Investigation and Analysis Report for Supplemental Watershed Plan No. 1 for Santaquin Flood Prevention

Appendix D

Santaquin East Bench
Utah County, Utah

The purpose of the Investigation and Analyses Report is to present information that supports the formulation, evaluation and conclusions of the Draft Supplemental Watershed Plan and Environmental Assessment for Santaquin East Bench Flood Prevention (Draft Plan-EA). The report is required and must be included as an appendix to the Final Plan-EA.

The procedures, techniques, assumptions, and the scope and intensity of the investigations for each subject is described in sufficient detail so that a reader not familiar with the watershed or its problems can form an opinion on the adequacy of the Draft Plan-EA. This report supplements information contained in the Draft Plan-EA and is not intended to replace or duplicate information contained therein.

October 2019

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D.1 Introduction

The planning studies presented in this Investigation and Analysis Report (I&A Report) are based on standard methods, procedures, and computer programs used and approved for use by the United States Department of Agriculture Natural Resources Conservation Service (NRCS). The following information gives a summary of the investigation and analysis for the key planning studies in the preparation of the Environmental Assessment (EA) for the Santaquin East Bench Debris Basins. Additional information relevant to each of the sections provided in this report is available upon request as part of the administrative record for the project. Requests for additional information can be submitted to the following address:

USDA-NRCS
Wallace F. Bennett Federal Building
125 S State St., Room 4010
Salt Lake City, UT 84138-1100

Santaquin City is located in the southernmost part of Utah County just south of Utah Lake. It is bordered on two sides by portions of the Wasatch Mountain range (on the west by West Mountain and Rocky Ridge and on the east by Dry Mountain. The Uinta-Wasatch-Cache National Forest is located east of Santaquin and is managed by the U.S. Forest Service (USFS). In 2001, the 8000-acre Mollie Fire burned across the steep mountain watersheds above Santaquin to the east, denuding the mountainside of all vegetation that stabilized the soils and retarded runoff. Because of the lack of soil-stabilizing vegetation on the east benches of Santaquin, intense storm bursts in 2002 and 2004 created two debris flows that damaged residential homes and property, flowed through agricultural land, and filled in and overtopped the Highline Canal, which is a critical regional irrigation distribution canal. The debris flow event in 2002 was nearly large enough to impact I-15, the major interstate freeway in the area. The purpose of the project is to control and prevent storm water flooding and associated debris flow resulting from erosion off the east bench hillsides that constitute the Santaquin Canyon subwatershed and from impacting private properties and public infrastructure. The project is intended to provide substantial flood reduction from the 100-year-storm event and to prevent flooding from the 25-year fire-related event and debris flow from the typical 5-year storm event.

Note on Vertical Datum: All elevations provided in this I&A Report for current conditions are in North American Vertical Datum of 1988 (NAVD88).

Debris basins and the subwatersheds they would protect against are shown in Figure D-1.

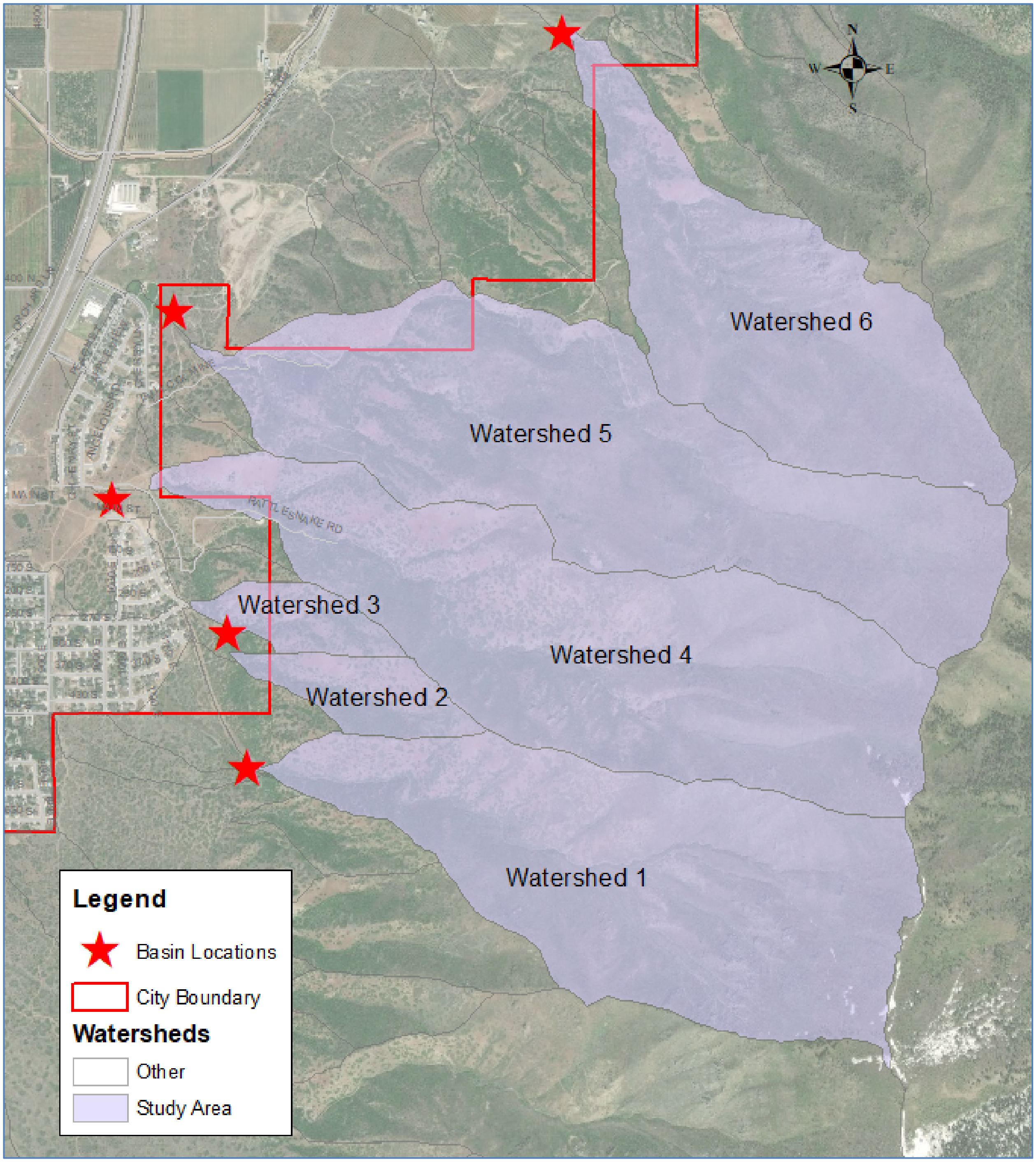

Figure D-1. Debris Basin and Watershed Map

Table D-1. Anticipated Structure Data

Basin Option (Approach B)	Total Height (ft)	Height at Aux. Spillway (ft)	Height at Principal Spillway (ft)	Aux. Spillway Width (ft)	Outlet Pipe Diameter (in)	Total Storage (ac-ft)	Active Storage (ac-ft)	Sediment Storage (ac-ft)
Basin 1 Below Grade	16	13	12	50	30	27.15	23.4	3.75
Basin 3A Below Grade	16	13	12	50	30	4.25	3.7	0.55
Basin 4E Above Grade (Watershed 4 Only)	16	13	12	50	30	25.9	23.4	2.5
Basin 5 Below Grade	16	13	12	50	30	20.8	18.8	2.0
Basin 6A Above Grade	16	13	12	50	30	18.6	16.1	2.5

D.2 Sedimentation

The sedimentation analysis conducted by Horrocks Engineers (Attachment 3-Sedimentation Report), includes event based, and long-term estimates for determining sediment yield. Multiple approaches were used and results from each were compared to arrive at an estimated sediment volume. The RHEM method was used for event-based volumes while the PSIAC is used for annual yields. Trap efficiencies, deposition volumes, and required sediment volumes for each basin are included in Attachment 3-Sedimentation Report. Sediment volumes are based on the 25-year cumulative load. The Sponsor will be responsible for periodic sediment removal. 50 and 25-year sediment storage volumes were investigated The 25-year sediment volume was used because it is large enough that it does not require constant maintenance by Santaquin City, but is not so large that makes the debris basins too large to construct based on hillside site constraints.

Table D-2. Sediment Volumes

Basin	Sediment Volume (ac-ft)
1	3.75
3A	0.55
4	2.5
5	2.0
6	2.5

D.3 Flooding and Risk Analysis

D.3.1 Breach Analysis

The flooding and risk associated with a dam breach analyses conducted by Horrocks Engineers (Attachment 2-Hydraulics Report) includes a breach inundation study and hazard classification for Basins 4 and 6. These are the basins that will be partially above grade. The other basins will be constructed below grade and not susceptible to breaching. Breach flows from Basin 4 would have high velocities combined with moderate depths. There is some residential and commercial development downstream, as well as SR-198 and I-15, which would be impacted by a breach. For these reasons, and based on the criteria established in NEM Part 520, this would be a Class C dam. Breach flows from Basin 6 indicate velocities in excess of 15 ft/s with typical depths ranging from 1-3 feet and maximum depths at about 5 feet. Debris basins that are constructed above grade with an embankment holding the debris or water volume back have been found to be high hazard per NRCS and Utah Dam Safety guidelines. These basins will require additional inspections, maintenance, embankment, design, etc.

The inundation area encompasses 90 acres from Basin 4 and 75 acres from Basin 6, and flows through, residential properties, orchards, businesses and major roadways. The hazard classification of both dams is "high".

D.3.2 Induced Flooding Analysis

Induced flooding is causing flooding to occur where it did not previously historically occur. In order to prevent induced flooding, proposed debris basins will be constructed at or adjacent to the historic flow paths. The outlet and spillway works will be constructed such that the flows are directed to the historic flow path. Induced flooding has thus been greatly minimized. The spillway channels will be areas of induced flooding for either option. The induced flooding areas are minor/are incidental to the property that will be required to construct the debris basins. As the water reaches the end of the spillway channel, it enters its historic flow path. Induced flooding maps are included in Attachment 2.

D.4 Geology

Santaquin is located in Utah Valley, a deep, sediment-filled structural basin of Cenozoic age flanked by uplifted blocks, the Wasatch Range on the east ant the Spring Mountains and Western Mountains to the west. The proposed basins are located in Utah County, Utah. The basins are bound to the east by Dry Mountain and to the west by alluvial deposits on the bench and in the valley. The near-surface geology of Santaquin is dominated by sediments which were deposited within the last 30,000 years by Lake Bonneville. The near surface geology at the mouth of the drainage basins evaluated are mapped as age alluvial fan deposits overlying deltaic deposits. Landslide and colluvial deposits are mapped within the drainage basins and canyon walls. (GeoStrata, 2018)

Additional information regarding geologic conditions at the debris basins is described in the geotechnical report prepared by GeoStrata. The report is included as Attachment 5-Geotechnical Report.

D.4.1 Tectonic/Seismic Setting

Analysis of the ground shaking hazard along the Wasatch Front suggests that the Wasatch Fault Zone is the single greatest contributor to the seismic hazard in the Salt Lake City region. Each of the nearby faults show evidence of Holocene-age movement and are therefore considered active.

The likelihood of a seismic event occurring while one of the debris basins is loaded to be very low; therefore, seismic design of a fully loaded basin will not be required; however, the Nephi section of the Wasatch Fault Zone lies in close proximity to the proposed debris basin locations. An evaluation of the proximity of the fault to each of the proposed debris basin locations will be performed during final design as fault rupture could impact the stability and performance of the debris basin embankments/slopes. A preliminary fault study should include examining the footprint of the proposed debris basins compared to the mapped location of the Nephi section of the Wasatch Fault Zone to determine whether further studies will be required, including trenching within the footprint of the proposed debris basins, to clear the sites of faults and/or identify the locations of faults. All fault studies should be completed by a licensed Professional Geologist.

D.5 Seismic Analysis

A preliminary seismic analysis was completed by a professional geotechnical engineer to ensure that the proposed slopes would be stable during a seismic event. The Wasatch Fault is located near the project location and has the greatest potential to generate the largest seismic event close to the debris basins. Several analysis types were used including full-static, full-pseud-ostatic, rapid drawdown, dry-static and dry- pseudo-static. Slope stability analysis for the basins assume embankments have a 3:1 sideslope, 12 foot top widths, and a height/depth of 16 feet. The seismic parameters are summarized in the table below:

Table D-3 Seismic Parameters

Drainage	1	2+3	4	5	6
Lat	39.9662	39.9705	39.9757	39.9817	39.9912
Long	-111.759	-111.76	-111.765	-111.761	-111.744
SS	1.303	1.32	1.341	1.355	1.362
S1	0.48	0.484	0.489	0.494	0.503
SMS	1.303	1.32	1.341	1.355	1.362
SM1	0.73	0.734	0.739	0.744	0.755
SDS	0.869	0.88	0.894	0.903	0.908
SD1	0.486	0.489	0.493	0.496	0.503
Fa	1	1	1	1	1
Fv	1.52	1.516	1.511	1.506	1.5
PGA	0.591	0.598	0.607	0.613	0.615
FPGA	1	1	1	1	1
PGAM	0.591	0.598	0.607	0.613	0.615

The seismic and slope stability analysis indicates that the debris basins will be meet minimum design requirements. A more in-depth seismic analysis will be conduted during the design phase of the project. The full preliminary seismic analysis is located in Attachment 5.

D.6 Geotechnical Analysis

The geotechnical investigation for this Plan-EA was conducted primarily to determine overall feasibility of the proposed debris basins and to assist in determining debris volumes. Additional geotechnical and geologic analysis will be required during the design phase of the project.

D.6.2 Subsurface Explorations

A subsurface investigation was conducted at several locations along the east bench of Santaquin. The exploration included multiple test pits near the planned debris basin locations. Test pits were dug to a depth of 6-10 feet. Stratigraphy was observed, photographed and logged. In general, the soils exposed in the test pits consisted of alluvial fan flooding sediments ranging from fluvial to debris flow deposits. Deeper subsurface investigations such as borings will be required during the design phase to determine bearing capacity and the suitability of the material for embankments.

D.6.3 Debris Volumes

Two methods were used to estimate debris flow volumes. The first method is based on a burned condition 25-yr peak flow rate with an assumed bulking rate of 75%. The second method uses a unit-volume approach which involves measuring and estimating the stored erodible material in the channel. These volumes are compared with 100-year 24-hour storm event volumes. To meet NRCS requirements the actual volumes used in the study are based on the 100-yr 24-hour storm event. Volumes estimating using Method 2 match the 100-yr 24-hour volumes reasonably well.

D.6.4 Geotechnical Recommendations

In order to evaluate the engineering properties of the existing soils in the vicinity of the proposed debris basins, a test pit was excavated in the approximate location of proposed debris retention/detention structures. A description of each of the test pits excavated and subsurface conditions encountered in each test pit is presented in Attachment 5-Geotechnical Report and the test pit locations are shown on Figure 2, Exploration Location Map.

Deeper subsurface investigations will be required in order to assess excavatability of subsurface soils if basins are to be constructed below the existing site grade or to assess bearing capacity of the subsurface strata if embankments are to be constructed above the existing site grade. Test pits TP-1, TP-2, TP-3, TP-5, and TP-6 were able to be excavated to depths requested for this preliminary investigation with a rubber-tired backhoe while digging was difficult and refusal was encountered in test pit TP-4 on either bedrock or large boulders.

A design level geotechnical investigation should be performed for each of the proposed debris basins including boreholes to sufficient depth to evaluate excavatability and bearing capacity of the subsurface soils, soil strength testing, soil permeability testing, slope stability analysis of proposed cuts and fills, foundation soil bearing capacity, and identification of borrow areas for proposed embankments (as needed).

Based on our preliminary engineering analysis of the proposed debris basin sites, the proposed locations are suitable for the proposed construction provided that design level geotechnical evaluations of each of the locations are performed and that recommendations from these studies are incorporated into the final design of the structures.

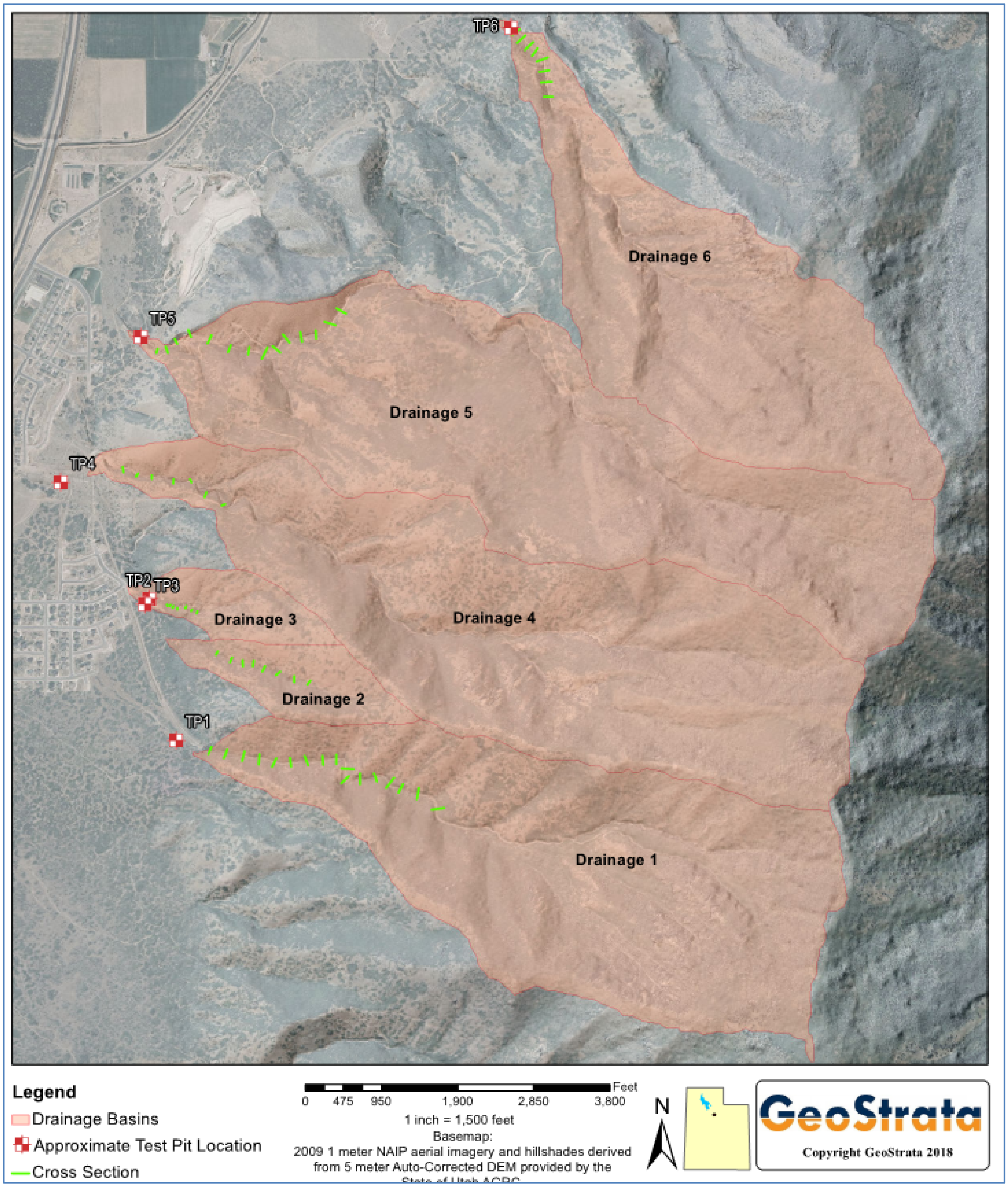

Figure D-2. Exploration Location Map

D.7 Water Quality

There is no permanent pool or perennial stream associated with the Santaquin Debris Basins. There will only be an improvement in water quality in that debris and sediment will be captured in the basins. Water quality is not anticipated to be an issue at the Santaquin Debris Basins.

D.8 Hydrologic Analysis

The Hydrologic Analyses (Attachment 1-Hydrology Report) included the identification of three design floods. They include the Freeboard Hydrograph (FBH) also referred to as the Inflow Design Flood (IDF) for the State of Utah, the Spillway Design Hydrograph (SDH), and the Principal Spillway Hydrograph (PSH). The FBH was defined as the 6-hour Spillway Evaluation Flood (SEF).

Various precipitation events were evaluated for each of the six watersheds to address various planning and design needs. The general categories and specific events evaluated are listed in Table D-4 below.

Table D-3. Precipitation Events

Purpose	Events Evaluated	Description
Economic Impact Analysis/Reservoir Sizing	2-, 5-, 10-, 25-, 50-, 100-, 200-, 500-year 24-hour precipitation events	Used for flood modeling to quantify changes in flood impacts after construction of basins. Sizing of reservoir.
Principal Spillway Sizing	PSH (Rainfall/Curve Number Method and Runoff Method, TR-60/NEH-4/SITES)	Used to evaluate minimum sizing of principal spillway and minimum elevation of auxiliary spillway
Auxiliary Spillway, Freeboard Evaluation, Wave Run-up	PMF, SEF, SDH, FBH, 100-year ARC III event	Auxiliary spillway sizing and minimum freeboard height.
Burned Condition Runoff	10-year 24-hour event	Reservoir Capacity Check
Debris Flow Event	5-year 1-hour event	Reservoir Capacity Check

The SCS Type II distribution was used as the temporal rainfall distribution. Curve numbers were generated using hydrologic soil type shape files (SSURGO) overlaid with land use data. The curve number of the watershed as a whole was obtained through ArcMap by calculating a weighted average based on the area and estimated CN of each region within the watershed. WIN TR-20 was used as the software to generate hydrographs and to import them into SITES software for routing calculations.

The land use data was obtained from the National Land Cover Dataset (NLCD), Multi-Resolution Land Characteristics (MRLC) Consortium. The land cover classification values were assigned comparable cover types from Chapter 9 of the National Engineering Handbook, Part 630 (NEH-630).

Time of concentration values were estimated using the velocity method with sheet flow, shallow concentrated flow and channel flow components.

Point Precipitation Frequency Estimates with 90% confidence levels were collected for 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 200-year, and 500-year 24-hour storm events. All depths were sourced from NOAA Atlas 14, Volume 1, Version 5, using the Precipitation Frequency Data Server (PFDS). The centroid of each watershed was used as the point to evaluate rainfall depths. The latitude and longitude of the analysis point used for each watershed and the corresponding depth for each 24-hr event is shown in Attachment 1-Hydrology Report

Table D-5 contains watershed data used in the hydrologic analysis.

Table D-4. Watershed Data

Watershed ID	Area (miles)	Area (acres)	Tc (hr)	CN	Burned Condition CN
1	0.627	401.9	0.54	71.8	77.8
2	0.069	44.3	0.21	69.2	75.2
3	0.053	34.1	0.21	70.9	76.9
4	0.688	440.7	0.53	70.9	76.9
5	0.711	455.2	0.68	67.3	73.3
6	0.451	288.9	0.45	72.1	78.1

Peak flow rates and volumes for each watershed are shown in Table D-6. These values were used in the economic analysis models.

Table D-5. Peak Flow Rates, Volumes

	Watershed	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
Peak Flow (cfs)	1	11.9	41.8	79.6	149	217.1	300.6	403.8	569.7
Volume (ac-ft)		4.7	8.5	12.4	18.3	23.4	28.7	34.5	42.6
Peak Flow (cfs)	2	0.6	3.8	8.6	18.2	27.9	40.3	55.2	80.4
Volume (ac-ft)		0.1	0.5	1.0	1.6	2.1	2.6	3.1	3.9
Peak Flow (cfs)	3	0.8	4.2	8.7	17.1	25.7	36.4	49.4	71.1
Volume (ac-ft)		0.1	0.4	0.7	1.2	1.6	2.0	2.5	3.2
Peak Flow (cfs)	4	8.8	35.9	71.2	139.1	207.8	291.6	395.8	563.8
Volume (ac-ft)		4.3	8.2	12.1	18.2	23.4	29.0	35.1	43.5
Peak Flow (cfs)	5	3.1	15.6	38.6	88.4	142.1	209.5	295.7	438.2
Volume (ac-ft)		2.5	5.6	8.8	14.2	18.8	23.8	29.4	37.2
Peak Flow (cfs)	6	9.5	35.3	67.9	127.8	188.8	262.5	352.6	502.1
Volume (ac-ft)		3.2	5.8	8.5	12.6	16.1	19.9	23.9	29.4

Detailed peak flow rate and volume information regarding Auxiliary Spillway events is included in Attachment 1-Hydrology Report.

D.9 Hydraulic Analysis

Numerous scenarios were modeled to analyze the impacts of different debris basin configurations. The modeling efforts included routing, spillway analysis, induced flooding and pre and post flood patterns. The various configurations included having some of the basins be constructed entirely below existing grade, or partly below and partly above existing grade. Watersheds 2 and 3 were modeled separately with separate debris basins. The debris basins were also combined into one basin (referred to as 3A, preferred option). The location of basin 4 was modeled such that it would intercept flows from the upstream basins, as well as being tucked up against the hillside so upstream basin flows would completely bypass it (preferred option).

D.9.1 Reservoir Routing and Sizing

The methodologies inherent in the SITES program developed and distributed by the NRCS was utilized to route the storms through the reservoirs. The program permits the designation of basic auxiliary spillway dimensions. Principal spillway combinations including low level outlets and upper weir crests, are all

directed to an outlet pipe. Combined spillways and direct input of stage-discharge curves are also possible. Basic assumptions are shown below:
Reservoir Dimensions:
Initial Volume: +/- 25-year 24-hour event volume at Auxiliary Spillway for Approach A; 50-year 24-hour event volume for Approach B
Initial Elevation of Auxiliary Spillway: 3 feet below crest
Internal Depth of Basin/Structural Height: 16 feet
Cut and Fill Slopes: 3:1

Auxiliary Spillway Dimensions:
Width: 50 feet
Length of Flat Section (spillway crest): 40 feet
Upstream Slope: 3:1
Downstream Slope: -2%
Side Slopes: 3:1

Principal Spillway:
Type: NRCS Standard Riser with Piped Outlet
Low Elevation Outlet: (2) 6”x12” openings (Approach A); Orifice as needed to meet 10-day draw down (Approach B)
Low Elevation Outlet Elevation: at +/- 20% Volume of Basin (Sediment Storage Elev.); Orifice as needed to meet 10-day draw down (Approach B)
Upper Weir Elevation: 1 foot below the auxiliary crest elevation
Upper Weir Length: 6 feet on each side of structure, total of 12 feet
Outlet Pipe Size: 30” (NRCS minimum size)

The principal spillway evaluation events were routed to verify the principal spillway met the regulations for size and capacity as stated in TR-60. The principal spillway hydrograph was routed through the reservoirs using standard NRCS methodology. The required input data were taken from the hydrologic analysis. All structures were able to pass all spillway design flows through a combined spillway while meeting freeboard requirements. Drawdown within 10 days was achieved in all debris basins. Refer to Attachment 2-Hydraulics report for more information.

Peak flow pre and post data are shown in Tables D-7 below.

Table D-6. Peak Flow Rates by Return Event

Watershed	Data/Option	Peak Flow by Return Interval (Approach B)				
		5-yr	10-yr	25-yr	50-yr	100-yr
1	Inflow (cfs)	41.8	79.6	149	217.1	300.6
	Inflow (ac-ft)	8.5	12.4	18.3	23.4	28.7
	Basin 1 Outflow	1.2	1.6	2.1	2.5	15.2
2,3	Inflow (cfs) (2 & 3 Combined)	8	17.3	35.3	53.6	76.7
	Inflow (ac-ft) (2 & 3 Combined)	0.9	1.7	2.8	3.7	4.6
	Basin 3A Below Grade Outflow (2 & 3 Combined)	0.6	0.9	1.1	1.3	3.6
4	Inflow (cfs) (Single Basin)	35.9	71.2	139.1	207.8	291.6
	Inflow (ac-ft) (Single Basin)	8.2	12.1	18.2	23.4	29.0
	Basin 4 Outflow	1.0	1.5	1.9	2.3	16.5
5	Inflow (cfs)	15.6	38.6	88.4	142.1	209.5
	Inflow (ac-ft)	5.6	8.8	14.2	18.8	23.8
	Basin 5 Outflow	0.7	1.1	1.5	1.8	

Watershed	Data/Option	Peak Flow by Return Interval (Approach B)				
		5-yr	10-yr	25-yr	50-yr	100-yr
6	Inflow (cfs)	35.3	67.9	127.8	188.8	262.5
	Inflow (ac-ft)	5.8	8.5	12.6	16.1	19.9
	Basin 6 Outflow	0.8	1.1	1.4	1.7	14.5

D.9.2 Flood Modeling

Because there is no outfall channel for the debris basins, a two-dimensional model was used to determine the existing and proposed condition flooding extents and damages. Existing hydrographs and proposed routed hydrographs were taken from SITES and used as input in a FLO-2D model. Output data from the FLO-2D model was obtained to map the depth, velocity, and inundation area for the existing and proposed conditions. Detailed flood maps are included in Attachment 2-Hydraulics Report. 2-D model input is listed in Table D-8.

Table D-7. 2-D Model Parameters

Model Component	Parameter Used
2-D Software	FLO-2D
Typical Floodplain Roughness Coefficients	0.04
Grid Size	10’x10’
Topographic Data	2 foot contour data

D.10 Design Criteria

The entities with jurisdiction over this project is Utah Dam Safety and NRCS. Utah Dam Safety requires compliance with Utah’s Administrative Code R655-11 Requirements for the Design and Construction and Abandonment of Dams while NRCS requires compliance with Technical Release 60 (TR-60), and the National Engineering Handbook (NEH). The most conservative design criteria outlined in either the Utah’s Administrative Code R655-11, TR-60, or NEH will be followed.

Because the debris basins have not been designed to a 100% level, some design criteria are assumed and will be finalized during the design phase of the project, pending design-level geotechnical analysis.

Typical design criteria are detailed in Attachment 1-Hydrology Report and Attachment 2-Hydraulics Report and are summarized in Table D-9.

Table D-8. Design Criteria

Description	Criterion
Principal Spillway Capacity (above grade dam)	Pass the 50-yr 24-Hour Event without activating the aux. spillway
Principal Spillway Capacity (below grade dam)	Pass the 50-yr 24-Hour Event without activating the aux. spillway
Auxiliary Spillway Capacity	Pass the freeboard hydrograph while maintaining freeboard
Side Slopes	3:1
Freeboard	3 feet
Top Width	15 feet
Height	Typically 16 feet
Drawdown Time	10 days
Principal Spillway Conduit Diameter	30 Inches, with a smaller orifice in the tower to allow for drainage

D.11 Agency Coordination

During the preliminary scoping period for the project, scoping questions, comments, and concerns were requested from government agencies, both orally at public meetings and via written submittal of comments. A scoping notice was prepared and mailed to interested parties. The scoping comment period was open for 30 days and several comments were received.

A public notice of availability of the Draft Plan-EA will be mailed to interested parties, published in the local newspaper or included in a utility mailer and posted to the NRCS project website. The Draft Plan-EA will be released for public review and comment and a public meeting will be held

Agency coordination and consultation is summarized and documented in the Plan-EA.

D.12 Alternatives Evaluation

The formulation process of alternatives for the Santaquin Debris Basins followed NRCS watershed planning policy. Numerous alternatives were developed by the project team. They were evaluated based on cost, constructability, whether they meet the purpose and need of the project, and net monetary benefit. Comments provided by the public and other agencies were incorporated into the evaluation process

Numerous alternatives were developed by the project team based on the ability to address the purpose and need of the project, and were formulated in consideration of four criteria outlined in the P&G (USWRC 1983): completeness, effectiveness, efficiency, and acceptability. If scoping comments had been received during the scoping period they would have been incorporated into the formulation process for the initial alternatives. General concepts evaluated include check structures, diversion berms, level spreaders and debris basins, each with several different types and variations.

D.12.1 Alternatives Studied in Detail

This section discusses the evaluation of alternatives for the Santaquin Debris Basins Project that were studied in detail. Three alternatives were evaluated in detail which include 1) the No Action, 2) Debris Basins with an extensive downstream pipe network, and 3) Larger debris basins without an extensive downstream pipe network. Concept design drawings for the Dam Rehabilitation Alternative are included in Attachment 4-Concept Drawings.

D.12.1.1 No Action Alternative

The No Action Alternative is the alternative in which no NRCS action occurs to mitigate potential flood damages along the east bench. This alternative must be studied to discover if it the alternative that makes the most sense from an economic, environmental and flood protection standpoint.

D.12.1.2 Debris Basins with Extensive Downstream Pipe Network (Option A)

This Alternative consists of debris basins which would roughly contain the 25-year volume. The basins would be constructed with an auxiliary spillway and principal spillway outlet structure which would be connected to a conduit network that together with the basin, can safely convey the entire 100-year flows. The approach is based on the assumption that there is adequate capacity for the flows located several miles to the north in Spring Creek and under Red Bridge in western Payson. The pipe conduit system for conveying the flows would need to go over or under (most likely under) the Strawberry-Highline Canal, and be piped or possibly kept in an open channel southward through private property, until it reaches Spring Creek. The pipe system would go under several overpass embankments, and be bored underneath I-15. In addition, several large diameter culverts downstream would need to be enlarged. Based on flow estimates and average slope, the downstream pipe system would be a 60 inch diameter pipe or equivalent from the Strawberry-Highline Canal and northward.

The alternative listed above represents an anticipated construction cost of $15.5M plus a property cost of $2.44M (paid for by Sponsor) and technical assistance costs of $1.37M for a total installation cost of $19.3M. The Sponsors estimated O&M costs are $20,920 per year. The cost estimates are included as Attachment 6-Cost Estimate.

D.12.1.3 Larger Debris Basins without Extensive Downstream Pipe Network (Option B)

Approach B consists of debris basins which would completely contain the 50-year volume. The basins would have a principal spillway tower with an outlet pipe. The principal spillway would have an orifice in the side of it to allow the basin to drain while restricting flows to a minimal flow rate. The principal spillway would be open only at the top and would only be activated when water within the basin is deep. This approach would not include an extensive downstream pipe network. Flows for events larger than the 50-year event would first fill up the basin, and then exit through the principal spillway tower and eventually overtop the auxiliary spillway, as needed. The flows would be directed into their historic flow paths so as to not cause induced flooding. Although this approach does not provide full containment of the 100-year event, it significantly reduces flood damages associated with the 100-yr event by reducing the peak flow rate to a non-threatening level.

This alternative represents an anticipated construction cost of $8.1M plus a property cost of $2.77M (paid for by Sponsor) and technical assistance costs of $1.41M for a total installation cost of $12.3M. The Sponsors estimated O&M costs are $20,920 per year. The cost estimates are included as Attachment 6 Cost Estimates.

D.13 Economic Evaluation

The NRCS National Watershed Manual was used as a reference for the economic analysis along with the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) (U.S. Water Resources Council 1983). P&G was developed to define a consistent set of project formulation and evaluation instructions for federal agencies that carry out water and related land resource implementation studies.

The objective of P&G is to determine whether or not benefits from proposed actions exceed project costs for federally funded projects. P&G also requires that the “National Economic Development” or NED Alternative, which maximizes monetary net benefits, is selected for implementation unless there is an overriding reason for selecting another alternative based on federal, state, local, or international concerns related to the social and environmental accounts.

Damage reduction benefits from floodwater and debris flow were analyzed for this project according to the P&G and the Manual.

D.13.1 Installation Costs

The total installation cost estimated for the preferred alternative (Option B) is $12,279,633 as detailed in the table below.

Table D-9. Summary of Installation Cost for the Preferred Alternative

Measure	Construction	Engineering	Real Property Rights	Admin	Total
Basin 1	$ 2,643,408	$ 440,418	$ 924,000	$ 22,021	$ 4,029,847
Basin 3A	$ 570,133	$ 95,022	$ 300,000	$ 4,751	$ 969,906
Basin 4	$ 1,060,079	$ 176,680	$ 700,000	$ 8,834	$ 1,945,593

Measure	Construction	Engineering	Real Property Rights	Admin	Total
Basin 5	$ 2,554,266	$ 425,711	$ 58,100	$ 21,286	$ 3,059,363
Basin 6	$ 1,265,467	$ 210,911	$ 788,000	$ 10,546	$ 2,274,924
Total	$ 8,093,353	$ 1,348,742	$ 2,770,100	$ 67,438	$ 12,279,633

D.13.1.1 Damage Reduction Benefits

Damage reduction benefits were assessed based on the equivalent annual damage reduction expected through implementation of the preferred alternative compared to the no action/existing alternative baseline. The life of the measures proposed in the preferred alternative are estimated at 100 years. The period of analysis is therefore 100 years, with all costs and benefits calculated at the Fiscal Year 2018 Federal Water Resources Discount Rate of 2.875%.

The sum of damages accrued due to the 2, 5, 10, 25, 50, 100, 200 and 500 year storm events were compared between all three alternatives. These damages are estimated by developing inundation extents of each of the storm events using a hydraulic model, overlaying the boundaries of the various events onto aerial maps, determining the structures that intersect the storm event extents, and estimating the damages based on the severity of exposure for each structure.

D.13.1.2 Floodwater/Debris flow

Residential Property and Contents

Monetary damage from debris flow to residences was differentiated between those exposed to less than 1 foot of flood waters and debris flow, 1 to 3 feet, and greater than 3 feet. The U.S. Army Corps of Engineers Catalog of Residential Depth Damage Functions (USACE) was used to estimate damage to the homes affected. Damages were not differentiated between debris flow and floodwater.

A median home structure value of $216,500 was estimated from a sample of houses in the damage area from tax records. This was used as a proxy value for all homes affected. A replacement value of eighty percent of this value was used to estimate the actual dollar value of structure damages to flooded homes. Fifty percent of this replacement value was used to estimate contents value, as per suggested from the USACE document. Although a basement survey was not conducted, in observations from field visits, it was assumed that all the homes in the area had basements.

Damage to outbuildings, landscaping, and automobiles was estimated at fifteen percent of the average annual damages to the property damage to homes hit with flooding and debris flow.

Homeowner time away from employment to deal with damages was estimated by assuming one week of income lost for each home inundated, calculated by dividing the median household income per year of the project area by 52 weeks.

Other (Road) Damages

Road damage was estimated by using a square footage repair cost based on the depth of flooding. Pavement/asphalt repair costs range $2 to $3 per square foot, depending on the total area to be worked on. For roads flooded less than 1 foot, $.50 per square foot was estimated for a post-flood repair cost, and $1 per square foot was estimated for roads flooded greater than 1 foot. These cost estimates account for the large volume of work that would need to be performed after a flood, and the assumption that damage would most likely be uneven or sporadic along streets.

Agricultural Damages

Agricultural flood damage was estimated using procedures outlined in SCS Technical Note UD-28 (1972). Monthly damage factors for hay were used for estimation, as it is the predominant crop in Utah County (NASS, 2012). Crop values were estimated from hay crop budgets. A monthly flash flood distribution for Utah was estimated from NOAA Technical Memorandum NWS WR-147 (1979). Using the damage factors, crop value, and flood distribution, a weighted per acre damage was estimated. This was applied to the acres flooded by storm event to arrive at an average annual flood damage for crop land.

Table D-11 provides damages calculated for floodwater for the With Project and Without Project, and the resulting damage reduction.

Table D-110. Debris Flow Damage Reduction Benefits

Item	Estimated Average Annual Damage Reduction Benefits		
	With Project[1]	Without Project	Damage Reduction
Crop and Pasture	$400	$4,900	$4,500
Residential	$34,300	$488,700	$454,400
Other	$800	$3,000	$2,200
Total	$35,500	$496,600	$461,100

D.13.1.3 Benefit Cost Ratio

The total average annual economic benefits are $461,100 for the preferred alternative. Table D-12 provides the calculated annual benefits, costs, benefit cost ratio, and net annual benefit for each of the alternatives.

Table D-12. Alternatives Benefit Cost Ratios and Net Benefits[1]

Alternative	Total Annual Benefits	Total Annual Costs	Benefit Cost Ratio	Net Annual Economic Benefit
No Action Alternative	$ --	$ --	--	$ --
Alternative A	$487,100	$633,500	0.77	$-146,400
Alternative B	$461,100	$397,000	1.16	$64,100

1/ Price base 2018. Calculated using FY 2019 Water Resources Discount Rate (2.875%), annualized over 100 year period of analysis.

D.13.1.4 Economic Evaluation Summary

The economic analysis determined that alternative B has the highest net economic benefits, and therefore is the NED plan. It has a benefit cost ratio of 1.16 to 1. The other alternative evaluated resulted in a benefit cost ratio of .77 to 1. Alternative A provides a higher level of protection, but at much higher cost. Alternative B, the preferred alternative, provides a level of protection that is adequate at a lower cost.

D.15 References

U.S. Army Corps of Engineers (USACE), 1992. Catalog of Residential Depth Damage Functions.

U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), 2014. Title 390: National Watershed Program Manual.

National Oceanic and Atmospheric Administration (NOAA). 1979. Technical Memorandum NWS WR-147. Occurrence and Distribution of Flash Floods in the Western Region.

Soil Conservation Service (SCS). 1972. TSC Technical Note: Watersheds: UD-28. A Manual Procedure to Estimate Annual Crop and Pasture Flood Damages.

National Agricultural Statistics Service (NASS). 2012 Census of Agriculture. Utah County, Utah Profile.

U.S. Water Resources Council, 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies.

NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service). 2005. Earth Dams and Reservoirs Technical Release – 60. 210-VI. Conservation Engineering Division. July 2005.

NRCS, 2014c. National Engineering Handbook.

UAC (Utah Administrative Code). 2019. Natural Resources, Water Rights; Requirements for the Design, Construction and Abandonment of Dams. As in effect on February 26, 2019.

ATTACHMENT 1

HYDROLOGY REPORT

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To: **Nathaniel Todea**
Natural Resources Conservation Service (NRCS), USDA

From: **Aaron Spencer, P.E.**

Date: August 23, 2018

Technical Memo

Subject: **Santaquin City Flood Control Plan-EA – Hydrology Report**

Project: **UT-1024-1801**

1.0 INTRODUCTION

In order to determine the proper size and nature of flood control structures for the watersheds along the eastern boundary of Santaquin City multiple storm events must be evaluated for each site. This memo summarizes the methods, data sources, and results of these analyses. Events had to be evaluated for several purposes:

- Evaluating the economic impact of the improvements based on the change in flood impacts
- Determining the likely runoff volume after a wildfire including sediment to ensure it could be contained
- Determining the likely volume of debris flow that must be contained
- Determining the governing storms for sizing spillways and required freeboard.
- Provide supporting data for sedimentation analysis (see Sedimentation Technical Memo)

These evaluations were performed in accordance with requirements of the NRCS as a funding partner and agency with technical oversight, and Utah Dam Safety requirements. Other design goals which are not directly covered by either agency's design criteria, such as debris flow and burned condition analysis, used the best available methods and information, with assistance from NRCS and other technical experts.

The input data collected and evaluations done are broken out and discussed below in the following sections:

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2.0 BACKGROUND

The City of Santaquin is in the process of developing a storm drain master plan which was the impetus for planning and seeking funding from the NRCS for flood and debris control structures for the watersheds studied in this report. The six most critical watersheds were identified based on a combination of factors, including past issues and proximity of threatened infrastructure and development.

The watersheds that are the subject of this report lie to the southeast of Santaquin. They are steep, dry canyons located at the base of the Wasatch Front. The watersheds drain onto alluvial fans, with no defined outlet channels down through the community. The regionally critical Highline Canal crosses along the base of the alluvial fans. Heavily used highways and arterials, including the regionally critical I-15 freeway, are also located downstream. Over time development has moved up the alluvial fan towards the watersheds, with further development anticipated in a community that is experiencing rapid growth.

The Mollie Fire in 2001 caused subsequent debris flows from five of the canyons directly above Santaquin, with at least two of those resulting in significant damage to homes and public property, and threatening the safety of residents. Development below these canyons has only continued, increasing the need for measures to be taken to control flooding and debris flows. Multiple other canyons in the burned area also experienced debris or hyperconcentrated flows (Giraud & McDonald, 2007)

Initial analysis and sizing of the basins was done using the generalized criteria of the draft Santaquin Storm Drain Master Plan (SDMP), but those criteria were reevaluated when NRCS funding was secured in order to meet NRCS design criteria, and to refine the concept design. All the data possible was carried over from that report, such as basin characteristics, curve numbers, and burned flow and debris flow data and evaluations. The data, sources, and development are repeated in this memo such that reference to the SDMP is not required.

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3.0 STORM EVENTS

Multiple different precipitation events were evaluated for each of the six watersheds to address various planning and design needs. The general categories and specific events evaluated are listed in Table 1 below.

Table 1. Storms Evaluated.

Purpose	Events Evaluated	Description
Economic Impact Analysis/Reservoir Sizing	2-, 5-, 10-, 25-, 50-, 100-, 200-, 500-year 24-hour precipitation events	Used for flood modeling to quantify changes in impact after construction. Sizing of reservoir.
Principal Spillway Sizing	PSH (Rainfall/Curve Number Method and Runoff Method, TR-60/NEH-4/SITES)	Used to evaluate minimum sizing of principal spillway and minimum elevation of auxiliary spillway
Auxiliary Spillway, Freeboard Evaluation, Wave Runup	PMF, SEF, SDH, FBH, 100-year ARC III event	Auxiliary spillway sizing and minimum freeboard height.
Burned Condition Runoff	10-year 24-hour event	Reservoir Capacity Check
Debris Flow Event	5-year 1-hour event	Reservoir Capacity Check

3.1 Precipitation Depth

The sources, methods, and resulting precipitation depths for the design storms are outlined below according to the evaluation and storm type.

3.1.1 Economic Analysis Events Precipitation

Point Precipitation Frequency Estimates with 90% confidence levels were collected for 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 200-year, and 500-year 24-hour storm events. All depths were sourced from NOAA Atlas 14, Volume 1, Version 5, using the Precipitation Frequency Data Server (PFDS). The centroid of each watershed was used as the point to evaluate rainfall depths. Table 2 below displays the latitude and longitude of the analysis point used for each watershed and the corresponding depth for each 24-hr event.

Table 2. NOAA Rainfall 24-Hour ARI Depths – Economic Analysis Events

Watershed 1 (Latitude: 39.9818, Longitude: -111.7354)							
2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
1.57	1.88	2.14	2.49	2.76	3.10	3.30	3.66

Watershed 2 (Latitude: 39.9691, Longitude: -111.7535)							
2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
1.60	1.92	2.18	2.54	2.81	3.09	3.36	3.73

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Watershed 3 (Latitude: 39.9716, Longitude: -111.7564)							
2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
1.57	1.88	2.14	2.49	2.76	3.03	3.30	3.66

Watershed 4 (Latitude: 39.9709, Longitude: -111.7432)							
2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
1.58	1.90	2.16	2.52	2.79	3.06	3.34	3.70

Watershed 5 (Latitude: 39.977, Longitude: -111.7428)							
2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
1.58	1.90	2.16	2.52	2.79	3.06	3.34	3.70

Watershed 6 (Latitude: 39.9818, Longitude: -111.7354)							
2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
1.57	1.88	2.14	2.49	2.76	3.03	3.30	3.66

3.1.2 Principal Spillway Evaluation Events Precipitation

Precipitation depths used in the Principal Spillway Hydrograph (PSH) analysis were developed in accordance with NRCS Technical Release 60 (TR-60). TR-60 requires that the principal spillway pass the greater of two different methods of determining runoff prior to allowing flow to pass over the auxiliary spillway, the Runoff Method and the Curve Number Method.

In order to make initial decisions on hazard dependent designs, guidance was provided by the Utah NRCS office as follows, which they stated is arbitrary and must be verified, but provides a reasonable starting assumption: fully excavated ponds were generally considered low hazard, single purpose dams unless they were located in series, in which case the lower dam was considered significant or high hazard depending on its design and location. For earthfill embankment structures high hazard criteria was assumed. These hazard rating assumptions will be validated utilizing breach analysis and floodplain mapping based on the breach flow and classification methods outlined in TR-60. This analysis will be included in the Hydraulics Technical Memo to be submitted separately.

3.1.2.a Principal Spillway Runoff Method

The PSH Runoff Method (also referred to as the "snowmelt" method) utilizes Table 2.2 to determine the design event, and Figures 2-2 and 2-3 in TR-60 to determine total runoff. Assuming a vegetated spillway, single purpose structure, and a storage/effective height product below 30,000, these result in the following precipitation depth values:

High Hazard, 100-year event:
- 10-day runoff = 3.0 in.
- 1-day runoff = 0.9 in.

Low Hazard, 25-year event (see note, Fig. 2.2):
- 10-day runoff = 2.25 in.
- 1-day runoff = 0.675 in.

In the case of dams in series, high hazard will be assumed for the lower structure PSH.

3.1.2.b Principal Spillway Curve Number Method

The TR-60 PSH curve number procedure (referred to as the "Rainfall" method in SITES) used rainfall depths gathered from NOAA Atlas 14 shown in the previous section. The recurrence interval is selected and the depth is adjusted as necessary from these values in accordance with the criteria shown in Table 2-2 of TR-60. Vegetated spillways, single purpose structures with storage/effective height products less the 30,000 were assumed in all cases. Low and high hazard structures were assumed as described previously. If upstream dams were anticipated the high hazard rating result will be used. The resulting design storms were evaluated as follows:

- Low hazard structures - P_{25} storm
- High hazard structures - P_{100} storm

The precipitation values are as follows:

Table 3.Precipitation Values – Principal Spillway Evaluation Events

Basin	Hazard Rating	Event	10-day Precipitation
Basin 1 Above Grade	High	P_{100}	5.96
Basin 1 Below Grade	Low	P_{25}	4.16
Basin 2 Above Grade	High	P_{100}	5.82
Basin 2 Below Grade	Low	P_{25}	4.75
Basin 3 Above Grade	High	P_{100}	5.57
Basin 3 Below Grade	Low	P_{25}	4.56
Basin 4 Above Grade	High	P_{100}	5.81
Basin 4 Below Grade	Low	P_{25}	4.74
Basin 5 Above Grade	High	P_{100}	5.78
Basin 5 Below Grade	Low	P_{25}	4.74
Basin 6 Above Grade	High	P_{100}	5.78
Basin 6 Below Grade	Low	P_{25}	4.72

3.1.3 Auxiliary Spillway Evaluation Events Precipitation

Freeboard Hydrographs (FBH) and Stability Design Hydrographs (SDH) were generated according to the criteria in Table 2-5 of TR-60. Separate evaluations were given for "Above Grade" and "Below Grade" options for each watershed. These correspond to traditional earthfill dam type structures, or basins that are fully excavated having no significant earthfill, respectively. Earthfill dams were evaluated as high hazard, and excavated basins were assumed to be low hazard per correspondence with Nathaniel Todea of the NRCS. If the excavated basin was located downstream of other basins it will be evaluated as a significant or high hazard structure per TR-60 policy.

Precipitation data for the 100-year event used in the calculation of the SDH or FBH for each watershed was taken from NOAA Atlas 14 and are shown previously in the Economic Analysis Events section in Table 2.

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Probable Maximum Precipitation values were taken from the studies by Jensen (1995) and Jensen (2003) that were studies performed in cooperation with the Utah - Dam Safety Section to develop adjusted values from Hydrometeorological Report No. 49 (HMR49) (NOAA, 1984) to compensate for local variables unique to Utah. Utah Administrative Code R655-11 requires that all high and moderate hazard dams in Utah route the critical precipitation value obtained USUS (Jensen, 1995), or USUL (Jensen, 2003). The NRCS in Utah has adopted the same approach.

Precipitation depths developed from HMR49 are referred to as Probable Maximum Precipitation (PMP). Precipitation developed from USUS or USUL are referred to as Spillway Evaluation Precipitation (SEP) per the Utah Code. The values used and shown in Table 4 as the "PMP" in the formulas for the SDH and FBH as prescribed in TR-60 are in fact the "SEP" values determined from these studies. In partnership with the Utah - Dam Safety Section a program was also developed in which latitude, longitude, and duration can be entered to determine the rainfall depths. The Utah Code requires the evaluation of the 6-hour and 72-hour events. TR-60 requires the evaluation of the 6-hour and 24-hour events.

Table 4. Precipitation Values – Auxiliary Spillway Evaluation Events.

	Precipitation Event	6hr	24hr	72hr
Basin 1	Basin 1 Above Grade (High Hazard)			
	PMP (in)	5.04	9.14	10.87
	SDH (in)	3.60	4.67	5.12
	FBH (in)	5.04	9.14	10.87
	Basin 1 Below Grade (Low Hazard)			
	PMP (in)	5.04	9.14	10.87
	SDH (in)	3.1	3.1	3.1
	FBH (in)	3.33	3.83	4.03

	Event	6hr	24hr	72hr
Basin 2	Basin 2 Above Grade (High Hazard)			
	PMP (in)	5.37	9.22	10.96
	SDH (in)	3.68	4.68	5.14
	FBH (in)	5.37	9.22	10.96
	Basin 2 Below Grade (Low Hazard)			
	PMP (in)	5.37	9.22	10.96
	SDH (in)	3.09	3.09	3.09
	FBH (in)	3.36	3.83	4.03

	Event	6hr	24hr	72hr
Basin 3	Basin 3 Above Grade (High Hazard)			
	PMP (in)	5.39	9.25	10.99
	SDH (in)	3.64	4.65	5.10

	FBH (in)	5.39	9.25	10.99
	Basin 3 Below Grade (Low Hazard)			
	PMP (in)	5.39	9.25	10.99
	SDH (in)	3.03	3.03	3.03
	FBH (in)	3.13	3.78	3.99

	Event	6hr	24hr	72hr
Basin 4	Basin 4 Above Grade (High Hazard)			
	PMP (in)	5.10	9.15	10.88
	SDH (in)	3.59	4.64	5.09
	FBH (in)	5.1	9.16	10.88
	Basin 4 Below Grade (Low Hazard*)			
	PMP (in)	5.10	9.15	10.88
	SDH (in)	3.06	3.06	3.06
	FBH (in)	3.31	3.79	4.00

	Event	6hr	24hr	72hr
Basin 5	Basin 5 Above Grade (High Hazard)			
	PMP (in)	5.1	9.14	10.87
	SDH (in)	3.59	4.64	5.09
	FBH (in)	5.1	9.14	10.87
	Basin 5 Below Grade (Low Hazard)			
	PMP (in)	5.1	9.14	10.87
	SDH (in)	3.06	3.06	3.06
	FBH (in)	3.30	3.79	4.00

	Event	6hr	24hr	72hr
Basin 6	Basin 6 Above Grade (High Hazard)			
	PMP (in)	5.23	9.11	10.83
	SDH (in)	3.60	4.61	5.06
	FBH (in)	5.23	9.11	10.83
	Basin 6 Below Grade (Low Hazard)			
	PMP (in)	5.23	9.11	10.83
	SDH (in)	3.03	3.03	3.03
	FBH (in)	3.29	3.76	3.97

*High hazard results will be used in the case that other dams are located upstream.

3.1.3.a State of Utah Freeboard Wave Runup Event Precipitation

The State of Utah Administrative Rules (R-655-11-4) requires that sufficient freeboard be provided to contain the wave runup on the dam while passing a 100-year precipitation event occurring on a saturated watershed. The duration of the event is dependent on whether the local or general SEF event controls. In order to perform this evaluation precipitation for either the 6-hour or the 24-hour precipitation event is required, depending on which SEP event produces the controlling flood (local or general). The 24-hour precipitation depths are the same as those reported for the matching economic analysis events, but are repeated here for convenience. The precipitation depths are shown in Table 5 below.

Table 5. Freeboard Wave Runup Analysis Precipitation

Freeboard 100-year Wave Runup Event Precipitation		
Watershed	6-Hour (Local)	24-Hour (General)
1	2.16	3.10
2	2.14	3.09
3	2.11	3.03
4	2.15	3.06
5	2.15	3.06
6	2.15	3.03

3.1.4 Burned Condition Events Precipitation

The purpose of performing the TR-20 models with watersheds 1 thru 6 during a 10-year 24-hour event in ‘post-burn’ conditions is to assure that the debris basin volumes would be sufficient to reduce the risk of injury and damage after a wildfire. The resulting volumes and peak flows from the TR-20 volume will then be bulked in accordance with NRCS TN-4 in order obtain the final design values.

The precipitation values are the same as those for the 10-year 24-hour events included in the section 3.1.1 Economic Analysis Event Precipitation.

3.1.5 Debris Flow Events Precipitation

In accordance with the publication by the USGS “Predicting the Probability and Volume of Post-Wildfire Debris flows in the Intermountain Western United States” (Cannon, Gartner, Rupert, Michael, Rea, Parrett, 2010) the types of events that “most strongly control the debris-flow response of burned basin in the Intermountain West” are short-duration, low-recurrence-interval convective thunderstorms. The study identifies these as less than one hour and less than 2-year or up to 10-year recurrence intervals. To match the recommended criteria, and to select an event that would be likely to occur in the lifespan of the structure, a 1-hour 5-year event was chosen based on engineering judgement. In the study “The 2000–2004 fire-related debris flows in Northern Utah” by Giraud and McDonald (2007) they examined both recent debris flows (including those above Santaquin) and other past studies to conclude that triggering rainfall typically has a recurrence interval of two years or less, and the durations cited were all less than an hour.

The rainfall depth for the event was based on one common point in the area of the drainages in question. Since all of the watersheds are in such close proximity the same value was used for all watersheds in the debris flow calculations. This matches the approach taken in Santaquin City's Storm Drain Master Plan, so it was adopted in this study as well.

Table 6. Debris Flow Precipitation Depth

Debris Flow Precipitation (all basins)	
Event	Depth (in)
5-year 1-hour	0.729

3.2 Hyetographs

The source and development of temporal distributions for rainfall depended on the type of event being analyzed, and the requirements of the agency with jurisdiction. The distribution development is described in the sections below based on event type.

3.2.1 Economic Analysis Events Hyetographs

The NOAA Atlas Data with Smoothing is a function within the WinTR-20 software that, "In order to best reflect the updated NOAA Atlas 14 & Northeast Regional Climate Center (NRCC) precipitation data, a site specific distribution is developed based on the CSV/text file download from the web site (English units only)." The process critically stacks events starting with the shortest duration and adding longer durations up to the 24-hour storm. This process is done for each recurrence interval. Reference is made to NRCS WinTR-20 supporting documentation for further information, which is available freely online. The NOAA Atlas 14 data was downloaded using the longitude and Latitude of each centroid (calculated in GIS) for each of the six basins. Due to the limitations of the WinTR-20 software (the software can only import one (1) set of NOAA Atlas data per model), six separate models were created, one for each watershed. An example of the distribution developed for Basin 1 is provided below.

3.2.2 Principal Spillway Analysis Events Hyetographs

The hyetograph for the principal spillway evaluation is developed in accordance with the procedure in chapter 21, NEH-4, and uses both the 1-day and 10-day runoff volumes. The SITES software performs this analysis automatically, and was used to develop the hyetograph as part of the program run.

3.2.3 Auxiliary Spillway Evaluation Events Hyetographs

TR-60 provides a temporal distribution (Figure 2-4) which can be used where no temporal distribution from a NWS publication is available. This distribution is termed the "6-Hour storm" in the SITES program. TR-60 titles the distribution "Dimensionless design storm distribution, auxiliary spillway and freeboard."

The NWS publication applicable to Utah is HMR-49. It contains sufficient data to develop a 6-hour local storm temporal distribution, but despite providing precipitation data for the 72-hour event, it does not have data to develop a distribution for the 72-hour storm.

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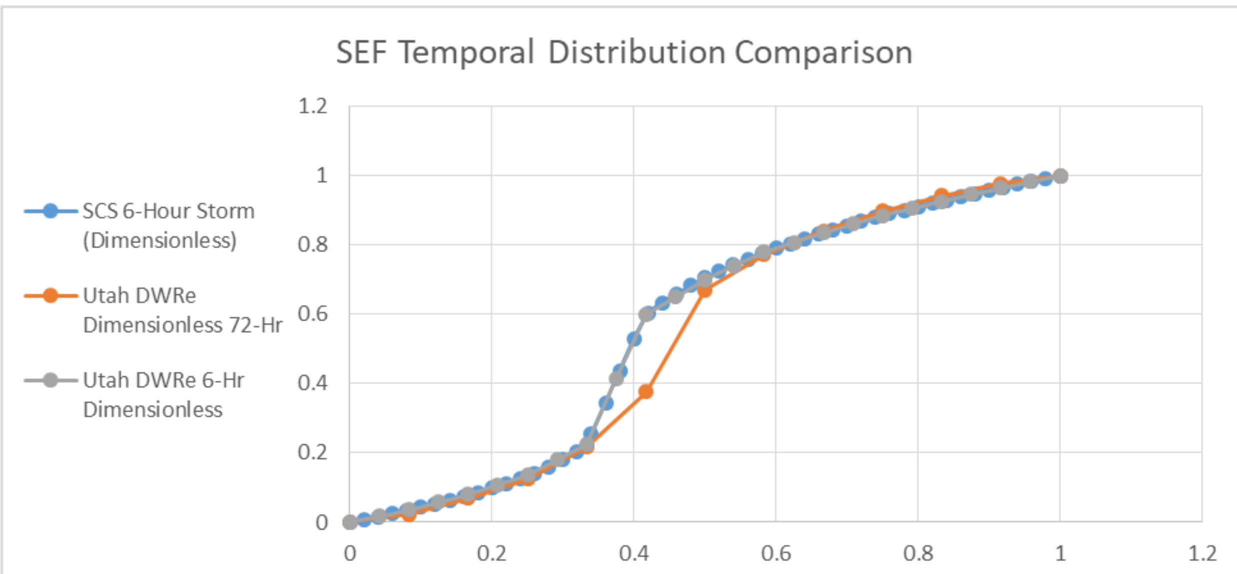
Evaluation of the 72-hour storm is required by the Administrative Rules of the State of Utah.

The Utah Division of Water Resources (DWRe) developed and has used in general practice a curve for the 72-hour general storm in Utah. For short duration storms the DWRe internally developed program "STORM" uses the SCS 6-hour storm. When compared as a dimensionless curve to the SCS 6-hour curve, the 72-hour distribution is similar, though the peak rainfall period for the general 72-hour storm appears to have a comparatively flatter, or less severe, peak rainfall period. In reality, applied to a 72-hour period, this peak rainfall period would be longer in duration, but would generally have a relatively lower intensity, dependent upon the total precipitation. This is consistent with typical general storm behavior. Use of the DWRe 72-Hour distribution is documented and suggested for use in Utah in the publication by Norm Stauffer of the Utah Division of Water Resources (1992). A comparison of the distributions is shown below in Figure 1.

Figure 1. Auxiliary Spillway Evaluation Temporal Distributions



The office of the NRCS in Utah has adopted the USUL and USUS studies (Jensen) discussed previously in developing the Probable Maximum Flood (PMF) and Spillway Evaluation Flood (SEF), and has made a practice of coordinating the use of matching temporal distributions with the State of Utah. This study used the same approach. Therefore, the SCS 6-hour storm was used for local events (6-Hour), and the DWRe 72-Hour distribution was used for the 72-hour general storm. For the 24-hour storm a dimensionless version of the SCS 6-Hour storm was used. This is in line with TR-60 since no curve is provided for the 24-Hour storm in any of the adopted NWS or State of Utah publications, so use of this curve is permitted.

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3.2.3.a State of Utah Freeboard Wave Runup Event Hyetograph

The State of Utah Administrative Rules (R-655-11-4) requires that sufficient freeboard be provided to contain the wave runup on the dam while passing a 100-year precipitation event occurring on a saturated watershed. The State of Utah does not specify a specific hyetograph to be used. For the 6-hour storm, An NRCS Type II storm was modified to a 6-hour duration by extracting the peak six hours in the distribution and scaling the percentages of rainfall accordingly.

TR-60 also requires that the design height of an earth embankment must be sufficient to prevent overtopping during passage of either the freeboard hydrograph or stability design Hydrograph, plus the freeboard required for frost conditions or wave action, whichever is larger. This will be evaluated in the Hydraulics Technical Memo.

3.2.4 Burned Condition Hyetograph

The analysis discussed here is normal flow on burned watersheds with typical sediment loads. It is not for debris flow, which is discussed in the next section.

A 10-year storm was deemed reasonable for the burned condition analysis because the combined probability of both a wildfire and a 10-year storm event is still quite low. In “The 2000-2004 Fire-Related Debris Flows in Northern Utah” (Giraud & McDonald, 2007) the authors cite Forest Service reports indicating the fire return period for mountain brush as 20 to 40 years, and for subalpine forest as 150 to 300 years. Using the lower end of this scale the probability of the evaluated event would be 0.5% in a given year, or a return interval of 200 years.

The temporal distribution used was the NOAA Atlas Data with Smoothing method which is integrated into the WinTR-20 program.

3.2.5 Debris Flow Events Hyetograph

In the method for determining debris flow volume outlined in the study by Cannon, et al (2010) only the precipitation volume is required. Therefore, there is no temporal distribution associated with this analysis. A separate debris flow analysis being undertaken by the geotechnical engineer using channel cross-sectioning methods uses data from the economic analysis events to inform the debris flow volume analysis. Their analysis will be submitted independently of this report.

4.0 WATERSHED DATA

The specific watershed data required to perform the necessary hydrologic analysis are outlined below with explanations of their development, including the loss method, time of concentration, and unit hydrograph used.

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4.1 Geometric Watershed Characteristics

Tools within the ArcGIS software were used to delineate each watershed and to evaluate critical parameters, such as the watershed area and the longest flow path. The basins as delineated are shown in Appendix 1. Basic geometric data is provided in Table 7 below.

Table 7. Basic Geometric Watershed Data

Watershed	Area (Mi^2)	Area (Acre)	Longest Flow Path (ft)
BASIN 1	0.6266	401.9	9003.2
BASIN 2	0.0688	44.3	3396.6
BASIN 3	0.0531	34.1	2883.3
BASIN 4	0.6875	440.7	11099.6
BASIN 5	0.7109	455.2	12349.6
BASIN 6	0.4510	288.9	8552.7

4.2 Runoff Methodology

The Curve Number method was used to evaluate the precipitation loss and total runoff. The Curve Numbers were developed using the data as outlined below.

4.2.1 Soil Data

The SSURGO soil data was downloaded in GIS format and the Hydrologic Soil Group. A soil region covering much of the watersheds did not have a Hydrologic Soil Group (HSG) identified in the GIS data. It was noted that both above and at the downstream ends of the watersheds the soils HSG was identified as C. Similar neighboring watersheds were identified primarily as B and C, with some locations showing group D. It was assumed based on the location of neighboring type C soils, and the type of soils seen in neighboring watersheds, that an HSG of C was a reasonable assumption for the region with none identified. A figure showing the soil group layout is included in Appendix 2.

4.2.2 Land Use Data

Land use data was determined by downloading GIS data National Land Cover Dataset (NLCD) from the Multi-Resolution Land Characteristics (MRLC) Consortium. The land cover classification values were assigned comparable cover types from Chapter 9 of the National Engineering Handbook, Part 630 (NEH-630). A copy of the spreadsheet showing the cover types used for each NLCD land cover classification is included as Appendix 4. A figure showing the NLCD land cover types is included in Appendix 3.

4.2.3 Curve Number Development

Utilizing the table in Appendix 4, each region of overlapping land use a soil type was assigned a Curve Number (CN). The CN of the watershed as a whole was obtained through ArcGIS by performing a weighted average based on the area and the CN of each region within the watershed. The resulted weighted Curve Numbers are shown below.

Table 8. Curve Number

Watershed	Weighted CN
1	71.8
2	69.2
3	70.9
4	70.9
5	67.3
6	72.1

4.3 Time of Concentration

Time of Concentration (Tc) was originally calculated as part of the Santaquin SDMP and were carried over for use in this Plan-EA, but the process is fully described herein. The longest flow paths were identified using GIS, and by visual review of site conditions broken down into lengths of overland, shallow concentrated, and channel flow. TR-55 methods were used, except that for shallow concentrated flow the formula in HEC-22 was used since it is more directly adaptable to spreadsheet use. The calculations are included in Appendix 5. Basic assumptions used in the calculations include the following:

Table 9. SDMP Times of Concentration Assumptions

Time of Concentration Assumptions		
Parameter	**Value**	**Description**
Sheet Flow Roughness, n	0.4	Woods: Light Underbrush (TR-55 Table 3-1)
Shallow Conc. Intercept coeff., k	0.076	Forest with heavy ground litter (HEC-22, Table 3-3)
Channel Roughness, n	.035	Mountain streams (Chow, 1959)
Hydraulic Radius, R	0.7	Approx. 2 foot wide channel, 1.25 feet deep, 1:1 slopes, other configurations possible

In an effort to review and refine the Tc for the Plan-EA analysis, the velocities of each section were checked. It was noted that sheet flow velocities were very low and the channel velocities high, though the overall average velocities were reasonable, though perhaps faster than typical. To verify the Tc calculations, an independent check of the lengths and slopes was undertaken, the roughness values were revisited, and the method of calculation of the shallow concentrated flow velocity was changed to use the velocity lookup table in Chapter 15 of NEH-630. The revised calculations are included as Attachment 6. The following changes were made:

Table 10. Time of Concentration Quality Control Check Adjustments

Time of Concentration Quality Control Adjustments		
Parameter/Method	**Value**	**Description**
Shallow Concentrated Flow, V	3.0 to 3.75	Used "…woodlands" line in Figure 15-4 of NEH-630, Ch. 15 (value varies with slope)
Channel Roughness, n	0.07	Mountain Stream, upper limit
Hydraulic Radius, R	.8	Approx. 2 foot wide channel, 1.5 feet deep, 1:1 side slopes, other configurations possible

The adjustments resulted in more reasonable velocities for each type of flow, but the overall time and velocity did not change significantly, except in the case of Basin 5. The results are as follows:

Table 11. Time of Concentration Quality Control Check Results

Time of Concentration QC Results			
Basin	**SDMP Results (hr)**	**QC Results (hr)**	**Difference (hr)**
1	0.572	0.537	-0.035
2	0.293	0.207	-0.087
3	0.263	0.210	-0.053
4	0.602	0.527	-0.075
5	0.406	0.667	0.261
6	0.406	0.454	0.048

By observation, most of these differences were recognized as not being large enough to have a significant impact, and are certainly within the margin of error of either method. All of the evaluations for Basin 5 were rerun though with the adjusted time of concentration since its change was sufficient to merit correction.

4.4 Burned Condition Runoff Methodology Adjustments

For burned condition analysis the values determined under normal conditions had to be adjusted to accommodate the changes that occur after a wildfire. The changes were made in accordance with the general recommendations of "Suggested Changes to AGWA to Account for Fire (V 2.1)" (Canfield and Goodrich, USDA-ARS, 2005) and the NRCS Technical Note #4 (TN-4).
Canfield et al (2005) and McLin et al. (2001) noted that post-fire total runoff generally does not have a significant change in volume, but peak flows can increase up to an order of magnitude.
In order to accommodate this, Canfield et al (2005) recommended using a change in the cover when evaluating the curve number to obtain a new CN value for post-burn conditions. Their paper provided tables of new curve numbers based on NLCD land use type, for several common land uses.

4.4.1 Curve Number Post-Burn Adjustments

In order to accommodate the change in volume, Canfield et al (2005) recommended using a change in the cover when evaluating the curve number to obtain a new curve number value for post-burn conditions. Their paper recommended numerical changes in quantity of cover based on burn severity, and they provided tables of new curve numbers based on NLCD land use type for several common land uses. Cerelli (2005) also suggested a method of adjusting the curve number based on adjusting the hydrologic condition, or "cover type".

To accomplish the same end, the hydrologic condition we used to determine the curve number for normal conditions, (see NEH-630 - Chapter 9) was adjusted to the next worse condition from its current state, and the curve number adjusted accordingly. For example, a hydrologic condition of "good" was reduced to "fair", and so forth. Since the soil type in the watersheds southeast of Santaquin are largely Type C, with similar land use types across them, the increase in Curve Number was fairly consistent averaging about 4, and ranging from 2 to 7 for the predominant cover types in the area. Therefore, to be conservative, a uniform increase of 6 was applied to the Curve Numbers on these basins to obtain new runoff results. The resulting curve numbers are shown in Table 12. The adjusted curve number calculations are shown on the second page of Appendix 4.

4.4.2 Time of Concentration Post-Burn Adjustments

The "Suggested Changes to AGWA" and TN-4 publications both suggest that for the velocity method time of concentration, the manning's roughness value be adjusted. This results in a higher peak flow, even with minimal increase in volume. Adjusting the Manning's n only changes the overland flow portion of the calculation, which is over a relatively short distance. The n values were adjusted from 0.4 (Woods with light underbrush, TN-4, Table 10) to 0.11. The adjusted times of concentration are reflected in Table 12.

Table 12. Burned Condition Data and Results

BURN CONDITIONS INPUT AND RESULTS SUMMARY						
BASIN	Curve Number	Time of Concentration (T_c)	AREA	Precipitation Q_{10}	Peak Flow Q_{10}	Volume Q_{10}
		[HR]	[SQ MI]	[IN]	[CFS]	[AC-FT]
Watershed 1	77.8	0.469	0.6266	0.586	174	19.6
Watershed 2	75.2	0.232	0.0688	0.477	19	1.8
Watershed 3	76.9	0.188	0.0531	0.494	21	1.4
Watershed 4	76.9	0.531	0.6875	0.533	157	19.5
Watershed 5	73.3	0.330	0.7109	0.404	147	15.3
Watershed 6	78.1	0.321	0.4510	0.569	154	13.7

Upon review it was realized that the burned condition roughness used for sheet flow, 0.11, was a typo. It was intended to put in a highly conservative value of 0.011 (smooth surface, concrete, asphalt, bare soil, etc.). A value of 0.11 was still considered a reasonable assumption, as it reflected roughness one fourth of the unburned condition. Upon review of the roughness values in Table 15-1 of NEH-630, Ch. 15, it was decided that a value of 0.05 (Fallow, no residue) would be a conservative but realistic assumption. But, upon applying this value the changes in the times of concentration were so small that the changes were deemed unnecessary and the original values were retained.

4.5 Hydrograph Development

Both the WinTR-20 and SITES programs from NRCS utilize integrated unit hydrographs to develop the storm hydrograph. A full discussion of their methodologies will not be attempted here. These programs are designed to follow specific NRCS hydrograph generation methodologies. These programs were utilized to develop all of the discharge hydrographs for the watersheds.

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5.0 COMPARISON AND VALIDATION OF MAGNITUDE OF RESULTS

The watersheds in question do not have regular stream flows, only producing runoff during significant storm events or high snowmelt. No stream gauges exist. Comparisons to local stream gauges would have considerable unknown errors due to the many differing characteristics of these watersheds from those that produce continuous measurable flows.

Streamstats (USGS) was used to estimate 100-year flows, but reported that the watershed parameters were outside the limits of the method, resulting in unknown errors. It produced considerably lower design flows.

The USGS streamgage analysis performed as part of the Santaquin Canyon hydrology technical memorandum (McMillen, 2016) was also consulted for comparison. This study found that the average flow in cubic-feet per second per square mile of area (CSM) for the streams in the area was roughly 21. The results for streams in the region tended to cluster between 15 CSM and 30 CSM, with the two highest results at 37.6 and 40.6 CSM. The higher values corresponded to some of the smaller watersheds analyzed, and the general trend appeared to be that the smaller the watersheds the higher the CSM values. The table below uses Basin 1 to show how the results from our analysis compare to these other statistical methods for the 100-year event. This comparison also assumes that the 100-year precipitation corresponds with the 100-year stream flow, which is not necessarily the case.

Table 13. Magnitude Validation Summary

	Basin 1	Streamstats
100-Year Peak Flow (cfs)	300.6	39.6
CSM	480	62

With the very high CSM values, this data both suggests that our calculated flows are likely conservative, but also demonstrates that the conditions between the small, steep watersheds being analyzed in this study and the conditions in the larger watersheds that produce regular streamflows cannot be readily compared statistically. The synthetic, deterministic methods utilized in this study will therefore be relied upon without further calibration. Calibration appears merited, but no reliable means of such is available. Refining and comparing time of concentration and lag time methods does affect the peak flows, but not sufficiently to alter the order of magnitude difference shown in Table 12.

6.0 MODELING RESULTS

WinTR-20 could be used to perform hydrologic analysis only, but the nature of modeling in SITES merges the input and output for both the hydrologic and hydraulic analysis together. Therefore, the section below tabulates some of the key data points derived from these models, but not all of the data generated by the SITES model runs. The number of models and runs are significant, so the input and output data are not included directly with this memo, but can be supplied separately.

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6.1 Economic Analysis Events Modeling Results

Table 14 includes the peak inflows and total volumes of the Economic Analysis Events. The corresponding hydrographs were generated based on the precipitation depths shown in Table 2 and the time of concentration, area and CN determined for each watershed. Example hydrographs for Watershed 1 are shown in Figure 2 below.

