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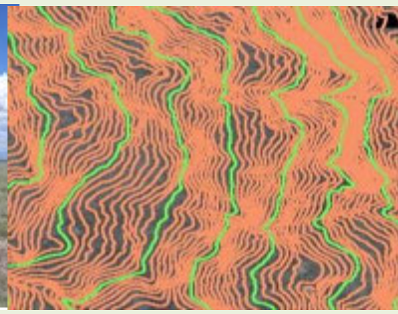

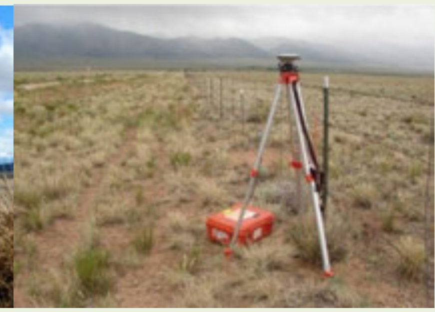

BLM SOLAR ENERGY ZONE HYDROLOGY CONSULTING SERVICES

DE TILLA GULCH SOLAR ENERGY ZONE

FINAL SUBMITTAL

April 25, 2014

TETRA TECH

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TETRA TECH

April 25, 2014

Mr. Joe Vieira
Project Manager
Bureau of Land Management
Colorado - Renewable Energy Team
1803 West Hwy 160
Monte Vista, Colorado 81144

RE: De Tilla Gulch BLM Solar Energy Zone
Final Report

Dear Mr. Vieira,

Tetra Tech, Inc. is pleased to present the De Tilla Gulch Solar Energy Zone Water Resources Inventory and Analysis (Final Report) in compliance with Delivery Order L13PD1218, PR 0040097987This report presents the water resource characterization, hydrologic modeling, and development recommendations for the De Tilla Gulch Solar Energy Zone, located in Saguache County, Colorado.

It has been a pleasure working with the BLM Colorado Renewable Energy Team to complete this inventory and analysis. If you have any questions, comments or need additional information please do not hesitate to contact either Alaina Smith or Peggy Bailey.

Sincerely,

TETRA TECH, INC.

Peggy Bailey, PE
Senior Project Manager, Tetra Tech
(720) 864-4589

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Table of Contents

APPENDICES:

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOS

DE TILLA GULCH SOLAR ENERGY ZONE WATER RESOURCES INVENTORY REPORT

EXECUTIVE SUMMARY

This document presents the water resources inventory and hydrologic analysis report for the De Tilla Gulch Solar Energy Zone (DTG SEZ) prepared for the Bureau of Land Management Colorado Renewable Energy Program (BLM). The study is being performed with the purpose of assembling relevant water resources data, evaluation of surface water features including the determination of the 100-year floodplain, review of the groundwater in the vicinity of the DTG SEZ and a geospatial compilation of water resources data.

The De Tilla Gulch Solar Energy Zone is a 430 hectare (1,064 acre) area of land located approximately 11 km (6 miles) to the east of Saguache, Colorado off of U.S. 285. This area has been identified by the BLM as one of four sites in Colorado with potential for the development of solar energy facilities (Figure 1).

Hydrologic Data

There are two hydrologic units in the vicinity of the project site identified using the USGS Hydrologic Unit Code (HUC) system. HUC 130100040704 and 130100040706. The latter covers the majority of the DTG SEZ and approximately one-third of the offsite watersheds while the former contains the other two-thirds of the offsite watershed and a small portion of the DTG SEZ on the western end of the site.

The SEZ area contains no named drainage ways through the site and no perennial streams. Approximately 3,180 hectares (7,856 acres) of offsite watershed contributes flows across the DTG SEZ flowing northwest to southeast, entering the project area through a series of 14 culverts under U.S. 285 (Figure 2).

There are no trees on the DTG SEZ. The vegetation consists of grasses and shrubs typical of the high elevation desert. The majority of the soils in the watershed and at the DTG SEZ are Type B soils, defined by the National Resource Conservation Service as moderate to well-draining soils with moderate infiltration and transmissivity rates, and coarse in texture.

Terrain Spatial Data

The DTG SEZ is located on a relatively flat, alluvial fan. LiDAR information for the DTG SEZ and immediate surrounding area was supplied by the BLM as a digital elevation model with 1 meter post-spacing.

Hydrologic Input Data

A 100-year, 24-hour rainfall storm is used in the analysis with a distribution pattern that follows the SCS Type II storm distribution. Information from isopluvial maps generated by NOAA are used to estimate the 100-year, 24-hour rainfall depth is 2.32 inches (58.9 mm) for the upper watershed and 2.11 inches (53.59 mm) for the DTG SEZ.

The influence of snowmelt was evaluated by reviewing the long term discharge at Saguache Creek.

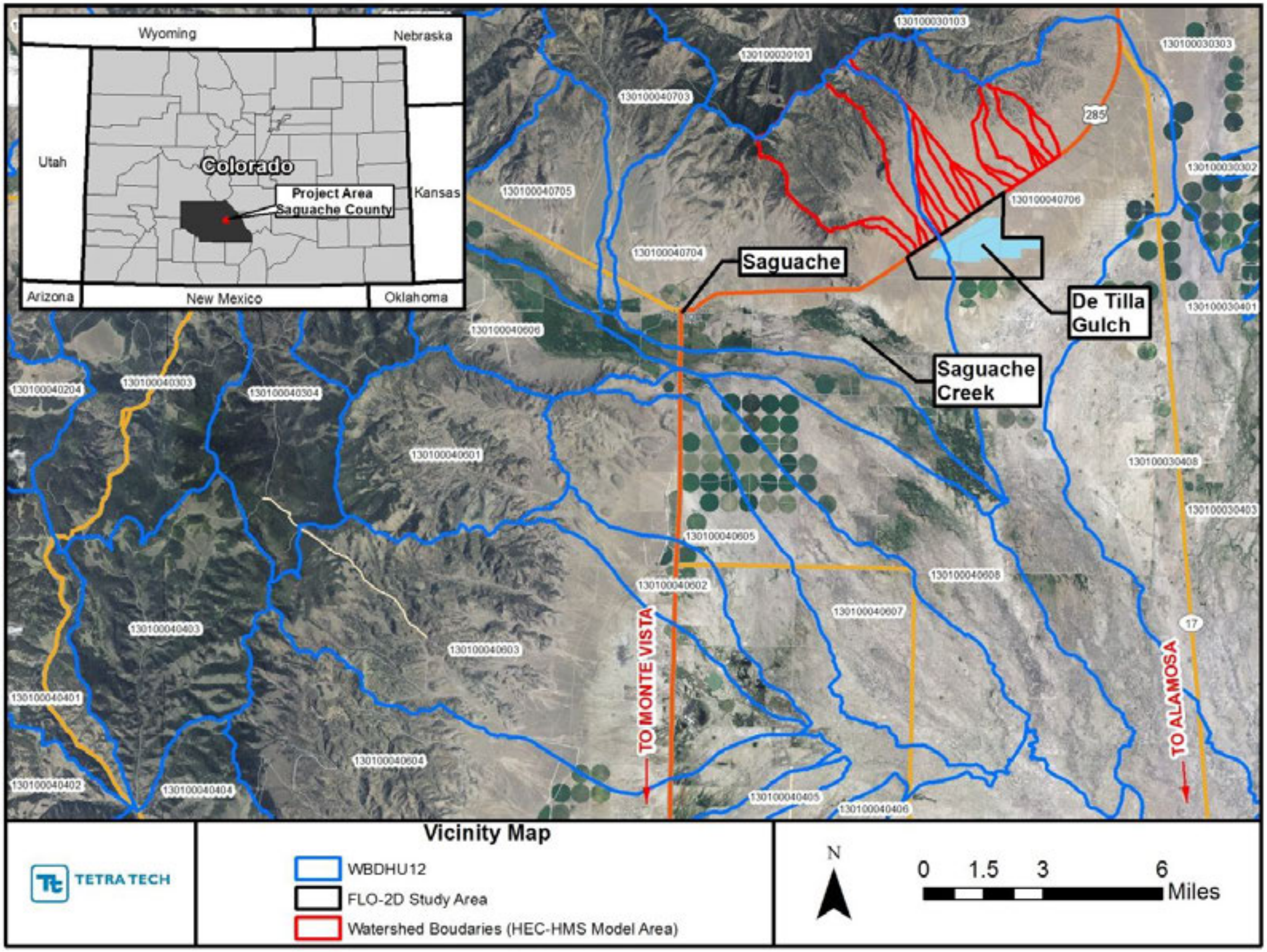

Figure 1. Vicinity map.

FLO-2D Model Input Data

A goal of this study is to provide informative water resources data to future solar array developers, including an estimate of the 100-year floodplain, or the floodplain created by the 1-percent chance rainfall. This is accomplished by assessing the offsite runoff tributary to the 14 culverts under U.S. 285. These flows are combined with rainfall-runoff on the DTG SEZ and routed in total, across the site. Most of the total runoff converges to one of 10 locations along the downfan or southern boundary of the study area (County Road AA). An additional 15 convergence points are also analyzed at the southern boundary of the DTG SEZ. These locations are the points of analysis where the peak runoff rates and volumes under future, developed conditions should be at or less than those determined under existing conditions. Detention and/or retention basins are recommended to accomplish this as presented in the final recommendations and further discussed under 'Impacts of Development on Surface Water.

1. The program HEC-HMS (Hydrologic Engineering Center – Hydrologic Modeling System) is used to estimate offsite flows that travel onto the DTG SEZ through a series of 14 culverts under U.S. 285.
2. The FLO-2D computer program, a two dimensional finite element analysis program, is utilized to estimate the extents of the 100-year floodplain at the DTG SEZ, and to estimate the volume of required detention and/or retention utilizing the following inputs: For the DTG SEZ area, a grid system is created using FLO-2D, nodes are located every 10 meters for the area located downfan of U.S. 285.
3. The 100-year 24-hour rainfall storm using a storm pattern represented by the SCS Type II curve.
4. The Green Ampt methodology is used in the analysis for rainfall losses due to initial abstraction and infiltration in both the HEC-HMS and FLO-2D models. The soils at the site are primarily loam and gravelly loam,
5. The surface roughness is represented by the Manning roughness coefficient. The natural low-lying grasses and low shrubs are represented with a Manning's n value of 0.055. In locations where gravel roads exist, a value of 0.04 is used and channels are represented with a value of 0.045, and a value of 0.035 is used to represent U.S. 285.
6. Outflow nodes are assigned with the FLO-2D model along the downstream boundary of the model.

Regulatory Floodplain Determination

On September 18, 2013 Saguache County became a participant in the NFIP. At this time, only the 100-year (1% annual chance occurrence) floodplain along three miles of Saguache Creek is mapped in Saguache County. The DTG SEZ is north of Saguache Creek in an area with no determination and/or an area outside a 100-year floodplain.

The position of the Colorado Water Conservation Board (CWCB) is that the area will not be required to have an officially designated floodplain through the NFIP process for this project. Further, the DTG SEZ is not located within a populated area with homes and structures that would be subject to flood insurance, and is therefore not required by Saguache County Land Use Planning Office to be incorporated into official floodplain maps.

The focus of the DTG SEZ analysis is to identify and map flood prone areas in compliance with FEMA criteria established for AE, AH and AO zones. Specifically AH and AO zones have depths between 1 and

3 feet (0.3 and 1 m), and AE zones have depths greater than 3 feet (1 m). This will provide guidance for development that would be FEMA compliant should it be required in the future by either the County or CWCB. Thus to that end, the DTG SEZ floodplain mapping reflects those areas that exceed one foot (or 0.3 meters).

SEZ Floodplain Mapping Protocol

For the purposes of this study, all areas of concentrated flow between 0.3 -1 m on the DTG SEZ are designated as the 100-year floodplain (shallow flooding). Flow paths with flows greater than 1 m are designated as 100-year floodplain (concentrated flows).

Site Visit

A site visit and field data collection efforts were conducted in conjunction with this water resources inventory report. A preliminary visit occurred on November 4, 2013 following the project kick off meeting. The purpose of the initial visit was to get a general sense of the DTG SEZ area and the contributing watershed, as well as the type and density of vegetation and soil cover. A second day of site visit observations were made and recorded on November 5, 2013. During that same time, field data collection efforts were conducted. Data was collected using RTK GPS equipment, also soils were sampled the largest discernable channel downstream of U.S. 285, photographs were taken and observations of the site were recorded.

Modeled Floodplain Results

The model input parameters are included in the two FLO-2D models and executed to complete this task. The results of the 100-year rainfall runoff modeling effort are presented in several figures.

FLO-2D Mapper can depict results in a variety of ways, including maximum flow depth and maximum velocity, which are the two variables most important to this study. It is important to understand that the reported value at each node is the maximum which occurs at that node, regardless of time. The resultant map is not at a particular snapshot in time but rather a depiction of the maximum value which occurs at each node throughout the model execution time. The models were executed for 48 hours, the first 24 of which receive rainfall.

The 100-year floodplain has been delineated into two types: ***100-year floodplain - shallow flooding*** represents areas with ephemeral drainages that have depths between 0.3 and 1 m (or approximately 1 to 3 feet). In general, construction in these areas can proceed with minimal drainage issues (culverts or at-grade road crossings can be used to manage surface flows through development).

The ***100-year floodplain - concentrated flooding*** represents ephemeral drainages with depths greater than 1 m. These areas should be avoided for future development except where required for road crossings.

Within the boundaries of the DTG SEZ, rainfall runoff occurs primarily as sheet and unconcentrated overland flow with limited areas of well-defined ephemeral drainages. The only areas of significant flooding occur at the outlets of the culverts under U.S. 285 and where ponding occurs along CR AA.

Channel Stability

A hydraulic analysis of the two of the largest channels entering the DTG SEZ is performed using the geometry of the surveyed cross sections coupled with the flow information derived from offsite, HEC-

HMS model. An incipient-motion analysis (i.e., an evaluation of flows required to move the bed material) was performed for cross sections of interest by evaluating the effective shear stress on the channel bed in relation to the amount of shear stress that is required to move the bed material.

The shear stress in the channel associated with the 100-year rainfall resultant runoff flow, determined with the HEC-RAS model, is used to analyze the stable particle size of the channel. The stability of the channel is analyzed at the outfall of Culvert #5, which has the highest peak flow within the study area. In this area, the stable particle size is estimated to be 150 mm while the median particle size found in the area of deposition is 50 mm.

Within the DTG SEZ, rainfall runoff primarily occurs as sheet flow and unconcentrated overland flow. The lack of well-defined channels results in a lack of the shear force needed to cause erosion. If future development alters the landscape such that flows are more concentrated and shear forces increased, necessary erosion protections measures are recommended in the design of such channels.

Groundwater

The San Luis Valley aquifer system has been studied and written about extensively since as early as 1904. In addition to the literature, databases containing well and water rights records, water well logs and construction information, and groundwater levels are available from the Colorado Division of Water Resources and Colorado Water Conservation Board, the Rio Grande Water Conservation District, and the USGS. Groundwater in the San Luis Valley is present in a shallow unconfined aquifer and in two deeper confined aquifers that extend nearly throughout the San Luis Valley. The aquifers occur primarily in the valley-fill sediments. The shallowest groundwater is present in the Alamosa Formation under unconfined (water table) conditions. The clay beds and volcanics interlayered with the valley fill throughout most of the valley form confining units and result in confined (artesian) conditions except near the edges of the valley. HRS mapped the northern edge of the clay confining beds as being approximately two miles south of the DTG SEZ site; that interpretation is supported by logs of water wells in the site vicinity. The aquifers at and in the immediate vicinity of the site therefore contain groundwater only under unconfined conditions. Flowing water wells are present south of the SEZ site, indicating that confined conditions can be encountered starting about two to three miles south of the SEZ.

Impacts of Development on Surface Water

The need to demonstrate the effects of any future development on offsite / downstream receiving lands and waters is an important aspect of this report. The potential impact is evaluated using FLO-2D as previously described.

The overall impact on rainfall runoff by solar array equipment is assumed to be negligible. Rain or snow that would have fallen on vegetation or the bare ground will instead be intercepted by panels of various sizes, shapes and orientations and then fall to the ground.

The largest impact to flow routing at a solar array is the interference of flow patterns due to supporting structures for the solar equipment as well as any changes to the ground surface associated with roads or support buildings. As a baseline estimate of future development an assumption of 15 percent of ground cover being unavailable for flow routing is incorporated into a "proposed conditions" model.

To evaluate the impact of development on the DTG SEZ and importantly on downstream properties, the peak discharge (cms) and the volume of flow (m^3) are summarized at the 7 design points for both the existing and proposed conditions. As expected, there is slight impact due to an assumed 15% reduction in flow area. The peak discharge and total volume at each design point increases between existing and proposed conditions. To avoid any impact to downstream properties, existing flow patterns can be maintained at the boundary, by providing detention and/or retention facilities. Detention can be provided on the DTG SEZ to capture the volume of flow that is represented by the increase between existing and proposed conditions.

Impacts of Development on Groundwater

Development of the DTG SEZ for solar energy production has the potential to cause impacts to groundwater resources. Sources of potential impacts include construction disturbance of the land surface, water-supply production for construction and operational water needs, wastewater generation and disposal, and on-site structures.

Potential impacts of future site development on groundwater resource availability are difficult to predict, particularly under the regulatory setting in which any water development for solar energy development at the site would need to occur. Any additional groundwater development in the San Luis Valley for uses other than domestic would be subject to approval by the Water Court, review by the CDWR and limitations imposed by existing laws, regulations, interstate water compacts, and court decisions. The limitations would likely require purchase of existing water rights and transfer of those rights to a new point of diversion, pending approval by the CDWR following their review of potential impacts to existing water rights.

Construction Considerations

The location of the 100-year floodplain at the ephemeral streams should be taken into consideration when planning for solar development. To account for any potential channel migration, it is suggested that a floodplain corridor be defined and construction excluded from that corridor for 100-year floodplain – concentrated flow. A minimum of 300 feet on each side of the channel centerline is suggested based on site observations and the channel stability analysis. Any fill or disturbance within the streams will most likely require a permit through the US Army Corps of Engineers Clean Water Act, Section 404.

If roads are required to cross the 100-year floodplain – shallow flow, culverts or at-grade crossings such as a Texas dip could be constructed to mitigate drainage.

A scour analysis should be performed for any support structures for the solar array devices. The FLO-2D model reports velocity at each node which can be used to estimate scour and provide guidance on footer depths or scour protection design, if deemed necessary.

Regulatory Agencies

Regarding water resources, there are several regulatory agencies that may need to be involved in the event of future solar development; these are summarized in the main body of the report.

Relevant Literature

A literature review was conducted to identify additional water resources issues associated with the DTG SEZ.

BLM Citrix SEZ-Specific eGIS Draft Database

The De Tilla Gulch SEZ draft ESRI file geodatabase is subdivided into seven feature datasets, five raster datasets, and five tables. The data fall in to seven categories including FLO-2D results, geology, groundwater, hydrology, project feature classes, surface water, and topography. A detailed description of all data contained in the seven datasets is included in the main body of the report.

1.0 INTRODUCTION

This report contains the De Tilla Gulch Solar Energy Zone (DTG SEZ) Water Resources Inventory Final Report. The specific scope of work (SOW) is outlined in the contract titled BLM Solar Energy Zone Hydrology Consulting Services, executed September 13, 2013.

