by ICP	
Lithium Dissolved by ICP	
Magnesium Dissolved by ICP	
Manganese Dissolved by ICP	
pH	
Potassium Dissolved by ICP	
Silica Dissolved by ICP Package	
Sodium Dissolved by ICP	
Solids, Total Dissolved (TDS)	
Solids, Total Suspended (TSS)	
Strontium Dissolved by ICP	
Sulfate by IC	
Silica Dissolved by ICP Package subanalyses:	
Silicon Dissolved by ICP	