Figure 2. Economic Analysis Events Example Hydrographs

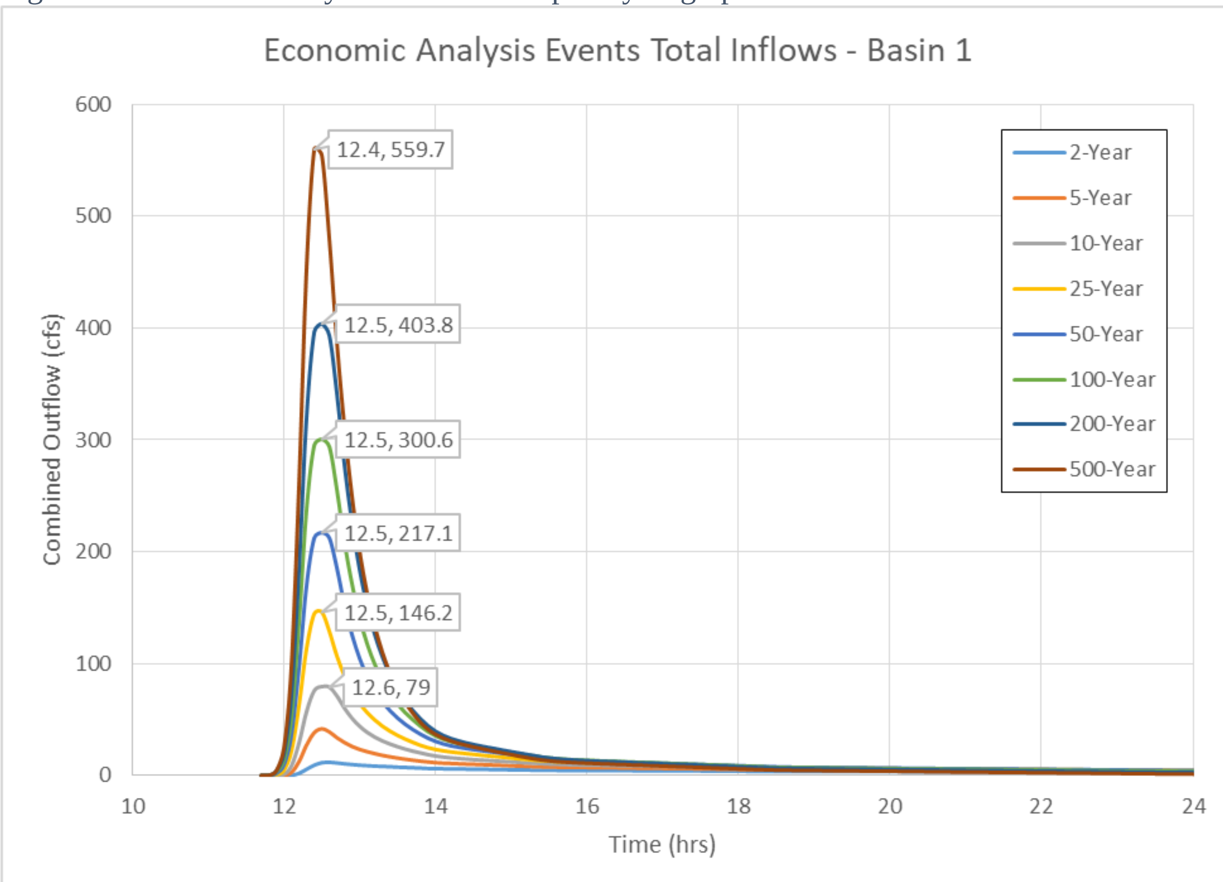

Table 14. Peak Flow and Total Volume – Economic Analysis Events

Watershed 1	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
Peak Flow (cfs)	11.9	41.8	79.6	149	217.1	300.6	403.8	569.7
Volume (acre-ft)	4.7	8.5	12.4	18.3	23.4	28.7	34.5	42.6

Watershed 2	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
Peak Flow (cfs)	0.6	3.8	8.6	18.2	27.9	40.3	55.2	80.4
Volume (acre-ft)	0.1	0.5	1.0	1.6	2.1	2.6	3.1	3.9

Watershed 3	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
Peak Flow (cfs)	0.8	4.2	8.7	17.1	25.7	36.4	49.4	71.1
Volume (acre-ft)	0.1	0.4	0.7	1.2	1.6	2.0	2.5	3.2

Watershed 4	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
Peak Flow (cfs)	8.8	35.9	71.2	139.1	207.8	291.6	395.8	563.8
Volume (acre-ft)	4.3	8.2	12.1	18.2	23.4	29.0	35.1	43.5

Watershed 5	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
Peak Flow (cfs)	3.1	15.6	38.6	88.4	142.1	209.5	295.7	438.2
Volume (acre-ft)	2.5	5.6	8.8	14.2	18.8	23.8	29.4	37.2

Watershed 6	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr
Peak Flow (cfs)	9.5	35.3	67.9	127.8	188.8	262.5	352.6	502.1
Volume (acre-ft)	3.2	5.8	8.5	12.6	16.1	19.9	23.9	29.4

6.2 Principal Spillway Analysis Events Modeling Results

Table 15 includes the peak inflow values for the PSH Curve Number Method ("Rainfall Method") and the PSH Runoff Method. Precipitation depths shown in Table 3 resulted in the flows shown for the PSH CN Method. Refer to the Precipitation Depth section of this report for further details on the events analyzed.

Table 15. Peak Inflow – Principal Spillway Analysis Events

Basin	Peak Flow	PSH CN Method	PSH Runoff Method
Basin 1	Basin 1 Above Grade (High Hazard - P_{100})		
	Peak Flow (cfs)	61.44	67.51
	Basin 1 Below Grade (Low Hazard – P_{25})		
	Peak Flow (cfs)	50.33	50.72

Basin	Peak Flow	PSH CN Method	PSH Runoff Method
Basin 2	Basin 2 Above Grade (High Hazard - P_{100})		
	Peak Flow (cfs)	5.65	7.58
	Basin 2 Below Grade (Low Hazard – P_{25})		
	Peak Flow (cfs)	0.3	5.7

Basin	Peak Flow	PSH CN Method	PSH Runoff Method
Basin 3	Basin 3 Above Grade (High Hazard - P_{100})		
	Peak Flow (cfs)	5.07	5.85
	Basin 3 Below Grade (Low Hazard – P_{25})		
	Peak Flow (cfs)	2.7	4.38

Basin	Peak Flow	PSH CN Method	PSH Runoff Method
Basin 4	Basin 4 Above Grade (High Hazard - P_{100})		
	Peak Flow (cfs)	61.27	73.83
	Basin 4 Below Grade (Low Hazard – P_{25})		
	Peak Flow (cfs)	33.37	55.39

Basin	Peak Flow	PSH CN Method	PSH Runoff Method
Basin 5	Basin 5 Above Grade (High Hazard - P_{100})		
	Peak Flow (cfs)	44.0	75.44
	Basin 5 Below Grade (Low Hazard – P_{25})		
	Peak Flow (cfs)	13.0	56.56

Basin	Peak Flow	PSH CN Method	PSH Runoff Method
Basin 6	Basin 6 Above Grade (High Hazard - P_{100})		
	Peak Flow (cfs)	44.74	49.52
	Basin 6 Below Grade (Low Hazard – P_{25})		
	Peak Flow (cfs)	24.55	37.16

6.3 Auxiliary Spillway Evaluation Events Modeling Results

Table 16 shows the resulting peak flows and total volumes generated by the storm events shown in Table 4. Below grade and above grade options exist for the same watershed, and the precipitation depth considered varies based on the hazard classification as described in Section 3.1.3. The runoff results of the 100-year 6-hour saturated watershed are also

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included for use in the freeboard analysis which will be discussed in the Hydraulics Technical Memo.

Table 16. Peak Inflow – Auxiliary Spillway Analysis Events

	Event	6hr SEF	24hr SEF	72hr SEF	6hr ARCIII
Basin 1	Basin 1 Above Grade				
	Peak Flow (cfs)	548	507	183.5	418.5
	Volume (acre-ft)	73.9	189.9	242.5	#
	Basin 1 Below Grade				
	Peak Flow (cfs)	221.1	110.5	42.7	418.5
	Volume (acre-ft)	33.4	44.4	49.0	#

	Event	6hr SEF	24hr SEF	72hr SEF	6hr ARCIII
Basin 2	Basin 2 Above Grade				
	Peak Flow (cfs)	76.5	55.1	19.8	60.7
	Volume (acre-ft)	8.2	19.9	25.6	#
	Basin 2 Below Grade				
	Peak Flow (cfs)	26.4	11	4.3	60.7
	Volume (acre-ft)	3.2	4.3	4.8	#

	Event	6hr SEF	24hr SEF	72hr SEF	6hr ARCIII
Basin 3	Basin 3 Above Grade				
	Peak Flow (cfs)	65.5	44.6	15.7	51.8
	Volume (acre-ft)	6.8	16.1	20.5	#
	Basin 3 Below Grade				
	Peak Flow (cfs)	23.1	6.2	3.5	51.8
	Volume (acre-ft)	2.7	3.5	3.9	#

	Event	6hr SEF	24hr SEF	72hr SEF	6hr ARCIII
Basin 4	Basin 4 Above Grade				
	Peak Flow (cfs)	582.7	544.7	199.4	442.5
	Volume (acre-ft)	80.1	204.6	262.0	#
	Basin 4 Below Grade				
	Peak Flow (cfs)	215.6	111.6	44.5	442.5
	Volume (acre-ft)	34.2	45.7	50.9	#

	Event	6hr SEF	24hr SEF	72hr SEF	6hr ARCIII
Basin 5	Basin 5 Above Grade				
	Peak Flow (cfs)	476.6	510.4	196.0	355.9
	Volume (acre-ft)	71.9	194.2	251.7	#
	Basin 5 Below Grade				
	Peak Flow (cfs)	157.5	91.3	39.2	355.9
	Volume (acre-ft)	28.8	39.2	44.1	#

	Event	6hr SEF	24hr SEF	72hr SEF	6hr ARCIII
Basin 6	Basin 6 Above Grade				
	Peak Flow (cfs)	494.6	373.5	132.3	367
	Volume (acre-ft)	57.4	136.9	174.7	#
	Basin 6 Below Grade				
	Peak Flow (cfs)	251.7	80.4	30.5	367
	Volume (acre-ft)	31.3	31.3	34.8	#

Value Not Reported in SITES Output

6.4 Burned Condition Runoff Modeling Results

The peak flows and volume from the hydrographs developed for the burned condition analysis are summarized below. The peak flows were then bulked using the methodology described in the NRCS Technical Note 4, "Sediment Bulking", using equation 11. It should be noted, Equation 11 in TN-4 appears to have an error in the denominator. The correct form is shown below.

$$BF = \frac{Q_w + Q_{sed}}{Q_w} = \frac{1}{1 - C_v}$$

The volumes were bulked using a simple assumption that:

$$V_{bulked} = V_{water} + V_{sediment}$$

An assumption of 20% sediment concentration was assumed to be conservative. A 20% concentration is generally assumed to be the transition point between standard flow and hyper-concentrated flow (TN-4, Elliot et al. 2005, Santi et al. 2006, Pierson 2005). According to documentation by USGS (Pierson 2005), which is cited in TN-4, normal suspended sediment concentrations are 5 to 10 percent.

Table 17. Post-Burn Conditions Analysis Results

BURN CONDITIONS INPUT AND RESULTS SUMMARY					
BASIN	Precipitation Q_{10} [IN]	Peak Flow Q_{10} [CFS]	Bulked Peak Flow Q_{10} [CFS]	Volume Q_{10} [AC-FT]	Bulked Volume Q_{10} [AC-FT]
Watershed 1	0.586	174	218	19.6	23.52
Watershed 2	0.477	19	24	1.8	2.16
Watershed 3	0.494	21	26	1.4	1.68
Watershed 4	0.533	157	196	19.5	23.4
Watershed 5	0.404	147	184	15.3	18.36
Watershed 6	0.569	154	193	13.7	16.44

6.5 Debris Flow Event Modeling Results

The debris flow volumes determined for each of the watersheds are tabulated below in Table 18. The calculations can be seen in Attachment 9. For comparison, the largest estimated debris flow volume reported in the ten "Dry Mountain" watersheds that had similar flows, which includes the watersheds in this study, was 20,000 cubic yards, or 12.4 acre-feet (assumed to be Watershed 4 in this study). The remainder ranged from 30 to 13,000 cubic yards, or 0.02 to 8.1 acre-feet, respectively (Giraud and McDonald, 2007).

Table 18. Debris Flow Volumes

Debris Flow Volumes	
Watershed	Volume (acre-feet)
1	11.0
2	1.62
3	1.25
4	11.9
5	11.6
6	7.6

7.0 CONCLUSIONS

The events considered most critical to the scale of the basins are the economic analysis events, burned condition events, and debris flows. These design events are larger than previously considered in the preliminary Santaquin SDMP due to the addition of the 24-hour duration into the analysis as part of the NRCS required analysis, and have higher peak flows due to the more conservative critically stacked temporal distributions used in the WinTR-20 program. NOAA Atlas 14 distributions, which were used in the draft SDMP, attempt to mimic historic storms in the region. The end result is that the approach of retaining the entire 100-storm originally contemplated for the city will likely be infeasible, making the outflow system a critical part of the design in order to handle the flows that may be encountered. The storm for which we provide "full protection" may also have to be reconsidered based on the economics and feasibility of designing flood control systems to handle the larger events. This is especially true considering that NRCS criteria require that if the auxiliary spillway is earthen or vegetated the Principal Spillway Hydrograph (a 100-year 10-day storm) must be able to pass through the outlet system ("principal spillway") without any flow going over the auxiliary spillway. This will be addressed in the Hydraulics Technical Memo.

The assumptions involved in the bulking calculations may deserve reevaluation if they prove to have a significant effect on the final system design.

No final conclusions can be drawn from this data, as this data must be routed through the proposed reservoirs before the full meaning of these results can be determined. This will be discussed in the Hydraulics Technical Memo. It is acknowledged that in the case of the SITES program much of this hydraulic analysis was performed simultaneously with the hydrologic modeling. A summary

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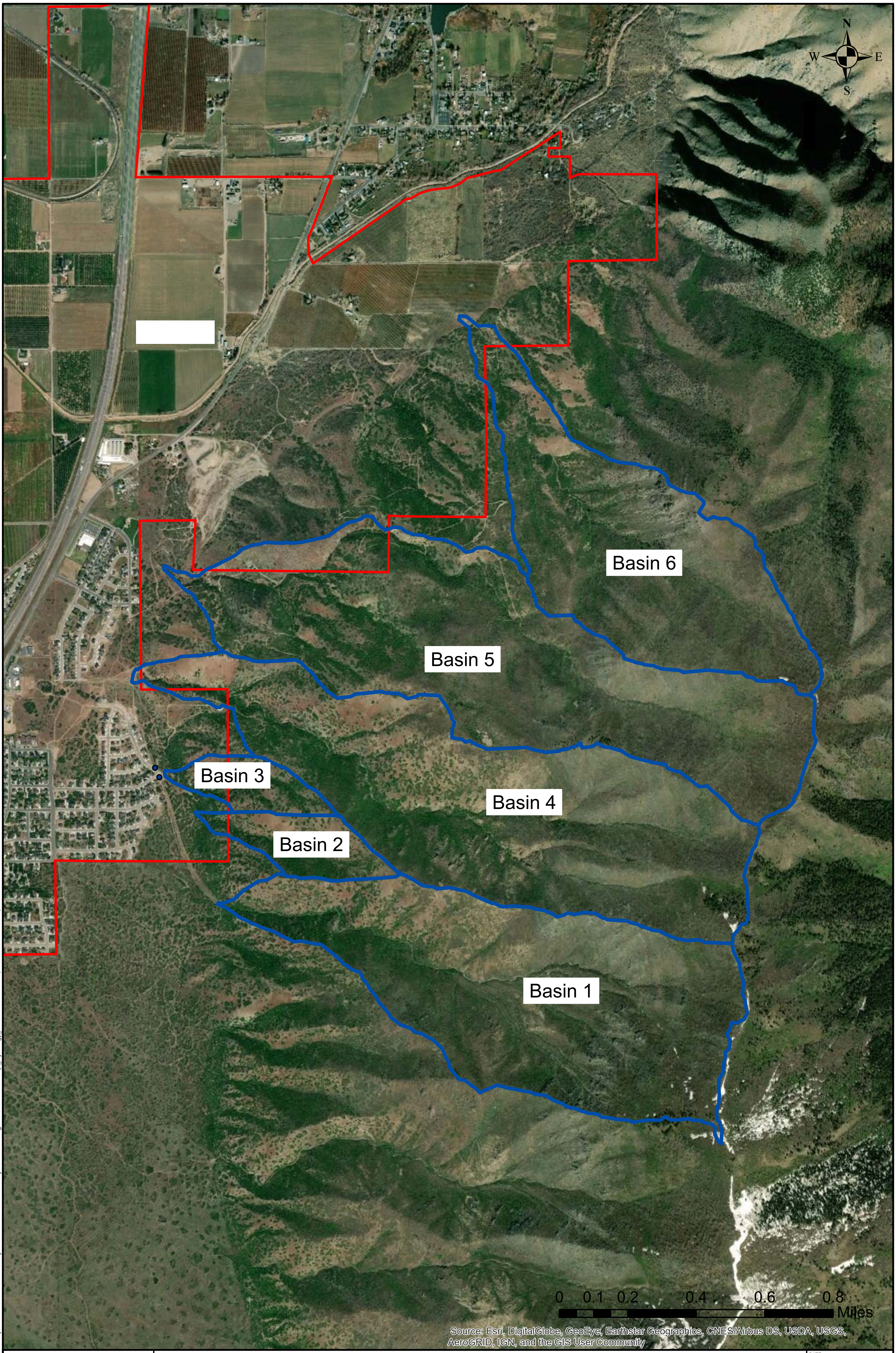
of the combined results will be included in the Hydraulics Technical Memo. A separate sedimentation memo will also be prepared and submitted.

8.0 APPENDICES

1. Watershed Map
2. Soil Map
3. Land Use Map
4. NLCD Land Use Curve Number Table
5. Time of Concentration Calculations
6. Time of Concentration Calculations Quality Control Check
7. Time of Concentration Calculations – Burned Condition
8. Burned Watershed Bulking Calculations
9. Debris Flow Volume Calculations



Santaquin Flood Control Plan-EA

Watershed Delineation

DATE 7/18/2018

DRAWN

Figure 1

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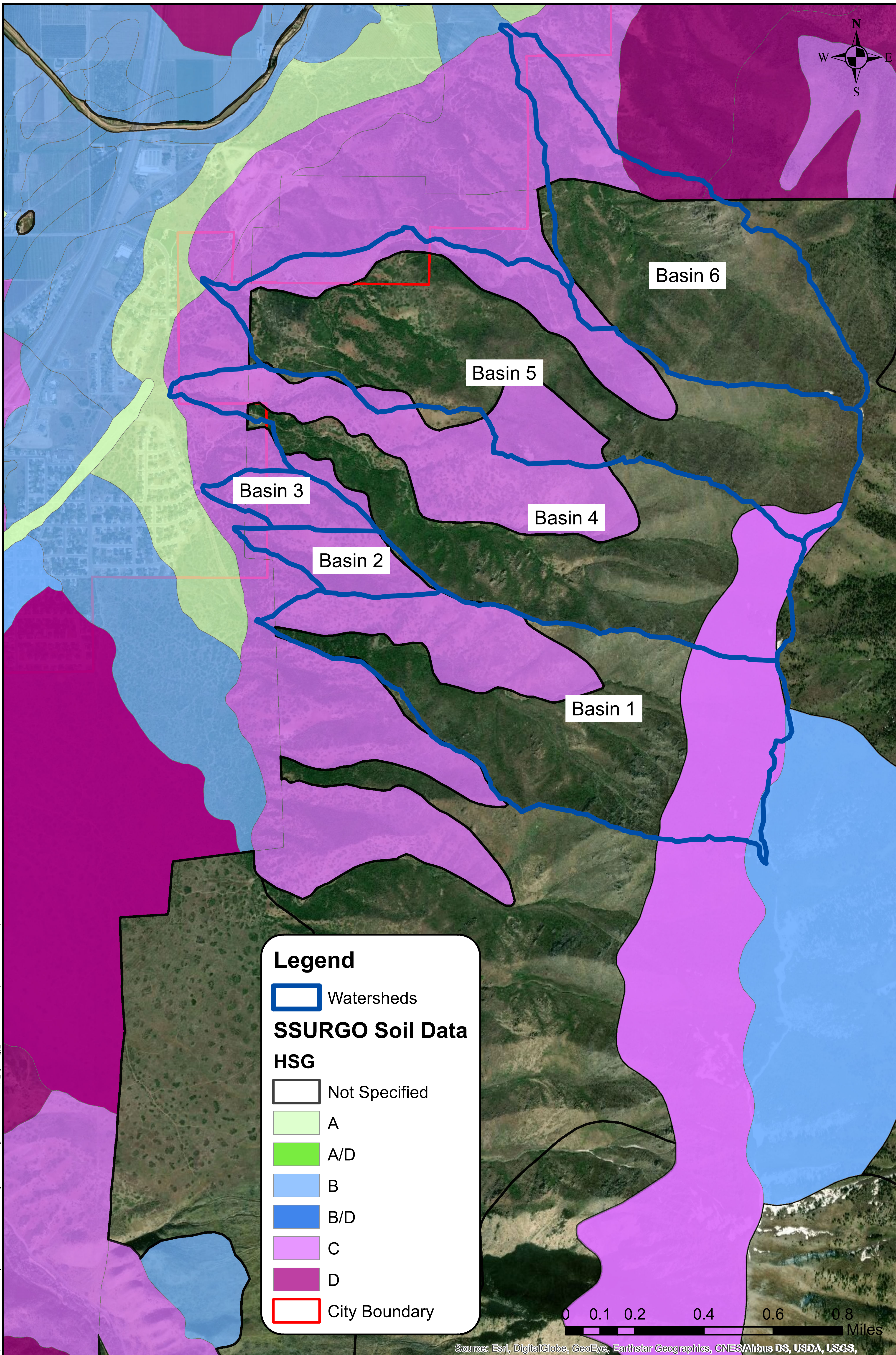

Santaquin Flood Control Plan-EA

Soil Groups

DATE 7/18/2018

DRAWN

Figure 1

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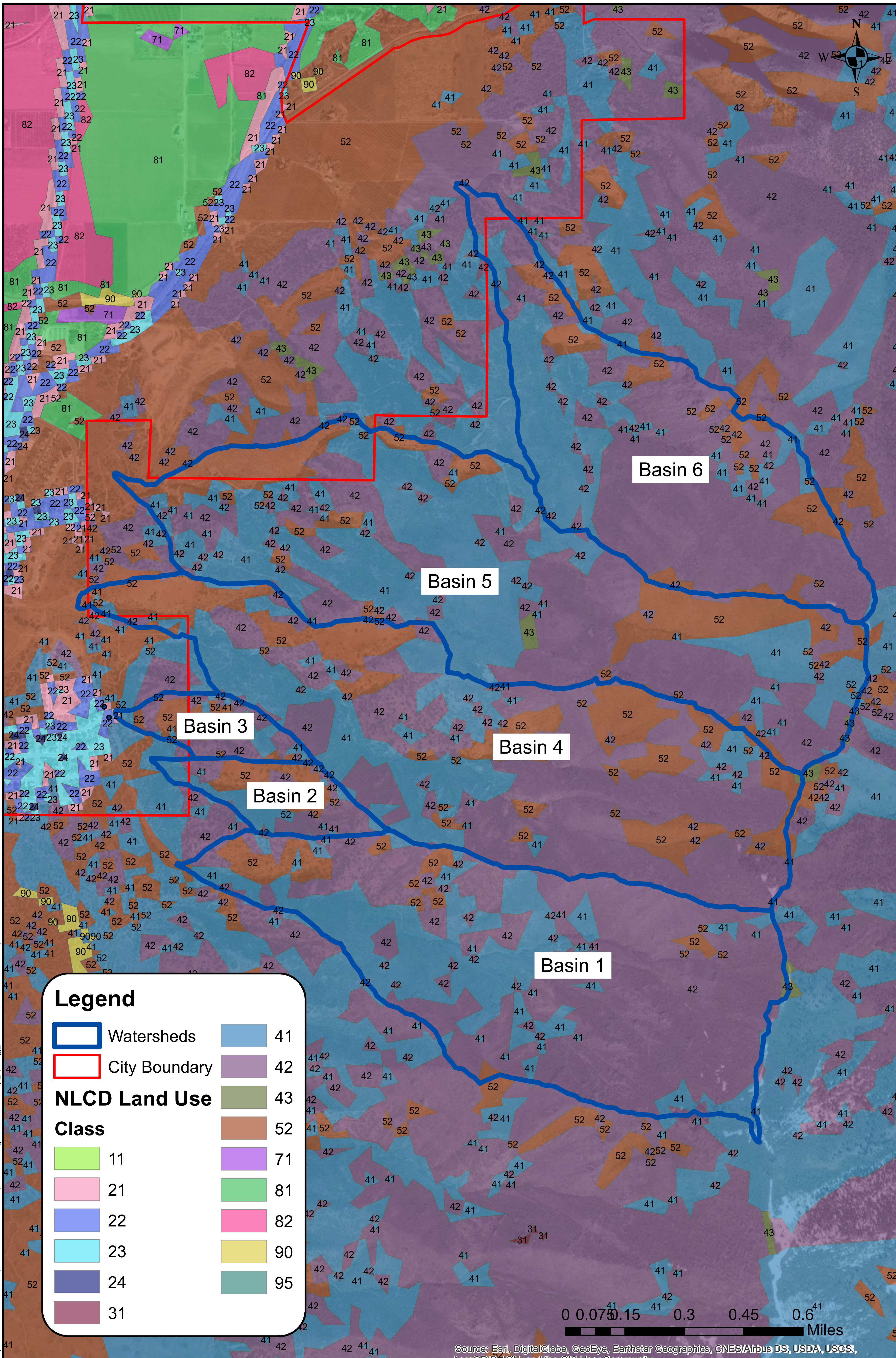

Santaquin

Santaquin Flood Control Plan-EA

NLCD Land Use Classes

DATE 7/18/2018

DRAWN

Figure _

Mountain Watersheds Curve Number Table

National Land Cover Database (NLCD)		NRCS Land Use Equivalent		Hydrologic Soil Group				
Value	Definition	NRCS Description Used	Condition	A	B	C	D	Notes
1	Unknown	Impervious	NA	98	98	98	98	
11	Open Water - All areas of open water, generally with less than 25% cover or vegetation or soil	Open Water	NA	100	100	100	100	
12	Perennial Ice/Snow - All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.	Impervious	NA	98	98	98	98	
21	Developed, Open Space - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.	Open Space	Good	49	69	79	84	
22	Developed, Low Intensity -Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.	Residential, 1 acre lots	NA	51	68	79	84	
23	Developed, Medium Intensity - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.	Residential, 1/2 acre lots	NA	54	70	80	85	
24	Developed, High Intensity - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.	Residential, 1/8 acre or less (townhouses)	NA	77	85	90	92	
31	Barren Land (Rock/Sand/Clay) - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.	Fallow, Bare Soil	NA	77	86	91	94	
32	Unknown	Impervious	NA	98	98	98	98	
41	Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.	Woods	Fair	36	60	73	79	
42	Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.	Woods	Fair	36	60	73	79	
43	Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.	Woods	Fair	36	60	73	79	
51	Dwarf Scrub - Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.	NA	NA	0	0	0	0	
52	Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.	Desert Shrub	Good (minimal runoff reported)	49	68	79	84	
71	Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.	Herbaceous	Good (minimal runoff reported)	39	62	74	85	No A type soil in described for semiarid herbaceous rangeland, agricultural pasture/grassland/range used to determine value for soil type A
72	Sedge/Herbaceous - Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.	NA						
73	Lichens - Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.	NA						
74	Moss - Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.	NA						
81	Pasture/Hay - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.	Pasture, grassland, or range - forage for grazing	Fair	49	69	79	84	
82	Cultivated Crops - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.	Small Grain, Straight row & Crop residue	Good	63	75	83	87	
90	Woody Wetlands - Areas where forest or shrub land vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	*Wetlands-Forested	NA	45	66	77	83	*Pineview Reservoir Utah DEQ Pineview Study (3/26/2002), https://deq.utah.gov/ProgramsServices/programs/water/watersheds/docs/2006/09Sep/Pineview_Res_Appendix_B.pdf
95	Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	*Wetlands-nonforested	NA	49	69	79	84	*Pineview Reservoir Utah DEQ Pineview Study (3/26/2002), https://deq.utah.gov/ProgramsServices/programs/water/watersheds/docs/2006/09Sep/Pineview_Res_Appendix_B.pdf

Mountain Watersheds Curve Number Table

Burned Conditions Adjustment

National Land Cover Database (NLCD)		NRCS Land Use Equivalent		Original Curve Number Hydrologic Soil Group				**Burned Curve Number**								
Value	**Definition**	**NRCS Description Used**	**Condition**	**A**	**B**	**C**	**D**	Condition	A	B	C	D	A	B	C	D
41	Deciduous Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.	Woods	Fair	36	60	73	79	Poor	45	66	77	83	9	6	4	4
42	Evergreen Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.	Woods	Fair	36	60	73	79	Poor	45	66	77	83	9	6	4	4
43	Mixed Forest - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.	Woods	Fair	36	60	73	79	Poor	45	66	77	83	9	6	4	4
52	Shrub/Scrub - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.	Desert Shrub	Good (minimal runoff reported)	49	68	79	84	Fair	55	72	81	86	6	4	2	2
71	Grassland/Herbaceous - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.	Herbaceous	Good (minimal runoff reported)	39	62	74	85	Fair	49	71	81	89	10	9	7	4
												Average Change	8.6	6.2	4.2	3.6

3.9	Average of C and D soil types (predominant in mountain watersheds)

Time of Concentration Calculations - Mountain Watersheds

GIS Data | Identifier | Data Entry | Computation | Basins Not Part of Study

Normal Watershed Conditions

Velocity Checks

Gridcode	Shape_Leng	Shape_Length	Shape_Area	CN	Basin #	Hillside Location	Flow_Slope	Flow_Length	Sheet Flow Length	Sheet Flow Slope	2-yr, 24-hr rainfall	Roughness Coefficient, n	Sheet Flow Time	Shallow Concentrated Length	Shallow Concentrated Slope	Intercept Coeff, k	Shallow Concentrated Time	Channel Flow Length	Channel Slope	Roughness Coeff, n	Hydraulic Radius	Channel Flow Time	Total Time	Sheet Flow	Shallow Conc. Velocity	Channel Velcity	Overall Velocity Check
15	6676.9	6464.5	1625603.7	71.8	1	East	0.4	9003.2	100	0.4	1.59	0.4	0.16	2070.0	0.6	0.076	0.31	6833.2	0.3	0.035	0.7	0.10	0.572	0.174	1.867	18.205666	4.3730693
14	2187.8	2184.9	179203.9	69.2	2	East	0.4	3396.6	100	1.3	1.59	0.4	0.09	1230.0	0.7	0.076	0.16	2066.6	0.2	0.035	0.7	0.03	0.293	0.294	2.076	16.76437	3.21731104
34	2191.6	1834.8	137890.9	70.9	3	East	0.4	2883.3	100	0.8	1.59	0.4	0.12	665.0	0.4	0.076	0.12	2118.3	0.3	0.035	0.7	0.03	0.263	0.239	1.584	19.70847	3.04849893
0	7482.9	7381.5	1782638.8	70.9	4	East	0.3	11099.6	100	0.9	1.59	0.4	0.11	2070.0	0.5	0.076	0.34	8929.6	0.2	0.035	0.7	0.15	0.602	0.253	1.675	16.687007	5.12375763
1	7954.5	7736.1	1841030.9	67.3	5	East	0.3	12349.6	100	0.8	1.59	0.4	0.12	500.0	0.3	0.076	0.10	11749.6	0.3	0.035	0.7	0.19	0.406	0.236	1.425	17.098056	8.44522691
7	5722.2	5719.3	1168359.1	72.1	6	East	0.4	8552.7	100	0.6	1.59	0.4	0.13	940.0	0.4	0.076	0.17	7512.7	0.4	0.035	0.7	0.10	0.406	0.210	1.539	20.026381	5.85018751

QC Check - Normal Conditions

Time of Concentration Calculations - Mountain Watersheds

GIS Data | Identifier | Data Entry | Computation | Basins Not Part of Study

TR-55 USDA-NRCS

Gridcode	Shape_Area	CN	CN Change	CN-Burned	Basin #	Hillside Location	Flow_Slope	Flow_Length	Start Elev	Sheet Flow Length	Sheet Flow Slope	2-yr, 24-hr rainfall	Roughness Coefficient, n	Sheet Flow Time	Mid Elev	Shallow Concentrated Length	Shallow Concentrated Slope	Flow Velocity	Shallow Concentrated Time	Low Elev	Channel Flow Length	Channel Slope	Roughness Coeff, n	Hydraulic Radius	Bottom Elev	Channel Flow Time	Total Time				
							feet/feet	feet	m	feet	ft/ft	in	Table 3-1 (TR-55)	hour	m	feet (Revised Values)	ft/ft (Revised)	Figure 15-4 NEH Ch. 15 (…and woodlands)	hour	m	feet (Revised Values)	ft/ft	FHWA-NHI-08-090, Table B-2	feet	m	hour	hour	Sheet Average	Shallow Average	Channel Average	Overall Average
15	1625603.7	71.8	6.0	77.8	1	East	0.4	9003.2	2638.0	100	0.4	1.59	0.40	0.16	2627.0	2584.0	0.4	3.000	0.24	2273.0	5760.0	0.4	0.070	0.8	1660	0.14	0.537	0.2	3.0	11.6	4.7
14	179203.9	69.2	6.0	75.2	2	East	0.4	3396.6	2039.7	100	1.3	1.59	0.40	0.09	1998.8	600.0	0.5	3.500	0.05	1738.8	2700.0	0.4	0.070	0.8	1581.6	0.06	0.207	0.3	3.5	11.6	4.6
34	137890.9	70.9	6.0	76.9	3	East	0.4	2883.3	1911.9	100	0.8	1.59	0.40	0.12	1887.6	550.0	0.6	3.750	0.04	1805.7	1900.0	0.3	0.070	0.8	1583	0.05	0.210	0.2	3.8	10.0	3.8
0	1782638.8	70.9	6.0	76.9	4	East	0.3	11099.6	2537.0	100	0.9	1.59	0.40	0.11	2509.0	1870.0	0.5	3.500	0.15	2224.0	9725.0	0.3	0.070	0.8	1551	0.27	0.527	0.3	3.5	10.0	5.8
1	1841030.9	67.3	6.0	73.3	5	East	0.3	12349.6	2511.0	100	0.8	1.59	0.40	0.12	2487.5	1725.0	0.4	3.000	0.16	2437.7	11500.0	0.2	0.070	0.8	1508	0.39	0.667	0.2	3.0	8.2	5.1
7	1168359.1	72.1	6.0	78.1	6	East	0.4	8552.7	2511.9	100	0.6	1.59	0.40	0.13	2494.3	1300.0	0.5	3.000	0.12	2385.0	7300.0	0.3	0.070	0.8	1569.5	0.20	0.454	0.2	3.0	10.0	5.2

Time of Concentration Calculations - Mountain Watersheds

GIS Data | Identifier | Data Entry | Computation | Basins Not Part of Study

Post-Burn Conditions

Gridcode	Shape_Area	CN	CN Change	CN-Burned	Basin #	Hillside Location	Flow_Slope	Flow_Length	Sheet Flow Length	Sheet Flow Slope	2-yr, 24-hr rainfall	Roughness Coefficient, n	Sheet Flow Time	Shallow Concentrated Length	Shallow Concentrated Slope	Intercept Coeff, k	Shallow Concentrated Time	Channel Flow Length	Channel Slope	Roughness Coeff, n	Hydraulic Radius	Channel Flow Time	Total Time
							feet/feet	feet	feet	ft/ft	in	Table 3-2 (HEC 22)	hour	feet	ft/ft	Table 3-3	hour	feet	ft/ft	Table 3-4	feet	hour	hour
15	1625603.7	71.8	6.0	77.8	1	East	0.4	9003.2	100	0.4	1.59	0.11	0.06	2070.0	0.6	0.076	0.31	6833.2	0.3	0.035	0.7	0.10	0.469
14	179203.9	69.2	6.0	75.2	2	East	0.4	3396.6	100	1.3	1.59	0.11	0.03	1230.0	0.7	0.076	0.16	2066.6	0.2	0.035	0.7	0.03	0.232
34	137890.9	70.9	6.0	76.9	3	East	0.4	2883.3	100	0.8	1.59	0.11	0.04	665.0	0.4	0.076	0.12	2118.3	0.3	0.035	0.7	0.03	0.188
0	1782638.8	70.9	6.0	76.9	4	East	0.3	11099.6	100	0.9	1.59	0.11	0.04	2070.0	0.5	0.076	0.34	8929.6	0.2	0.035	0.7	0.15	0.531
1	1841030.9	67.3	6.0	73.3	5	East	0.3	12349.6	100	0.8	1.59	0.11	0.04	500.0	0.3	0.076	0.10	11749.6	0.3	0.035	0.7	0.19	0.330
7	1168359.1	72.1	6.0	78.1	6	East	0.4	8552.7	100	0.6	1.59	0.11	0.05	940.0	0.4	0.076	0.17	7512.7	0.4	0.035	0.7	0.10	0.321

Santaquin Flood Control Plan-EA
Post Burn Analysis (10-yr 24-hr Event)

Bulking Calculations

$$BF = \frac{Q_w + Q_{sed}}{Q_w} = \frac{1}{1 + C_v}$$

C_v	20%	Sediment Concentration

Label	Hydrograph Volume (ac-ft)	Peak Flow (ft^3/s)	Bulking Factor (BF)	Bulked Peak Flow (cfs)	Volume Bulking Factor	Bulked Volume (ft^3)
1	19.6	174	1.25	218	1.20	23.52
2	1.8	19	1.25	24	1.20	2.16
3	1.4	21	1.25	26	1.20	1.68
4	19.5	157	1.25	196	1.20	23.4
5	15.3	147	1.25	184	1.20	18.36
6	13.7	154	1.25	193	1.20	16.44

Debris Flow Volumes

Santaquin City Storm Drain Master Plan

May-17

Cannon et al. (2010)

$$\ln V = 7.2 + 0.6(\ln A) + 0.7(B)^{1/2} + 0.2(T)^{1/2} + 0.3$$

Variable	Units	Description
A	km^2	Area of basin w/slopes 30% or greater
B	km^2	Area of basin burned at high and moderate Severity
T	mm	Rainfall Depth
V	m^3	Volume of Material

R^2*	0.83
Std. Error*	0.9

*Based on basins used to develop the formula

Assumptions:

(1) Entire Basin is burned

(2) Percentage burned at high to moderate severity matches percentage of Molley Fire that was moderate to high severity based on federal GIS Data (29.3%)

(3) 1-Hour, 5-Year Storm Depth Used - <2 to 10-Yr Recommended due to limited time burned area is in debris flow type conditions and history of debris flows occuring in higher recurrance interval storms.

Basin (Object ID)	Critical Watershed #	A (km^2)	Percentage of area over 30% Slope	Basin Area (ft^2)	B (km^2)	Rainfall Depth (in)	T (mm)	V (m^3)	V (ac-ft)	Notes
20	1	1.56	0.957940171	17,506,605	1.626417	0.729	18.5166	13621.18	11.04288	
15	2	0.17	0.959211787	1,929,894	0.179293	0.729	18.5166	1999.781	1.621251	
13	3	0.12	0.856360733	1,484,982	0.137959	0.729	18.5166	1539.33	1.247957	
16	4	1.64	0.920565032	19,197,765	1.783531	0.729	18.5166	14661.16	11.88601	
14	5	1.53	0.829957075	19,826,618	1.841953	0.729	18.5166	14261.45	11.56196	
12	6	1.04	0.891894829	12,582,443	1.168947	0.729	18.5166	9343.735	7.575097	

ATTACHMENT 2

HYDRAULICS REPORT

Santaquin City Flood Control Plan- EA Hydraulics Report

PREPARED FOR: RESOURCES CONVERVATION SERVICE (NRCS), USDA

DECEMBER 2018

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Contents

1.0 Introduction

This technical report documents the hydraulic aspects of the existing and proposed scenarios pertaining to the construction of debris basins along the east bench of Santaquin. The goal of this document and the hydrology report is to demonstrate compliance with State and Federal design guidelines for the purpose of establishing a footprint which can be evaluated for an environmental assessment.

The data from the hydrology, sedimentation, and other studies were brought together in the hydraulics analysis to determine volume and capacity requirements for the reservoir and the principal and auxiliary spillways for applicable alternatives. The resulting flows were then used to analyze the downstream effects of the various debris basin options for the purposes of determining the economic benefits from the potential structures, to verify effects on floodplains and potential induced flooding from spillways, and to determine downstream system capacities and requirements.

Additional analysis has also been performed to verify adequate freeboard for wave action, to meet spillway regulations, and to confirm the hazard rating of the basin.

In order to determine the most cost effective and appropriate option for control of floods and debris flow above the East Bench areas of Santaquin, several mitigation options were considered. Through a vetting process debris basins were determined to offer the highest level of protection from both flood and debris flows.

Two main approaches were taken with regard to how the debris basins would be built, function, and what level of protection they would provide. They will be referred to as “Approach A” and “Approach B” and are described below. Both approaches have been analyzed for economic purposes to see which provides the greatest net monetary benefit. The monetary benefit is based on capital and maintenance costs as well as protection from flood damages provided by each option. Both options will be discussed in this report so as to document the hydraulic methods used.

Approach A was the approach that was modeled first. As the design progressed and the plan-environmental assessment process advanced, several options became more desirable than others based on cost, grading, client preference, overall impacts, etc. For this reason, there are fewer combinations and types of debris basins modeled for Approach B. The less desirable options were purposely excluded from further study.

Approach A

Approach A consists of debris basins which would roughly contain the 25-year volume. It also has adequate volume for 50 years’ of sediment. The basins would be constructed with a spillway and outlet structure which would be connected to a pipe network that together with the basin, can safely convey the entire 100-year flows. The approach is based on the assumption that there is adequate capacity for the flows located several miles to the north in Spring Creek and under Red Bridge in western Payson. The pipe system for conveying the flows would need to go over or under (most likely under) the Strawberry-Highline Canal, and be piped or possibly kept in an open channel southward through private property, until it reaches Spring Creek. The pipe system would go under several overpass embankments, and be bored underneath I-15. In addition, several large diameter culverts downstream would need to be enlarged. Based on flow estimates and average slope, the downstream pipe system would be a 60 inch diameter pipe or equivalent from the Strawberry-Highline Canal and northward.

Approach B

Approach B consists of debris basins which would completely contain the 50-year volume. The basin also has volume for 25 years' worth of sediment. The basins would have a tower with an outlet pipe. The tower would have an orifice in the side of it to allow the basin to drain while restricting flows to a minimal flow rate. The tower would be open only at the top and would only be activated when water within the basin is deep. This approach would not include an extensive downstream pipe network. Flows for events larger than the 50-year event would first fill up the basin, and then exit through the tower and eventually overtop the emergency concrete spillway, as needed. The flows would be directed into their historic flow paths so as to not cause induced flooding. Although this approach does not provide full containment of the 100-year event, it significantly reduces flood damages associated with the 100-year event by reducing the peak flow rate to a non-threatening level.

Figure 1 on the following page shows the general location of the proposed basins along the east bench in Santaquin.

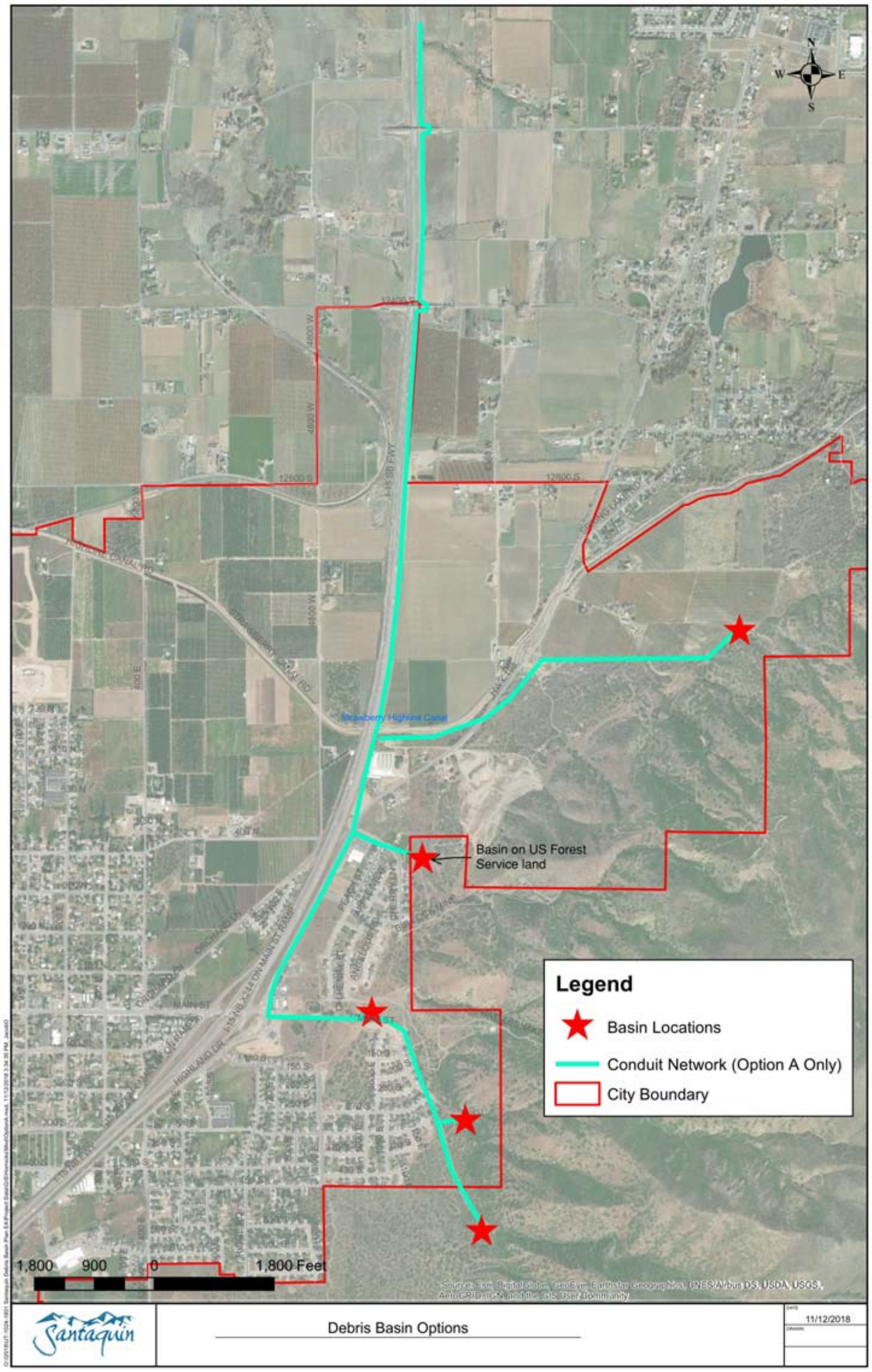

Figure 1 Debris Basin Options

To better view the watersheds in relation to the debris basin locations, see Figure 2.

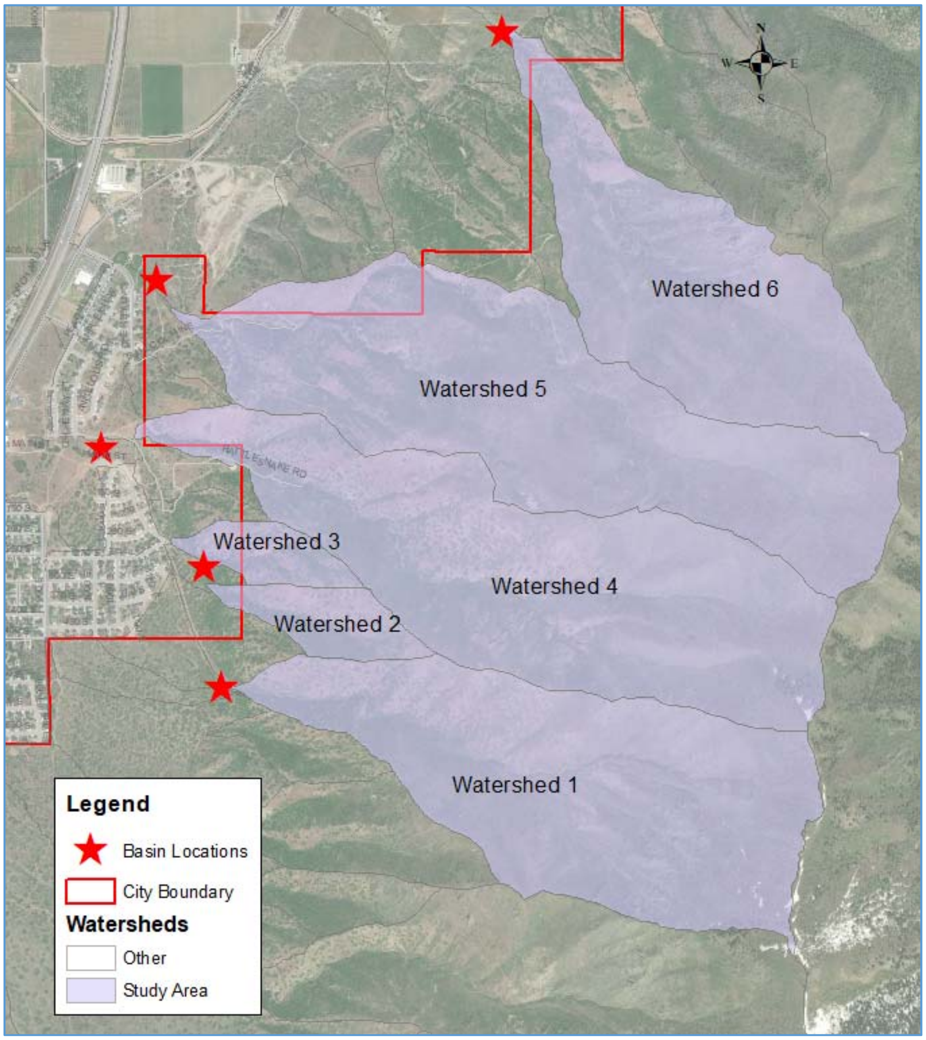

Figure 2. Watersheds

Debris basins may be constructed as earthen embankments or fully excavated basins. In the hydraulic analysis these were referred to as “above grade” and “below grade” options, respectively. In order to determine the nature, scale, and benefits of each type, reservoir routing for principal and auxiliary spillway capacity, freeboard and other criteria were evaluated to enable the geometric layout, comparison, and then selection of the preferred option. The analysis was done in accordance with the design criteria of both the NRCS Technical Release 60 (TR60) and the State of Utah dam safety rules and regulations (State Code) located in the Administrative Rules Title R-655, and Utah Code Title 73, Chapters 1-6, and 22. Although these basins could be low hazard and have a storage times height less than 3,000, TR-60 was still used for guidance.

Sediment capacity is also highly critical in the design of any structure. Due to the compressed schedule we were attempting to meet, it was initially assumed that 20% of the volume in the basin was reserved for sediment and was assumed to be unavailable for reservoir routing, with the intent that any additional capacity required would be worked into the final design concept as the sediment yield study was completed. This volume was refined as the analysis progressed.

Determining the size, nature, and footprint of the potential structures is necessary for the environmental analysis process to proceed.

The hydrology and outflow data from the reservoir routing and sizing was used to model the change in flows in the downstream floodplain from the current conditions to the post-construction condition. This flood modeling enabled the determination of the changes in flood and debris flow impacts, enabling economic analysis of the project to be performed.

2.0 Design Goals and Criteria

As the project is in a Plan-EA phase at this time, the goals of the project are defined in the EA document as: prevent all flooding from the 50-year storm event and provide significant flood reduction from the 100-year storm event by reducing peak flow rates to a safe level.

The PL-566 program design goals were used in conjunction with NRCS specific design criteria. This required considering the 100-year, 10-day, and 24-hour storms using NRCS rainfall distributions. The principal design goals were as outlined below (not all-inclusive):

2.1 Standard Debris Basin Primary Design Concept and Goals (Approach A)

High Hazard Structure (“Above Grade”):
Description: Earth fill embankment with structural principal spillway and vegetated earth auxiliary spillway.
NRCS Criteria: Pass the 100-year 10-day Principal Spillway Hydrograph (PSH) through the principal spillway without activating the auxiliary spillway.
Design Goal: Pass the 100-year 24-hour event, and 50-year 24-hour event without activating the auxiliary spillway, for Approach A and Approach B, respectively.

Low Hazard Structure (“Below Grade”):
Description: Fully excavated basin with structural principal spillway and vegetated earth auxiliary spillway.
NRCS Criteria: Do not activate the auxiliary spillway until the 25-year PSH.
Design Goal: Pass the 50-year and/or 100-year 24-hour event without activating the auxiliary spillway.

The auxiliary spillway design events and freeboard requirements dictated by the NRCS and Utah Dam Safety were also used to determine final auxiliary spillway elevation dimensions and dam crest elevations.

2.2 Alternative Debris Basin Design Concept and Goals (Approach B)

As the analysis process proceeded it became apparent that flows discharging from the principal spillway were smaller but still significant and had to be conveyed downstream even during more frequent events. Santaquin has no existing outflow channel, creek, or river in the vicinity to carry any discharge flows. Approach A would require a long conveyance system constructed up to Spring Creek approximately 2 miles to the north. In addition, several large culverts downstream of Spring Creek would need to be enlarged. To avoid having a piped system that would discharge the collective flow of all basins into a single location during all events regardless of return interval, a second option was studied.

The consideration of an alternative set of design criteria would allow the elimination of the extensive conveyance works, but still provide significant safety and economic benefits. In order to eliminate significant frequent principal spillway flows, and still meet NRCS criteria, a combined structural spillway was proposed, rather than a separate principal spillway and vegetated auxiliary spillway. Based on our correspondence with NRCS and our review of NRCS technical criteria, this approach negates most capacity and design regulations on the low level outlet, potentially permitting an outlet that passes much lower flows up to the design event. The basins in this approach would be sized to hold the entire 50-year event volume, with all larger storms passing excess flows over the combined spillway and flowing in historic paths. It is desirable to be able to drain the basin after runoff events without human intervention, so an ungated opening would be sized to drain the full volume of the basin within ten days, with an auxiliary gate as backup if deemed advisable. This alternative design criteria is summarized below:

Guidelines for All Structures:

NRCS Criteria: Pass all spillway design flows through a combined structural spillway while meeting freeboard requirements. Provide 10-day drawdown capacity through a restricted outlet pipe.

Design Goal: Fully contain all storms within the basin up to the 50-year event, reduce 100-year flows to safe level, limiting flows and volumes to amounts that could be handled within existing infrastructure without flooding. Excess from larger storms would pass over the spillway. The spillway will be located such that flows are directed in historic paths, thus eliminating induced flooding.

3.0 Reservoir Routing and Sizing

The various design storms as outlined in the hydrology report were routed through each reservoir to verify and fine tune the reservoir volume, principal and auxiliary spillway and crest, and the size of the spillways and outlet pipes. This also allowed us to produce hydrographs to use in flood mapping for economic analysis.

3.1 Methodology

The methodologies inherent in the SITES program developed and distributed by the NRCS was utilized to route the storms through the reservoirs. Refer to the technical documentation for SITES available from the NRCS website or included with the program for further information on the methodologies used for performing hydraulic analysis by the program.

The program permits the designation of basic auxiliary spillway dimensions. Principal spillway combinations including low level outlets and upper weir crests, are all directed to an outlet pipe. Combined spillways and direct input of stage-discharge curves are also possible.

The program is designed to follow the general design criteria and approach of the NRCS, and can perform hydrology for specific events such as the PSH and Freeboard Hydrograph (FBH) based on TR-60 criteria as discussed in the Hydrology Memo. It can also accept direct input of hydrographs determined elsewhere. These features were used during the routing process for each event analyzed, as applicable. Further detail is provided in this report under the heading for each type of analysis.

3.2 Assumptions

Due to the number of analyses which had to be run, some initial assumptions had to be made and used in all scenarios to accelerate the modeling work. These assumptions were made to establish feasibility. Some were refined during the concept design, with the understanding that the rest will be fine-tuned where required during the final design. These initial assumptions included:

Reservoir Dimensions:

- Initial Volume: +/- 25-year 24-hour event volume at Auxiliary Spillway for Approach A; 50-year 24-hour event volume for Approach B
- 50 and 25-years' of sediment volume
- Initial Elevation of Auxiliary Spillway: 3 feet below crest/top of dam
- Internal Depth of Basin/Structural Height: 15 feet
- Cut and Fill Slopes: 3:1

Auxiliary Spillway Dimensions:

- Width: 50 feet
- Length of Flat Section (spillway crest): 40 feet

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Upstream Slope: 3:1
Downstream Slope: -2%
Side Slopes: 3:1

Principal Spillway:

Type: NRCS Standard Riser with Piped Outlet
Low Elevation Outlet: (2) 6"x12" openings (Approach A); Orifice as needed to meet 10-day draw down (Approach B)
Low Elevation Outlet Elevation: at +/- 20% Volume of Basin (Sediment Storage Elev.); Orifice as needed to meet 10-day draw down (Approach B)
Upper Weir Elevation: 1 foot below the auxiliary crest elevation
Upper Weir Length: 6 feet on each side of structure, total of 12 feet
Outlet Pipe Size: 30" (NRCS minimum size)

An existing open channel runs from some of the southern watersheds and would be used to collect the outflows from the basins. Based on measurements of the existing channel, the following approximation was used in the SITES models when routing these basins into a lower one:

Inter-Basin Channel Routing:

Slope: 0.013 ft/ft
Bottom Width: 5.74 feet
Channel Depth: 7 feet
Side Slopes: 2:1

The spillway widths, elevations, and pipe sizes were adjusted as required to meet the design goals and criteria as was determined during modeling. Final results will be provided below.

3.3 Modeling and Concept Design Process

The reservoir routing and basin concept design process was iterative in nature. In order to size the basins, several analysis steps were taken and adjustments were made throughout the process. Early in this study, basins were modeled in CAD. The basin volume was obtained from the draft Storm Drain Master Plan. These basins matched the concept design assumptions used in this study, except for overall volume. To develop the initial stage-storage curves to enter into SITES the stage-storage data from these initial basins were scaled in Excel to match the 25-year storm volumes used in this study (for Approach A). The modeling process then proceeded as illustrated below:

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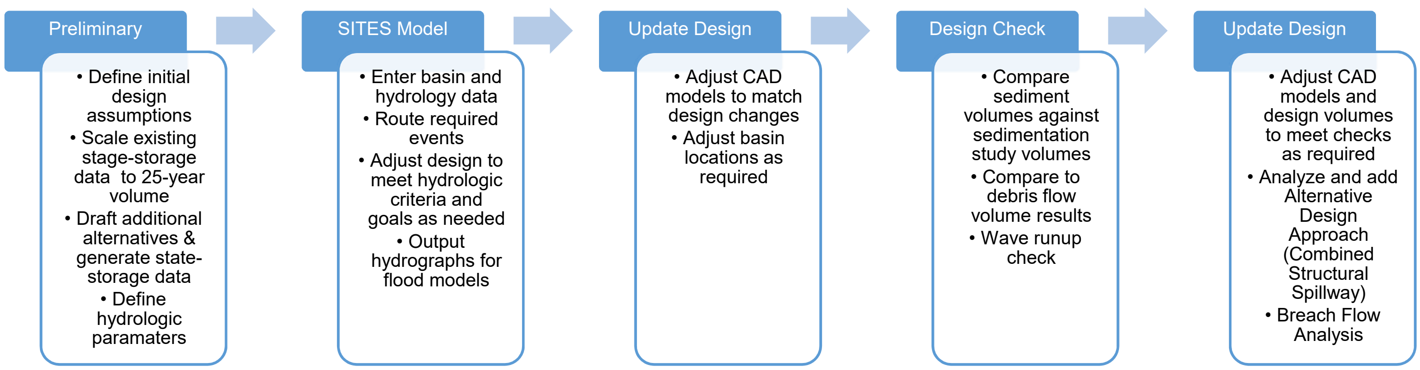

Figure 3. Modeling Process

It may be noted that the SITES models were not run again after the final design update. Since the sediment storage was assumed full initially, and any additional required volume could be accommodated by cutting the floor of the basins lower, and freeboard adjustments for wave run-up did not affect the routing, no adjustment to the SITES runs were required. In some cases, the relocation of the basins to better fit the adjusted designs to the topography does mean that the elevations in the SITES model may not match exactly with the elevation that the basin is shown at in the final CAD drawings, but the overall volume and relative spillway elevations were kept the same. Refinements to the calculations and drawings will be made in the final design process.

3.4 Options Modeled

Each site included the modeling of various options depending on the site conditions and to compare potential options. The main categories of options analyzed are as follows:

Option Types:

- "Above Grade" – Standard basin with earthen embankment, riser tower principal spillway, and vegetated earthen auxiliary spillway. Evaluated as high hazard structure based on observation, to be confirmed with flood modeling after completion of concept design.
- "Below Grade" – Fully excavated basin with riser tower principal spillway
- "Multi-Basin" – SITES model included all outflows from basins upstream of the basin being analyzed. To be conservative, whatever option for upstream basins produced the most outflow was used.
- "Watershed Only" – Options where flows from upstream basin are diverted around the basin being analyzed, and only the watershed directly associated with the basin is included.

A list of the options modeled for each site is provided below, with a basis of the justification for inclusion of the option in the analysis:

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Table 1. Modeling Scenarios

Watershed	Basin Option Title (Approach A)	Basin Option Title (Approach B)	Notes
1	Basin 1 Above Grade		
	Basin 1 Below Grade	Basin 1 Below Grade	Low Hazard Option
2	Basin 2 Above Grade		
	Basin 2 Below Grade		Low Hazard Option
3	Basin 3 Above Grade		
	Basin 3 Below Grade		Low Hazard Option
	Basin 3A Below Grade	Basin 3A Below Grade	Routes inflow from watershed 2 and 3 into a single low hazard basin.
4	Basin 4E Above Grade (Watershed Only)	Basin 4E Above Grade (Watershed Only)	Includes only inflows from the watershed associated with Basin 4 and not upstream basins.
	Basin 4E Above Grade (Multi-Basin)		Includes inputs from the watershed associated with Basin 4 as well as the outputs from the Below Grade alternatives in Basin 1, 2, and 3.
	Basin 4D Below Grade (Watershed Only)		Includes only inflows from the watershed associated with Basin 4 and not upstream basins.
	Basin 4D Below Grade (Multi-Basin)		Includes inputs from the watershed associated with Basin 4 as well as the outputs from the Below Grade alternatives in Basin 1, 2, and 3.
	Basin 4A-4B Below Grade (Watershed Only)		Includes only inflows from the watershed associated with Basin 4 and not upstream basins.
	Basin 4A-4B Below Grade (Multi-Basin)		Includes inputs from the watershed associated with Basin 4 as well as the outputs from the Below Grade alternatives in Basin 1, 2, and 3.
	Basin 4A-4B Above Grade (Multi-Basin)		Includes inputs from the watershed associated with Basin 4 as well as the outputs from the Below Grade alternatives in Basin 1, 2, and 3.
5	Basin 5 Below Grade	Basin 5 Below Grade	

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	Basin 5 Above Grade		
6	Basin 6A Above Grade		Offset from mouth of canyon to avoid orchards
	Basin 6A Below Grade		Offset from mouth of canyon to avoid orchards
	Basin 6B Below Grade		At mouth of canyon
	Basin 6B Above Grade	Basin 6B Above Grade	At mouth of canyon

3.4 Events Modeled

The routed storm events are listed below, along with the purpose for their inclusion in each model. An event was not included in a specific option where it did not apply. For further information on the development of the hydrographs for each of the events refer to the hydrology technical memo.

Table 2. Events Modeled

Category	Sub-Category	Notes/Reason For Inclusion
Principal Spillway Hydrograph	Curve Number Method	Principal Spillway Sizing per TR-60
	Runoff Method (Governing Storm)	
Auxiliary Spillway Hydrograph (PMP)	6-Hour (Local Storm) (Governing Storm)	Auxiliary Spillway Sizing and Freeboard Design. Induced Flooding Analysis
	24-Hour (General Storm)	
	72-Hour (General Storm	
	6-Hour ARC III (for wave run-up analysis)	
Economic Analysis	5-year 24-hr storm	Post-Construction Impact Analysis, Reservoir and for the 50 and 100-year events, Spillway Sizing for the 100-year event
	10-year 24-hr storm	
	25-year 24-hr storm	
	50-year 24-hr storm	
	100-year 24-hr storm (Design Criteria Storm)	
	200-year 24-hr storm	
	500-year 24-hr storm	
Burned Conditions Hydrograph	10-year 100-year storm (Burned Conditions)	Verify containment of storm under burned conditions
Debris Flow	5-year 1-Hour precip. Depth	Not actually routed, total volume compared to volume of basin

Principal Spillway Evaluation Events

The principal spillway evaluation events were routed to verify the principal spillway met the regulations for size and capacity as stated in TR-60. Given the required runoff and basin characteristics, SITES will route the principal spillway hydrograph (PSH) through the reservoir using standard NRCS methodology. The required input data were taken from hydrology study. Reference is made the Hydrology Report Memo for further details.

The principal spillway hydrograph (PSH) must be routed through the reservoir without activating the auxiliary spillway. Given specific data on the principal spillway design, and a stage-storage curve for the basin, SITES will determine the required elevation for the auxiliary spillway. In all cases the method from TR-60 utilizing stream gage results (“Runoff” or “Snowmelt” method) governed over the Curve Number Method. The final concept design met these requirements, and was in fact larger than required by these events since the 100-year 24-hour storm design criteria governed. SITES also confirmed during this analysis that the 10-day drawdown requirements have also been met. Key SITES input and output data can be reviewed in the table in Appendix A.

Approach B Drawdown Calculations

Per TR-60, all basins must be able to drain 85% of the total volume within 10 days. The drainage flows can be directed safely from the basins to historic flow paths, along local streets, etc. while the basins decrease the discharge rates and total volumes of larger events as they pass over the spillway.

The proposed basins will have a tower with a relatively small orifice located several feet above the bottom basin surface. To ensure that the basin can completely drain within 10 days, the orifice elevation was modeled 0.5 feet from the basin bottom as well as 3 feet from the bottom. Both approaches indicate a drawdown time which is less than 10 days. The top of the tower would be open to allow water to enter it to prevent the auxiliary spillway from functioning more frequently than is permissible.

The table below shows the results of the drawdown calculations. Tables with full drawdown calculations are located in Appendix B.

Table 3. Drawdown Time

Basin	Peak Flow Out (cfs)	Drawdown Time (days)
1	2.5	7.9
2-3	1.3	2.3
4	2.3	8.3
5	1.8	8.3
6	1.7	8.1

Auxiliary Spillway Evaluation Events

Given some basic geometric and hydraulic criteria, SITES will route the Freeboard Hydrographs, Stability Design Hydrograph, or other required design hydrographs through the spillway in accordance with NRCS standard criteria and methods. For hydrologic input parameters reference is made to the Hydrology Report Memo. The auxiliary spillways were sized in accordance with the Assumptions section of this report. Events routed included the 6-hour SEF, 24-hour SEF, 72-hour SEF, and the 6-hour or 24-hour 100-year events on a saturated watershed to check State of Utah freeboard criteria, depending on which SEF event governed. In all cases the 6-hour SEF event governed, except for the Basin 5 Above-Grade Option, where the 24-hour event governed. In this case the 24-hour 100-year event was used to check State of Utah freeboard criteria, while a 6-hour 100-year event was used to check all other events. Spillway widths did not have to be changed from the assumed 50 feet except in the case of the Basin 4A-4B Multi-basin option, which uses two basins in series, and captures all flows from Basins 1, 2 and 3, which are located upstream. The spillway width and governing water depth over the spillway for each storm was as follows. Further data is available in Appendix C. More information regarding reservoir routing can be found in the hydrology report.

Table 4. Spillway Data

Watershed	Basin Option Title	Aux. Spillway Width (ft)	Water Height Above Spillway (ft)	Governing Storm
1	Basin 1 Above Grade	50	2.06	6-hr SEF
	Basin 1 Below Grade	50	0.72	6-Hr SEF

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Watershed	Basin Option Title	Aux. Spillway Width (ft)	Water Height Above Spillway (ft)	Governing Storm
2	Basin 2 Above Grade	50	0.15	6-Hr SEF
	Basin 2 Below Grade	50	-0.36	ARC III 6-Hr 100-year
3	Basin 3 Above Grade	50	0.15	6-Hr SEF
	Basin 3 Below Grade	50	-0.52	ARC III 6-Hr 100-year
	Basin 3A Below Grade	50	-0.87	
4	Basin 4E Above Grade (Watershed Only)	50	1.90	6-Hr SEF
	Basin 4E Above Grade (Multi-Basin)	50	2.35	6-Hr SEF
	Basin 4D Below Grade (Watershed Only)	50	0.92	ARC III 6-Hr 100-year
	Basin 4D Below Grade (Multi-Basin)	50	1.52	ARC III 6-Hr 100-year
	Basin 4A-4B Below Grade (Watershed Only)	60	0.64	ARC III 6-Hr 100-year
	Basin 4A-4B Below Grade (Multi-Basin)	60	1.69	6-Hr SEF
	Basin 4A-4B Above Grade (Multi-Basin)	50	2.26	6-Hr SEF
5	Basin 5 Below Grade	50	0.78	ARC III 6-Hr 100-year
	Basin 5 Above Grade	50	1.6	6-Hr SEF
6	Basin 6A Above Grade	50	1.79	6-Hr SEF
	Basin 6A Below Grade	50	1.31	6-Hr SEF
	Basin 6B Below Grade	50	0.62	6-Hr SEF
	Basin 6B Above Grade	50	1.96	6-Hr SEF

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Economic Analysis Events

The events listed previously were routed through the reservoir to provide hydrograph inputs to the post-construction flow model to allow evaluation of the change in flood and debris flow impact on the property located downstream of the watersheds being analyzed. The 100-year 24-hour storm was also used to size the reservoir and principal spillway elevation and size to prevent activation of the auxiliary spillway elevation up to the 100-year event for Approach A, and the 50-year event for Approach B. In this case, this turned out to be a more strict criteria than the NRCS criteria, which requires sizing the principal spillway to pass the PSH. Refer to Appendix A for peak discharges and water surface elevations, as well as final volumes, elevations, and sizes of the various components for each basin. Further discussion on the flood modeling and impact analysis will be provided later in this report. All of the basins generated similar results for the various return events.

The table below compares the some of the storms most critical in evaluating the effectiveness of the basins. The 2-, 200-, and 500-year event results can be seen in Appendix A. The table shows the inflow rates and volumes, and then compares them to the outflow rates for the various basin options modeled. Significant peak flow reductions were realized, but the outflows if considered together still represents a considerable flow rate to be accommodated downstream.

Table 5. Pre, Post Flows (Approach A)

		Peak Flow by Return Interval (Approach A)				
Watershed	**Data/Option**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**
1	Inflow (cfs)	41.8	79.6	149	217.1	300.6
	Inflow (ac-ft)	8.5	12.4	18.3	23.4	28.7
	Basin 1 Above Grade Outflow	6.6	9.1	12	18	60.5
	Basin 1 Below Grade Outflow	6.7	9.6	12.1	29.4	84.8
2	Inflow (cfs)	3.8	8.6	18.2	27.9	40.3
	Inflow (ac-ft)	0.5	1.0	1.6	2.1	2.6
	Basin 2 Above Grade Outflow	2.1	4.3	7.9	10	11.9
	Basin 2 Below Grade Outflow	2.1	4.5	8.3	10.3	12.4
3	Inflow (cfs)	4.2	8.7	17.1	25.7	36.4
	Inflow (ac-ft)	0.4	0.7	1.2	1.6	2.0
	Inflow (cfs) (2 & 3 Combined)	8	17.3	35.3	53.6	76.7
	Inflow (ac-ft) (2 & 3 Combined)	0.9	1.7	2.8	3.7	4.6

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		Peak Flow by Return Interval (Approach A)				
Watershed	**Data/Option**	**5-year**	**10-year**	**25-year**	**50-year**	**100-year**
	Basin 3 Above Grade Outflow	2.5	4.9	8.2	10.4	12.2
	Basin 3 Below Grade Outflow	2.4	2.4	9.1	11.6	21.8
	Basin 3A Below Grade Outflow (2 & 3 Combined)	3.2	6.5	9.9	12.2	27.7
4	Inflow (cfs) (Single Basin)	35.9	71.2	139.1	207.8	291.6
	Inflow (ac-ft) (Single Basin)	8.2	12.1	18.2	23.4	29.0
	Inflow (cfs) (Multi-Basin)	41.8	82.6	162.7	217.3	326.4
	Inflow (ac-ft) (Multi-Basin)	17.6	26.2	39.3	50.5	62.3
	Basin 4E Above Grade Outflow (Watershed Only)	6.7	9.5	12.3	30.7	71.8
	Basin 4E Above Grade Outflow (Multi-Basin)	10	13	27.9	84.2	189.5
	Basin 4D Below Grade Outflow (Watershed Only)	6.7	9.3	12	42.6	115.4
	Basin 4D Below Grade Outflow (Multi-Basin)	10.1	23	32.3	91.3	183.2
	Basin 4A-4B Above Grade (Multi-Basin)	9.9	24.9	47.6	95.2	213.8
	Basin 4A-4B Below Grade Outflow (Watershed Only)	6.8	9.3	12.7	42.3	115.2
	Basin 4A-4B Below Grade Outflow (Multi-Basin)	10.3	13.4	32.7	92.5	208.2
5	Inflow (cfs)	15.6	38.6	88.4	142.1	209.5
	Inflow (ac-ft)	5.6	8.8	14.2	18.8	23.8
	Basin 5 Above Grade Outflow	5	8.2	11.7	29.7	82.2
	Basin 5 Below Grade Outflow	4.9	8.2	11.7	19.9	68.3
6	Inflow (cfs)	35.3	67.9	127.8	188.8	262.5
	Inflow (ac-ft)	5.8	8.5	12.6	16.1	19.9
	Basin 6A Above Grade Outflow	5.7	8.7	11.6	19.4	57.4
	Basin 6A Below Grade Outflow	6.1	8.8	11.7	20.2	63.7
	Basin 6B Above Grade Outflow	6.1	8.9	12	18.6	63.2
	Basin 6B Below Grade Outflow	6.1	8.9	12	18.5	61.8

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Table 6 Pre, Post Flows (Approach B)

Watershed	Data/Option	Peak Flow* by Return Interval (Approach B)				
		5-year	10-year	25-year	50-year	100-year
1	Inflow (cfs)	41.8	79.6	149	217.1	300.6
	Inflow (ac-ft)	8.5	12.4	18.3	23.4	28.7
	Basin 1 Above Grade Outflow	1.2	1.6	2.1	2.5	15.2
2,3	Inflow (cfs) (2 & 3 Combined)	8	17.3	35.3	53.6	76.7
	Inflow (ac-ft) (2 & 3 Combined)	0.9	1.7	2.8	3.7	4.6
	Basin 3A Below Grade Outflow (2 & 3 Combined)	0.6	0.9	1.1	1.3	3.6
4	Inflow (cfs) (Single Basin)	35.9	71.2	139.1	207.8	291.6
	Inflow (ac-ft) (Single Basin)	8.2	12.1	18.2	23.4	29.0
	Basin 4E Above Grade (Watershed Only)	1.0	1.5	1.9	2.3	16.5
5	Inflow (cfs)	15.6	38.6	88.4	142.1	209.5
	Inflow (ac-ft)	5.6	8.8	14.2	18.8	23.8
	Basin 5 Below Grade Outflow	0.7	1.1	1.5	1.8	
6	Inflow (cfs)	35.3	67.9	127.8	188.8	262.5
	Inflow (ac-ft)	5.8	8.5	12.6	16.1	19.9
	Basin 6 Above Grade Outflow	0.8	1.1	1.4	1.7	14.5

*Outflows in 5, 10, 25 and 50-year are restricted drawdown flows through an orifice.

Burned Condition Event

Post-fire flows were routed using SITES to verify the basins had sufficient capacity to accommodate them. It was assumed that the sediment would settle out into the sediment basin, and the net effect on the spillways would be similar to passing the event without sediment loading. The additional volume determined from the bulking calculations in the hydrology report would therefore have to fit within the provided sediment pool. Table 9 in the Design Checks section of this report compares the extra bulked volume to the sediment volume available in each option modeled.

3.5 Adjusted Concept Designs

The size and elevation of spillways and pipes were adjusted in order to meet the NRCS design criteria and design goals. The key design data for each option modeled is shown in the following Table. Total Storage is measured at the auxiliary spillway crest. Options 4A and 4B are not included because the two-tier basin option was eliminated during the analysis process due to its obstructing access across the site, and anticipated additional

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cost with multiple sets of spillways and outlet works, and the lower basin was not significantly reducing the footprint of the upper basin. Approach A has a 50-year sediment volume. Approach B has a 25-year sediment volume.