2.0 PROJECT DESCRIPTION

The DTG SEZ is a 430-hectare (1,064-acre)) area of land located approximately 11 km (6 miles) to the east of Saguache, Colorado on the south side of U.S. 285. This area has been identified by the BLM as one of four sites in Colorado with potential for the development of solar energy facilities. As such, Draft, Supplemental, and Final BLM-DOE Solar Energy Programmatic Environmental Impact Statements (PEIS) were created (BLM, 2011) which identified the need to further evaluate the water resources at the DTG SEZ. This study is performed to fulfill that need. Further details on the DTG SEZ location and information can be found in the PEIS (BLM, 2011).

The DTG SEZ is a triangular shaped site located approximately 11 km (6 miles) to the east of Saguache, Colorado off of U.S. 285. The northeast border of the DTG SEZ runs parallel to U.S. 285, offset by approximately 1,500 feet. The south border runs parallel to County Road (CR) AA and north by approximately 2,500 feet, and the east border extends to CR 55 with a small portion of the DTG SEZ extending past CR 55 on the east. The area of analysis (study area) is extended to the bounding roads. See Figure 2.

The project approach includes evaluating information from the previous PEIS studies available on the BLM Citrix server, researching baseline hydrologic data, performing hydrologic and hydraulic routing analyses including a site level analysis of soil / channel stability, identifying regulatory issues associated with water resources, evaluating ground water in the vicinity of the DTG SEZ, and identifying how potential solar array development may affect water resources.

In general, the DTG SEZ is located on a sparsely vegetated, gently sloping desert alluvial fan (Photo 1). The contributing watershed is located in the Ute Hills which contain a series of alluvial fans. This area was subject to land management techniques in the early 1960s by the BLM in an effort to retain water and promote vegetative growth, primarily for grazing by the diversion and collection of surface water runoff. Evidence of these efforts can be seen today in the form of swales and detention basins. The contributing watershed is approximately 3,174 hectares (12.27 km^2) (see Figure 3).

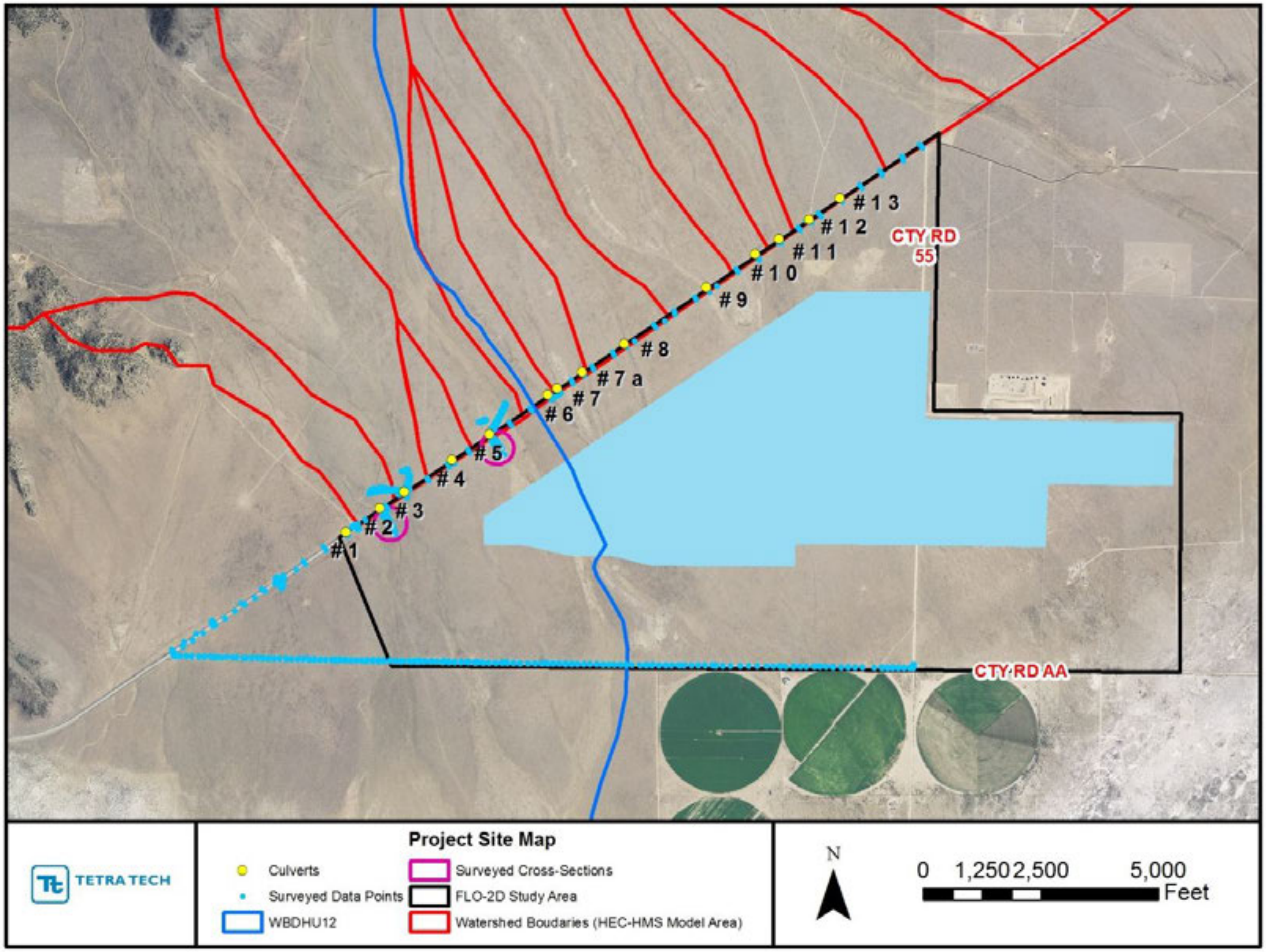

Figure 2. Project site map.

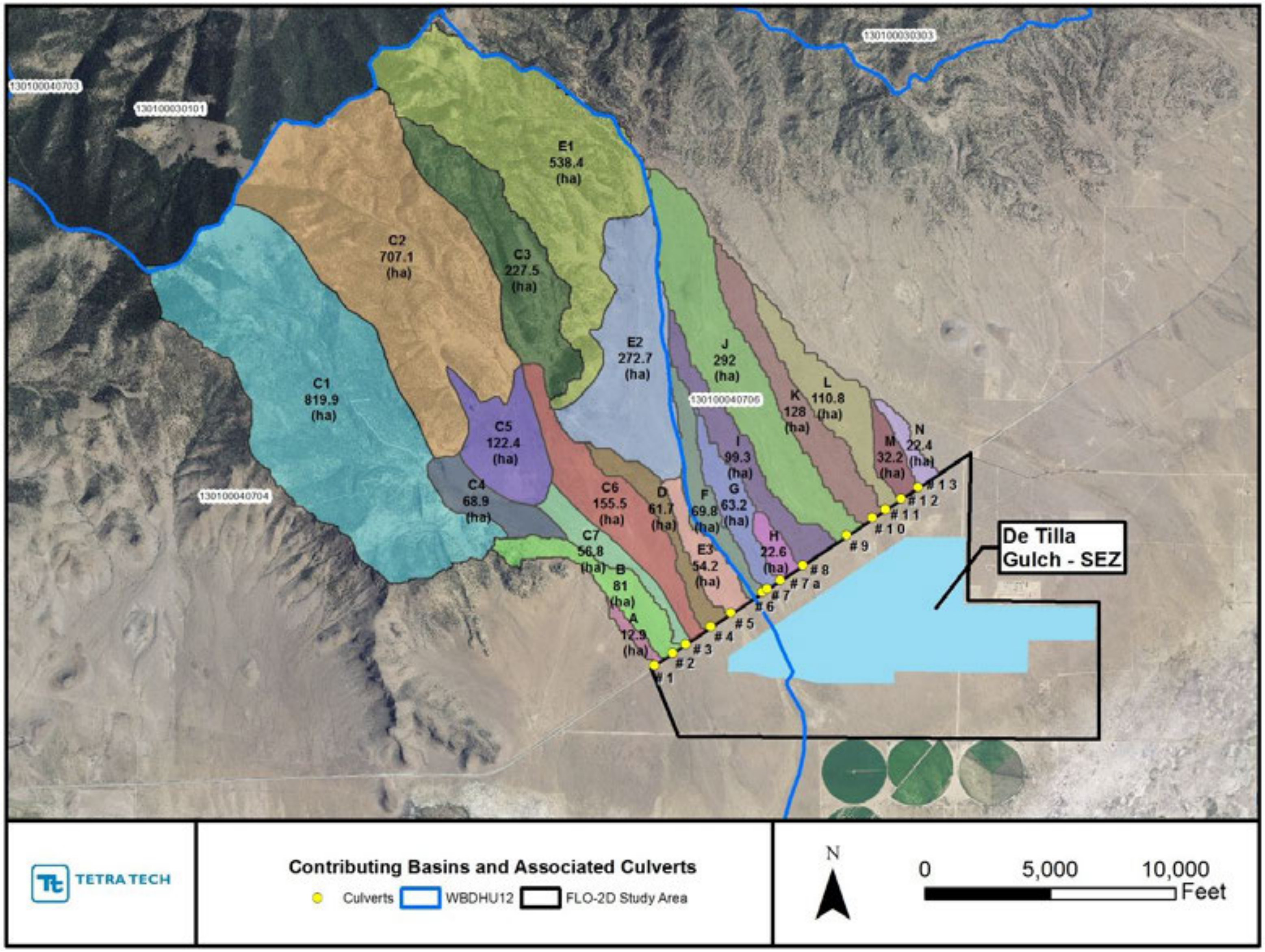

Figure 3. Offsite Contributing Basins to the De Tilla Gulch SEZ.

The Scope of Work (SOW) for this effort includes the following excerpts:

> "The BLM Colorado Renewable Energy Program requires consulting services to advance water resource action plan recommendations made for Colorado in 2011 in the Supplemental Solar PEIS. The scope of work for this project encompasses water resource characterization, hydrologic modeling, and analytical recommendations made for Colorado in the Solar PEIS. This is a 1-year project that includes agency coordination and consultation on surface and sub-surface water resources, compilation and organization of existing baseline hydrological data, data collection including but not limited to GPS field survey, identification, GIS mapping and characterization of ephemeral channels and other water features such as riparian communities or wetland features (if any), hydrological modeling, including flow path and runoff-routing, USACOE Clean Water Act and FEMA 100-year floodplain determinations. Project information will be used to inform environmentally responsible solar energy generation"
>
> "project information will inform developer best management through site-level water run-off characterization to guide cost-efficient design of utility-scale solar energy generation facilities, DTG SEZ-specific hydrologic information generated under this contract will augment planning-level information in the Solar PEIS to best avoid, minimize, and mitigate adverse water resource impact resulting from any future solar energy development project".

Items specific to the Scope of Work presented in this report include the following:

Task A.1 De Tilla SEZ – Northern San Luis Valley Water Resources Inventory Completed

- Task A.1.1 Hydrologic & Terrain Spatial Data Complied, Draft List BLM Approved, and Data Delivered to BLM (including but not limited to Canals, Streams, HUCs, -USGS-NRCS-DNR-BLM-DEMs, LiDAR)
- Task A.1.2 Hydrologic Tabular and Model Input Data Compiled, Draft List BLM Approved, and Data Delivered to BLM
- Task A.1.3 BLM Citrix SEZ-Specific eGIS Draft Database Organized, BLM Reviewed, Approved and Final Database Delivered
- Task A.1.4 BLM Citrix SEZ-Specific eGIS ArcGIS Draft Water Resources Inventory Project Presented, Approved, and Delivered

Task B.1: De Tilla SEZ – Floodplain Determination Completed and FEMA Approved

- Task B.1.1 Federal-State-Local Agency (FEMA, DNR, etc.) 100-year floodplain consultation requested, launched, and documented
- Task B.1.2 SEZ Floodplain Field Survey and Mapping Protocol Approved by FEMA and DNR
- Task B.1.3 SEZ Floodplain Field Survey Completed (Channel Geometries, High-Water Indictor Maps, NHD Channel Network Ground Truthed)

Task B.1.4	SEZ hydrological surface pathways, runoff routing, inundation areas, flood frequency GIS modeled, field verified, and characterized for future monitoring (within and adjacent)
Task B.1.5	SEZ Hydrologic Analysis completed, presented, report, model & data delivered

3.0 WATER RESOURCES INVENTORY (TASK A.1)

3.1 Hydrologic and Terrain Spatial Data (Task A.1.1)

Hydrologic & Terrain Spatial Data Complied, Draft List BLM Approved, and Data Delivered to BLM (including but not limited to Canals, Streams, HUCs, - USGS-NRCS-DNR-BLM-DEMs, LiDAR)

Hydrologic and Terrain Spatial Data obtained from the BLM eGIS data set, is assembled in an ESRI GIS platform to provide data both incorporated into the analysis and relative to the water resources inventory report. The information collected to support this task is discussed in the following sections.

3.1.1 Hydrologic Data

3.1.1.1 Hydrologic Unit Codes and Contributing Watershed

The first step in the hydrologic analysis process requires identification of the contributing watersheds to the project site. The hydrologic units in the vicinity of the project site were identified using the USGS Hydrologic Unit Code (HUC) system (see Figure 1).

HUC 130100040706 contains the majority of the DTG SEZ and approximately one-third of the offsite contributing watershed. HUC 130100040704 contains approximately two-thirds of the offsite watershed and a small portion of the DTG SEZ. These are sub units within the Subregion 1301 – Rio Grande Headwaters: The Rio Grande basin from its headwaters to the river's intersect with the Colorado-New Mexico State Line including the San Luis Valley Closed Basin, Colorado, and the Cataloging Unit of 13010002 Alamosa-Trinchera, Colorado

The upstream watershed area that contributes flow to the project site is delineated into subbasins. The delineation is performed using the topography derived from the LiDAR obtained from the BLM.

3.1.1.2 Canals, Streams and Ephemeral Drainages

The DTG SEZ area contains no named drainage ways and no perennial streams. Saguache Creek is located south of the DTG SEZ and runs east-west to confluence with the San Luis Creek south and east of the DTG SEZ (Figure 4).

3.1.1.3 Vegetation

Vegetation is typical of high elevation desert plains with a treeless sparse mix including sagebrush, rubber rabbitbrush and wintererfat bushes as well as western wheatgrass, green needlegrass, blue grama and needle–and-thread grasses. (BLM PEIS, 2011) (Photo 1). The vegetation is sparse as it is supported by minimal amounts of rainfall and is located over mainly well-draining soils. There are no larger trees located on the DTG SEZ and no vegetation indicative of wetlands such as willows or sedges. The offsite watershed reaches elevations of 3215m (10,550 feet) at Saguache Peak. Juniper and scrub pine trees were observed in the upper portion of the watershed, in addition to the smaller high desert bushes and grasses.

3.1.1.4 Soils

The soils in the area of the contributing watershed have been classified by the National Resource Conservation Service (NRCS). As the area is quite vast, the classification done by NRCS is the best available information for general characteristics of the soil properties. Geospatial soil information is available through the NRCS STATSGO program. The soil data was obtained through the STATSGO site on a watershed level. The majority of the soils in the watershed consist of Rock River gravelly loam (24.2 percent), Graypoint gravelly sandy loam (23 percent), Mosca loamy sand (13.2 percent), Platoro loam (12.2 percent), Villa Grove sandy clay loam (9.4 percent) (see Figure 5 and Table 1).

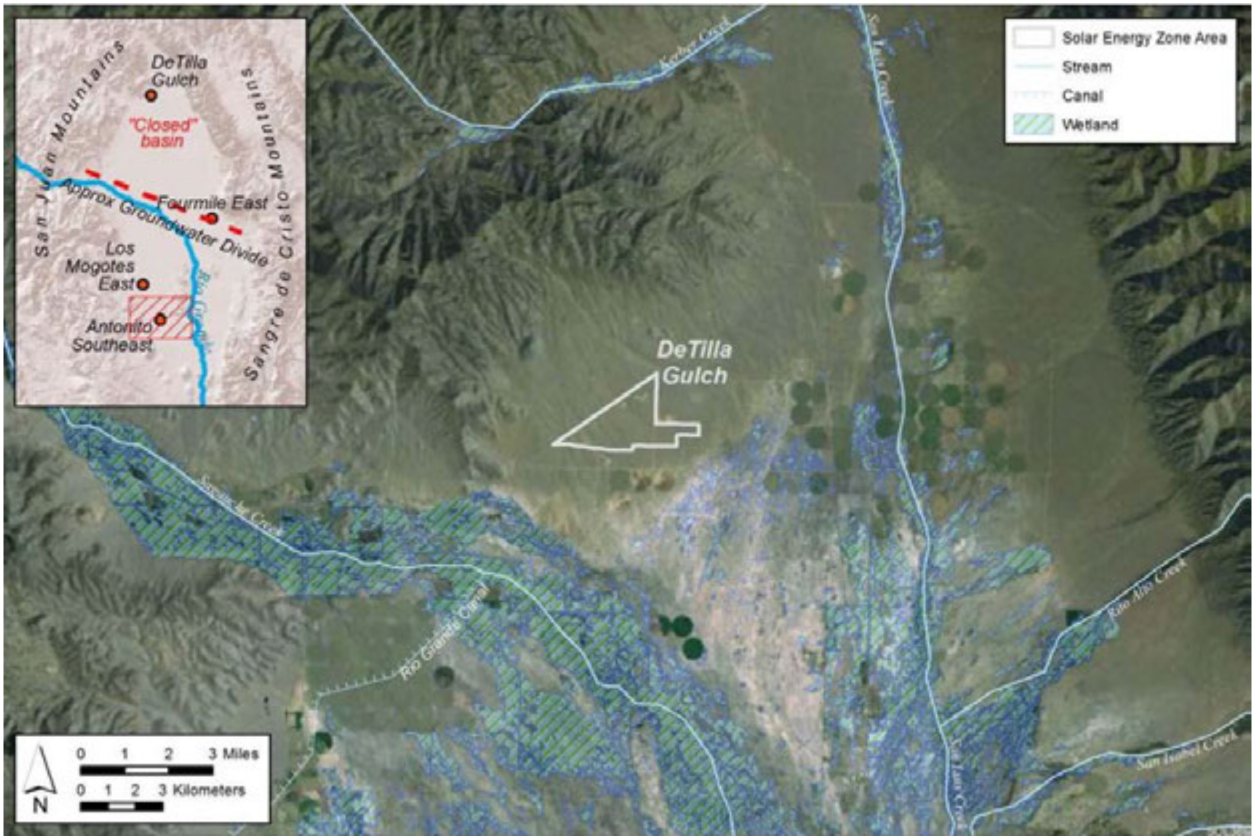

Figure 4. Surface water in the De Tilla Gulch SEZ Area (PEIS, 2011).