Table 7. Basin Dimensions (Approach A)

Basin Option (Approach A)	Total Height (ft)	Height at Aux. Spillway (ft)	Height at Principal Spillway (ft)	Aux. Spillway Width (ft)	Principal Spillway Width (ft)	Outlet Pipe Diameter (in)	Total Storage (ac-ft)	Active Storage (ac-ft)	Sediment Storage (ac-ft)
Basin 1 Above Grade	16.5	13.5	12	50	14	42	20.35	16.92	5.63
Basin 1 Below Grade	16.5	13.5	11.9	50	12	30	20.47	16.76	5.63
Basin 2 Above Grade	15	12	11	50	12	30	1.77	1.51	0.35
Basin 2 Below Grade	14.68	11.68	10.68	50	12	30	1.62	1.34	0.35
Basin 3 Above Grade	15	12	11	50	12	30	1.31	1.12	0.35
Basin 3 Below Grade	16	13	12	50	12	30	1.25	1.02	0.35
Basin 3A Below Grade	17	14	13	50	12	30	2.98	2.43	0.35
Basin 4E Above Grade (Watershed 4 Only)	16	13	12	50	20	42	18.99	15.65	4.0
Basin 4E Above Grade (Multi-Basin)	17	14	12	50	20	42	20.97	17.63	4.0
Basin 4D Below Grade (Watershed 4 Only)	16.5	13.5	12	50	20	42	19.98	15.39	4.0
Basin 4D Below Grade (Multi-Basin)	17	14	12	50	20	42	20.96	16.37	4.0
Basin 5 Above Grade	15.5	12.5	11	50	12	42	14.64	11.75	3.16
Basin 5 Below Grade	16.3	13.3	12	50	12	42	15.88	12.79	3.16

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Basin Option (Approach A)	Total Height (ft)	Height at Aux. Spillway (ft)	Height at Principal Spillway (ft)	Aux. Spillway Width (ft)	Principal Spillway Width (ft)	Outlet Pipe Diameter (in)	Total Storage (ac-ft)	Active Storage (ac-ft)	Sediment Storage (ac-ft)
Basin 6A Above Grade	15.5	12.5	11	50	12	30	13.43	10.84	4.25
Basin 6A Below Grade	16.2	13.2	12	50	12	30	14.6	11.8	4.25
Basin 6B Above Grade	16.5	13.5	12	50	12	30	14.99	12.4	4.25
Basin 6B Below Grade	16.2	13.2	12	50	12	30	14.52	11.98	4.25

Table 8. Basin Dimensions (Approach B)

Basin Option (Approach B)	Total Height (ft)	Height at Aux. Spillway (ft)	Height at Principal Spillway (ft)	Aux. Spillway Width (ft)	Outlet Pipe Diameter (in)	Total Storage (ac-ft)	Active Storage (ac-ft)	Sediment Storage (ac-ft)
Basin 1 Below Grade	16	13	12	50	30	27.15	23.4	3.75
Basin 3A Below Grade	16	13	12	50	30	4.25	3.7	0.55
Basin 4E Above Grade (Watershed 4 Only)	16	13	12	50	30	25.9	23.4	2.5
Basin 5 Below Grade	16	13	12	50	30	20.8	18.8	2.0

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Basin Option (Approach B)	Total Height (ft)	Height at Aux. Spillway (ft)	Height at Principal Spillway (ft)	Aux. Spillway Width (ft)	Outlet Pipe Diameter (in)	Total Storage (ac-ft)	Active Storage (ac-ft)	Sediment Storage (ac-ft)
Basin 6A Above Grade	16	13	12	50	30	18.6	16.1	2.5

3.6 Design Checks

In order to ensure the concept designs resulting from the storm routing in SITES met all design goals and criteria, the resulting volumes were compared to the debris flow volumes and sediment volumes. Further detail is provided below.

Debris Flow Events

The debris flow volumes determined in the hydrology report and in the geotechnical report must be considered in the final sizing of the reservoir. The final volumes determined through the reservoir routing process are compared below to the debris flow volumes. The basin volumes are measured at the auxiliary crest elevation. The values are compared in the table below:

Table 9. Debris Flow Volumes

Basin Option	Total Volume (ac-ft)	Active Volume (ac-ft)	Watershed(s) Contributing Debris Flow	Empirical Debris Flow Volume (ac-ft)	Geotech Report Estimated Debris Flow (ac-ft)
Basin 1 Above Grade	20.35	16.92	1	11.08	23.6
Basin 1 Below Grade	20.47	16.76	1	11.08	23.6
Basin 1 Below Grade (Approach B)	27.15	23.4	1	11.08	23.6
Basin 2 Above Grade	1.77	1.51	2	1.62	3.6

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Basin Option	Total Volume (ac-ft)	Active Volume (ac-ft)	Watershed(s) Contributing Debris Flow	Empirical Debris Flow Volume (ac-ft)	Geotech Report Estimated Debris Flow (ac-ft)
Basin 2 Below Grade	1.62	1.34	2	1.62	3.6
Basin 3 Above Grade	1.31	1.12	3	1.25	1.0
Basin 3 Below Grade	1.25	1.02	3	1.25	1.0
Basin 3A Below Grade	2.98	2.43	2 and 3	2.87	4.6
Basin 3A Below Grade (Approach B)	4.25	3.7	2 and 3	2.87	4.6
Basin 4E Above Grade (Watershed 4 Only)	18.99	15.65	4	11.88	12.6
Basin 4E Above Grade (Watershed 4 Only) (Approach B)	25.9	23.4	4	11.88	12.6
Basin 4E Above Grade (Multi-Basin)	20.97	17.63	4	11.88	12.6
Basin 4D Below Grade (Watershed 4 Only)	19.98	15.39	4	11.88	12.6
Basin 4D Below Grade (Multi-Basin)	20.96	16.37	4	11.88	12.6
Basin 5 Above Grade	14.64	11.75	5	11.56	14.6
Basin 5 Below Grade	15.88	12.79	5	11.56	14.6
Basin 5 Below Grade (Approach B)	20.8	18.8	5	11.56	14.6
Basin 6A Above Grade	13.43	10.84	6	7.57	17.4
Basin 6A Below Grade	14.6	11.8	6	7.57	17.4
Basin 6B Above Grade	14.99	12.4	6	7.57	17.4
Basin 6B Above Grade (Approach B)	18.6	16.1	6	7.57	17.4
Basin 6B Below Grade	14.52	11.98	6	7.57	17.4

Sedimentation

In order to expedite analysis, it was initially assumed that 20% of the initial storage was reserved as a sediment pool. To ensure that the sediment pool had sufficient volume, the sediment volumes from the Sedimentation Analysis Technical Memo are compared below to the initial assumptions. The sediment load from post-fire flows as discussed in this report are also compared. The sediment volumes in Table 10 are based on an annual sedimentation rate multiplied by the number of years listed.

Table 10. Sediment Volumes

Basin Option	Total Volume (ac-ft)	Concept Sediment Volume (ac-ft)	25-year Sedimentation (ac-ft)	50-year Sedimentation (ac-ft)	Bulked Post-Fire Runoff (ac-ft)	Direct Post-Fire Runoff (ac-ft)	Post-Fire Event Sediment (ac-ft)
Basin 1 Above Grade	20.35	3.43	2.7	5.63	23.5	19.6	3.9
Basin 1 Below Grade	20.47	3.71	2.7	5.63	23.5	19.6	3.9
Basin 1 Below Grade (Approach B)	27.15	3.71	3.75	5.63	23.5	19.6	3.9
Basin 2 Above Grade	1.77	0.26	0.16	0.35	2.2	1.8	0.4
Basin 2 Below Grade	1.62	0.28	0.16	0.35	2.2	1.8	0.4
Basin 3 Above Grade	1.31	0.19	0.16	0.35	1.7	1.4	0.3
Basin 3 Below Grade	1.25	0.23	0.16	0.35	1.7	1.4	0.3
Basin 3A Below Grade (2 and 3 combined)	2.98	0.55	0.32	0.7	3.9	3.5	0.4
Basin 3A Below Grade (2 and 3 combined) (Approach B)	4.25	0.55	0.55	0.7	3.9	3.5	0.4
Basin 4E Above Grade (Watershed 4 Only)	18.99	3.34	1.98	4.0	23.4	19.5	3.9
Basin 4E Above Grade (Watershed 4	25.9	3.34	2.5	4.0	23.4	19.5	3.9

Basin Option	Total Volume (ac-ft)	Concept Sediment Volume (ac-ft)	25-year Sedimentation (ac-ft)	50-year Sedimentation (ac-ft)	Bulked Post-Fire Runoff (ac-ft)	Direct Post-Fire Runoff (ac-ft)	Post-Fire Event Sediment (ac-ft)
Only) (Approach B)							
Basin 4E Above Grade (Multi-Basin)	20.97	3.34	1.98	4.0	23.4	19.5	3.9
Basin 4D Below Grade (Watershed 4 Only)	19.98	4.59	1.98	4.0	23.4	19.5	3.9
Basin 4D Below Grade (Multi-Basin)	20.96	4.59	1.98	4.0	23.4	19.5	3.9
Basin 5 Above Grade	14.64	2.89	1.50	3.16	18.4	15.3	3.1
Basin 5 Below Grade	15.88	3.09	1.50	3.16	18.4	15.3	3.1
Basin 5 Below Grade (Approach B)	20.8	3.09	2.0	3.16	18.4	15.3	3.1
Basin 6A Above Grade	13.43	2.59	2.05	4.25	16.4	13.7	2.7
Basin 6A Below Grade	14.6	2.8	2.05	4.25	16.4	13.7	2.7
Basin 6B Above Grade	14.99	2.59	2.05	4.25	16.4	13.7	2.7
Basin 6B Above Grade (Approach B)	18.6	2.59	2.5	4.25	16.4	13.7	2.7
Basin 6B Below Grade	14.52	2.54	2.05	4.25	16.4	13.7	2.7

All of the methods used to determine sediment loads are highly subjective, and subject to significant error. No reliable method of calibration is readily available. Therefore, a sediment storage volume must be selected which the Owner is comfortable with given the uncertainty, with the knowledge of roughly how often they may have to perform maintenance. 50 to 100-year design life is typical NRCS standard. 50-year sediment load is recommended due to site and cost constraints. Less volume may also be acceptable if the Owner is willing and able to perform the maintenance as needed.

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4.0 Economic Analysis Flood Modeling

2-D Model

FLO-2D software was used to determine the effects on the downstream floodplain that would result from constructing debris basins. FLO-2D has been approved by multiple government agencies including FEMA. A pre and post-construction model was created and ran for each return event. The use of a two-dimensional model provides better results than a one-dimensional model as the flow directions are calculated, rather than assumed. The model is based on the best available GIS data and topographic data including LiDAR survey, field measurements and reconnaissance. It should be noted that the model output is useful for determining general effects of flooding and provides a good understanding of what is likely to occur. However, exact depths at specific locations should not be considered absolute.

Model Input

Model input includes elevation data, topographic data for homes, buildings and street locations, as well as for channels. Various sources were used for the east bench elevation data. Two-foot contour data is available form Utah's Automated Geographic Reference Center (AGCR). In addition, detailed topographic/elevation data was supplied by Santaquin City for the development in the 1030 East and 200 South vicinity.

The elevation data is converted into an elevation grid to represent the ground surface within the 2-D model. A ten foot grid element size was used in the model.

The model limits extend from Watershed 1 all the way north into Spring Lake, and include I-15 and the Highline-Strawberry Canal.

For the existing condition models, inflow nodes are located at the mouth of each watershed being analyzed. In the proposed condition, the inflow nodes are located where the spillway would be. A hydrograph is applied at each inflow node. The hydrographs were developed for existing conditions as well as for proposed conditions. The proposed condition hydrographs represent the flows being routed through the basins and associated outlet structures. The proposed condition hydrographs were developed using SITES. Also, proposed hydrographs for the basins which hold the 50-year volume were developed using the existing flow hydrograph and modifying it such that the 50-year volume is contained within the basin. Flow which exceed that volume would spill over the spillway into their historic flow path.

The model was set to run for at least as long as the storm duration (24 hours). In some cases it was run longer to make sure the full effects of the flooding had been propagated downstream. Generally, the peak flows occur early in the model. However, the full area of inundation is better understood by running the simulation for a longer period of time.

The channel at the base of Watershed 1 was not clearly represented in the 2-foot contours obtained from AGRC. This channel has a significant enough impact on the flows coming from Watershed 1 that this issue needed to be corrected. To mitigate this lack of data, field measurements were taken at approximately 200-300 foot intervals to determine bottom width, bank slopes, top width, etc. Other smaller channels which may exist, such as curb and gutter were not captured within the model.

The grid elements along the northern and western edges of the model were made outflow nodes. This allows water to flow off the model domain at a normal depth.

Floodplain roughness coefficients within the model are 0.04 for typical floodplain and 0.015 for streets and paved areas. The model also adjusts the roughness coefficient for very shallow flows to be as rough as 0.2.

A pipe network was developed for the proposed model in the alternative that includes an extensive pipe network downstream. The pipe inflow and outflow nodes were assigned a rating table of flow to depth based on average slope between the points, and the estimated pipe size. The outfall of the combined pipe network cannot extend beyond the model boundaries to determine its ultimate effects on the entire downstream system in Payson and to Utah Lake. However, because this model was proven to have a very low benefit to cost ratio, and for other reasons, this alternative is not recommended as the preferred alternative.

Model Output

FLO-2D model output for maximum depths, water surface elevations, and velocity are exported as shapefiles. The FLO-2D shapefiles were then superimposed with aerial imagery and other shapefiles for existing infrastructure such as homes, buildings, roads, etc. This data was used to quantify where flood flows of varying depths intersected with homes and roads. The velocity multiplied by the depth was also provided for the economic analysis. This information is included on maps in Appendix D.

Economic Analysis

An economic analysis was conducted by an NRCS certified economist using the results of the FLO-2D model as well as cost estimates for the projects, and projected maintenance costs. The results of the economic analysis indicate a benefit cost ratio as follows:

Table 11. Benefit Cost Ratio

Approach	Benefit/Cost Ratio
A	1.24
B	1.88

The full economic analysis is contained in a separate document.

Induced Flooding Analysis

Induced flooding is causing flooding to occur where it did not previously/historically occur. In order to prevent induced flooding, proposed debris basins will be constructed at or adjacent to the historic flow paths. The outlet and spillway works will be constructed such that the flows are directed to the historic flow path. Induced flooding has thus been greatly minimized. The spillway channels will be areas of induced flooding for either option. However, property for these areas will be acquired for the project. As the water reaches the end of the spillway channel, it enters its historic flow path. Induced flooding maps are included in Appendix E.

Outflow System Analysis

In order to ensure that the recommended measures did not increase flooding hazards at any point downstream of the lower limits of the project area, the flows were measured in the flood model at several locations where the water flows out of the study area and to the north. These flows were then compared to the post-construction flood models to check the potential impacts.

Maps showing the flood extents, depths, and peak flows both under existing conditions and post-project conditions are included in Appendix F. Table 12 provides a summary of the flow results.

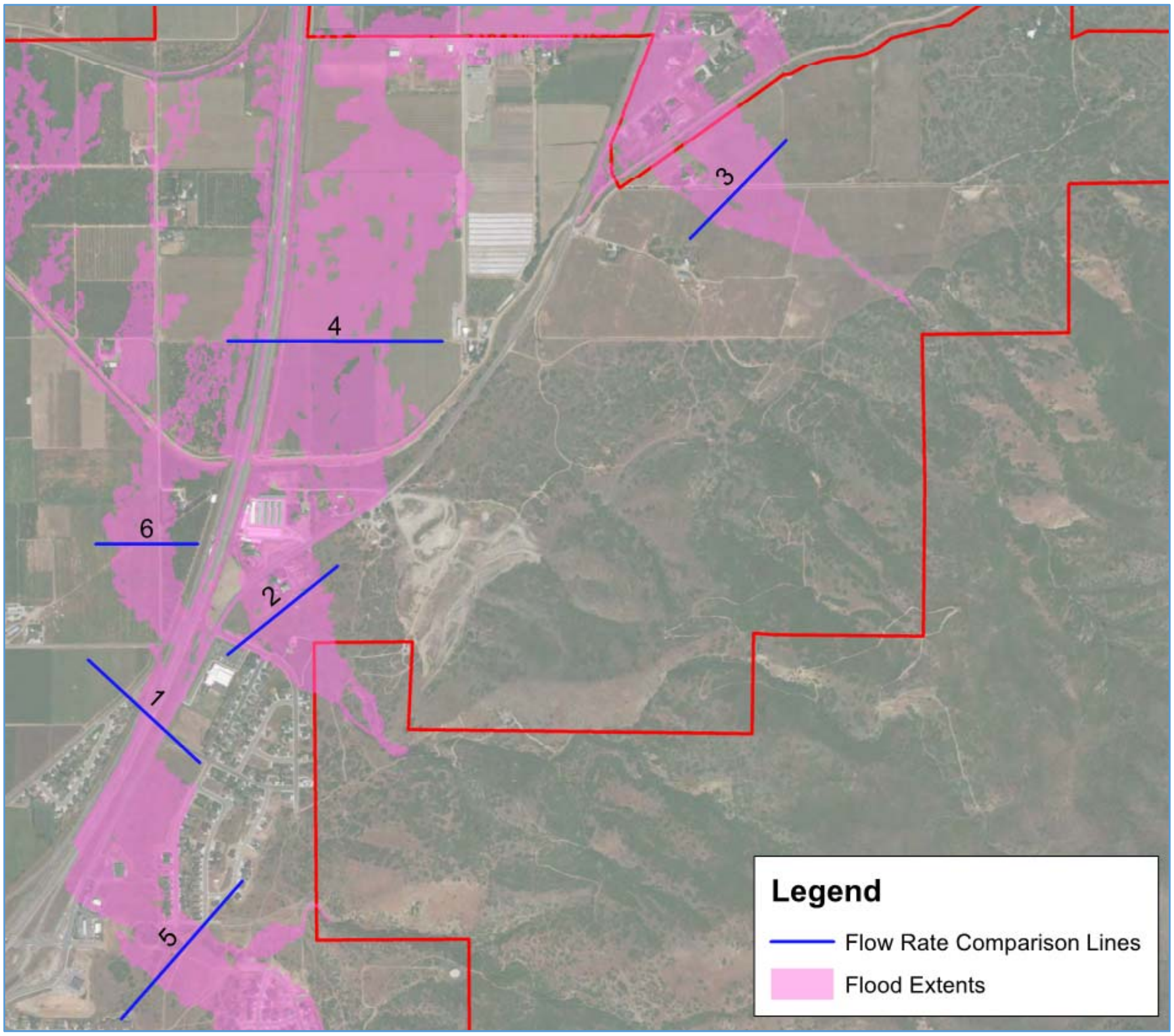

Figure 4. Floodplain Comparison Lines

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Table 12. Flow Comparisons

2-Year (cfs)			
Section	Existing	Proposed A	Proposed B
1	11.3	0	0
2	6.2	0	0
3	12.1	0	0
4	10	0	0
5	13.3	0	0
6	0	0	0
5-Year (cfs)			
Section	Existing	Proposed A	Proposed B
1	158	0	0
2	9.1	0	0
3	38.6	0	0
4	134.1	0	0
5	187.2	0	0
6	1.7	0	0
25-Year (cfs)			
Section	Existing	Proposed A	Proposed B
1	315.2	0	0
2	71.8	0	0
3	118.7	0	0
4	277.4	0	0
5	373.7	0	0
6	20	0	0
50-Year (cfs)			
Section	Existing	Proposed A	Proposed B
1	445.6	0	0
2	130.6	0	0
3	167.6	0	0
4	385.9	0	0
5	489.7	0	0
6	50	0	0

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100-Year (cfs)			
Section	Existing	Proposed A	Proposed B
1	576.7	0	28.4
2	200.4	0	10.2
3	246.7	0	15.2
4	495.8	0	19.2
5	622.5	0	33.6
6	80.6	0	0
200-Year (cfs)			
Section	Existing	Proposed A	Proposed B
1	774.5	174.4	216.2
2	284.7	0	51.8
3	341.6	84.1	85.2
4	639.4	139.3	199.6
5	831.5	94.9	244.8
6	156.1	0	8.3
500-Year (cfs)			
Section	Existing	Proposed A	Proposed B
1	1107.1	505.5	657.7
2	414.6	116.3	223.5
3	499	228.8	218.1
4	929.2	444.4	475.5
5	1155.7	461.0	928.8
6	334.9	52.4	90.1

Hazard Rating and Dam Breach Analysis

Breach Flow Analysis

Peak flow rates and hydrographs were developed using criteria outlined in TR-60 and using a spreadsheet titled “Dambreach Hydrographs via TRs 60 & 66 NRCS Guidance” obtained from the NRCS website.

A dam breach analysis was conducted for Basin 4 and Basin 6 as they are the basins which are proposed as being partly constructed above grade.

Breach Flood Inundation Analysis

The breach hydrograph values were input into FLO-2D to determine the downstream effects of a breach. Velocity and depth information was extracted from the model and maps were created using ArcMap. Breach hydrographs and breach maps are included in Appendix G.

Hazard Rating

Dam classification guidance is found in NEM Part 520C:
(1) Low Hazard Potential—Dams in rural or agricultural areas where failure may damage farm buildings, agricultural land, or township and country roads.

(2) Significant Hazard Potential— Dams in predominantly rural or agricultural areas where failure may damage isolated homes, main highways, or minor railroads or interrupt service of relatively important public utilities.

(3) High Hazard Potential— Dams where failure may cause loss of life or serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.

Breach flows from Basin 4 would have high velocities combined with moderate depths. There is some residential and commercial development downstream, as well as SR-198 and I-15 which would be impacted by a breach. For these reasons, and based on the criteria established in NEM Part 520, this would be a High Hazard dam.

Breach flows from Basin 6 indicate velocities in excess of 15 ft/s with typical depths ranging from 1-3 feet and maximum depths at about 5 feet.

See the breach flow maps in Appendix G for more information.

Debris basins that are constructed above grade with an embankment holding the debris or water volume back have been found to be high hazard per NRCS and Utah Dam Safety guidelines. These basins will require additional inspections, maintenance, embankment, design, etc.

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Conclusion

Two similar options for handling flooding along the east bench have been analyzed for the purpose of understanding the footprint that will be required for an environmental assessment. It can be seen by the flow comparison maps that both options clearly provide significant reductions in flow rates and in flood damages. Multiple options for each basin were modeled for reservoir routing, floodplain analysis and breach analysis.

Both options have a reasonable limit in how far the impacts have been studied. Further downstream analysis is possible but would impact schedule, analysis budget and would have a diminished return value.

Option A's extensive pipe network would be constructed to a downstream point where it appears there is adequate capacity for these flows. However, the discharge location down to Utah Lake has not been modeled.

Option B does not completely contain the 100-year flows but it does reduce them to a much safer level.

While this report was being finalized, Santaquin City Council made the decision to continue with Approach B instead of Approach A. The reasons for making this selection include: greater monetary benefit, less pipe maintenance requirements and potentially more overall protection from typical debris flows by having a larger basin.

A full geotechnical analysis will be needed when the projects are fully designed. When further funding for the basins is procured, it may only cover a portion of the overall 5-basin project. If that is the case, coordination with NRCS and Santaquin City must occur to determine which basin is the most critical at that time.

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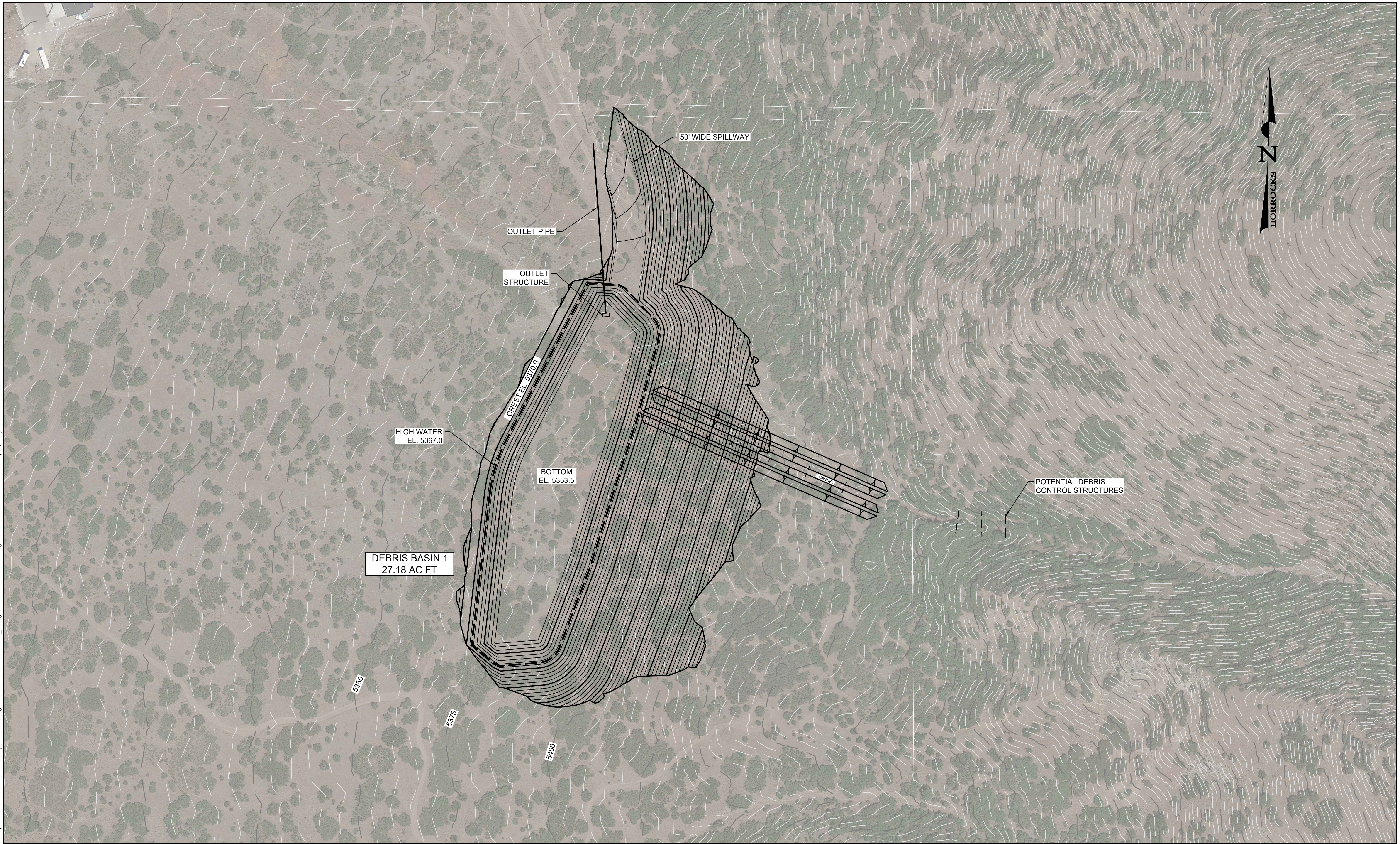
Attachments

Debris Basin Drawings



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REV	DATE	BY	DESCRIPTION
REVISIONS			

PRELIMINARY
NOT FOR CONSTRUCTION

SCALE
HORIZONTAL 1" = 150'
VERTICAL N/A

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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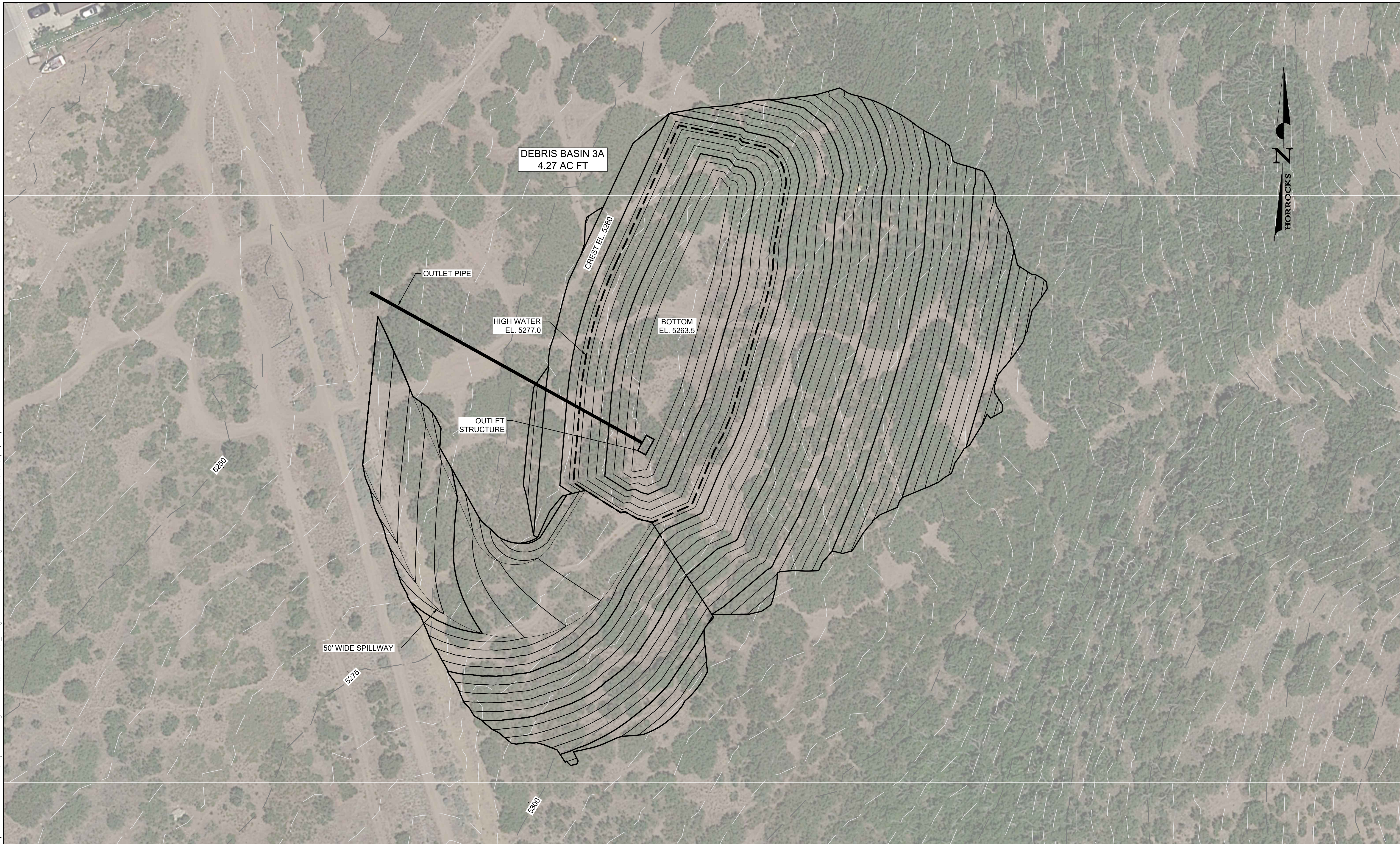
SANTAQUIN DEBRIS BASINS

BASIN 1 - BELOW GRADE

DESIGNED ####	DATE ####	PROJECT NO. PG-1024-1801
DRAWN ####	DATE ####	SHEET NO. # OF #
CHECKED ####	DATE ####	DRAWING NO. P-01



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PRELIMINARY
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REV	DATE	BY	DESCRIPTION

REVISIONS

SCALE	
HORIZONTAL	1" = 60'
VERTICAL	N/A

WARNING
0 1/2 1
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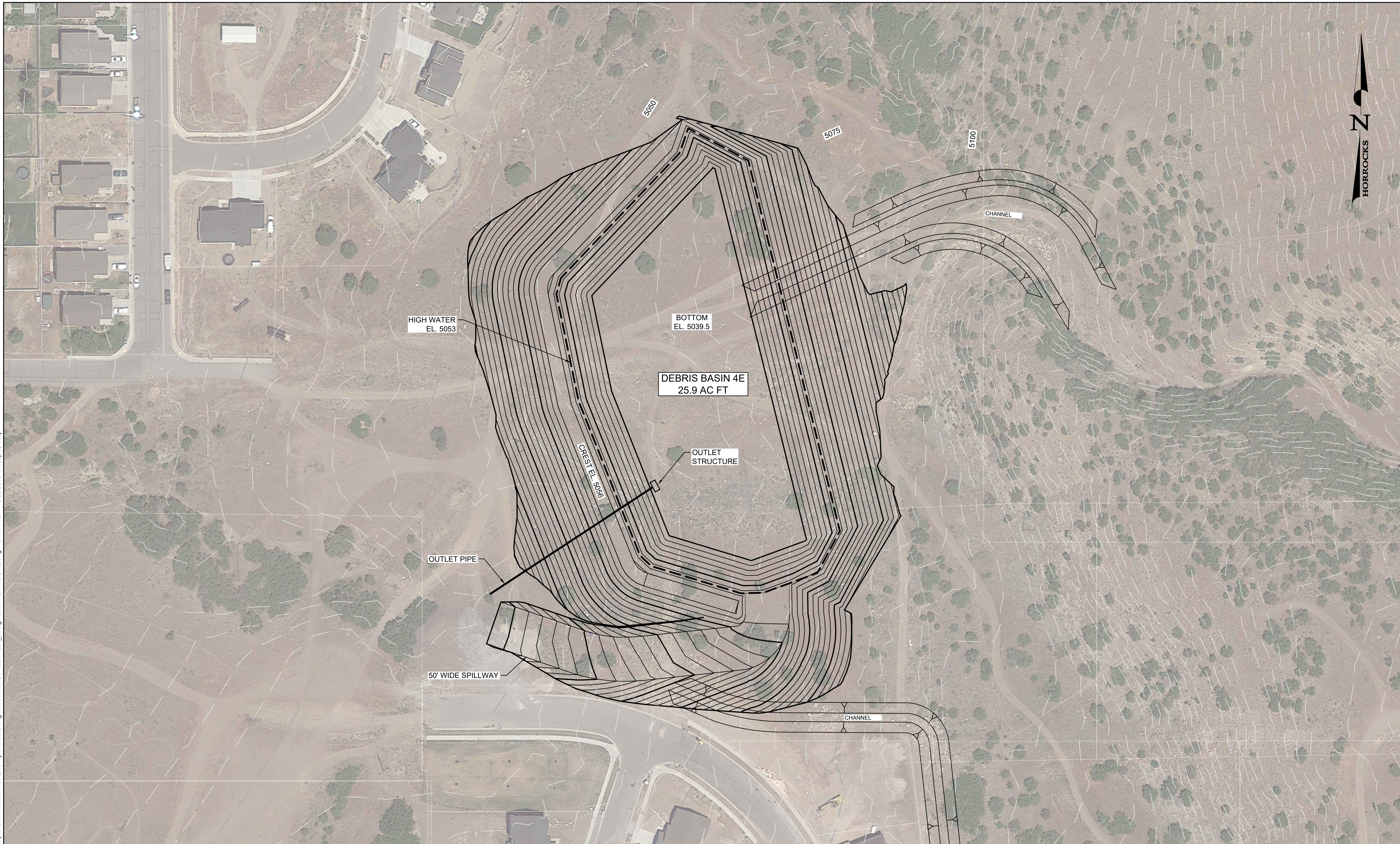
SANTAQUIN DEBRIS BASINS

BASIN 3A - BELOW GRADE (WATERSHEDS 2 & 3 COMBINED)

DESIGNED	DATE	PROJECT NO.
####	####	PG-1024-1801
DRAWN	DATE	SHEET NO.
####	####	# OF #
CHECKED	DATE	DRAWING NO.
####	####	P-05



PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION

REVISIONS

SCALE
HORIZONTAL 1" = 100'
VERTICAL N/A

WARNING
0 1/2 1
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SANTAQUIN DEBRIS BASINS

BASIN 4E - ABOVE GRADE (WATERSHED ONLY)

DESIGNED	DATE	PROJECT NO.
####	####	PG-1024-1801
DRAWN	DATE	SHEET NO.
####	####	5 OF 12
CHECKED	DATE	DRAWING NO.
####	####	P-05

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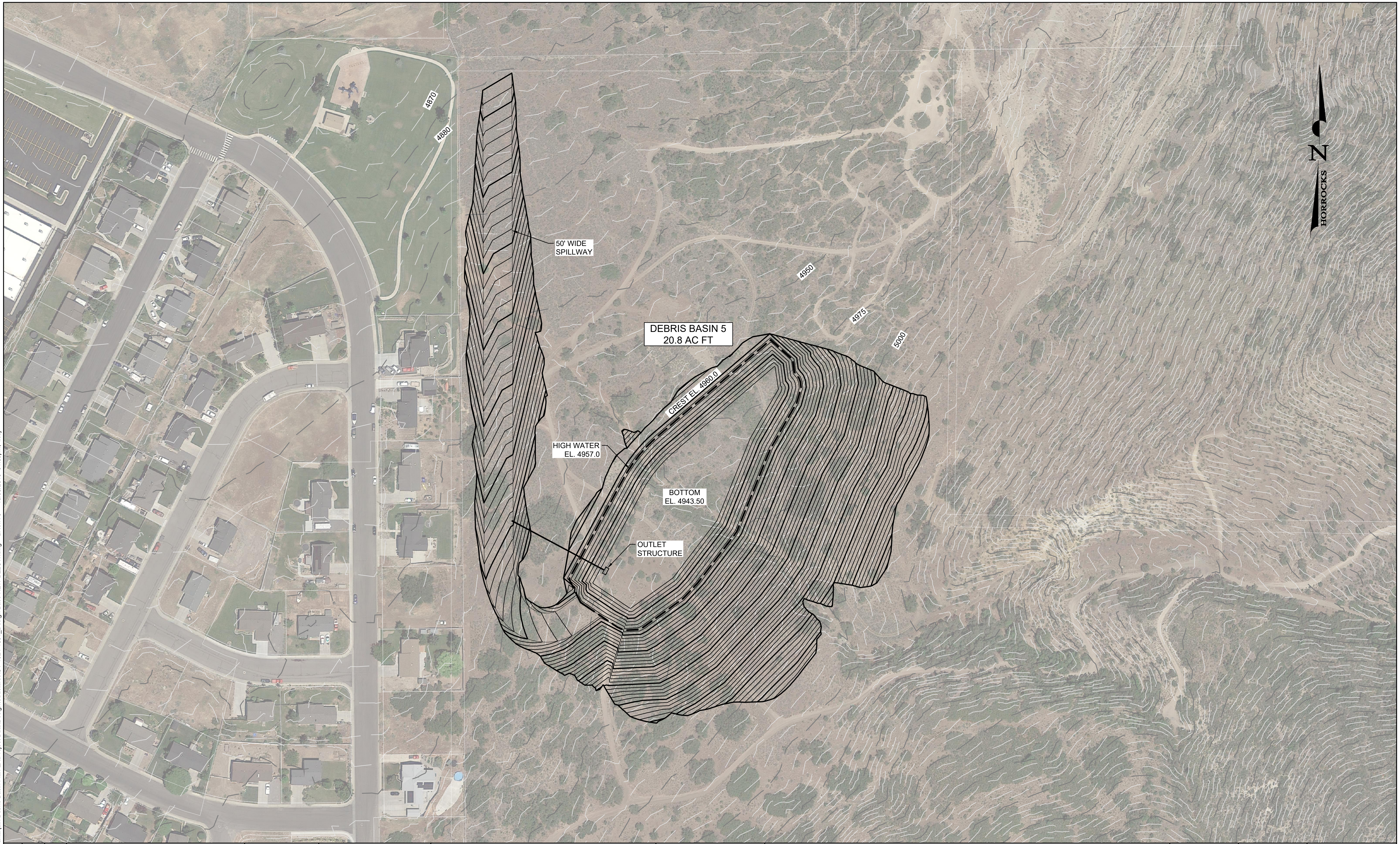

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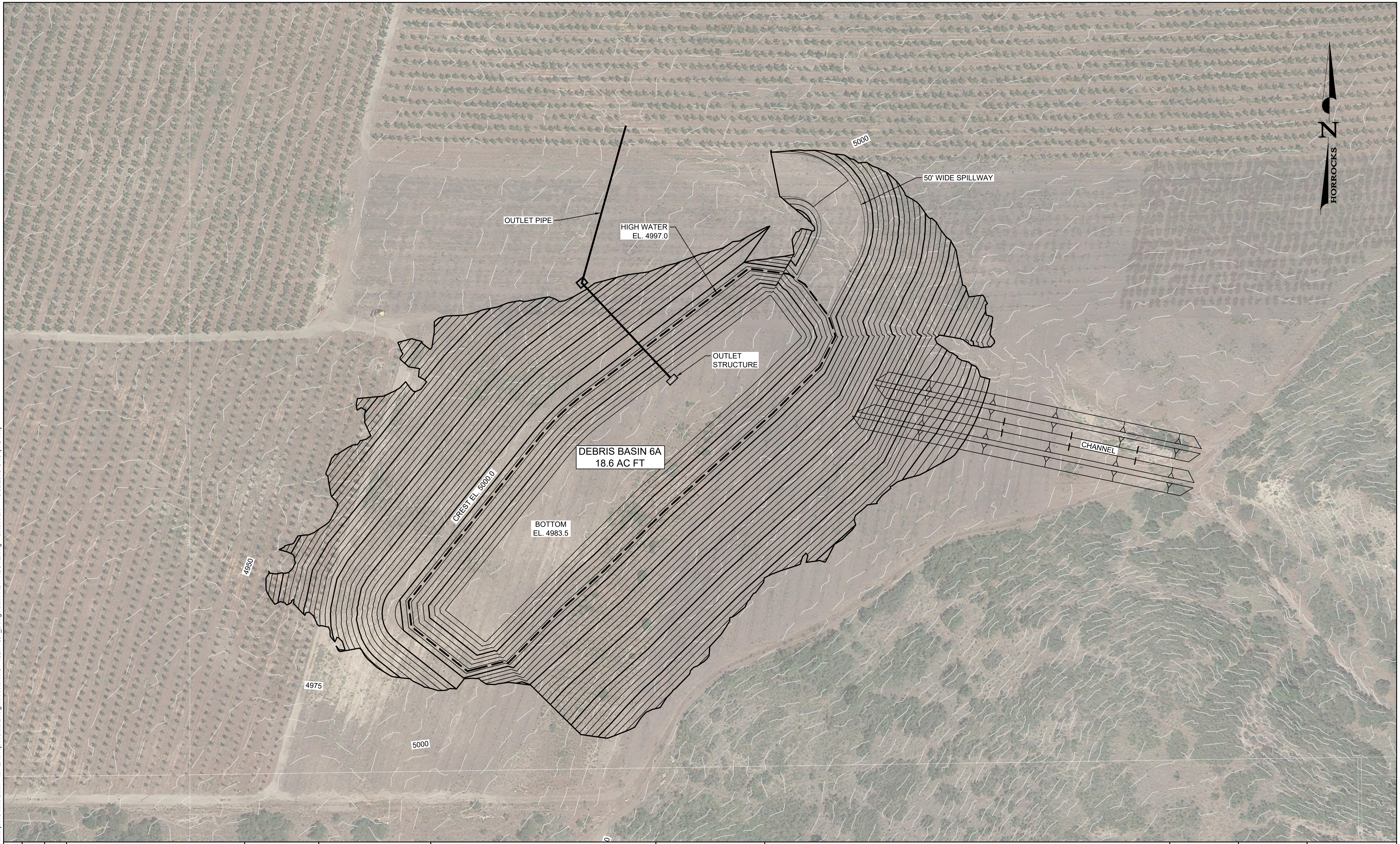
REV DATE BY DESCRIPTION REVISIONS							



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PRELIMINARY NOT FOR CONSTRUCTION REV / DATE / BY / DESCRIPTION REVISIONS	SCALE HORIZONTAL 1" = 100' VERTICAL N/A	WARNING 0 1/2 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE	HORROCKS ENGINEERS	2162 West Grove Parkway Suite 400 Pleasant Grove, UT 84062 (801) 763-5100

SANTAQUIN DEBRIS BASINS

BASIN 6A - ABOVE GRADE

DESIGNED ####	DATE ####	PROJECT NO. PG-1024-1801
DRAWN ####	DATE ####	SHEET NO. # OF #
CHECKED ####	DATE ####	DRAWING NO. P-07

Appendices

- Appendix A: Reservoir Routing and Basin Design Summary
- Appendix B: Approach B Drawdown Calculations
- Appendix C: Spillway
- Appendix D: Pre and Post Velocity and Depth Flood Maps
- Appendix E: Induced Flooding Maps
- Appendix F: Flow Comparison Maps
- Appendix G: Dam Breach Hydrographs, Dam Breach Maps
- Appendix H: Wave Runup Calculations

Appendix A: Reservoir Routing and Basin Design Summary

Santaquin Debris Basin SITES Results Summary **NOTE: All Runs Below are singular basin systems unless otherwise stated. Results from multi-basin systems will be identified in the Site Title.**

Prepared by: Mickey Navidomskis

Date Started: 5/23/2018 Most Recent Update: 7/26/2018

Site	1 Above Grade															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5395	5395	5395	5395	5395	5395	5395	5395	5395	5395	5395	5395	5395	NA	5395	5395
Original Dam Crest (ft)	5410	5410	5410	5410	5410	5410	5410	5410	5410	5410	5410	5410	5410	NA	5410	5410
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	NA	5398.5	5398.5
Principal Spillway Elevation Weir (ft)	5406.64	5407.07	5407	5407	5407	5407	5407	5407	5407	5407	5407	5407	5407	NA	5407	5407
Auxillary Spillway Elevation (ft)	5406.65	5407.08	5408.5	5408.5	5408.5	5408.5	5408.5	5408.5	5408.5	5408.5	5408.5	5408.5	5408.5	NA	5408.5	5408.5
Volume at Principal Spillway (acre-ft)	*	*	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	NA	17.2	17.2
Volume at Auxilliary Spillway (acre-ft)	*	*	20.35	20.35	20.35	20.35	20.35	20.35	20.35	20.35	20.35	20.35	20.35	NA	20.35	20.35
Volume at Low Stage Orifice Crest (acre-ft)	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	3.43	NA	3.43	3.43
Principal Spillway Weir Length (ft)	14	14	14	14	14	14	14	14	14	14	14	14	14	NA	14	14
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	NA	42	42
Scaling Factor	1.316	1.316	1.316	1.316	1.316	1.316	1.316	1.316	1.316	1.316	1.316	1.316	1.316	NA	1.316	1.316
PSH Peak Inflow (cfs)	61.44	67.51	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	13.71	15.88	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5406.64	5407.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	548	548	548	507	183.5	11.9	41.8	79.6	146.2	217.1	300.6	403.8	559.7	NA	418.5	174
FBH/Storm Peak Outflow (cfs)	465.2	445.9	515.1	502.6	183.4	3.4	6.6	9.1	12	18	60.5	146.4	334.8	NA	149	12.8
FBH/Storm Peak Principal Spillway Outflow (cfs)	109.2	87.9	135.1	203.6	145.4	3.4	6.6	9.1	12	18	60.5	121.4	196.8	NA	125	12.8
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	356	358	380	299	38	0	0	0	0	0	0	25	138	NA	24	0
FBH/Storm Initial Water Surface Elevation (ft)	5398.52	5398.52	5407	5407	5407	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	5398.5	NA	5398.5	5398.5
FBH/Storm Max Water Surface Elevation (ft)	5408.5	5409.04	5410.56	5410.29	5409.08	5399.80	5401.01	5402.51	5405.10	5407.16	5408.03	5408.82	5409.59	NA	5408.86	5405.95
Height of Water Above Auxillary Spillway (ft)	1.85	1.96	2.06	1.79	0.58	-8.7	-7.49	-5.99	-3.4	-1.34	-0.47	0.32	1.09	NA	0.36	-2.55
Final Dam Crest (ft)	5409.65	5410.08	5411.5	5411.5	5411.5	5411.5	5411.5	5411.5	5411.5	5411.5	5411.5	5411.5	5411.5	NA	5411.5	5411.5

Site	1 Below Grade															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5363.1	5363.1	5363.1	5363.1	5363.1	5363.1	5363.1	5363.1	5363.1	5363.1	5363.1	5363.1	5363.1	NA	5363.1	5363.1
Original Dam Crest (ft)	5378	5378	5378	5378	5378	5378	5378	5378	5378	5378	5378	5378	5378	NA	5378	5378
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	NA	5366.5	5366.5
Principal Spillway Elevation Weir (ft)	5371.84	5375.12	5375	5375	5375	5375	5375	5375	5375	5375	5375	5375	5375	NA	5375	5375
Auxillary Spillway Elevation (ft)	5371.85	5375.13	5376.6	5376.6	5376.6	5376.6	5376.6	5376.6	5376.6	5376.6	5376.6	5376.6	5376.6	NA	5376.6	5376.6
Volume at Principal Spillway (acre-ft)	*	*	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	NA	17.2	17.2
Volume at Auxilliary Spillway (acre-ft)	20.47	20.47	20.47	20.47	20.47	20.47	20.47	20.47	20.47	20.47	20.47	20.47	20.47	NA	20.47	20.47
Volume at Low Stage Orifice Crest (acre-ft)	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	NA	3.71	3.71
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	30	30	30	30	30	30	30	30	30	30	30	30	30	NA	42	30
Scaling Factor	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	NA	1.226	1.226
PSH Peak Inflow (cfs)	50.33	50.72	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	11	12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5371.84	5372.86	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	221.1	221.1	221.1	110.5	42.7	11.9	41.8	79.6	144.7	217.1	300.6	403.8	559.7	NA	418.5	174
FBH/Storm Peak Outflow (cfs)	131.3	101.1	166.4	103	41.5	3.5	6.7	9.6	12.1	29.4	84.8	183.1	317.6	NA	149.6	12.9
FBH/Storm Peak Principal Spillway Outflow (cfs)	36.3	47.1	112.4	99	41.5	3.5	6.7	9.6	12.1	29.4	84.8	90.1	91.6	NA	122.6	12.9
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	95	54	54	4	0	0	0	0	0	0	0	93	226	NA	27	0
FBH/Storm Initial Water Surface Elevation (ft)	5366.52	5366.52	5375	5375	5375	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	5366.5	NA	5377.02	5366.5
FBH/Storm Max Water Surface Elevation (ft)	5372.81	5375.8	5377.32	5376.72	5375.79	5367.81	5369.04	5370.88	5373.21	5375.54	5376.52	5377.54	5378.11	NA	5372.69	5374.07
Height of Water Above Auxillary Spillway (ft)	0.96	0.67	0.72	0.12	-0.81	-8.79	-7.56	-5.72	-3.39	-1.06	-0.08	0.94	1.51	NA	-3.91	-2.53
Final Dam Crest (ft)	5374.85	5378.13	5379.6	5379.6	5379.6	5379.6	5379.6	5379.6	5379.6	5379.6	5379.6	5379.6	5379.6	NA	5379.6	5379.6

Site	2 Above Grade															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5305	5305	5305	5305	5305	5305	5305	5305	5305	5305	5305	5305	5305	NA	5305	5305
Original Dam Crest (ft)	5320	5320	5320	5320	5320	5320	5320	5320	5320	5320	5320	5320	5320	NA	5320	5320
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5309	5309	5309	5309	5309	5309	5309	5309	5309	5309	5309	5309	5309	NA	5309	5309
Principal Spillway Elevation Weir (ft)	5310.31	5310.95	5316	5316	5316	5316	5316	5316	5316	5316	5316	5316	5316	NA	5316	5316
Auxillary Spillway Elevation (ft)	5310.32	5310.96	5317	5317	5317	5317	5317	5317	5317	5317	5317	5317	5317	NA	5317	5317
Volume at Principal Spillway (acre-ft)	*	*	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	NA	1.5	1.5
Volume at Auxilliary Spillway (acre-ft)	*	*	1.774	1.774	1.774	1.774	1.774	1.774	1.774	1.774	1.774	1.774	1.774	NA	1.774	1.774
Volume at Low Stage Orifice Crest (acre-ft)	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	NA	0.26	0.26
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	30	30	30	30	30	30	30	30	30	30	30	30	30	NA	30	30
Scaling Factor	1.0313	1.0313	1.0313	1.0313	1.0313	1.0313	1.0313	1.0313	1.0313	1.0313	1.0313	1.0313	1.0313	NA	1.0313	1.0313
PSH Peak Inflow (cfs)	5.65	7.58	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	5.12	6.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5310.31	5310.95	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	76.5	76.5	76.5	55.1	19.8	0.6	3.8	8.6	18.2	27.9	40.3	55.2	80.4	NA	60.7	19
FBH/Storm Peak Outflow (cfs)	76.3	76	76.4	55.1	19.7	0.5	2.1	4.3	7.9	10	11.9	28.6	70.3	NA	20.1	7.5
FBH/Storm Peak Principal Spillway Outflow (cfs)	15.3	16	59.4	52.1	19.7	0.5	2.1	4.3	7.9	10	11.9	28.6	57.3	NA	20.1	7.5
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	61	60	17	3	0	0	0	0	0	0	0	0	13	NA	0	0
FBH/Storm Initial Water Surface Elevation (ft)	5309.02	5309.02	5316	5316	5316	5309	5309	5309	5309	5309	5309	5309	5309	NA	5309	5309
FBH/Storm Max Water Surface Elevation (ft)	5310.72	5311.34	5317.15	5317.03	5316.32	5309.19	5309.74	5310.57	5312.08	5313.63	5315.48	5316.55	5317.11	NA	5316.34	5311.75
Height of Water Above Auxillary Spillway (ft)	0.4	0.38	0.15	0.03	-0.68	-7.81	-7.26	-6.43	-4.92	-3.37	-1.52	-0.45	0.11	NA	-0.66	-5.25
Final Dam Crest (ft)	5313.32	5313.96	5320	5320	5320	5320	5320	5320	5320	5320	5320	5320	5320	NA	5320	5320

Site	2 Below Grade															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5269.32	5269.32	5269.32	5269.32	5269.32	5269.32	5269.32	5269.32	5269.32	5269.32	5269.32	5269.32	5269.32	NA	5269.32	5269.32
Original Dam Crest (ft)	5284	5284	5284	5284	5284	5284	5284	5284	5284	5284	5284	5284	5284	NA	5284	5284
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5273	5273	5273	5273	5273	5273	5273	5273	5273	5273	5273	5273	5273	NA	5273	5273
Principal Spillway Elevation Weir (ft)	5273.29	5274.99	5280	5280	5280	5280	5280	5280	5280	5280	5280	5280	5280	NA	5280	5280
Auxillary Spillway Elevation (ft)	5273.3	5275	5281	5281	5281	5281	5281	5281	5281	5281	5281	5281	5281	NA	5281	5281
Volume at Principal Spillway (acre-ft)	*	*	1.385	1.385	1.385	1.385	1.385	1.385	1.385	1.385	1.385	1.385	1.385	NA	1.385	1.385
Volume at Auxilliary Spillway (acre-ft)	*	*	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	1.62	NA	1.62	1.62
Volume at Low Stage Orifice Crest (acre-ft)	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	NA	0.28	0.28
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	30	30	30	30	30	30	30	30	30	30	30	30	30	NA	30	30
Scaling Factor	0.716	0.716	0.716	0.716	0.716	0.716	0.716	0.716	0.716	0.716	0.716	0.716	0.716	NA	0.716	0.716
PSH Peak Inflow (cfs)	2.93	5.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	2.87	5.18	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5273.29	5274.34	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	26.4	26.4	26.4	11	4.3	0.6	3.8	8.6	18.2	27.9	40.3	55.2	80.4	NA	60.7	19
FBH/Storm Peak Outflow (cfs)	26	26.2	18.8	12.5	12.5	0.5	2.1	4.5	8.3	10.3	12.4	32.2	70.2	NA	32.5	7.7
FBH/Storm Peak Principal Spillway Outflow (cfs)	8	10.2	18.8	12.5	12.5	0.5	2.1	4.5	8.3	10.3	12.4	32.2	62.2	NA	32.5	7.7
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	18	16	0	0	0	0	0	0	0	0	0	0	8	NA	0	0
FBH/Storm Initial Water Surface Elevation (ft)	5273.02	5273.02	5280	5280	5280	5273	5273	5273	5273	5273	5273	5273	5273	NA	5273	5273
FBH/Storm Max Water Surface Elevation (ft)	5273.84	5275.25	5280.28	5280	5280	5273.19	5273.75	5274.61	5276.35	5277.90	5279.90	5280.64	5281.20	NA	5280.64	5275.87
Height of Water Above Auxillary Spillway (ft)	0.54	0.25	-0.72	-1	-1	-7.81	-7.25	-6.39	-4.65	-3.1	-1.1	-0.36	0.2	NA	-0.36	-5.13
Final Dam Crest (ft)	5276.3	5278	5284	5284	5284	5284	5284	5284	5284	5284	5284	5284	5284	NA	5284	5284

Site	3 Above Grade															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5255	5255	5255	5255	5255	5255	5255	5255	5255	5255	5255	5255	5255	NA	5255	5255
Original Dam Crest (ft)	5270	5270	5270	5270	5270	5270	5270	5270	5270	5270	5270	5270	5270	NA	5270	5270
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5259	5259	5259	5259	5259	5259	5259	5259	5259	5259	5259	5259	5259	NA	5259	5259
Principal Spillway Elevation Weir (ft)	5260.23	5260.5	5266	5266	5266	5266	5266	5266	5266	5266	5266	5266	5266	NA	5266	5266
Auxillary Spillway Elevation (ft)	5260.24	5260.51	5267	5267	5267	5267	5267	5267	5267	5267	5267	5267	5267	NA	5267	5267
Volume at Principal Spillway (acre-ft)	*	*	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	NA	1.1	1.1
Volume at Auxilliary Spillway (acre-ft)	*	*	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	1.31	NA	1.31	1.31
Volume at Low Stage Orifice Crest (acre-ft)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	NA	0.19	0.19
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	30	30	30	30	30	30	30	30	30	30	30	30	30	NA	30	30
Scaling Factor	0.859	0.859	0.859	0.859	0.859	0.859	0.859	0.859	0.859	0.859	0.859	0.859	0.859	NA	0.859	0.859
PSH Peak Inflow (cfs)	5.07	5.85	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	4.79	5.39	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5260.23	5260.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	65.5	65.5	65.5	44.6	15.7	0.8	4.2	8.7	17.1	25.7	36.4	49.4	71.1	NA	51.8	21
FBH/Storm Peak Outflow (cfs)	65.8	0	64.4	44.4	15.6	0.6	2.5	4.9	8.2	10.4	12.2	32.2	68.8	NA	24.7	8.9
FBH/Storm Peak Principal Spillway Outflow (cfs)	23.8	0	59.4	44.4	15.6	0.6	2.5	4.9	8.2	10.4	12.2	32.2	61.8	NA	24.7	8.9
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	42	0	5	0	0	0	0	0	0	0	0	0	7	NA	0	0
FBH/Storm Initial Water Surface Elevation (ft)	5259.02	5259.02	5266	5266	5266	5259	5259	5259	5259	5259	5259	5259	5259	NA	5259	5259
FBH/Storm Max Water Surface Elevation (ft)	5260.84	0	5267.15	5266.88	5266.14	5259.21	5259.92	5260.79	5262.34	5263.95	5265.74	5266.64	5267.19	NA	5266.45	5262.83
Height of Water Above Auxillary Spillway (ft)	0.6	-5260.51	0.15	-0.12	-0.86	-7.79	-7.08	-6.21	-4.66	-3.05	-1.26	-0.36	0.19	NA	-0.55	-4.17
Final Dam Crest (ft)	5263.24	5263.51	5270	5270	5270	5270	5270	5270	5270	5270	5270	5270	5270	NA	5270	5270
Site	3 Below Grade															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5225	5225	5225	5225	5225	5225	5225	5225	5225	5225	5225	5225	5225	NA	5225	5225
Original Dam Crest (ft)	5240	5240	5240	5240	5240	5240	5240	5240	5240	5240	5240	5240	5240	NA	5240	5240
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5229	5229	5229	5229	5229	5229	5229	5229	5229	5229	5229	5229	5229	NA	5229	5229
Principal Spillway Elevation Weir (ft)	5229.55	5230.52	5237	5237	5237	5237	5237	5237	5237	5237	5237	5237	5237	NA	5237	5237
Auxillary Spillway Elevation (ft)	5229.56	5230.53	5238	5238	5238	5238	5238	5238	5238	5238	5238	5238	5238	NA	5238	5238
Volume at Principal Spillway (acre-ft)	*	*	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	NA	1.1	1.1
Volume at Auxilliary Spillway (acre-ft)	*	*	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	NA	1.25	1.25
Volume at Low Stage Orifice Crest (acre-ft)	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	NA	0.23	0.23
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	30	30	30	30	30	30	30	30	30	30	30	30	30	NA	30	30
Scaling Factor	0.2404	0.2404	0.2404	0.2404	0.2404	0.2404	0.2404	0.2404	0.2404	0.2404	0.2404	0.2404	0.2404	NA	0.2404	0.2404
PSH Peak Inflow (cfs)	2.7	4.38	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	2.7	4.34	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5229.55	5230.01	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	23.1	23.1	23.1	6.2	3.5	0.8	4.2	8.7	17.1	25.7	36.4	49.4	71.1	NA	51.8	21
FBH/Storm Peak Outflow (cfs)	23.1	0	13.3	13.3	13.3	0.5	2.4	2.4	9.1	11.6	21.8	46.5	80.8	NA	26.8	9.3
FBH/Storm Peak Principal Spillway Outflow (cfs)	7.1	0	13.3	13.3	13.3	0.5	2.4	2.4	9.1	11.6	21.8	46.5	69.8	NA	26.8	9.3
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	16	0	0	0	0	0	0	0	0	0	0	0	11	NA	0	0
FBH/Storm Initial Water Surface Elevation (ft)	5229.02	5229.02	5237	5237	5237	5229	5229	5229	5229	5229	5229	5229	5229	NA	5229	5229
FBH/Storm Max Water Surface Elevation (ft)	5229.77	5229.02	5237	5232.05	5237	5229.19	5229.89	5229.89	5232.98	5235.19	5237.36	5237.90	5238.30	NA	5237.48	5233.17
Height of Water Above Auxillary Spillway (ft)	0.21	-1.51	-1	-5.95	-1	-8.81	-8.11	-8.11	-5.02	-2.81	-0.64	-0.1	0.3	NA	-0.52	-4.83
Final Dam Crest (ft)	5232.56	5233.53	5241	5241	5241	5241	5241	5241	5241	5241	5241	5241	5241	NA	5241	5241

Site	**3A Below Grade** (combined watersheds 2 &3)															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5220	5220	5220	5220	5220	5220	5220	5220	5220	5220	5220	5220	5220	NA	5220	5220
Original Dam Crest (ft)	5235	5235	5235	5235	5235	5235	5235	5235	5235	5235	5235	5235	5235	NA	5235	5235
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5225	5225	5225	5225	5225	5225	5225	5225	5225	5225	5225	5225	5225	NA	5225	5225
Principal Spillway Elevation Weir (ft)	5226.19	5226.69	5233	5233	5233	5233	5233	5233	5233	5233	5233	5233	5233	NA	5233	5233
Auxillary Spillway Elevation (ft)	5226.2	5226.7	5234	5234	5234	5234	5234	5234	5234	5234	5234	5234	5234	NA	5234	5234
Volume at Principal Spillway (acre-ft)	*	*	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	NA	2.6	2.6
Volume at Auxilliary Spillway (acre-ft)	*	*	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	2.98	NA	2.98	2.98
Volume at Low Stage Orifice Crest (acre-ft)	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	NA	0.55	0.55
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	30	30	30	30	30	30	30	30	30	30	30	30	30	NA	30	30
Scaling Factor	0.8802	0.8802	0.8802	0.8802	0.8802	0.8802	0.8802	0.8802	0.8802	0.8802	0.8802	0.8802	0.8802	NA	0.8802	0.8802
PSH Peak Inflow (cfs)	5.64	7.57	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	4.86	5.92	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5226.19	5226.69	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	72.4	72.4	49.4	20.2	7.8	1.4	7.4	17.3	35.3	52.3	75.4	104.6	151.5	NA	112.4	39
FBH/Storm Peak Outflow (cfs)	72.2	72.6	16.3	13.4	13.4	1	3.2	6.5	9.9	12.2	27.7	67.4	144.5	NA	53.3	9.9
FBH/Storm Peak Principal Spillway Outflow (cfs)	25.2	25.6	16.3	13.4	13.4	1	3.2	6.5	9.9	12.2	27.7	61.4	94.5	NA	52.3	9.9
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	47	47	0	0	0	0	0	0	0	0	0	6	50	NA	1	0
FBH/Storm Initial Water Surface Elevation (ft)	5225.05	5225.02	5233	5233	5233	5225	5225	5225	5225	5225	5225	5225	5225	NA	5225	5225
FBH/Storm Max Water Surface Elevation (ft)	5226.83	5227.33	5233.13	5233	5233	5225.29	5226.24	5227.42	5229.68	5231.78	5233.51	5234.17	5234.69	NA	5234.02	5229.62
Height of Water Above Auxillary Spillway (ft)	0.63	0.63	-0.87	-1	-1	-8.71	-7.76	-6.58	-4.32	-2.22	-0.49	0.17	0.69	NA	0.02	-4.38
Final Dam Crest (ft)	5229.2	5229.7	5237	5237	5237	5237	5237	5237	5237	5237	5237	5237	5237	NA	5237	5237

Site	**4E Above Grade (Watershed 4 only)** NOTICE: different auxilliary crest elevation from 4E Multi-Basin															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	NA	5040	5040
Original Dam Crest (ft)	5055	5055	5055	5055	5055	5055	5055	5055	5055	5055	5055	5055	5055	NA	5055	5055
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5043	5043	5043	5043	5043	5043	5043	5043	5043	5043	5043	5043	5043	NA	5043	5043
Principal Spillway Elevation Weir (ft)	5051.59	5052.25	5052	5052	5052	5052	5052	5052	5052	5052	5052	5052	5052	NA	5052	5052
Auxillary Spillway Elevation (ft)	5051.6	5052.26	5053	5053	5053	5053	5053	5053	5053	5053	5053	5053	5053	NA	5053	5053
Volume at Principal Spillway (acre-ft)	*	*	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	NA	17.09	17.09
Volume at Auxilliary Spillway (acre-ft)	*	*	18.99	18.99	18.99	18.99	18.99	18.99	18.99	18.99	18.99	18.99	18.99	NA	18.99	18.99
Volume at Low Stage Orifice Crest (acre-ft)	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	NA	3.34	3.34
Principal Spillway Weir Length (ft)	20	20	20	20	20	20	20	20	20	20	20	20	20	NA	20	20
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	NA	42	42
Scaling Factor	1	1	1	1	1	1	1	1	1	1	1	1	1	NA	1	1
PSH Peak Inflow (cfs)	61.27	73.83	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	14.2	28.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5051.59	5052.25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	582.7	582.7	582.7	544.7	199.4	8.8	35.9	71.2	139.1	207.8	291.6	395.8	563.8	NA	442.5	157
FBH/Storm Peak Outflow (cfs)	523.7	507.3	558.3	541.1	199.3	3.3	6.7	9.5	12.3	30.7	71.8	236.7	452.7	NA	217.2	13
FBH/Storm Peak Principal Spillway Outflow (cfs)	179.7	200.3	230.3	230.1	148.3	3.3	6.7	9.5	12.3	30.7	71.8	166.7	228.7	NA	157.2	13
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	344	307	328	311	51	0	0	0	0	0	0	70	224	NA	60	0
FBH/Storm Initial Water Surface Elevation (ft)	5043.02	5043.02	5052	5052	5052	5043	5043	5043	5043	5043	5043	5043	5043	NA	5043	5043
FBH/Storm Max Water Surface Elevation (ft)	5053.51	5054.07	5054.9	5054.85	5053.66	5044.26	5045.59	5047.30	5049.86	5052.40	5052.94	5053.81	5054.54	NA	5053.73	5050.7
Height of Water Above Auxillary Spillway (ft)	1.91	1.81	1.9	1.85	0.66	-8.74	-7.41	-5.7	-3.14	-0.6	-0.06	0.81	1.54	NA	0.73	-2.3
Final Dam Crest (ft)	5054.6	5055.26	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	5056	NA	5056	5056

Site	**Basin 4E Above Grade Multi-Basin** (includes Watershed 4 and inputs from Basin 1below, 2below, and 3 below)															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	NA	5040	5040
Original Dam Crest (ft)	5055	5055	5055	5055	5055	5055	5055	5055	5055	5055	5055	5055	5055	NA	5055	5055
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5043	5043	5043	5043	5043	5043	5043	5043	5043	5043	5043	5043	5043	NA	5043	5043
Principal Spillway Elevation Weir (ft)	5052.74	5053.12	5052	5052	5052	5052	5052	5052	5052	5052	5052	5052	5052	NA	5052	5052
Auxillary Spillway Elevation (ft)	5052.75	5053.13	5054	5054	5054	5054	5054	5054	5054	5054	5054	5054	5054	NA	5054	5054
Volume at Principal Spillway (acre-ft)	*	*	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	NA	17.09	17.09
Volume at Auxilliary Spillway (acre-ft)	*	*	20.97	20.97	20.97	20.97	20.97	20.97	20.97	20.97	20.97	20.97	20.97	NA	20.97	20.97
Volume at Low Stage Orifice Crest (acre-ft)	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	3.34	NA	3.34	3.34
Principal Spillway Weir Length (ft)	20	20	20	20	20	20	20	20	20	20	20	20	20	NA	20	20
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	NA	42	42
Scaling Factor	1	1	1	1	1	1	1	1	1	1	1	1	1	NA	1	1
PSH Peak Inflow (cfs)	73.49	97.24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	55.11	92.28	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5052.74	5053.12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	609.4	609.6	754.2	654.3	247.8	11.9	41.8	82.6	162.7	217.3	326.4	493.5	889.1	NA	504.8	183
FBH/Storm Peak Outflow (cfs)	520.6	504.1	729.9	649	246	6	10	13	27.9	84.2	189.5	438.9	825	NA	338.2	34.2
FBH/Storm Peak Principal Spillway Outflow (cfs)	228.6	230.1	236.9	236	228	6	10	13	27.9	84.2	189.5	232.9	238	NA	230.9	34.2
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	292	274	493	413	18	0	0	0	0	0	0	206	587	NA	107.3	0
FBH/Storm Initial Water Surface Elevation (ft)	5043.02	5043.02	5052	5052	5052	5043	5043	5043	5043	5043	5043	5043	5043	NA	5043	5043
FBH/Storm Max Water Surface Elevation (ft)	5054.52	5054.85	5056.35	5056.14	5054.39	5045.34	5047.75	5050.67	5052.27	5053.05	5053.99	505.46	5056.59	NA	5055.03	5052.39
Height of Water Above Auxillary Spillway (ft)	1.77	1.72	2.35	2.14	0.39	-8.66	-6.25	-3.33	-1.73	-0.95	-0.01	-4548.54	2.59	NA	1.03	-1.61
Final Dam Crest (ft)	5055.75	5056.13	5057	5057	5057	5057	5057	5057	5057	5057	5057	5057	5057	NA	5057	5057

Site	**4D Below Grade (Watershed 4 inputs)**															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	NA	5025	5025
Original Dam Crest (ft)	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	NA	5040	5040
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5029	5029	5029	5029	5029	5029	5029	5029	5029	5029	5029	5029	5029	NA	5029	5029
Principal Spillway Elevation Weir (ft)	5033.61	5037.39	5037	5037	5037	5037	5037	5037	5037	5037	5037	5037	5037	NA	5037	5037
Auxillary Spillway Elevation (ft)	5033.62	5037.4	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	NA	5038.5	5038.5
Volume at Principal Spillway (acre-ft)	*	*	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	NA	17.09	17.09
Volume at Auxilliary Spillway (acre-ft)	*	*	19.98	19.98	19.98	19.98	19.98	19.98	19.98	19.98	19.98	19.98	19.98	NA	19.98	19.98
Volume at Low Stage Orifice Crest (acre-ft)	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	NA	4.59	4.59
Principal Spillway Weir Length (ft)	20	20	20	20	20	20	20	20	20	20	20	20	20	NA	20	20
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	42	42	42	30	42	42	42	42	42	42	42	42	42	NA	30	42
Scaling Factor	1	1	1	1	1	1	1	1	1	1	1	1	1	NA	1	1
PSH Peak Inflow (cfs)	33.37	55.39	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	10.24	12.72	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5033.61	5036.09	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	215.6	215.6	215.6	111.6	44.5	8.8	35.9	71.2	139.1	207.8	291.6	395.8	563.8	NA	442.5	157
FBH/Storm Peak Outflow (cfs)	160.9	102.6	185.2	107.6	43.9	3.3	6.7	9.3	12	42.6	115.4	244	450.5	NA	202.5	12.8
FBH/Storm Peak Principal Spillway Outflow (cfs)	65.9	65.6	171.2	107.6	43.9	3.3	6.7	9.3	12	42.6	115.4	115	252.5	NA	115.5	12.8
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	95	37	14	0	0	0	0	0	0	0	0	129	198	NA	87	0
FBH/Storm Initial Water Surface Elevation (ft)	5029.02	5029.02	5037	5037	5029	5029	5029	5029	5029	5029	5029	5029	5029	NA	5029	5029
FBH/Storm Max Water Surface Elevation (ft)	6034.54	5037.88	5038.85	5038.31	5037.6	5030.20	5031.47	5033.14	5035.61	5037.59	5038.36	5039.14	5039.93	NA	5039.42	5036.43
Height of Water Above Auxillary Spillway (ft)	1000.92	0.48	0.35	-0.19	-0.9	-8.3	-7.03	-5.36	-2.89	-0.91	-0.14	0.64	1.43	NA	0.92	-2.07
Final Dam Crest (ft)	5036.62	5040.4	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	NA	5041.5	5041.5

Site	**Basin 4D Below Grade Multi-Basin** (includes Watershed 4 and inputs from Basin 1below, 2below, and 3 below)															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	NA	5025	5025
Original Dam Crest (ft)	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	NA	5040	5040
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5029	5029	5029	5029	5029	5029	5029	5029	5029	5029	5029	5029	5029	NA	5029	5029
Principal Spillway Elevation Weir (ft)	5037.2	5038.13	5037	5037	5037	5037	5037	5037	5037	5037	5037	5037	5037	NA	5037	5037
Auxillary Spillway Elevation (ft)	5037.21	5038.14	5039	5039	5039	5039	5039	5039	5039	5039	5039	5039	5039	NA	5039	5039
Volume at Principal Spillway (acre-ft)	*	*	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	17.09	NA	17.09	17.09
Volume at Auxilliary Spillway (acre-ft)	*	*	20.96	20.96	20.96	20.96	20.96	20.96	20.96	20.96	20.96	20.96	20.96	NA	20.96	20.96
Volume at Low Stage Orifice Crest (acre-ft)	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	4.59	NA	4.59	4.59
Principal Spillway Weir Length (ft)	20	20	20	20	20	20	20	20	20	20	20	20	20	NA	20	20
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	NA	30	42
Scaling Factor	1	1	1	1	1	1	1	1	1	1	1	1	1	NA	1	1
PSH Peak Inflow (cfs)	48.52	97.23	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	25.41	92.41	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5037.2	5038.13	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	244	244	379.5	226.9	93.1	9.8	42.8	149.1	162.8	238.6	335.1	486.3	875	NA	504.8	182.9
FBH/Storm Peak Outflow (cfs)	193.6	192.4	350.7	215.6	91.9	6.1	10.1	23	32.3	91.3	183.2	374.2	820.2	NA	349.7	38.4
FBH/Storm Peak Principal Spillway Outflow (cfs)	91.6	153.4	252.7	116.6	91.9	6.1	10.1	23	32.3	91.3	183.2	253.2	259.2	NA	232	38.4
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	102	39	98	99	0	0	0	0	0	0	0	121	561	NA	117.7	0
FBH/Storm Initial Water Surface Elevation (ft)	5029.02	5029.02	5037	5037	5029	5029	5029	5029	5029	5029	5029	5029	5029	NA	5029	5029
FBH/Storm Max Water Surface Elevation (ft)	5038.16	5038.71	5039.98	5039.98	5038.14	5031.24	5033.76	5037.19	5037.37	5038.14	5038.94	5040.10	5041.53	NA	5040.52	5037.49
Height of Water Above Auxillary Spillway (ft)	0.95	0.57	0.98	0.98	-0.86	-7.76	-5.24	-1.81	-1.63	-0.86	-0.06	1.1	2.53	NA	1.52	-1.51
Final Dam Crest (ft)	5040.21	5041.14	5042	5042	5042	5042	5042	5042	5042	5042	5042	5042	5042	NA	5042	5042

	Site	**Basin 4A-4B Above Grade Multi-Basin** (includes Watershed 4 and inputs from Basin 1below, 2below, and 3 below)															
	Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
	Reservoir Bottom Elevation (ft)	5015.58	5015.58	5015.58	5015.58	5015.58	5015.58	5015.58	5015.58	5015.58	5015.58	5015.58	5015.58	5015.58	NA	5015.58	5015.58
	Original Dam Crest (ft)	5030	5030	5030	5030	5030	5030	5030	5030	5030	5030	5030	5030	5030	NA	5030	5030
	Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5019	5019	5019	5019	5019	5019	5019	5019	5019	5019	5019	5019	5019	NA	5019	5019
	Principal Spillway Elevation Weir (ft)	*	*	5027	5027	5027	5027	5027	5027	5027	5027	5027	5027	5027	NA	5027	5027
	Auxillary Spillway Elevation (ft)	*	*	5029.6	5029.6	5029.6	5029.6	5029.6	5029.6	5029.6	5029.6	5029.6	5029.6	5029.6	NA	5029.6	5029.6
	Volume at Principal Spillway (acre-ft)	*	*	15.353	15.353	15.353	15.353	15.353	15.353	15.353	15.353	15.353	15.353	15.353	NA	15.353	15.353
	Volume at Auxilliary Spillway (acre-ft)	*	*	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	NA	20.2	20.2
	Volume at Low Stage Orifice Crest (acre-ft)	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	NA	3.55	3.55
	Principal Spillway Weir Length (ft)	16	16	16	16	16	16	16	16	16	16	16	16	16	NA	16	16
	Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
	Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	NA	42	42
4B	Scaling Factor	1.447	1.447	1.447	1.447	1.447	1.447	1.447	1.447	1.447	1.447	1.447	1.447	1.447	NA	1.447	1.447
	PSH Peak Inflow (cfs)	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Peak Outflow (cfs)	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Max Water Surface Elevation (ft)	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	FBH/Storm Peak Inflow (cfs)	*	*	719.6	*	*	*	*	*	*	*	335.35	*	*	NA	504.7	*
	FBH/Storm Peak Outflow (cfs)	*	*	719.1	*	*	*	*	*	*	*	214.5	*	*	NA	345.6	*
	FBH/Storm Peak Principal Spillway Outflow (cfs)	*	*	303.1	*	*	*	*	*	*	*	214.5	*	*	NA	292.9	*
	FBH/Storm Peak Auxillary Spillway Outflow (cfs)	*	*	416	*	*	*	*	*	*	*	0	*	*	NA	52.7	*
	FBH/Storm Initial Water Surface Elevation (ft)	*	*	5027	5027	5027	5019	5019	5019	5019	5019	5019	5019	5019	NA	5019	5019
	FBH/Storm Max Water Surface Elevation (ft)	*	*	5031.57	*	*	*	*	*	*	*	5029.52	*	*	NA	5030.31	*
	Height of Water Above Auxillary Spillway (ft)	*	*	1.97	*	*	*	*	*	*	*	-0.08	*	*	NA	0.71	*
	Final Dam Crest (ft)	*	*	5032.6	5032.6	5032.6	5032.6	5032.6	5032.6	5032.6	5032.6	5032.6	5032.6	5032.6	NA	5032.6	5032.6

	Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
	Reservoir Bottom Elevation (ft)	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	NA	4991	4991
	Original Dam Crest (ft)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	NA	5000	5000
	Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	4993	4993	4993	4993	4993	4993	4993	4993	4993	4993	4993	4993	4993	NA	4993	4993
	Principal Spillway Elevation Weir (ft)	4997.97	4998.21	4997	4997	4997	4997	4997	4997	4997	4997	4997	4997	4997	NA	4997	4997

4A	Auxillary Spillway Elevation (ft)	4997.98	4998.22	4999.2	4999.2	4999.2	4999.2	4999.2	4999.2	4999.2	4999.2	4999.2	4999.2	4999.2	NA	4999.2	4999.2
	Volume at Principal Spillway (acre-ft)	*	*	1.747	1.747	1.747	1.747	1.747	1.747	1.747	1.747	1.747	1.747	1.747	NA	1.747	1.747
	Volume at Auxilliary Spillway (acre-ft)	*	*	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	NA	2.7	2.7
	Volume at Low Stage Orifice Crest (acre-ft)	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	NA	0.44	0.44
	Principal Spillway Weir Length (ft)	20	20	20	20	20	20	20	20	20	20	20	20	20	NA	20	20
	Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
	Principal Spillway Outlet Pipe Diameter (in)	48	48	48	48	48	48	48	48	48	48	48	48	48	NA	48	48
	Scaling Factor	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	NA	1.2	1.2
	PSH Peak Inflow (cfs)	66	88.77	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Peak Outflow (cfs)	65.66	88.39	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Max Water Surface Elevation (ft)	4997.97	4998.21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	FBH/Storm Peak Inflow (cfs)	486.8	520.4	719.2	647.6	246.9	6.1	9.9	25	47.9	97	214.5	440.2	810.7	NA	346.6	41.1
	FBH/Storm Peak Outflow (cfs)	485.9	518.5	717.9	647.1	246.7	5.9	9.9	24.9	47.6	95.2	213.8	439.2	805.8	NA	345.4	40.9
	FBH/Storm Peak Principal Spillway Outflow (cfs)	243.9	252.5	258.9	258.1	240.7	5.9	9.9	24.9	47.6	95.2	213.8	255.2	259.8	NA	253.4	40.9
	FBH/Storm Peak Auxillary Spillway Outflow (cfs)	242	266	459	389	6	0	0	0	0	0	0	184	546	NA	92	0
	FBH/Storm Initial Water Surface Elevation (ft)	4993.02	4993.02	4997	4997	4997	4993	4993	4993	4993	4993	4993	4993	4993	NA	4993	4993
	FBH/Storm Max Water Surface Elevation (ft)	4999.58	4999.93	5001.46	5001.27	4999.39	4994.82	4997.01	4997.29	4997.71	4998.22	4999.2	5000.57	5001.7	NA	5000.15	4997.58
	Height of Water Above Auxillary Spillway (ft)	1.6	1.71	2.26	2.07	0.19	-4.38	-2.19	-1.91	-1.49	-0.98	0	1.37	2.5	NA	0.95	-1.62
	Final Dam Crest (ft)	5000.98	5001.22	5002.2	5002.2	5002.2	5002.2	5002.2	5002.2	5002.2	5002.2	5002.2	5002.2	5002.2	NA	5002.2	5002.2
	Site	**Basin 4A-4B Below Grade Multi-Basin** (includes Watershed 4 and inputs from Basin 1below, 2below, and 3 below) NOTE: 60ft wide auxilliary spillway															
4B	Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
	Reservoir Bottom Elevation (ft)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	NA	5000	5000
	Original Dam Crest (ft)	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	NA	5015	5015
	Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5003	5003	5003	5003	5003	5003	5003	5003	5003	5003	5003	5003	5003	NA	5003	5003
	Principal Spillway Elevation Weir (ft)	*	*	5012	5012	5012	5012	5012	5012	5012	5012	5012	5012	5012	NA	5012	5012
	Auxillary Spillway Elevation (ft)	*	*	5014.4	5014.4	5014.4	5014.4	5014.4	5014.4	5014.4	5014.4	5014.4	5014.4	5014.4	NA	5014.4	5014.4
	Volume at Principal Spillway (acre-ft)	*	*	15.268	15.268	15.268	15.268	15.268	15.268	15.268	15.268	15.268	15.268	15.268	NA	15.268	15.268
	Volume at Auxilliary Spillway (acre-ft)	*	*	19.58	19.58	19.58	19.58	19.58	19.58	19.58	19.58	19.58	19.58	19.58	NA	19.58	19.58
	Volume at Low Stage Orifice Crest (acre-ft)	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	NA	2.89	2.89
	Principal Spillway Weir Length (ft)	18	18	18	18	18	18	18	18	18	18	18	18	18	NA	18	18
	Auxillary Spillway Width (ft)	60	60	60	60	60	60	60	60	60	60	60	60	60	NA	60	60
	Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	NA	42	42
	Scaling Factor	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	NA	1.273	1.273
	PSH Peak Inflow (cfs)	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Peak Outflow (cfs)	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Max Water Surface Elevation (ft)	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	FBH/Storm Peak Inflow (cfs)	*	*	379.5	*	*	*	*	*	*	238.59	335.4	*	*	NA	*	*
	FBH/Storm Peak Outflow (cfs)	*	*	348.7	*	*	*	*	*	*	92.9	210.9	*	*	NA	*	*
	FBH/Storm Peak Principal Spillway Outflow (cfs)	*	*	243.5	*	*	*	*	*	*	92.9	210.9	*	*	NA	*	*
	FBH/Storm Peak Auxillary Spillway Outflow (cfs)	*	*	105.2	*	*	*	*	*	*	0	0	*	*	NA	*	*
	FBH/Storm Initial Water Surface Elevation (ft)	*	*	5003	*	*	*	*	*	*	5003	5003	*	*	NA	*	*
	FBH/Storm Max Water Surface Elevation (ft)	*	*	5014.89	*	*	*	*	*	*	5013.22	5014.30	*	*	NA	*	*
	Height of Water Above Auxillary Spillway (ft)	*	*	0.49	*	*	*	*	*	*	-1.18	-0.1	*	*	NA	*	*
	Final Dam Crest (ft)	*	*	5017.4	5017.4	5017.4	5017.4	5017.4	5017.4	5017.4	5017.4	5017.4	5017.4	5017.4	NA	5017.4	5017.4
	Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
	Reservoir Bottom Elevation (ft)	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	NA	4981	4981
	Original Dam Crest (ft)	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	NA	4991	4991
	Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	4983	4983	4983	4983	4983	4983	4983	4983	4983	4983	4983	4983	4983	NA	4983	4983
	Principal Spillway Elevation Weir (ft)	4988.91	4989.24	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	NA	4988	4988
	Auxillary Spillway Elevation (ft)	4988.92	4989.25	4990.4	4990.4	4990.4	4990.4	4990.4	4990.4	4990.4	4990.4	4990.4	4990.4	4990.4	NA	4990.4	4990.4
	Volume at Principal Spillway (acre-ft)	*	*	1.732	1.732	1.732	1.732	1.732	1.732	1.732	1.732	1.732	1.732	1.732	NA	1.732	1.732
	Volume at Auxilliary Spillway (acre-ft)	*	*	2.66	2.66	2.66	2.66	2.66	2.66	2.66	2.66	2.66	2.66	2.66	NA	2.66	2.66
	Volume at Low Stage Orifice Crest (acre-ft)	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	NA	0.36	0.36
	Principal Spillway Weir Length (ft)	18	18	18	18	18	18	18	18	18	18	18	18	18	NA	18	18
	Auxillary Spillway Width (ft)	60	60	60	60	60	60	60	60	60	60	60	60	60	NA	60	60

4A	Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	NA	42	42
	Scaling Factor	1	1	1	1	1	1	1	1	1	1	1	1	1	NA	1	1
	PSH Peak Inflow (cfs)	62.1	92.55	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Peak Outflow (cfs)	61.8	92.25	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Max Water Surface Elevation (ft)	4988.91	4989.24	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	FBH/Storm Peak Inflow (cfs)	527.3	192.8	348.7	162.8	92	6.25	10.5	13.4	32.8	92.9	211	407	790.7	NA	346	39.3
	FBH/Storm Peak Outflow (cfs)	526.5	14978	348.3	161.8	91.9	6.2	10.3	13.4	32.7	92.5	208.2	404.8	790.7	NA	345.8	39.2
	FBH/Storm Peak Principal Spillway Outflow (cfs)	209.5	14935	214.3	161.8	91.9	6.2	10.3	13.4	32.7	92.5	208.2	214.8	220	NA	213.8	39.2
	FBH/Storm Peak Auxillary Spillway Outflow (cfs)	317	43	134	0	0	0	0	0	0	0	0	190	570.7	NA	132	0
	FBH/Storm Initial Water Surface Elevation (ft)	4983.02	4983.02	4988	4988	4988	4983	4983	4983	4983	4983	4983	4983	4983	NA	4983	4983
	FBH/Storm Max Water Surface Elevation (ft)	4990.61	4989.82	4991.56	4989.92	4989.26	4984.9	4987.82	4988.07	4988.45	4989.26	4990.35	4991.66	4992.72	NA	4991.47	4988.57
	Height of Water Above Auxillary Spillway (ft)	1.69	0.57	1.16	-0.48	-1.14	-5.5	-2.58	-2.33	-1.95	-1.14	-0.05	1.26	2.32	NA	1.07	-1.83
	Final Dam Crest (ft)	4991.92	4992.25	4993.4	4993.4	4993.4	4993.4	4993.4	4993.4	4993.4	4993.4	4993.4	4993.4	4993.4	NA	4993.4	4993.4
	Site	**Basin 4A-4B Below Grade (watershed 4 inputs only)** NOTE: 60ft wide auxilliary spillway															
4B	Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
	Reservoir Bottom Elevation (ft)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	NA	5000	5000
	Original Dam Crest (ft)	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	NA	5015	5015
	Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5003	5003	5003	5003	5003	5003	5003	5003	5003	5003	5003	5003	5003	NA	5003	5003
	Principal Spillway Elevation Weir (ft)	*	*	5012	5012	5012	5012	5012	5012	5012	5012	5012	5012	5012	NA	5012	5012
	Auxillary Spillway Elevation (ft)	*	*	5013.5	5013.5	5013.5	5013.5	5013.5	5013.5	5013.5	5013.5	5013.5	5013.5	5013.5	NA	5013.5	5013.5
	Volume at Principal Spillway (acre-ft)	*	*	15.268	15.268	15.268	15.268	15.268	15.268	15.268	15.268	15.268	15.268	15.268	NA	15.268	15.268
	Volume at Auxilliary Spillway (acre-ft)	*	*	17.91	17.91	17.91	17.91	17.91	17.91	17.91	17.91	17.91	17.91	17.91	NA	17.91	17.91
	Volume at Low Stage Orifice Crest (acre-ft)	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	NA	2.89	2.89
	Principal Spillway Weir Length (ft)	18	18	18	18	18	18	18	18	18	18	18	18	18	NA	18	18
	Auxillary Spillway Width (ft)	60	60	60	60	60	60	60	60	60	60	60	60	60	NA	60	60
	Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	NA	42	42
	Scaling Factor	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	1.273	NA	1.273	1.273
	PSH Peak Inflow (cfs)	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Peak Outflow (cfs)	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Max Water Surface Elevation (ft)	*	*	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	FBH/Storm Peak Inflow (cfs)	*	*	215.6	*	*	8.8	35.9	71.2	139.1	207.8	291.6	395.8	563.8	NA	442.5	183.3
	FBH/Storm Peak Outflow (cfs)	*	*	190.7	*	*	*	*	*	*	*	115.7	*	*	NA	241.8	*
	FBH/Storm Peak Principal Spillway Outflow (cfs)	*	*	165	*	*	*	*	*	*	*	115.7	*	*	NA	189.9	*
	FBH/Storm Peak Auxillary Spillway Outflow (cfs)	*	*	25.7	*	*	*	*	*	*	*	0	*	*	NA	51.9	*
	FBH/Storm Initial Water Surface Elevation (ft)	*	*	5012	5012	5012	5003	5003	5003	5003	5003	5003	5003	5003	NA	5003	5003
	FBH/Storm Max Water Surface Elevation (ft)	*	*	5013.93	*	*	*	*	*	*	*	5013.48	*	*	NA	5014.13	*
	Height of Water Above Auxillary Spillway (ft)	*	*	0.43	*	*	*	*	*	*	*	-0.02	*	*	NA	0.63	*
	Final Dam Crest (ft)	*	*	5016.5	5016.5	5016.5	5016.5	5016.5	5016.5	5016.5	5016.5	5016.5	5016.5	5016.5	NA	5016.5	5016.5
4A	Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
	Reservoir Bottom Elevation (ft)	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	4981	NA	4981	4981
	Original Dam Crest (ft)	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	4991	NA	4991	4991
	Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	4983	4983	4983	4983	4983	4983	4983	4983	4983	4983	4983	4983	4983	NA	4983	4983
	Principal Spillway Elevation Weir (ft)	4987.64	4988.42	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	NA	4988	4988
	Auxillary Spillway Elevation (ft)	4987.65	4988.43	4989.5	4989.5	4989.5	4989.5	4989.5	4989.5	4989.5	4989.5	4989.5	4989.5	4989.5	NA	4989.5	4989.5
	Volume at Principal Spillway (acre-ft)	*	*	1.732	1.732	1.732	1.732	1.732	1.732	1.732	1.732	1.732	1.732	1.732	NA	1.732	1.732
	Volume at Auxilliary Spillway (acre-ft)	*	*	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	2.29	NA	2.29	2.29
	Volume at Low Stage Orifice Crest (acre-ft)	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	NA	0.36	0.36
	Principal Spillway Weir Length (ft)	18	18	18	18	18	18	18	18	18	18	18	18	18	NA	18	18
	Auxillary Spillway Width (ft)	60	60	60	60	60	60	60	60	60	60	60	60	60	NA	60	60
	Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	NA	42	42
	Scaling Factor	1	1	1	1	1	1	1	1	1	1	1	1	1	NA	1	1
	PSH Peak Inflow (cfs)	10.65	31.89	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Peak Outflow (cfs)	10.16	31.74	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	PSH Max Water Surface Elevation (ft)	4987.64	4988.42	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	FBH/Storm Peak Inflow (cfs)	96.1	57.7	162.6	107.5	43.8	3.4	7.1	9.9	12.7	40	115.7	253.6	470.5	NA	241.8	13.7

FBH/Storm Peak Outflow (cfs)	96.2	95.7	189.6	107.5	43.8	6.4	6.8	9.3	12.7	42.3	115.2	253.6	470.5	NA	241.4	13.6
FBH/Storm Peak Principal Spillway Outflow (cfs)	36.2	57.7	162.6	107.5	43.8	6.4	6.8	9.3	12.7	42.3	115.2	192.6	211.5	NA	187.4	13.6
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	60	38	27	0	0	0	0	0	0	0	0	61	259	NA	54	0
FBH/Storm Initial Water Surface Elevation (ft)	4983.02	4983.02	4988	4988	4988	4983	4983	4983	4983	4983	4983	4983	4983	NA	4983	4983
FBH/Storm Max Water Surface Elevation (ft)	4988.24	4988.88	4989.94	4989.43	4988.68	4984.07	4985.34	4987.05	4988.05	4988.66	4989.51	4990.18	4991.01	NA	4990.14	4988.08
Height of Water Above Auxillary Spillway (ft)	0.59	0.45	0.44	-0.07	-0.82	-5.43	-4.16	-2.45	-1.45	-0.84	0.01	0.68	1.51	NA	0.64	-1.42
Final Dam Crest (ft)	4990.65	4991.43	4992.5	4992.5	4992.5	4992.5	4992.5	4992.5	4992.5	4992.5	4992.5	4992.5	4992.5	NA	4992.5	4992.5
Site	5 Above Grade															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Original Dam Crest (ft)	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015	5015
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5
Principal Spillway Elevation Weir (ft)	5011.16	5011.98	5011	5011	5011	5011	5011	5011	5011	5011	5011	5011	5011	5011	5011	5011
Auxillary Spillway Elevation (ft)	5011.17	5011.99	5012.5	5012.5	5012.5	5012.5	5012.5	5012.5	5012.5	5012.5	5012.5	5012.5	5012.5	5012.5	5012.5	5012.5
Volume at Principal Spillway (acre-ft)	*	*	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21
Volume at Auxilliary Spillway (acre-ft)	*	*	14.64	14.64	14.64	14.64	14.64	14.64	14.64	14.64	14.64	14.64	14.64	14.64	14.64	14.64
Volume at Low Stage Orifice Crest (acre-ft)	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.89
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
Scaling Factor	1.154	1.154	1.154	1.154	1.154	1.154	1.154	1.154	1.154	1.154	1.154	1.154	1.154	1.154	1.154	1.154
PSH Peak Inflow (cfs)	44	75.44	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	13.6	55.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5011.16	5011.98	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	476.6	476.6	475.3	510.4	196	3.1	15.6	38.6	88.4	142.1	209.5	295.7	438.2	501.8	355.9	102.6
FBH/Storm Peak Outflow (cfs)	460.2	430.9	462.8	509.3	195.6	2.3	5	8.2	11.7	29.7	82.2	189.9	385.3	442.8	77.2	11.9
FBH/Storm Peak Principal Spillway Outflow (cfs)	111.2	170.9	218.8	231.3	135.6	2.3	5	8.2	11.7	29.7	82.2	132.9	196.3	213.8	11.2	11.9
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	349	260	244	278	60	0	0	0	0	0	0	57	189	229	66	0
FBH/Storm Initial Water Surface Elevation (ft)	5003.52	5003.52	5011	5011	5011	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5	5003.5
FBH/Storm Max Water Surface Elevation (ft)	5013.05	5013.6	5014.1	5014.23	5013.19	5004.32	5005.31	5006.74	5009.71	5011.57	5012.49	5013.16	5013.87	5014.05	5012.50	5010
Height of Water Above Auxillary Spillway (ft)	1.88	1.61	1.6	1.73	0.69	-8.18	-7.19	-5.76	-2.79	-0.93	-0.01	0.66	1.37	1.55	0	-2.5
Final Dam Crest (ft)	5014.17	5014.99	5015.5	5015.5	5015.5	5015.5	5015.5	5015.5	5015.5	5015.5	5015.5	5015.5	5015.5	5015.5	5015.5	5015.5
Site	5 Below Grade															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	4974	4974	4974	4974	4974	4974	4974	4974	4974	4974	4974	4974	4974	NA	4974	4974
Original Dam Crest (ft)	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	4988	NA	4988	4988
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	4977.52	4977.52	4977.5	4977.5	4977.5	4977.5	4977.5	4977.5	4977.5	4977.5	4977.5	4977.5	4977.5	NA	4977.5	4977.5
Principal Spillway Elevation Weir (ft)	4980.41	4986.81	4986	4986	4986	4986	4986	4986	4986	4986	4986	4986	4986	NA	4986	4986
Auxillary Spillway Elevation (ft)	4980.42	4986.82	4987.3	4987.3	4987.3	4987.3	4987.3	4987.3	4987.3	4987.3	4987.3	4987.3	4987.3	NA	4987.3	4987.3
Volume at Principal Spillway (acre-ft)	*	*	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	NA	13.8	13.8
Volume at Auxilliary Spillway (acre-ft)	*	*	15.88	15.88	15.88	15.88	15.88	15.88	15.88	15.88	15.88	15.88	15.88	NA	15.88	15.88
Volume at Low Stage Orifice Crest (acre-ft)	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	3.09	NA	3.09	3.09
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	42	42	42	42	42	42	42	42	42	42	42	42	42	NA	42	42
Scaling Factor	0.8655	0.8655	0.8655	0.8655	0.8655	0.8655	0.8655	0.8655	0.8655	0.8655	0.8655	0.8655	0.8655	NA	0.8655	0.8655
PSH Peak Inflow (cfs)	13.03	56.56	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	7.92	13.85	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	4980.41	4985.79	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	123.2	123.2	157.5	91.3	21.6	3.1	15.6	38.6	88.4	142.1	209.5	295.7	438.2	NA	355.9	102.6
FBH/Storm Peak Outflow (cfs)	141.9	81.6	135.8	88.1	38	0	4.9	8.2	11.7	19.9	68.3	171	374.2	NA	194.7	12
FBH/Storm Peak Principal Spillway Outflow (cfs)	43.9	58.6	105.8	79.1	38	2.3	4.9	8.2	11.7	19.9	68.3	119	180.2	NA	126.7	12
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	98	23	30	9	0	0	0	0	0	0	0	52	194	NA	68	0
FBH/Storm Initial Water Surface Elevation (ft)	4977.52	4977.52	4986	4986	4986	4977.5	4977.5	4977.5	4977.5	4977.5	4977.5	4977.5	4977.5	NA	4977.5	4977.5
FBH/Storm Max Water Surface Elevation (ft)	4981.37	4987.12	4987.81	4987.44	4986.72	4978.35	4979.35	4980.73	4983.75	4986.24	4987.27	4987.98	4988.69	NA	4988.08	4984.04

Height of Water Above Auxillary Spillway (ft)	0.95	0.3	0.51	0.14	-0.58	-8.95	-7.95	-6.57	-3.55	-1.06	-0.03	0.68	1.39	NA	0.78	-3.26
Final Dam Crest (ft)	4983.42	4989.82	4990.3	4990.3	4990.3	4990.3	4990.3	4990.3	4990.3	4990.3	4990.3	4990.3	4990.3	NA	4990.3	4990.3
Site	**6A Above Grade**															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5010	5010	5010	5010	5010	5010	5010	5010	5010	5010	5010	5010	5010	NA	5010	5010
Original Dam Crest (ft)	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	NA	5025	5025
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5014	5014	5014	5014	5014	5014	5014	5014	5014	5014	5014	5014	5014	NA	5014	5014
Principal Spillway Elevation Weir (ft)	5020.18	5020.79	5021	5021	5021	5021	5021	5021	5021	5021	5021	5021	5021	NA	5021	5021
Auxillary Spillway Elevation (ft)	5020.19	5020.8	5022.5	5022.5	5022.5	5022.5	5022.5	5022.5	5022.5	5022.5	5022.5	5022.5	5022.5	NA	5022.5	5022.5
Volume at Principal Spillway (acre-ft)	*	*	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	11.04	NA	11.04	11.04
Volume at Auxilliary Spillway (acre-ft)	*	*	13.43	13.43	13.43	13.43	13.43	13.43	13.43	13.43	13.43	13.43	13.43	NA	13.43	13.43
Volume at Low Stage Orifice Crest (acre-ft)	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	NA	2.59	2.59
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	30	30	30	30	30	30	30	30	30	30	30	30	30	NA	30	30
Scaling Factor	1.248	1.248	1.248	1.248	1.248	1.248	1.248	1.248	1.248	1.248	1.248	1.248	1.248	NA	1.248	1.248
PSH Peak Inflow (cfs)	44.74	49.52	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	11.8	12.57	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5020.18	5020.79	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	494.6	487.7	494.6	373.5	132.5	9.5	35.3	67.9	127.8	188.8	262.5	352.6	502.1	NA	367	154
FBH/Storm Peak Outflow (cfs)	464.8	438.6	467.8	370.4	131.6	2.7	5.7	8.7	11.6	19.4	57.4	127.8	288.9	NA	143.5	11.3
FBH/Storm Peak Principal Spillway Outflow (cfs)	114.8	101.6	170.8	170.4	112.6	2.7	5.7	8.7	11.6	19.4	57.4	110.8	169.9	NA	117.5	11.3
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	350	337	297	200	19	0	0	0	0	0	0	17	119	NA	26	0
FBH/Storm Initial Water Surface Elevation (ft)	5014.02	5014.02	5021	5021	5021	5014	5014	5014	5014	5014	5014	5014	5014	NA	5014	5014
FBH/Storm Max Water Surface Elevation (ft)	5022.74	5022.73	5024.29	5023.95	5022.91	5014.97	5016.03	5017.65	5020.19	5021.31	5022.11	5022.89	5023.60	NA	5022.98	5019.85
Height of Water Above Auxillary Spillway (ft)	2.55	1.93	1.79	1.45	0.41	-7.53	-6.47	-4.85	-2.31	-1.19	-0.39	0.39	1.1	NA	0.48	-2.65
Final Dam Crest (ft)	5023.19	5023.8	5025.5	5025.5	5025.5	5025.5	5025.5	5025.5	5025.5	5025.5	5025.5	5025.5	5025.5	NA	5025.5	5025.5
Site	**6A Below Grade**															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	4955	4955	4955	4955	4955	4955	4955	4955	4955	4955	4955	4955	4955	NA	4955	4955
Original Dam Crest (ft)	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	4970	NA	4970	4970
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	4959	4959	4959	4959	4959	4959	4959	4959	4959	4959	4959	4959	4959	NA	4959	4959
Principal Spillway Elevation Weir (ft)	4968.19	4968.19	4967	4967	4967	4967	4967	4967	4967	4967	4967	4967	4967	NA	4967	4967
Auxillary Spillway Elevation (ft)	4968.2	4968.2	4968.2	4968.2	4968.2	4968.2	4968.2	4968.2	4968.2	4968.2	4968.2	4968.2	4968.2	NA	4968.2	4968.2
Volume at Principal Spillway (acre-ft)	*	*	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	NA	12.6	12.6
Volume at Auxilliary Spillway (acre-ft)	*	*	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	NA	14.6	14.6
Volume at Low Stage Orifice Crest (acre-ft)	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	NA	2.8	2.8
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	30	30	30	30	30	30	30	30	30	30	30	30	30	NA	30	30
Scaling Factor	1.433	1.433	1.433	1.433	1.433	1.433	1.433	1.433	1.433	1.433	1.433	1.433	1.433	NA	1.433	1.433
PSH Peak Inflow (cfs)	24.55	37.16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	8.8	10.64	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	4968.19	4963.99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	80.4	80.4	251.7	80.4	30.5	9.5	35.3	67.9	127.8	188.8	262.5	352.6	502.1	NA	367	154
FBH/Storm Peak Outflow (cfs)	76.1	35.1	194.1	74.2	26.3	2.7	6.1	8.8	11.7	20.2	63.7	140.1	308.5	NA	107.1	11.4
FBH/Storm Peak Principal Spillway Outflow (cfs)	36.1	22.1	94.1	71.2	26.3	2.7	6.1	8.8	11.7	20.2	63.7	93.1	95.5	NA	92.1	11.4
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	40	13	100	3	0	0	0	0	0	0	0	47	213	NA	15	0
FBH/Storm Initial Water Surface Elevation (ft)	4959	4959	4967	4967	4967	4959	4959	4959	4959	4959	4959	4959	4959	NA	4959	4959
FBH/Storm Max Water Surface Elevation (ft)	4963.26	4966.28	4969.51	4968.32	4967.47	4960.01	4961.26	4962.74	4965.30	4967.28	4968.21	4969.10	4970.10	NA	4968.70	4964.96
Height of Water Above Auxillary Spillway (ft)	-4.94	-1.92	1.31	0.12	-0.73	-8.19	-6.94	-5.46	-2.9	-0.92	0.01	0.9	1.9	NA	0.5	-3.24
Final Dam Crest (ft)	4971.2	4971.2	4971.2	4971.2	4971.2	4971.2	4971.2	4971.2	4971.2	4971.2	4971.2	4971.2	4971.2	NA	4971.2	4971.2

Site	6B Above Grade															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	5025	NA	5025	5025
Original Dam Crest (ft)	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	5040	NA	5040	5040
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	NA	5028.5	5028.5
Principal Spillway Elevation Weir (ft)	5034.94	5035.59	5037	5037	5037	5037	5037	5037	5037	5037	5037	5037	5037	NA	5037	5037
Auxillary Spillway Elevation (ft)	5034.95	5035.6	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	5038.5	NA	5038.5	5038.5
Volume at Principal Spillway (acre-ft)	*	*	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	NA	12.6	12.6
Volume at Auxilliary Spillway (acre-ft)	*	*	14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99	14.99	NA	14.99	14.99
Volume at Low Stage Orifice Crest (acre-ft)	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	NA	2.59	2.59
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	30	30	30	30	30	30	30	30	30	30	30	30	30	NA	30	30
Scaling Factor	1.215	1.215	1.215	1.215	1.215	1.215	1.215	1.215	1.215	1.215	1.215	1.215	1.215	NA	1.215	1.215
PSH Peak Inflow (cfs)	44.7	49.54	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	12	12.69	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	5034.94	5035.59	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	494.6	494.6	494.6	373.5	132.3	9.5	35.3	67.9	127.8	188.8	262.5	352.6	502.1	NA	367	154
FBH/Storm Peak Outflow (cfs)	463.8	454.2	470.5	371.9	132.4	2.7	6.1	8.9	12	18.6	63.2	143.6	325.5	NA	11.6	11.6
FBH/Storm Peak Principal Spillway Outflow (cfs)	99.8	101.2	107.5	106.9	104.4	2.7	6.1	8.9	12	18.6	63.2	104.6	106.5	NA	99.3	11.6
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	364	353	363	265	28	0	0	0	0	0	0	39	219	NA	7	0
FBH/Storm Initial Water Surface Elevation (ft)	5028.52	5028.52	5037	5037	5037	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	5028.5	NA	5028.5	5028.5
FBH/Storm Max Water Surface Elevation (ft)	5036.97	5097.58	5040.46	5040.16	5039.01	5029.52	5030.82	5032.35	5035.04	5037.21	5038.18	5039.10	5040.01	NA	5038.72	5034.66
Height of Water Above Auxillary Spillway (ft)	2.02	61.98	1.96	1.66	0.51	-8.98	-7.68	-6.15	-3.46	-1.29	-0.32	0.6	1.51	NA	0.22	-3.84
Final Dam Crest (ft)	5037.95	5038.6	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	5041.5	NA	5041.5	5041.5

Site	6B Below Grade															
Storm Scenario	6hrBase	Snowmelt	6hr SEF	24hr SEF	72hr SEF	2yr	5yr	10yr	25yr	50yr	100yr	200yr	500yr	Type 2 ARCIII 24hr 100yr	ARCIII 6hr	10yr Burn Condition
Reservoir Bottom Elevation (ft)	4985	4985	4985	4985	4985	4985	4985	4985	4985	4985	4985	4985	4985	NA	4985	4985
Original Dam Crest (ft)	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	NA	5000	5000
Low Stage Orifice Crest (ft) (2' x 0.5' Orifice)	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	NA	4988.5	4988.5
Principal Spillway Elevation Weir (ft)	4992.04	4995.57	4997	4997	4997	4997	4997	4997	4997	4997	4997	4997	4997	NA	4997	4997
Auxillary Spillway Elevation (ft)	4992.05	4995.58	4998.2	4998.2	4998.2	4998.2	4998.2	4998.2	4998.2	4998.2	4998.2	4998.2	4998.2	NA	4998.2	4998.2
Volume at Principal Spillway (acre-ft)	*	*	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	NA	12.6	12.6
Volume at Auxilliary Spillway (acre-ft)	*	*	14.52	14.52	14.52	14.52	14.52	14.52	14.52	14.52	14.52	14.52	14.52	NA	14.52	14.52
Volume at Low Stage Orifice Crest (acre-ft)	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	2.54	NA	2.54	2.54
Principal Spillway Weir Length (ft)	12	12	12	12	12	12	12	12	12	12	12	12	12	NA	12	12
Auxillary Spillway Width (ft)	50	50	50	50	50	50	50	50	50	50	50	50	50	NA	50	50
Principal Spillway Outlet Pipe Diameter (in)	30	30	30	30	30	30	30	30	30	30	30	30	30	NA	30	30
Scaling Factor	1.1667	1.1667	1.1667	1.1667	1.1667	1.1667	1.1667	1.1667	1.1667	1.1667	1.1667	1.1667	1.1667	NA	1.1667	1.1667
PSH Peak Inflow (cfs)	24.54	37.17	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Peak Outflow (cfs)	8.94	10.75	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PSH Max Water Surface Elevation (ft)	4992.04	4993.62	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
FBH/Storm Peak Inflow (cfs)	182.9	182.9	182.9	80.4	30.5	3.2	19.1	50.6	119.4	193.6	286.7	404.9	601.8	NA	367	154
FBH/Storm Peak Outflow (cfs)	146	78.2	146	75.8	24.5	2.7	6.1	8.9	12	18.5	61.8	159.2	342	NA	113.7	11.6
FBH/Storm Peak Principal Spillway Outflow (cfs)	46	32.2	104	71.8	24.5	2.7	6.1	8.9	12	18.5	61.8	104.2	106	NA	92.7	11.6
FBH/Storm Peak Auxillary Spillway Outflow (cfs)	100	46	42	4	0	0	0	0	0	0	0	55	236	NA	21	0
FBH/Storm Initial Water Surface Elevation (ft)	4988.52	4988.52	4997	4997	4997	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	4988.5	NA	4988.5	4988.5
FBH/Storm Max Water Surface Elevation (ft)	4993.02	4996.22	4998.82	4998.33	4997.42	4989.53	4990.83	4992.36	4995.03	4997.19	4998.17	4998.92	4999.77	NA	4998.63	4994.66
Height of Water Above Auxillary Spillway (ft)	0.97	0.64	0.62	0.13	-0.78	-8.67	-7.37	-5.84	-3.17	-1.01	-0.03	0.72	1.57	NA	0.43	-3.54
Final Dam Crest (ft)	4995.05	4998.58	5001.2	5001.2	5001.2	5001.2	5001.2	5001.2	5001.2	5001.2	5001.2	5001.2	5001.2	NA	5001.2	5001.2

Basin 1					
Time (hr)	Q (cfs)	Incremental Volume (ft3)	Incremental Volume (ac-ft)	Cumulative Volume (ft3)	Cumulative Volume (ac-ft)
11.8	0	0		0	0.00
11.9	1.5	270	0.006	270	0.01
12	9.6	1,998	0.046	2,268	0.05
12.1	42.4	9,360	0.215	11,628	0.27
12.2	116.5	28,602	0.657	40,230	0.92
12.3	214.5	59,580	1.368	99,810	2.29
12.4	278.1	88,668	2.036	188,478	4.33
12.47	291.6	71,782	1.648	260,260	5.97
12.5	289.6	31,385	0.720	291,645	6.70
12.6	262.1	99,306	2.280	390,951	8.97
12.7	218.2	86,454	1.985	477,405	10.96
12.8	180.7	71,802	1.648	549,207	12.61
12.9	150.4	59,598	1.368	608,805	13.98
13	126.1	49,770	1.143	658,575	15.12
13.1	106.9	41,940	0.963	700,515	16.08
13.2	91.6	35,730	0.820	736,245	16.90
13.3	79.1	30,726	0.705	766,971	17.61
13.4	69	26,658	0.612	793,629	18.22
13.5	60.5	23,310	0.535	816,939	18.75
13.6	53.5	20,520	0.471	837,459	19.23
13.7	47.6	18,198	0.418	855,657	19.64
13.8	42.3	16,182	0.371	871,839	20.01
13.9	38	14,454	0.332	886,293	20.35
14	34.6	13,068	0.300	899,361	20.65
14.1	32.1	12,006	0.276	911,367	20.92
14.2	30.2	11,214	0.257	922,581	21.18
14.3	28.6	10,584	0.243	933,165	21.42
14.4	27.2	10,044	0.231	943,209	21.65
14.5	26	9,576	0.220	952,785	21.87
14.6	24.8	9,144	0.210	961,929	22.08
14.7	23.7	8,730	0.200	970,659	22.28
14.8	22.6	8,334	0.191	978,993	22.47
14.9	21.5	7,938	0.182	986,931	22.66
15	20.5	7,560	0.174	994,491	22.83
15.1	19.4	7,182	0.165	1,001,673	23.00
15.2	18.3	6,786	0.156	1,008,459	23.15
15.3	17.4	6,426	0.148	1,014,885	23.30
15.4	16.5	6,102	0.140	1,020,987	23.44
15.5	15.8	5,814	0.133	1,026,801	23.57
15.6	15.2	5,580	0.128	1,032,381	23.70
15.7	14.8	5,400	0.124	1,037,781	23.82
15.8	14.4	5,256	0.121	1,043,037	23.94
15.9	14.1	5,130	0.118	1,048,167	24.06
16	13.8	5,022	0.115	1,053,189	24.18
16.1	13.5	4,914	0.113	1,058,103	24.29
16.2	13.3	4,824	0.111	1,062,927	24.40
16.3	13	4,734	0.109	1,067,661	24.51
16.4	12.7	4,626	0.106	1,072,287	24.62
16.5	12.5	4,536	0.104	1,076,823	24.72
16.6	12.2	4,446	0.102	1,081,269	24.82
16.7	12	4,356	0.100	1,085,625	24.92
16.8	11.7	4,266	0.098	1,089,891	25.02
16.9	11.5	4,176	0.096	1,094,067	25.12
17	11.2	4,086	0.094	1,098,153	25.21
17.1	11	3,996	0.092	1,102,149	25.30
17.2	10.7	3,906	0.090	1,106,055	25.39
17.3	10.5	3,816	0.088	1,109,871	25.48
17.4	10.2	3,726	0.086	1,113,597	25.56
17.5	9.9	3,618	0.083	1,117,215	25.65
17.6	9.7	3,528	0.081	1,120,743	25.73
17.7	9.4	3,438	0.079	1,124,181	25.81
17.8	9.2	3,348	0.077	1,127,529	25.88
17.9	8.9	3,258	0.075	1,130,787	25.96
18	8.6	3,150	0.072	1,133,937	26.03
18.1	8.4	3,060	0.070	1,136,997	26.10
18.2	8.1	2,970	0.068	1,139,967	26.17
18.3	7.9	2,880	0.066	1,142,847	26.24
18.4	7.7	2,808	0.064	1,145,655	26.30
18.5	7.5	2,736	0.063	1,148,391	26.36
18.6	7.3	2,664	0.061	1,151,055	26.42
18.7	7.2	2,610	0.060	1,153,665	26.48

18.8	7.1	2,574	0.059	1,156,239	26.54
18.9	7.1	2,556	0.059	1,158,795	26.60
19	7	2,538	0.058	1,161,333	26.66
19.1	6.9	2,502	0.057	1,163,835	26.72
19.2	6.8	2,466	0.057	1,166,301	26.77
19.3	6.8	2,448	0.056	1,168,749	26.83
19.4	6.7	2,430	0.056	1,171,179	26.89
19.5	6.6	2,394	0.055	1,173,573	26.94
19.6	6.6	2,376	0.055	1,175,949	27.00
19.7	6.5	2,358	0.054	1,178,307	27.05
19.8	6.4	2,322	0.053	1,180,629	27.10
19.9	6.4	2,304	0.053	1,182,933	27.16
20	6.3	2,286	0.052	1,185,219	27.21
20.1	6.2	2,250	0.052	1,187,469	27.26
20.2	6.2	2,232	0.051	1,189,701	27.31
20.3	6.1	2,214	0.051	1,191,915	27.36
20.4	6.1	2,196	0.050	1,194,111	27.41
20.5	6	2,178	0.050	1,196,289	27.46
20.6	5.9	2,142	0.049	1,198,431	27.51
20.7	5.9	2,124	0.049	1,200,555	27.56
20.8	5.8	2,106	0.048	1,202,661	27.61
20.9	5.7	2,070	0.048	1,204,731	27.66
21	5.7	2,052	0.047	1,206,783	27.70
21.1	5.6	2,034	0.047	1,208,817	27.75
21.2	5.5	1,998	0.046	1,210,815	27.80
21.3	5.5	1,980	0.045	1,212,795	27.84
21.4	5.4	1,962	0.045	1,214,757	27.89
21.5	5.3	1,926	0.044	1,216,683	27.93
21.6	5.3	1,908	0.044	1,218,591	27.98
21.7	5.2	1,890	0.043	1,220,481	28.02
21.8	5.1	1,854	0.043	1,222,335	28.06
21.9	5.1	1,836	0.042	1,224,171	28.10
22	5	1,818	0.042	1,225,989	28.14
22.1	4.9	1,782	0.041	1,227,771	28.19
22.2	4.9	1,764	0.040	1,229,535	28.23
22.3	4.8	1,746	0.040	1,231,281	28.27
22.4	4.7	1,710	0.039	1,232,991	28.31
22.5	4.7	1,692	0.039	1,234,683	28.34
22.6	4.6	1,674	0.038	1,236,357	28.38
22.7	4.5	1,638	0.038	1,237,995	28.42
22.8	4.5	1,620	0.037	1,239,615	28.46
22.9	4.4	1,602	0.037	1,241,217	28.49
23	4.3	1,566	0.036	1,242,783	28.53
23.1	4.3	1,548	0.036	1,244,331	28.57
23.2	4.2	1,530	0.035	1,245,861	28.60
23.3	4.1	1,494	0.034	1,247,355	28.64
23.4	4	1,458	0.033	1,248,813	28.67
23.5	4	1,440	0.033	1,250,253	28.70
23.6	3.9	1,422	0.033	1,251,675	28.73
23.7	3.8	1,386	0.032	1,253,061	28.77
23.8	3.8	1,368	0.031	1,254,429	28.80
23.9	3.7	1,350	0.031	1,255,779	28.83
24	3.6	1,314	0.030	1,257,093	28.86
24.1	3.5	1,278	0.029	1,258,371	28.89
24.2	3.2	1,206	0.028	1,259,577	28.92
24.3	2.6	1,044	0.024	1,260,621	28.94
24.4	1.9	810	0.019	1,261,431	28.96
24.5	1.3	576	0.013	1,262,007	28.97
24.6	0.8	378	0.009	1,262,385	28.98
24.7	0.5	234	0.005	1,262,619	28.99

Basin 2,3					
Time (hr)	Q (cfs)	Incremental Volume (ft3)	Incremental Volume (ac-ft)	Cumulative Volume (ft3)	Cumulative Volume (ac-ft)
0	0	0		0	0.00
11.9	0.7	14,994	0.344	14,994	0.34
12	7.1	1,404	0.032	16,398	0.38
12.1	31.4	6,930	0.159	23,328	0.54
12.2	71.7	18,558	0.426	41,886	0.96
12.23	76.7	8,014	0.184	49,900	1.15
12.3	69.8	18,459	0.424	68,359	1.57
12.4	49.1	21,402	0.491	89,761	2.06
12.5	35	15,138	0.348	104,899	2.41
12.6	26.9	11,142	0.256	116,041	2.66
12.7	21	8,622	0.198	124,663	2.86
12.8	16.9	6,822	0.157	131,485	3.02
12.9	14.5	5,652	0.130	137,137	3.15
13	12.8	4,914	0.113	142,051	3.26
13.1	11.2	4,320	0.099	146,371	3.36
13.2	9.9	3,798	0.087	150,169	3.45
13.3	8.7	3,348	0.077	153,517	3.52
13.4	8	3,006	0.069	156,523	3.59
13.5	7.1	2,718	0.062	159,241	3.66
13.6	6.4	2,430	0.056	161,671	3.71
13.7	5.8	2,196	0.050	163,867	3.76
13.8	5.3	1,998	0.046	165,865	3.81
13.9	5	1,854	0.043	167,719	3.85
14	4.8	1,764	0.040	169,483	3.89
14.1	4.7	1,710	0.039	171,193	3.93
14.2	4.5	1,656	0.038	172,849	3.97
14.3	4.3	1,584	0.036	174,433	4.00
14.4	4.1	1,512	0.035	175,945	4.04
14.5	3.9	1,440	0.033	177,385	4.07
14.6	3.8	1,386	0.032	178,771	4.10
14.7	3.6	1,332	0.031	180,103	4.13
14.8	3.4	1,260	0.029	181,363	4.16
14.9	3.2	1,188	0.027	182,551	4.19
15	3	1,116	0.026	183,667	4.22
15.1	2.9	1,062	0.024	184,729	4.24
15.2	2.7	1,008	0.023	185,737	4.26
15.3	2.6	954	0.022	186,691	4.29
15.4	2.5	918	0.021	187,609	4.31
15.5	2.5	900	0.021	188,509	4.33
15.6	2.5	900	0.021	189,409	4.35
15.7	2.4	882	0.020	190,291	4.37
15.8	2.3	846	0.019	191,137	4.39
15.9	2.3	828	0.019	191,965	4.41
16	2.3	828	0.019	192,793	4.43
16.1	2.2	810	0.019	193,603	4.44
16.2	2.2	792	0.018	194,395	4.46
16.3	2.1	774	0.018	195,169	4.48
16.4	2.1	756	0.017	195,925	4.50
16.5	2.1	756	0.017	196,681	4.52
16.6	2	738	0.017	197,419	4.53
16.7	2	720	0.017	198,139	4.55
16.8	1.9	702	0.016	198,841	4.56
16.9	1.9	684	0.016	199,525	4.58
17	1.8	666	0.015	200,191	4.60
17.1	1.8	648	0.015	200,839	4.61
17.2	1.8	648	0.015	201,487	4.63
17.3	1.7	630	0.014	202,117	4.64
17.4	1.6	594	0.014	202,711	4.65
17.5	1.6	576	0.013	203,287	4.67
17.6	1.6	576	0.013	203,863	4.68
17.7	1.6	576	0.013	204,439	4.69
17.8	1.4	540	0.012	204,979	4.71
17.9	1.4	504	0.012	205,483	4.72
18	1.4	504	0.012	205,987	4.73
18.1	1.4	504	0.012	206,491	4.74
18.2	1.3	486	0.011	206,977	4.75
18.3	1.3	468	0.011	207,445	4.76
18.4	1.2	450	0.010	207,895	4.77
18.5	1.2	432	0.010	208,327	4.78
18.6	1.2	432	0.010	208,759	4.79
18.7	1.2	432	0.010	209,191	4.80
18.8	1.2	432	0.010	209,623	4.81

18.9	1.2	432	0.010	210,055	4.82
19	1.2	432	0.010	210,487	4.83
19.1	1.2	432	0.010	210,919	4.84
19.2	1.2	432	0.010	211,351	4.85
19.3	1.2	432	0.010	211,783	4.86
19.4	0.6	324	0.007	212,107	4.87
19.4	4.3	0	0.000	212,107	4.87
19.5	4.3	1,548	0.036	213,655	4.90
19.6	4.2	1,530	0.035	215,185	4.94
19.7	4.2	1,512	0.035	216,697	4.97
19.8	4.1	1,494	0.034	218,191	5.01
19.9	4.1	1,476	0.034	219,667	5.04
20	4	1,458	0.033	221,125	5.08
20.1	4	1,440	0.033	222,565	5.11
20.2	3.9	1,422	0.033	223,987	5.14
20.3	3.9	1,404	0.032	225,391	5.17
20.4	3.9	1,404	0.032	226,795	5.21
20.5	3.8	1,386	0.032	228,181	5.24
20.6	3.8	1,368	0.031	229,549	5.27
20.7	3.7	1,350	0.031	230,899	5.30
20.8	3.7	1,332	0.031	232,231	5.33
20.9	3.6	1,314	0.030	233,545	5.36
21	3.6	1,296	0.030	234,841	5.39
21.1	3.5	1,278	0.029	236,119	5.42
21.2	3.5	1,260	0.029	237,379	5.45
21.3	3.5	1,260	0.029	238,639	5.48
21.4	3.4	1,242	0.029	239,881	5.51
21.5	3.4	1,224	0.028	241,105	5.54
21.6	3.3	1,206	0.028	242,311	5.56
21.7	3.3	1,188	0.027	243,499	5.59
21.8	3.2	1,170	0.027	244,669	5.62
21.9	3.2	1,152	0.026	245,821	5.64
22	3.1	1,134	0.026	246,955	5.67
22.1	3.1	1,116	0.026	248,071	5.69
22.2	3.1	1,116	0.026	249,187	5.72
22.3	3	1,098	0.025	250,285	5.75
22.4	3	1,080	0.025	251,365	5.77
22.5	2.9	1,062	0.024	252,427	5.79
22.6	2.9	1,044	0.024	253,471	5.82
22.7	2.8	1,026	0.024	254,497	5.84
22.8	2.8	1,008	0.023	255,505	5.87
22.9	2.7	990	0.023	256,495	5.89
23	2.7	972	0.022	257,467	5.91
23.1	2.6	954	0.022	258,421	5.93
23.2	2.6	936	0.021	259,357	5.95
23.3	2.6	936	0.021	260,293	5.98
23.4	2.5	918	0.021	261,211	6.00
23.5	2.5	900	0.021	262,111	6.02
23.6	2.4	882	0.020	262,993	6.04
23.7	2.4	864	0.020	263,857	6.06
23.8	2.3	846	0.019	264,703	6.08
23.9	2.3	828	0.019	265,531	6.10
24	2.2	810	0.019	266,341	6.11
24.1	2.1	774	0.018	267,115	6.13
24.2	1.6	666	0.015	267,781	6.15
24.3	1	468	0.011	268,249	6.16
24.4	0.5	270	0.006	268,519	6.16
24.5	0	90	0.002	268,609	6.17

Basin 4					
Time (hr)	Q (cfs)	Incremental Volume (ft3)	Incremental Volume (ac-ft)	Cumulative Volume (ft3)	Cumulative Volume (ac-ft)
0	0	0		0	0.00
11.8	0	0	0.000	0	0.00
11.9	1.5	270	0.006	270	0.01
12	9.6	1,998	0.046	2,268	0.05
12.1	42.4	9,360	0.215	11,628	0.27
12.2	116.5	28,602	0.657	40,230	0.92
12.3	214.5	59,580	1.368	99,810	2.29
12.4	278.1	88,668	2.036	188,478	4.33
12.47	291.6	71,782	1.648	260,260	5.97
12.5	289.6	31,385	0.720	291,645	6.70
12.6	262.1	99,306	2.280	390,951	8.97
12.7	218.2	86,454	1.985	477,405	10.96
12.8	180.7	71,802	1.648	549,207	12.61
12.9	150.4	59,598	1.368	608,805	13.98
13	126.1	49,770	1.143	658,575	15.12
13.1	106.9	41,940	0.963	700,515	16.08
13.2	91.6	35,730	0.820	736,245	16.90
13.3	79.1	30,726	0.705	766,971	17.61
13.4	69	26,658	0.612	793,629	18.22
13.5	60.5	23,310	0.535	816,939	18.75
13.6	53.5	20,520	0.471	837,459	19.23
13.7	47.6	18,198	0.418	855,657	19.64
13.8	42.3	16,182	0.371	871,839	20.01
13.9	38	14,454	0.332	886,293	20.35
14	34.6	13,068	0.300	899,361	20.65
14.1	32.1	12,006	0.276	911,367	20.92
14.2	30.2	11,214	0.257	922,581	21.18
14.3	28.6	10,584	0.243	933,165	21.42
14.4	27.2	10,044	0.231	943,209	21.65
14.5	26	9,576	0.220	952,785	21.87
14.6	24.8	9,144	0.210	961,929	22.08
14.7	23.7	8,730	0.200	970,659	22.28
14.8	22.6	8,334	0.191	978,993	22.47
14.9	21.5	7,938	0.182	986,931	22.66
15	20.5	7,560	0.174	994,491	22.83
15.1	19.4	7,182	0.165	1,001,673	23.00
15.2	18.3	6,786	0.156	1,008,459	23.15
15.3	17.4	6,426	0.148	1,014,885	23.30
15.4	16.5	6,102	0.140	1,020,987	23.44
15.5	15.8	5,814	0.133	1,026,801	23.57
15.6	15.2	5,580	0.128	1,032,381	23.70
15.7	14.8	5,400	0.124	1,037,781	23.82
15.8	14.4	5,256	0.121	1,043,037	23.94
15.9	14.1	5,130	0.118	1,048,167	24.06
16	13.8	5,022	0.115	1,053,189	24.18
16.1	13.5	4,914	0.113	1,058,103	24.29
16.2	13.3	4,824	0.111	1,062,927	24.40
16.3	13	4,734	0.109	1,067,661	24.51
16.4	12.7	4,626	0.106	1,072,287	24.62
16.5	12.5	4,536	0.104	1,076,823	24.72
16.6	12.2	4,446	0.102	1,081,269	24.82
16.7	12	4,356	0.100	1,085,625	24.92
16.8	11.7	4,266	0.098	1,089,891	25.02
16.9	11.5	4,176	0.096	1,094,067	25.12
17	11.2	4,086	0.094	1,098,153	25.21
17.1	11	3,996	0.092	1,102,149	25.30
17.2	10.7	3,906	0.090	1,106,055	25.39
17.3	10.5	3,816	0.088	1,109,871	25.48
17.4	10.2	3,726	0.086	1,113,597	25.56
17.5	9.9	3,618	0.083	1,117,215	25.65
17.6	9.7	3,528	0.081	1,120,743	25.73
17.7	9.4	3,438	0.079	1,124,181	25.81
17.8	9.2	3,348	0.077	1,127,529	25.88
17.9	8.9	3,258	0.075	1,130,787	25.96
18	8.6	3,150	0.072	1,133,937	26.03
18.1	8.4	3,060	0.070	1,136,997	26.10
18.2	8.1	2,970	0.068	1,139,967	26.17
18.3	7.9	2,880	0.066	1,142,847	26.24
18.4	7.7	2,808	0.064	1,145,655	26.30
18.5	7.5	2,736	0.063	1,148,391	26.36
18.6	7.3	2,664	0.061	1,151,055	26.42
18.7	7.2	2,610	0.060	1,153,665	26.48

18.8	7.1	2,574	0.059	1,156,239	26.54
18.9	7.1	2,556	0.059	1,158,795	26.60
19	7	2,538	0.058	1,161,333	26.66
19.1	6.9	2,502	0.057	1,163,835	26.72
19.2	6.8	2,466	0.057	1,166,301	26.77
19.3	6.8	2,448	0.056	1,168,749	26.83
19.4	6.7	2,430	0.056	1,171,179	26.89
19.5	6.6	2,394	0.055	1,173,573	26.94
19.6	6.6	2,376	0.055	1,175,949	27.00
19.7	6.5	2,358	0.054	1,178,307	27.05
19.8	6.4	2,322	0.053	1,180,629	27.10
19.9	6.4	2,304	0.053	1,182,933	27.16
20	6.3	2,286	0.052	1,185,219	27.21
20.1	6.2	2,250	0.052	1,187,469	27.26
20.2	6.2	2,232	0.051	1,189,701	27.31
20.3	6.1	2,214	0.051	1,191,915	27.36
20.4	6.1	2,196	0.050	1,194,111	27.41
20.5	6	2,178	0.050	1,196,289	27.46
20.6	5.9	2,142	0.049	1,198,431	27.51
20.7	5.9	2,124	0.049	1,200,555	27.56
20.8	5.8	2,106	0.048	1,202,661	27.61
20.9	5.7	2,070	0.048	1,204,731	27.66
21	5.7	2,052	0.047	1,206,783	27.70
21.1	5.6	2,034	0.047	1,208,817	27.75
21.2	5.5	1,998	0.046	1,210,815	27.80
21.3	5.5	1,980	0.045	1,212,795	27.84
21.4	5.4	1,962	0.045	1,214,757	27.89
21.5	5.3	1,926	0.044	1,216,683	27.93
21.6	5.3	1,908	0.044	1,218,591	27.98
21.7	5.2	1,890	0.043	1,220,481	28.02
21.8	5.1	1,854	0.043	1,222,335	28.06
21.9	5.1	1,836	0.042	1,224,171	28.10
22	5	1,818	0.042	1,225,989	28.14
22.1	4.9	1,782	0.041	1,227,771	28.19
22.2	4.9	1,764	0.040	1,229,535	28.23
22.3	4.8	1,746	0.040	1,231,281	28.27
22.4	4.7	1,710	0.039	1,232,991	28.31
22.5	4.7	1,692	0.039	1,234,683	28.34
22.6	4.6	1,674	0.038	1,236,357	28.38
22.7	4.5	1,638	0.038	1,237,995	28.42
22.8	4.5	1,620	0.037	1,239,615	28.46
22.9	4.4	1,602	0.037	1,241,217	28.49
23	4.3	1,566	0.036	1,242,783	28.53
23.1	4.3	1,548	0.036	1,244,331	28.57
23.2	4.2	1,530	0.035	1,245,861	28.60
23.3	4.1	1,494	0.034	1,247,355	28.64
23.4	4	1,458	0.033	1,248,813	28.67
23.5	4	1,440	0.033	1,250,253	28.70
23.6	3.9	1,422	0.033	1,251,675	28.73
23.7	3.8	1,386	0.032	1,253,061	28.77
23.8	3.8	1,368	0.031	1,254,429	28.80
23.9	3.7	1,350	0.031	1,255,779	28.83
24	3.6	1,314	0.030	1,257,093	28.86
24.1	3.5	1,278	0.029	1,258,371	28.89
24.2	3.2	1,206	0.028	1,259,577	28.92
24.3	2.6	1,044	0.024	1,260,621	28.94
24.4	1.9	810	0.019	1,261,431	28.96
24.5	1.3	576	0.013	1,262,007	28.97
24.6	0.8	378	0.009	1,262,385	28.98
24.7	0.5	234	0.005	1,262,619	28.99

Basin 5					
Time (hr)	Q (cfs)	Incremental Volume (ft3)	Incremental Volume (ac-ft)	Cumulative Volume (ft3)	Cumulative Volume (ac-ft)
0	0	0		0	0.00
11.9	0	0	0.000	0	0.00
12	2.2	396	0.009	396	0.01
12.1	17.4	3,528	0.081	3,924	0.09
12.2	58.6	13,680	0.314	17,604	0.40
12.3	123.3	32,742	0.752	50,346	1.16
12.4	179.5	54,504	1.251	104,850	2.41
12.5	206.8	69,534	1.596	174,384	4.00
12.55	209.5	37,467	0.860	211,851	4.86
12.6	205.6	37,359	0.858	249,210	5.72
12.7	184.2	70,164	1.611	319,374	7.33
12.8	157.1	61,434	1.410	380,808	8.74
12.9	134	52,398	1.203	433,206	9.95
13	114.7	44,766	1.028	477,972	10.97
13.1	98.6	38,394	0.881	516,366	11.85
13.2	85.3	33,102	0.760	549,468	12.61
13.3	74.3	28,728	0.660	578,196	13.27
13.4	65	25,074	0.576	603,270	13.85
13.5	57.3	22,014	0.505	625,284	14.35
13.6	50.7	19,440	0.446	644,724	14.80
13.7	45.1	17,244	0.396	661,968	15.20
13.8	40.3	15,372	0.353	677,340	15.55
13.9	36.3	13,788	0.317	691,128	15.87
14	32.9	12,456	0.286	703,584	16.15
14.1	30.2	11,358	0.261	714,942	16.41
14.2	28.1	10,494	0.241	725,436	16.65
14.3	26.4	9,810	0.225	735,246	16.88
14.4	25.1	9,270	0.213	744,516	17.09
14.5	23.9	8,820	0.202	753,336	17.29
14.6	22.8	8,406	0.193	761,742	17.49
14.7	21.7	8,010	0.184	769,752	17.67
14.8	20.7	7,632	0.175	777,384	17.85
14.9	19.8	7,290	0.167	784,674	18.01
15	18.8	6,948	0.160	791,622	18.17
15.1	17.8	6,588	0.151	798,210	18.32
15.2	16.9	6,246	0.143	804,456	18.47
15.3	16	5,922	0.136	810,378	18.60
15.4	15.2	5,616	0.129	815,994	18.73
15.5	14.5	5,346	0.123	821,340	18.86
15.6	14	5,130	0.118	826,470	18.97
15.7	13.5	4,950	0.114	831,420	19.09
15.8	13.2	4,806	0.110	836,226	19.20
15.9	12.8	4,680	0.107	840,906	19.30
16	12.6	4,572	0.105	845,478	19.41
16.1	12.3	4,482	0.103	849,960	19.51
16.2	12	4,374	0.100	854,334	19.61
16.3	11.8	4,284	0.098	858,618	19.71
16.4	11.6	4,212	0.097	862,830	19.81
16.5	11.3	4,122	0.095	866,952	19.90
16.6	11.1	4,032	0.093	870,984	20.00
16.7	10.9	3,960	0.091	874,944	20.09
16.8	10.7	3,888	0.089	878,832	20.18
16.9	10.4	3,798	0.087	882,630	20.26
17	10.2	3,708	0.085	886,338	20.35
17.1	10	3,636	0.083	889,974	20.43
17.2	9.8	3,564	0.082	893,538	20.51
17.3	9.5	3,474	0.080	897,012	20.59
17.4	9.3	3,384	0.078	900,396	20.67
17.5	9.1	3,312	0.076	903,708	20.75
17.6	8.8	3,222	0.074	906,930	20.82
17.7	8.6	3,132	0.072	910,062	20.89
17.8	8.4	3,060	0.070	913,122	20.96
17.9	8.1	2,970	0.068	916,092	21.03
18	7.9	2,880	0.066	918,972	21.10
18.1	7.7	2,808	0.064	921,780	21.16
18.2	7.4	2,718	0.062	924,498	21.22
18.3	7.2	2,628	0.060	927,126	21.28
18.4	7	2,556	0.059	929,682	21.34
18.5	6.8	2,484	0.057	932,166	21.40
18.6	6.7	2,430	0.056	934,596	21.46
18.7	6.6	2,394	0.055	936,990	21.51
18.8	6.5	2,358	0.054	939,348	21.56

18.9	6.4	2,322	0.053	941,670	21.62
19	6.3	2,286	0.052	943,956	21.67
19.1	6.3	2,268	0.052	946,224	21.72
19.2	6.2	2,250	0.052	948,474	21.77
19.3	6.2	2,232	0.051	950,706	21.83
19.4	6.1	2,214	0.051	952,920	21.88
19.5	6	2,178	0.050	955,098	21.93
19.6	6	2,160	0.050	957,258	21.98
19.7	5.9	2,142	0.049	959,400	22.02
19.8	5.8	2,106	0.048	961,506	22.07
19.9	5.8	2,088	0.048	963,594	22.12
20	5.7	2,070	0.048	965,664	22.17
20.1	5.7	2,052	0.047	967,716	22.22
20.2	5.6	2,034	0.047	969,750	22.26
20.3	5.6	2,016	0.046	971,766	22.31
20.4	5.5	1,998	0.046	973,764	22.35
20.5	5.4	1,962	0.045	975,726	22.40
20.6	5.4	1,944	0.045	977,670	22.44
20.7	5.3	1,926	0.044	979,596	22.49
20.8	5.3	1,908	0.044	981,504	22.53
20.9	5.2	1,890	0.043	983,394	22.58
21	5.2	1,872	0.043	985,266	22.62
21.1	5.1	1,854	0.043	987,120	22.66
21.2	5	1,818	0.042	988,938	22.70
21.3	5	1,800	0.041	990,738	22.74
21.4	4.9	1,782	0.041	992,520	22.79
21.5	4.9	1,764	0.040	994,284	22.83
21.6	4.8	1,746	0.040	996,030	22.87
21.7	4.7	1,710	0.039	997,740	22.90
21.8	4.7	1,692	0.039	999,432	22.94
21.9	4.6	1,674	0.038	1,001,106	22.98
22	4.6	1,656	0.038	1,002,762	23.02
22.1	4.5	1,638	0.038	1,004,400	23.06
22.2	4.4	1,602	0.037	1,006,002	23.09
22.3	4.4	1,584	0.036	1,007,586	23.13
22.4	4.3	1,566	0.036	1,009,152	23.17
22.5	4.3	1,548	0.036	1,010,700	23.20
22.6	4.2	1,530	0.035	1,012,230	23.24
22.7	4.1	1,494	0.034	1,013,724	23.27
22.8	4.1	1,476	0.034	1,015,200	23.31
22.9	4	1,458	0.033	1,016,658	23.34
23	4	1,440	0.033	1,018,098	23.37
23.1	3.9	1,422	0.033	1,019,520	23.40
23.2	3.8	1,386	0.032	1,020,906	23.44
23.3	3.8	1,368	0.031	1,022,274	23.47
23.4	3.7	1,350	0.031	1,023,624	23.50
23.5	3.6	1,314	0.030	1,024,938	23.53
23.6	3.6	1,296	0.030	1,026,234	23.56
23.7	3.5	1,278	0.029	1,027,512	23.59
23.8	3.5	1,260	0.029	1,028,772	23.62
23.9	3.4	1,242	0.029	1,030,014	23.65
24	3.3	1,206	0.028	1,031,220	23.67
24.1	3.2	1,170	0.027	1,032,390	23.70
24.2	3	1,116	0.026	1,033,506	23.73
24.3	2.6	1,008	0.023	1,034,514	23.75
24.4	2	828	0.019	1,035,342	23.77
24.5	1.5	630	0.014	1,035,972	23.78

Basin 6					
Time (hr)	Q (cfs)	Incremental Volume (ft3)	Incremental Volume (ac-ft)	Cumulative Volume (ft3)	Cumulative Volume (ac-ft)
0	0	0		0	0.00
11.8	0.074	1,572	0.036	1,572	0.04
11.9	3.8	697	0.016	2,269	0.05
12	18.7	4,050	0.093	6,319	0.15
12.1	73.2	16,542	0.380	22,861	0.52
12.2	184.8	46,440	1.066	69,301	1.59
12.3	258.8	79,848	1.833	149,149	3.42
12.34	262.5	37,534	0.862	186,683	4.29
12.4	244.1	54,713	1.256	241,395	5.54
12.5	189	77,958	1.790	319,353	7.33
12.6	146	60,300	1.384	379,653	8.72
12.7	114.2	46,836	1.075	426,489	9.79
12.8	90.6	36,864	0.846	463,353	10.64
12.9	73.8	29,592	0.679	492,945	11.32
13	62.4	24,516	0.563	517,461	11.88
13.1	53.7	20,898	0.480	538,359	12.36
13.2	46.4	18,018	0.414	556,377	12.77
13.3	40.2	15,588	0.358	571,965	13.13
13.4	35.6	13,644	0.313	585,609	13.44
13.5	31.8	12,132	0.279	597,741	13.72
13.6	28.5	10,854	0.249	608,595	13.97
13.7	25.5	9,720	0.223	618,315	14.19
13.8	23.1	8,748	0.201	627,063	14.40
13.9	21.3	7,992	0.183	635,055	14.58
14	20.1	7,452	0.171	642,507	14.75
14.1	19.1	7,056	0.162	649,563	14.91
14.2	18.3	6,732	0.155	656,295	15.07
14.3	17.5	6,444	0.148	662,739	15.21
14.4	16.8	6,174	0.142	668,913	15.36
14.5	16.1	5,922	0.136	674,835	15.49
14.6	15.4	5,670	0.130	680,505	15.62
14.7	14.6	5,400	0.124	685,905	15.75
14.8	13.9	5,130	0.118	691,035	15.86
14.9	13.2	4,878	0.112	695,913	15.98
15	12.5	4,626	0.106	700,539	16.08
15.1	11.8	4,374	0.100	704,913	16.18
15.2	11.1	4,122	0.095	709,035	16.28
15.3	10.5	3,888	0.089	712,923	16.37
15.4	10.1	3,708	0.085	716,631	16.45
15.5	9.8	3,582	0.082	720,213	16.53
15.6	9.5	3,474	0.080	723,687	16.61
15.7	9.3	3,384	0.078	727,071	16.69
15.8	9.2	3,330	0.076	730,401	16.77
15.9	9	3,276	0.075	733,677	16.84
16	8.8	3,204	0.074	736,881	16.92
16.1	8.6	3,132	0.072	740,013	16.99
16.2	8.5	3,078	0.071	743,091	17.06
16.3	8.3	3,024	0.069	746,115	17.13
16.4	8.1	2,952	0.068	749,067	17.20
16.5	8	2,898	0.067	751,965	17.26
16.6	7.8	2,844	0.065	754,809	17.33
16.7	7.6	2,772	0.064	757,581	17.39
16.8	7.5	2,718	0.062	760,299	17.45
16.9	7.3	2,664	0.061	762,963	17.52
17	7.1	2,592	0.060	765,555	17.57
17.1	6.9	2,520	0.058	768,075	17.63
17.2	6.8	2,466	0.057	770,541	17.69
17.3	6.6	2,412	0.055	772,953	17.74
17.4	6.4	2,340	0.054	775,293	17.80
17.5	6.3	2,286	0.052	777,579	17.85
17.6	6.1	2,232	0.051	779,811	17.90
17.7	5.9	2,160	0.050	781,971	17.95
17.8	5.7	2,088	0.048	784,059	18.00
17.9	5.6	2,034	0.047	786,093	18.05
18	5.4	1,980	0.045	788,073	18.09
18.1	5.2	1,908	0.044	789,981	18.14
18.2	5	1,836	0.042	791,817	18.18
18.3	4.9	1,782	0.041	793,599	18.22
18.4	4.8	1,746	0.040	795,345	18.26
18.5	4.7	1,710	0.039	797,055	18.30
18.6	4.7	1,692	0.039	798,747	18.34
18.7	4.6	1,674	0.038	800,421	18.38

18.8	4.5	1,638	0.038	802,059	18.41
18.9	4.5	1,620	0.037	803,679	18.45
19	4.5	1,620	0.037	805,299	18.49
19.1	4.4	1,602	0.037	806,901	18.52
19.2	4.4	1,584	0.036	808,485	18.56
19.3	4.3	1,566	0.036	810,051	18.60
19.4	4.3	1,548	0.036	811,599	18.63
19.5	4.3	1,548	0.036	813,147	18.67
19.6	4.2	1,530	0.035	814,677	18.70
19.7	4.2	1,512	0.035	816,189	18.74
19.8	4.1	1,494	0.034	817,683	18.77
19.9	4.1	1,476	0.034	819,159	18.81
20	4	1,458	0.033	820,617	18.84
20.1	4	1,440	0.033	822,057	18.87
20.2	3.9	1,422	0.033	823,479	18.90
20.3	3.9	1,404	0.032	824,883	18.94
20.4	3.9	1,404	0.032	826,287	18.97
20.5	3.8	1,386	0.032	827,673	19.00
20.6	3.8	1,368	0.031	829,041	19.03
20.7	3.7	1,350	0.031	830,391	19.06
20.8	3.7	1,332	0.031	831,723	19.09
20.9	3.6	1,314	0.030	833,037	19.12
21	3.6	1,296	0.030	834,333	19.15
21.1	3.5	1,278	0.029	835,611	19.18
21.2	3.5	1,260	0.029	836,871	19.21
21.3	3.5	1,260	0.029	838,131	19.24
21.4	3.4	1,242	0.029	839,373	19.27
21.5	3.4	1,224	0.028	840,597	19.30
21.6	3.3	1,206	0.028	841,803	19.33
21.7	3.3	1,188	0.027	842,991	19.35
21.8	3.2	1,170	0.027	844,161	19.38
21.9	3.2	1,152	0.026	845,313	19.41
22	3.1	1,134	0.026	846,447	19.43
22.1	3.1	1,116	0.026	847,563	19.46
22.2	3.1	1,116	0.026	848,679	19.48
22.3	3	1,098	0.025	849,777	19.51
22.4	3	1,080	0.025	850,857	19.53
22.5	2.9	1,062	0.024	851,919	19.56
22.6	2.9	1,044	0.024	852,963	19.58
22.7	2.8	1,026	0.024	853,989	19.60
22.8	2.8	1,008	0.023	854,997	19.63
22.9	2.7	990	0.023	855,987	19.65
23	2.7	972	0.022	856,959	19.67
23.1	2.6	954	0.022	857,913	19.69
23.2	2.6	936	0.021	858,849	19.72
23.3	2.6	936	0.021	859,785	19.74
23.4	2.5	918	0.021	860,703	19.76
23.5	2.5	900	0.021	861,603	19.78
23.6	2.4	882	0.020	862,485	19.80
23.7	2.4	864	0.020	863,349	19.82
23.8	2.3	846	0.019	864,195	19.84
23.9	2.3	828	0.019	865,023	19.86
24	2.2	810	0.019	865,833	19.88
24.1	2.1	774	0.018	866,607	19.89
24.2	1.6	666	0.015	867,273	19.91
24.3	1	468	0.011	867,741	19.92
24.4	0.5	270	0.006	868,011	19.93
24.5	0	90	0.002	868,101	19.93

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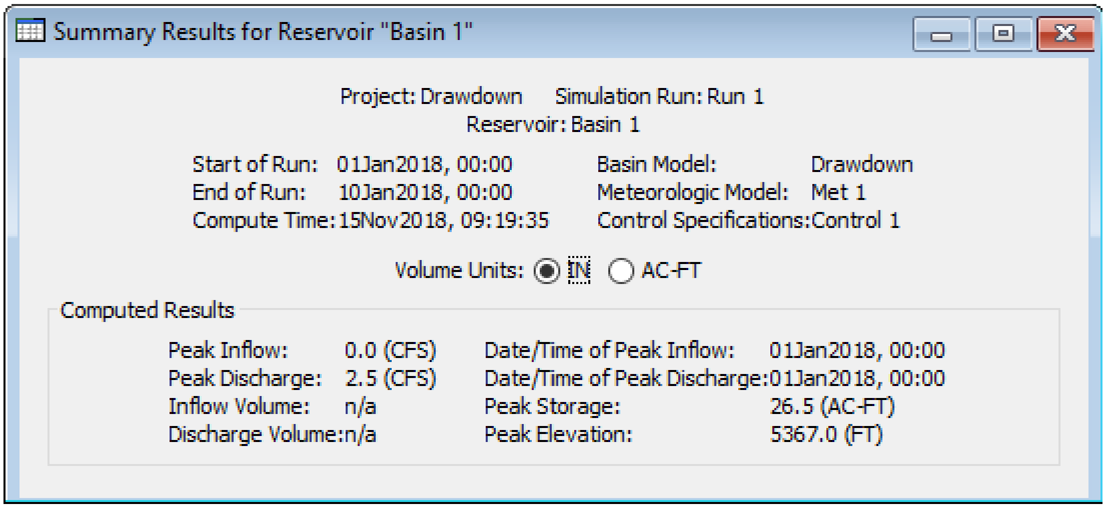
Appendix B: Approach B Drawdown Calculations

Drawdown Reports (Approach B)



Summary Results for Reservoir "Basin 1"

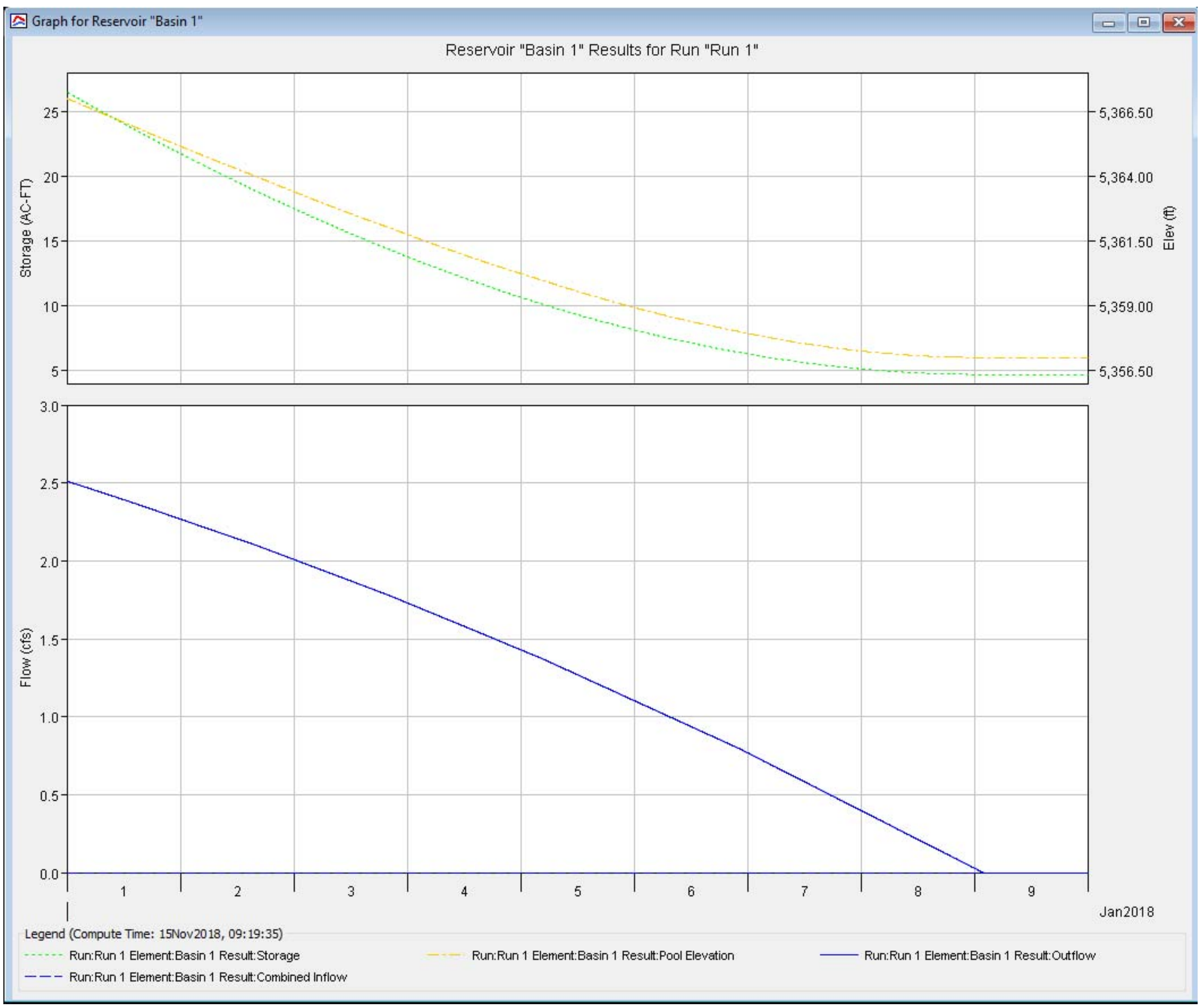
Project: Drawdown   Simulation Run: Run 1
Reservoir: Basin 1