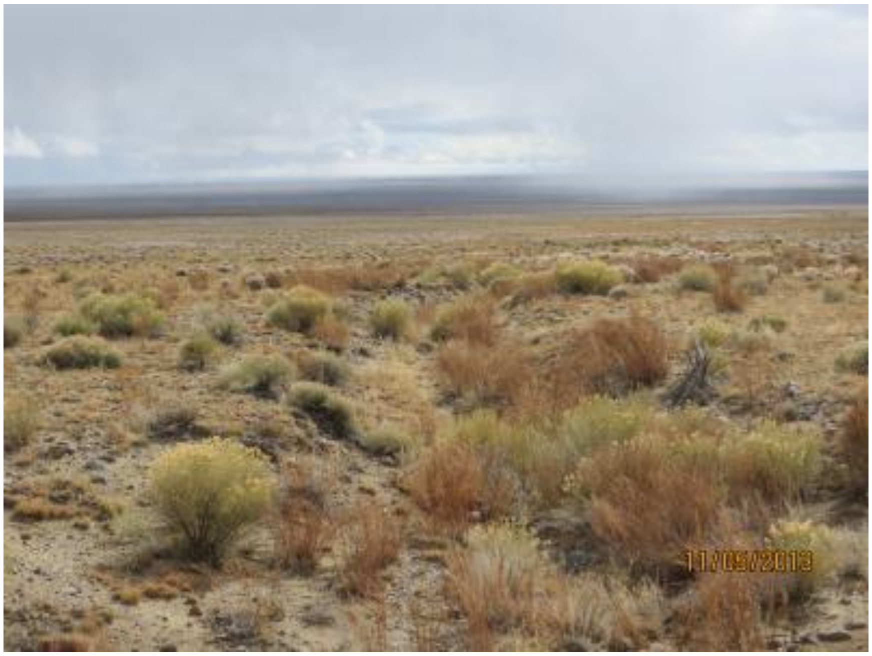

Photo 1. Vegetation typical of the DTG SEZ.

Rock River gravelly loam is typically found on fans and valley sides. It is a well-drained soil with typical depth to water table more than 80 inches, with a parent material of Calcareous alluvium. The Graypoint gravelly sandy loam is an alluvium derived from basal, typically found on fans on valley floors. It too is a well-drained soil with the depth to water table also more than 80 inches.

For more detailed information on the soils within the DTG SEZ, a detailed soil survey report was also obtained from the NRCS interactive web soil survey (WSS). The WSS report is included in Appendix B.1 (offsite) and Appendix B.2 (on-site).

In addition to soil information available from the NRCS, field samples were also taken in the form of Wolman Pebble counts (Wolman, 1954) as well as two grab samples all from the largest channel which near the outlet Culvert 5 which conveys flows from offsite Basin E, the main ephemeral channel. These samples provide detailed information on the size of the material in the channel that is subject to the erosive forces of confined flow. The results of the laboratory analysis of the grab samples are included in Appendix B.1.

3.1.2 Terrain Spatial Data (topography)

The DTG SEZ is located on a relatively flat alluvial fan, most likely initially formed by the volcanic activity and subsequent erosion and deposition which occurred as part of the Neogene volcanism mechanisms (Burroughs, 1974). There are some steeper sloping areas (20 to 25 percent) near the uphill portion of the offsite watershed, however, average slopes range from 1 to 5 percent in the watershed. Elevations in the offsite watershed range from 2,340 to 3,205 m.

The DTG SEZ slopes average 1 to 2 percent running primarily northwest towards the southeast. Natural and man-made depressions exist and form ephemeral drainages across the watershed. There are two fairly well defined channels near the outlets of Culvert 3 and 5 under U.S. 285; however, the channels dissipate quickly in the downstream direction.

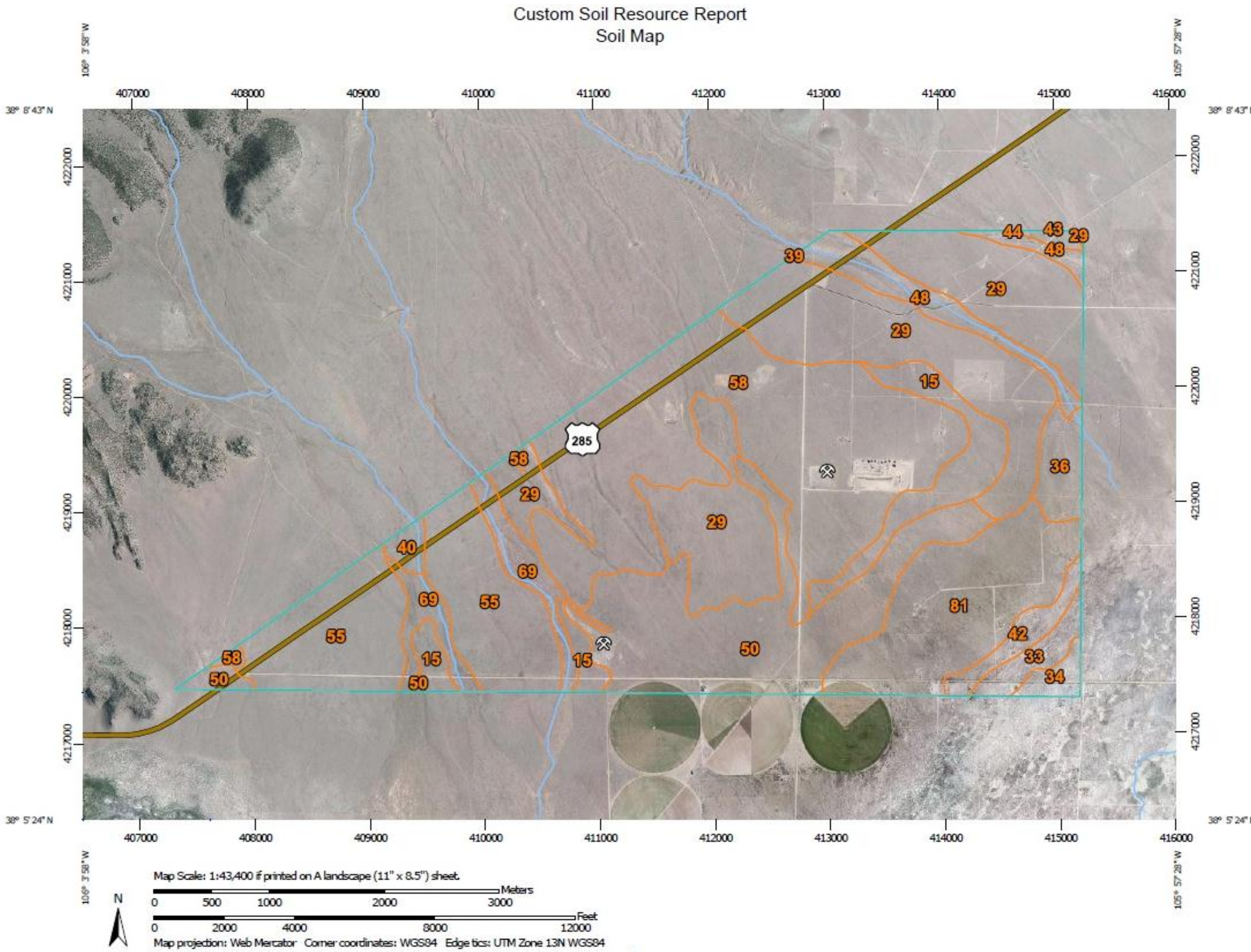

Figure 5. Soil Map of the DTG SEZ Study Area.

Table 1. Soils of the De Tilla SEZ Study Area.

Saguache County Area, Colorado (CO633)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
15	Costilla fravelly loamy sand, 0 to 3 percent slopes	251.6	5.0%
29	Graypoint gravelly sandy loam, 0 to 3 percent slopes	1173.6	23.3%
33	Hapney clay loam	64.5	1.3%
34	Harlem, dry, Clickspots complex	38.2	0.8%
36	Hooper clay loam	86.9	1.7%
39	Jodero loam, 0. to 3 percent slopes	0.01	0.0%
40	Jodero-Lolo, wet complex, 0 to 6 percent slopes	29.1	0.6%
42	Laney loam, 0 to 3 percent slopes	70.8	1.4%
43	Luhon loam, 0 to 3 percent slopes	13.7	0.3%
44	Luhon loam, 3 to 6 percent slopes	0.9	0.0%
48	Monte loam, 0 to 3 percent slopes	164.8	3.3%
50	Mosca loamy sand, 0 to 3 percent slopes	666.7	13.2%
55	Platuro loam, 0 to 3 percent slopes	611.7	12.2%
58	Rock River gravelly loam, 0 to 3 percent slopes	1218	24.2%
69	Shawna loam, 0 to 4 percent slopes	170.4	3.4%
81	Villa Grove sandy clay loam	471.4	9.4%
Totals for Area of Interest (AOI)		**5032.3**	**100%**

The LiDAR information for the DTG SEZ and immediate surrounding area was supplied by the BLM as a digital elevation model with 1 meter post-spacing. The topographic information for the remainder of the watershed was obtained from the USGS National Elevation Dataset with 10 meter post-spacing. This information was used to create contour maps on 1-foot and 1-meter intervals for use in Task B.1 Floodplain Determination.

3.2 Hydrologic Tabular and Model Input Data (Task A.1.2)

Approximately 40.2 km^2 of watershed is tributary to 14 culverts that cross under U.S. 285, discharging flows along the northwest boundary of the DTG SEZ study area. The flows from the culverts run overland reaching and flowing over the DTG SEZ site from the northwest to the southeast, converging with onsite runoff. Ultimately the drainages and onsite runoff exit from the DTG SEZ along the southeast site boundary in multiple locations.

The overall approach to this hydrologic analysis is to calculate the overland rainfall runoff to each of the culverts using HEC-HMS and combine the hydrographs for the offsite basins with onsite rainfall runoff using FLO-2D.

3.2.1 Hydrologic Input Data

As outlined in the Final PEIS (Vol 6, Part 1, Appendix A, page A-23) the storm water evaluation for the DTG SEZ shall be conducted for the 100-year, 24-hour rainfall event. While summer thunderstorms can generate high peaks, the storms are generally short in duration and most likely do not occur over the entire watershed as is assumed for the 24-hour rainfall. Snowfall can also occur in the area, however, the daily diurnal runoff coupled with the high rate of sublimation in open fields are likely to result in lower flows compared to rainfall events. Further, review of climatic data collected at both Saguache (Station 57337) and Center (Station 51458) indicate very low snowfalls in this area with average snow falls of approximately 24.5 inches and a maximum snowfall for a season of approximately 60 inches. Thus a 24-hour rainfall is used in this analysis.

3.2.1.1 Rainfall Depth and Storm Pattern Distribution

The National Oceanic and Atmospheric Administration National Weather Service (NOAA - NWS) has performed extensive statistical analysis of rain gage data to create a series of isopluvial maps that are used for rainfall estimates when reliable local rain gages with extensive data are not available. The NOAA Atlas 2 Volume 3 publication includes a discussion of the development process for the rainfall isopluvial maps. The maps are created for a series of return periods for the 6-hour and 24-hour storms. The original maps for Colorado were created in 1973 and are available in paper form. Currently, there is an interactive website for determining precipitation estimates. The user inputs the latitude, longitude and elevation of the project location and the table is returned.

The rainfall depth is determined by accessing the NOAA Interactive Website at (http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nv) and the result is 2.32 inches (58.9 mm) for the upper watershed and 2.11 inches (53.59 mm) for the DTG SEZ for the 100-year (one percent annual chance occurrence), 24-hour storm.

The SCS Type II rainfall distribution is used to mimic the rainfall event. The rain is assumed to occur over the entire watershed simultaneously. In FLO-2D, there is an option to model the rainfall as a moving storm and to specify the direction of the storm movement. To be conservative, the storm is assumed to occur over the entire watershed for the 24-hour storm duration. The SCS Type II distribution is shown in Figure 6.

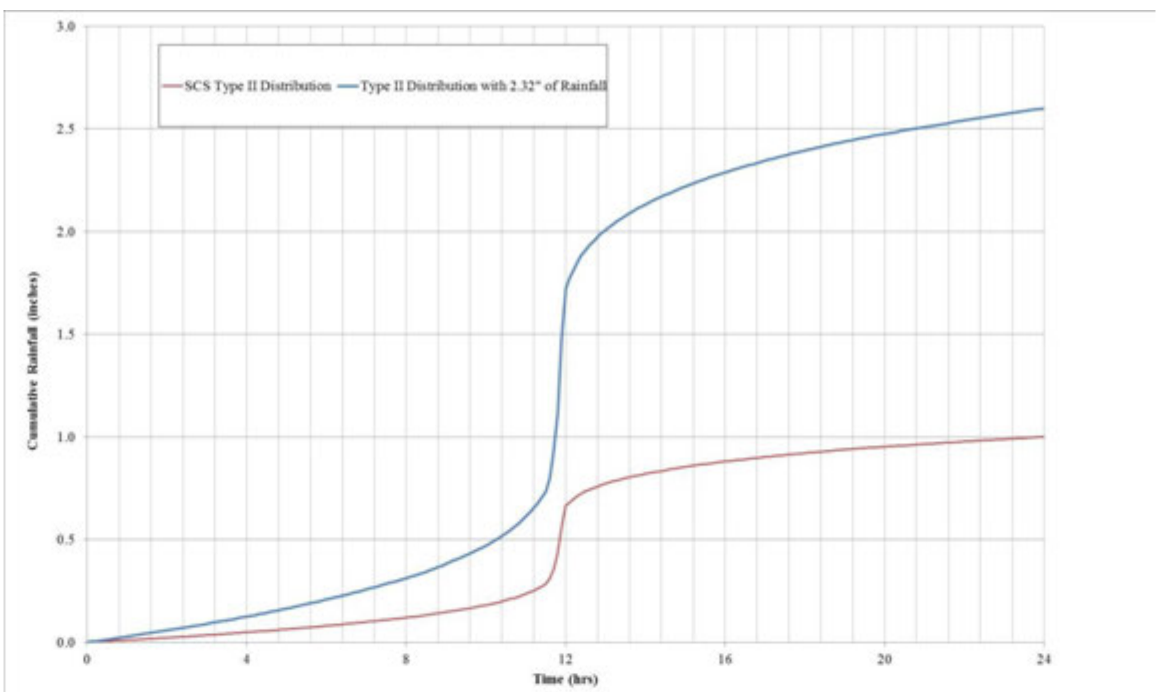

Figure 6. SCS Type II Distribution for 2.32” (58.9 mm) of Rainfall at DTG SEZ.

3.2.2 Model Input Data

3.2.2.1 Hydrology

The offsite HEC-HMS model includes the entire offsite area that contributes overland flow to the DTG SEZ. Rainfall runoff hydrographs are developed in HEC-HMS for 14 basins (labeled A – N) which drain to 14 culverts (labeled 1 through 14) that pass flows under U.S. 285. See Figure 3

The development of the runoff hydrographs includes losses and transformations. The loss method is Green Ampt (Green, 1911), and the transformation method is SCS Unit Hydrograph. The loss component which includes rainfall lost to infiltration and abstraction is discussed further in the next section. The transformation using the SCS Unit Hydrograph requires an estimated lag time for each basin (and sub basin as is the case for Basins C and E). Lag time is developed by estimating time for sheet flow, overland flow and channelized flow. Calculations are included in Appendix C.

The hydrographs generated from the HEC-HMS model are included as inflow nodes located on the downstream side of the culverts under U.S. 285 in the FLO-2D model.

The onsite hydrology is evaluated using the two-dimensional program, FLO-2D. This model uses the same SCS Type II rainfall pattern and Green Ampt losses combined with a finite element routine to determine rainfall runoff quantities (depth, velocity, hydrograph, etc.) for the entire study area (the DTG SEZ lies within the study area (see Figure 2).

3.2.2.2 Infiltration and Initial Abstraction

The Green Ampt methodology is used in the analysis for rainfall losses due to initial abstraction and infiltration for both the HEC-HMS model and the FLO-2D model. The Green and Ampt equation for estimating loss in a time interval is as follows:

$$f_1 = K\left[\frac{1+(\emptyset-\theta_1)S_f}{F_t}\right] \qquad (1)$$

In which f_1 = loss during period t, K = saturated hydraulic conductivity, $(\emptyset - \theta_1)$ = volume moisture deficit; S_f= wetting front suction; and F_t = cumulative loss at time *t*. (HEC, Oct 2011)

For the HEC-HMS model, the following parameters are used (see Table 2):

- Initial content – initial water content gives the initial saturation of the soil at the beginning of the simulation, it is specified in terms of volumetric moisture deficiency, using Table 1, it is assumed that the initial condition will be 25% (0.25) for loam and sandy loam for normal conditions. The majority of soils in the offsite watershed are classified as gravelly sandy loam and gravelly loam by STATSGO. As this classification is not specifically included HEC-HMS Table 5, the values listed for sandy loam are assumed to be representative of gravelly loam.

  However, the larger two offsite basins have visible signs of water retaining structures (detention basins or small dams). It is likely these were constructed in the early 1960s by the BLM. The following text was found on the internet from an old BLM report:

  > *Areas of the national land reserve in Colorado receive as little as 9 inches of rainfall. Water from the infrequent high intensity summer rainstorms runs off before much of it can penetrate the soil. To take advantage of all water*

possible, waterspreading systems are devised where soil and topography will permit, to reduce the rapid runoff of water and sediment and to permit more water to infiltrate the soil.

Waterspreading systems include various combinations of earthfill structures such as detention dams, contour ditches, dikes, pits, diversions, and check dams. The added soil moisture increases vegetative growth of native plants and grasses or species which may be planted between and adjacent to the structures."

"Nearly 200 water developments were strategically located on the national land reserve in 1961 in Colorado."

From "BLM at Work in Colorado, 1961"
http://archive.org/stream/blmatworkincolor9143unit/blmatworkincolor9143unit_djvu.txt

Physical evidence of the water spreading efforts still exists today in the offsite watersheds. Several berms, including reservoirs with dam structures with aluminum monument caps exist in Basins B and E. Contour ditches are also plain to see on aerial photographs (Figure 7).

To evaluate the impact of the individual structures on the runoff rates and volumes would require an intricate and detailed modeling effort beyond the scope of this study. After observing the structures in the watershed, it is estimated that the general impact is an increase in losses due to retention of approximately 20 percent. To account for this reduction, the initial content value for Basin C and Basin E is reduced by 20 percent from 0.25 to 0.20.

- Saturated content – saturated water content specifies the maximum water holding capacity in terms of volume ratio. It is often assumed to be the total porosity of the soil. A porosity value of 46.3 percent is assumed for the loam soils and 43.7 percent for the sandy loam (Table 2).
- Suction – the wetting front suction generally is assumed to be a function of the soil texture. This is represented by the wetting front suction listed in Table 1. For loam and sandy loam these value are 315 and 222 mm respectively.
- Conductivity – the hydraulic conductivity, listed in Table 2 is 25.9 and 61.1 mm/hr for loam and sandy loam, respectively.
- Impervious (%) - There is evidence of rock outcrop in the upper watershed, however, due to the sporadic and unconnected nature of the material, and minor horizontal coverage, the percent impervious is considered to be zero.

For the offsite watershed and the DTG SEZ existing conditions, a surface cover type of desert and rangeland is selected which has an initial abstraction of 0.35 inches or 8.89 mm.

For the FLO-2D model, the following parameters are used:

- The soils at the site are primarily gravelly sandy loam and loam. To provide conservative results, the lesser hydraulic conductivity value of 6.35 mm/hr (Loam soil type) is selected for the model, with a corresponding porosity of 0.437.

- The soil suction is assumed to be 222 mm. It is assumed that the soil will be dry prior to the modeled storm and therefore have a volumetric moisture deficiency of 25 percent.

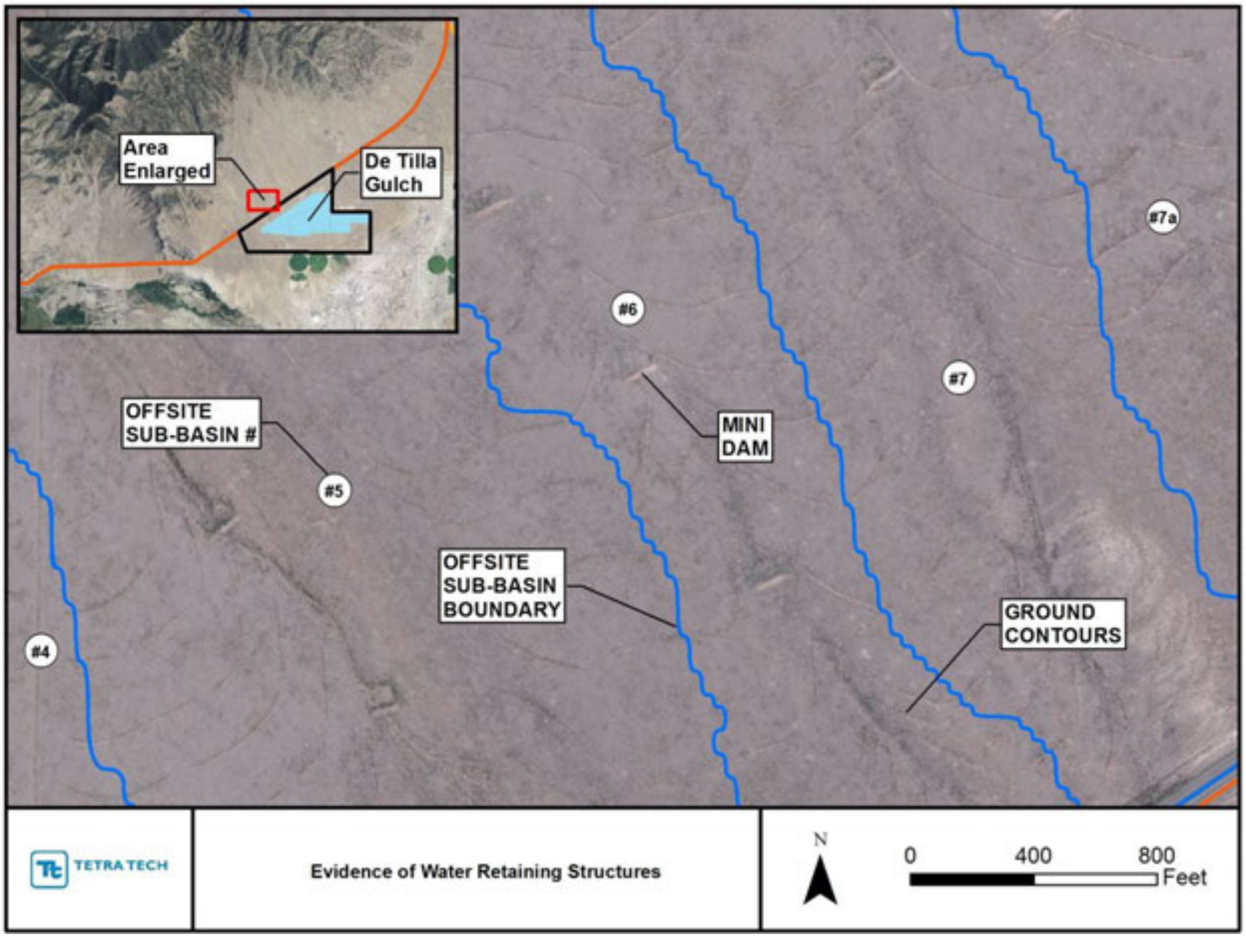

Figure 7. Evidence of Retaining Structures in the Offsite Basins.

3.2.2.3 Manning's Roughness Values

The natural low vegetation grass and low shrubs are represented with a Manning's n-value of 0.055. In locations where gravel roads exist, a value of 0.04 was selected to represent the compressed, graded bare ground. The paved roads are assigned a further reduced Manning's value of 0.035.

The nodes which cover the ephemeral drainage ways which are visually obvious from the aerial photographs are assigned a lower roughness value of 0.045 as the channel is comprised of angular, poorly sorted volcanic material, with limited vegetation.

Table 2. Green Ampt Parameters.

Classification	Volumetric Moisture Deficiency (% Diff)[1]		Porosity (%)[2]	Wetting Front Suction (cm)[3]	Hydraulic Conductivity (cm/hr)[3]	Hydraulic Conductivity (in/hr)/(mm/hr)[1]
	Dry	Normal				
Sand and loamy sand	35	30	0.437	14.2	21.00	1.20 / 30.48
Sandy loam	35	25	0.437	22.2	6.11	0.40 / 10.16
Loam	35	25	0.463	31.5	2.59	0.25 / 6.35
Silty loam	40	25	0.501	40.4	1.32	0.15 / 3.81
Silt	35	15	---	---	0.68	0.10 / 2.54
Sandy clay loam	25	15	0.398	44.9	0.43	0.06 / 1.52
Clay loam	25	15	0.464	44.6	0.23	0.04 / 1.02
Silty clay loam	30	15	0.471	58.1	0.15	0.04 / 1.02
Sandy clay	20	10	0.430	63.6	---	0.02 / 0.51
Silty clay	20	10	0.479	64.7	---	0.02 / 0.51
Clay	15	5	0.475	71.4		0.01 / 0.25

1. Maricopa County Drainage Design manual, 1992
2. COE Technical Engineering and Design Guide, No. 19. 1997
3. HEC-HMS Reference Manual, Table 5-2

3.2.2.4 Outflow Locations

Outflow nodes are assigned with the FLO-2D model along the downstream boundary of the model as well as the eastern and western edges of the model boundaries. These locations are selected based on the presence of culverts or low points in at the intersection with an existing road. Floodplain cross sections are included in the FLO-2D models to evaluate the hydrograph volumes at seven specific locations along the southern boundary of the project. The floodplain cross section data allows for comparison of existing to future conditions to evaluate potential impact and plan for remediation.

3.3 BLM Citrix SEZ-Specific Egis Draft Database (Task A.1.3)

The DTG SEZ draft ESRI file geodatabase is subdivided into seven feature datasets, five raster datasets, and five tables. The data falls in to seven categories including FLO-2D results, geology, groundwater, hydrology, project feature classes, surface water, and topography.

All of the terrain and model data will be organized and transferred to the eGIS data base on the BLM Citrix server. This data set and descriptions will be discussed in detail in the final report; however, the subcategories will include the following.

3.3.1 FLO-2D Results
3.3.1.1 Rainfall Maximum Depths 10-meter Grid

As the rainfall runoff travels with the 48 hours during and after the rainfall event, each node experiences a maximum depth at a given time. This output represents the maximum value at each node regardless of time. It is not a snapshot in time, but rather a pictorial demonstration of the worst case depth scenario at each node.

3.3.1.2 Rainfall Runoff Maximum Velocity 10-meter Grid

As the rainfall runoff travels with the 48 hours during and after the rainfall event, each node experiences a maximum velocity at a given time. This output represents the maximum value at each node regardless of time. It is not a snapshot in time, but rather a pictorial demonstration of the worst-case velocity scenario at each node.

3.3.1.3 Elevation at FLO-2D Cell 10-meter Grid

The data for each cell is determined using topographic data obtained from the LiDAR data set provided to Tetra Tech by the BLM. Values are determined for each node using a FLO-2D subroutine which assigns an elevation for each node using an averaging technique. The nodes are spaced every 10 meters for the onsite model. For each cell in the model, only one elevation represents $10m^2$.

3.3.2 Geology

3.3.2.1 Quaternary Faults

Faults within the general vicinity of the DTG SEZ project area. There are limited faults in the area of the project.

3.3.2.2 Quaternary Geology

The quaternary geology in the general vicinity of the project area.

3.3.2.3 Soil Grab Samples

Grab samples of the smaller material in the channel bed were taken to be analyzed in a laboratory setting for sediment size fraction analysis. The information obtained from the sieve analysis is used in the scour analysis to evaluate the stability of the existing channels on site. The samples were taken at the same locations as the Wolman Counts.

3.3.2.4 Pebble Counts

Pebble counts performed at cross sections with the main DTG SEZ channel. Pebble counts were performed to evaluate the sediment size fractions of the larger material located within the channel.

3.3.3 Groundwater

3.3.3.1 Groundwater Wells

This dataset includes the available data for groundwater wells in the general vicinity of the DTG SEZ site.

3.3.3.2 Groundwater Quality Well Data

This dataset includes the available water quality data of the groundwater in the general vicinity of the DTG SEZ site.

3.3.4 Hydrology

3.3.4.1 Cross Sections

The cross section information obtained in the field is used to create a HEC-RAS model to evaluate channel hydraulics and estimate sediment transport / scour issues at the site.

3.3.4.2 Hydrologic Unit Codes

The hydrologic unit codes are used to identify the contributing and surrounding watersheds in the vicinity of the DTG SEZ within the framework of the HUC numbering system. This is a system created by the USGS to numerically characterize watersheds throughout the US. The length of the code varies, increasing detail is added with each additional number in a series. For the DTG SEZ, the HUC-10 system is shown on the maps.

3.3.4.3 Hydrologic Soils Group

The hydrologic soils group is used in the rainfall runoff calculations when the SCS Curve number method is used. The initial approach at rainfall runoff estimation incorporated the SCS Curve Number method, however, that was later changed to the Green Amplitude method.

3.3.5 Project

3.3.5.1 Project Basin

The DTG SEZ is delineated into on-site drainage basins for the purposes of analysis and design of future development. The DTG SEZ is subdivided to better distinguish runoff patterns within the zone and to evaluate the design points relative to runoff (peak flows and volumes) under existing and proposed conditions.

3.3.5.2 Project Boundary

The DTG SEZ project boundary is used to define the extent of future development in this area of land owned and operated by the BLM.

3.3.5.3 Scour Analysis

Evaluation of potential scour based on velocity, shear stress and stable particle sizes. The potential for the existing ground to degrade due to any potential increases in velocities which may occur due to DTG SEZ development is assessed in the scour analysis.

3.3.6 Surface Water

3.3.6.1 Ephemeral Pathways

The ephemeral drainages are identified in the general vicinity of the DTG SEZ. Ephemeral drainages are pathways which are followed by rainfall runoff immediately following a storm or during snowmelt runoff. These depressions are not constantly flowing streams but rather conveyances for intermittent flow. The exact alignment of the drainages may vary slightly as the information is derived from large scale mapping.

3.3.6.2 100-Year Floodplain Map

The 100-Year floodplain map is defined as the flow areas that results from the runoff of a 100-year, 24-hour rainfall events. Based on guidance in the PEIS, the 100-year, 24-hour storm is used to represent the rainfall event. The distribution used for the storm is the SCS Type II. Flooding is separated into shallow floodplain (with depths between 0.3 m and 1 m) and concentrated flooding (depths greater than 1 m).

3.3.6.3 Major Waterways

Saguache Creek is the only major streams in the vicinity of the DTG SEZ. It is located to the south of the study area. Runoff from the DTG SEZ will eventually reach Saguache Creek.

3.3.6.5 Division of Water Resources Streams

The Colorado Division of Water Resource identified streams. In the vicinity of the project area, there are two majors streams defined (see Major Waterways).

3.3.6.6 Termination Points

These are key locations along the downstream DTG SEZ and the study area boundaries where existing versus future conditions are evaluated. The future condition is modeled with a very broad assumption of the entire DTG SEZ being developed such that 15 percent of the flow area is blocked. This is a conservative approach assuming the only major flow area disturbances are created by the support structures for the solar array equipment and potential small support buildings.

3.3.7 Topography

3.3.7.1 One Meter Contours

The 1-m contours were created for use in FLO-2D in averaging one elevation value for each node. The FLO-2D model can use contour files in a shape file to establish elevations for each node. Originally, a 1 foot contour interval was created, however the file was too large to use successfully in FLO-2D. This information was developed using the LIDAR data supplied by the BLM to Tetra Tech and is subject to the limitation of the LiDAR produced data.

3.3.7.2 DEM Provenance

The sources of the digital elevation model for the DTG SEZ project. The DEM was used to generate the 1-meter contours for use as elevation data in FLO-2D. The DEM provenance feature class depicts three DEM sources. The BLM provided Tetra Tech with LiDAR data for the DTG SEZ project area. Tetra Tech obtained NED data for the surrounding areas, however there were four relatively small gaps in the elevation coverage. The gaps were interpolated over using a TIN.

3.3.7.3 GPS Survey Points

Survey data collected in the field includes cross sections at two culvert outlets, associated topography in the area downstream of the project, culvert inlet and outlet invert elevation information and toes and tops of road along U.S. 285 and CR AA. The cross section information obtain in the field are used to create a HEC-RAS model to evaluate channel hydraulics and estimate sediment transport / scour issues at the site.

3.3.8 Raster Datasets and Tables

3.3.8.1 Geology – Soil Grab Samples Raster

This dataset is a raster depiction of the soil grab samples. Grab samples of the smaller material in the channel bed were taken to be analyzed in a laboratory setting for sediment size fraction analysis. The information obtained from the sieve analysis is used in the scour analysis to evaluate the stability of the existing channels on site. The samples were taken at the same locations as the Wolman Counts.

3.3.8.2 Geology –Pebble Counts Raster

This dataset is a raster depiction of the Wolman pebble counts. Pebble counts performed at the Culvert 5 outlet. Pebble counts were performed to evaluate the sediment size fractions of the larger material located within the channel.

3.3.8.3 Geology – Pebble Counts Table

This dataset contains the Wolman pebble counts in tabular format. Pebble counts performed at the Culvert 5 outlet. Pebble counts were performed to evaluate the sediment size fractions of the larger material located within the channel.

3.3.8.4 Groundwater – Well Data Table

The available well data in the area of the DTG SEZ from the Colorado Division of Water Resources in tabular format. Although not used extensively in this study, the well data is available for use and included in this study.

3.3.8.5 Surface Water – Green Ampt Values Table

Green Ampt parameters are used in the HEC-HMS and FLO-2D models to estimate the amount of rainfall lost to initial abstration and infiltration losses. Parameters required for the Green Ampt calculations include the initial abstraction, the hydraulic conductivity, porosity, soil suction and the volumetric moisture deficiency.

3.3.8.6 Surface Water – Manning's Roughness Values Table

The roughness value, n, is used in runoff modeling calculations. Manning's roughness values are assigned to each node in the FLO-2D models. In general, the nodes that represent the relatively open, high desert alluvial fan are assumed to have an n value of 0.055. Areas where gravel roads exist are assumed to have a decreased roughness of 0.04 and the ephemeral drainages are assumed to have a value of 0.045.

3.3.8.7 Surface Water – Water Table Contours Raster

This raster dataset shows the elevations of the estimated ground water table, modified from Topper et al., 2003.

3.3.8.8 Topography – LiDAR/NED Digital Elevation Model Raster

This dataset is a digital elevation model of the DTG SEZ was created using LiDAR data provided to Tetra Tech by the BLM, and 10-meter NED data obtained from the USGS.

3.3.8.9 Topography – LiDAR/NED Hillshade Relief Raster

This dataset is a hillshade relief raster generated from the DTG SEZ merged LiDAR and NED DEM for visualization and quality control purposes. The digital elevation model the was created using LiDAR data provided to Tetra Tech by the BLM, and 10-meter NED data obtained from the USGS.

3.4 BLM Citrix SEZ-Specific Egis Arc GIS Draft Water Resources Inventory Project (Task A.1.4)

The DTG SEZ ESRI file geodatabase will be uploaded to the BLM Citrix Server. The geodatabase will be saved in the DTG SEZ project folder upon completion of the final report.

4.0 FLOODPLAIN DETERMINATION (TASK B.1)

4.1 Federal-State-Local Agency Consultation (Task B.1.1)

4.1.1 Federal

On September 18, 2013, Saguache County became a participant in the NFIP. At this time, only the 100-year (1% annual chance occurrence) floodplain along three miles of Saguache Creek is mapped in Saguache County. The DTG SEZ is north of Saguache Creek in an area with no determination and/or an area outside a 100-year floodplain (Figure 8).

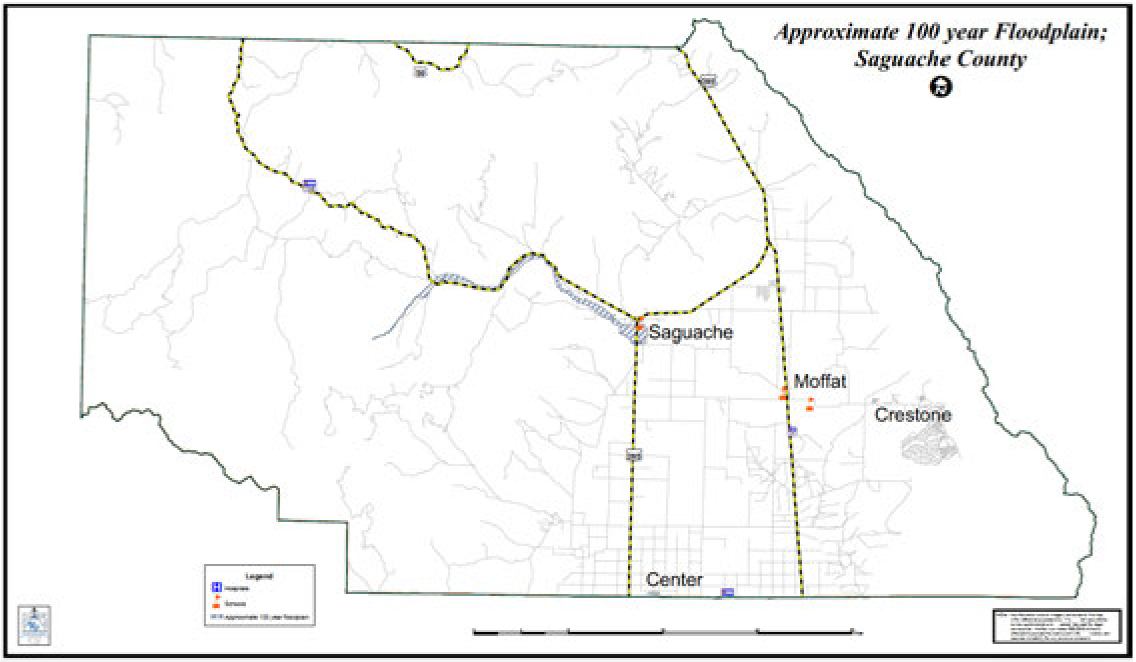

Figure 8. Floodplain mapping on Saguache Creek (Saguache County, CO).

FEMA defines flood hazard areas on Flood Insurance Rate Maps as Special Flood Hazard Areas (SFHA). SFHAs are defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. SFHAs are labeled as Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone A99, Zone AR, Zone AR/AE, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE, and Zones V1-V30. Moderate flood hazard areas, labeled Zone B or Zone X (shaded) are also shown on the FIRM, and are the areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood. The areas of minimal flood hazard, which are the areas outside the SFHA and higher than the elevation of the 0.2-percent-annual-chance flood, are labeled Zone C or Zone X (unshaded).

The focus of the DTG SEZ analysis is to identify and map the SFHA associated with the AE zones as defined below. This site is also subject to shallow flooding or unconfined overland flooding, defined below as AH and AO zones. Note that the shallow flooding areas are typically limited to depths that exceed one (1) foot and are less than 3 feet. Thus to that end the DTG SEZ floodplain mapping is limited to those areas that exceed one foot (or 0.3 meters).

AE, A1-A30	Areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods. BFEs are shown within these zones. (Zone AE is used on new and revised maps in place of Zones A1–A30.)
AH	Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually areas of ponding) where average depths are 1–3 feet. BFEs derived from detailed hydraulic analyses are shown in this zone.
AO	Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are 1–3 feet. Average flood depths derived from detailed hydraulic analyses are shown within this zone.