Start of Run:	01Jan2018, 00:00	Basin Model:	Drawdown
End of Run:	10Jan2018, 00:00	Meteorologic Model:	Met 1
Compute Time:	15Nov2018, 09:19:35	Control Specifications:	Control 1

Volume Units: (•) IN ( ) AC-FT

Computed Results

Peak Inflow:	0.0 (CFS)	Date/Time of Peak Inflow:	01Jan2018, 00:00
Peak Discharge:	2.5 (CFS)	Date/Time of Peak Discharge:	01Jan2018, 00:00
Inflow Volume:	n/a	Peak Storage:	26.5 (AC-FT)
Discharge Volume:	n/a	Peak Elevation:	5367.0 (FT)



Summary Results for Reservoir "Basin2-3"

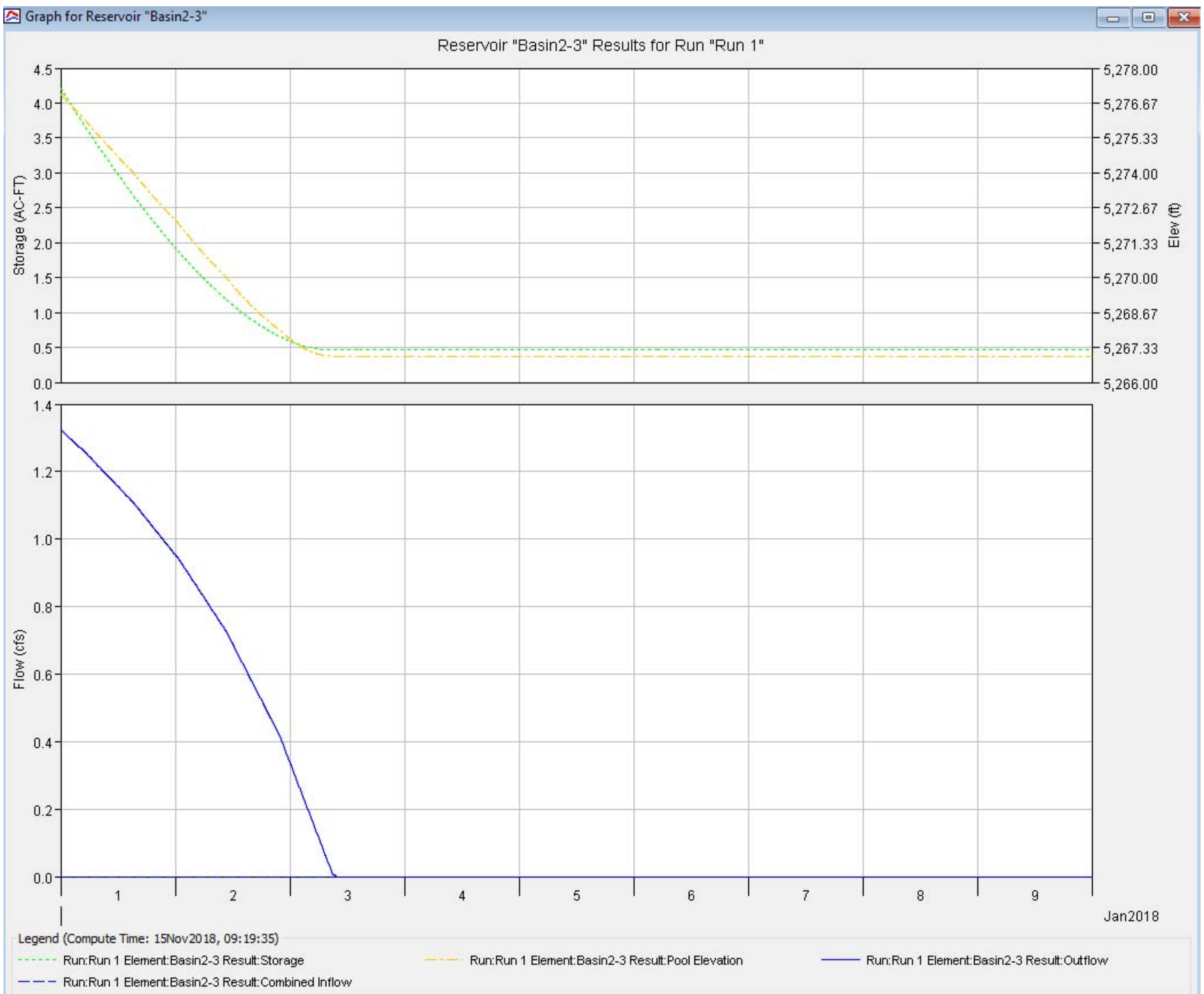
Project: Drawdown Simulation Run: Run 1
Reservoir: Basin2-3

Start of Run:	01Jan2018, 00:00	Basin Model:	Drawdown
End of Run:	10Jan2018, 00:00	Meteorologic Model:	Met 1
Compute Time:	15Nov2018, 09:19:35	Control Specifications:	Control 1

Volume Units: ◉ IN ○ AC-FT

Computed Results

Peak Inflow:	0.0 (CFS)	Date/Time of Peak Inflow:	01Jan2018, 00:00
Peak Discharge:	1.3 (CFS)	Date/Time of Peak Discharge:	01Jan2018, 00:00
Inflow Volume:	n/a	Peak Storage:	4.2 (AC-FT)
Discharge Volume:	n/a	Peak Elevation:	5277.0 (FT)



Summary Results for Reservoir "Basin 4"

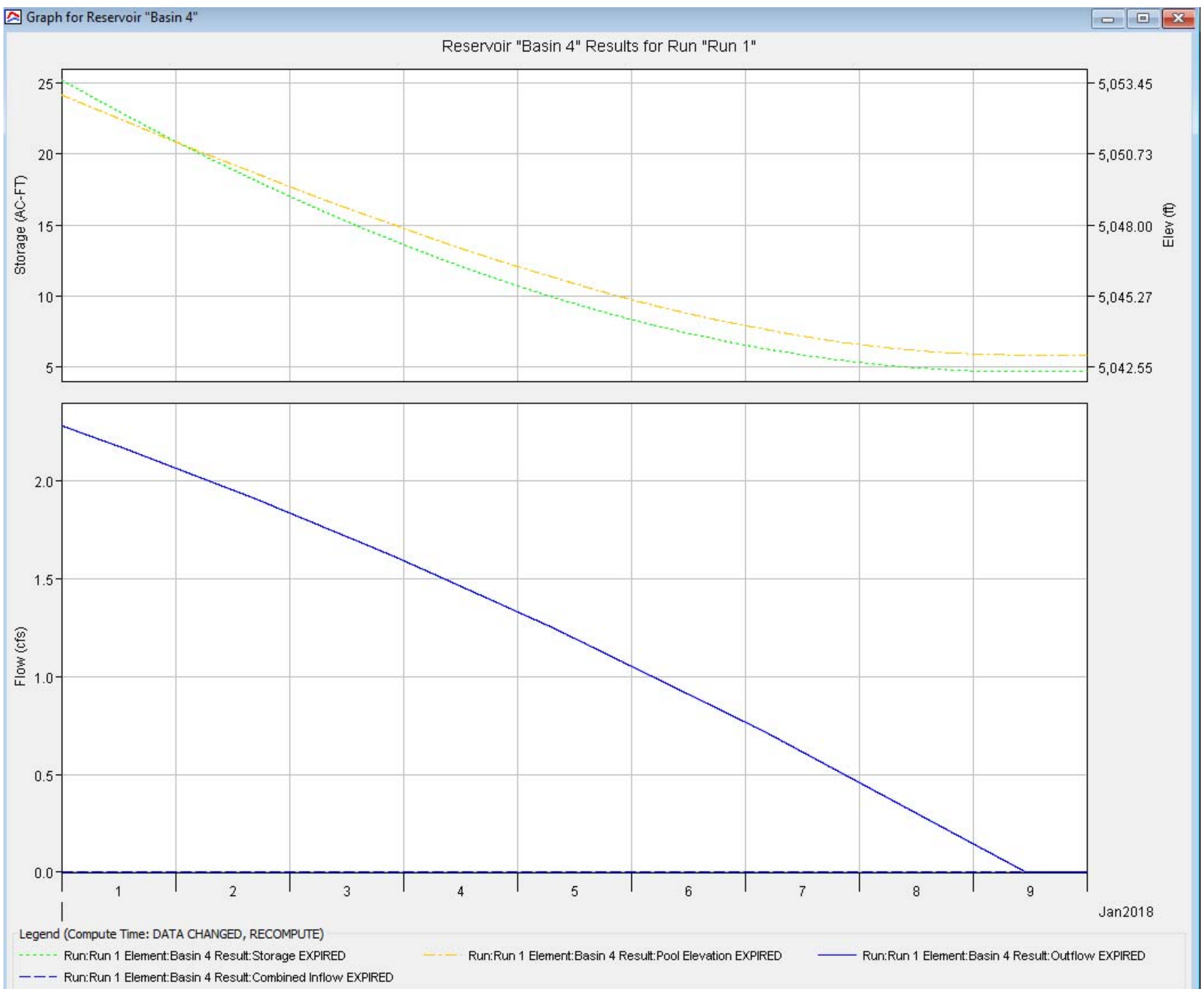
Project: Drawdown Simulation Run: Run 1
Reservoir: Basin 4

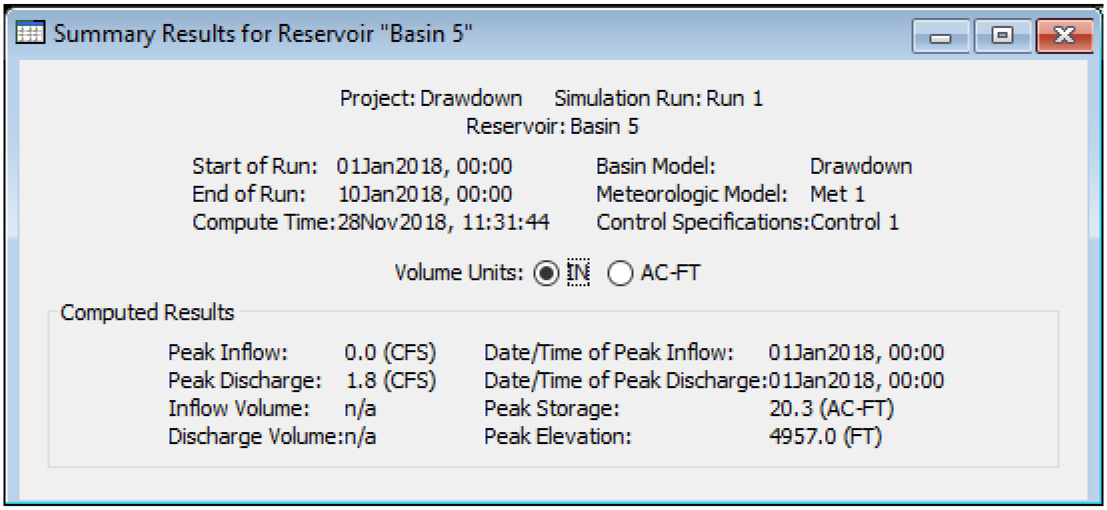
Start of Run:	01Jan2018, 00:00	Basin Model:	Drawdown
End of Run:	10Jan2018, 00:00	Meteorologic Model:	Met 1
Compute Time:	DATA CHANGED, RECOMPUTE	Control Specifications:	Control 1

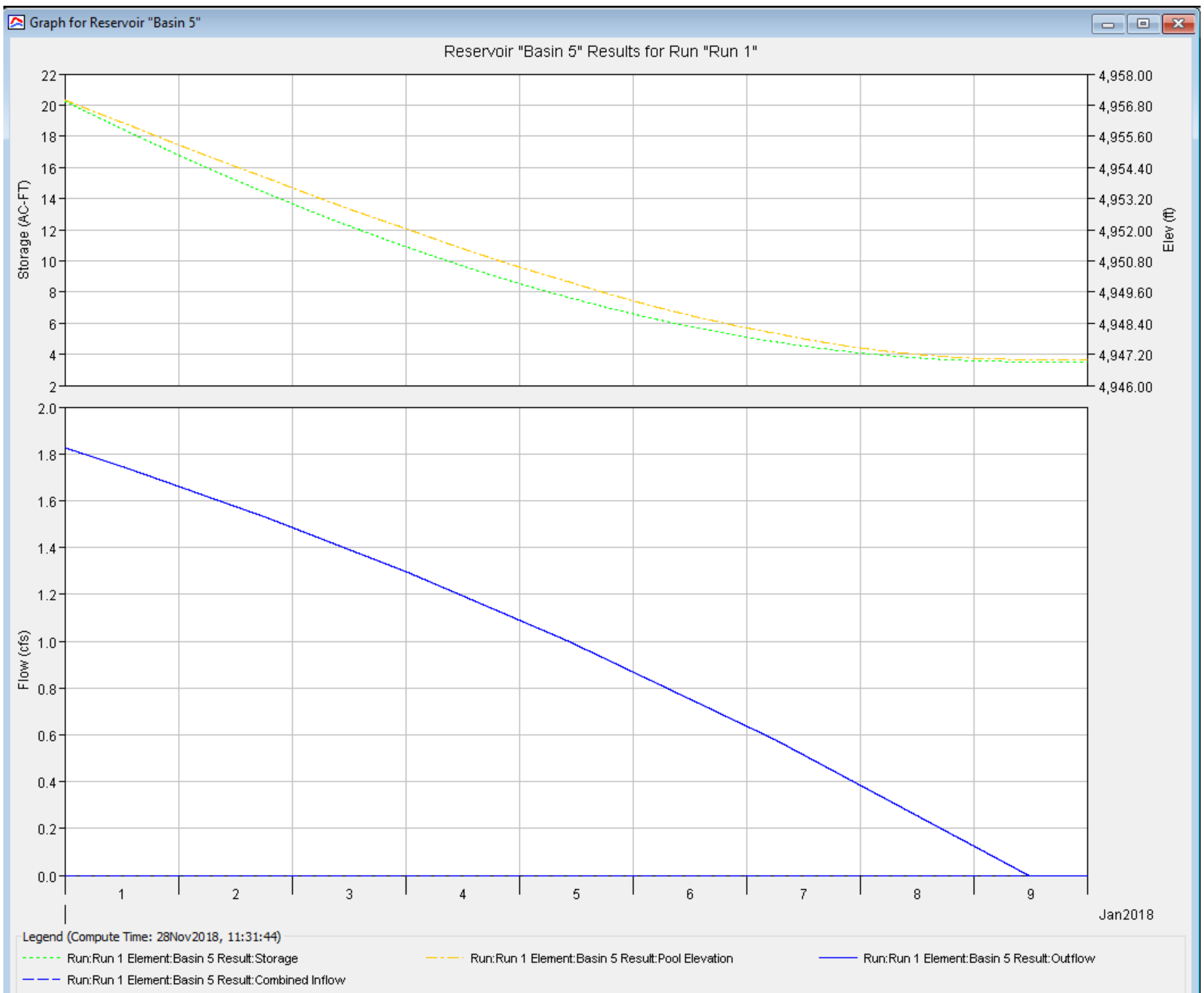
Volume Units: (•) IN ( ) AC-FT

Computed Results

Peak Inflow:	0.0 (CFS)	Date/Time of Peak Inflow:	01Jan2018, 00:00
Peak Discharge:	2.3 (CFS)	Date/Time of Peak Discharge:	01Jan2018, 00:00
Inflow Volume:	n/a	Peak Storage:	25.2 (AC-FT)
Discharge Volume:	n/a	Peak Elevation:	5053.0 (FT)




Summary Results for Reservoir "Basin 5"
Project: Drawdown Simulation Run: Run 1
Reservoir: Basin 5
Start of Run: 01Jan2018, 00:00
End of Run: 10Jan2018, 00:00
Compute Time: 28Nov2018, 11:31:44
Basin Model: Drawdown
Meteorologic Model: Met 1
Control Specifications: Control 1
Volume Units: IN AC-FT
Computed Results
Peak Inflow: 0.0 (CFS)
Peak Discharge: 1.8 (CFS)
Inflow Volume: n/a
Discharge Volume: n/a
Date/Time of Peak Inflow: 01Jan2018, 00:00
Date/Time of Peak Discharge: 01Jan2018, 00:00
Peak Storage: 20.3 (AC-FT)
Peak Elevation: 4957.0 (FT)


Graph for Reservoir "Basin 5"
Reservoir "Basin 5" Results for Run "Run 1"
Storage (AC-FT)
Elev (ft)
Flow (cfs)
Jan2018
Legend (Compute Time: 28Nov2018, 11:31:44)
Run:Run 1 Element:Basin 5 Result:Storage
Run:Run 1 Element:Basin 5 Result:Pool Elevation
Run:Run 1 Element:Basin 5 Result:Outflow
Run:Run 1 Element:Basin 5 Result:Combined Inflow

Summary Results for Reservoir "Basin 6"

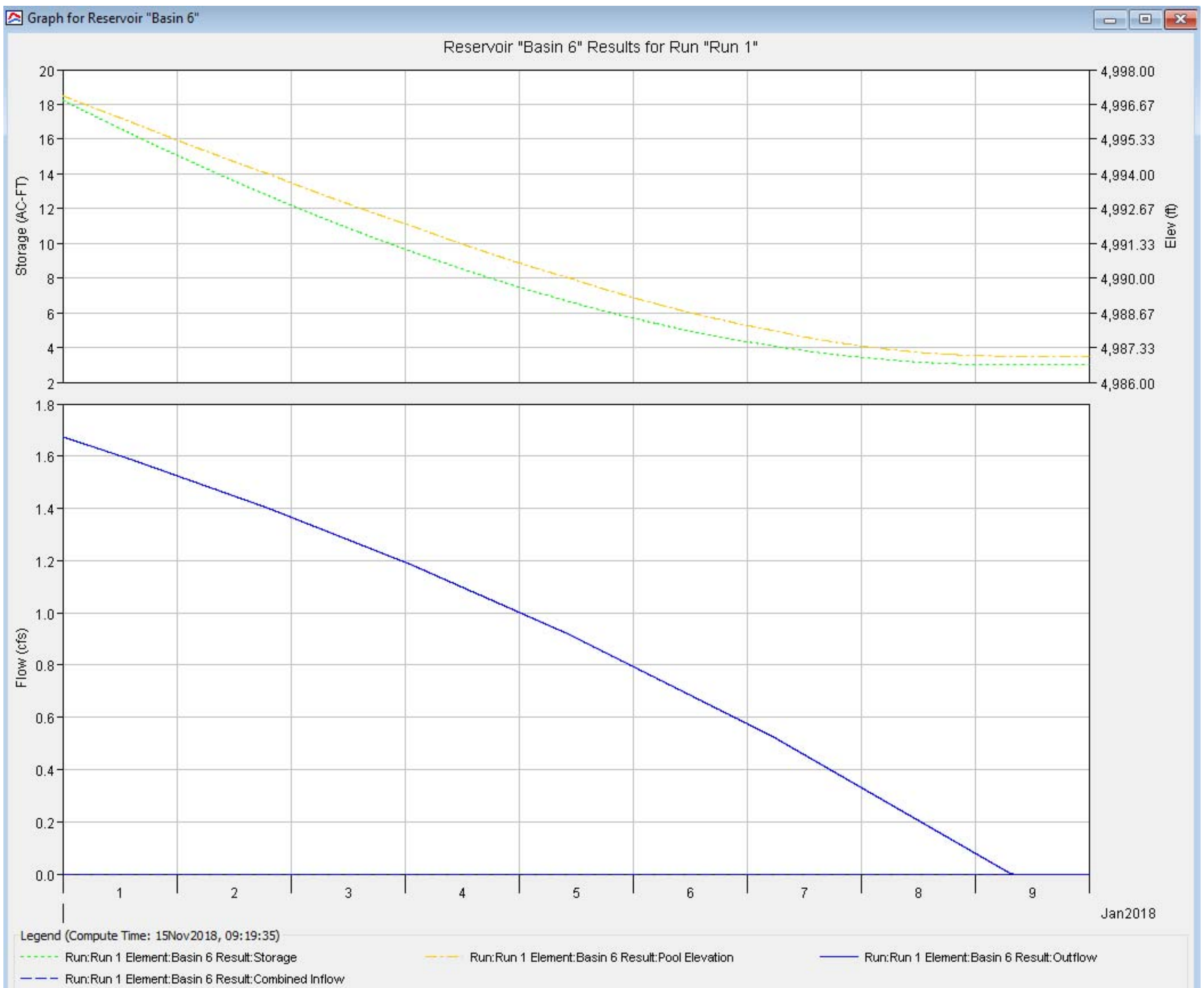
Project: Drawdown   Simulation Run: Run 1
Reservoir: Basin 6

Start of Run:	01Jan2018, 00:00	Basin Model:	Drawdown
End of Run:	10Jan2018, 00:00	Meteorologic Model:	Met 1
Compute Time:	15Nov2018, 09:19:35	Control Specifications:	Control 1

Volume Units: ◉ IN ○ AC-FT

Computed Results

Peak Inflow:	0.0 (CFS)	Date/Time of Peak Inflow:	01Jan2018, 00:00
Peak Discharge:	1.7 (CFS)	Date/Time of Peak Discharge:	01Jan2018, 00:00
Inflow Volume:	n/a	Peak Storage:	18.2 (AC-FT)
Discharge Volume:	n/a	Peak Elevation:	4997.0 (FT)



Elevation-Volume Input Tables

Basin 1		
Elevation	Area (ft)	
5354	61390	
5356	69503	
5358	77805	
5360	86297	
5362	94978	
5364	103848	
5366	112909	
5367	117452	FB
5368	134446	
5370	151750	

Elevation	Area (ac)	Vol. (ac-ft)
5354	1.40932	0
5356	1.595569	3.0048898
5358	1.786157	6.3866162
5360	1.981107	10.15388
5362	2.180395	14.315381
5364	2.384022	18.879798
5366	2.592034	23.855854
5367	2.696327	26.500034
5368	3.086455	29.391426
5370	3.483701	35.961582

Basin 2-3		
Elevation	Area (ft)	
5264	4541	
5266	7163	
5268	9980	
5270	12995	
5272	16206	
5274	19613	
5276	23218	
5277	25093	FB
5278	35896	
5280	40168	

Elevation	Area (ac)	Vol. (ac-ft)
5264	0.104247	0
5266	0.16444	0.2686869
5268	0.229109	0.662236
5270	0.298324	1.1896694
5272	0.372039	1.8600321
5274	0.450253	2.6823232
5276	0.533012	3.6655877
5277	0.576056	4.2201217
5278	0.824059	4.9201791
5280	0.92213	6.6663682

Basin 4		
Elevation	Area (ft)	
5040	61959	
5042	68576	
5044	75383	
5046	82381	
5048	89570	
5050	96949	
5052	104519	
5053	108456	FB
5054		
5056		

Elevation	Area (ac)	Vol. (ac-ft)
5040	1.422383	0
5042	1.574288	2.9966713
5044	1.730556	6.3015152
5046	1.891208	9.9232782
5048	2.056244	13.87073
5050	2.225643	18.152617
5052	2.399426	22.777686
5053	2.489807	25.222303

Basin 5		
Elevation	Area (ft)	
4944	45668	
4946	52177	
4948	58884	
4950	65788	
4952	72888	
4954	80185	
4956	87679	
4957	91749	FB
4958	100949	

Elevation	Area (ac)	Vol. (ac-ft)
4944	1.048393	0
4946	1.197819	2.24621212
4948	1.351791	4.79582185
4950	1.510285	7.65789715
4952	1.673278	10.8414601
4954	1.840794	14.3555326
4956	2.012833	18.2091598
4957	2.106267	20.2687098

Basin 6		
Elevation	Area (ft)	
4984	37800	
4986	44674	
4988	51743	
4990	59007	
4992	66465	
4994	74118	
4996	81967	
4997	85296	FB
4998	99762	
5000	107289	

Elevation	Area (ac)	Vol. (ac-ft)
4984	1	0
4986	1.025574	2.0255739
4988	1.187856	4.2390037
4990	1.354614	6.7814738
4992	1.525826	9.6619146
4994	1.701515	12.889256
4996	1.881703	16.472475
4997	1.958127	18.39239

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Appendix C: Spillway

Auxiliary Spillway Design Precipitation Calculations

TR-60 Requirements
PMP depths modified per Jensen (USUL, USUS)

Pond 1 Class: High Option: Full Embankment (Above Grade)

6-Hour			24-hour			72-hour		
			P100	3.1	inches			
PMP	5.04	inches	PMP	9.14	inches	PMP	10.87	inches
SDH	3.6044	inches	SDH	4.6704	inches	SDH	5.1202	inches
FBH	5.04	inches	FBH	9.14	inches	FBH	10.87	inches

Pond 2 Class: High Option: Full Embankment (Above Grade)

6-Hour			24-hour			72-hour		
			P100	3.09	inches			
PMP	5.37	inches	PMP	9.22	inches	PMP	10.96	inches
SDH	3.6828	inches	SDH	4.6838	inches	SDH	5.1362	inches
FBH	5.37	inches	FBH	9.22	inches	FBH	10.96	inches

Pond 3 Class: High Option: Full Embankment (Above Grade)

6-Hour			24-hour			72-hour		
			P100	3.03	inches			
PMP	5.39	inches	PMP	9.25	inches	PMP	10.99	inches
SDH	3.6436	inches	SDH	4.6472	inches	SDH	5.0996	inches
FBH	5.39	inches	FBH	9.25	inches	FBH	10.99	inches

Pond 4 Class: High Option: Full Embankment (Above Grade)

6-Hour			24-hour			72-hour		
			P100	3.06	inches			
PMP	5.1	inches	PMP	9.15	inches	PMP	10.88	inches
SDH	3.5904	inches	SDH	4.6434	inches	SDH	5.0932	inches
FBH	5.1	inches	FBH	9.15	inches	FBH	10.88	inches

Pond 5 Class: High Option: Full Embankment (Above Grade)

6-Hour			24-hour			72-hour		
			P100	3.06	inches			
PMP	5.1	inches	PMP	9.14	inches	PMP	10.87	inches
SDH	3.5904	inches	SDH	4.6408	inches	SDH	5.0906	inches
FBH	5.1	inches	FBH	9.14	inches	FBH	10.87	inches

Pond 6 Class: High Option: Full Embankment (Above Grade)

6-Hour			24-hour			72-hour		
			P100	3.03	inches			
PMP	5.23	inches	PMP	9.11	inches	PMP	10.83	inches
SDH	3.602	inches	SDH	4.6108	inches	SDH	5.058	inches
FBH	5.23	inches	FBH	9.11	inches	FBH	10.83	inches

Table 2-5 Minimum auxiliary spillway hydrologic criteria

Class of Dam	Product of storage X effective height	Existing or planned up-stream dams	Precipitation data for [1]	
			Auxiliary spillway hydrograph	Freeboard hydrograph
Low [2]	less than 30,000	none	P_{100}	$P_{100} + 0.12(PMP - P_{100})$
	greater than 30,000		$P_{100} + 0.06(PMP - P_{100})$	$P_{100} + 0.26(PMP - P_{100})$
	all	any [3]	$P_{100} + 0.12(PMP - P_{100})$	$P_{100} + 0.40(PMP - P_{100})$
Significant	all	none or any	$P_{100} + 0.12(PMP - P_{100})$	$P_{100} + 0.40(PMP - P_{100})$
High	all	none or any	$P_{100} + 0.26(PMP - P_{100})$	PMP

[1] P_{100} = Precipitation for 100-year return period. PMP = Probable maximum precipitation
[2] Dams involving industrial or municipal water are to use minimum criteria equivalent to that of Significant Hazard Class.
[3] Applies when the upstream dam is located so that its failure could endanger the lower dam

Auxiliary Spillway Design Precipitation Calculations

TR-60 Requirements
PMP depths modified per Jensen (USUL, USUS)

Pond 1 Class: Low Less than 30,000 Option: Below Grade

6-Hour		24-hour		72-hour	
		P100	3.1 inches		
PMP	5.04 inches	PMP	9.14 inches	PMP	10.87 inches
SDH	3.1 inches	SDH	3.1 inches	SDH	3.1 inches
FBH	3.3328 inches	FBH	3.8248 inches	FBH	4.0324 inches

Pond 1 Principal			100yr 10day
			5.96
Earth	Vegitated		
P50	P25		100yr 1 day
2.83	2.55	24hr	3.1
5.41	4.16	10 day	

Pond 2 Class: Low Less than 30,000 Option: Below Grade

6-Hour		24-hour		72-hour	
		P100	3.09 inches		
PMP	5.37 inches	PMP	9.22 inches	PMP	10.96 inches
SDH	3.09 inches	SDH	3.09 inches	SDH	3.09 inches
FBH	3.3636 inches	FBH	3.8256 inches	FBH	4.0344 inches

Pond 2 Principal			100yr 10day
			5.82
Earth	Vegitated		
P50	P25		100yr 1 day
2.81	2.54	24hr	3.09
5.28	4.75	10 day	

Pond 3 Class: Low Less than 30,000 Option: Below Grade

6-Hour		24-hour		72-hour	
		P100	3.03 inches		
PMP	5.39 inches	PMP	9.25 inches	PMP	10.99 inches
SDH	3.03 inches	SDH	3.03 inches	SDH	3.03 inches
FBH	3.3132 inches	FBH	3.7764 inches	FBH	3.9852 inches

Pond 3 Principal			100yr 10day
			5.57
Earth	Vegitated		
P50	P25		100yr 1 day
2.76	2.49	24hr	3.03
5.06	4.56	10 day	

Pond 4 Class: Low Less than 30,000 Option: Below Grade

6-Hour		24-hour		72-hour	
		P100	3.06 inches		
PMP	5.1 inches	PMP	9.15 inches	PMP	10.88 inches
SDH	3.06 inches	SDH	3.06 inches	SDH	3.06 inches
FBH	3.3048 inches	FBH	3.7908 inches	FBH	3.9984 inches

Pond 4 Principal			100yr 10day
			5.81
Earth	Vegitated		
P50	P25		100yr 1 day
2.79	2.52	24hr	3.06
5.27	4.74	10 day	

Pond 5 Class: Low Less than 30,000 Option: Below Grade

6-Hour		24-hour		72-hour	
		P100	3.06 inches		
PMP	5.1 inches	PMP	9.14 inches	PMP	10.87 inches
SDH	3.06 inches	SDH	3.06 inches	SDH	3.06 inches
FBH	3.3048 inches	FBH	3.7896 inches	FBH	3.9972 inches

Pond 5 Principal			100yr 10day
			5.81
Earth	Vegitated		
P50	P25		100yr 1 day
2.79	2.52	24hr	3.06
5.27	4.74	10 day	

Pond 6 Class: Low Less than 30,000 Option: Below Grade

6-Hour		24-hour		72-hour	
		P100	3.03 inches		
PMP	5.23 inches	PMP	9.11 inches	PMP	10.83 inches
SDH	3.03 inches	SDH	3.03 inches	SDH	3.03 inches
FBH	3.294 inches	FBH	3.7596 inches	FBH	3.966 inches

Pond 6 Principal			100yr 10day
			5.78
Earth	Vegitated		
P50	P25		100yr 1 day
2.76	2.49	24hr	3.03
5.24	4.72	10 day	

Table 2-5 Minimum auxiliary spillway hydrologic criteria

Class of Dam	Product of storage X effective height	Existing or planned up-stream dams	Precipitation data for [1]	
			Auxiliary spillway hydrograph	Freeboard hydrograph
Low [2]	less than 30,000	none	P_{100}	$P_{100} + 0.12(PMP - P_{100})$
	greater than 30,000		$P_{100} + 0.06(PMP - P_{100})$	$P_{100} + 0.26(PMP - P_{100})$
	all	any [3]	$P_{100} + 0.12(PMP - P_{100})$	$P_{100} + 0.40(PMP - P_{100})$
Significant	all	none or any	$P_{100} + 0.12(PMP - P_{100})$	$P_{100} + 0.40(PMP - P_{100})$
High	all	none or any	$P_{100} + 0.26(PMP - P_{100})$	PMP

[1] P_{100} = Precipitation for 100-year return period. PMP = Probable maximum precipitation
[2] Dams involving industrial or municipal water are to use minimum criteria equivalent to that of Significant Hazard Class.
[3] Applies when the upstream dam is located so that its failure could endanger the lower dam

Table 2-2 Minimum principal spillway hydrologic criteria

Class of dam	Purpose of dam	Product of storage X effective height	Existing or planned upstream dams	Precipitation data for maximum frequency of use of auxiliary spillway types: [1]	
				Earth	Vegetated
Low	single irrigation only [2]	less than 30,000	none	1/2 design life	1/2 design life
		greater than 30,000		3/4 design life	3/4 design life
	single or multiple [4]	less than 30,000	none	P_{50}	P_{25} [3]
		greater than 30,000		$1/2 (P_{50} + P_{100})$	$1/2 (P_{25} + P_{50})$
		all	any [5]	P_{100}	P_{50}
Significant	single or multiple	all	none or any	P_{100}	P_{50}
High	single or multiple	all	none or any	P_{100}	P_{100}

[1] Precipitation amounts by return period in years. In some areas, direct runoff amounts determined by figure 2-1 and 2-2 or procedures in chapter 21, NEH-4 should be used in lieu of precipitation data.

[2] Applies to irrigation dams on ephemeral streams in areas where the annual rainfall is less the 25 inches.

[3] The minimum criteria are to be increased from P_{25} to P_{100} for a ramp spillway.

[4] Low Hazard Class dams involving industrial or municipal water are to be designed with a minimum criteria equivalent to that of Significant Hazard Class.

[5] Applies when the upstream dam is located so that its failure could endanger the lower dam.

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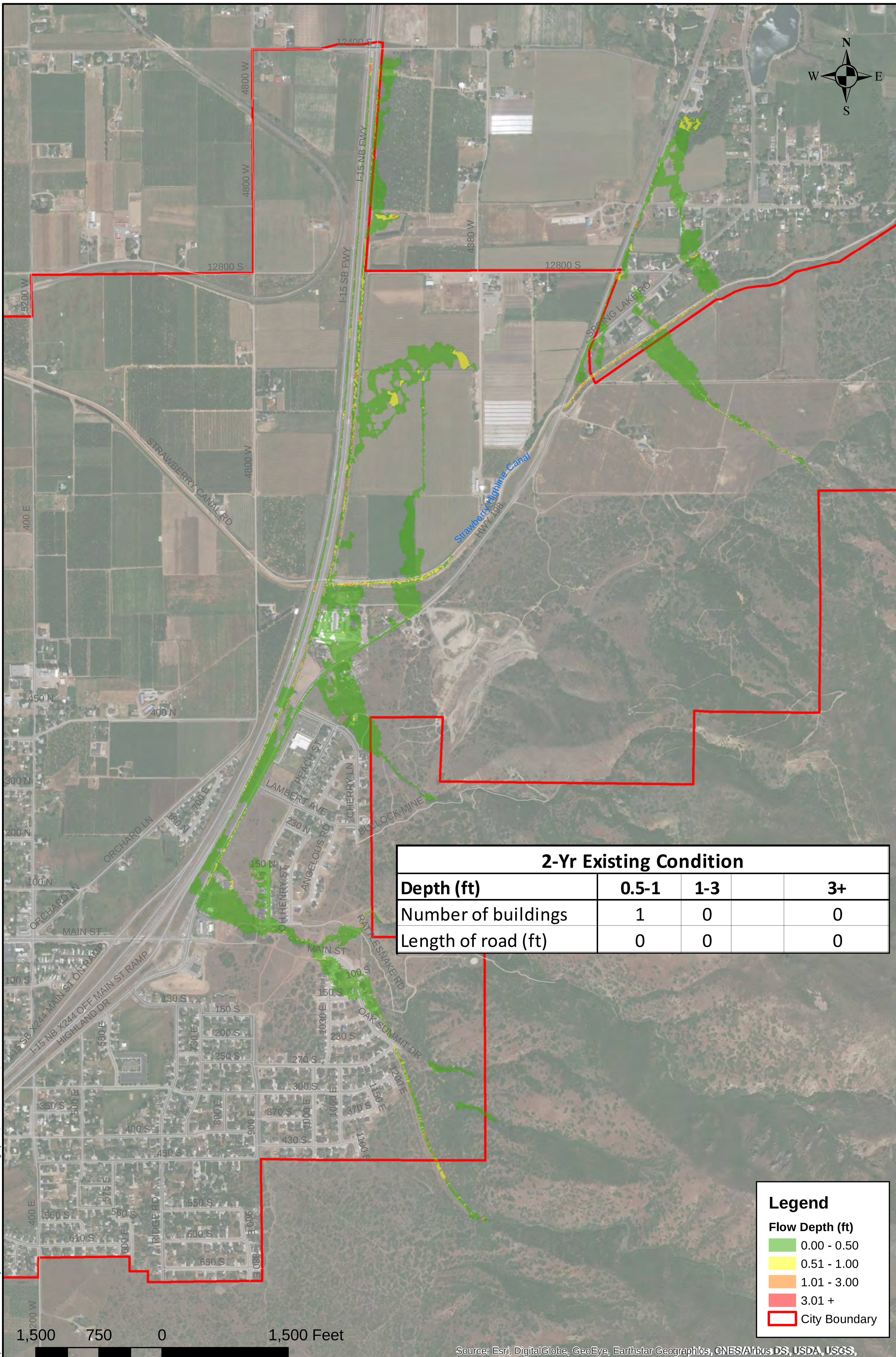
www.horrocks.com

Appendix D: Pre and Post Velocity and Flood Depth Maps



2-Yr Existing Condition

Depth (ft)	0.5-1	1-3		3+
Number of buildings	1	0		0
Length of road (ft)	0	0		0

Santaquin

2-Yr Existing Condition

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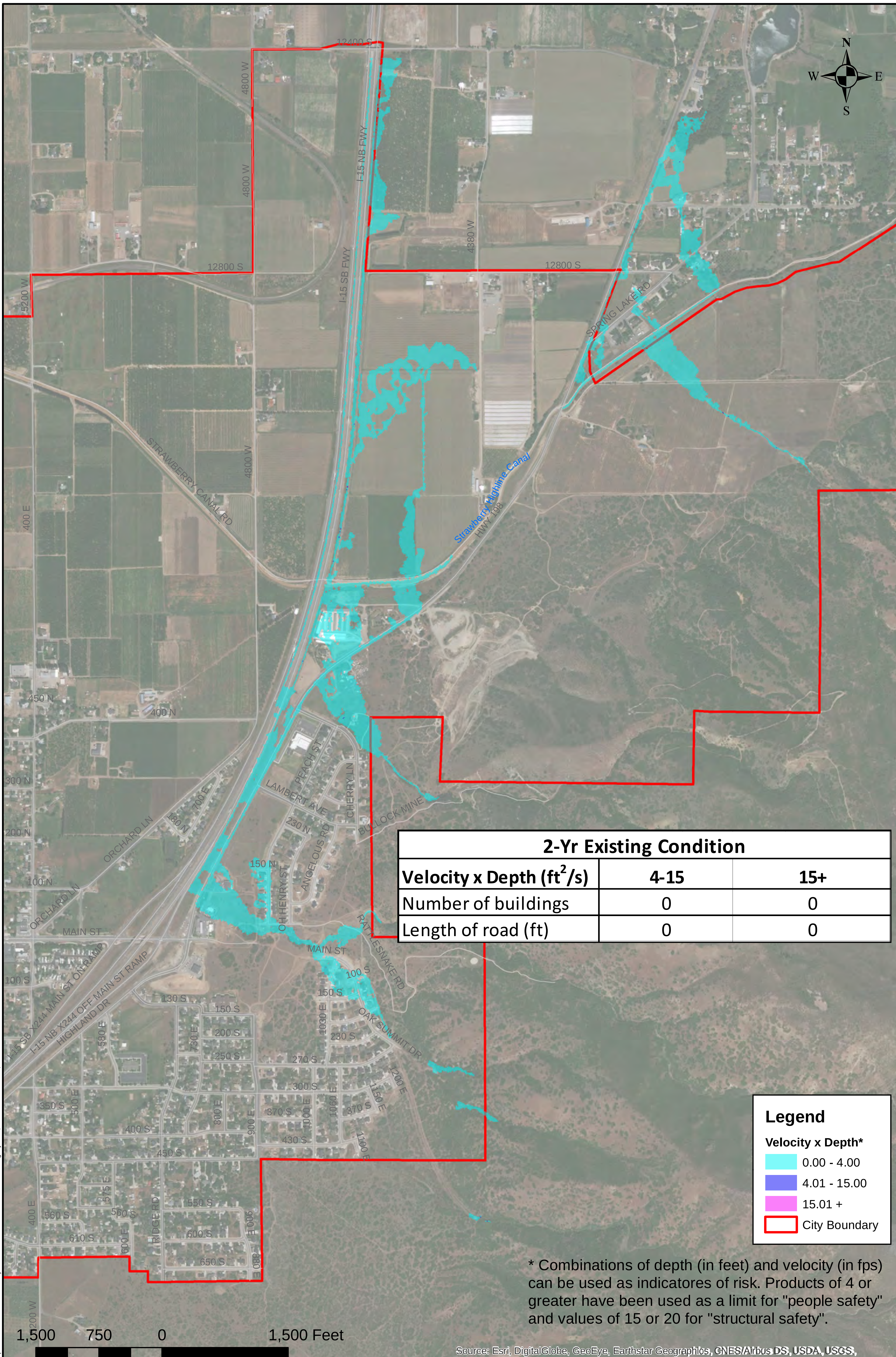

2-Yr Existing Condition

Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	0	0
Length of road (ft)	0	0

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2-Yr Existing Condition

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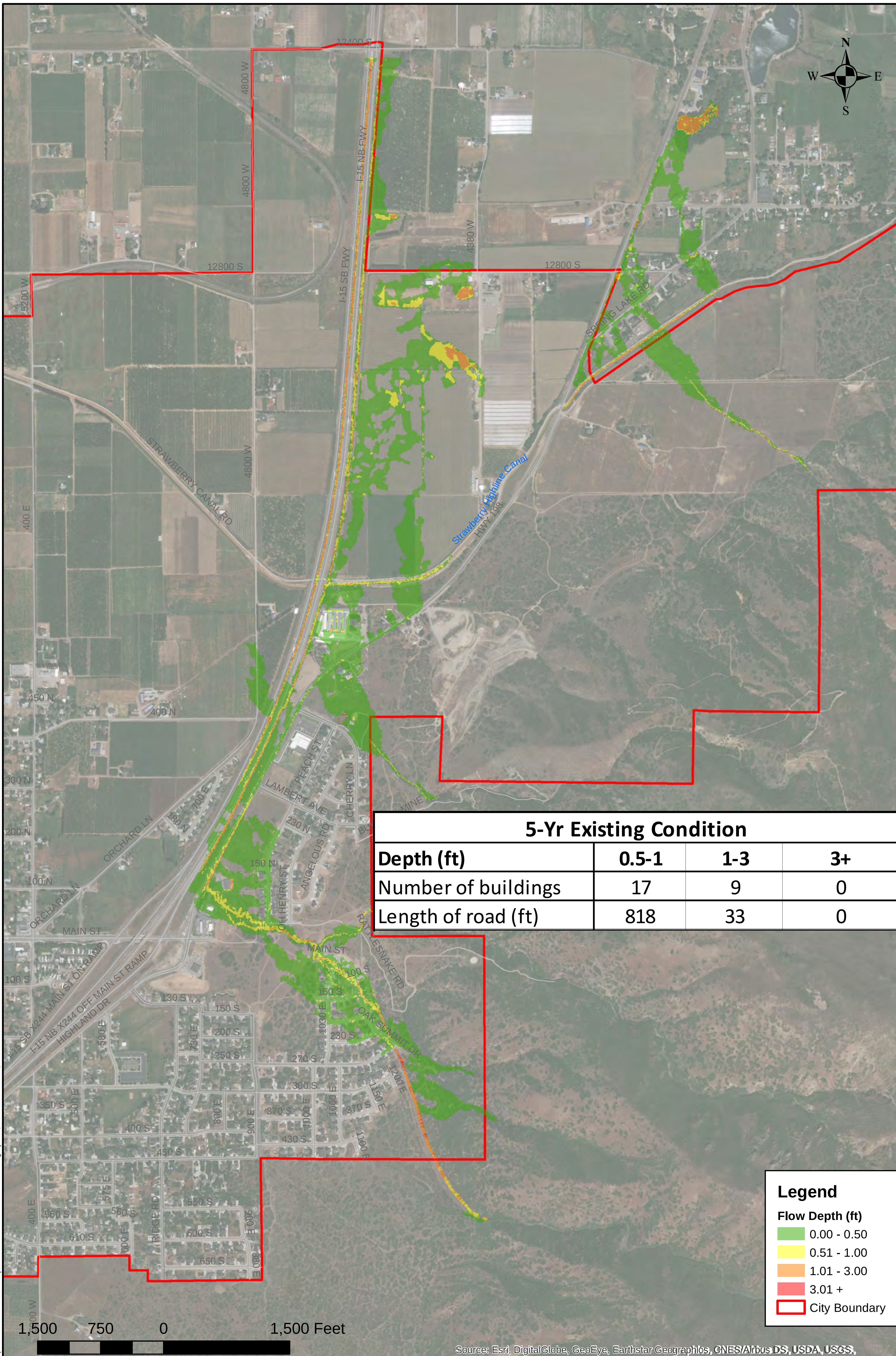

5-Yr Existing Condition

Depth (ft)	0.5-1	1-3	3+
Number of buildings	17	9	0
Length of road (ft)	818	33	0

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5-Yr Existing Condition

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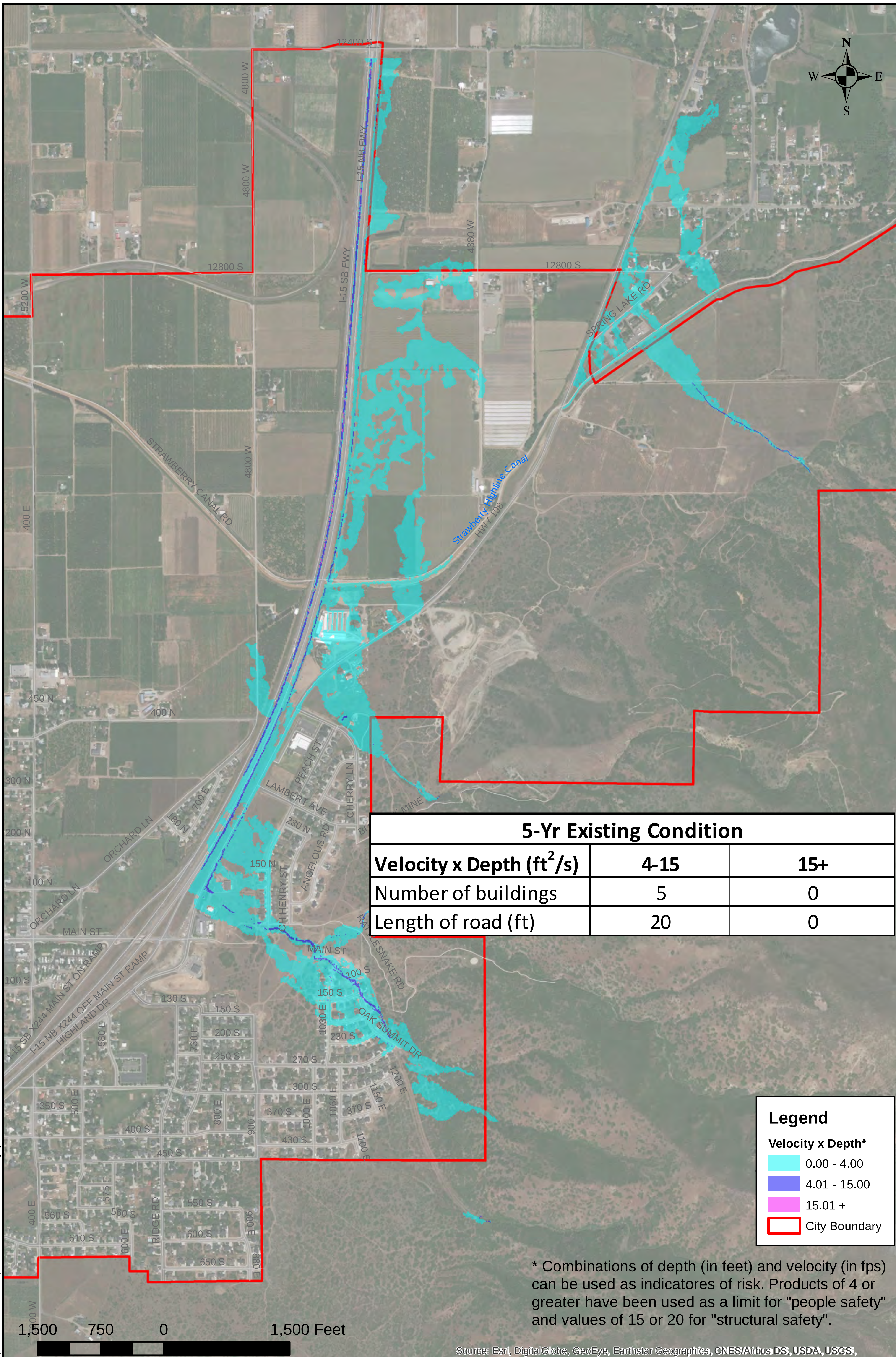

5-Yr Existing Condition

Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	5	0
Length of road (ft)	20	0

Legend

Velocity x Depth*

- 0.00 - 4.00
- 4.01 - 15.00
- 15.01 +
- City Boundary

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

1,500 750 0 1,500 Feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

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5-Yr Existing Condition

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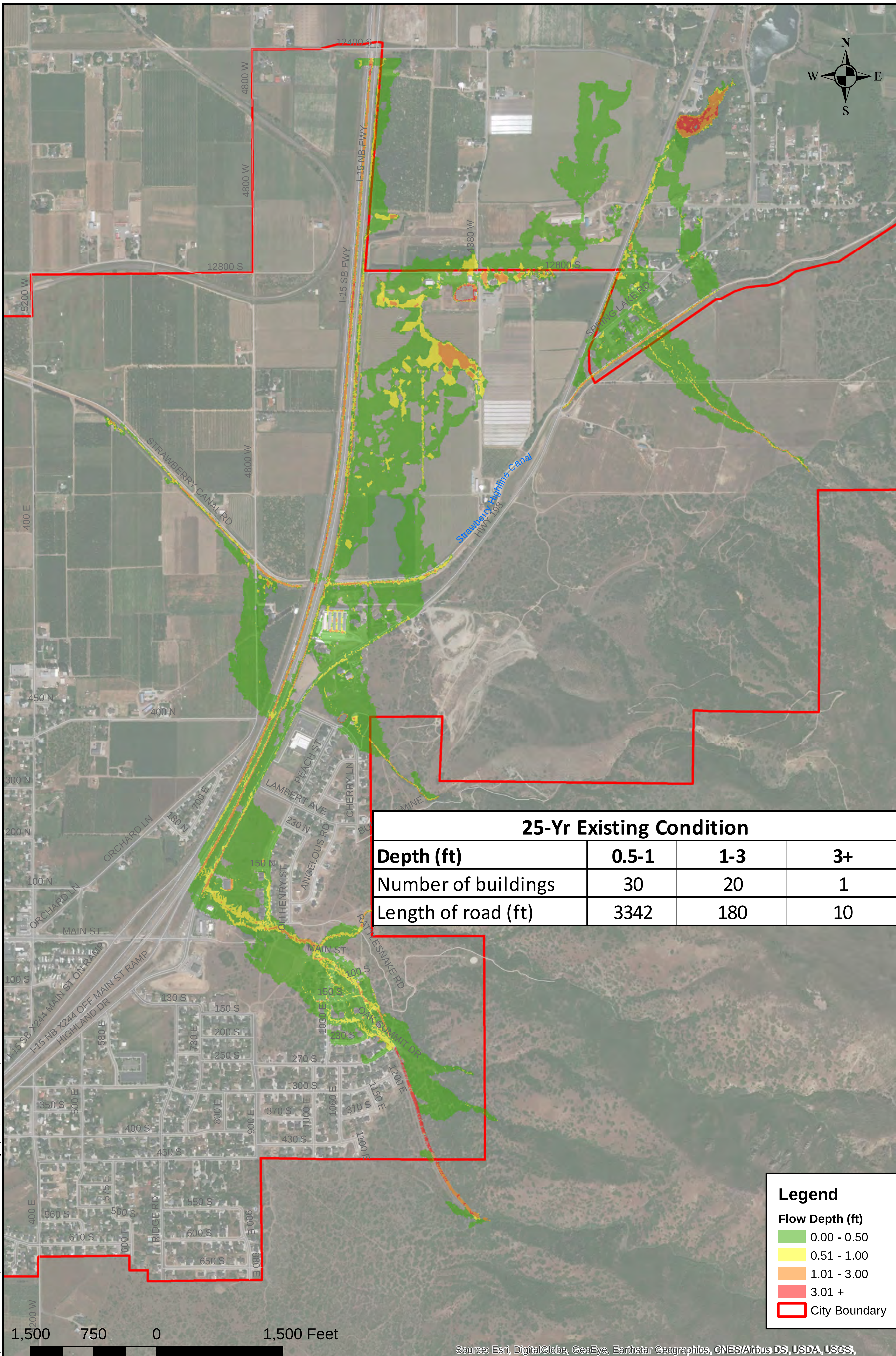

25-Yr Existing Condition

Depth (ft)	0.5-1	1-3	3+
Number of buildings	30	20	1
Length of road (ft)	3342	180	10

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25-Yr Existing Condition

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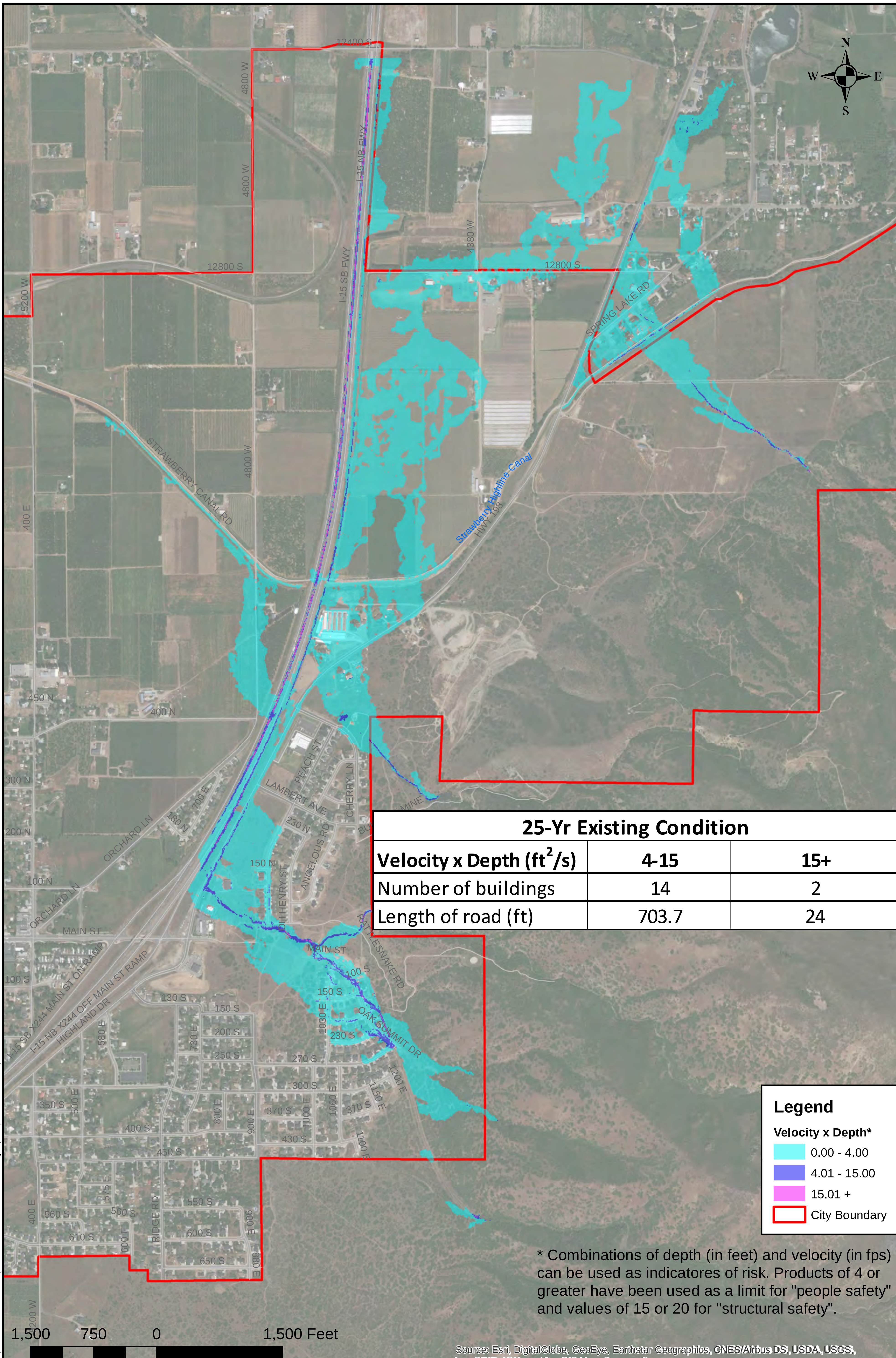

25-Yr Existing Condition

Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	14	2
Length of road (ft)	703.7	24

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

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25-Yr Existing Condition

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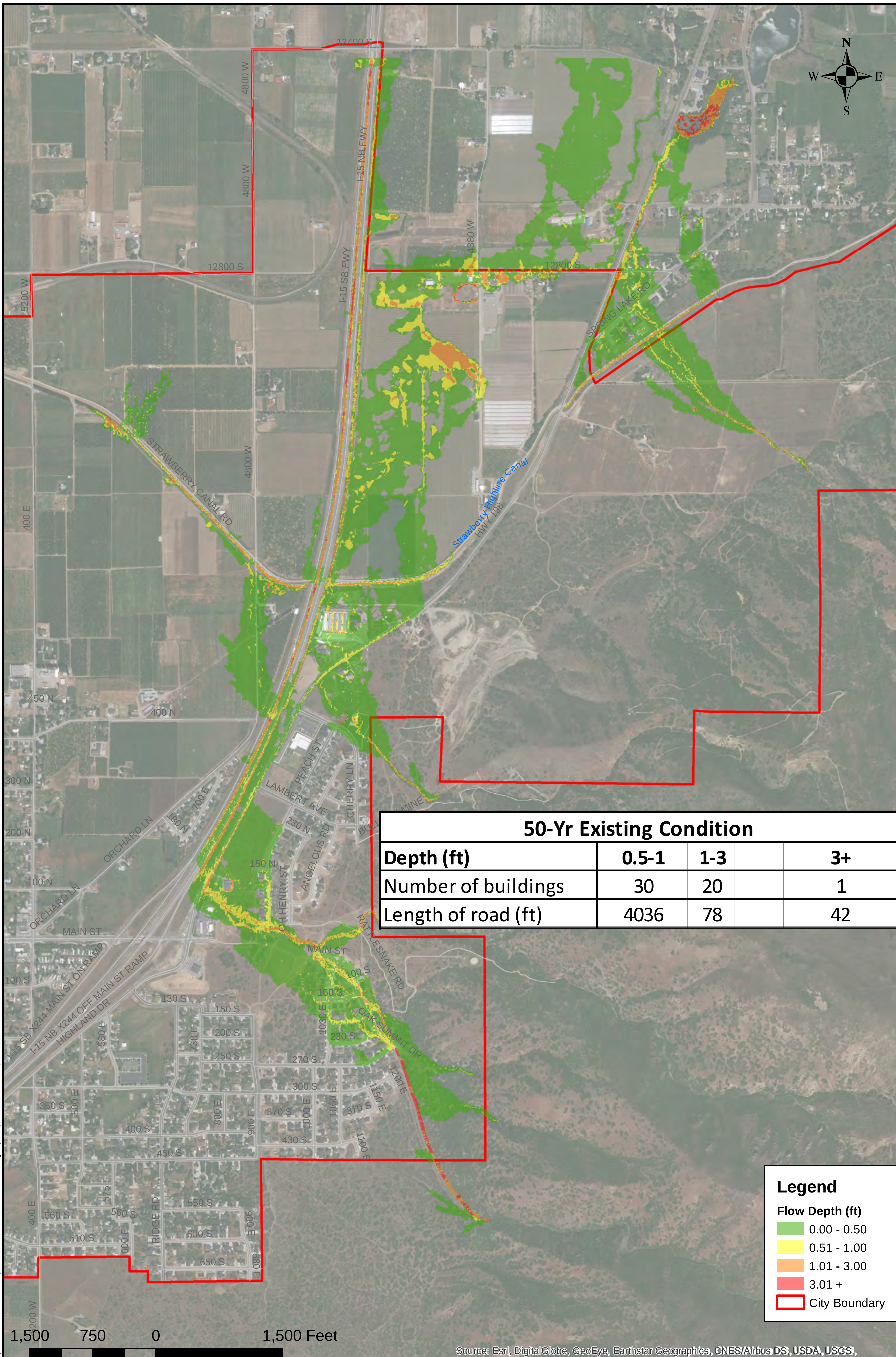

50-Yr Existing Condition

Depth (ft)	0.5-1	1-3		3+
Number of buildings	30	20		1
Length of road (ft)	4036	78		42

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50-Yr Existing Condition

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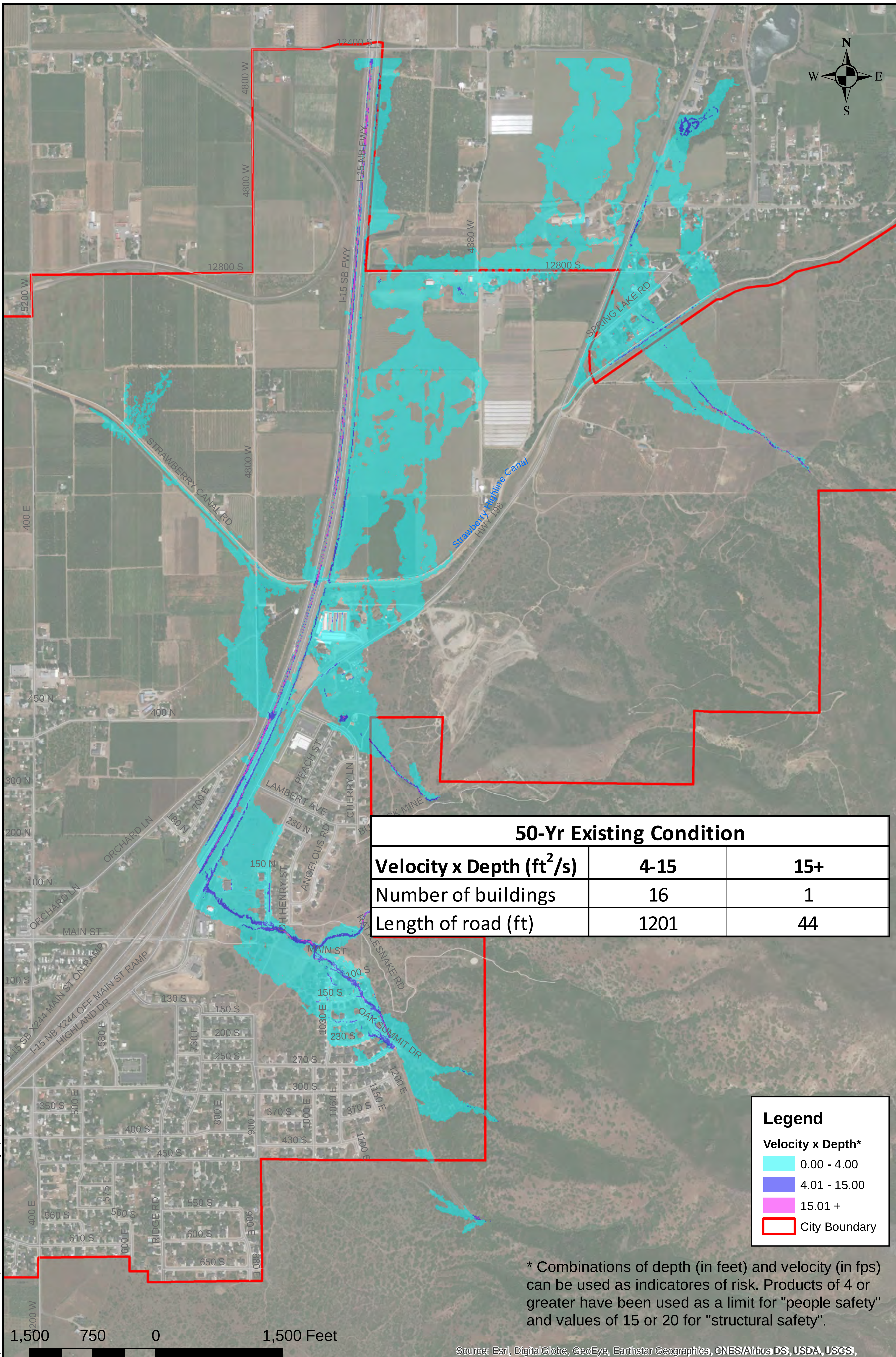

50-Yr Existing Condition

Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	16	1
Length of road (ft)	1201	44

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

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50-Yr Existing Condition

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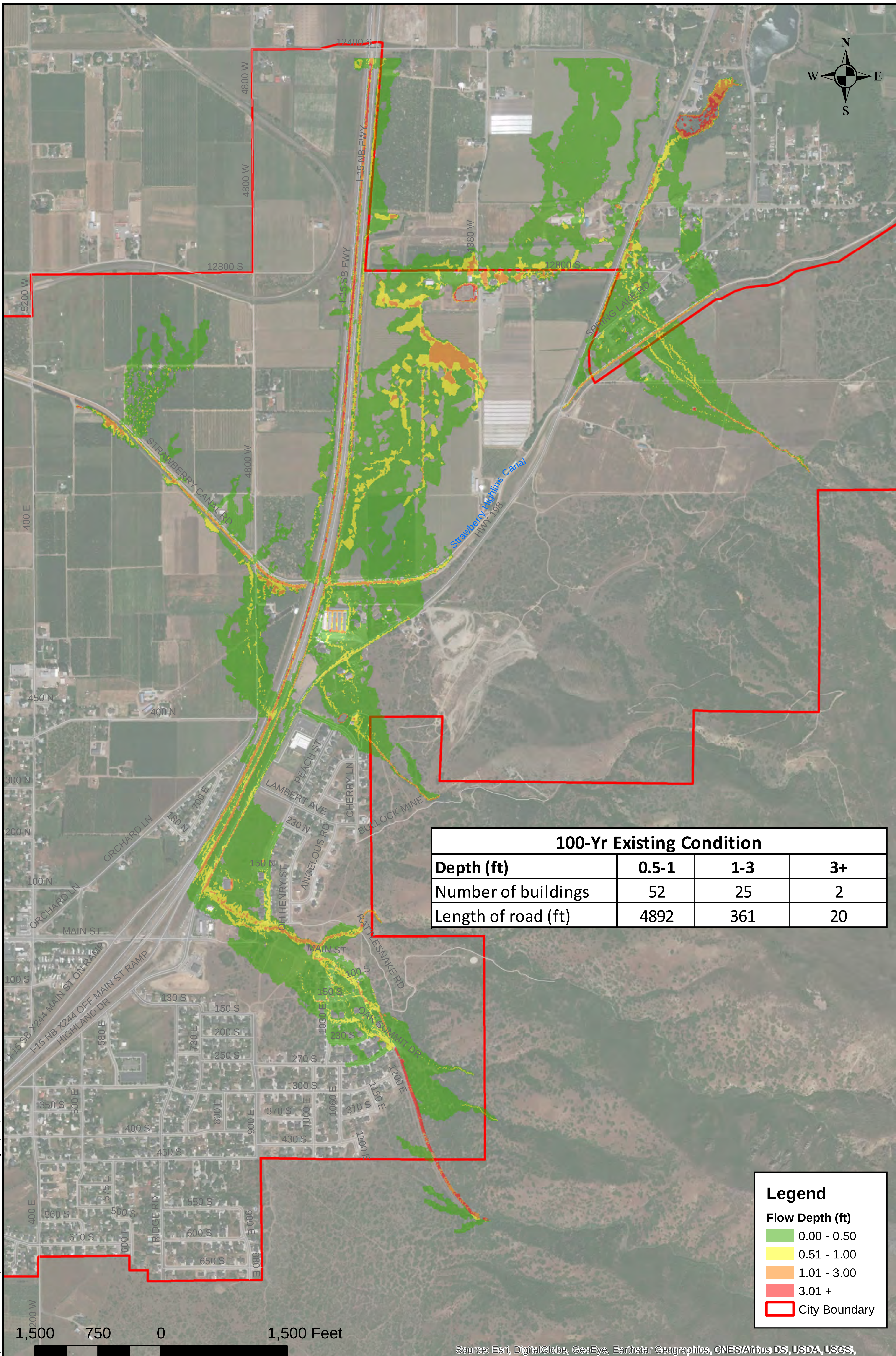

100-Yr Existing Condition

Depth (ft)	0.5-1	1-3	3+
Number of buildings	52	25	2
Length of road (ft)	4892	361	20

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100-Yr Existing Condition

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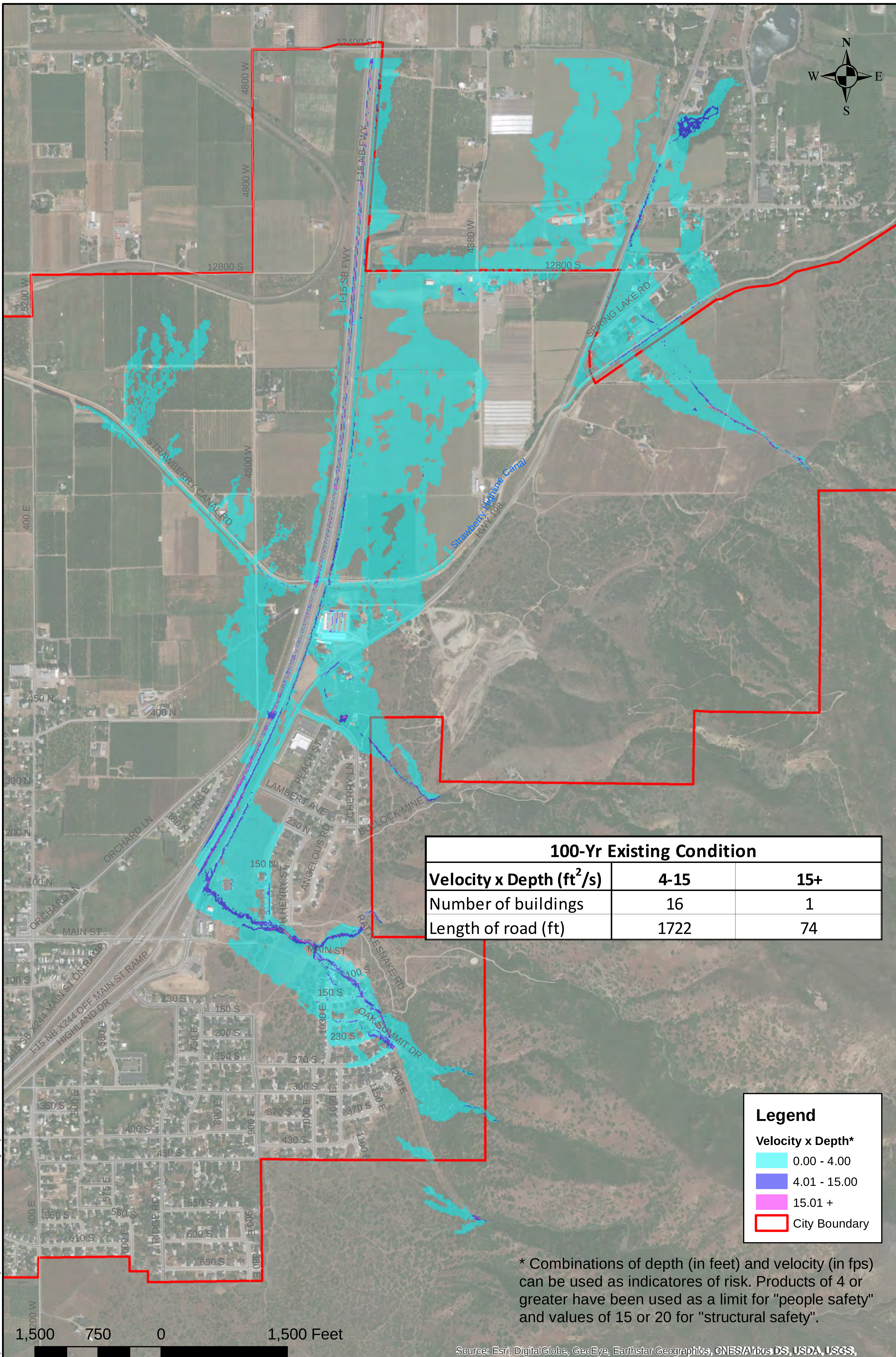

100-Yr Existing Condition

Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	16	1
Length of road (ft)	1722	74

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

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100-Yr Existing Condition

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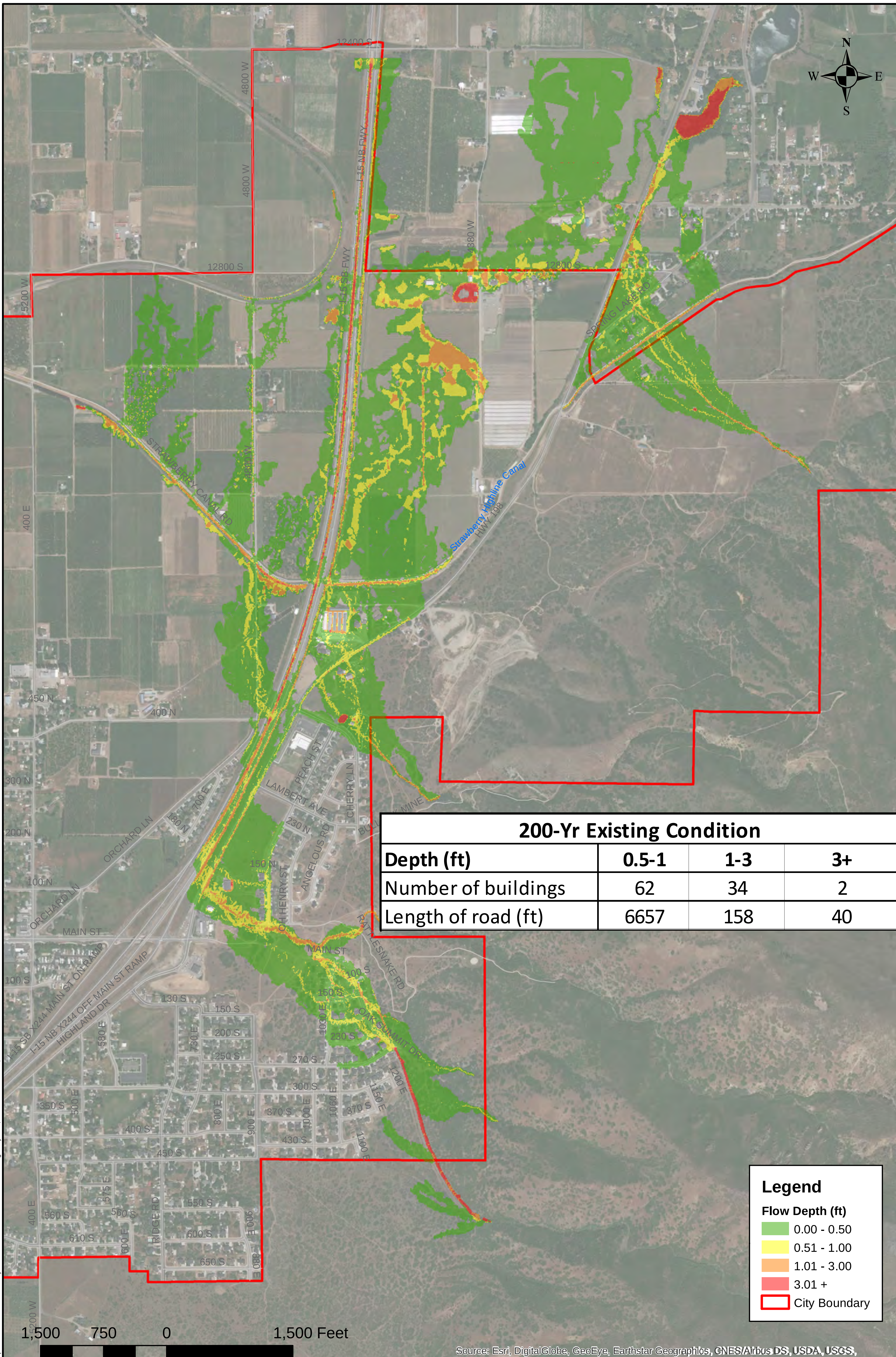

200-Yr Existing Condition

Depth (ft)	0.5-1	1-3	3+
Number of buildings	62	34	2
Length of road (ft)	6657	158	40

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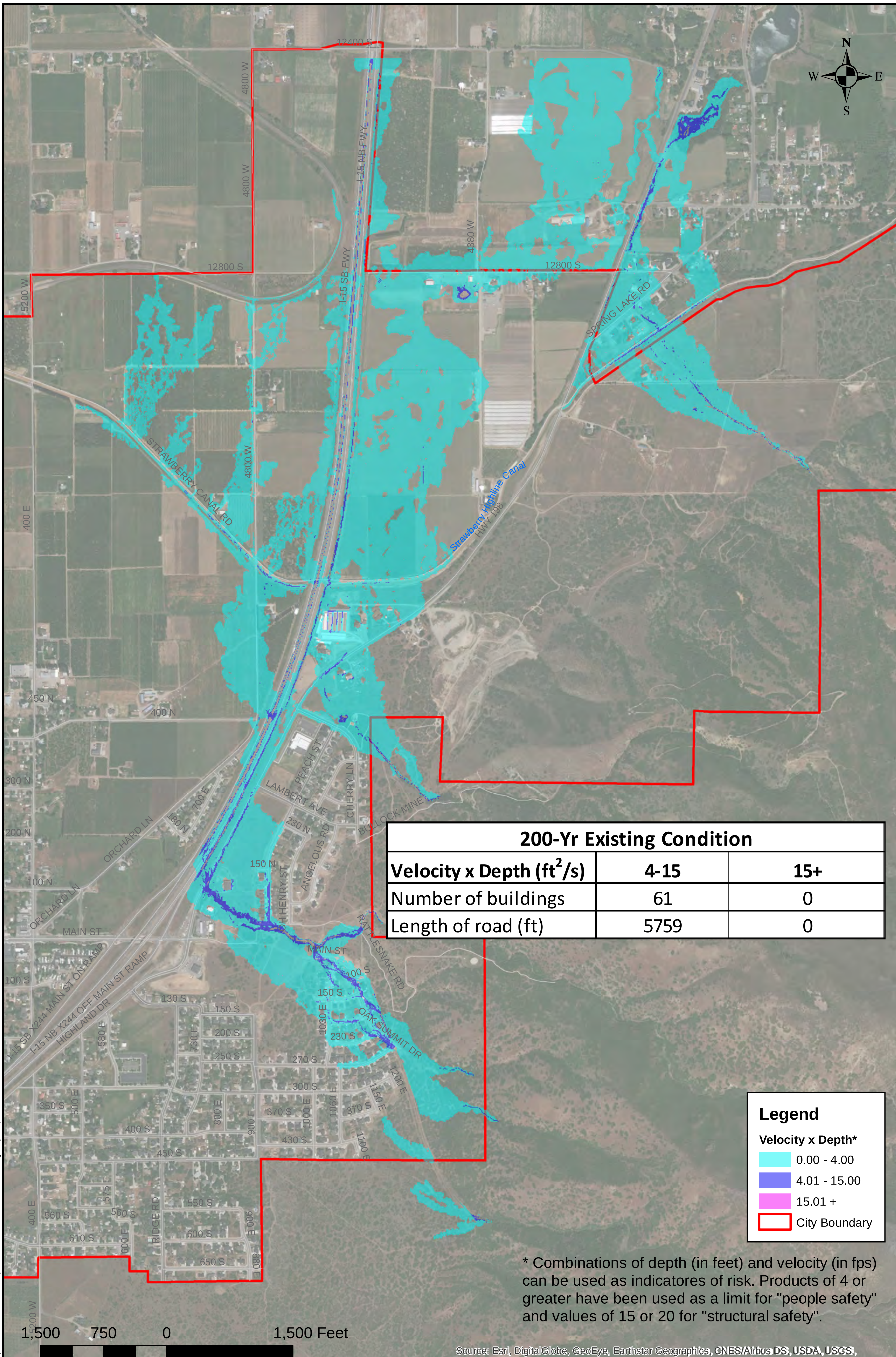

200-Yr Existing Condition

Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	61	0
Length of road (ft)	5759	0

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

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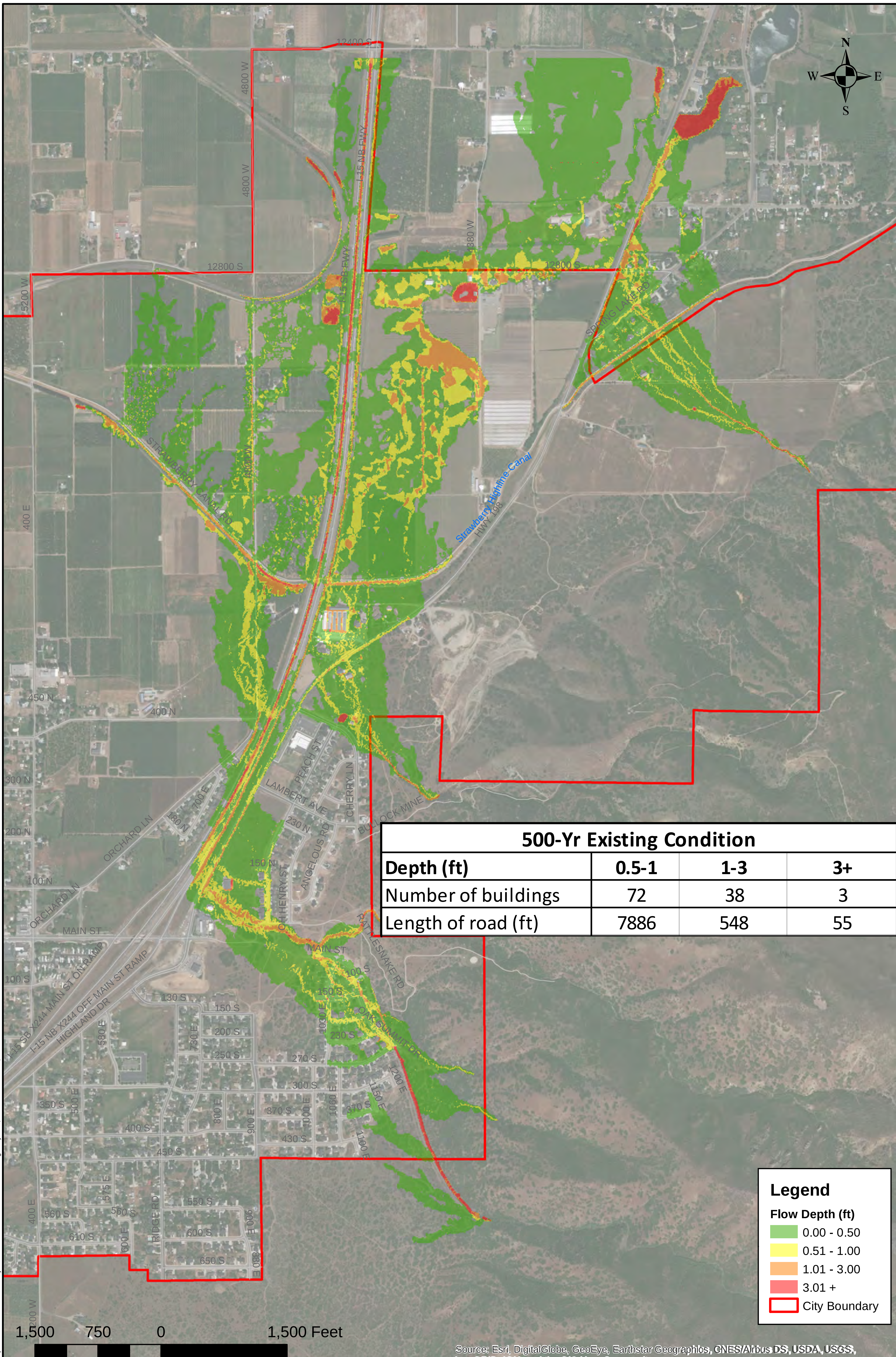

500-Yr Existing Condition

Depth (ft)	0.5-1	1-3	3+
Number of buildings	72	38	3
Length of road (ft)	7886	548	55

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500-Yr Existing Condition

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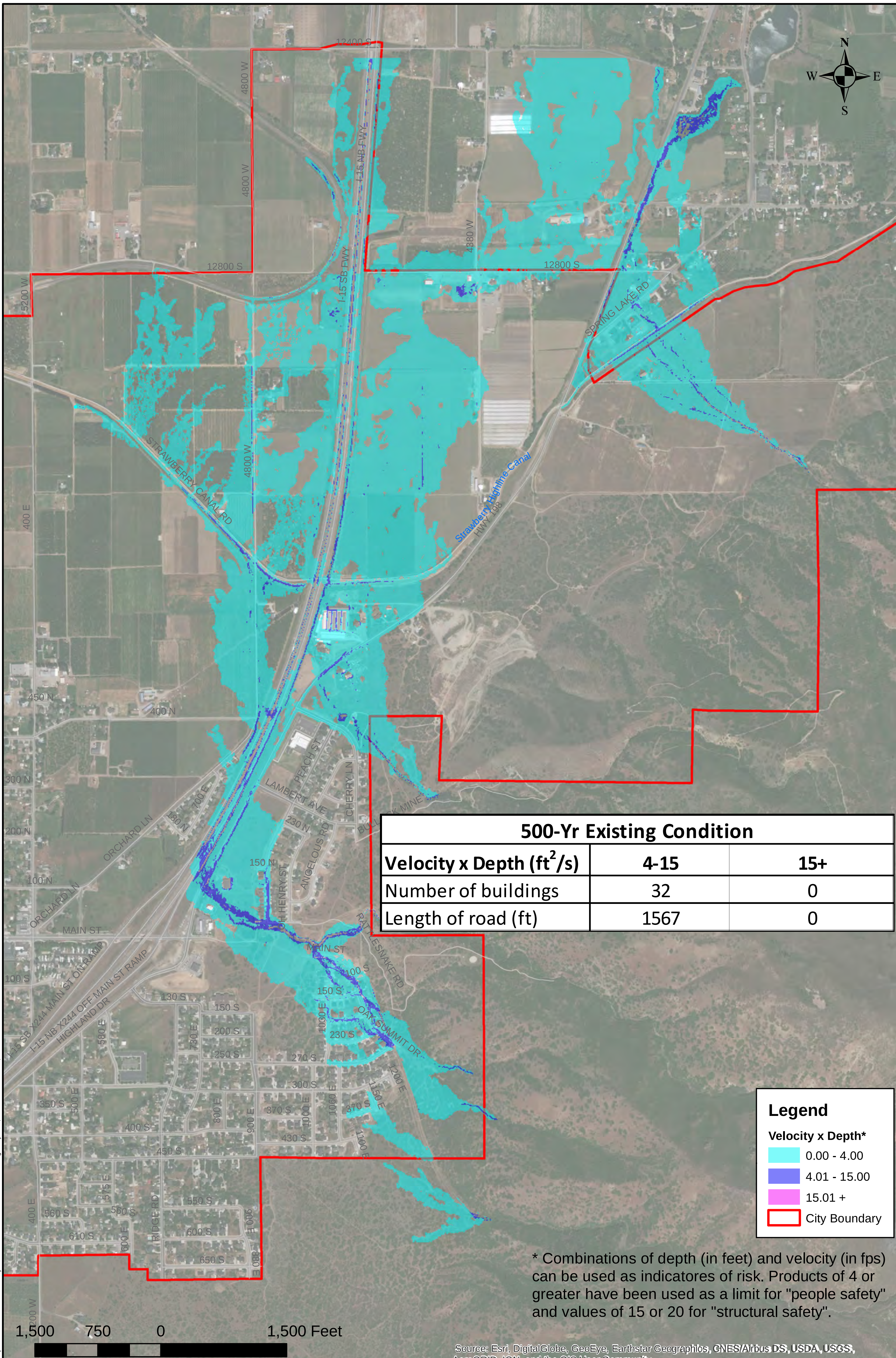

500-Yr Existing Condition

Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	32	0
Length of road (ft)	1567	0

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

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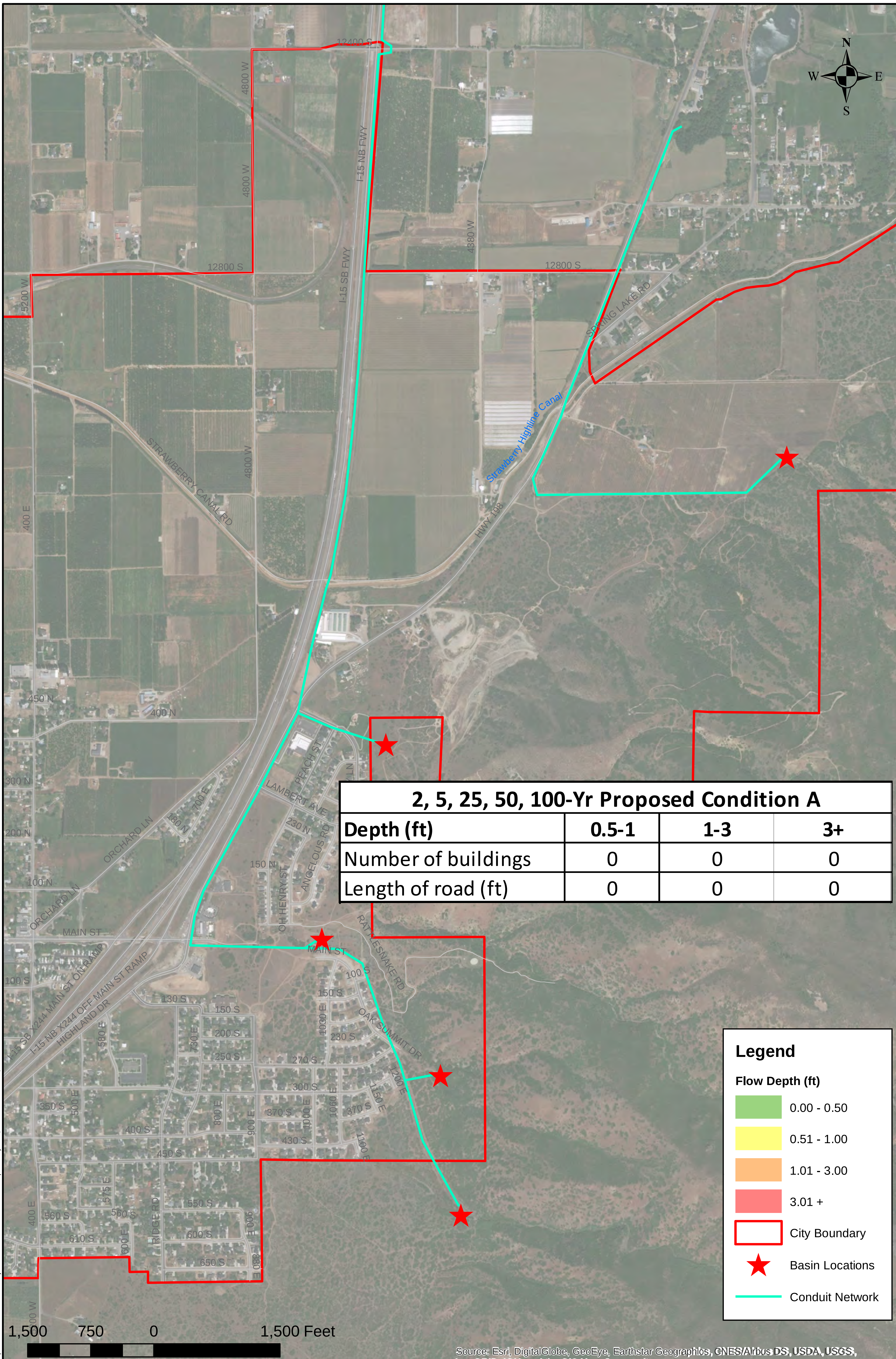

2, 5, 25, 50, 100-Yr Proposed Condition A

Depth (ft)	0.5-1	1-3	3+
Number of buildings	0	0	0
Length of road (ft)	0	0	0

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2, 5, 25, 50 100-Yr Proposed Condition A

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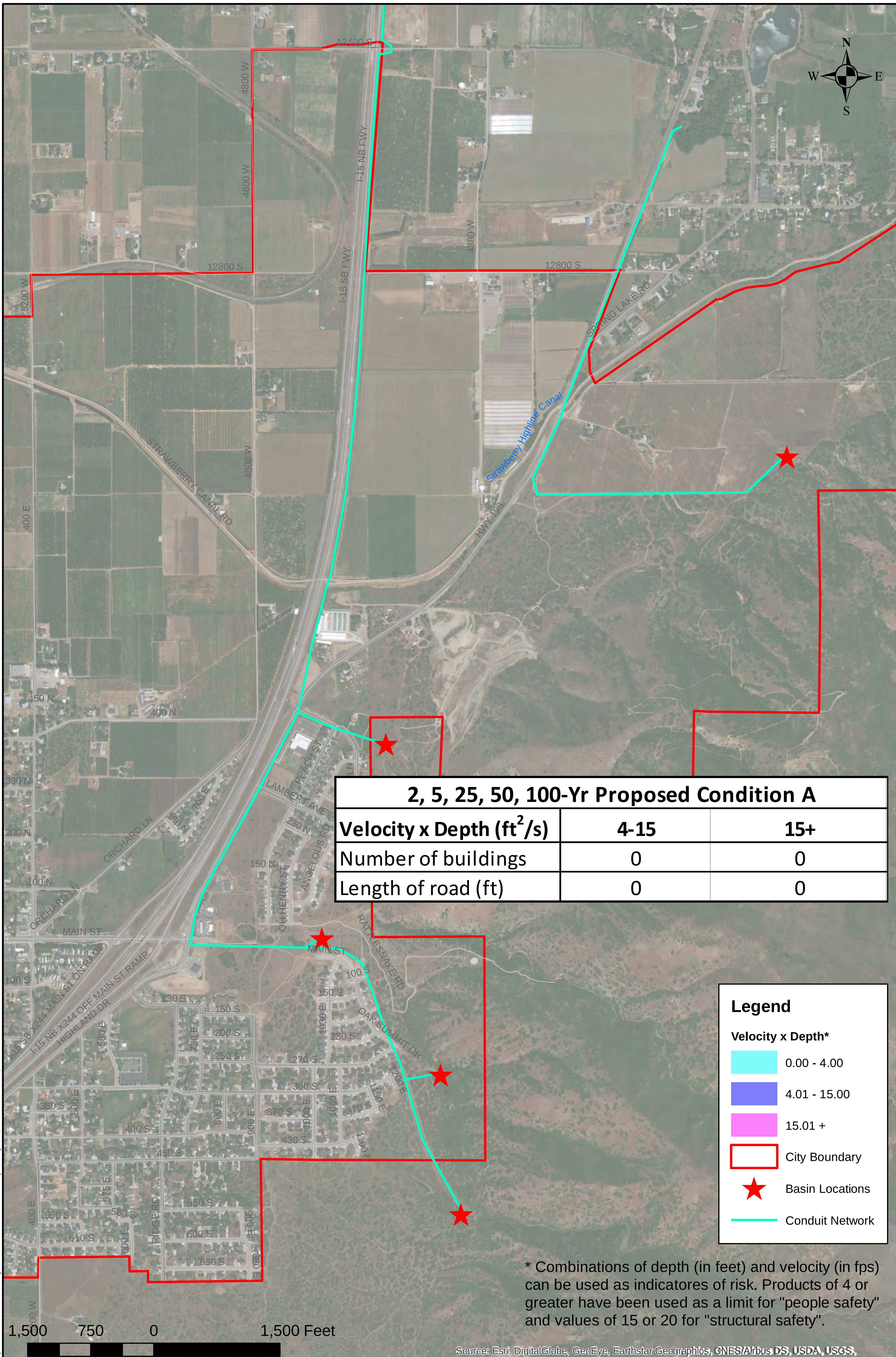

2, 5, 25, 50, 100-Yr Proposed Condition A

Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	0	0
Length of road (ft)	0	0

Legend

Velocity x Depth*

- 0.00 - 4.00
- 4.01 - 15.00
- 15.01 +
- City Boundary
- Basin Locations
- Conduit Network

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

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2, 5, 25, 50 100-Yr Proposed Condition A

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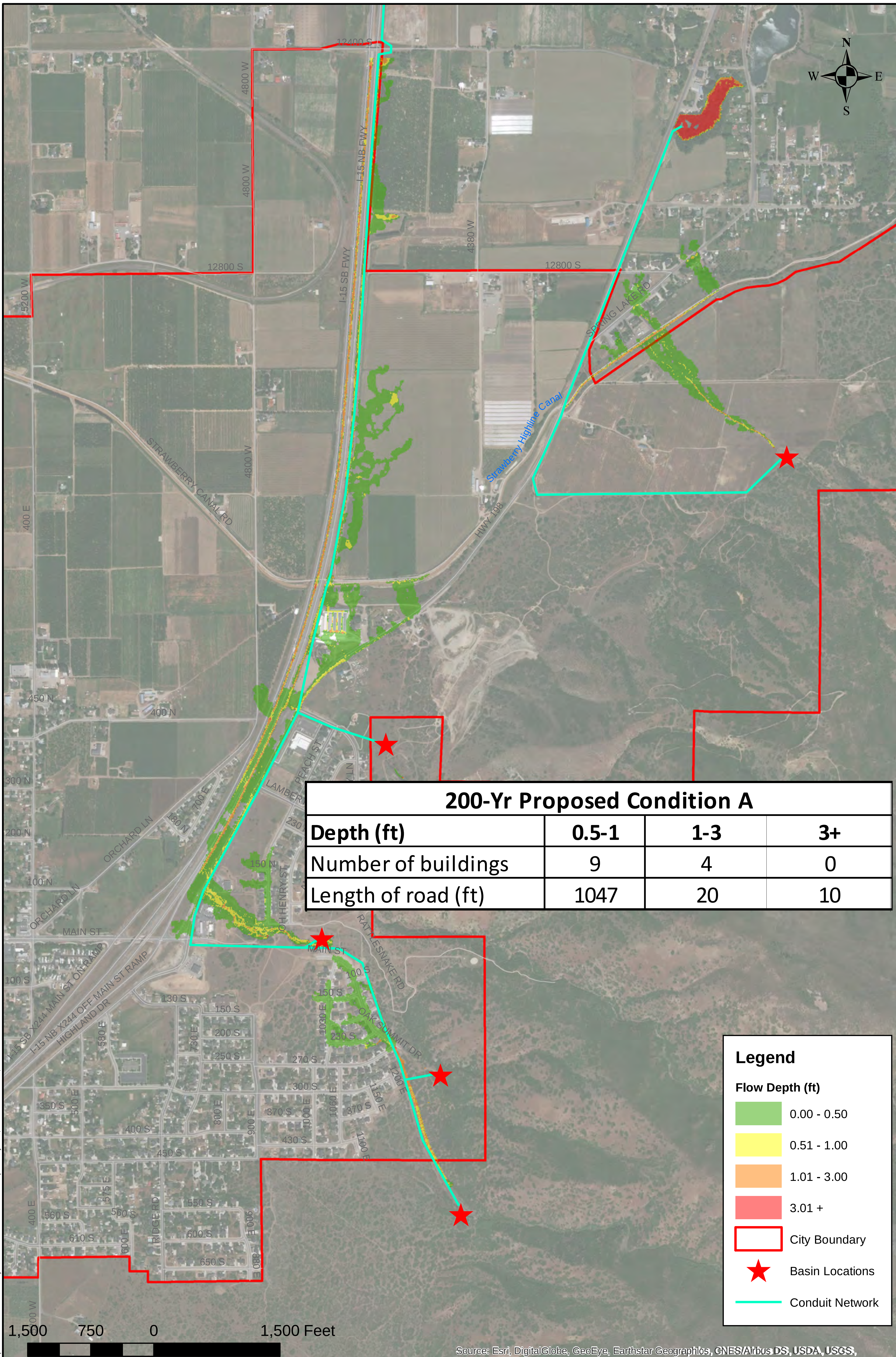

200-Yr Proposed Condition A

Depth (ft)	0.5-1	1-3	3+
Number of buildings	9	4	0
Length of road (ft)	1047	20	10

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200-Yr Proposed Condition A

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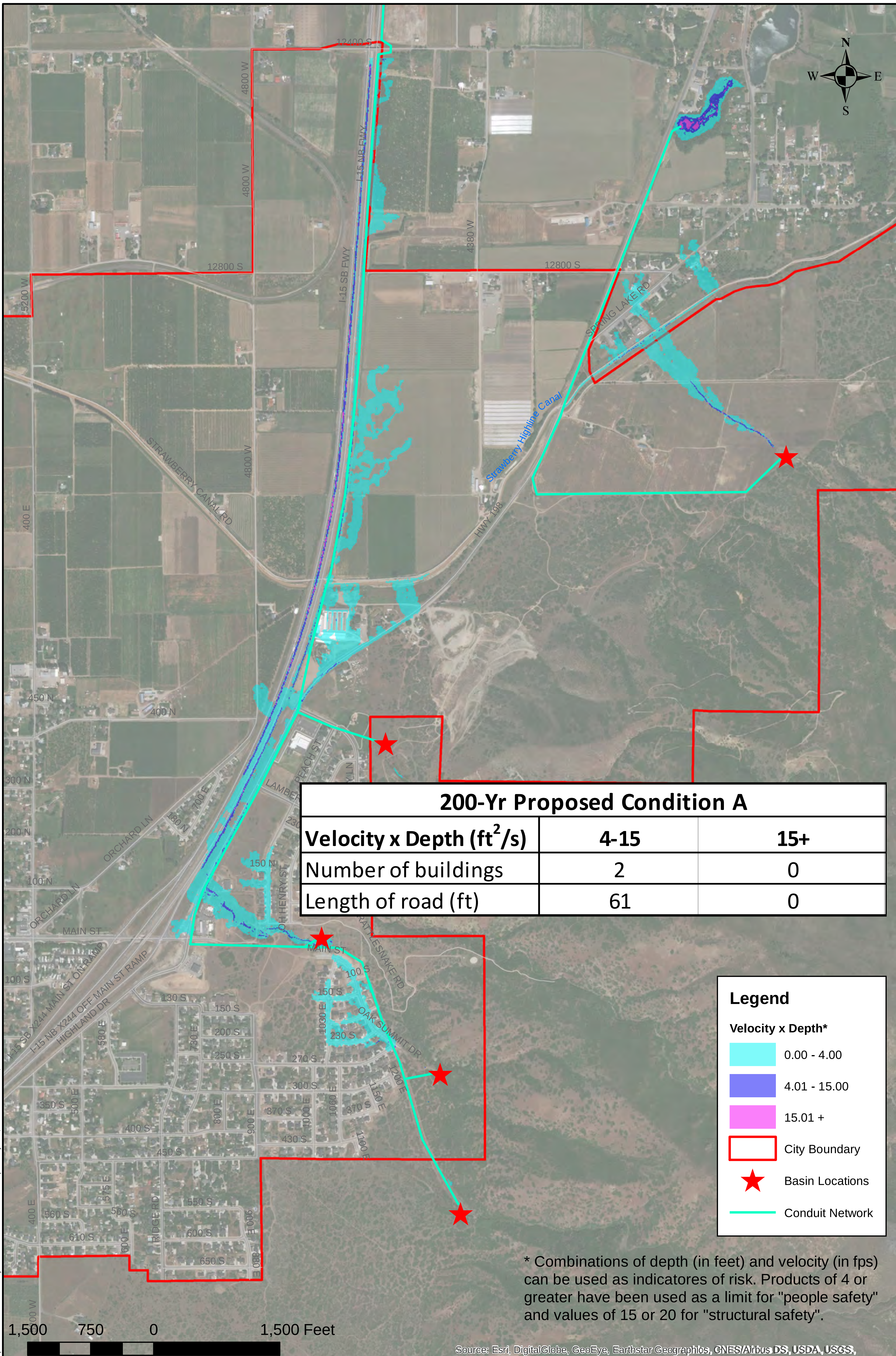

200-Yr Proposed Condition A		
Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	2	0
Length of road (ft)	61	0

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

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200-Yr Proposed Condition A

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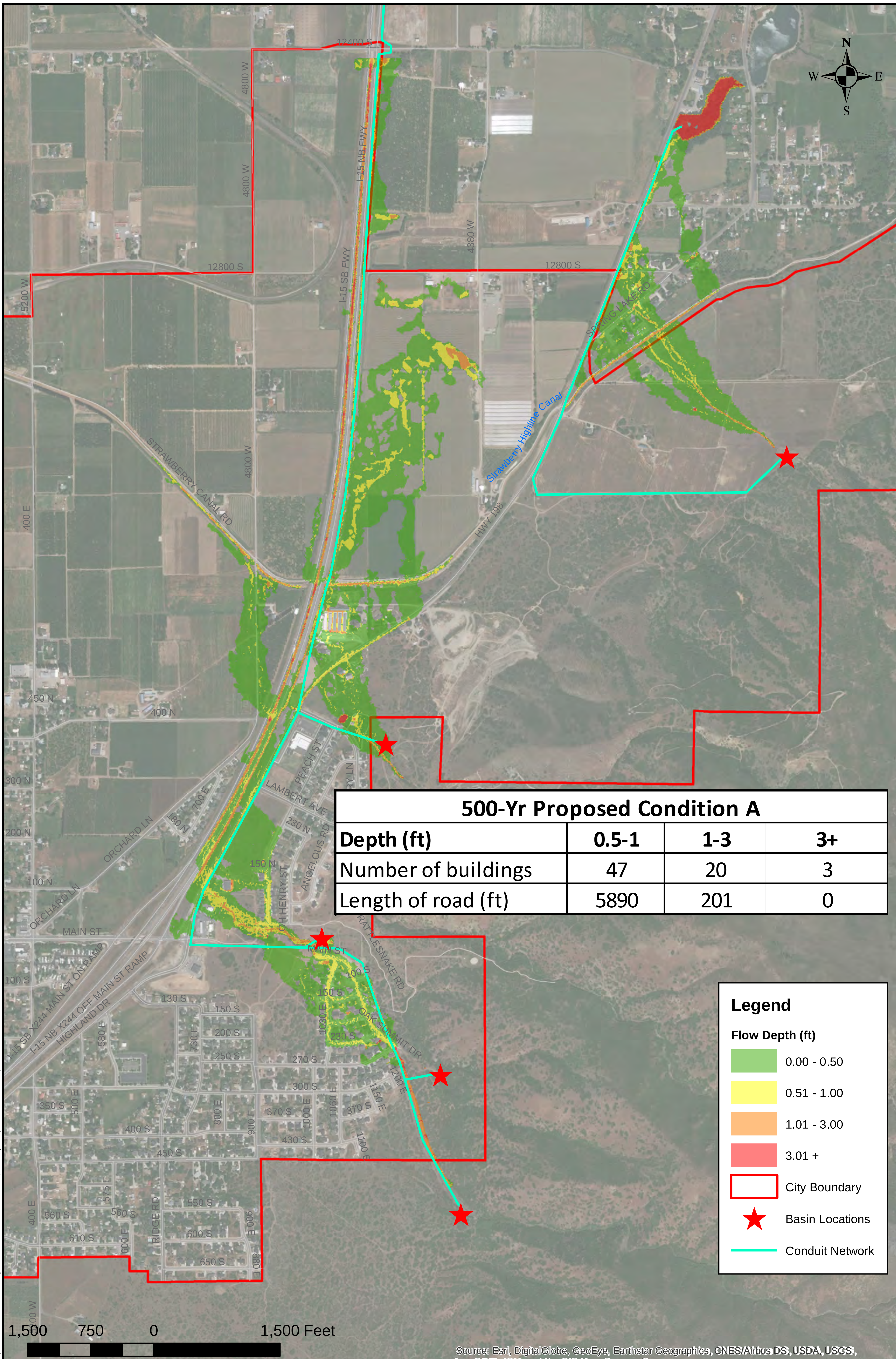

500-Yr Proposed Condition A

Depth (ft)	0.5-1	1-3	3+
Number of buildings	47	20	3
Length of road (ft)	5890	201	0

Santaquin

500-Yr Proposed Condition A

DATE 9/14/2018

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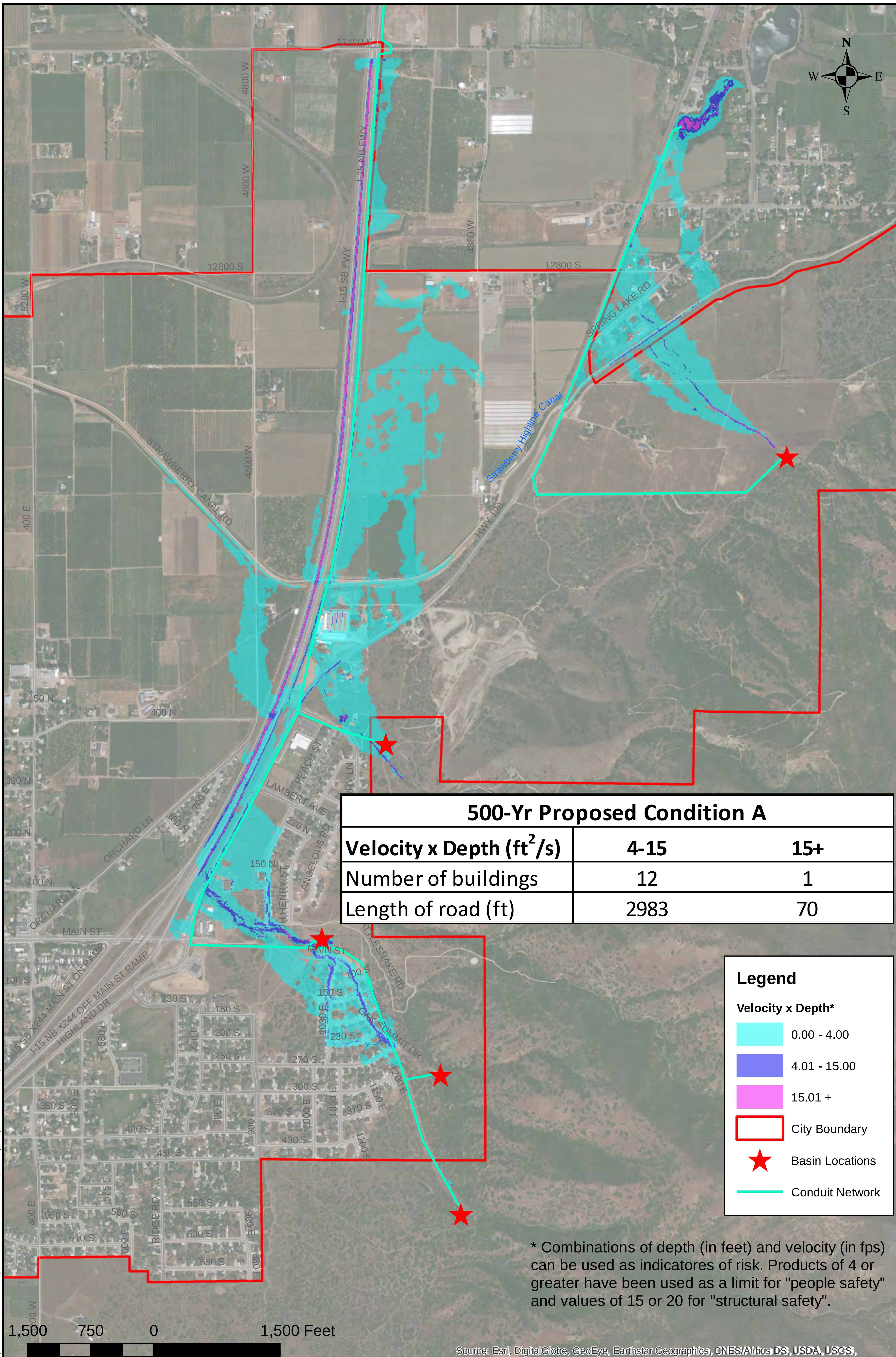

500-Yr Proposed Condition A

Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	12	1
Length of road (ft)	2983	70

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

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500-Yr Proposed Condition A

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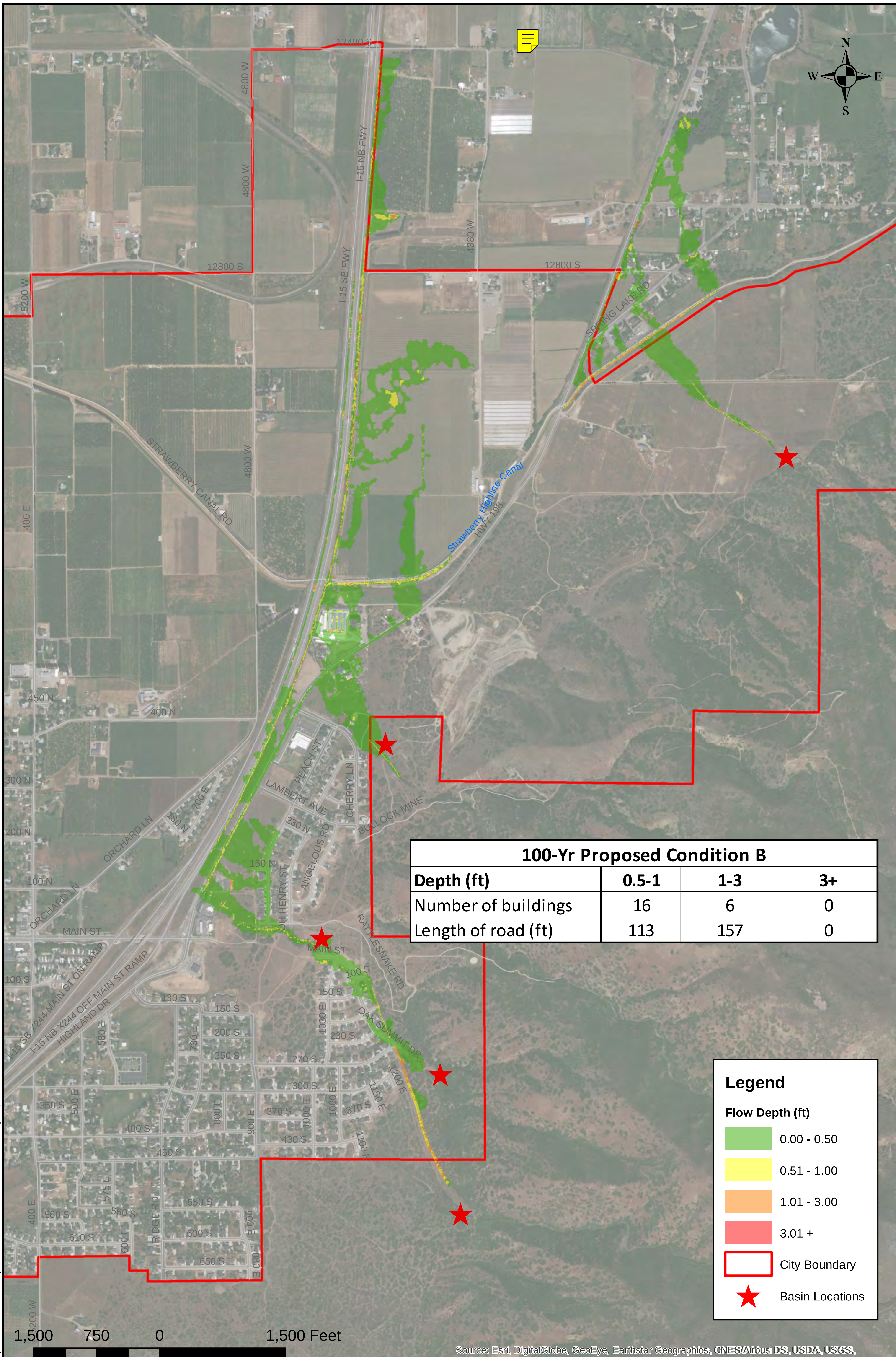

100-Yr Proposed Condition B

Depth (ft)	0.5-1	1-3	3+
Number of buildings	16	6	0
Length of road (ft)	113	157	0

100-Yr Proposed Condition B

DATE 8/29/2018

DRAWN

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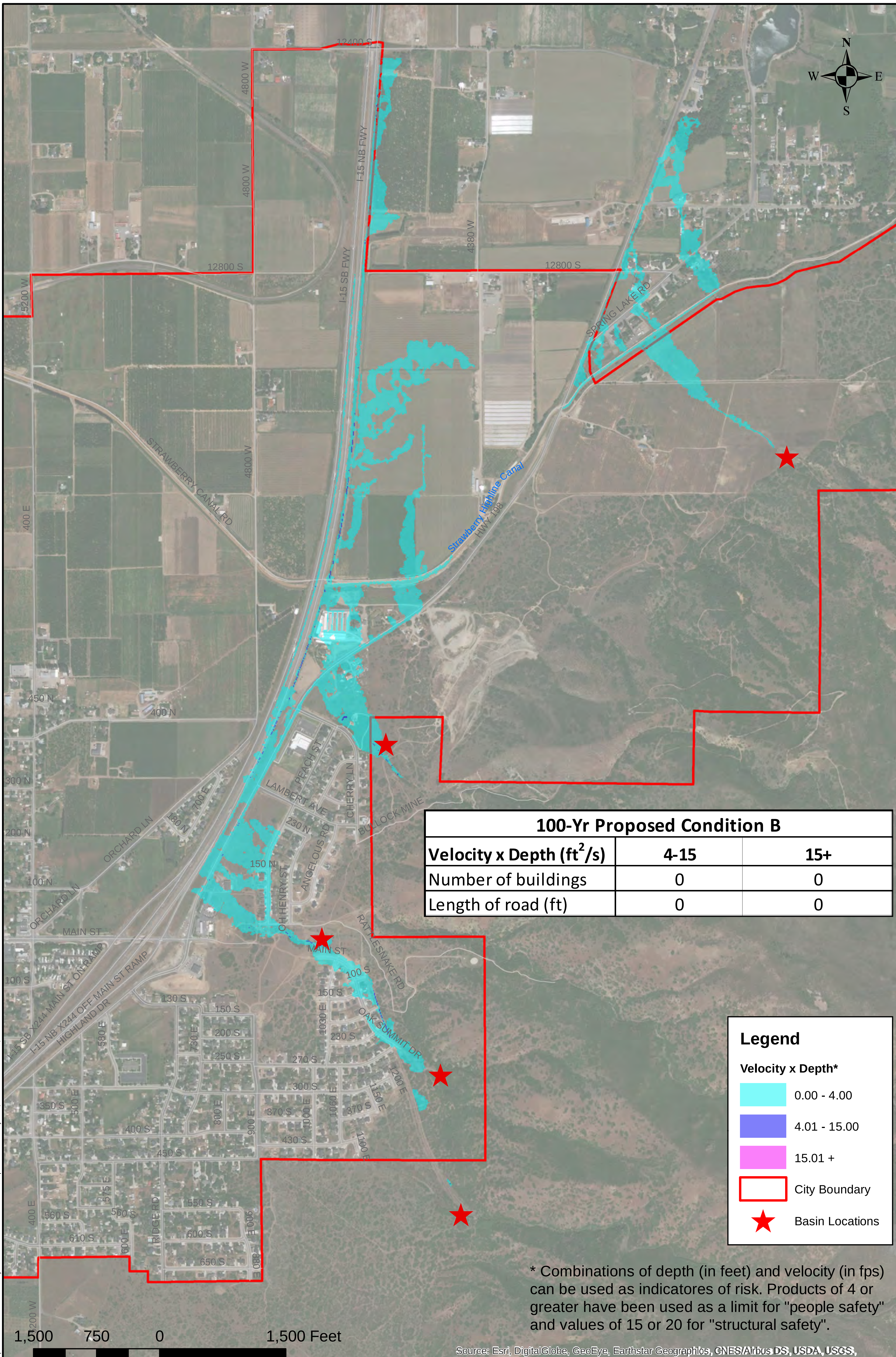

100-Yr Proposed Condition B		
Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	0	0
Length of road (ft)	0	0

Legend

Velocity x Depth*

- 0.00 - 4.00
- 4.01 - 15.00
- 15.01 +
- City Boundary
- Basin Locations

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

Santaquin

100-Yr Proposed Condition B

DATE 8/29/2018

DRAWN

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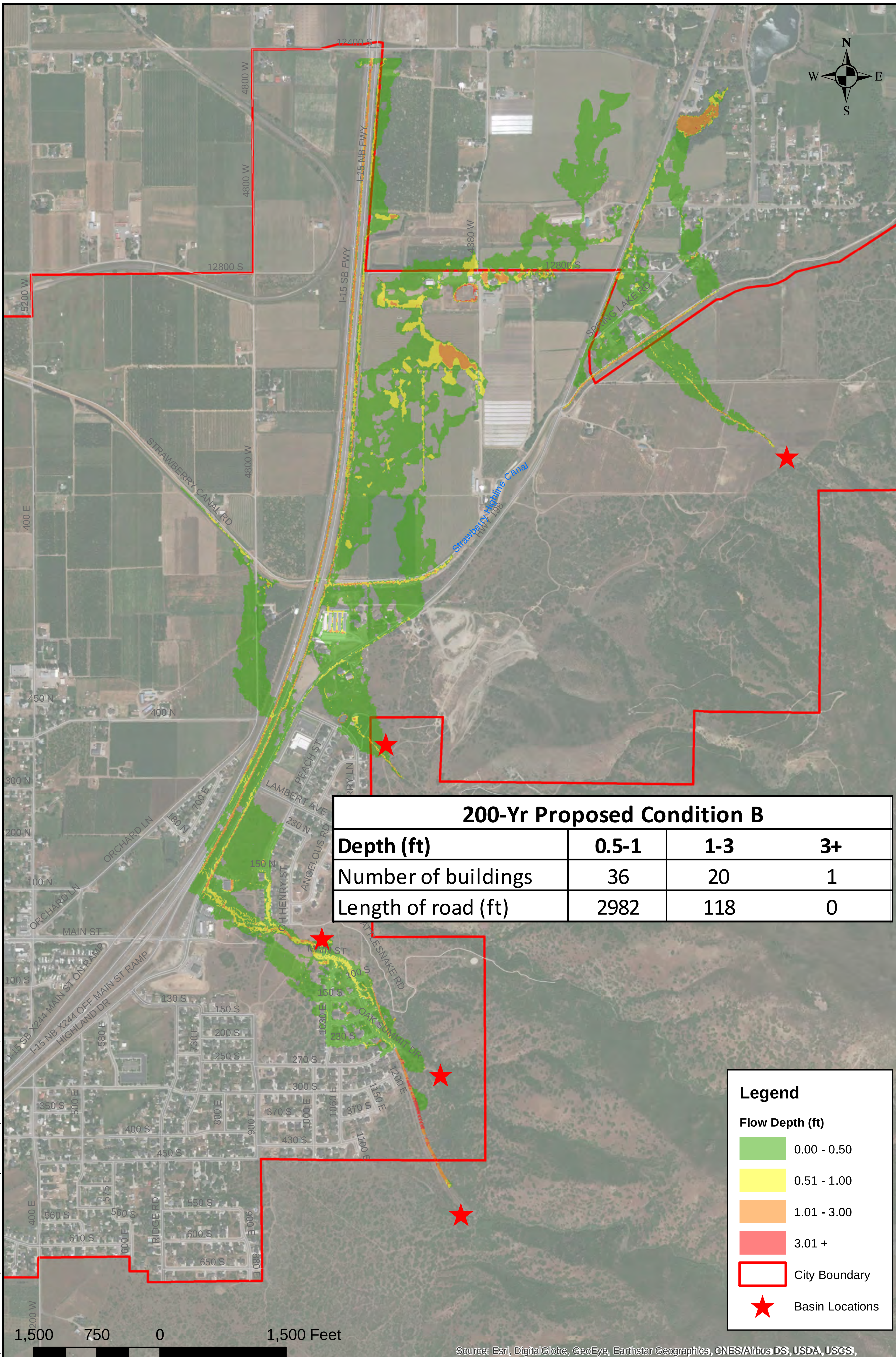

200-Yr Proposed Condition B

Depth (ft)	0.5-1	1-3	3+
Number of buildings	36	20	1
Length of road (ft)	2982	118	0

Santaquin

200-Yr Proposed Condition B

DATE 8/29/2018

DRAWN

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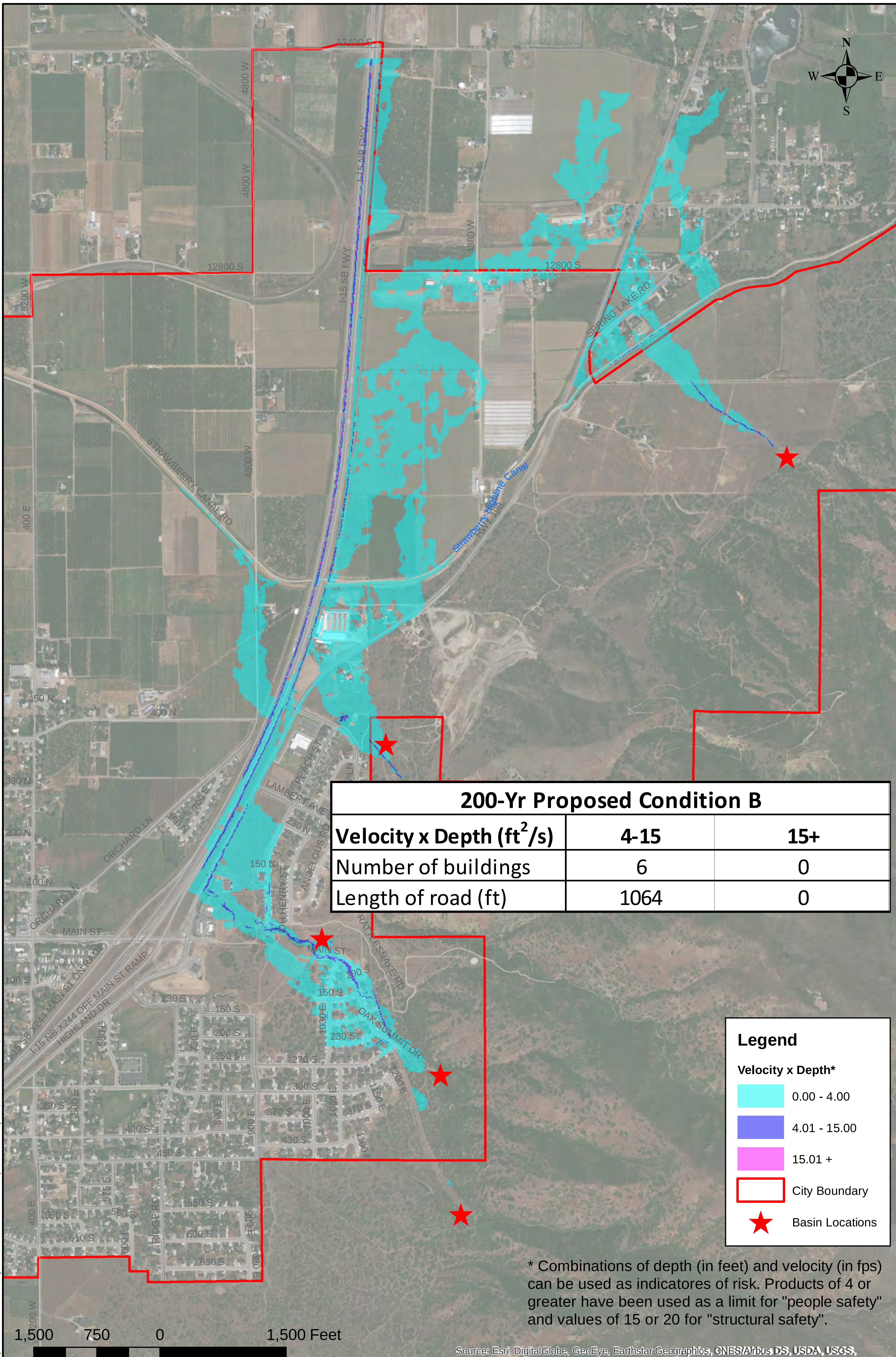


200-Yr Proposed Condition B		
Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	6	0
Length of road (ft)	1064	0

Legend

Velocity x Depth*

- 0.00 - 4.00
- 4.01 - 15.00
- 15.01 +
- City Boundary
- Basin Locations

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

1,500 750 0 1,500 Feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

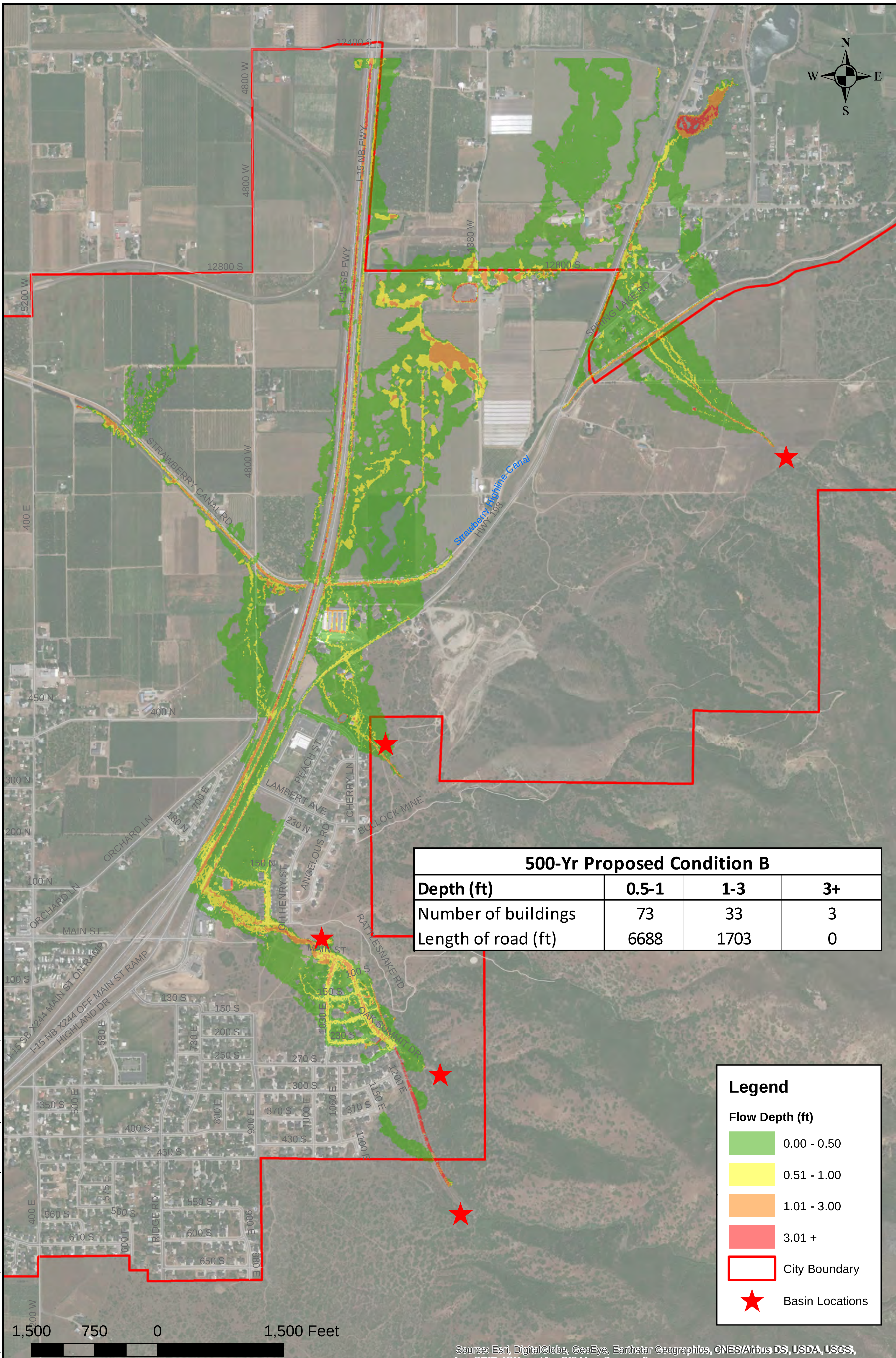
O:\2018\UT-1024-1801 Santaquin Debris Basin Plan EA\Project Data\GIS\Horrocks\Mxd\FLO-2D\post no outfall 200-yr.mxd, 8/29/2018 10:55:46 AM, abbk

Santaquin

200-Yr Proposed Condition B

DATE 8/29/2018

DRAWN



500-Yr Proposed Condition B			
Depth (ft)	0.5-1	1-3	3+
Number of buildings	73	33	3
Length of road (ft)	6688	1703	0

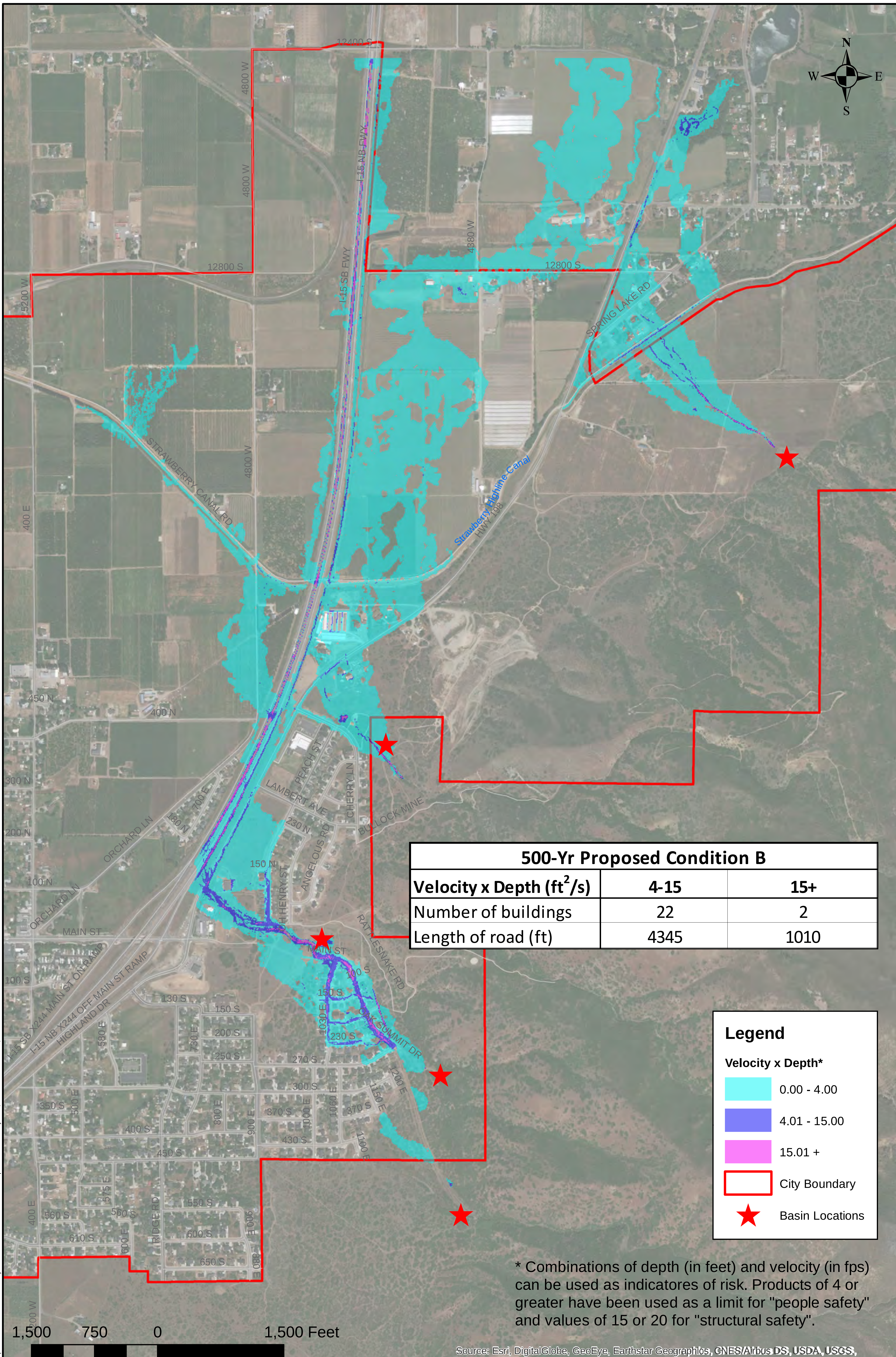
Santaquin

500-Yr Proposed Condition B

DATE 8/29/2018

DRAWN

O:\2018\UT-1024-1801 Santaquin Debris Basin Plan EA\Project Data\GIS\Horrocks\MxD\FLO-2D\post no outfall 500-yr.mxd, 8/29/2018 10:18:16 AM, abbk



500-Yr Proposed Condition B		
Velocity x Depth (ft^2/s)	4-15	15+
Number of buildings	22	2
Length of road (ft)	4345	1010

Legend

Velocity x Depth*

- 0.00 - 4.00
- 4.01 - 15.00
- 15.01 +
- City Boundary
- Basin Locations

* Combinations of depth (in feet) and velocity (in fps) can be used as indicatores of risk. Products of 4 or greater have been used as a limit for "people safety" and values of 15 or 20 for "structural safety".

1,500 750 0 1,500 Feet

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

O:\2018\UT-1024-1801 Santaquin Debris Basin Plan EA\Project Data\GIS\Horrocks\Mxd\FLO-2D\post no outfall 500-yr.mxd, 8/29/2018 10:17:11 AM, abbk

Santaquin

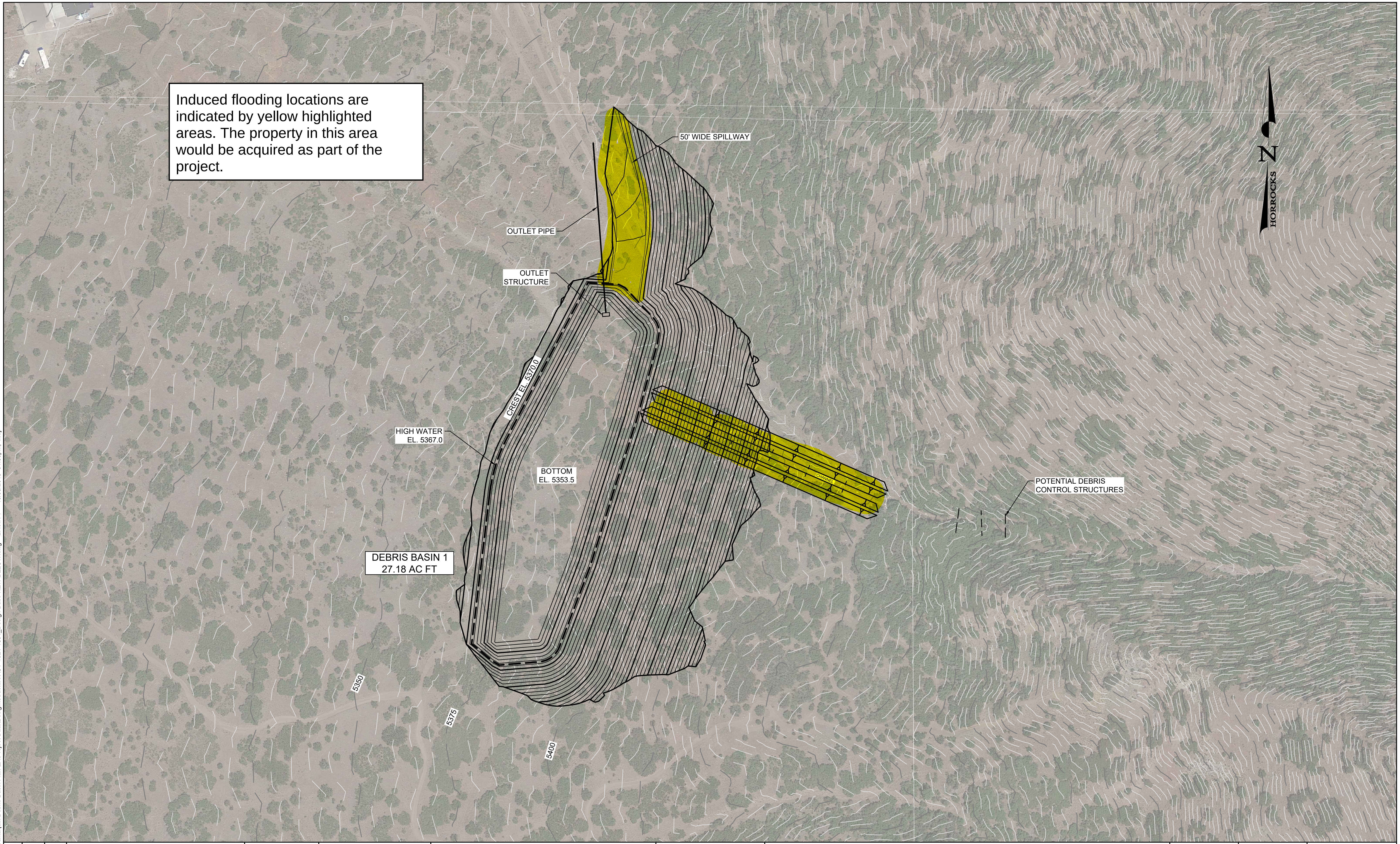
500-Yr Proposed Condition B

DATE 8/29/2018

DRAWN

2162 West Grove Parkway, Ste 400
Pleasant Grove, Utah 84062
801-763-5100
www.horrocks.com

Appendix E: Induced Flooding Maps



O:\2018\UT-1024-1801 Santaquin Debris Basin Plan EA\Project Data\DesignStructures\UT-1024-1801_Design Base NEW BELOW.dwg - BASIN 1 - 10/05/2018 01:36pm, lisaj

PRELIMINARY
NOT FOR CONSTRUCTION

REV | DATE | BY | DESCRIPTION

REVISIONS

SCALE	
HORIZONTAL	1" = 150'
VERTICAL	N/A

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

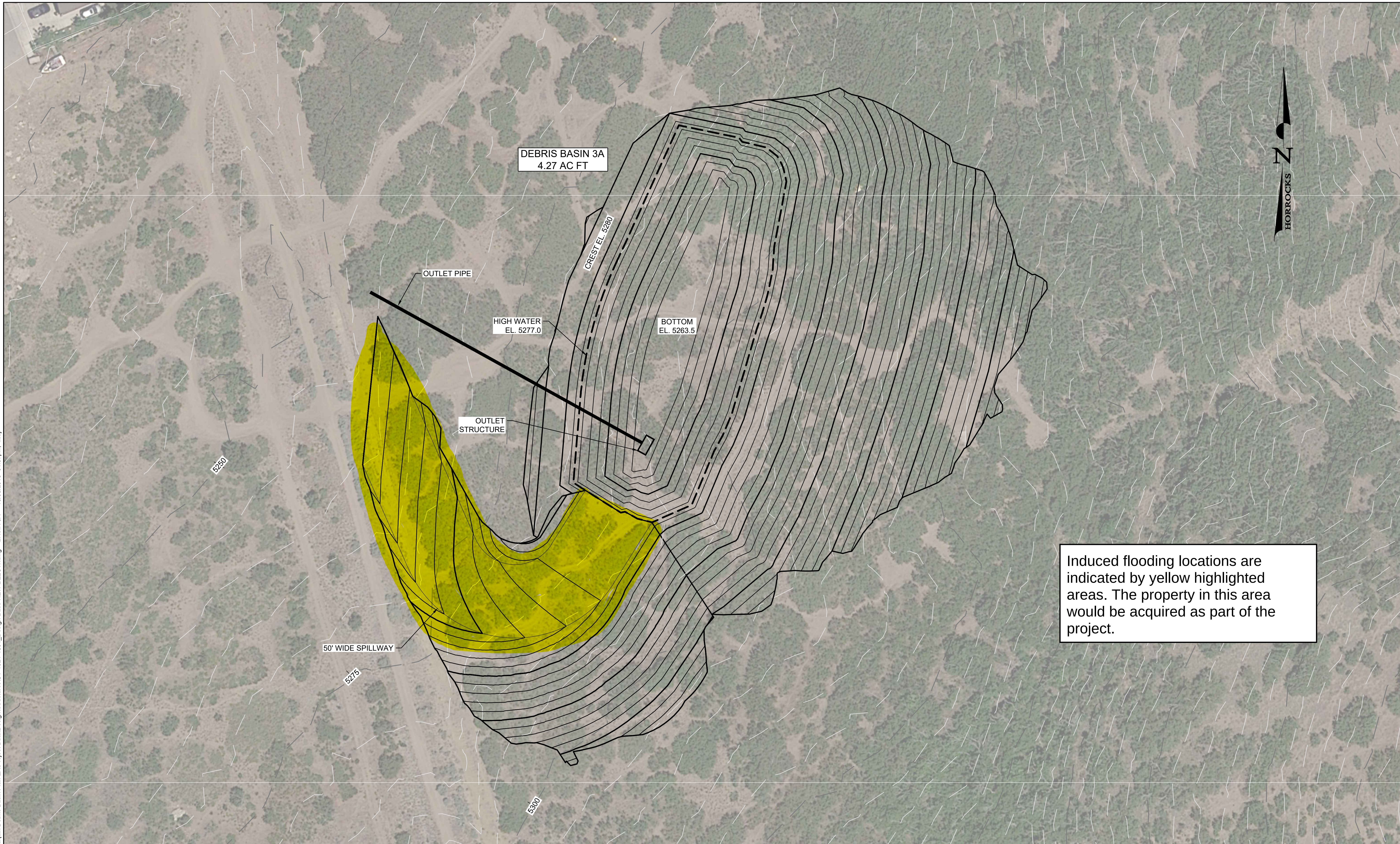
HORROCKS
ENGINEERS

2162 West Grove Parkway
Suite 400
Pleasant Grove, UT 84062
(801) 763-5100

SANTAQUIN DEBRIS BASINS

BASIN 1 - BELOW GRADE

DESIGNED	####	DATE	####	PROJECT NO.	PG-1024-1801
DRAWN	####	DATE	####	SHEET NO.	# OF #
CHECKED	####	DATE	####	DRAWING NO.	P-01



REV	DATE	BY	DESCRIPTION	
REVISIONS				

PRELIMINARY
NOT FOR CONSTRUCTION

SCALE
HORIZONTAL 1" = 60'
VERTICAL N/A

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

HORROCKS ENGINEERS

2162 West Grove Parkway
Suite 400
Pleasant Grove, UT 84062
(801) 763-5100

SANTAQUIN DEBRIS BASINS

BASIN 3A - BELOW GRADE (WATERSHEDS 2 & 3 COMBINED)

DESIGNED	DATE	PROJECT NO.
####	####	PG-1024-1801
DRAWN	DATE	SHEET NO.
####	####	# OF #
CHECKED	DATE	DRAWING NO.
####	####	P-05

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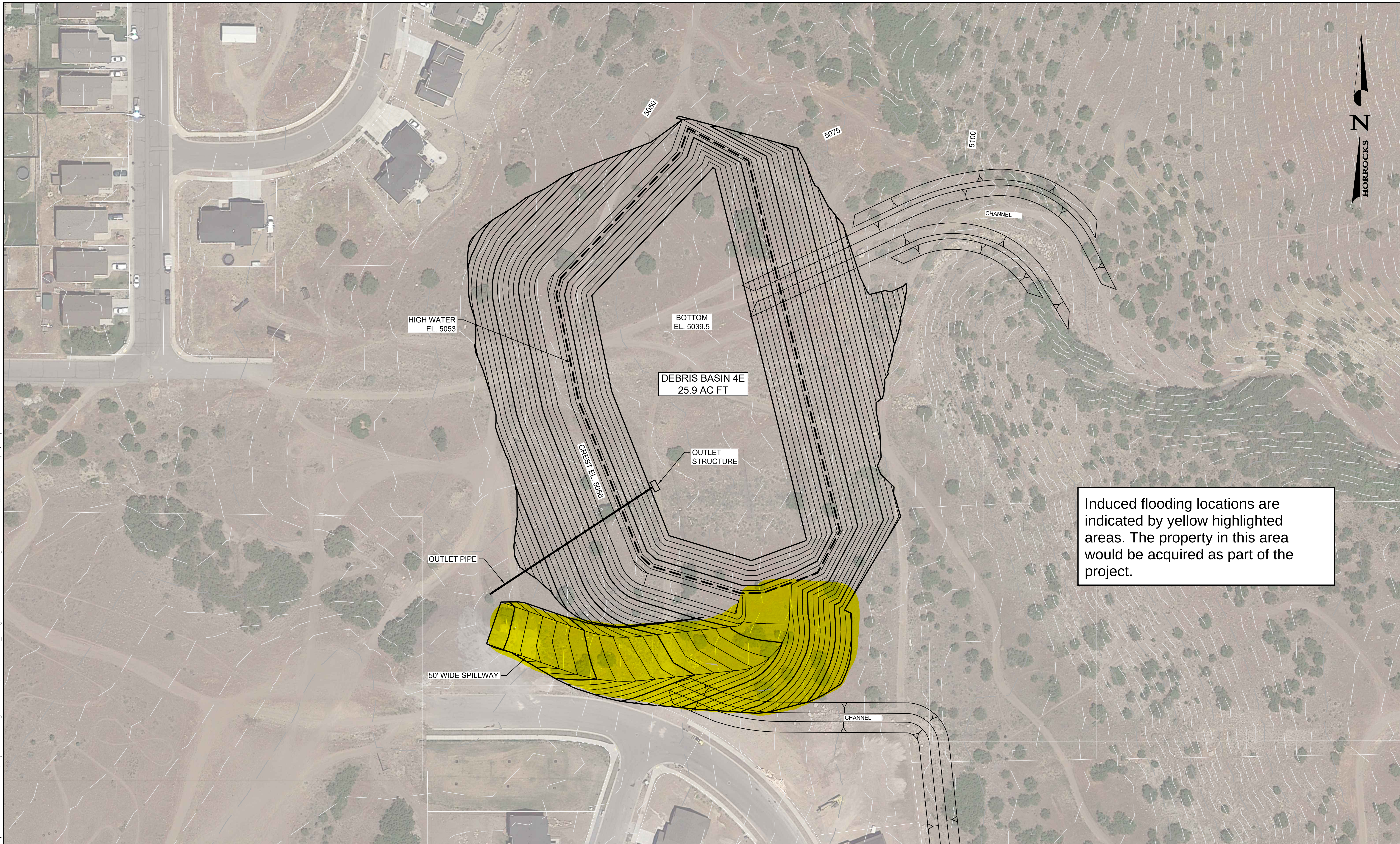


O:\2018\UT-1024-1801 Santaquin Debris Basin Plan EA\Project Data\Design\Structures\UT-1024-1801_Design Base NEW ABOVE.dwg - BASIN 4E - 10/05/2018 01:33pm, lisaj

PRELIMINARY
NOT FOR CONSTRUCTION

REV | DATE | BY | DESCRIPTION
REVISIONS

SCALE
HORIZONTAL 1" = 100'
VERTICAL N/A

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

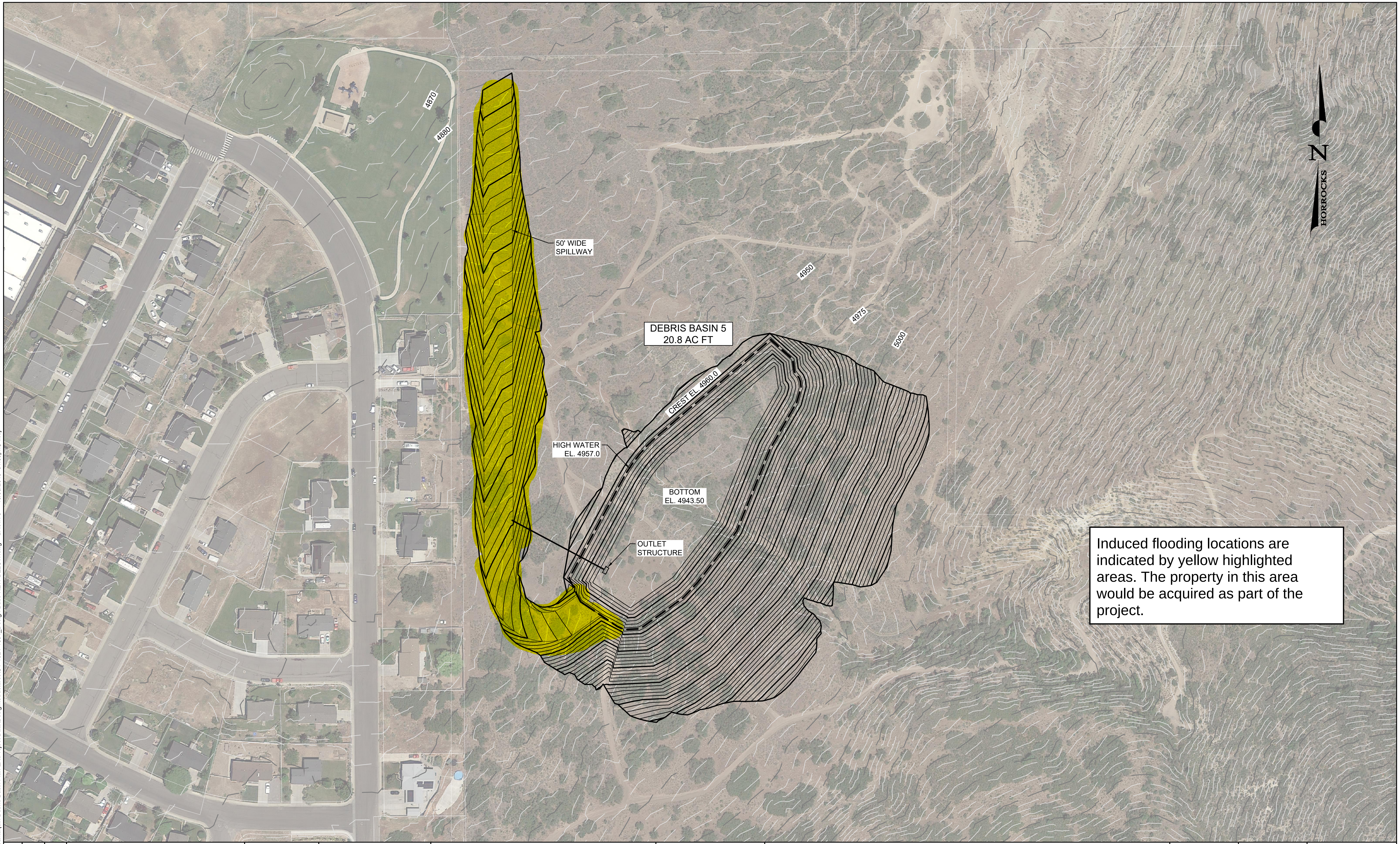
HORROCKS ENGINEERS

2162 West Grove Parkway
Suite 400
Pleasant Grove, UT 84062
(801) 763-5100

SANTAQUIN DEBRIS BASINS

BASIN 4E - ABOVE GRADE (WATERSHED ONLY)