4.1.2 State

The Colorado Department of Natural Resources, Colorado Water Conservation Board (CWCB) does not require the floodplain information to be submitted to FEMA, however, the CWCB would like any floodplain information that will be used by local officials to make land use decisions to be submitted to them for designation and approval. The process is contained in the rules located at: http://cwcb.state.co.us/Documents/FloodplainRulesRegsUpdate/CWCB_Adptd_FP_Rules_BasisPurp_%2011172010.pdf.

Mr. Kevin Houck (kevin.houck@state.co.us) is responsible for floodplain designations and Ms. Jamie Prochno is the NFIP floodplain coordinator for the State of Colorado.

4.1.3 Local

Ms. Wendi Maez with the Saguache County Administration office stated that at this time, the County has no requirements for floodplain areas. (Email correspondence, 12/3/13) Therefore, there are currently no local, state or Federal requirements for floodplain mapping and reporting for the DTG SEZ.

4.2 SEZ Floodplain Field Survey and Mapping Protocol (Task B.1.2)

Due to the nature of the site and lack of floodplain as defined by FEMA standards and therefore no floodplain mapping in the STG SEZ, a field survey approved by FEMA and CWCB (DNR) is not required.

4.3 SEZ Floodplain Field Survey Completed (Task B.1.3)

Floodplain field survey data collection typically consists of cross section surveys of channels, high water mark locations, locations of bridges, culverts, crossings, and locations of bed material / soil sampling, and any other relevant channel geometry data such as locations of significant deposition or scour. The cross sections were selected to properly characterize the nature of the channel.

The DTG SEZ site visit and field data collection effort took place on November 4th through November 6th. During the site visit, visual inspections were made of the entire project site, including the upper, offsite contributing watershed. In general, the DTG SEZ slopes from the northwest towards the southeast at an overall slope of 1 - 2% with very sparse vegetation. The drainage patterns are not readily discernible by visual inspection. The offsite drainage comes onto the site through a series of 14 culverts which pass under U.S. 285. Flows at the culverts are generated by runoff from the nearby Ute Hills. During the site visit, Peggy Bailey and Alaina Smith walked the length of the project area along U.S. 285 to visually inspect each of the culverts. The culverts were all found to be void of deposition and unobstructed at both the inlets and outlets, and appear to have storage on the inlet side of the culvert and show no major signs of erosion on the outlet end of the culvert (Photo 2).

Photo 2. Looking through Culvert #2 from downstream to upstream.

At the outlet of Culvert 5, the largest culvert (and associated largest contributing watershed area), there was minor deposition or possible armoring (removal of fines) of material that had been transported through the culvert. A defined channel exists in the vicinity of the outlet which quickly bifurcates and disperses approximately 500 feet downstream. A pebble count was performed on the larger deposited material and two bed grab samples were also taken at this location. One grab sample was taken near the outlet of the culvert, and the second was taken approximately 100 feet downstream at the location of the pebble count (Photo 3). The lab results of the grab sample and the pebble count sediment size distributions are shown in Figure 9. All other culverts had undiscernible channels at the outlet with little to no deposition or signs of localized armoring.

Photo 3. Downstream of Culvert #5 outlet, area of deposition.

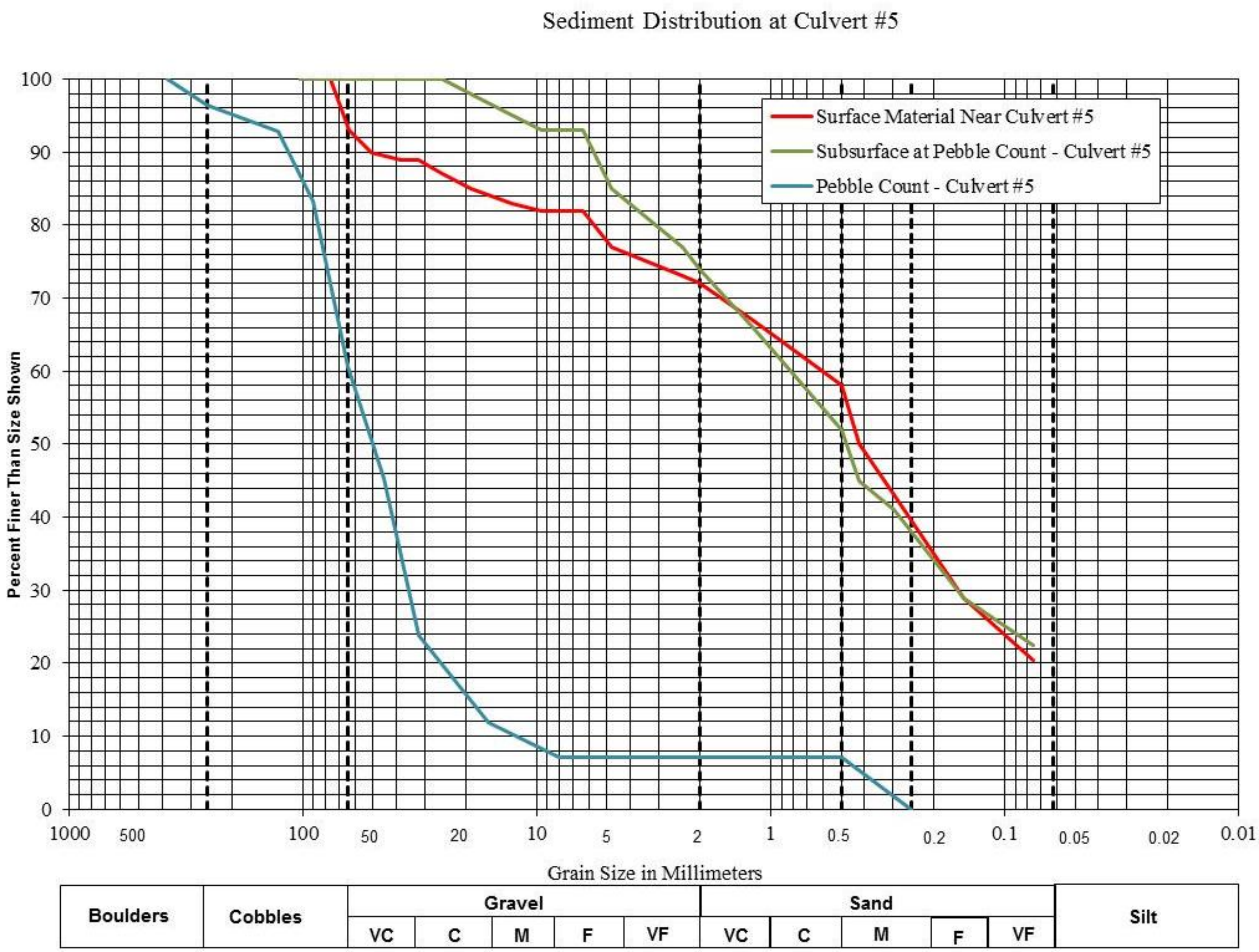

Figure 9. Size Distribution of Field Sampled Bed Material.

Field data that were surveyed includes:

- Culvert information such as invert and top elevations of the inlets and outlets, locations, diameters and type of material.
- Top of U.S. 285
- Toe of U.S. 285 on the northeast side (uphill, inlet)
- Topographic information at culverts that have obvious land alterations on the upstream side of the inlet that provide storage and peak flow attenuation
- Cross sections at the largest culvert outlet

Floodplain field survey data was collected using a Leica Viva GS15 survey-grade GPS system, all data was collected in UTM Zone 13 North coordinate system. A single established control point was available near the project area, NGS Control Point X-171. The base station was set up over this point and several temporary hubs were placed to establish temporary control in the project area. Once temporary control was established, the base station was moved into the project area and the survey was completed. All control points checked in within 0.09 feet horizontally and 0.09 feet vertically. In addition to the control points survey data was spot checked against a digital elevation model created with LiDAR data supplied by BLM.

Downstream of the project site, the land is sparsely vegetated with the exception of two circle crops and associated infrastructure (irrigation pumps, pipes and storage facilities). There is a small inconsistent ditch which runs along the SEZ side of County Road AA. There is also a small ditch on the downstream side of County Road AA. On both sides of the road, the ditch size, shape and capacity varies throughout the length of the road. For this analysis, it will be assumed that the conveyance of the ditches is negligible.

There are ten points of relatively confined drainage along the downfan or southern and eastern edges of the study area along County Roads AA and County Road 55. Note the study area extends south of the currently defined DTG SEZ boundary. This extra southern area is included in the analysis in the event the DTG SEZ boundary is moved in the future and also to be able to evaluate impacts to the downfan properties (i.e. circle crop and irrigation locations) immediately downfan of county Road AA.

During the site visit conducted on November 4 through 6, Peggy Bailey and Alaina Smith walked and drove these roads and located 3 culverts, along County Road AA and all were entirely filled with sand and debris and had damaged end sections, rendering the culverts ineffective for the transmission of surface water runoff. Here and at the remaining seven locations, surface water runoff will ultimately collect along the road and overtop when flows are of sufficient volume and rates.

Photographs taken during the field survey are included in Appendix A – Photo Log.

4.4 SEZ Hydrologic analysis (Task B.1.4)

4.4.1 Model Results-Offsite Flow

The HEC-HMS analysis results in the creation of hydrographs from the 14 basins (A – N) that are expected to occur due to the 100-year rainfall. The points of concentration in each basin coincide with the 14 culverts located under U.S. 285. The peak flows of each hydrograph are summarized in Table 3.

The information presented in Section 3.0 is incorporated into the HEC-HMS and FLO-2D models and executed to complete this task. Table 3 contains a summary of the offsite hydrologic analysis.

The capacity of each of the 14 culverts under U.S. 285 in the vicinity of the DTG SEZ project is estimated using the methods outlined by the Federal Highway Administration in Hydraulic Design Series Number 5 – Hydraulic Design of Highway Culverts (FHWA, 2012). All 14 of the culverts are made of corrugated metal and are assumed to be unobstructed (100% clear) consistent with field observations, and under inlet control during a 100-year rainfall runoff event. A nomograph for inlet controlled corrugated metal pipes, published by the Federal Highway Administration (FHWA, 2012), is used to estimate the capacity of each culvert. Data needed to use the nomograph include the entrance type, the head water depth, and the culvert diameter. The entrance type is the same for all culverts and is assumed to be projecting from the road embankment. The difference between the elevation of the upstream culvert invert and the edge of road on the upstream side of U.S. 285 is used to estimate the maximum upstream head. The 14 culverts range in size from approximately 18 to 60 inches in diameter. The nomograph allowed for each culvert's capacity to be directly estimated in cubic feet per second based on these criteria.

The results of the 14 estimated culvert capacities are summarized in Table 3. In all but one case the capacity of the culvert is greater than the calculated inflow. Thus for purposes of this analysis, any lag or attenuation that might occur at the culvert inlet is conservatively assumed to be negligible.

Table 3. Summary of HEC-HMS and Culvert Capacity Calculations.

Basin	SubBasin	Culvert #	Acres	Km2	Q (m3/s)	Q (ft3/s)	Culvert Capacity (cfs)
A		1	32	0.1	0.2	7	16
B		2	200	0.8	0.6	21	26
C		3	5333	21.6	7.0	247	220
	C1		2025	8.2			
	C2		1747	7.1			
	C3		562	2.3			
	C4		170	0.7			
	C5		302	1.2			
	C6		384	1.6			
	C7		140	0.6			
D		4	152	0.6	0.6	21	22
E		5	2138	8.7	3.2	113	220
	E1		1330	5.4			
	E2		675	2.7			
	E3		134	0.5			
F		6	172	0.7	0.7	25	30
G		7	156	0.6	0.3	11	75
H		7A	56	0.2	0.2	7	17
I		8	245	1.0	0.4	14	60
J		9	721	2.9	0.9	32	80
K		10	316	1.3	0.5	18	240
L		11	274	1.1	0.5	18	110
M		12	80	0.3	0.2	7	20
N		13	55	0.2	0.2	7	11

4.4.2 Model Results-Onsite Flow

The results of the FLO-2D model show the surface pathways and inundation areas. The results are available in GIS format and also categorized by the maximum flow depth and maximum flow velocity, created with the FLO-2D Mapper program for the DTG SEZ area. This area receives little precipitation (2.32" for the 100-year rainfall) and has well-draining soils. The majority of the rain that falls on the study area is lost to infiltration and initial abstraction. The gentle slopes consist primarily of gravelly loam and do not contain many well defined channels. Channels which are formed on the downstream side of the U.S. 285 culverts quickly bifurcate and in most locations become dispersed to the point of non-existence. As such, there are very few areas in the study area that experience concentrated flooding. The areas which do have depths between 0.3 m and 1 m (shallow flooding) and greater than 1 m (concentrated flooding) are typically in the vicinity of the U.S. 285 culverts and the points of concentration along CR AA. See Figure 10 for the maximum flood depths and Figure 11 for the maximum velocities for the 100-year, 24-hour rainfall runoff for existing conditions. It is important to understand that the reported value at each node is the maximum which occurs at that node, regardless of time. The resultant figures (10 and 11) do not depict a particular snapshot in time but rather show the maximum value which occurs at each node throughout the model execution time. The models were executed for 48 hours, the first 24 of which receive rainfall.

Figure 12 depicts the flood mapping for the shallow and concentrated flooding for the 100-year 24-hour rainfall runoff. There are no areas with the boundary of the DTG SEZ expected to experience flooding above 0.3 m during a rainfall runoff event.

4.4.3 Model Results at Downfan Locations

Future conditions at the DTG SEZ are modeled by assuming a conservative 15 percent of the flow area is blocked by infrastructure. The infrastructure is assumed as the support structures for the solar equipment as well as any associated buildings. All of the nodes located within the DTG SEZ boundary are reduced by 15% in the future conditions model.

There are two boundaries at which the flows are evaluated for project impacts; the downfan boundary of the DTG SEZ and the more southern downfan edge of the study area along County Road AA. Both are analyzed for existing and future conditions. While the current DTG SEZ boundary does not extend to County Road AA, that location is analyzed in the event the future SEZ boundary is altered and also to be able to evaluate impacts at that location.

Peak runoff rates and volumes of flow are assessed at the fifteen locations along the DTG SEZ boundary and at ten locations along CR AA. At each of these locations it is anticipated that flow rates and volumes will increase as a result of development, thus requiring detention and/or retention. Because most of the locations have uncontrolled or poorly controlled releases it is likely many of these sites should be designed for retention with little to no outlet flows, or released in level spreaders to mimic unconfined flows. The results of the analysis are shown in Table 4.

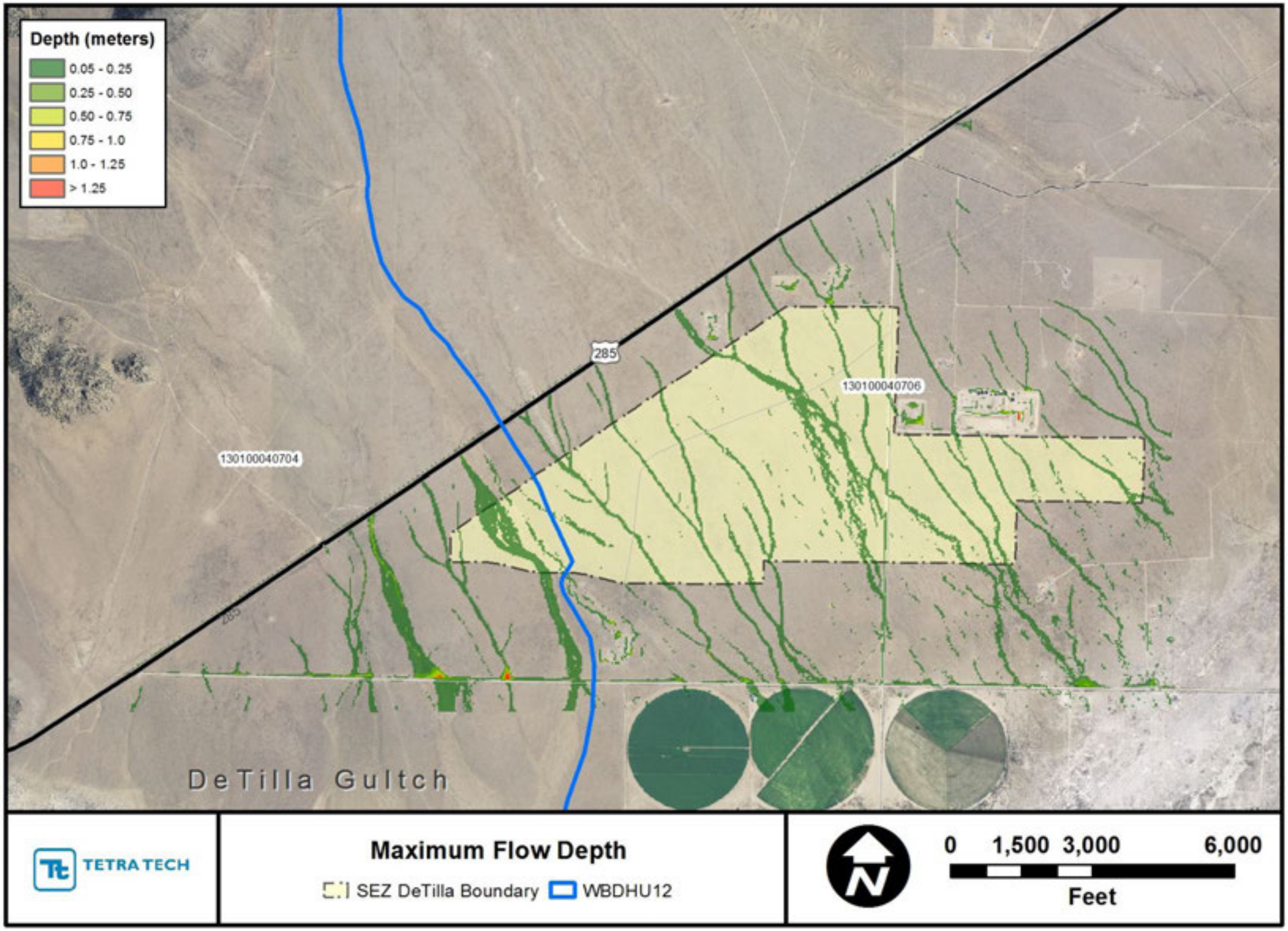

Figure 10. Maximum Flow Depths for the 100-year 24-hour Rainfall Runoff.