DESIGNED ####	DATE ####	PROJECT NO. PG-1024-1801
DRAWN ####	DATE ####	SHEET NO. 5 OF 12
CHECKED ####	DATE ####	DRAWING NO. P-05



PRELIMINARY
NOT FOR CONSTRUCTION

REV | DATE | BY | DESCRIPTION
REVISIONS

SCALE
HORIZONTAL 1" = 150'
VERTICAL N/A

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

HORROCKS ENGINEERS

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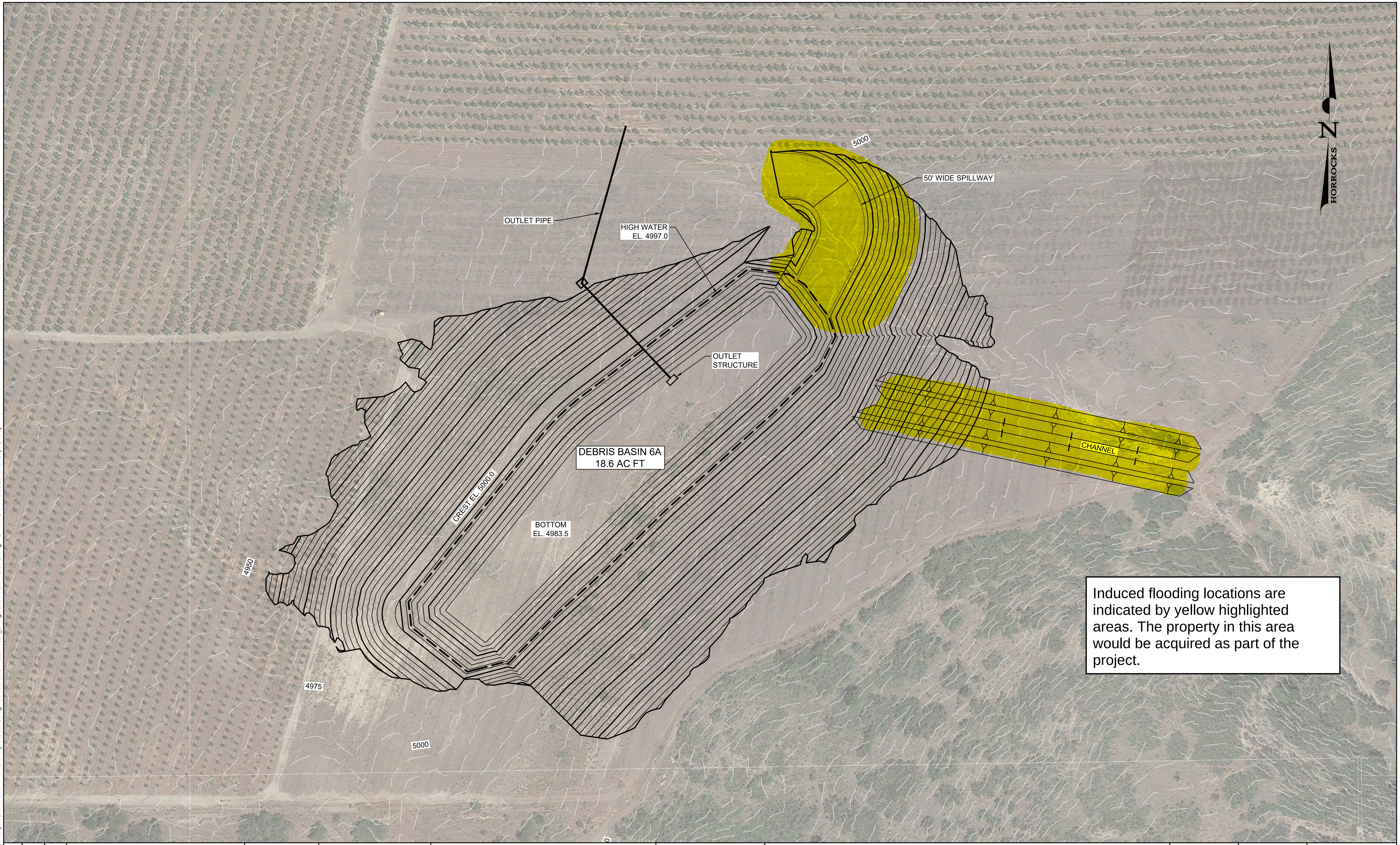
Suite 400
Pleasant Grove, UT 84062
(801) 763-5100

SANTAQUIN DEBRIS BASINS

BASIN 5 - BELOW GRADE

DESIGNED	DATE	PROJECT NO.
####	####	PG-1024-1801
DRAWN	DATE	SHEET NO.
####	####	# OF #
CHECKED	DATE	DRAWING NO.
####	####	P-12

O:\2018\UT-1024-1801 Santaquin Debris Basin Plan EA\Project Data\Design\Structures\UT-1024-1801_Design Base NEW BELOW.dwg - BASIN 5 - 10/05/2018 01:39pm, lisaj



O:\2018\UT-1024-1801 Santaquin Debris Basin Plan EA\Project Data\Design\Structures\UT-1024-1801_Design Base NEW ABOVE.dwg - BASIN 6A - 10/05/2018 01:34pm. lisaj

PRELIMINARY
NOT FOR CONSTRUCTION

REV	DATE	BY	DESCRIPTION

REVISIONS

SCALE
HORIZONTAL 1" = 100'
VERTICAL N/A

WARNING
0 1/2 1
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

HORROCKS ENGINEERS

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Suite 400
Pleasant Grove, UT 84062
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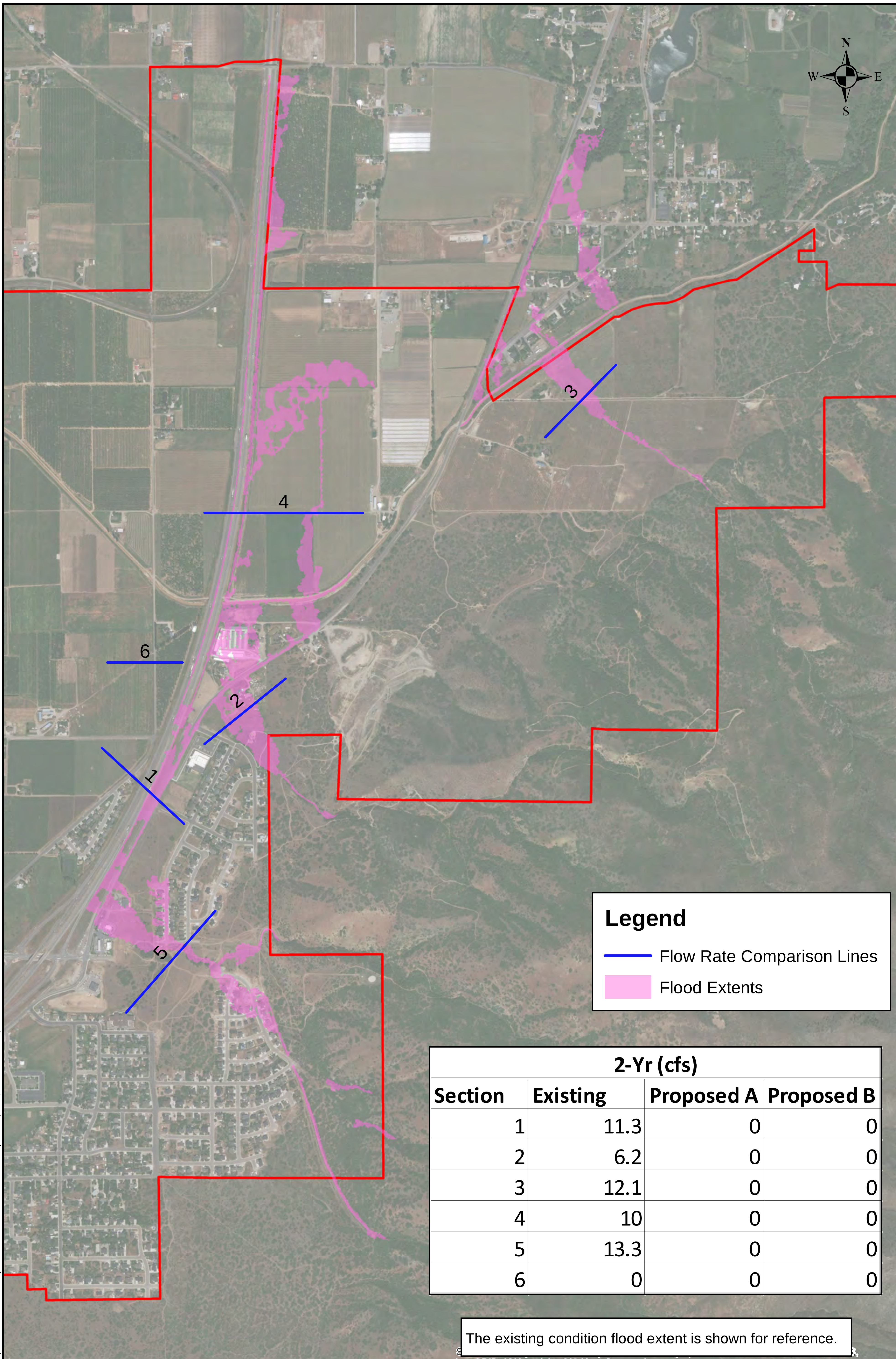
SANTAQUIN DEBRIS BASINS

BASIN 6A - ABOVE GRADE

DESIGNED	DATE	PROJECT NO.
####	####	PG-1024-1801
DRAWN	DATE	SHEET NO.
####	####	# OF #
CHECKED	DATE	DRAWING NO.
####	####	P-07

2162 West Grove Parkway, Ste 400
Pleasant Grove, Utah 84062
801-763-5100
www.horrocks.com

Appendix F: Flow Comparison Maps



2-Yr (cfs)			
Section	Existing	Proposed A	Proposed B
1	11.3	0	0
2	6.2	0	0
3	12.1	0	0
4	10	0	0
5	13.3	0	0
6	0	0	0

The existing condition flood extent is shown for reference.

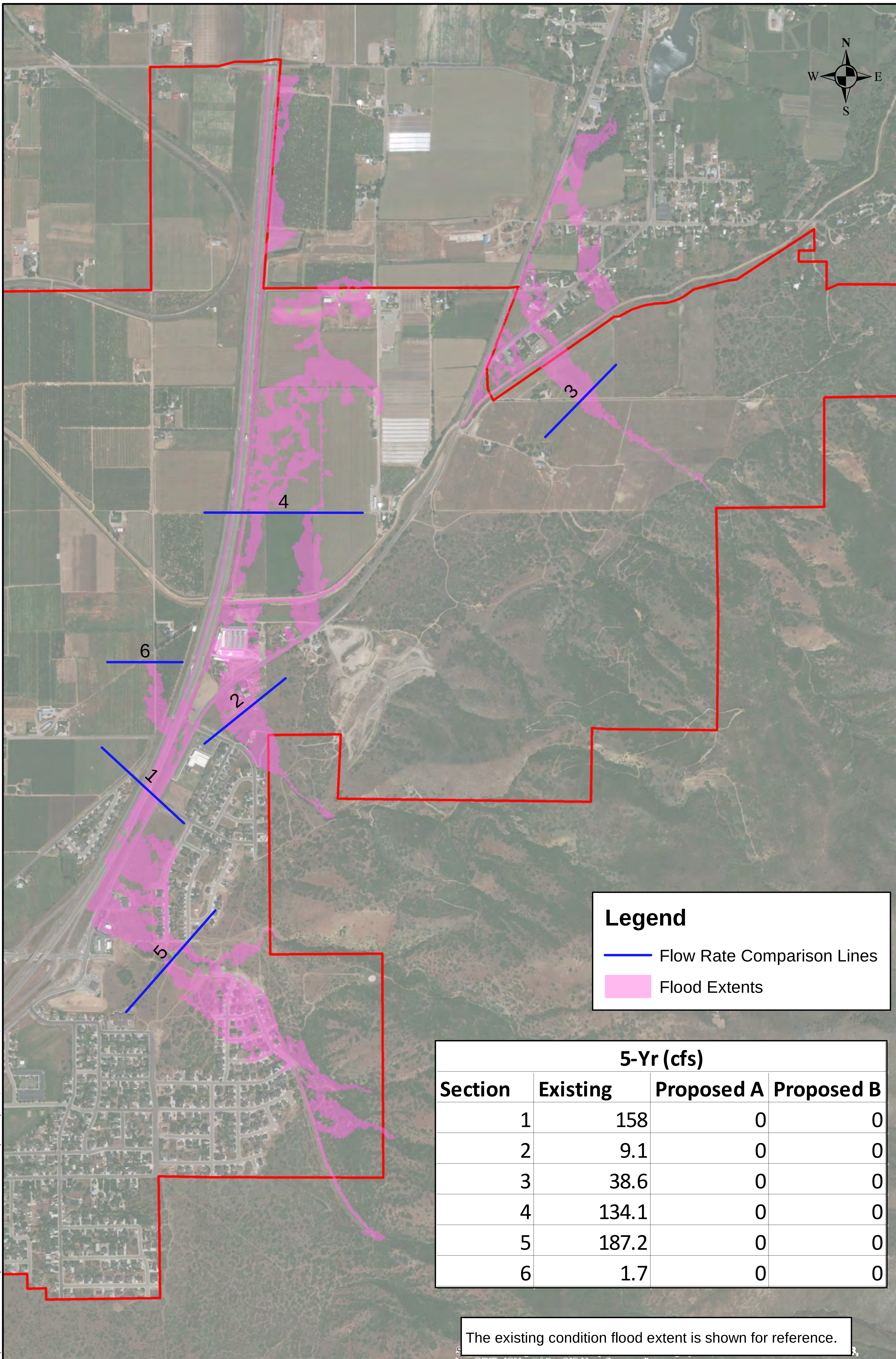
Santaquin

2-Yr Flow Rate Comparison

DATE 9/13/2018

DRAWN

O:\2018\UT-1024-1801 Santaquin Debris Basin Plan EA\Project Data\GIS\Horrocks\Mxd\FLO-2D\Flow Comparison Map 2.mxd, 9/13/2018 7:25:54 PM, JacobO



5-Yr (cfs)			
Section	Existing	Proposed A	Proposed B
1	158	0	0
2	9.1	0	0
3	38.6	0	0
4	134.1	0	0
5	187.2	0	0
6	1.7	0	0

The existing condition flood extent is shown for reference.

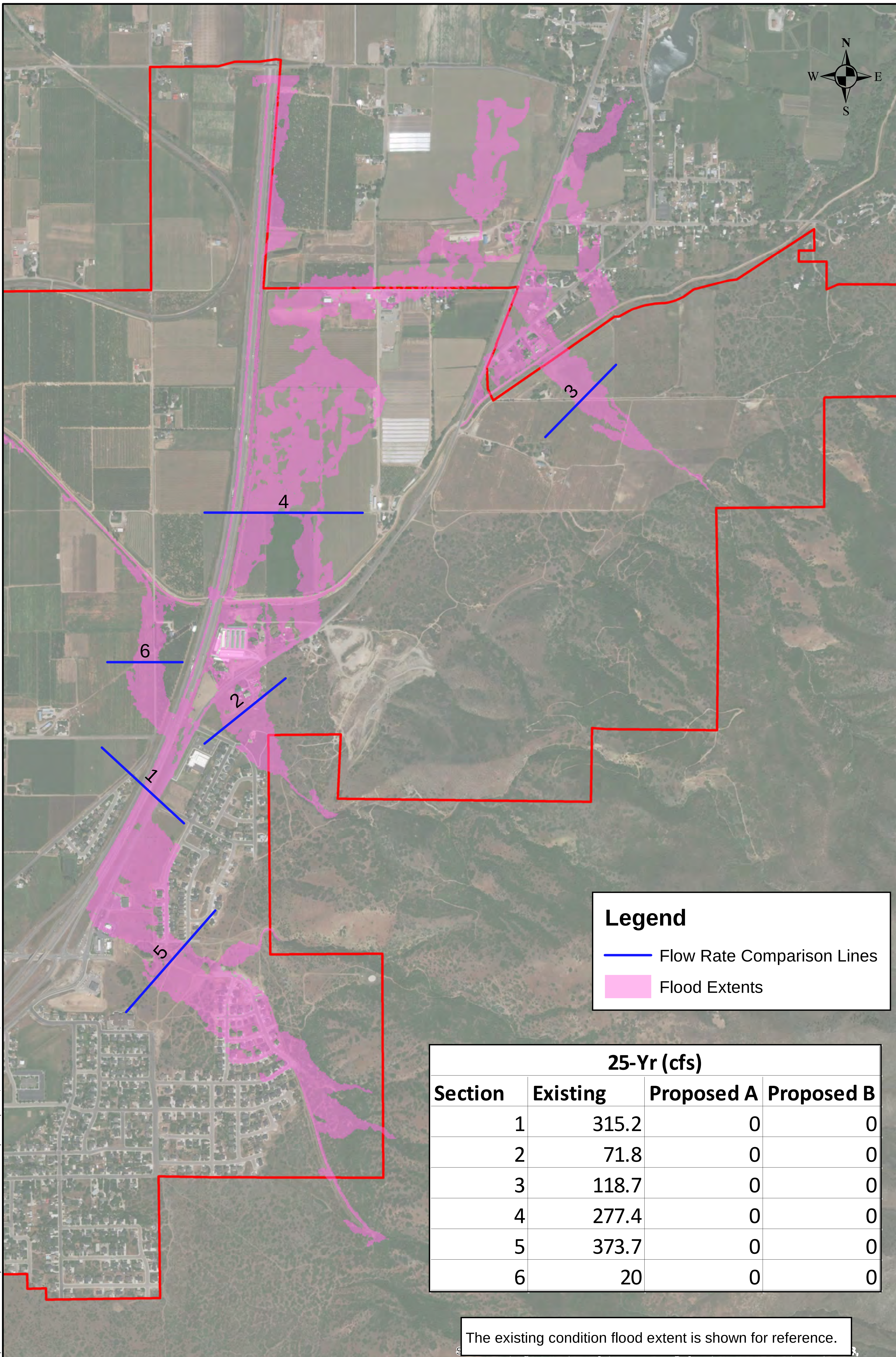
Santaquin

5-Yr Flow Rate Comparison

DATE 9/13/2018

DRAWN

O:\2018\UT-1024-1801 Santaquin Debris Basin Plan EA\Project Data\GIS\Horrocks\Mxd\FLO-2D\Flow Comparison Map 5.mxd, 9/13/2018 7:27:56 PM, JacobO



25-Yr (cfs)			
Section	Existing	Proposed A	Proposed B
1	315.2	0	0
2	71.8	0	0
3	118.7	0	0
4	277.4	0	0
5	373.7	0	0
6	20	0	0

The existing condition flood extent is shown for reference.

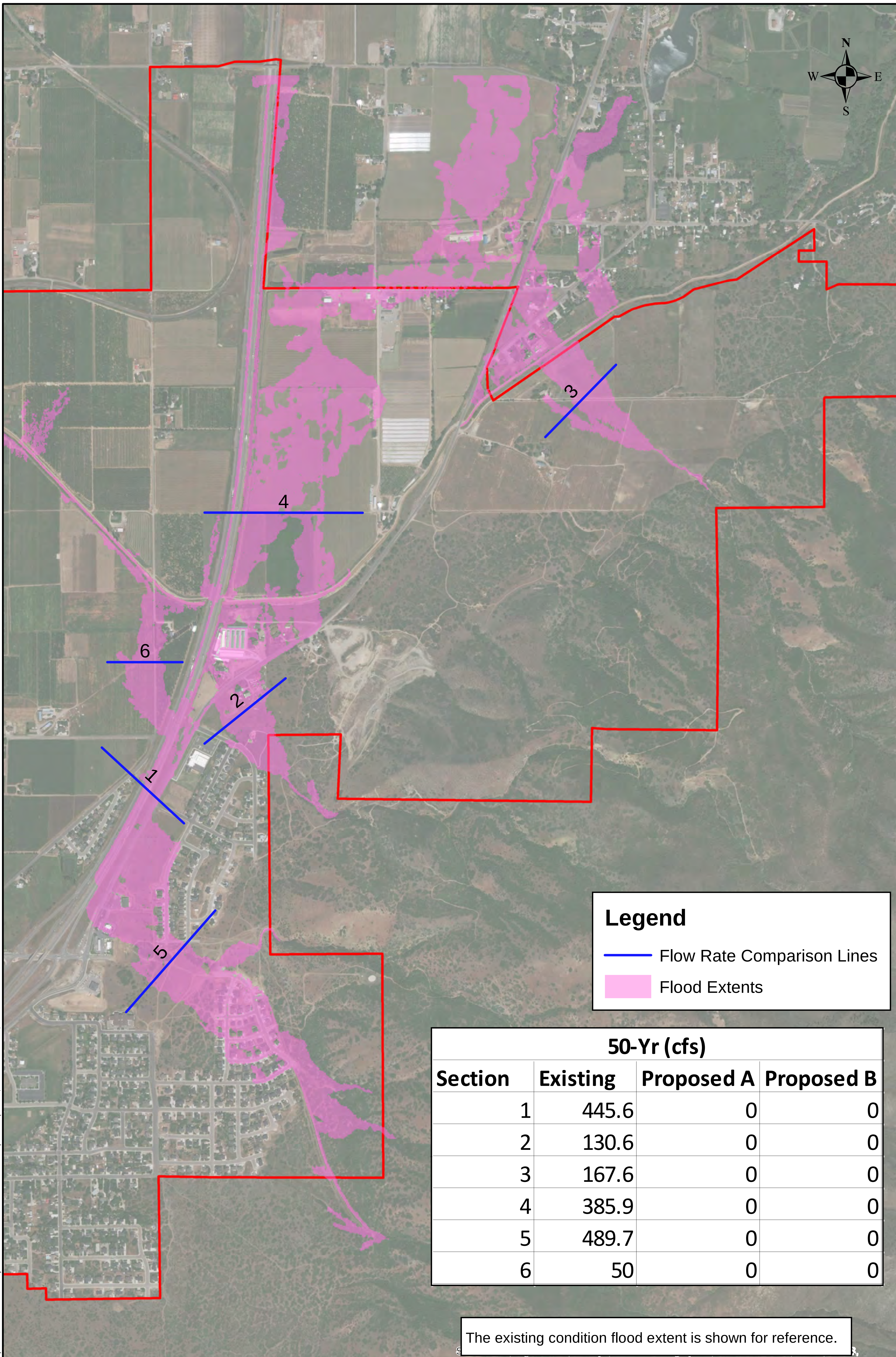
Santaquin

25-Yr Flow Rate Comparison

DATE 9/13/2018

DRAWN

O:\2018\UT-1024-1801 Santaquin Debris Basin Plan EA\Project Data\GIS\Horrocks\Mxd\FLO-2D\Flow Comparison Map 25.mxd, 9/13/2018 7:30:36 PM, JacobO



50-Yr (cfs)			
Section	Existing	Proposed A	Proposed B
1	445.6	0	0
2	130.6	0	0
3	167.6	0	0
4	385.9	0	0
5	489.7	0	0
6	50	0	0

Santaquin

50-Yr Flow Rate Comparison

DATE 9/13/2018

DRAWN

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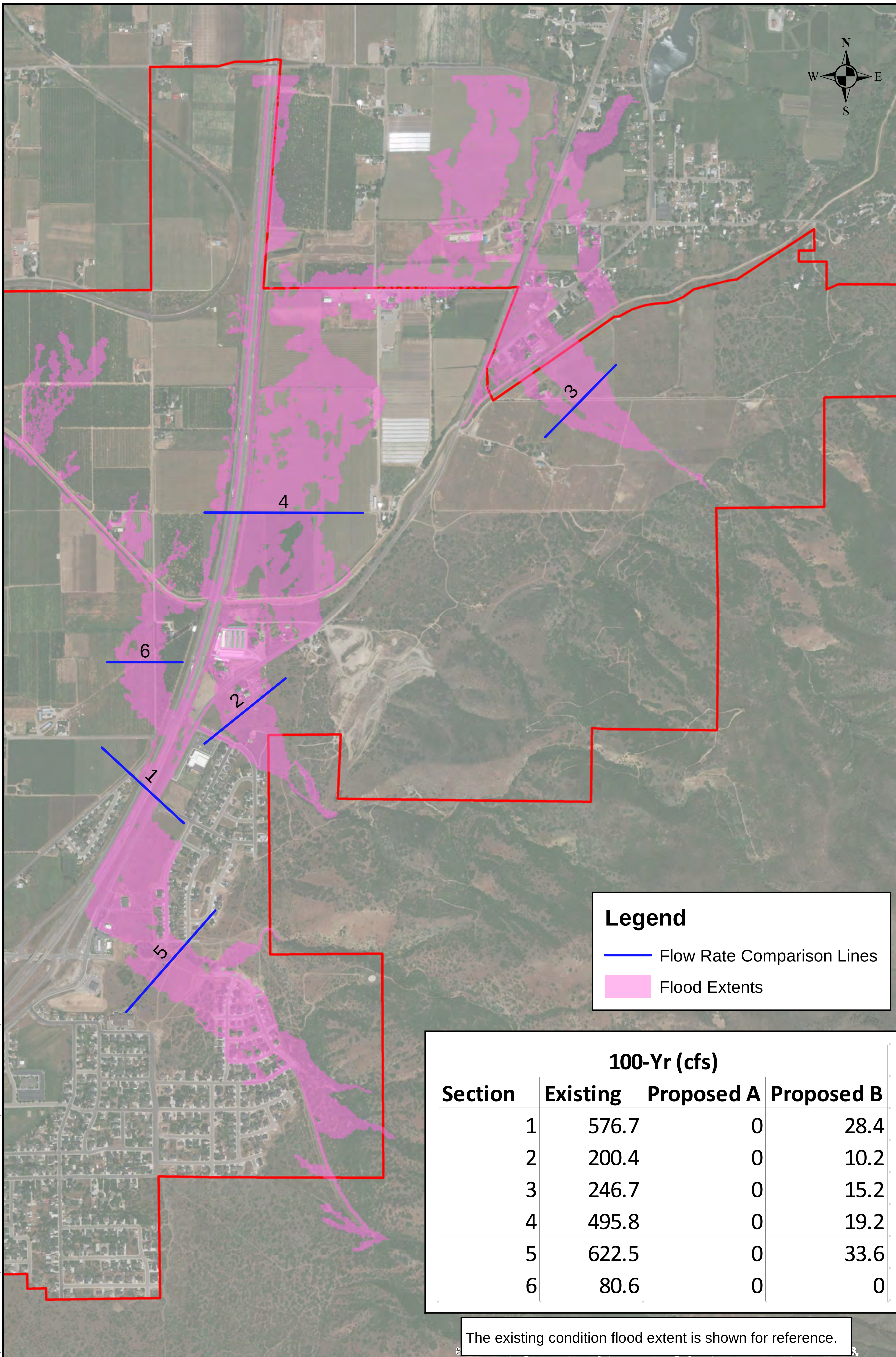

100-Yr (cfs)			
Section	Existing	Proposed A	Proposed B
1	576.7	0	28.4
2	200.4	0	10.2
3	246.7	0	15.2
4	495.8	0	19.2
5	622.5	0	33.6
6	80.6	0	0

Santaquin

100-Yr Flow Rate Comparison

DATE 9/13/2018

DRAWN

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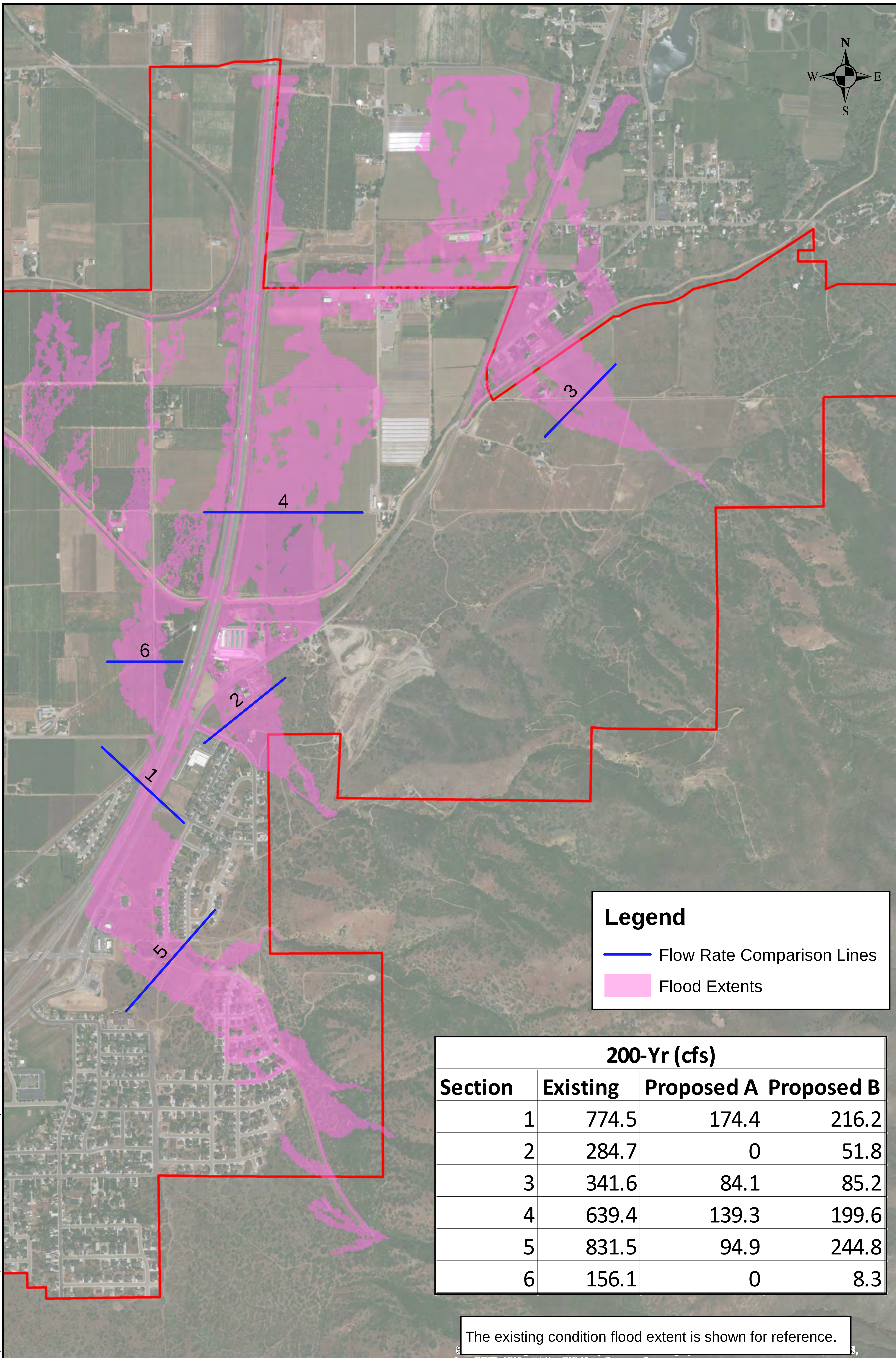

200-Yr (cfs)			
Section	Existing	Proposed A	Proposed B
1	774.5	174.4	216.2
2	284.7	0	51.8
3	341.6	84.1	85.2
4	639.4	139.3	199.6
5	831.5	94.9	244.8
6	156.1	0	8.3

The existing condition flood extent is shown for reference.

Santaquin

200-Yr Flow Rate Comparison

DATE 9/13/2018

DRAWN

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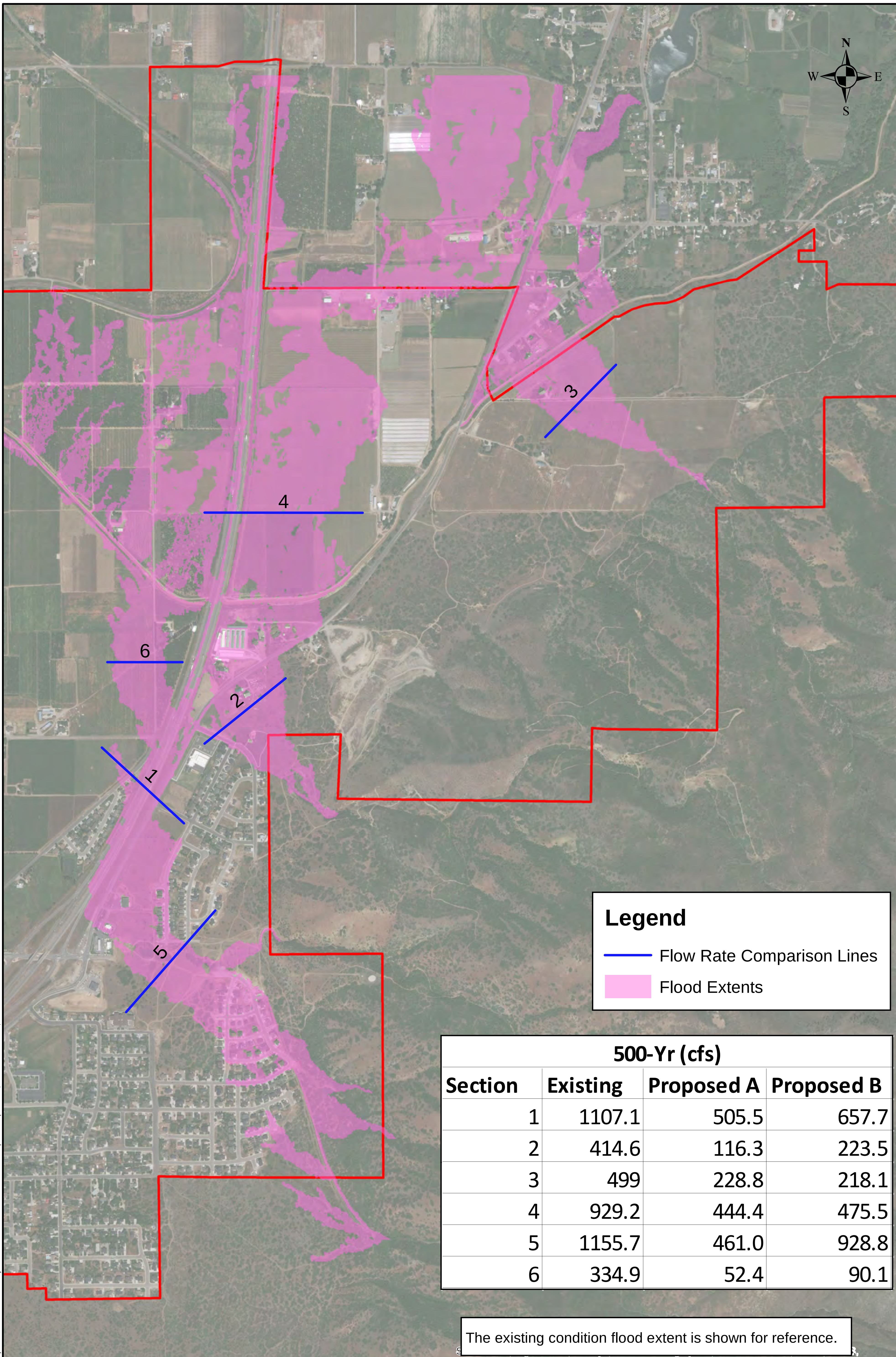

500-Yr (cfs)			
Section	Existing	Proposed A	Proposed B
1	1107.1	505.5	657.7
2	414.6	116.3	223.5
3	499	228.8	218.1
4	929.2	444.4	475.5
5	1155.7	461.0	928.8
6	334.9	52.4	90.1

The existing condition flood extent is shown for reference.

Santaquin

500-Yr Flow Rate Comparison

DATE 9/13/2018

DRAWN

2162 West Grove Parkway, Ste 400
Pleasant Grove, Utah 84062
801-763-5100
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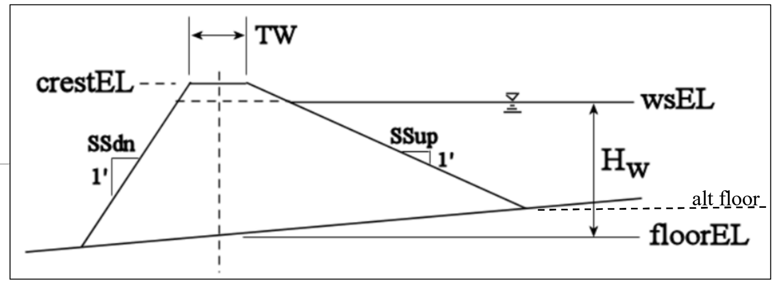
Appendix G: Dam Breach Hydrographs, Dam Breach Maps

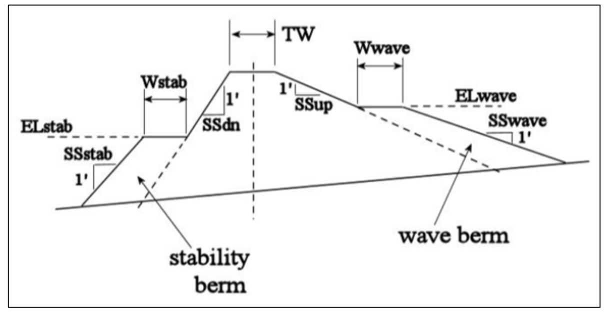
Dambreach Hydrographs via TRs 60 & 66 NRCS guidance

version 3, July 2018

Input data required:

data	variable	explanation
5057	crestEL	dam crest elevation
5054	wsEL	w.s. elev at time of breach
15	TW	dam top width (feet)
3	SSup	dam side slope (upstream, SSup:1)
3	SSdn	dam side slope (downstream, SSdn:1)
5040	floorEL	valley floor elev (see note)
25.9	Vs	resv vol at time of breach (acre-feet)
370	L	valley width at dam axis & w.s. elev (feet)
	ELwave	top of wave berm elevation
8	Wwave	width of top of wave berm feet
3	SSwave	wave berm side slope (SSwave:1)
	ELstab	top of stability berm elevation
5	Wstab	width of top of stability berm (feet)
2.5	SSstab	stability berm side slope (SSstab:1)
2	ts	timestep (minutes) for breach hydrograph





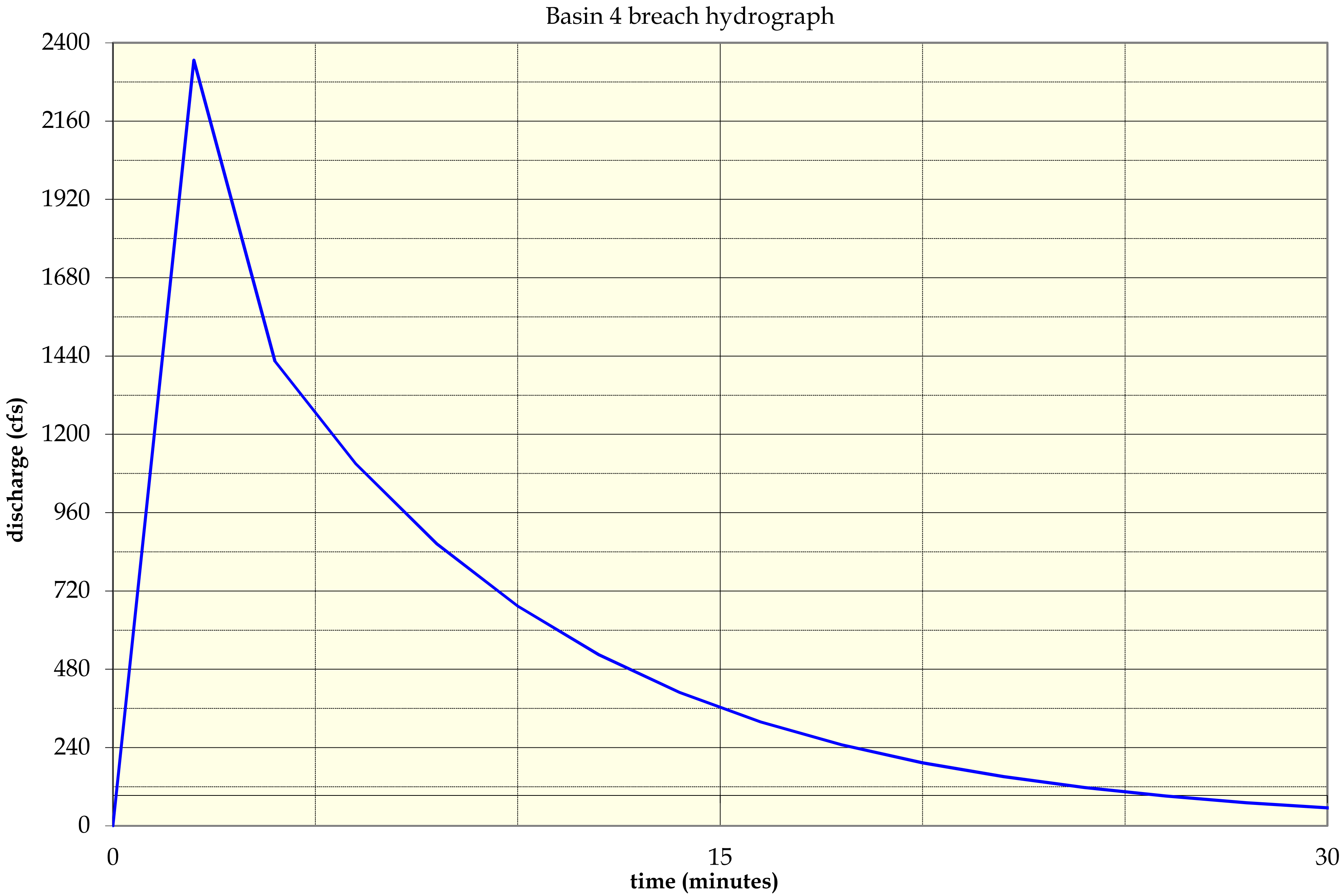
auto-scale

output

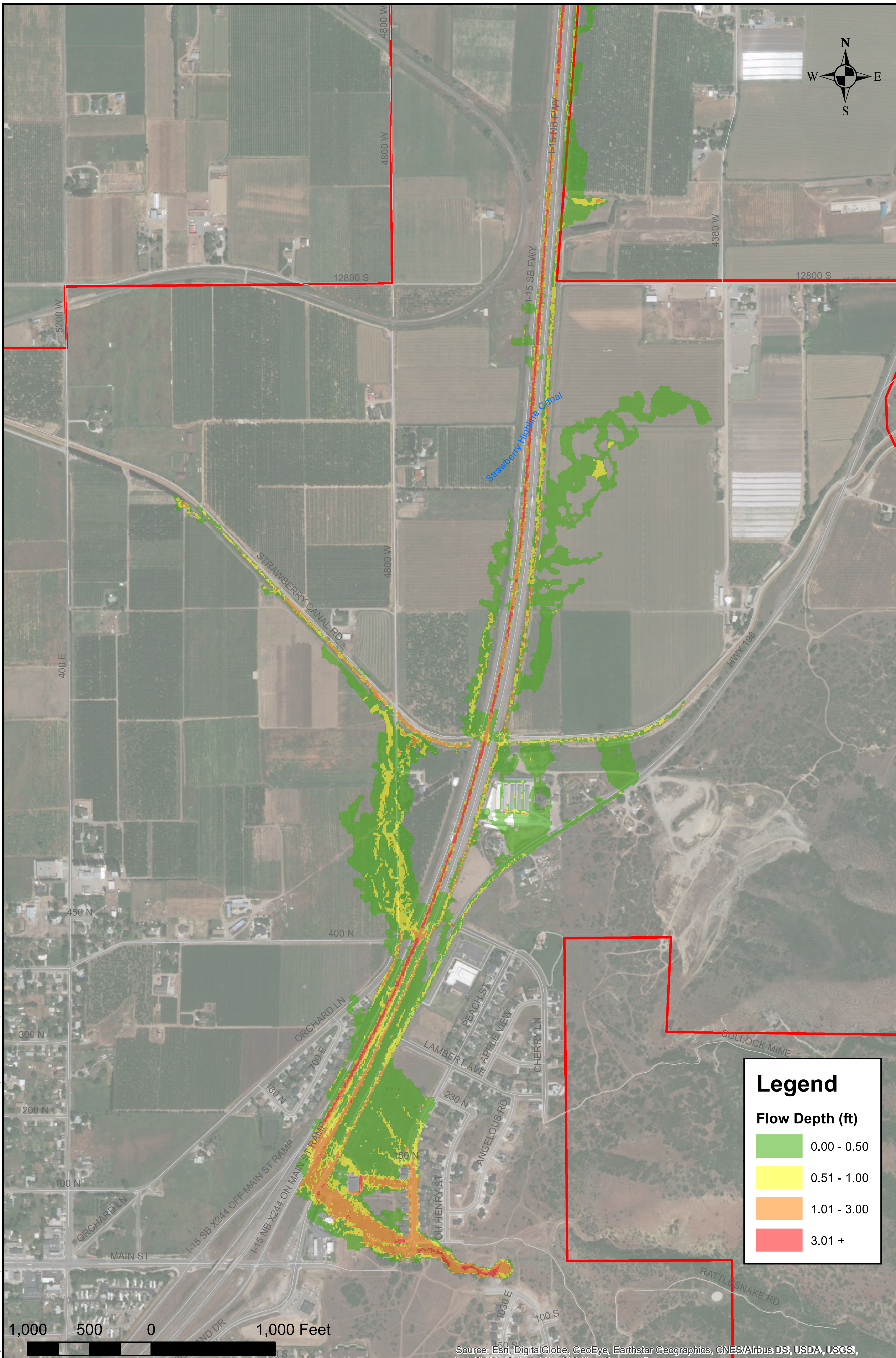
variable	results
T	394
(L < T)?	Y
H_w	14
Q_1	8063
(H_w < 103)?	Y
Awave	0
Astab	0
A	1122
Br	0
Q_2	239
Q_{min}	2347
($Q_2 < Q_{min}$)?	Y
($Q_2 > Q_1$)?	N
($Q_1 < Q_{min}$)?	N
Q_{max}	**2347**

breach hydrograph

time (min)	Q (cfs)
0	0
2	**2347**
4	1424
6	1110
8	865
10	674
12	525
14	409
16	319
18	248
20	193
22	151
24	117
26	91
28	71
30	56
32	43
34	34
36	26
38	20
40	16
42	12
44	10
46	8
48	6
50	5
52	4
54	3
56	2
58	2
60	1
62	1
64	1
66	1
68	0
70	0
72	0



Basin 4 breach hydrograph
2400
2160
1920
1680
1440
1200
960
720
480
240
0
discharge (cfs)
0
15
30
time (minutes)



Santaquin

Basin 4 Dam Breach Analysis

DATE 11/15/2018

DRAWN

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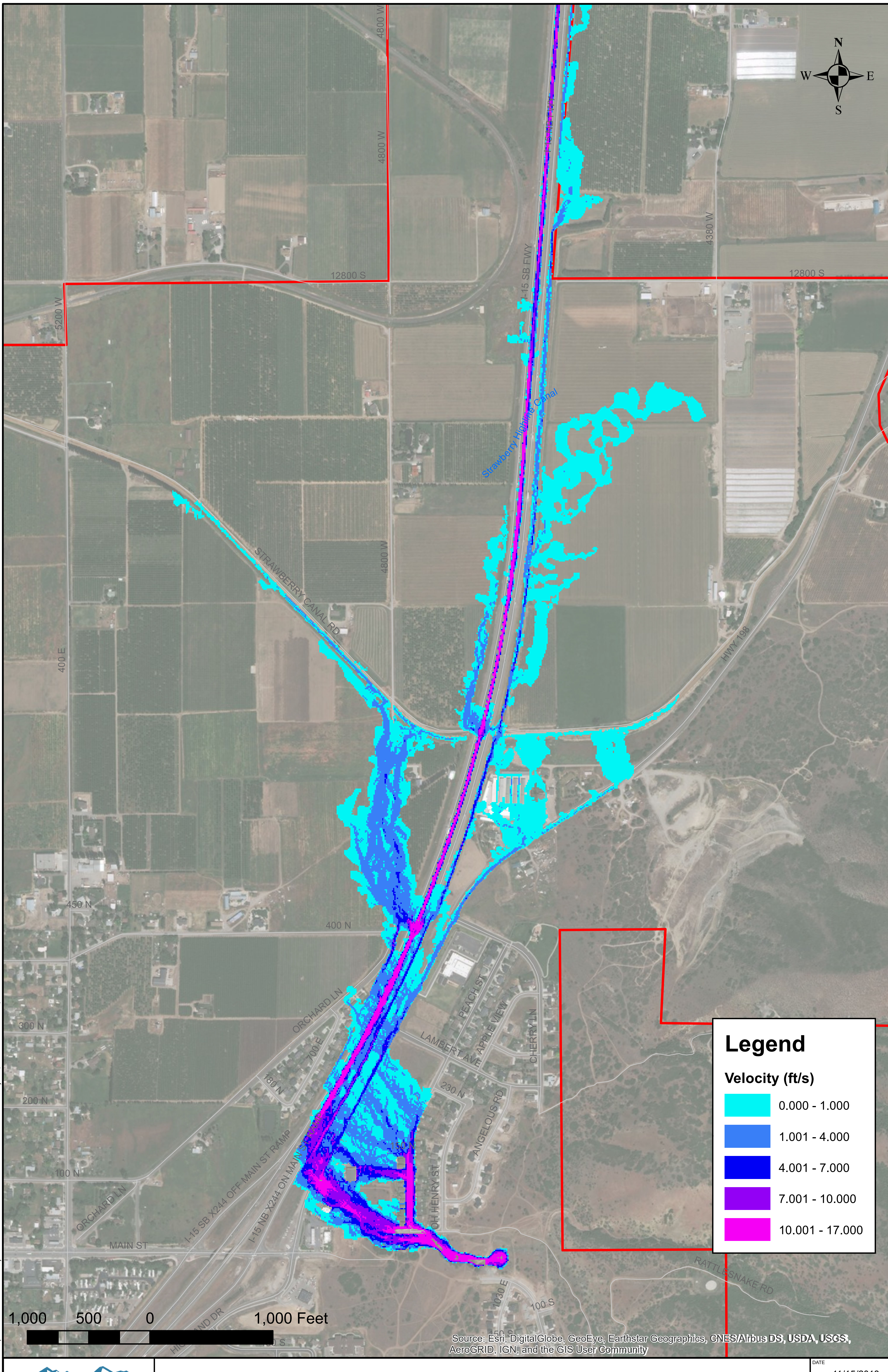

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Santaquin

Basin 4 Dam Breach Analysis

DATE 11/15/2018

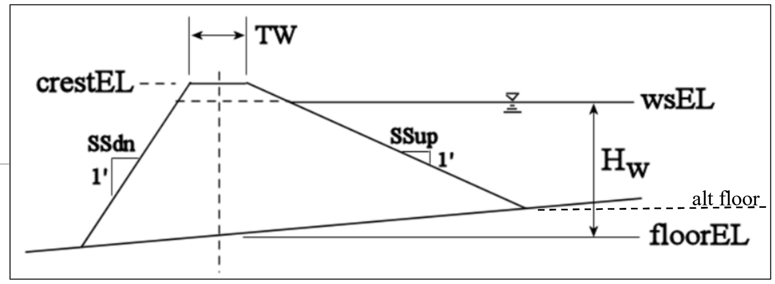
DRAWN

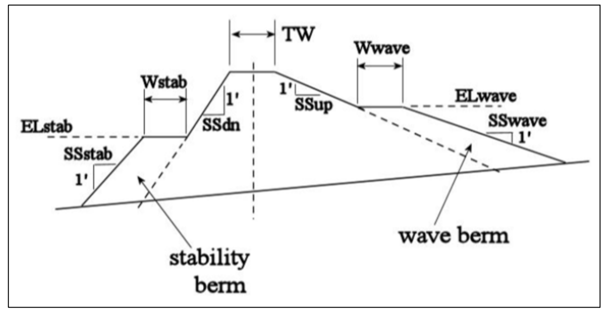
Dambreach Hydrographs via TRs 60 & 66 NRCS guidance

version 3, July 2018

Input data required:

data	variable	explanation
5000	crestEL	dam crest elevation
4997	wsEL	w.s. elev at time of breach
15	TW	dam top width (feet)
3	SSup	dam side slope (upstream, SSup:1)
3	SSdn	dam side slope (downstream, SSdn:1)
4983.5	floorEL	valley floor elev (see note)
18.6	Vs	resv vol at time of breach (acre-feet)
512	L	valley width at dam axis & w.s. elev (feet)
	ELwave	top of wave berm elevation
8	Wwave	width of top of wave berm feet
3	SSwave	wave berm side slope (SSwave:1)
	ELstab	top of stability berm elevation
5	Wstab	width of top of stability berm (feet)
2.5	SSstab	stability berm side slope (SSstab:1)
2	ts	timestep (minutes) for breach hydrograph





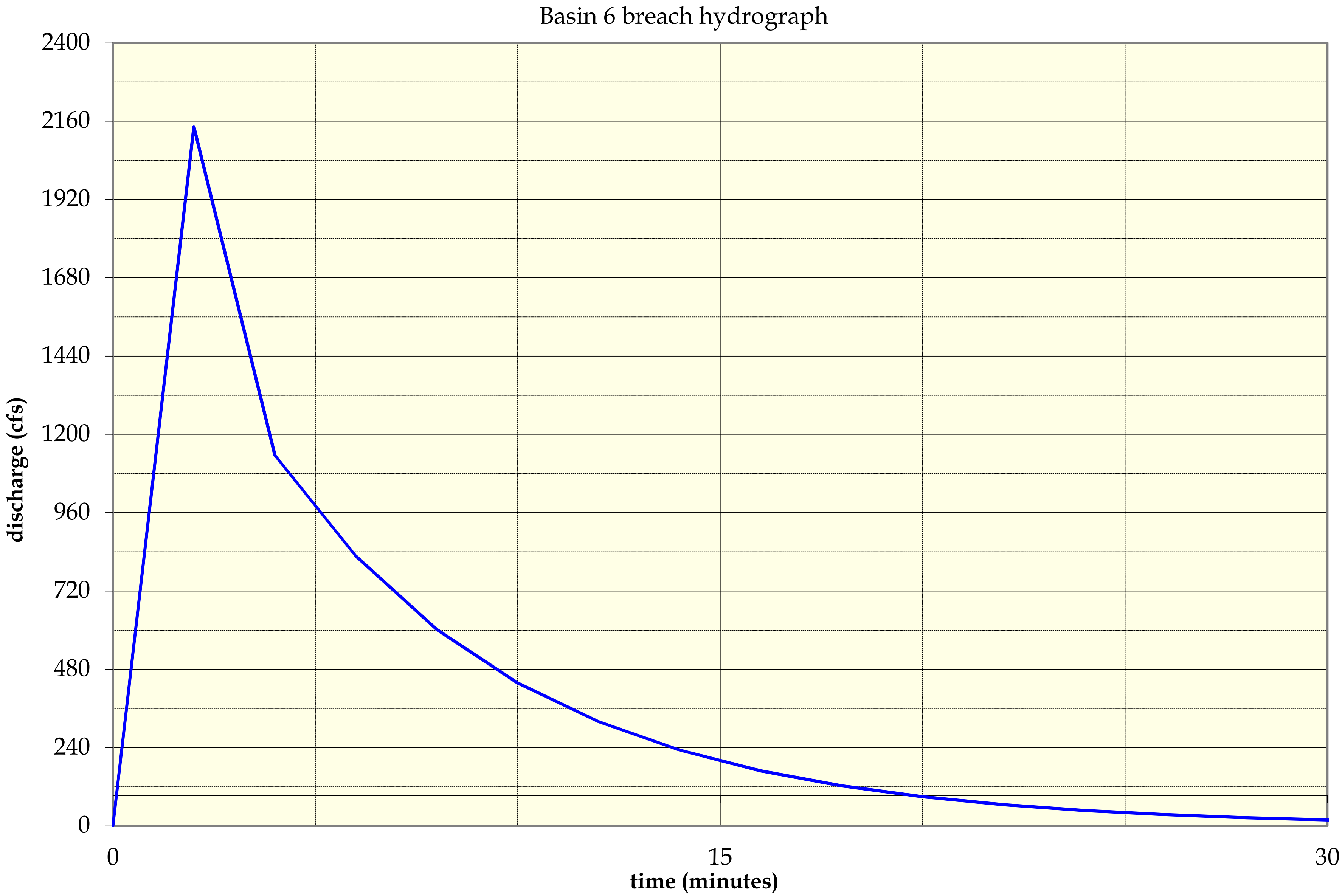
auto-scale

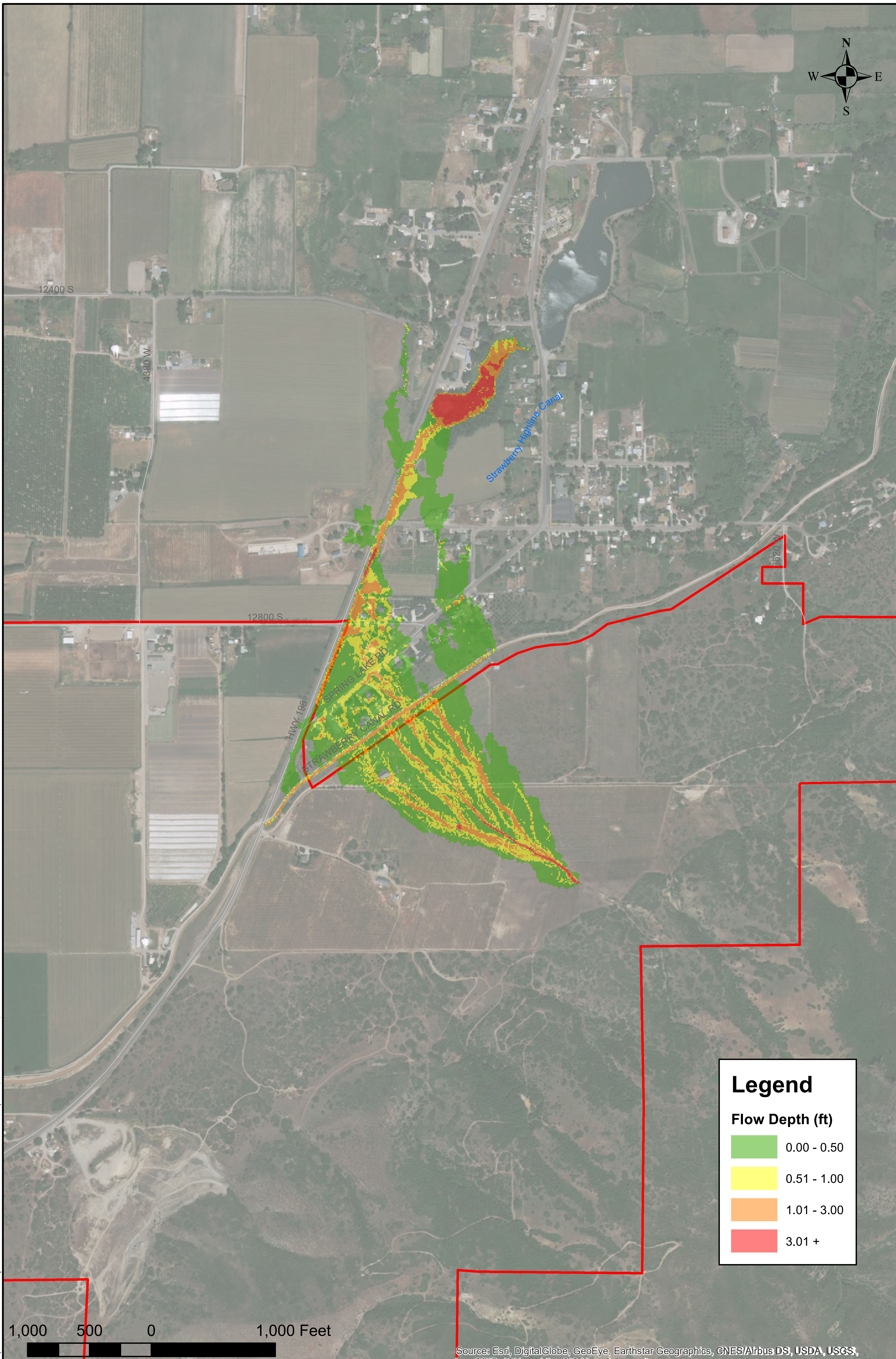
output

variable	results
T	389
(L < T)?	N
H_w	13.5
Q_1	8017
(H_w < 103)?	Y
Awave	0
Astab	0
A	1064
Br	0
Q_2	157
Q_{min}	2143
($Q_2 < Q_{min}$)?	Y
($Q_2 > Q_1$)?	N
($Q_1 < Q_{min}$)?	N
Q_{max}	**2143**

breach hydrograph

time (min)	Q (cfs)
0	0
2	**2143**
4	1136
6	827
8	602
10	438
12	319
14	232
16	169
18	123
20	90
22	65
24	48
26	35
28	25
30	18
32	13
34	10
36	7
38	5
40	4
42	3
44	2
46	1
48	1
50	1
52	1
54	0
56	0
58	0
60	0
62	0
64	0
66	0
68	0
70	0


Basin 6 breach hydrograph
2400
2160
1920
1680
1440
1200
960
720
480
240
0
discharge (cfs)
0
15
30
time (minutes)



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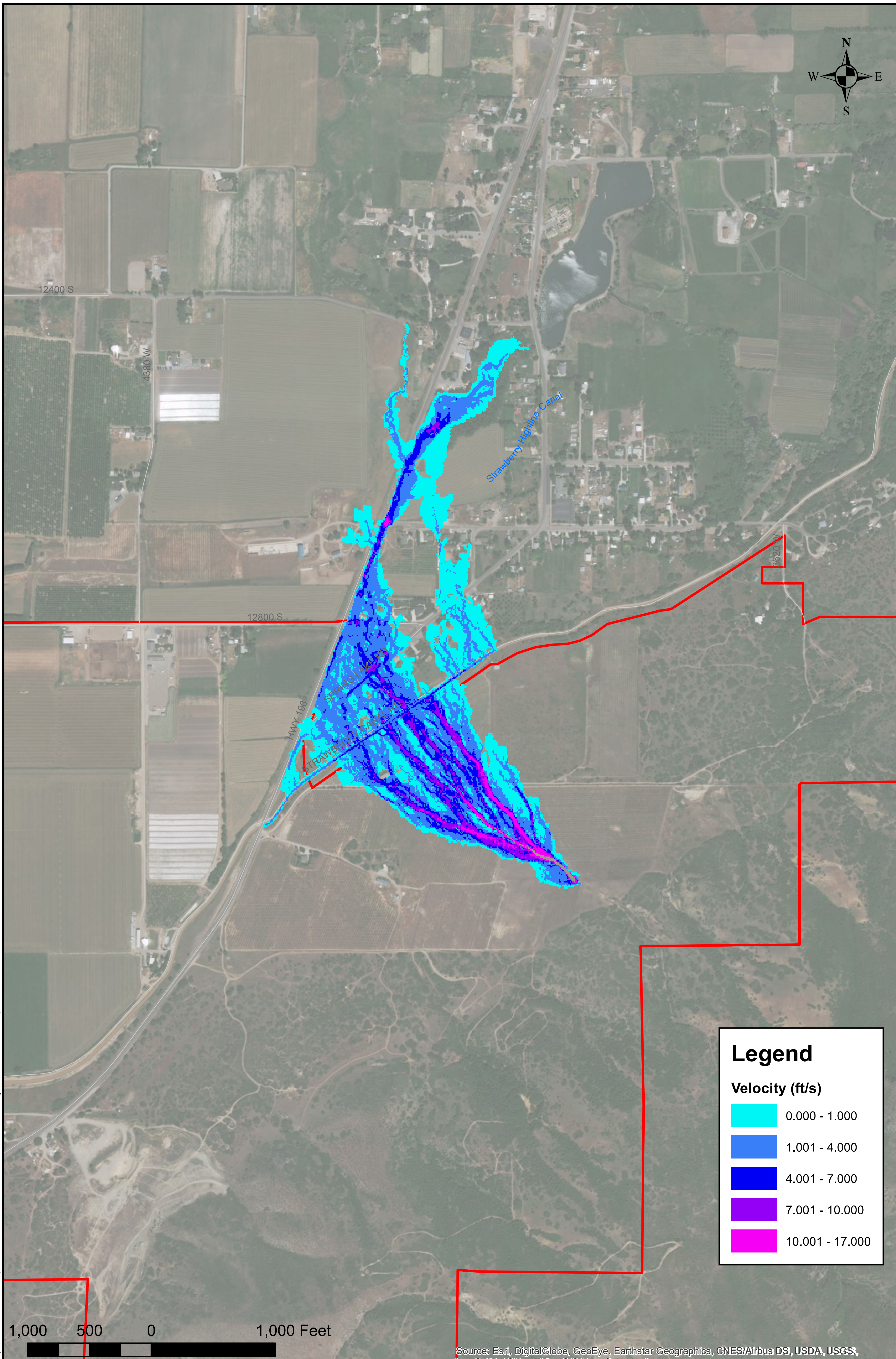
Santaquin

Basin 6 Dam Breach Analysis

DATE 11/15/2018

DRAWN



Santaquin

Basin 6 Dam Breach Analysis

DATE
11/15/2018
DRAWN

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Appendix H: Wave Runup Calculations

Santaquin Wave Runup Summary Sheet
Made by Mickey Navidomskis
7/10/2018

References:
(1) Albert Holler "New Information For Design of Dam Freeboard" (2005, ASDSO Dam Safety Conference)
(2) Albert Holler "Computation Of Dam Freeboard For Wind Generated Waves" (2001, ASDSO Dam Safety Conference)

Key:

inputs	outputs	Dam attributes

Basin	Fetch used (maximum distance)	fetch used	Average Water Depth	Overland wind speed	Roughness	Wave Height	Wave Steepnesss	Significant Runup	Max Runup	Wind Tide Setup	Freeboard for average of highest 1/3 of waves - 13% could exceed	For maximum wave action	Principal Spillway	Auxilliary Spillway	Dam Crest	Principal Spillway Freeboard	Auxilliary Spillway Freeboard
	ft	miles	mph	mph		ft		ft	ft	ft	ft	ft	elev (ft)	elev (ft)	elev (ft)	ft	ft
Basin 1 Above Grade	342.6	0.0649	12	100	Grass	0.9	0.238	2.2	3.6	0.03	**2.2**	3.7	5407	5408.5	5411.5	4.5	3
Basin 2 Above Grade	170.2	0.0322	12	100	Grass	0.6	0.273	1.6	2.7	0.02	**1.7**	2.7	5316	5317	5320	4	3
Basin 3 Above Grade	148.5	0.0281	12	100	Grass	0.6	0.279	1.5	2.6	0.01	**1.5**	2.6	5266	5267	5270	4	3
Basin 4E Above Grade	285.7	0.0541	12	100	Grass	0.8	0.246	2	3.4	0.02	**2**	3.4	5052	5054	5057	5	3
Basin 4B Above Grade	337.7	0.0640	12	100	Grass	0.9	0.238	2.2	3.6	0.03	**2.2**	3.6	5027	5029.2	5032.2	5.2	3
Basin 4A Above Grade	200.1	0.0379	12	100	Grass	0.7	0.264	1.7	2.9	0.02	**1.8**	2.9	4997	4999.2	5002.2	5.2	3
Basin 5 Above Grade	366.5	0.0694	12	100	Grass	0.9	0.235	2.2	3.7	0.05	**2.3**	3.8	5011	5012.5	5015.5	4.5	3
Basin 6A Above Grade	391.8	0.0742	12	100	Grass	0.9	0.233	2.3	3.9	0.05	**2.4**	3.9	5021	5022.5	5025.5	4.5	3
Basin 6B Above Grade	329.1	0.0623	12	100	Grass	0.8	0.24	2.1	3.6	0.04	**2.2**	3.6	5037	5038.5	5041.5	4.5	3

Note: Input values assume water is at Auxilliary Spillway, overland wind is 100mph, the dam is grass lined, the longest fetch is perpendicular to the dam, and the average water depth is 12 feet

Basin	Fetch used (maximum distance)	fetch used	Average Water Depth	Overland wind speed	Roughness	Wave Height	Wave Steepnesss	Significant Runup	Max Runup	Wind Tide Setup	Freeboard for average of highest 1/3 of waves - 13% could exceed	For maximum wave action	100-yr Water Surface	Principal Spillway	Auxilliary Spillway	Dam Crest	Principal Spillway Freeboard	100-yr Event Freeboard	Auxilliary Spillway Freeboard
	ft	miles	mph	mph		ft		ft	ft	ft	ft	ft	elev (ft)	elev (ft)	elev (ft)	elev (ft)	ft	ft	ft
Basin 1 Above Grade	342.6	0.0649	12	50	Grass	0.4	0.189	1.1	1.8	0.01	**1.1**	1.8	5408.03	5407	5408.5	5411.5	4.5	3.47	3
Basin 2 Above Grade	170.2	0.0322	12	50	Grass	0.3	0.213	0.8	1.3	0	**0.8**	1.3	5315.48	5316	5317	5320	4	4.52	3
Basin 3 Above Grade	148.5	0.0281	12	50	Grass	0.3	0.218	0.7	1.2	0	**0.7**	1.2	5263.95	5266	5267	5270	4	6.05	3
Basin 4E Above Grade	285.7	0.0541	12	50	Grass	0.4	0.195	1	1.6	0.01	**1**	1.6	5053.99	5052	5054	5057	5	3.01	3
Basin 4B Above Grade	337.7	0.0640	12	50	Grass	0.4	0.19	1.1	1.8	0.01	**1.1**	1.8	5029.52	5027	5029.6	5032.6	5.6	3.08	3
Basin 4A Above Grade	200.1	0.0379	12	50	Grass	0.3	0.207	0.8	1.4	0.01	**0.8**	1.4	4999.2	4997	4999.2	5002.2	5.2	3	3
Basin 5 Above Grade	366.5	0.0694	12	50	Grass	0.4	0.187	1.1	1.8	0.01	**1.1**	1.9	5012.49	5011	5012.5	5015.5	4.5	3.01	3
Basin 6A Above Grade	391.8	0.0742	12	50	Grass	0.5	0.185	1.1	1.9	0.01	**1.2**	1.9	5022.11	5021	5022.5	5025.5	4.5	3.39	3
Basin 6B Above Grade	329.1	0.0623	12	50	Grass	0.4	0.191	1	1.7	0.01	**1.1**	1.8	5038.18	5037	5038.5	5041.5	4.5	3.32	3

Note: Input values assume water is at Auxilliary Spillway, overland wind is 50mph, the dam is grass lined, the longest fetch is perpendicular to the dam, and the average water depth is 12 feet

ATTACHMENT 3

SEDIMENTATION REPORT

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To: Nathaniel Todea
Natural Resources Conservation Service (NRCS), USDA

From: Aaron Spencer, P.E.

Date: July 30, 2018

Technical Memo

Subject: Santaquin City Flood Control Plan-EA – Sedimentation Analysis

Project: UT-1024-1801

INTRODUCTION

Sediment transport into reservoirs and debris basins is a major design consideration, since the volume taken up by the sediment reduces the capacity of the basin, and its ability to control flood flows. Additional volume must be provided for sediment so that throughout its design life the basin will function as intended. In order to determine the required volume the sediment yield must be calculated. The NRCS normally requires that a no-maintenance design life of 50 or 100 years be considered. Other solutions may be considered if meeting the sediment demands is not reasonable or feasible, such as regular cleaning and maintenance, but such solutions must be compared to the standard requirements and be approved.

BACKGROUND AND BASIS OF DESIGN

The NRCS has performed a similar study (Todea, 2015, unpublished) on the nearby Santaquin Canyon watershed as part of its work to address any deficiencies in the existing debris basin there. It and other resources provided by the NRCS have been used as general references to guide this study, including: Technical Release No. 12, Procedure – Sediment Storage Requirements (TR-12), and Chapter 8 of the National Engineering Handbook – Sedimentation.

Due to an accelerated schedule, initial sizing of the basins for use in hydraulic analysis required some assumptions be made on the sediment volume in the proposed basins. Based on past experience it was assumed approximately 20% of the total volume was reserved for sediment. This study refines the volumes that are recommended for planning and design.

APPROACH

In order to arrive at a reasonable sediment yield and sediment pool volume for the watersheds and basins in question, multiple methodologies for calculating sediment yield were used and compared. With no stream gages or existing basins collecting sediment to compare to, this limited the ability to calibrate the estimates. The NRCS study for the nearby Santaquin Canyon was used as a general reference (Todea, 2015), and empirical hydrologic calculations using the curve number method were used to give a rough order of magnitude check on the values determined. This memo gives a brief introduction to the types of analysis performed, and summarizes the final results. Further detail on each method is provided in the method-specific attached technical memos.

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ANALYSIS

The analysis included determining sediment yield using several methods, performing rough checks on the order of magnitude of the results, and selection of the most appropriate yield values based on review of the sites and the applicability of each model. The trap efficiency of the basins, which determines how much of the sediment is actually trapped in the reservoir, is then applied to the recommended yield values to determine sediment pool volume requirements based on various design life intervals.

SEDIMENT YIELD

To evaluate sediment yield several methods were employed. These included the Rangeland Hydrology and Erosion Model (RHEM), the Pacific Southwest Inter-Agency Committee (PSIAC) method, and consulting the Bridges (1973) map. Further detail on each method is provided below. There is no ready means of evaluating historical yield or to calibrate the methods used at the sites other than general observations from geological investigation. The geological and geotechnical investigation is in process, and any significant findings will be taken into consideration upon completion.

RHEM

Rangeland Hydrology and Erosion Model (RHEM) is a formula designed to estimate runoff and sediment yield. United States Department of Agriculture (USDA) provides a user friendly web tool through the Southwest Watershed Research Center, http://dss.tucson.ars.ag.gov/rhem/, which runs the RHEM using input parameters. The RHEM method is an adaptation of the Water Erosion Prediction Model (WEPP), and accommodates rangeland instead of croplands by modifying slope and infiltration based on land cover. The RHEM Web Tool uses storm data, soil types, land cover information, and slope as input parameters. Detailed information on the collection of input parameters for Santaquin debris basins is found in the “RHEM Technical Memo” appendix. The table below shows results produced by the RHEM Web Tool. As described in the “RHEM Technical Memo,” each basin has a lower and higher yield limit based on a range of criteria used as parameters. The RHEM tool is designed as an event based model, but annualizes the results of a range of events from 2 years to 100 years to produce a final annual average.

Table 1. RHEM Sediment Yield Results

	Basin 1		Basin 2		Basin 3		Basin 4		Basin 5		Basin 6	
Lower / Higher Yield	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Sediment Yield (Ac-Ft/Sq-Mi/Yr)	0.07	0.27	0.03	0.13	0.02	0.08	0.04	0.14	0.03	0.12	0.06	0.21
Total Annual Yield (Ac-Ft)	0.05	0.17	0.002	0.01	0.001	0.01	0.024	0.08	0.024	0.08	0.026	0.10

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PSIAC

In 1974 the Pacific Southwest Inter-Agency Committee (PSIAC) evaluated methods for estimating erosion and sediment yield. Ten contributing factors were identified: surface geology, soils, climate, runoff, topography, effective ground cover, land type/management quality, upland erosion, and channel erosion/sediment transport. The PSIAC Method for estimating sediment yield requires field observations and data collection for each contributing factor. Norm Evenstad with the Natural Resources Conservation Service (NRCS) provided a 1991 revision of the PSIAC procedures. Details about the use of this scale are in the "PSIAC Technical Memo" appendix. Below is a table showing the results of the PSIAC Method.