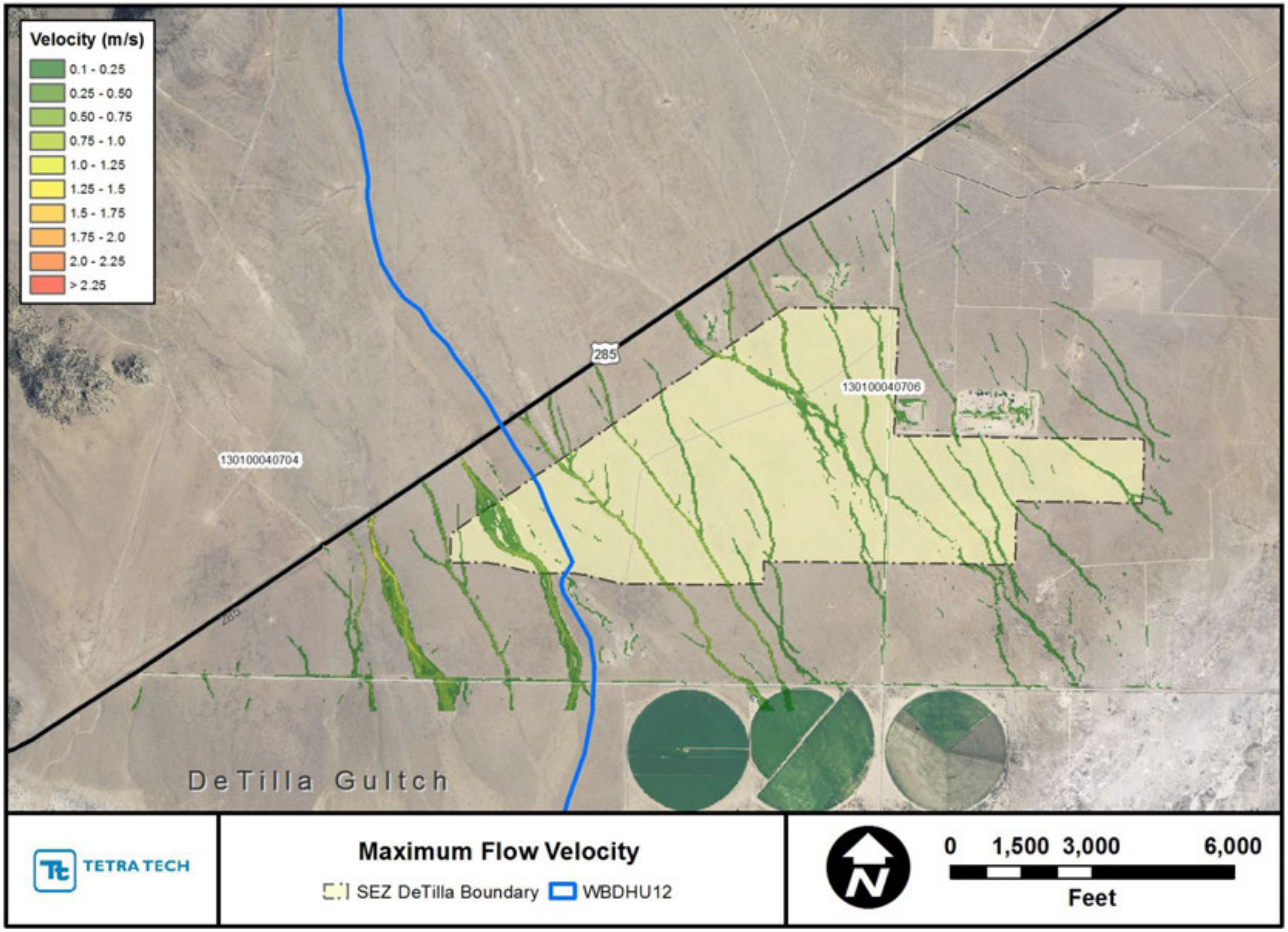

Figure 11. Maximum Flow Velocity for the 100-year 24-hour Rainfall Runoff.

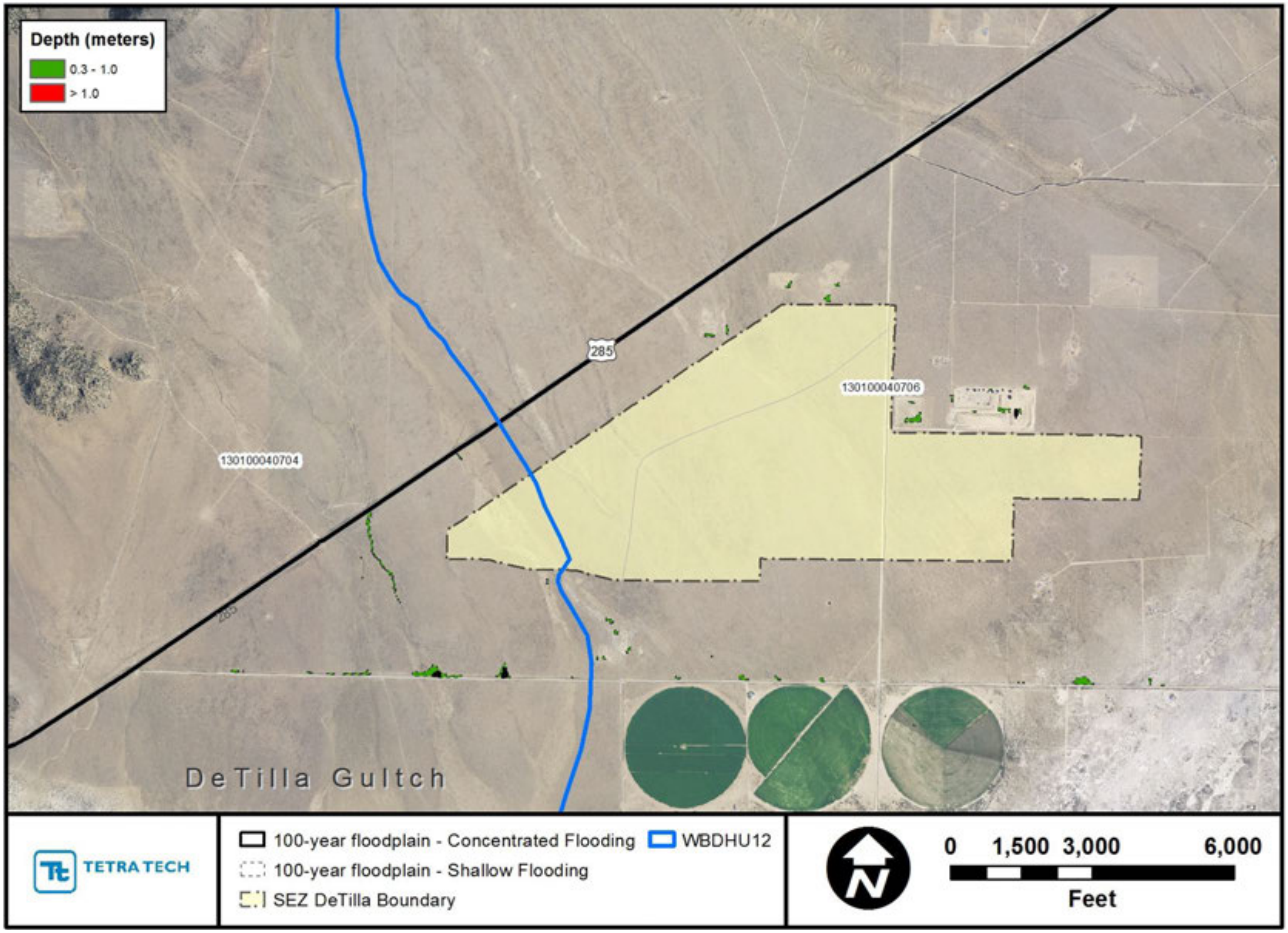

Figure 12. Flood Zones in the De Tilla Gulch Study Area.

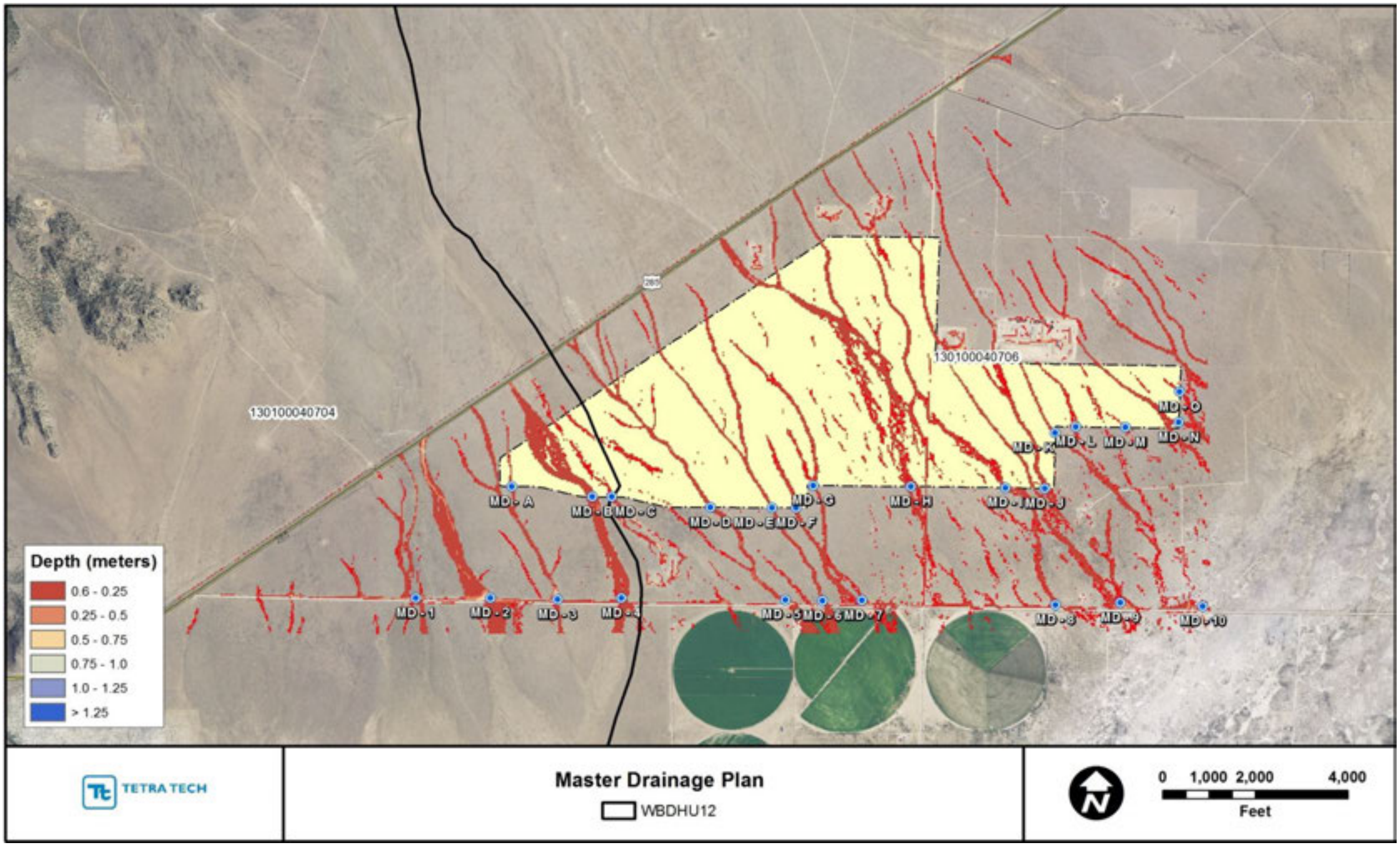

Figure 13. Master Drainage Plan.

Table 4. Results of Future Conditions Impact Analysis.

Design Boundary	Design Point	Existing Conditions		Proposed Conditions*		Required Volume Detention (m^3)
		Peak Q (cms)	Volume (m^3)	Peak Q (cms)	Volume (m^3)	
De Tilla Gulch Boundary Concentration Points	MP-A	0.58	3,600	0.58	3,700	100
	MP-B	3.83	14,400	3.96	16,000	1,600
	MP-C	0.15	500	0.24	800	300
	MP-D	1.66	12,600	2.50	15,900	3,300
	MP-E	0.76	6,400	1.52	9,200	2,800
	MP-F	0.20	1,000	0.49	1,700	700
	MP-G	0.21	1,200	0.52	2,500	1,300
	MP-H	0.36	3,100	0.65	7,900	4,800
	MP-I	0.29	1,400	0.54	3,400	2,000
	MP-J	0.50	2,400	1.2	4,500	2,100
	MP-K	0.32	1,000	0.56	1,400	400
	MP-L	0.15	600	0.23	900	300
	MP-M	0.20	800	0.32	1,300	500
	MP-N	0.55	2,100	0.79	3,000	900
	MP-O	0.22	700	0.31	800	100
Southern Study Boundary County Road AA Concentration Points	MP-1	1.66	7,500	1.66	7,500	0
	MP-2	0.23	1,900	0.23	1,900	0
	MP-3	0.12	900	0.12	1,100	200
	MP-4	2.74	19,900	2.83	33,400	13,500
	MP-5	0.93	4,300	0.97	4,400	100
	MP-6	1.09	9,800	2.11	14,200	4,400
	MP-7	16.5	57,300	16.94	57,500	200
	MP-8	1.09	18,800	1.19	19,200	400
	MP-9	3.56	27,700	5.28	34,500	6,800
	MP-10	0.80	4,800	0.81	5,500	700

*Values based on assumed 15% impervious area, final values subject to modification pending final site design

4.4.4 Channel Stability

The runoff patterns are primarily shallow flooding with the deepest areas being those associated with confined flows at culverts

Due to the lack of well-defined channels and no evidence of scour and deposition normally associated with riverine systems, multiple sediment samples were unnecessary for characterization of channel stability across the site. The sediment data collected at the outlet of the largest culvert is representative of the most concentrated flows in the area and therefore is used to estimate channel stability.

A series of 5 cross sections were surveyed in two channels near the outlets of Culvert 3 and 5. A hydraulic analysis of the channel is performed using the geometry of the cross sections coupled with the flow information derived from the FLO-2D model. The analysis is done using HEC-RAS (Hydrologic Engineering Center – River Analysis System, version 4.1.0).

Pebble counts were performed to evaluate the bed material sizes in the main ephemeral channel as discussed in Section 3.3, Soils. At each location, 100 individual pieces of bed material were removed from the bed and the median axis was measured and recorded. The results of the samples are plotted

(Figure 9) and used to determine the D_{50} or median size of the bed material. Results of the pebble count at Culvert 5 reveal a D_{50} of 50 mm.

An incipient-motion analysis (i.e., an evaluation of flows required to move the bed material) was performed for cross sections of interest by evaluating the effective shear stress on the channel bed in relation to the amount of shear stress that is required to move the bed material. The shear stress required for bed mobilization was estimated from the standard Shields (1936) relation, given by:

$$\tau_c = \tau_{*c} (\gamma_s - \gamma) D_{50} \qquad (2)$$

where τ_c = critical shear stress for particle motion, lbs/ft^2
τ_{*c} = dimensionless critical shear stress (often referred to as the Shields parameter),
γ_s = unit weight of sediment (~165 lb/ft^3),
γ = unit weight of water (62.4 lb/ft^3), and
D_{50} = median particle size of the bed material (mm)

The shear stress in the channel associated with the 100-year rainfall resultant runoff flow, determined with the HEC-RAS model, is used to analyze the stable particle size of the channel. The stable particle size or critical diameter is determined by setting the critical shear stress to the grain shear stress and solving for D_{50}. This is the size of material which is at incipient motion for the given shear stress.

Calculations using Shields incipient motion equation reveal a stable particle size of 150 mm for a peak modeled flow of 7.0 cms. Comparison of this value to the sampled bed material indicates that the median size of the bed material is approximately 50 mm, (See Figure 9) therefore erosion could be expected in the channelized section below the culvert during a peak flow of 7 cms. The lack of material on the order of the stable particle size indicates the channel at the outlet of the culvert has not experienced flows of that magnitude in recent history.

Within the DTG SEZ, rainfall runoff primarily occurs as sheet flow and unconcentrated overland flow. The lack of well-defined channels results in a lack of the shear force needed to cause erosion. If future development alters the landscape such that flows are more concentrated and shear forces increased, necessary erosion protections measures are recommended in the design of such channels.

4.5 SEZ Hydrologic Analysis completed, presented, report, model and data delivered (Task B.1.5)

This report represents the completed report and model. Data is delivered to the BLM Citrix EGIS site.

5.0 GROUNDWATER ANALYSIS

Collect, assess and report on existing available data, studies and assessments of surface water and groundwater at the SEZ site and areas with regional applicability, including gaged streamflow data, precipitation records, snow fall records, and soils information. Extensive studies have been performed on the surface and groundwater characteristics of the closed aquifer system in the San Luis Valley by various agencies. This information will also be collected, reviewed and summarized with interpretation of applicability and potential impacts for future site development.

The San Luis Valley aquifer system has been studied and written about extensively since as early as 1904. Siebenthal (1910) documented the geology and groundwater conditions he observed in 1904, within a few years after artesian groundwater supplies in the valley were first developed on a large scale. Thus, he provided the first comprehensive study of the geology and water resources of the valley. A more recent comprehensive description of the hydrogeology of the San Luis Valley, with emphasis on the deep confined aquifers, was prepared by HRS Water Consultants (1987). The HRS report presents information on the structural geology and stratigraphy of the valley, the occurrence, flow and quality of groundwater, the water budget of the valley, and the potential for groundwater development. Summary descriptions of the valley's hydrogeology were presented by Emery (undated) and Topper et al. (2003). The United States Geological Survey (USGS), in at least 30 publications, has reported on a wide variety of hydrogeologic topics in the San Luis Valley, including groundwater resources, groundwater use, groundwater levels and water-level changes through time, water quality and water-quality changes through time, soils and geochemistry, and groundwater flow modeling. A more recent discussion of groundwater flow in the valley is presented by Mayo et al. (2007). Other relevant sources are cited in the discussion below.

In addition to the literature, databases containing well and water rights records, water well logs and construction information, and groundwater levels are available from the Colorado Division of Water Resources (CDWR) and Colorado Water Conservation Board (CWCB) (CDWR and CWCB, 2013), the Rio Grande Water Conservation District (2013), and the USGS (2013a, 2013b).

5.1 Hydrogeologic Setting

5.1.1 San Luis Valley

The San Luis Valley is an alluvium-filled, east-dipping half-graben structure that is part of the Rio Grande Rift which extends generally northward from southern New Mexico to central Colorado. The valley is flanked by the San Juan Mountains on the west and northwest and the Sangre de Cristo Range on the east. The San Juan Mountains consist mainly of Tertiary-age volcanic rocks comprising andesitic and rhyolitic flows, tuffs, and breccias capped locally with basalt flows (Mayo et al., 2007). In contrast, the Sangre de Cristo Range consists mainly of Precambrian-age metamorphic rocks overlain in places by Paleozoic-age sedimentary rocks. Secondary fracturing of the volcanic rocks of the San Juan Mountains has created generally moderate to high permeability, whereas the metamorphic and sedimentary rocks of the Sangre de Cristo Range typically exhibit low permeability.

The volcanic rocks west of and extending into the west side of the San Luis Valley generally dip east toward and into the valley. The east side of the valley is sharply defined by the Sangre de Cristo fault, a normal fault along which the mountain block east of the valley was displaced upward while the San Luis Valley west of the fault subsided. Sediments weathered from the adjacent mountain ranges fill the valley and are reported to be up to about 14,000 feet thick (Topper et al., 2003). The valley fill sediments interfinger with the volcanic rocks on the west side of the valley and grade from coarse-grained alluvium near the valley margins to fine-grained alluvium near the center of the valley. Interspersed with these sediments are lenticular clay beds of probable lacustrine origin (Emery, undated; Machette et al., 2007).

Surficial deposits in the valley include Quaternary-age alluvium deposited by the Rio Grande and other major streams, as well as fan alluvium and outwash gravels associated with the Pinedale and Bull Lake glaciations and eolian sand deposits from the time of the Pinedale Glaciation to Holocene time. In general terms, the coarser valley-fill sediments exhibit relatively high permeability and form highly productive aquifers.

The northern part of the San Luis Valley is divided by a series of en-echelon faults trending north-northwest, roughly parallel to the Sangre de Cristo Fault. These faults produced down-dropped blocks called the Baca and Monte Vista grabens on the east and west sides of the valley, separated by an uplifted block called the Alamosa Horst near the center of the valley. A set of west-northwest trending faults also crosses the San Luis Valley, creating a relatively complex geometry on the upper surface of the Precambrian basement rocks beneath the valley. In the northern part of the valley, the west-northwest set of faults show upward displacement to the north, resulting in a step-wise thinning of the valley-fill sediments toward the margin of the valley.

5.1.2 DTG SEZ

The DTG SEZ is on the northwestern flank of the San Luis Valley. The SEZ is underlain by valley fill sediments consisting of Quaternary-age alluvial fan and gravel deposits, also mapped as the Alamosa Formation (Figure 14.). This unit consists of interbedded, unconsolidated clays, silts, sands and gravels. Although the valley fill sediments are up to about 14,000 feet thick in the central part of the San Luis Valley, at the DTG SEZ the unconsolidated deposits are estimated to be only 100 to 200 feet thick, based on logs of water wells at and adjacent to the SEZ (CDWR, 2013). The unconsolidated sediments at the SEZ rest directly on Precambrian-age gneisses and granitic rocks which are exposed in the hills immediately north and northwest of the SEZ. The Precambrian granitic rocks and gneisses are similar to those of the Sangre de Cristo Range.

The DTG SEZ is on the Alamosa Horst block and also is north of the northernmost of the west-northwest oriented cross-faults. The combined uplift of the horst block and the block north of the northernmost cross-fault is the likely cause of the exposure of Precambrian rocks north of the SEZ. The Precambrian rocks north of the SEZ are bounded on the east and west by faults with displacements consistent with the horst geometry, and logs of water wells at and south of the SEZ indicate a cross-fault within two miles south of the SEZ which displaces the Precambrian rocks upward beneath the DTG SEZ. The upward displacement of the Precambrian rocks beneath the SEZ limits the thickness of the valley-fill sediments at the SEZ.

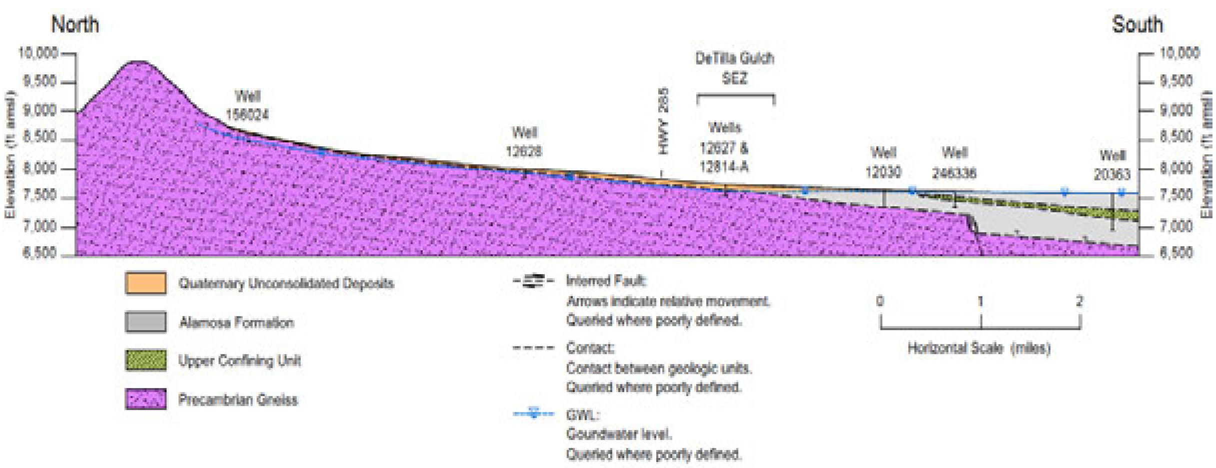

Figure 14. North-South Geologic Cross Section through DTG SEZ.

5.1.3 Groundwater Occurrence and Flow

Groundwater in the San Luis Valley is present in a shallow unconfined aquifer and in two deeper confined aquifers that extend nearly throughout the San Luis Valley. The aquifers occur primarily in the valley-fill sediments. The shallowest groundwater is present in the Alamosa Formation under unconfined (water table) conditions. The clay beds and volcanics interlayered with the valley fill throughout most of the valley form confining units and result in confined (artesian) conditions except near the edges of the valley. HRS (1987) mapped the northern edge of the clay confining beds as being approximately two miles south of the DTG SEZ site (Figure 14*)*; that interpretation is supported by logs of water wells in the site vicinity. The aquifers at and in the immediate vicinity of the site therefore contain groundwater only under unconfined conditions. Flowing water wells are present south of the SEZ site, indicating that confined conditions can be encountered starting about two to three miles south of the SEZ.

The San Luis Valley receives groundwater recharge through seepage into the unconfined aquifer from streams, irrigation canals and return-flow ditches, through seepage into the confined aquifer from infiltration along the mountain fronts on both sides of the valley, and through underflow into the west side of the valley from rocks in the San Juan Mountains (HRS, 1987; Emery, undated; Mayo et al., 2007). The recharge is ultimately derived from infiltration of snowmelt from the San Juan Mountains and the Sangre de Cristo Range. Because of the low precipitation and high evaporation and evapotranspiration rates in the central San Luis Valley, very little direct recharge occurs from precipitation falling on the valley floor. The shallow unconfined aquifer also receives inflow through upward seepage from the underlying confined aquifer, though this does not occur throughout the valley. Discharge from the groundwater system is through outflow to the Rio Grande in the southern part of the valley, natural evaporation and evapotranspiration in the north-central part of the valley, and evapotranspiration in riparian areas and agricultural lands elsewhere.

Groundwater flow is generally from the valley margins toward the center of the San Luis Valley (Figure 15). In the unconfined aquifer, a divide exists north of the Rio Grande; groundwater north of the divide flows northward into the closed basin section of the San Luis Valley, and groundwater south of the divide flows southward, ultimately discharging to the Rio Grande or leaving the southern end of the valley as underflow (Mayo et al., 2007). The pattern of groundwater flow in the confined aquifer is thought to be similar to that in the unconfined aquifer but is less well understood. The divide reportedly affects the unconfined aquifer but not the confined aquifer (HRS, 1987; Mayo et al., 2007).

Based on reported water level data from water wells at and near the DTG SEZ (CDWR, 2013; CDWR and CWCB, 2013; Rio Grande Water Conservation District, 2013; USGS, 2013a), groundwater at the SEZ can be expected to be encountered at depths of approximately 100 to 140 feet below ground surface, depending on location within the SEZ. Water level elevations in wells in the vicinity indicate that groundwater flow at the DTG SEZ site is generally southeastward, from the uplands north and northwest of the site toward the central part of the San Luis Valley, as shown on Figure 15. The water table gradient is steep (approximately 200 feet per mile) northwest of the site but flattens in the vicinity of the site to become less than 10 feet per mile southeast of the SEZ. The water level elevations reported for the few monitoring wells in the vicinity of the SEZ (USGS, 2013a; RGWCD, 2013) are consistent with the water level elevations shown on Figure 16.

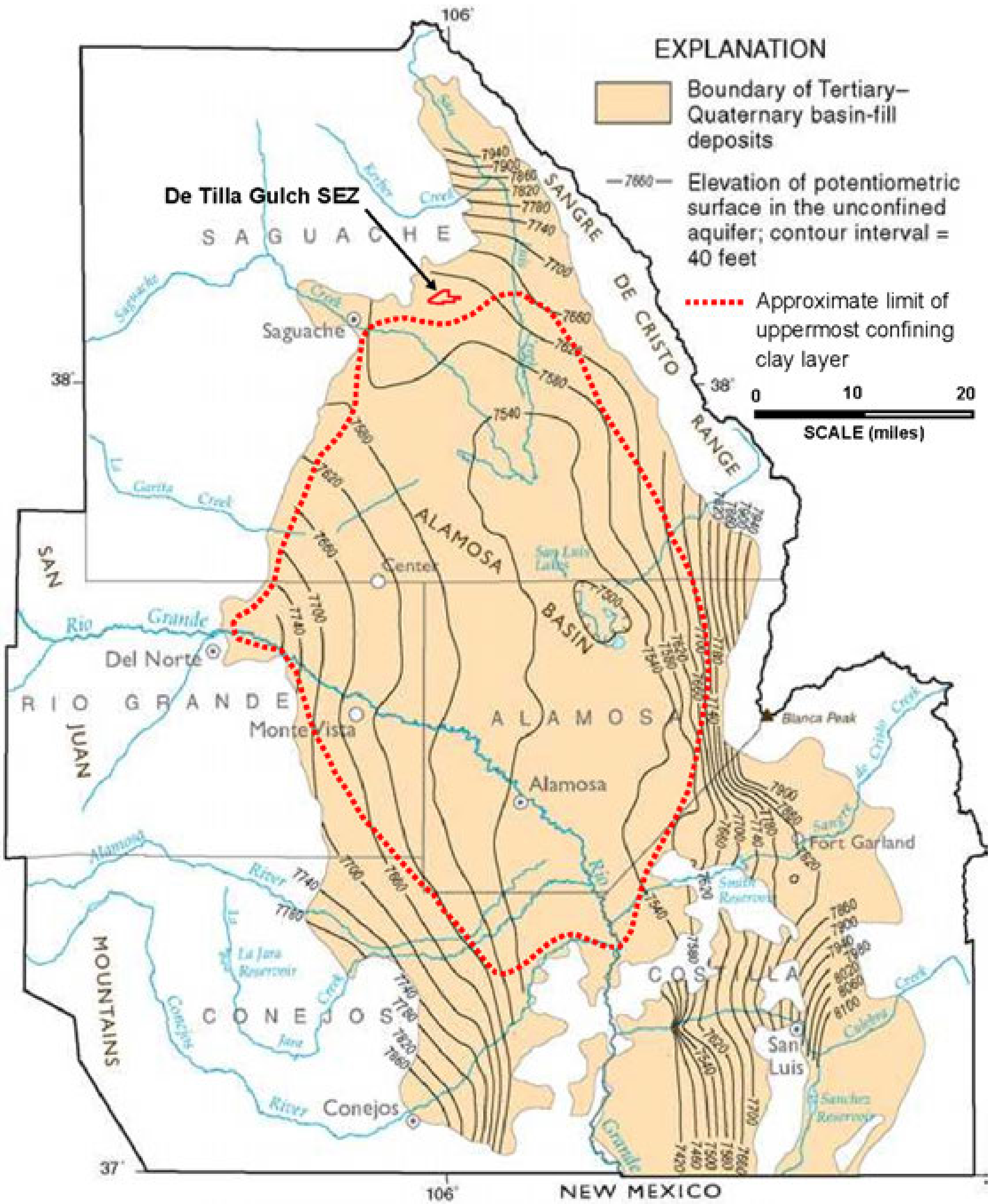

Figure 15. Water Table Elevation in the San Luis Valley (modified from Topper et al., 2003).

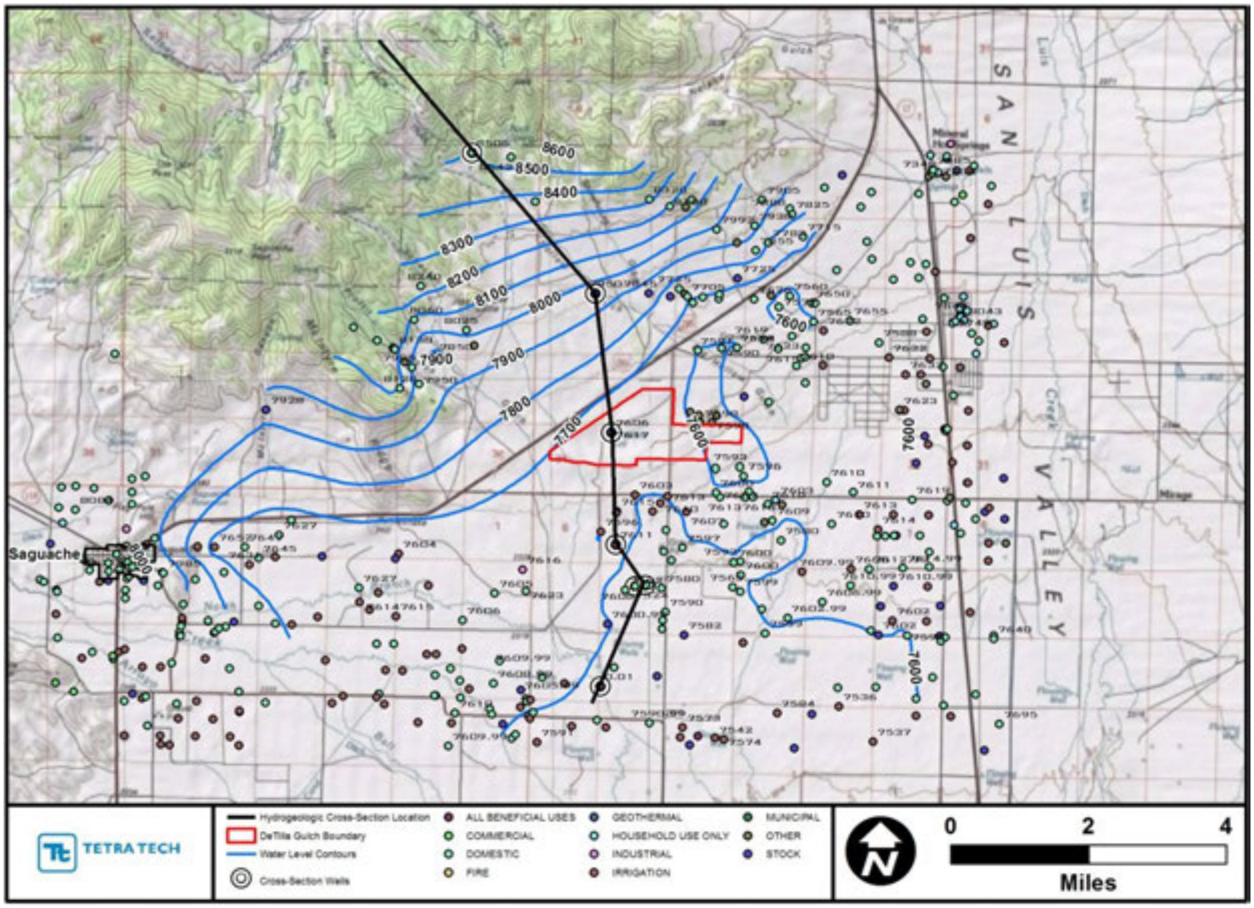

Figure 16. Water Table Elevation in the Vicinity of the DTG SEZ.

5.2 Groundwater Quality

Groundwater quality is highly varied in the San Luis Valley. Total dissolved solids (TDS) contents reportedly range from less than 100 milligrams per liter (mg/L) near the valley margins to more than 20,000 mg/L in the unconfined aquifer near the center of the closed basin (Mayo, 2007). In general, groundwater in the confined aquifer is lower in TDS than groundwater in the unconfined aquifer except in areas where seepage of low-TDS surface water from streams and canals recharges the unconfined aquifer. Water-quality data for two wells about one-half mile south of the DTG SEZ and another about 2.6 miles southeast of the SEZ are listed in Table 5 (USGS, 2013b, 2013c). The TDS concentrations three reported samples were 162, 172 and 192 mg/L. The water was of the calcium-bicarbonate type. No water quality data were found for any locations upgradient (north or northwest) of or within the SEZ.

5.3 Water Budget

Numerous estimates of the overall water budget for the San Luis Valley have been made through the years (e.g., HRS, 1987; Emery, undated; SLV Development Group, 2007; Mayo et al., 2007), but no estimates for the area of the DTG SEZ were discovered through the literature search. HRS (1987) estimated that inflow to the San Luis Valley was approximately 3.35 million acre-feet per year (ac-ft/yr) and that outflow was approximately 2.63 million ac-ft/yr. Mayo (2007, citing HRS) indicates that evapotranspiration from irrigated land and riparian vegetation accounts for 84.9 percent of the combined surface water and groundwater outflow from the valley, while the Rio Grande River accounts for only 12.5 percent and groundwater accounts for only 2.4 percent.

Table 5. Summary of Water Quality Data for Wells near the DTG SEZ.

Parameter	Units	USGS 380605106002501 NA04400905ABB	USGS 380600106000001 NA04400905AAA	USGS 380515105570501 SC04400911ABB
Approx. location relative to DTG SEZ		0.5 mile south	0.5 mile south	2.6 miles southeast
Sample Date		8/6/1968	8/21/1968	8/6/1968
Temperature	°C	14	14	16
Specific Conductance	µS/cm	258	263	295
pH	s.u.	7.2	7.8	7
Acid Neutralization Capacity as CaCO3	mg/L		107	
Carbon Dioxide	mg/L	13	3.3	20
Bicarbonate	mg/L	126	130	126
Carbonate	mg/L	0	0	0
Nitrate as N	mg/L	0.136	0.16	0.136
Orthophosphate	mg/L	0.01		0.06
Hardness as CaCO3	mg/L	92	110	120
Noncarbonate Hardness as CaCO3	mg/L	0	1	18
Calcium	mg/L	29	35	39
Magnesium	mg/L	3.9	4.1	5.6
Sodium	mg/L	20	16	16
Sodium Adsorption Ratio		0.93	0.7	0.63
Potassium	mg/L	1.7	1.3	1.1
Chloride	mg/L	5.1	2.6	2
Sulfate	mg/L	26	17	43
Fluoride	mg/L	0.6	0.6	0.3
Silica	mg/L	23	21	22
Boron	mg/L	20	30	10
Total Dissolved Solids	mg/L	172	162	192
Nitrate	mg/L	0.6	0.7	0.6

Aquifer properties of transmissivity, hydraulic conductivity and storativity reported in published literature for the San Luis Valley, including values used in the Final Solar PEIS (BLM and DOE, 2012), pertain to the valley-fill aquifers in the parts of the San Luis Valley where the aquifers are much thicker than at the DTG SEZ. Consequently, the published values cannot be applied to estimate the groundwater budget at the SEZ. However, CDWR (2013) records for one well at the DTG SEZ (permit no. 128014-A) and seven wells near the SEZ provided basic data for well tests from which transmissivity and hydraulic conductivity could be estimated, as summarized in Table 6, and used in calculations for water budget estimates.

Specific capacity is pumping rate divided by drawdown.

Transmissivity was calculated as follows:

$$T = 1500 * Q/s \text{ (for an unconfined aquifer)} \quad (3)$$
$$T = 2000 * Q/s \text{ (for a confined aquifer)} \quad (4)$$

where T = Transmissivity, in gallons per day per foot, gpd/ft, Q/s = Specific Capacity, in gallons per minute per foot, gpm/ft. See Driscoll (1986) for assumptions.

Hydraulic conductivity is transmissivity divided by saturated thickness; saturated thickness was assumed to be equal to well screen length.
The volumetric flow of groundwater through the DTG SEZ was estimated by applying Darcy's Law,

$$Q = T \times W \times I, \quad (5)$$

where:

Q = the flow rate,
T = the aquifer transmissivity,
W = the width of aquifer (perpendicular to the hydraulic gradient) through which the flow occurs, and
I = the hydraulic gradient.

The volumetric rate of groundwater flow through the DTG SEZ was estimated using the transmissivity for the permit no. 128014-A well at the site (88 ft^2/d), the average hydraulic gradient from Figure 14 (approximately 162 ft/mile, or 0.031 ft/ft), and the width of the site as measured parallel to the elevation 7,700 ft amsl potentiometric contour (14,000 ft) on Figure 15. The Darcy's Law equation with these values substituted for the variables gives:

$$Q = T \times W \times I \quad (6)$$

$$= 88 \text{ ft}^2\text{/d} \times 14{,}000 \text{ ft} \times 0.031$$

$$= 38{,}192 \text{ ft}^3\text{/d}$$

That volumetric rate (38,192 cubic feet per day) equates to approximately 200 gallons per minute or 320 acre-feet per year.

5.4 Groundwater Use

Groundwater use in the San Luis Valley is primarily for irrigation. Average annual irrigation withdrawals are estimated to be 2 million acre-feet (Topper et al., 2003). The majority of wells within, upgradient and cross-gradient from the DTG SEZ are permitted for domestic/household and/or stock use and have reported yields of 20 gpm or less. In contrast, downgradient of the SEZ, where the valley fill aquifers are much thicker, the majority of the permitted uses are irrigation and domestic/household, in about equal numbers. Secondary uses are typically listed as stock. Reported yields of irrigation wells south of the SEZ area typically range from about 800 gpm to about 2,000 gpm (CDWR, 2013).

Groundwater in the San Luis Valley is over-appropriated, and surface water and groundwater are managed jointly. Consequently, any proposal to develop groundwater as a supply for solar energy development at the site would be subject to approval by the District 3 Colorado Water Court, review by the CDWR, regulation under State law and court orders related to San Luis Valley water rights, and regulation under interstate water compacts. Any groundwater withdrawal would require development of an augmentation plan to replace the water withdrawal, and that plan would be subject to review and approval by the CDWR. Augmentation plans in over-allocated basins generally rely on purchases or trades of existing water rights and transfer of the points of diversion.

Table 6. Summary of Well Data and Estimated Aquifer Properties near the DTG SEZ.

Well Permit No.	Aquifer Description	Pumping Rate (gpm)	Drawdown (ft)	Well Depth (ft)	Screen length (ft)	Specific Capacity (gpm/ft)	Trans-missivity (ft^2/d)	Hydraulic Conductivity (ft/d)
156024	Unconfined, gneiss	17	15	150	10	1.1	227	23
266462	Unconfined, granite	10	118	200	40	0.085	17	0.42
12628	Unconfined, gneiss	0.5	150	156	101	0.0033	0.67	0.0066
12627	Unconfined, gneiss	5	2.5	148	22	2	401	18
128014-A	Unconfined, sand and gravel	25	57	194	20	0.44	88	4.4
Maximum, unconfined aquifer						1.1	227	23
Minimum, unconfined aquifer						0.0033	0.67	0.0066
ean, unconfined aquifer						0.73	147	9.2
Median, unconfined aquifer						0.44	88	4.4
11030-R	Confined, sand and gravel	1200	25	310	210	48	12834	61
246336	Confined, sand , gravel, boulders	8	56	140	25	0.14	38	1.5
208917	Confined, sand and gravel	15	26	258	60	0.58	154	2.6
Maximum, confined aquifer						48	12834	61
Minimum, confined aquifer						0.14	38	1.5
Mean, confined aquifer						16	4342	22
Median, confined aquifer						0.58	154	2.6

Water requirements for solar energy development at the DTG SEZ were estimated for the Final PEIS (BLM and DOE, 2012). The water requirements would vary, depending on the solar technology employed. The highest demand, estimated to be between 264 and 292 ac-ft/yr, would be during the peak construction year. Long-term water demand was estimated to range from 5 to 2,555 ac-ft/yr. The source most readily available and most likely to be developed to meet the water demand at the DTG SEZ is groundwater. However, based on the estimate of groundwater flow through the SEZ, sufficient groundwater may not be available at the SEZ to meet the water requirements, in which case water would need to be obtained from another source or sources.

5.5 Potential Impacts to Groundwater Resources

Development of the DTG SEZ for solar energy production has the potential to cause impacts to groundwater resources. Sources of potential impacts include construction disturbance of the land surface, water-supply production for construction and operational water needs, wastewater generation and disposal, and on-site structures. Potential impacts are summarized in Table 7.

Potential impacts of future site development on groundwater resource availability are difficult to predict, particularly under the regulatory setting in which any water development for solar energy development at the site would need to occur. Any additional groundwater development in the San Luis Valley for uses other than domestic would be subject to approval by the Water Court, review by the CDWR and limitations imposed by existing laws, regulations, interstate water compacts, and court decisions. The limitations would likely require purchase of existing water rights and transfer of those rights to a new point of diversion, pending approval by the CDWR following their review of potential impacts to existing water rights.

Potential impacts to existing water rights and to riparian areas could result from water-level declines caused by groundwater pumping of water supplies for solar energy development at the site. The relatively limited availability of groundwater beneath the DTG SEZ site and the substantial number of existing water wells and water rights near the site, both groundwater and surface water, will necessitate detailed investigation of site-specific groundwater conditions and aquifer properties in order to allow better assessment of groundwater availability and prediction of water-level changes related to development of groundwater supplies for the site. Potential impacts to riparian area biota could be evaluated based on predicted water-level changes related to groundwater supply development for the SEZ. Existing tools provided by the Colorado Decision Support System (CDWR, 2013) and possibly existing groundwater flow models developed for water rights management in the San Luis Valley could be used for at least part of the detailed impacts prediction and evaluation.

Table 7. Summary of Potential Impacts to Groundwater Resources.

Area of Potential Impact	Description of Potential Impact	Comments
Groundwater quantity	Water supply availability could limit site development options	Sufficient groundwater to meet the water requirements may not be available from wells constructed on site. The estimated flux of groundwater through the site is 320 ac-ft/yr. Consequently, the water requirements of technologies using wet cooling (474 to 2,555 ac-ft/yr) could not be met from on-site sources.
	Groundwater recharge at the site could be reduced due to interception of precipitation by solar panels or mirrors.	The net change in groundwater recharge would likely be negligible. Direct recharge from precipitation at the site is likely to be very small, and any reduction would likely be offset by infiltration of increased runoff down-slope from the site.
	Groundwater recharge immediately down-slope from the site could increase slightly due to infiltration of increased runoff from the site.	
	Pumping of groundwater to meet water supply requirements for solar energy development would remove water from the groundwater system and could reduce groundwater availability locally.	The maximum water requirement of 2,555 ac-ft/yr is approximately eight times the estimated groundwater flow across the site but only about 0.35 percent of the annual basin-wide groundwater withdrawals. Given the requirement for an augmentation plan to replace any groundwater withdrawals for solar energy development at the site, it is unlikely that any substantial reduction in groundwater availability would occur at the site or in the vicinity.
Groundwater levels	Pumping would lower groundwater levels by some amount, which could increase pumping costs for nearby water wells.	Predictive modeling of water-level drawdowns (BLM and DOE, 2012) was based on published values for aquifer hydraulic properties, which are not applicable at the DTG SEZ site. Consequently, the predicted water-level drawdowns are not accurate. Detailed, site-specific groundwater studies and field investigation, including more detailed modeling, would be necessary for planning and development to proceed. Development would be subject to restrictions of existing laws, regulations, compacts and court decisions.
	Lowered water levels could reduce the productivity of nearby water wells.	
	Lowered water levels could impact biological resources in riparian areas.	
Groundwater quality	Sanitary wastewater generated during construction and operations would require management and disposal.	Wastewater disposal would be subject to existing State standards and State and local regulations.
	Cooling system blowdown water generated during operations would require management and disposal.	

6.0 IMPACTS OF DEVELOPMENT ON WATER RESOURCES

6.1. Impacts to Surface Water

General guidance for identifying drainage criteria for development of DTG SEZ can be found in Saguache County's subdivision regulations, which states:

> *…the entire subdivision area shall be designed by a Colorado-registered professional engineer qualified to perform such work, and shall be shown graphically. All existing drainage features, which are to be incorporated in the design, shall be so identified. If the final plat is to be presented in filings, a drainage plan for the entire area shall be presented with the first filing and appropriate development stages for the drainage system for each filing shall be indicated. The drainage and flood plain system shall be designed to permit the unimpeded flow of natural water courses and to insure adequate drainage of all low points*."

To that end, this Water Resources Report addresses the entire SEZ site, allowing for a single or phased development, and provides recommendations to permit the unimpeded flow of natural water courses and to insure adequate drainage at all low points. The one exception to this overall approach is that the presence of the existing 14 culverts under U.S. 285 have altered the natural flow patterns as runoff enters the SEZ site, compared to flow patterns before the highway culverts were installed. For the purposes of developing the Plan, the conditions as they exist today are considered 'base-line conditions' for which to compare the impacts of development on the flow of water.

Further, the overall goal of the Plan is to provide areas for detention and/or retention basins that should be constructed if development occurs in the basin that is tributary to the specific design point. For purposes of this Plan, development is defined as those areas with roads and buildings, as further described herein.

6.1.1 Rainfall Interception and Infiltration

Based on conversations with various people in the hydrology and solar energy fields of study[1], including Ben O'Conner from the Argonne National Lab, the overall impact on rainfall runoff by solar array equipment is assumed to be negligible. There simply have not been extensive studies done at this time.

The construction of solar array infrastructure interrupts the normal conveyance of precipitation. Rain or snow that would have fallen on vegetation or the bare ground will instead be intercepted by panels of various sizes, shapes and orientations. To our knowledge, no formal studies have been performed to evaluate the impact of solar array development on hydrologic flow patterns. However, it is a general industry wide assumption that while the natural flow of precipitation to the ground is interrupted, the ultimate infiltration is not. There may be some concentrated infiltration in a drip line (depending upon the shape and configuration of the solar panels), however, it is likely the water is not concentrated enough to alter the eventual runoff patterns over the project site. The extent of the influence of the panel in

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[1] Inquiries regarding hydrologic research were made of the following agencies, all of which stated that there has not been research done to evaluate how solar equipment affects local hydrology at their respective agency:

1. National Renewable Energy Laboratory (NREL) a department of the US Department of Energy
2. Argonne National Laboratory, a department of the US Department of Energy
3. Alamosa County Land Use Planning Department
4. The Solar Energy Group at the University of Sydney

interrupting the natural flow is dependent upon not only the shape and orientation of the structure but also the direction of the rainfall. For example, if the rain is falling at the same angle as the solar panel, the interference will be almost negligible. In general, the overland flow patterns will not be significantly altered due to solar array development.

There may be local increases in rainfall-runoff rates if the permeability of the ground is changed due to the construction of buildings and roads, which will need to be accounted for in future design. Also, if there is extensive grading which occurs due to development, runoff patterns would need to be evaluated and compared to existing conditions with differences planned for accordingly. Development of the DTG SEZ site is not expected to result in extensive land disturbances. The typical impact will likely be a few gravel roads, several buildings and a few drainage ditches.

6.1.2 Obstruction to Flow Routing

The largest impact to flow routing at a solar array is the interference of flow patterns due to supporting structures for the solar equipment as well as any changes to the ground surface associated with roads or support buildings.

As a baseline estimate of future development an assumption of 15 percent of ground cover within the entire DTG SEZ being unavailable for flow routing is incorporated into a “proposed conditions” model.

6.1.3 Impacts to Downstream Properties

The results of the proposed conditions model are represented in tabular form on Table 3. Figure 13 also presents a basic master drainage plan. In this plan, there are fifteen drainage points of concentration labeled MD-A through MD-O (DTG SEZ boundary) and ten points of concentration along the downstream border of the study area (MD-1 through MD-11).

To evaluate the impact of development on the DTG SEZ and importantly on downstream properties, the peak discharge (cms) and the volume of flow (m3) are summarized at the design points for both the existing and proposed conditions, and summarized in Table 4.

As expected, there is slight impact due to an assumed 15% reduction in flow area at the points of concentration. The two without increases are located west of the proposed DTG SEZ footprint and therefore will not have development in their respective watersheds.

To avoid any impact to downstream properties, existing flow patterns can be maintained at the boundary, by providing detention and/or retention facilities. Detention can be provided on the DTG SEZ to capture the volume of flow that is represented by the increase between existing and proposed conditions. Retention would be utilized to capture all the volume of flow tributary to the point of analysis with little to no overland surface water releases. All release points along the DTG SEZ will need to be designed to avoid erosion. Along CR AA, all release points will require a new culvert, bridge crossing or a dip crossing.

The broad assumption of 15% area reduction should be reviewed in detail once development plans are formed for the DTG SEZ. The area of reduction may be significantly less and most likely concentrated in the areas of buildings and paved roadways.

6.2 Potential Impacts to Groundwater Resources

Development of the DTG SEZ for solar energy production has the potential to cause impacts to groundwater resources. Sources of potential impacts include construction disturbance of the land surface, water-supply production for construction and operational water needs, wastewater generation and disposal, and on-site structures. Potential impacts are summarized in Table 4.

Potential impacts of future site development on groundwater resource availability are difficult to predict, particularly under the regulatory setting in which any water development for solar energy development at the site would need to occur. Any additional groundwater development in the San Luis Valley for uses other than domestic would be subject to approval by the Water Court, review by the CDWR and limitations imposed by existing laws, regulations, interstate water compacts, and court decisions. The limitations would likely require purchase of existing water rights and transfer of those rights to a new point of diversion, pending approval by the CDWR following their review of potential impacts to existing water rights.

Potential impacts to existing water rights and to riparian areas could result from water-level declines caused by groundwater pumping of water supplies for solar energy development at the site. The relatively large number of existing water wells and water rights, both groundwater and surface water, will necessitate detailed investigation of site-specific groundwater conditions and aquifer properties in order to allow prediction of water-level changes related to development of groundwater supplies for the site. Potential impacts to riparian area biota could be evaluated based on predicted water-level changes related to groundwater supply development for the DTG SEZ. Existing tools provided by the Colorado Decision Support System (CDWR, 2013) and possibly existing groundwater flow models developed for water rights management in the San Luis Valley could be used for at least part of the detailed impacts prediction and evaluation.

6.3 Construction Considerations

The location of the 100-year floodplain at the ephemeral streams should be taken into consideration when planning for solar development. However, the area within the current DTG SEZ boundaries does not experience any flooding greater than 0.3 meters. The very shallow flooding that is expected to occur can be easily mitigated during development design.

The results of this analysis are based on current topography. Should future grading alter the site and create channels for concentrated runoff conveyance, appropriate design will need to incorporate potential channel migration, crossings and erosion.

A scour analysis should be performed for any support structures for the solar array devices. The FLO-2D model reports velocity at each node which can be used to estimate scour and provide guidance on footer depths or scour protection design, if deemed necessary.

6.4 Regulatory Agencies

Regarding water resources, there are several regulatory agencies that may need to be involved in the event of future solar development. Table 8 lists the agency, contact information and applicable regulations.

Table 8. Water Resources Regulatory Agencies.

Agency	Contact Information	Applicable Regulations
Colorado Water Conservation Board (CWCB) http://cwcb.state.co.us	**Kevin Houck** (303) 866-3441 x3219 1313 Sherman St., Rm 721 Denver, CO 80203	100-year floodplain determination DOES NOT need to be submitted to the CWCB for review and approval as it will not be used for official designation within the FEMA NFIP.
Saguache County Land Use Department http://www.saguachecounty-co.gov/contact-us/30-public-health	**Wendi Maez** Land Use Director P.O. Box 326 Saguache, CO 81149 (719) 655-2321	The county participates in the NFIP, however, only 3 miles of Saguache Creek are mapped. Ms. Maez indicated that "at this time, we do not have any requirements for the floodplain areas."
FEMA National Flood Insurance Program (NFIP) http://www.fema.gov/national-flood-insurance-program		No formal mapping procedures are required
Colorado Division of Water Resources (CDWR) Division 3 http://water.state.co.us	**Pat McDermott** (719) 583-6683 x3126 Division 3 Main Office 301 Murphy Drive P.O. Box 269 Alamosa, CO 81101	Groundwater monitoring should be coordinated with the Rio Grande Decision Support System through CDWR Division 3.
US Army Corp of Engineers Regulatory Division Durango Field Office http://www.spa.usace.army.mil/	**Hildreth Copper** (970) 259-1582 1970 E 3rd Ave, Suite 109 Durango, CO 81301	A permit will be required if any fill will be placed in waters of the US. Applicability of the classification of waters for the US is determined on a case by case basis. It is best to contact USACE for a preliminary site visit prior to site planning.

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8.0 CONCLUSIONS

With the assembly of the necessary GIS and related water resources information, the modeling of the surface water for floodplain analysis and the evaluation of the groundwater for the DTG SEZ, the following conclusions are made for each task outlined in the scope of work for this effort.

Task A.1.1 – Hydrologic and Terrain Spatial Data

Hydrologic spatial data includes the rainfall precipitation amount for the 100-year, 24-hour storm as determined using the NOAA Interactive Precipitation Atlas. Values of rainfall are 2.32 in for the offsite watershed and 2.11 inches for the study area.

Terrain spatial data is derived from BLM supplied LiDAR information supplemented by NED data. Contours are created on a 1 m level, used for delineation of offsite watersheds and the elevation data for the FLO-2D models.

Task A.1.2 – Hydrologic Tabular and Model Input Data

Hydrologic and model input data includes parameters which describe rainfall runoff and includes:

- Losses (abstraction and infiltration modeled using the Green Ampt method)
- Manning's roughness (values vary by land use cover)
- Elevation data
- Hydrograph data generated for the offsite watershed used as inflow to the FLO-2D study area

Task A.1.3 – CLM Citrix SEZ Specific eGIS Draft Database

The database created for this effort is described in detail in the section. Information will be posted to the eGIS database upon final approval of the report.

Task B.1.1 – Federal-State-Local Agency Consultation

The regulations for floodplain mapping at the DTG SEZ are not extensive. The Colorado Water Conservation Board (CWCB) is the state liaison for the Federal Emergency Management Agency National Flood Insurance Program (FEMA NFIP). As the NFIP is primarily concerned with providing flood insurance to residential buildings (and reducing flood losses through well planned development), there is not a focused concern when residences are not located in a flood zone.

As such, the ***CWCB and FEMA NFIP do not require any floodplain mapping for the DTG SEZ****.*
In addition, the depths of flow within the boundaries of the DTG SEZ are less than those required to be mapped by the NFIP (flows are at or less than 0.25 m).

Saguache County has recently joined the NFIP program, however, only a small portion of the county (3 miles of Saguache Creek) is officially mapped.

According to county representative, ***the area of the DTG SEZ will not be required to provide flood plain mapping for Saguache County.***

Task B.1.2 – Floodplain Field Survey and Mapping Protocol

Official mapping protocol is not required as official mapping is not required. Field surveys were performed to gather information relative to the analysis and mapping for this effort.

Task B.1.3 – SEZ Floodplain Field Survey

A site visit and field surveys were performed at the DTG SEZ and offsite contributing watershed. Observations were made regarding the existing culverts at U.S. 285, CR AA, the general flow patterns and lack of defined channels, the vegetation and soils and water retaining structures in the upper watershed.

Task B.1.4 – SEZ Hydrologic Analysis

HEC-HMS and FLO-2D were both used to perform the hydrologic analysis for the study area. The FLO-2D study boundary extends further than the DTG SEZ boundary. ***Results of the analysis indicate that there is no significant flooding within the boundary of the DTG SEZ.*** Flows generated by the 100-year, 24-hour storm are expected to be at or less than 0.25 m, meaning most flow is conveyed as unconfined overland flow. Erosion is expected to be at a minimum.

Task B.1.5 – Hydrologic Analysis Complete (Report, Model and Data Delivered)

This report completes this task.

Ground Water Analysis

- Water supply availability could limit site development options
- Groundwater recharge at the site could be reduced due to interception of precipitation by solar panels or mirrors.
- Groundwater recharge immediately down-slope from the site could increase slightly due to infiltration of increased runoff from the site.
- Pumping of groundwater to meet water supply requirements for solar energy development would remove water from the groundwater system and could reduce groundwater availability locally.

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