Table 2. PSIAC Sediment Yield Results

	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Basin 6
Sediment Yield (Ac-Ft/Sq-Mi/Yr)	0.24	0.24	0.25	0.28	0.26	0.27
Total Annual Yield (Ac-Ft)	0.15	0.017	0.013	0.19	0.18	0.13

Bridges

Nathaniel Todea with NRCS provided a copy of the "Estimated Sediment Yield Rates for the State of Utah" map, also known as the 1973 Bridges map. The Bridges map was developed by the NRCS. It gives estimated yearly sediment yields per square mile of area across Utah. It is typically used for estimating sediment yield over very large areas and is not recommended for specific sites. Refer to the "Bridges Sediment Yield Map" appendix for information regarding results in the table below. The Bridges map gave a range of 0.2 to 0.5 acre-feet per square mile per year. From observation it was assumed that these watersheds would generally be on the lower end of the spectrum, so a value of 0.3 was used to prepare Table 3 below showing expected yields.

Table 3. Bridge Sediment Yield Results

	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Basin 6
Sediment Yield (Ac-Ft/Sq-Mi-Yr)	0.3	0.3	0.3	0.3	0.3	0.3
Total Annual Yield (Ac-Ft)	.19	.02	.02	.21	.21	.14

CHECK ON RESULTS

HYDROLOGIC ORDER OF MAGNITUDE

As an order of magnitude check on the yield quantities determined above, a backcheck was performed using design storm volumes and peak flows for 24-hour storms with 1-year and 2-year recurrence intervals that were evaluated as part of the hydrology study.

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Sediment concentrations of 10% were used to estimate yearly runoff values. The 1-year recurrence interval storms had such low peak flows that they were not considered representative, as they would have mobilized minimal sediment. Therefore the 2-year event was used, and then annualized. The results are shown below:

Table 4. Hydrologic Check on Magnitude

Basin	Area (sq. mi.)	Area (acres)	2-yr Runoff Volume (inches)	2-yr Runoff Volume (acre-ft)	2-yr Peak Flow (cfs)	2-yr Sediment Volume @ 10%	Yearly deposition at 10% (acre-ft)
1	0.627	401.28	0.14	4.682	12	0.47	0.234
2	0.069	44.16	0.015	0.055	0.6	0.01	0.003
3	0.053	33.92	0.021	0.059	0.9	0.01	0.003
4	0.688	440.32	0.118	4.330	8.8	0.43	0.216
5	0.711	455.04	0.067	2.540	3.1	0.25	0.127
6	0.451	288.64	0.134	3.223	9.5	0.32	0.161

This rough method of checking sediment loads is oversimplified, and therefore must be used only as a general order of magnitude check. The 2-year event peak flows are minimal, meaning that assuming the storm transports sediment equal to 10% of the event's runoff volume may be conservative, since during most of the storm the flows would be insufficient to mobilize significant sediment. This supports observations that there are not regular flows out of these watersheds that have a significant impact, and that the majority of sediment yield occurs during more extreme, less frequent events. A "yearly" sediment load would therefore need to be an average of the yield of larger infrequent events. The values do appear to confirm the general order of magnitude of the results of the other methods.

COMPARISON STUDIES

An intensive sediment yield study was performed by the NRCS on Santaquin Canyon, the mouth of which is located one to two miles southwest of the basins under consideration. The canyon is similar in most characteristics to the basins being studied in this analysis, except that it is larger, has a continuously flowing creek, and likely has a lower average slope. The Santaquin Canyon study examined the Bridges map, RHEM tool, and PSIAC just as this study has, but also included other methods such as AGWA modeling, RiverMorph, and others. There is an existing flood control and debris basin at the mouth of the canyon, and through examination of original design documentation they concluded the planned sedimentation rate for that basin was 0.12 acre-feet per square mile per year.

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The unit sediment yield per square mile that they found for the Bridges map and the RHEM methods resulted in similar sediment yields as found in this study. The PSIAC results they cited were notably higher.
The study in the end recommended using the results of a RiverMorph FlowSed model, which requires input of specific flow gage data and dimensionless sediment yield parameters selected based on site specific characteristics. They concluded that a yield equivalent to 0.07 acre-feet per square mile was appropriate. This is more in line with the RHEM results than those of PSIAC or the Bridges map.

SEDIMENT YIELD CONCLUSIONS

The RHEM method was adapted from a cropland erosion prediction method for individual events, and is designed around looking at a single hillslope, not necessarily an entire watershed. But considering that these watersheds do not have continuous flows, and sediment yield is the result of the accumulation of less frequent isolated rainfall events, the comparison may be appropriate. The values generally appear to reasonably match findings in other studies in the area. Therefore the results of the RHEM models are recommended for use in this study.

Visual observations of the test pits performed in the alluvial fans below the watersheds suggest that the material being mobilized in Watersheds 1, 4, 5, and 6 is a loam with limited clay content, and significant sand, gravel, cobbles and boulders that are mobilized in isolated larger events. Watersheds 2 and 3 showed significantly less gravel and cobbles, appearing to consist of a sandy loam. The prevalence of sand, gravels, and larger materials suggest that the highest yield values from RHEM may be conservative, and that the lower values may be acceptable. To be conservative the upper values are recommended, with one exception. Basin 1 has a range of 0.07 to 0.27 ac-ft/sq.mi./yr. This is a wide range with an upper value notably higher than the other basins. The test pit below this watershed showed significant sand, gravel and cobble, suggesting that the loamy sand associated with the lower limit is likely more appropriate. PSIAC predicts a yield of 0.24 ac-ft/sq.mi./yr, or 0.15 acre-feet per year, which is recommended for use. The recommended design values are shown in Table 5 below.

Table 5. Recommended Sediment Yield Values

	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Basin 6
Sediment Yield (Ac-Ft/Sq-Mi/Yr)	0.24	0.13	0.08	0.14	0.12	0.21
Total Annual Yield (Ac-Ft)	0.15	0.01	0.01	0.10	0.08	0.10

These values are not considered to include atypical events, such as those caused by runoff during burned conditions or debris flows, which would have to be cleaned out as they occurred.

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TRAP EFFICIENCY

Debris basins are designed to remove sediment suspended in runoff flows. This "trapped" sediment is deposited in the basin. Not all of the sediment can be removed before the flows continue downstream. The quantity of sediment retained in the basin is expressed as a ratio. This ratio is known as trap efficiency. The USDA-NRCS Technical Release No. 12 "Procedure – Sediment Storage Requirements for Reservoirs" provides an outline for estimating trap efficiency. The results of the analysis are shown in the tables below. Sediment yield conclusions found using RHEM, PSIAC, and Bridges methods were used to estimate the sediment yield. Average annual precipitation was found through the USDA online application, StreamStats. Annual runoff was determined for each basin by using the Curve Number determined in the Hydrology Technical Memo. Assuming the curve number method runoff would average out and therefore apply to the average annual precipitation, inflow was found in each basin. We consider this to be a conservative assumption, since snowmelt and smaller events tend to have a greater opportunity to percolate than larger events.

With estimated debris basin capacities from the preliminary hydrology and hydraulics analysis, capacity/inflow (C/I) ratios were determined. That number is converted directly into trap efficiency using the graph provided in Technical Release No. 12 (1975, see Trap Efficiency Calculations appendix for further detail). Basins 2 and 3 used the median curve because visual site observations and gradation test results from test pit samples showed that the sediment emanating from these watersheds was finer than the others. The sediment deposits below the watersheds for Basins 1, 4, 5, and 6 were coarser, with significant gravel, cobbles and boulders. Therefore the upper curve of the trap efficiency curve in TR-12 was used, which is identified as being for highly flocculated and course-grained sediment.

In the table below, basin volumes required given varying design lives of 25, 50, and 100 years are shown.

Table 6. Sediment Storage and Basin Volumes

	Required Flood Capacity (ac-ft)	25 Year Design Life			
		Sediment Yield (ac-ft)	Trap Efficiency	Deposition (ac-ft)	Required Basin (ac-ft)
Basin 1	16.76	3.75	72%	2.70	19.46
Basin 2	1.34	0.25	64%	0.16	1.50
Basin 3	1.02	0.3	64%	0.16	1.18
Basin 4	15.39	2.5	79%	1.98	17.37
Basin 5	12.79	2.0	75%	1.50	14.29
Basin 6	11.98	2.5	82%	2.05	14.03

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	Required Flood Capacity (ac-ft)	50 Year Design Life			
		Sediment Yield (ac-ft)	Trap Efficiency	Deposition (ac-ft)	Required Basin (ac-ft)
Basin 1	16.76	7.5	75%	5.63	22.39
Basin 2	1.34	0.5	69%	0.35	1.69
Basin 3	1.02	0.5	69%	0.35	1.37
Basin 4	15.39	5.0	80%	4.00	19.39
Basin 5	12.79	4.0	79%	3.16	15.95
Basin 6	11.98	5.0	85%	4.25	16.23

	Required Flood Capacity (ac-ft)	100 Year Design Life			
		Sediment Yield (ac-ft)	Trap Efficiency	Deposition (ac-ft)	Required Basin (ac-ft)
Basin 1	16.76	15.0	80%	12.00	28.76
Basin 2	1.34	1.0	74%	0.74	2.08
Basin 3	1.02	1.0	76%	0.76	1.78
Basin 4	15.39	10.0	85%	8.50	23.89
Basin 5	12.79	8.0	81%	6.48	19.27
Basin 6	11.98	10.0	88%	8.80	20.78

CONCLUSIONS

A 100-year design life requires significant additional capacity in the reservoirs, nearly doubling the volume in some cases. These calculations include some significant uncertainty when the yield estimates are extended over 100 years.

The 50-year design life results in sediment storage that can be accommodated with a 25% to 35% increase in volume over the required flood capacity. This would still be a relatively maintenance free option, perhaps except in extreme events that would likely initiate emergency cleanup operations anyway.

A 25-year design life requires only a 12% to 17% increase in volume over the required flood capacity, but would necessitate that the city plan on cleaning it out on a recurring basis. If the cleaning occurred only every 25 years, the likelihood of proper maintenance occurring when needed is highly questionable. Frequent cleaning would be recommended.

Final design recommendations will be provided in the final planning documents where economic, project sponsor, and stakeholder considerations will be evaluated.

APENDICES

- RHEM Technical Memo
- PSIAC Technical Memo
- Bridges Sediment Yield Map
- Trap Efficiency Calculations

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APPENDIX – RHEM TECHNICAL MEMO

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RHEM TECHNICAL MEMO

APPROACH

The Rangeland Hydrology and Erosion Model (RHEM) Web Tool is a software model able to produce estimates on watershed sediment yield based on varying types of data.

This memo summarizes the analysis process for one of the watersheds, “Basin 4”, to illustrate the process used for the remainder of the basins. Critical data used for analyzing the other basins is also tabulated in the conclusion section of this memo, or in other relevant sections. The range of data was collected for the RHEM model for “Basin 4” using 4 factors: Climate Station, Soil Texture Class, Slope, and Cover Characteristics. Climate data is determined by selecting a location in the RHEM interface, and the Santaquin, Utah region was selected. No specific data sets are available for the cover inputs required by the RHEM program, but it proved to be the biggest contributor to sediment yield variation. Information was interpolated from the land cover data sources that were available and field visits.

The RHEM model was run twice as shown in table 5 and table 6. The tables give upper and lower limits to the annual sediment yield based on the given ranges of input parameters. Climate and slope are assumed to be constants. Soil Texture Class assumes Loam as the higher sediment yield condition and Loamy Sand as the lower sediment yield condition. Cover Characteristics assumes 15% more foliar and 15% more ground cover for the lower sediment yield condition.

Additional information on each category of inputs is provided below, with Basin 4 used as the example to illustrate the analysis process.

CLIMATE

The RHEM Model has climate settings based on location. Basin 4 is in the Santaquin PH area.

SLOPE

GIS data processing calculated steep slopes averaging 58% across Basin 4.

United States Department of Agriculture (USDA) maps show Basin 4 to have a three slope conditions. Some of the lower parts of the basin range from 25% to 40% slopes (soil type YaE), as you move up the canyon slopes range from 30% to 70% (soil type ShF), and the west facing slopes at the mouth of the canyon range from 35% to 70% (soil type HKG).

GIS digital elevation data is assumed to be the most accurate data available and is consistent with most USDA slope ranges. The region average slope of 58% was used as constant in both high and low sediment yield conditions.

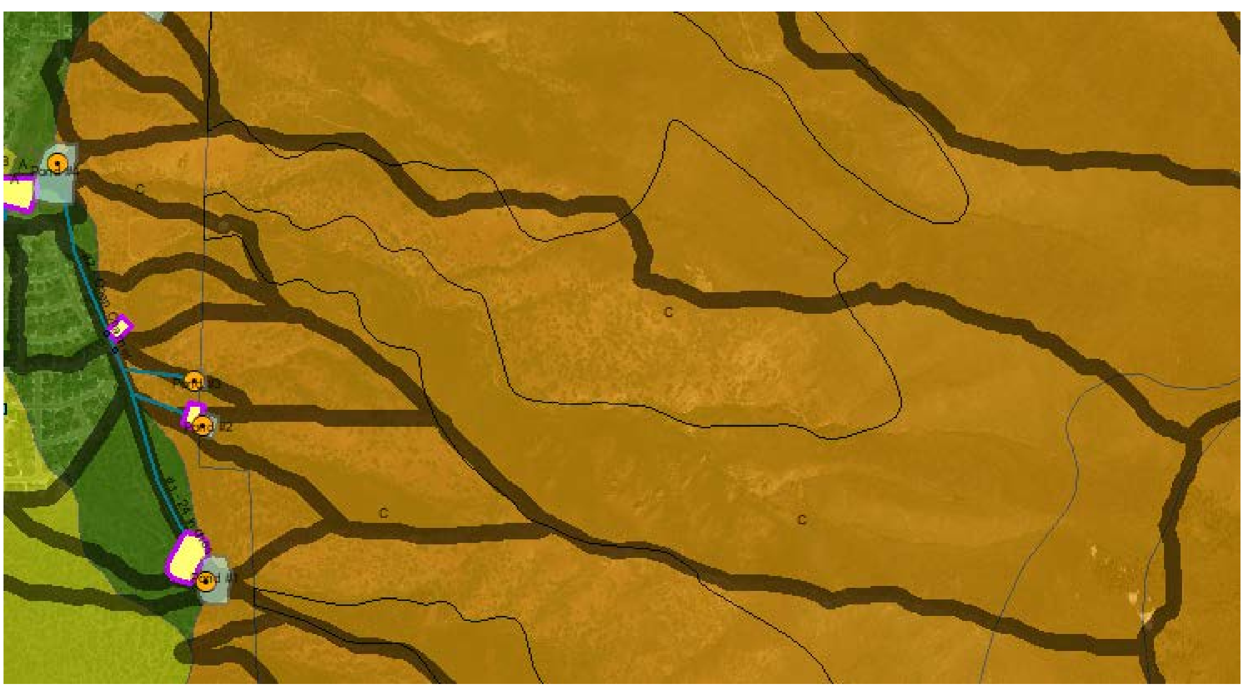
SOIL TEXTURE CLASS

USDA Soil maps showed Basin 4 as having four soil descriptions as shown in Figure 1. Henefer-Rake Association (HKG) described as a mountain shallow loam with a hydrologic group D; Yeats hollow Very Stony Loam (YaE) with a hydrologic group C; Pachic Cryoborolls (PD) soil derived from limestone, sandstone, shale and volcanic rocks; and Sheep Creek Very Cobbly Loam (ShF) with a hydrologic group C.

Figure 1 - USDA Soil Map, Basin 4

United States Geological Survey (USGS) soil type maps are shown in Figure 2. The entire Basin 4 region is classified as, or is assumed to be, Type C soil. See the Hydrology Technical Memo for further details on hydrologic soil group data and assumptions.

Figure 2 - USGS Soil Type Map, Basin 4



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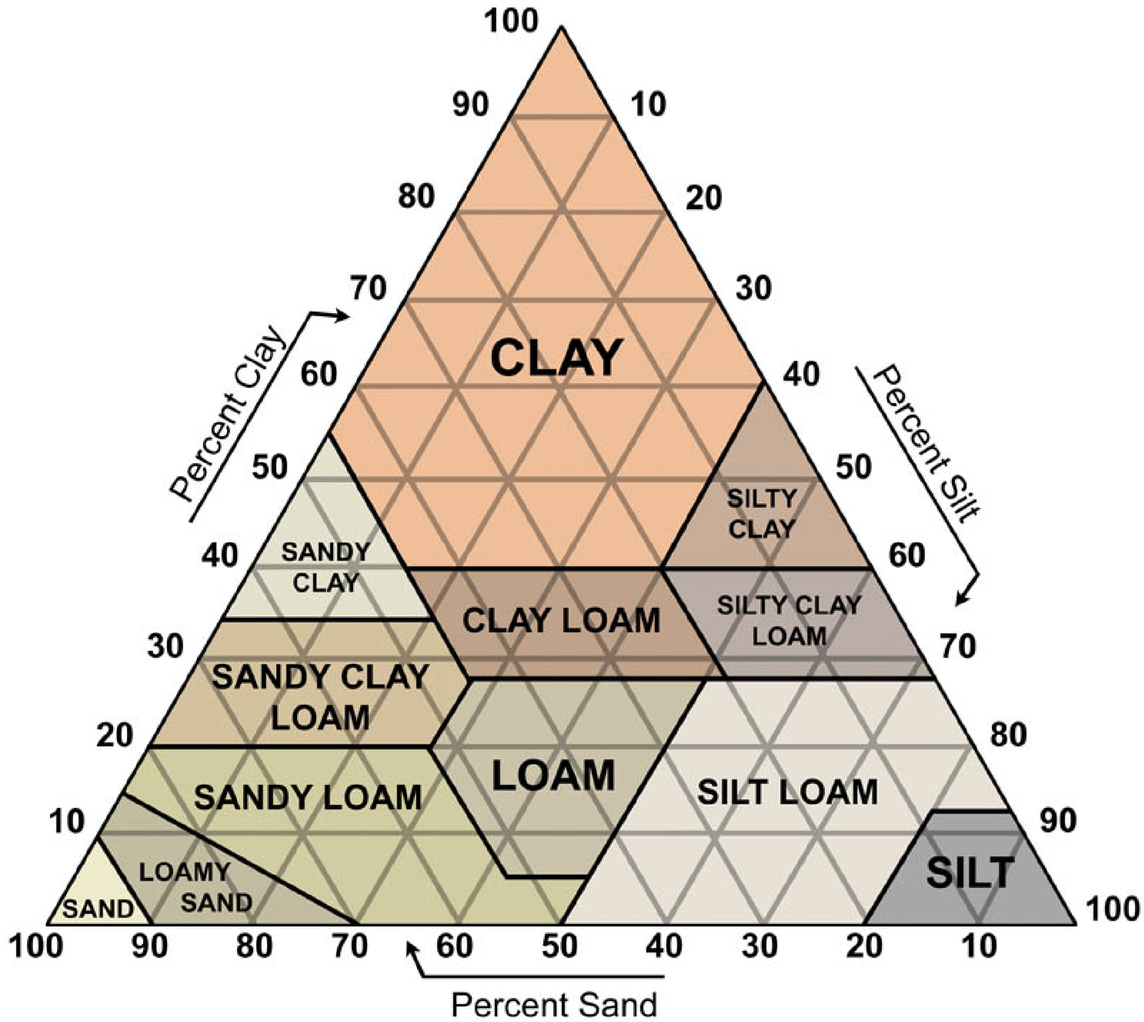
Comparing data from these sources it is concluded that most soils in this basin are classified primarily as group C and less than 5% group D. Soil types were assumed by comparing USDA soil types and hydraulic soil groups, and the soil profile chart in Figure 3. Soil classifications are described below from "Part 630 Hydrology, National Engineering Handbook" Chapter 7 – Hydrologic Soil Groups:

> "Group C—Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The limits on the diagnostic physical characteristics of group C are as follows. The saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters [20 inches] is between 1.0 micrometers per second (0.14 inches per hour) and 10.0 micrometers per second (1.42 inches per hour). The depth to any water impermeable layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils that are deeper than 100 centimeters [40 inches] to a restriction and a water table are in group C if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface exceeds 0.40 micrometers per second (0.06 inches per hour) but is less than 4.0 micrometers per second (0.57 inches per hour)"

> "Group D—Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters [20 inches] and all soils with a water table (210–VI–NEH, May 2007) 7–3 Part 630 National Engineering Handbook Chapter 7 Hydrologic Soil Groups within 60 centimeters [24 inches] of the surface are in this group, although some may have a dual classification, as described in the next section, if they can be adequately drained. The limits on the physical diagnostic characteristics of group D are as follows. For soils with a water impermeable layer at a depth between 50 centimeters and 100 centimeters [20 and 40 inches], the saturated hydraulic conductivity in the least transmissive soil layer is less than or equal to 1.0 micrometers per second (0.14 inches per hour). For soils that are deeper than 100 centimeters [40 inches] to a restriction or water table, the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface is less than or equal to 0.40 micrometers per second (0.06 inches per hour)."

Loam and Loamy Sand were assumed to be the primary soil types in Basin 4. Loamy Sand was used as the soil type with lower sediment yield limit and Loam was used in the higher sediment yield limit.

Figure 3 - Soil Profile Chart

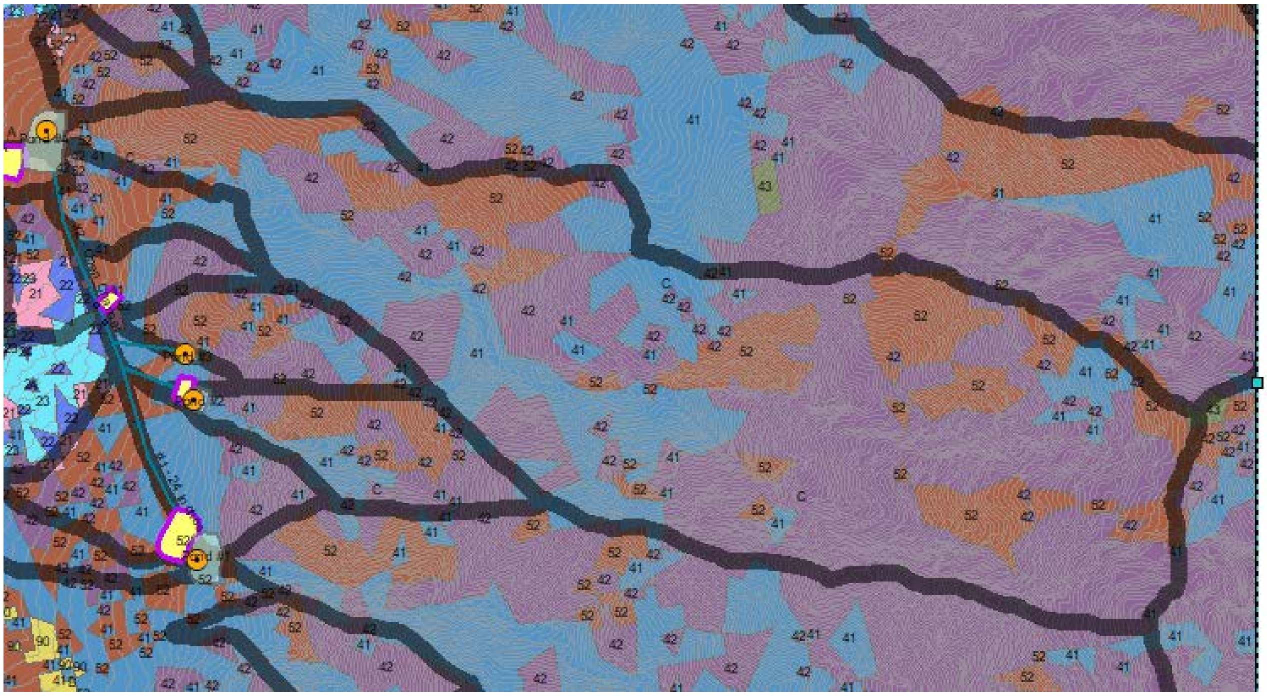


LAND COVER

National Land Cover Database (NLCD) maps evaluated on GIS show three land cover types as shown in Figure 4. GIS mapping was able to evaluate each land cover type percentage based on area in Basin 4: 51% Evergreen Forest, 24% Deciduous Forest and 25% shrub/scrub.

- *Evergreen Forest* - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
- *Deciduous Forest* - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
- *Shrub/Scrub* - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Figure 4 - NLCD Land Cover Map, Basin 4



Using the land cover information given in the NLCD, combined with knowledge of the area gained from on-site observation, the total foliar and ground cover estimations were made as shown in Table 3. Table 1 shows land cover type percentages derived from GIS data processing for all six basins.

Table 1 - Ground Cover Percentages

	Evergreen Forest	Deciduous Forest	Shrub/Scrub
Basin 1	65	29	6
Basin 2	48	23	29
Basin 3	41	29	30
Basin 4	51	24	25
Basin 5	28	44	18
Basin 6	60	26	11

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CONVERSION AND CONCLUSION

RHEM model results for sediment yield are given as “Avg. Sediment Yield (ton/ac/year).” In order to convert that into “Avg. Sediment Yield (ac-ft/sq-mi/year),” weight (tons) must be turned into volume (ac-ft) by dividing out density. Table 2 shows density for different sediments. All six basins are assumed to be 100% aerated and either sand-silt mixtures (equal parts) or poorly sorted sand and gravel based on observations during field visits and from test pits. Basins 1, 4, 5, and 6 were assumed to be 100 lb/cubic foot. Basins 2 and 3 were assumed to be 95 lb/cubic foot. Here is the resulting conversion factor:

> (640 acre / square mile), (2000 pounds / Ton), (cubic feet / 95-100 pounds), (acre feet / 43560 cubic feet).

Climate, Slope, Soil Type, and Land Cover are all input parameters needed to run the RHEM model for sediment yield. Basin 4 is located in the middle of all the basins and was chosen to be used as an example of the evaluation process and is the only basin with a thorough description of the development of input parameters. The same process for collecting input parameters was used for every basin. Screenshots from the RHEM model runs showing the high and low limits for sediment yield in Basin 4 are shown in figures 5 and 6. Tables 3 and 4 show the RHEM input parameters and results for all six basins. In table 3 the range of soil types and land covers used to evaluate the upper and lower limits on sediment yield are shown.

Table 2 – Soil Density - National Engineering Handbook Chapter 8

Table 8–1.—Volume-weight of sediment by grain size

Grain size	Volume-weight of sediment	
	Submerged	Aerated
	lb/ft³	*lb/ft³*
Clay	35–55	55–75
Silt	55–75	75–85
Clay-silt mixtures (equal parts)	40–65	65–85
Sand-silt mixtures (equal parts)	75–95	95–110
Clay-silt-sand mixtures (equal parts)	50–80	80–100
Sand	85–100	85–100
Gravel	85–125	85–125
Poorly sorted sand and gravel	95–130	95–130

Table 3 - RHEM Input Parameters

	Climate	Slope	Soil Type	Land Cover
Basin 1	Santaquin, Utah	66°	Loam and Loamy Sand	Bunch grass 20% to 25% Forbs/annuals 25% to 30% Shrubs 10% to 15% Basal 10% to 15% Rock 20% to 25% Litter 50% to 55%
Basin 2	Santaquin, Utah	58°	Loam and Loamy Sand	Bunch grass 15% to 20% Forbs/annuals 15% to 20% Shrubs 40% to 45% Basal 10% to 15% Rock 20% to 25% Litter 55% to 60%
Basin 3	Santaquin, Utah	47°	Loam and Loamy Sand	Bunch grass 15% to 20% Forbs/annuals 20% to 25% Shrubs 40% to 45% Basal 10% to 15% Rock 20% to 25% Litter 45% to 50%
Basin 4	Santaquin, Utah	58°	Loam and Loamy Sand	Bunch grass 15% to 20% Forbs/annuals 20% to 25% Shrubs 40% to 45% Basal 10% to 15% Rock 20% to 25% Litter 45% to 50%
Basin 5	Santaquin, Utah	50°	Loam and Loamy Sand	Bunch grass 15% to 20% Forbs/annuals 10% to 15% Shrubs 20% to 25% Basal 10% to 15% Rock 20% to 25% Litter 55% to 60%
Basin 6	Santaquin, Utah	59°	Loam and Loamy Sand	Bunch grass 20% to 25% Forbs/annuals 20% to 25% Shrubs 15% to 20% Basal 10% to 15% Rock 20% to 25% Litter 45% to 50%

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Table 4 – RHEM Sediment Yield

Watershed Area	Sediment Yield (TN/Ac/Yr)	Sediment Yield (Ac-Ft/Sq-Mi/Yr)	Annual Yield (Ac-Ft)	50 Year Yield (Ac-Ft)
Basin 1	0.25-0.915	0.07-0.27	0.05-0.17	2.31-8.44
Basin 2*	0.102-0.416	0.03-0.13	0.002-0.01	0.11-0.45
Basin 3*	0.062-0.252	0.02-0.08	0.001-0.01	0.05-0.21
Basin 4	0.121-0.479	0.04-0.14	0.024-0.097	1.22-4.85
Basin 5	0.114-0.400	0.03-0.12	0.024-0.08	1.19-4.18
Basin 6	0.198-0.724	0.06-0.21	0.026-0.10	1.31-4.80

**Denotes Basins with soil density 95 lbs/cubic foot (all other basins are 100)*

Figure 5 - RHEM Model, Higher Yielding Limit of Basin 4

Download results as CSV

SCENARIO INPUTS

	SANTAQUIN
Version	2.3
State ID	UT
Climate Station	Santaquin Ph
Soil Texture	Loam
Soil Water Saturation %	25
Slope Length (feet)	164.04
Slope Shape	Convex
Slope Steepness %	58
Bunch Grass Foliar Cover %	15
Forbs and/or Annual Grasses Foliar Cover %	20
Shrubs Foliar Cover %	40
Sod Grass Foliar Cover %	0
TOTAL FOLIAR COVER %	75
Basal Cover %	10
Rock Cover %	20
Litter Cover %	45
Biological Crusts Cover %	0
TOTAL GROUND COVER %	75

ANNUAL AVERAGES

	SANTAQUIN
Avg. Precipitation (inches/year)	7.090
Avg. Runoff (inches/year)	0.205
Avg. Sediment Yield (ton/ac/year)	0.479
Avg. Soil Loss (ton/ac/year)	0.485

RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

VARIABLE	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
Rain (inches)	1.207	1.602	1.951	2.373	2.900	2.995
Runoff (inches)	0.042	0.302	0.514	0.724	1.054	1.275
Soil Loss (ton/ac)	0.160	0.682	1.047	1.369	1.865	2.399
Sediment Yield (ton/ac)	0.156	0.679	1.047	1.364	1.859	2.396

RETURN FREQUENCY RESULTS FOR YEARLY TOTALS

VARIABLE	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
Rain (inches)	6.868	9.212	10.513	11.797	12.427	14.095
Runoff (inches)	0.049	0.385	0.593	0.971	1.177	1.765
Soil Loss (ton/ac)	0.179	0.872	1.384	1.927	2.412	3.182
Sediment Yield (ton/ac)	0.178	0.865	1.368	1.903	2.409	3.172

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Figure 6 - RHEM Model, Lower Yielding Limit of Basin 4

SCENARIO INPUTS

Download results as CSV

	SANTAQUIN
Version	2.3
State ID	UT
Climate Station	Santaquin Ph
Soil Texture	Loamy Sand
Soil Water Saturation %	25
Slope Length (feet)	164.04
Slope Shape	Convex
Slope Steepness %	58
Bunch Grass Foliar Cover %	20
Forbs and/or Annual Grasses Foliar Cover %	25
Shrubs Foliar Cover %	45
Sod Grass Foliar Cover %	0
TOTAL FOLIAR COVER %	90
Basal Cover %	15
Rock Cover %	25
Litter Cover %	50
Biological Crusts Cover %	0
TOTAL GROUND COVER %	90

ANNUAL AVERAGES

	SANTAQUIN
Avg. Precipitation (inches/year)	2.489
Avg. Runoff (inches/year)	0.047
Avg. Sediment Yield (ton/ac/year)	0.121
Avg. Soil Loss (ton/ac/year)	0.123

RETURN FREQUENCY RESULTS FOR YEARLY MAXIMUM DAILY

VARIABLE	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
Rain (inches)	0.983	1.444	1.781	2.371	2.780	3.006
Runoff (inches)	0.000	0.037	0.150	0.281	0.450	0.783
Soil Loss (ton/ac)	0.001	0.169	0.445	0.668	0.895	1.227
Sediment Yield (ton/ac)	0.000	0.167	0.433	0.660	0.890	1.216

RETURN FREQUENCY RESULTS FOR YEARLY TOTALS

VARIABLE	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
Rain (inches)	2.200	3.592	4.537	5.755	7.042	7.756
Runoff (inches)	0.000	0.038	0.154	0.291	0.454	0.783
Soil Loss (ton/ac)	0.001	0.182	0.481	0.781	0.971	1.225
Sediment Yield (ton/ac)	0.000	0.177	0.477	0.773	0.956	1.214

APPENDIX – PSIAC TECHNICAL MEMO

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PSIAC TECHNICAL MEMO

INTRODUCTION

The Pacific Southwest Interagency Committee Sediment Yield Procedure (PSIAC) – 1991 revision is a method of estimating watershed sediment yield over time. The PSIAC method evaluates on a numerical scale nine contributing factors to sediment yield.

- Surface geology
- Soils
- Climate
- Runoff
- Topography
- Effective Ground Cover
- Land Type / Management Quality
- Upland Erosion
- Channel Erosion / Sediment Transport

These nine contributing factors identified by the PSIAC method are each given a qualitative numerical score based on observed site conditions. The total score is then used to calculate sediment yield in a watershed area.

This memo summarizes the analysis process for one of the watersheds, “Basin 4”, to illustrate the process used for the remainder of the basins.

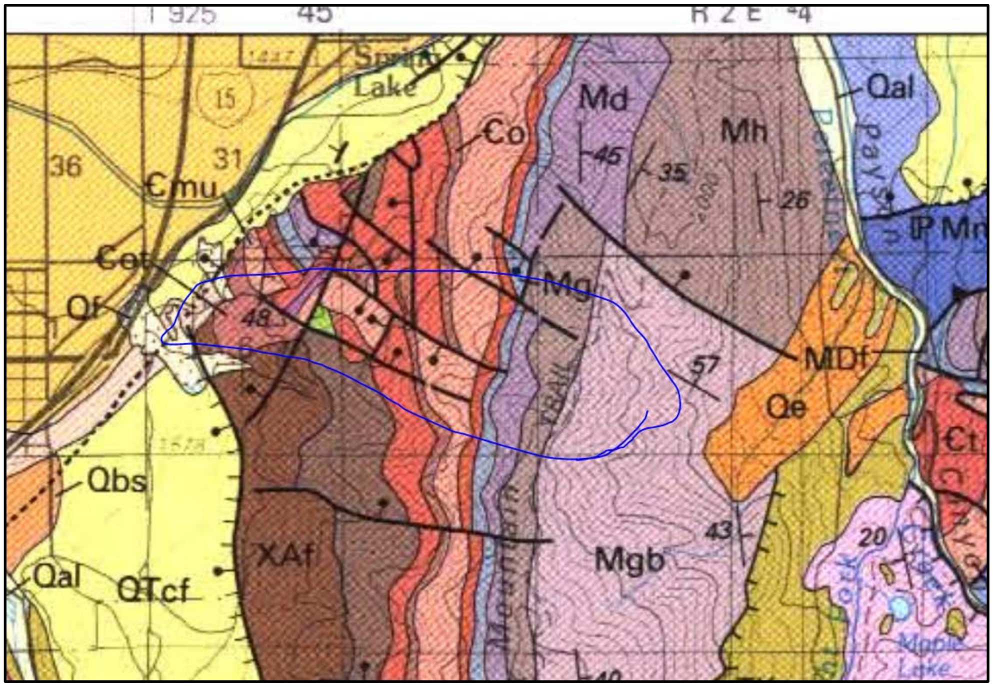
A copy of the spreadsheet used to score each category is shown in Table 4 at the end of this memo. This spreadsheet was supplied by the Utah office of the United States Department of Agriculture – Natural Resources Conservation Service. A few categories are derived by evaluating available GIS numerical data, such as soil type and vegetation, while many categories required qualitative observation and assumptions. In addition to the PSIAC documentation, the ranges of scores and the associated descriptions provided in the PSIAC spreadsheet are the basis of the score and justification used in determining the sediment yield.

SURFACE GEOLOGY

The Utah Geological Survey has geological maps identifying rock types as shown in Figure 1. The most common rock types identified in Basin 4 are Middle Camrien Rock made up of quartzite, dolomite, limestone, and some sandstone; Gardison, Desert, and Great Blue Limestones; and Big Cottonwood Formation made up of quartzite and sandstone.

These rock types are above average on the hardness scale; there is no shale, mudstone, or siltstone in this area. The bedrock at or near the surface includes lightly weathered rock, minimal amounts of highly fractured rock, and a few large rock formations. The Geology factor is given a PSIAC scale factor of 1.

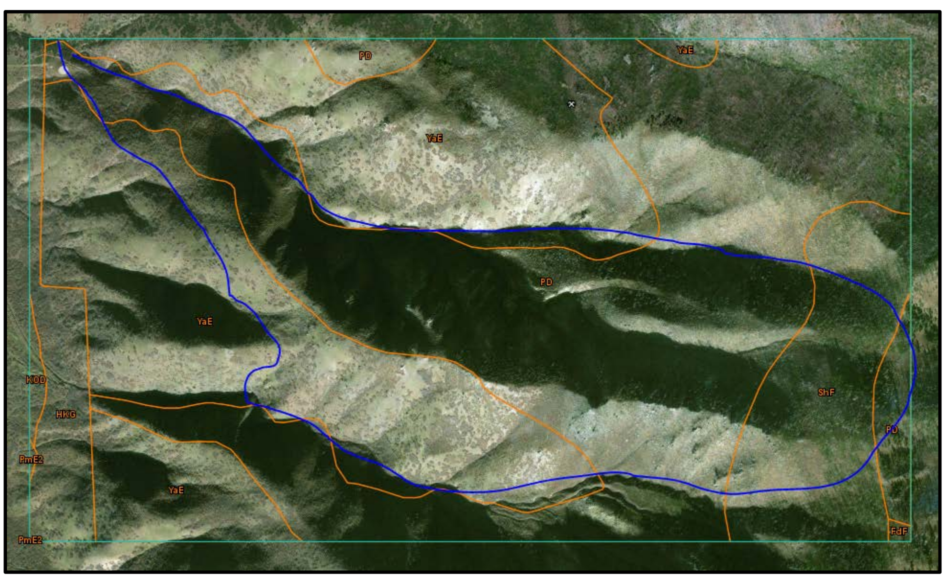
Figure 1 - UGS Geological Map, Basin 4



SOILS

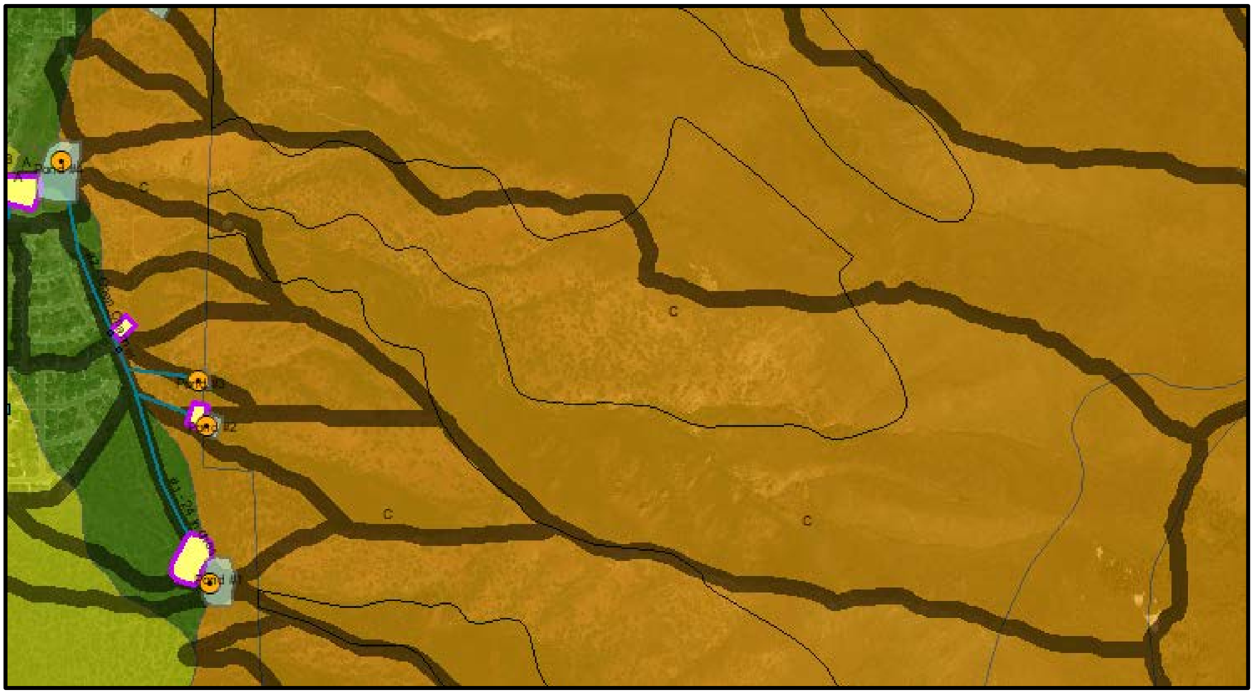
USDA Soil maps showed Basin 4 as having three soil descriptions as shown in Figure 2: Yeats Hollow Very Stony Loam (YaE) with a hydrologic soil group (HSG) of C; Pachic Cryoborolls (PD) soil derived from limestone, sandstone, shale and volcanic rocks (no hydrologic soil group provided, C assumed); and Sheep Creek Very Cobbly Loam (ShF) with a HSG of C.

Figure 2 - USDA Soil Map, Basin 4



United Stated Geological Survey soil type maps shown in Figure 3 show the majority of Basin 4 classified as HSG Type C soil. Areas with no specified hydrologic soil group were assumed to have a HSG of C (See Hydrology Technical Memo for further detail).

Figure 3 - USGS Soil Type Map, Basin 4



Comparing data from the USGS map and soil descriptions provided above it is concluded that most soils in this basin are classified primarily as group C and less than 5% group D. Soil types were assumed by comparing USDA soil types, soil classification group C, soil classification group D, and soil the classification in figure 4. Soil classifications are described below from "Part 630 Hydrology, National Engineering Handbook" Chapter 7 – Hydrologic Soil Groups:

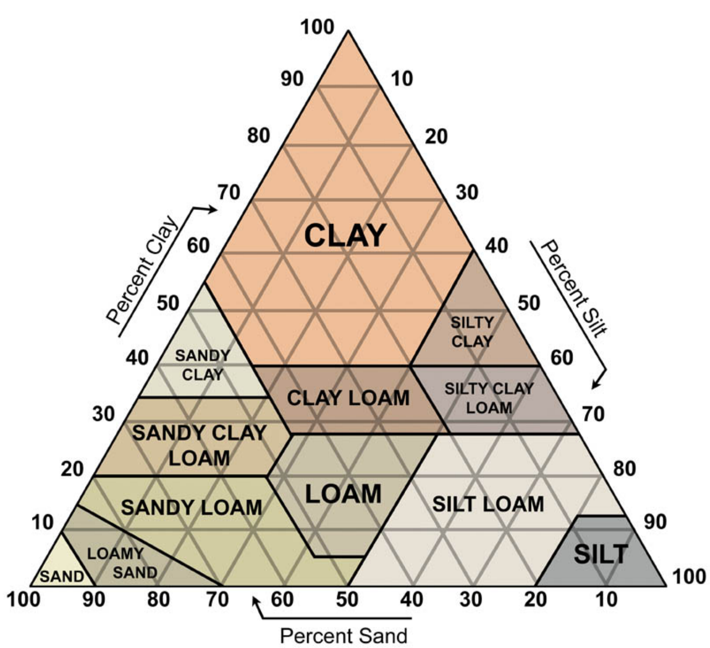
> "Group C—Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments. The limits on the diagnostic physical characteristics of group C are as follows. The saturated hydraulic conductivity in the least transmissive layer between the surface and 50 centimeters [20 inches] is between 1.0 micrometers per second (0.14 inches per hour) and 10.0 micrometers per second (1.42 inches per hour). The depth to any water impermeable layer is greater than 50 centimeters [20 inches]. The depth to the water table is greater than 60 centimeters [24 inches]. Soils that are deeper than 100 centimeters [40 inches] to a restriction and a water table are in group C if the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface

exceeds 0.40 micrometers per second (0.06 inches per hour) but is less than 4.0 micrometers per second (0.57 inches per hour)"

"Group D—Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters [20 inches] and all soils with a water table (210–VI–NEH, May 2007) 7–3 Part 630 National Engineering Handbook Chapter 7 Hydrologic Soil Groups within 60 centimeters [24 inches] of the surface are in this group, although some may have a dual classification, as described in the next section, if they can be adequately drained. The limits on the physical diagnostic characteristics of group D are as follows. For soils with a water impermeable layer at a depth between 50 centimeters and 100 centimeters [20 and 40 inches], the saturated hydraulic conductivity in the least transmissive soil layer is less than or equal to 1.0 micrometers per second (0.14 inches per hour). For soils that are deeper than 100 centimeters [40 inches] to a restriction or water table, the saturated hydraulic conductivity of all soil layers within 100 centimeters [40 inches] of the surface is less than or equal to 0.40 micrometers per second (0.06 inches per hour)."

Loam and Loamy Sand were assumed to be the primary soil types in Basin 4. Loamy Sand was used as the soil type in the analysis of lower sediment yield limit, and Loam was used in the upper sediment yield limit analysis.

Figure 4 - Soil Profile Chart



Soils in this watershed have a high percentage of rock fragments, aggregated clays, some organic matter, no caliche layers, no saline alkaline, no high shrink-swell characteristics, and medium textured soil. Based on these factors a scale factor of 3 was used.

CLIMATE

The National Climatic Data Center (NCDC) located in Asheville, North Carolina published a report titled "Climate of Utah" which presents a climatological summary of climate conditions in Utah. The report contains many relevant condition descriptions:

- "During the past 100 years approximately 300 flash floods, resulting from high intensity rainfall and 135 snowmelt floods, have been recorded."
- "Utah experiences relatively strong insolation during the day and rapid nocturnal cooling, resulting in wide daily ranges in temperature."
- "There are however, from 4.5 to five months of freeze-free growing weather"
- "The bulk of moisture falling over that area can be attributed to movement of Pacific storms through the region during the winter and spring months."
- "The eastern portion receives rain from summer thunderstorms."
- "Snowfall is moderately heavy in the mountains, especially over the northern part"
- "Flash floods from summer thunderstorms are more frequent, but they affect only small, local areas."

Using information collected from NCDC and general knowledge of the climate in the Santaquin area, a PSIAC scale factor of 5 was used. It is not humid, precipitation does come in the form of snow, it is an arid climate with low intensity storms, convective storms come in the form of high winds moderately frequent, freeze-thaw occurrences are high, and storm duration of several days are very rare.

RUNOFF

Hydrology models that were run with standard curve number loss methodologies and time of concentration calculations resulted in high runoff values per square mile (CSM) as compared to those reported in the NRCS and McMillen study for nearby stream gages.

GIS mapping resulted in steep slopes averaging 58% across Basin 4.

The basins consist predominately of soils in the Group C Hydrologic Soil Group. As described in the "Soils," section of this report, these soils have a moderately high runoff potential.

In addition to our deterministic model approach, the United States Geological Survey (USGS) StreamStats modeling software was utilized as a more statistical approach in preparing a representative range of flows. Figure 5 and Figure 6 are model runs for Basin 4. The inputs are outside the recommended range for the Streamstats model, so errors are unknown. The 100-year event is estimated at approximately 56 cfs. Give the basin area of 0.6266 square miles, which is 89 CSM, which is far higher than the highest CSM from the stream gages analysis of about 40 CSM. Our uncalibrated deterministic models produced much higher flows.

High peak flows per unit area result in a recommended PSIAC scale rating of 7.

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Figure 5 - StreamStats Model Profile, Basin 4

Region ID:	UT
Workspace ID:	UT20180601193029344000
Clicked Point (Latitude, Longitude):	39.97627, -111.76224
Time:	2018-06-01 13:30:43 -0600

Basin Characteristics

Parameter Code	Parameter Description	Value	Unit
DRNAREA	Area that drains to a point on a stream	0.68	square miles
LU92HRBN	Percent Natural Herbaceous Upland from NLCD1992	1.6	percent

Annual Flow Statistics Parameters (Mean Flow SIR08 5230 Regions 3 and 5)

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.68	square miles	1.98	450

Annual Flow Statistics Disclaimers (Mean Flow SIR08 5230 Regions 3 and 5)

Figure 6 - StreamStats Model Results, Basin 4

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errorsOne or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errorsOne or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Annual Flow Statistics Flow Report (Mean Flow SIR08 5230 Regions 3 and 5)

Statistic	Value	Unit
Mean Annual Flow	0.994	ft^3/s

Annual Flow Statistics Citations

Wilkowske, C.D., Kenney, T.A., and Wright, S.J.,2009, Methods for Estimating Monthly and Annual Streamflow Statistics at Ungaged Sites in Utah: U.S. Geological Survey Scientific Investigations Report 2008-5230, 62 p.

Peak-Flow Statistics Parameters (Region 3)

Parameter Code	Parameter Name	Value	Units	Min Limit	Max Limit
DRNAREA	Drainage Area	0.68	square miles	0.91	629
LU92HRBN	Percent Nat Herb Upland from NLCD1992	1.6	percent	2.14	15.6

Peak-Flow Statistics Disclaimers (Region 3)

One or more of the parameters is outside the suggested range. Estimates were extrapolated with unknown errors

Peak-Flow Statistics Flow Report (Region 3)

Statistic	Value	Unit
2 Year Peak Flood	5.49	ft^3/s
5 Year Peak Flood	14.1	ft^3/s
10 Year Peak Flood	21.5	ft^3/s
25 Year Peak Flood	32.8	ft^3/s
50 Year Peak Flood	42.8	ft^3/s
100 Year Peak Flood	55.7	ft^3/s
200 Year Peak Flood	71	ft^3/s
500 Year Peak Flood	96	ft^3/s

TOPOGRAPHY

GIS mapping resulted in steep slopes averaging 58% across Basin 4.

United States Department of Agriculture (USDA) maps show Basin 4 as having three slope conditions. Some of the lower parts of the basin range from 25% to 40% slopes (soil type YaE). As you move up the canyon slopes range from 30% to 70% (soil type ShF), and the west facing slopes at the mouth of the canyon range from 35% to 70% (soil type HKG).

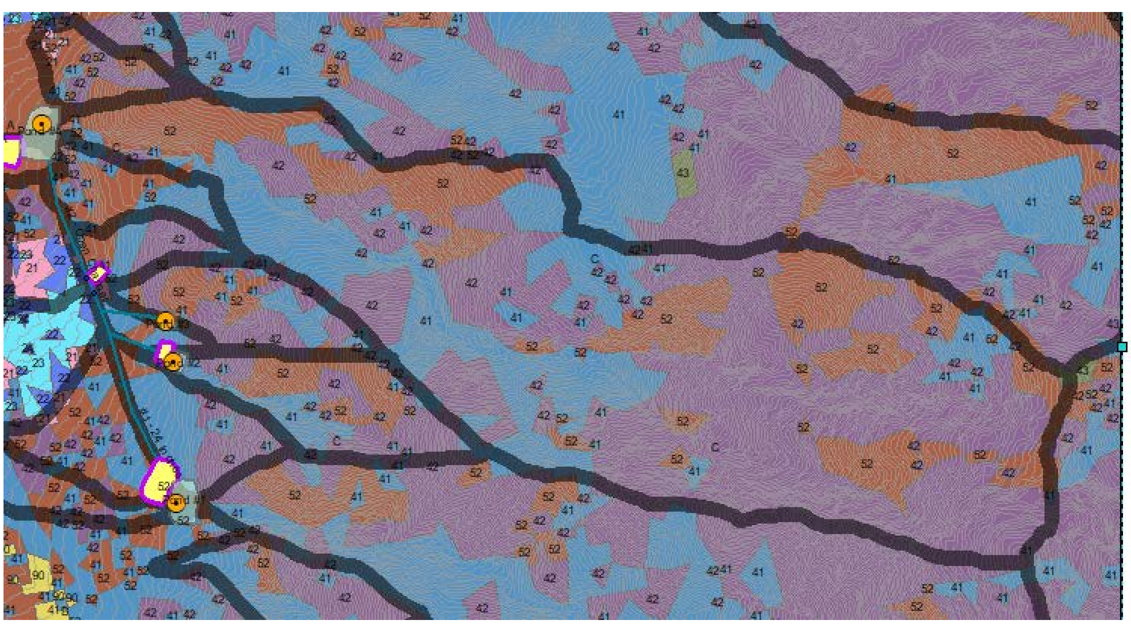
Extremely steep upland slopes and little or no floodplain development results in our recommending the maximum sediment contribution PSIAC scale factor of 20.

EFFECTIVE GROUND COVER

National Land Cover Database (NLCD) maps evaluated in GIS show three land cover types as shown in Figure 4. GIS data processing was able to evaluate each land cover type percentage based on area in Basin 4: 51% Evergreen Forest, 24% Deciduous Forest and 25% shrub/scrub.

- *Evergreen Forest* - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.
- *Deciduous Forest* - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.
- *Shrub/Scrub* - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Figure 7 - NLCD Land Cover Map, Basin 4



Using the information given combined with knowledge of the area gained from on-site observation, the total foliar cover estimation is 50% to 60% and total ground cover is 60% to 75%. Table 1 shows land cover type percentages derived from GIS mapping for all six basins.

Table 1 - Ground Cover Percentages

	Evergreen Forest	Deciduous Forest	Shrub/Scrub
Basin 1	65	29	6
Basin 2	48	23	29
Basin 3	41	29	30
Basin 4	51	24	25
Basin 5	28	44	18
Basin 6	60	26	11

Ground cover does exceed 20%; vegetation is not sparse; there is rock in surface soil cover; cover does exceed 40%; there is noticeable litter; trees are present but understory is not well developed; area is not completely protected by vegetation, rock fragments, litter; and there is moderate opportunity for rainfall to reach erodible material. Based on this description effective ground cover is given a PSIAC scale factor of -6.

LAND TYPE AND MANAGEMENT QUALITY

Observations obtained from field visits show Basin 4 to have no overgrazed area, no recent logging, no areas recently burned (this assumption is made due to the scope and time scale of this study), no badlands, and no roads cutting through this area. The recommended PSIAC sediment yield contribution scale factor is -8.

UPLAND EROSION

Observations obtained from field visits show Basin 4 to have much less than 25% of the area characterized by concentrated flow erosion with increasing gully development, but exhibiting some apparent signs of erosion. The recommended PSIAC sediment yield contribution scale factor is 4.

CHANNEL ERSOSION AND SEDIMENT TRANSPORT

Observations obtained from field visits show Basin 1 has some eroding banks at infrequent intervals, relatively shallow flow depths, minimal active headcuts, some degradation in tributary channels, no artificially controlled channels, rare channels in massive rock, occasional large boulders in the channel, channel banks with fair vegetation cover, and no wide channels with flat and short flow durations. This information collected results in PSIAC scale factor of 8.

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CONCLUSION

Surface geology, soils, climate, runoff, topography, effective ground cover, land type and management quality, upland erosion, and channel erosion / sediment transport are the nine contributing factors and are all input parameters needed in the evaluation process of the PSIAC method for sediment yield. Basin 4 is located in the middle of all the basins and was chosen to be used as an example of the evaluation process and is the only basin with information provided on the collection of input parameters. The same process for collecting input parameters was used for every basin. The resulting recommended parameters for each basin are shown in Table 2. Climate is applied over a large area covering all six basins and was assumed to be constant for every basin. Surface Geology, Soils, Topography, Land Type / Management Quality, Upland Erosion, and Channel Erosion / Sediment Transport were not considered constants but yielded similar data resulting in identical PSIAC scale factors for all six basins. All six basins are centrally located in consistent terrain, similar results were anticipated for these categories. Table 3 shows results for sediment yield derived from the PSIAC model in all six basins.

Table 2 - PSIAC Scale Factor Parameters

	Basin 1	Basin 2	Basin 3	Basin 4	Basin 5	Basin 6
Surface Geology	1	1	1	1	1	1
Soils	3	3	3	3	3	3
Climate	5	5	5	5	5	5
Runoff	5	3	3	7	6	5
Topography	20	20	20	20	20	20
Effective Ground Cover	-8	-6	-5	-6	-7	-6
Land Type / Management Quality	-8	-8	-8	-8	-8	-8
Upland Erosion	4	4	4	4	4	4
Channel Erosion / Sediment Transport	8	8	8	8	8	8

Table 3 - PSIAC Sediment Yield

Watershed Area	Sediment Yield (Ac-Ft/Sq-Mi/Yr)	Annual Yield (Ac-Ft)	50 Year Yield (Ac-Ft)
Basin 1	0.24	0.15	7.54
Basin 2	0.24	0.017	0.83
Basin 3	0.25	0.013	0.67
Basin 4	0.28	0.19	9.64
Basin 5	0.26	0.18	9.25
Basin	0.27	0.126	6.09

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Table 4 - PSIAC Model Evaluation Table

Pacific Southwest Interagency Committee Sediment Yield Procedure (PSIAC) - 1991 rev.					
Watershed:	SantaquinDB	**Square Miles:**	0.69	**Acres (sq mi * 640):**	442
Factor	**Discipline**		**PSIAC Rating**		**Points**
(a) Surface Geology	Geologist	Marine shales and related mudstones and siltstones	Rocks of Medium Hardness Moderately weathered Moderately fractured	Massive, hard formations	
		5	3	0	1
(b) Soils	Soil Scientist	Fine textured; easily dispersed; saline alkaline; high shrink swell characteristcis; single grain silt and fine sands	Medium textured soil	High percentage of rock fragments	
			Occasional rock fragements	Aggregated clays	
		Single grain silt and fine sands	Cliché layers	High in organic matter	
		10	5	0	3
(c) Climate	Local	Storms of several day's duration with short periods of intense rainfall	Storms of moderate duration and intensity	Humid climate with rainfall of low intensity	
		Frequent intense convective storms	Infrequent convective storms	Precipitation in form of snow	
				Arid climate, low intensity storm	
		Freeze-thaw occurrences		Arid climate; rare convective storms	
		10	5	0	5
(d) Runoff	Hydrologist	High peak flows per unit area	Moderate peak flows per unit area	Low peak flow per unit area	
		Large volume of flow per unit area	Moderate volume of flow per unit area	Low volume of runoff per unit area	
				Rare runoff events	
		10	5	0	7
(e) Topography	GIS Specialist	Steep upland slopes (in excess of 30%)	Moderate upland slopes (less than 20%)	Gentle upland slopes (less than 5%)	
		High relief; little or no floodplain development	Moderate fan or floodplain development	Extensive alluvial plains	
		20	10	0	20
(f) Effective Ground Cover	GIS Specialist	Ground cover does not exceed 20%	Cover not exceeding 40%	Area completely protected by vegetation, rock fragments, litter	
		Vegetation sparse; little or no litter	Noticeable litter		
		No rock in surface soil cover	If trees present, understory not well developed	Little opportunity for rainfall to reach erodible material	
		10	0	-10	-6
	Alternative Calculation	Alternative Calculation: Enter percent of surface covered by vegetation, litter and rock		Vegetation (%)	40
				Litter (%)	20
				Rock (%)	15
				Calculated Points	-6
(g) Land Type and Management Quality	GIS Specialist	Almost all of area overgrazed or historic overgrazing impacts still active	<50% of area overgrazed or with historic overgrazing impacts still active	No recent logging	
		All of area recently burned	<50% of area recently logged	Good grazing management or historic overgrazing impact under control	
		Roads in need of O&M or improved design	Ordinary road and other construction		
		Almost all of area is badlands with minimal armor	Almost all of area is badlands with 50% of area covered with armor	Badlands are totally armored	
		10	0	-10	-8
(h) Upland Erosion	Geologist	More than 50% of the area characterized by concentrated flow erosion with increasing gully development	About 25% of the area characterized by concentrated flow erosion with increasing gully development	No apparent signs of erosion	
		25	10	0	4
	Alternative Calculation		Percent of area with apparent erosion		10
				Calculated Points	4
(i) Channel Erosion and Sediment Transport	Geologist	Eroding banks, continously or at frequent intervals, with deep flow of long duration		Wide shallow channels with flat gradients and shor flow duration	
		Active headcuts and degradation in tributary channels	Moderate flow depths, medium flow duration with occasionally eroding banks or bed	Channels in massive rock, large boulders, or well vegetated	
				Articially controlled channels	
		25	10	0	8
				Subtotal (a) thru (g)	22
				Subtotal (h) thru (i)	12
				Grand total	34
				Soil Bulk Density (gram/cm3)	1.3
		Watershed:	SantaquinDB	**Sediment Yield (Ac ft/sq mi/year)**	0.28
		Acres:	442	**Sediment Yield (Tons/acre/year)**	0.86
				Total Sediment (Tons/year)	379

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APPENDIX – BRIDGES SEDIMENT YIELD MAP

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BRIDGES SEDIMENT YIELD MAP

INTRODUCTION

NRCS provided sediment yield maps of the Santaquin, Utah region shown in Figure 1 and Figure 2 (Bridges, 1973). This map is intended for analysis over very large areas and provided an approximation which supports data collected from other sources. The foothills above Santaquin are shown with a yield class of 4. Figure 2 shows the yield rate associated with this yield class as 0.2 to 0.5 acre-feet per square mile per year. The 80-20 marking indicating sheet versus rill erosion is consistent with our assumption of minimal rill erosion in the PSIAC method.

Figure 1 – NRSC Bridges Sediment Yield Map 4

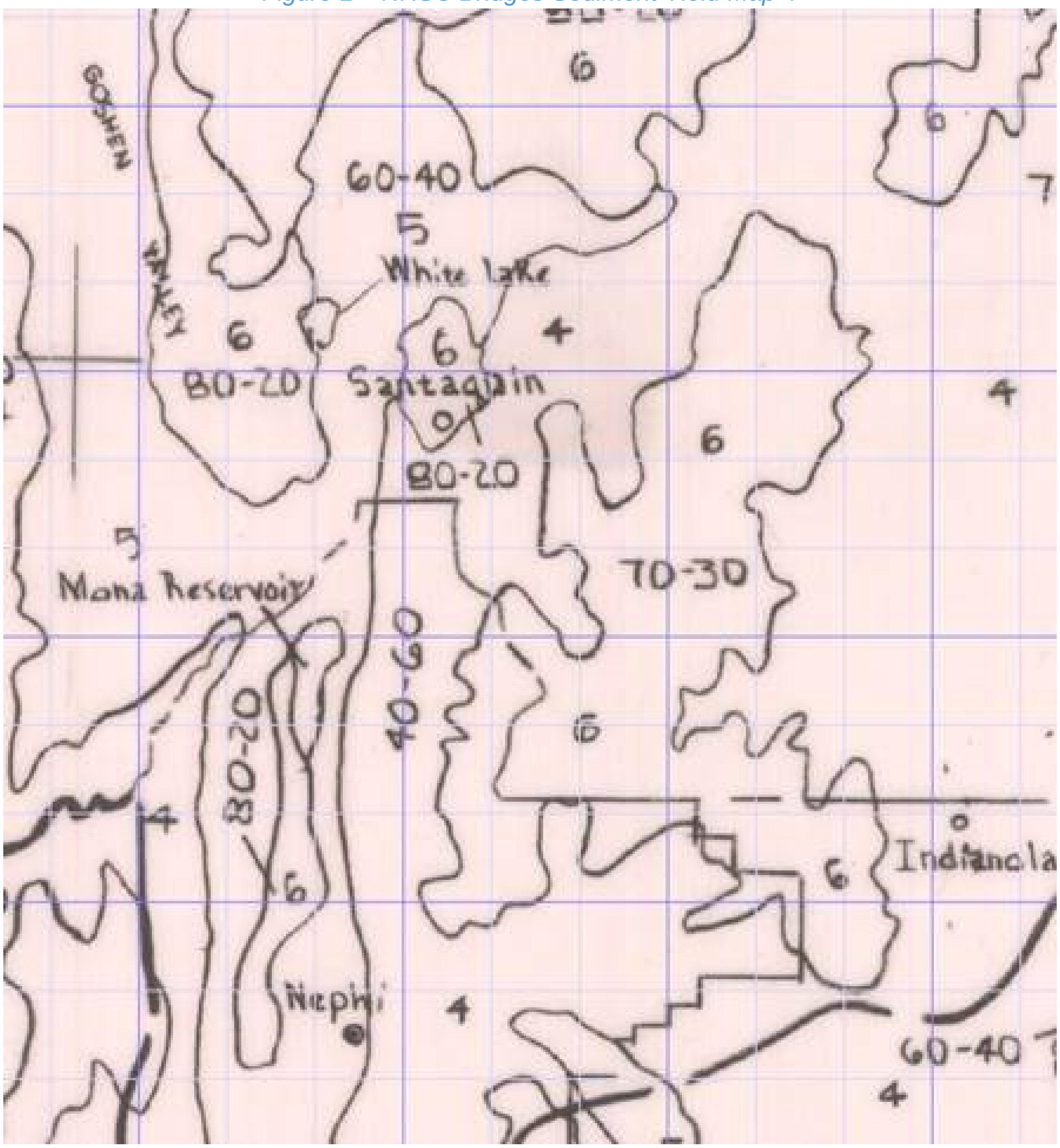

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Figure 2 – Trap Efficiency Calculations, Basin 4

- EXPLANATION -

Yield Class	Yield Rate 1/ (Ac.Ft/Sq.Mi/Yr.)	Total Area (Sq.Mi.)
1	> 3.0	____
2	1.0-3.0	____
3	0.5-1.0	____
4	0.2-0.5	____
5	0.1-0.2	____
6	< 0.1	____

▼ 0.45 Average annual suspended sediment yields determined from sediment transport records. Rates are in Ac.Ft/Sq.Mi/Yr.

80 - 20 ect. (Percent of sheet and rill erosion - Percent of channel and gully erosion.

Subregion Number	Subregions
6	Snake
[illegible]	Bear Lake
[illegible]	Great Salt Lake
[illegible]	Sevier Lake
[illegible]	Green River
[illegible]	San Juan - Colorado
[illegible]	Upper Main Stem
3	Lower Main Stem

1/ Do not use these rates to determine sediment yields at specific sites. Large variations in sediment rates may occur within the delineated areas.

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APPENDIX – TRAP EFFICIENCY CALCULATIONS

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TRAP EFFICIENCY CALCULATIONS

INTRODUCTION

NRCS Technical Memo No. 12 (1975) provides Figure 1 below to determine trap efficiency given a capacity/inflow (C/I) ratio. Tables 2 and 3 show the calculations used to determine the C/I ratio. The floodwater storage input was calculated from the volumes necessary to hold and pass the 100-year 24-hour storm as determined in our hydrology and hydraulic analysis, as discussed in the Hydraulics Technical Memo. The sediment yield used is the rate determined for each watershed in the Sediment Technical Memo. The curve number method was used to find the inflow volume from the precipitation depth (NEH-630, Ch. 10), utilizing an assumption that the event based runoff formula could be assumed to average out for all events throughout the year. This is likely a conservative assumption because on average precipitation in the form of snowmelt and in very small rainfall events has a greater chance to percolate. Separate volume and trap efficiencies are shown for different design life periods (25, 50, 75, and 100 years).

Figure 1 – USDA Trap Efficiency Graph, Basin 4

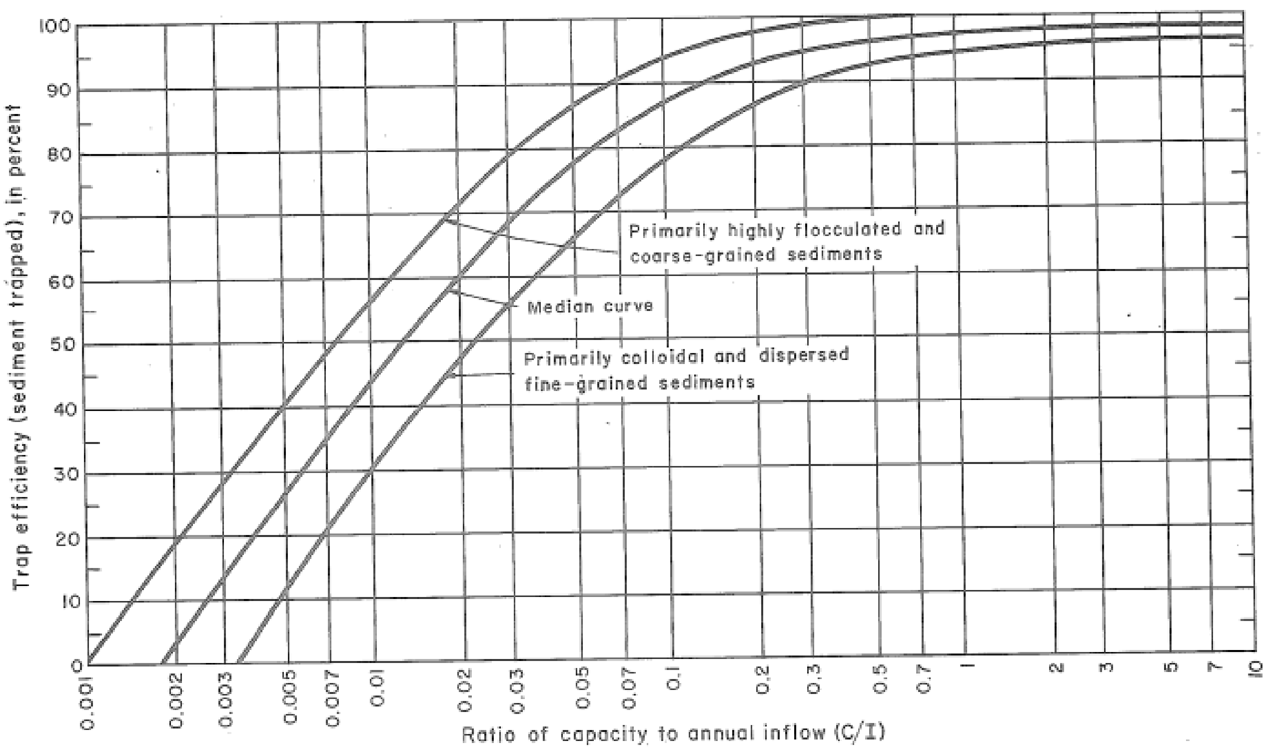

Figure 2. Trap Efficiency of Reservoirs

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Table 1 – Curve Numbers, Basins 1-6

	Curve Number (CN)
Basin 1	71.8
Basin 2	69.2
Basin 3	70.9
Basin 4	70.9
Basin 5	67.3
Basin 6	72.1

Table 2 – Trap Efficiency Calculations, Basin 1-3

Santequin Debri Basin 1												
Drainage Area	A. Capacity of Reservoir		1 --Sediment Storage				2 -- Flood Water		3 -- Sum of 1 and 2, Total Capacity	B. Average Annual Runoff		C. Divide B from A-3
sq. mi	acre-feet	inches	Acre feet/ year	years	acre feet total years	inches	acre-feet	inches	inches	Precip	inches	Capacity - Inflow (C/I) Ratio
0.63	20.51	0.61	0.15	25	3.75	0.112	16.76	0.500	0.61	20.3	16.24	0.038
0.63	24.26	0.72	0.15	50	7.5	0.224	16.76	0.500	0.724	20.3	16.24	0.045
0.63	28.01	0.84	0.15	75	11.25	0.34	16.76	0.500	0.836	20.3	16.24	0.051
0.63	31.76	0.95	0.15	100	15	0.448	16.76	0.500	0.948	20.3	16.24	0.058

Santequin Debri Basin 2												
Drainage Area	A. Capacity of Reservoir		1 --Sediment Storage				2 -- Flood Water		3 -- Sum of 1 and 2, Total Capacity	B. Average Annual Runoff		C. Divide B from A-3
sq. mi	acre-feet	inches	Acre feet/ year	years	acre feet total years	inches	acre-feet	inches	inches	Precip	inches	Capacity - Inflow (C/I) Ratio
0.07	1.59	0.43	0.01	25	0.25	0.068	1.34	0.365	0.43	20.3	15.79	0.027
0.07	1.84	0.50	0.01	50	0.5	0.136	1.34	0.365	0.501	20.3	15.79	0.032
0.07	2.09	0.57	0.01	75	0.75	0.20	1.34	0.365	0.570	20.3	15.79	0.036
0.07	2.34	0.64	0.01	100	1	0.273	1.34	0.365	0.638	20.3	15.79	0.040

Santequin Debri Basin 3												
Drainage Area	A. Capacity of Reservoir		1 --Sediment Storage				2 -- Flood Water		3 -- Sum of 1 and 2, Total Capacity	B. Average Annual Runoff		C. Divide B from A-3
sq. mi	acre-feet	inches	Acre feet/ year	years	acre feet total years	inches	acre-feet	inches	inches	Precip	inches	Capacity - Inflow (C/I) Ratio
0.05	1.27	0.45	0.01	25	0.25	0.088	1.02	0.360	0.45	20.3	16.09	0.028
0.05	1.52	0.54	0.01	50	0.5	0.177	1.02	0.360	0.537	20.3	16.09	0.033
0.05	1.77	0.63	0.01	75	0.75	0.26	1.02	0.360	0.625	20.3	16.09	0.039
0.05	2.02	0.71	0.01	100	1	0.353	1.02	0.360	0.713	20.3	16.09	0.044

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Table 3 – Trap Efficiency Calculations, Basin 4-6

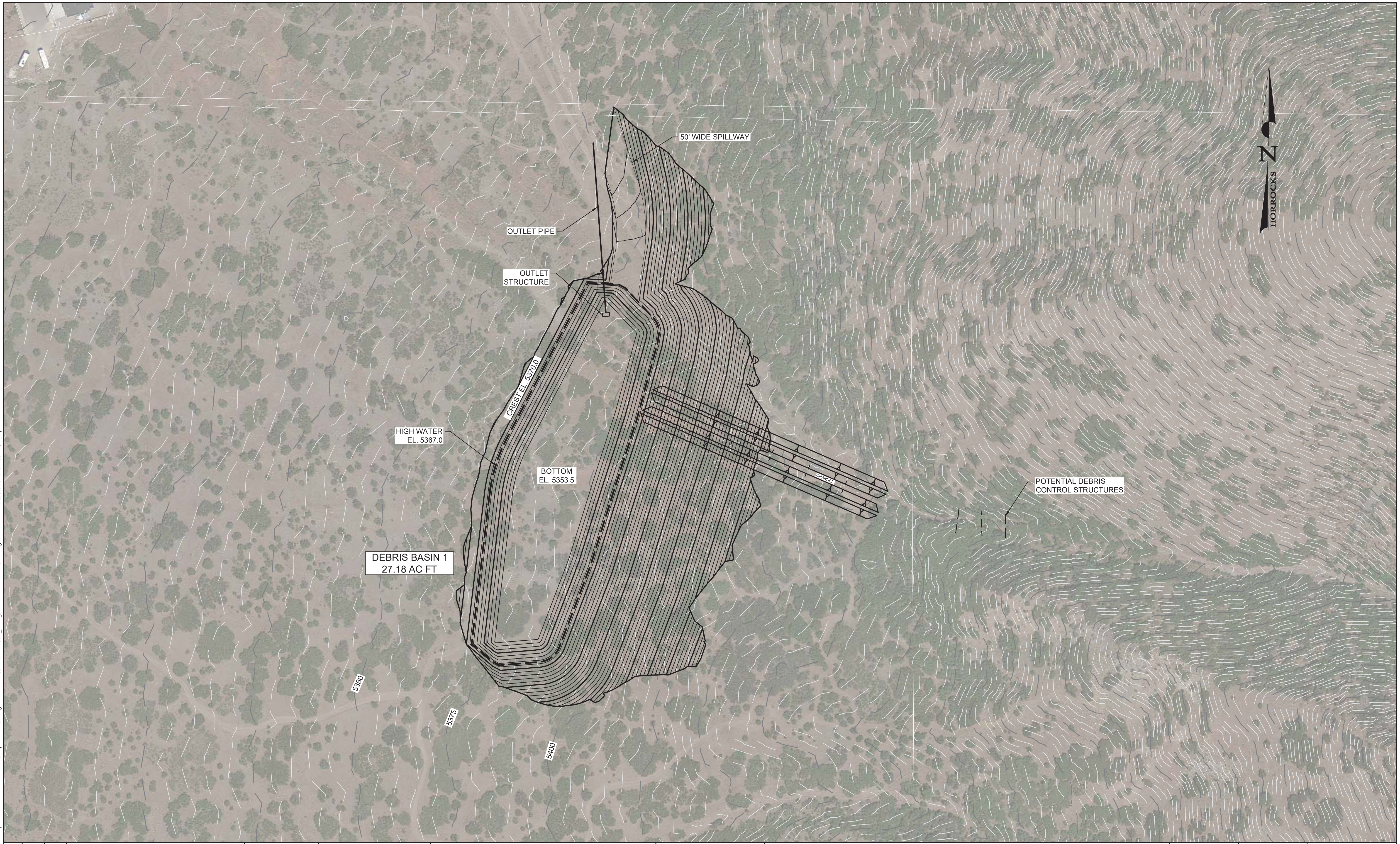
Santequin Debri Basin 4												
Drainage Area	A. Capacity of Reservoir		1 --Sediment Storage				2 -- Flood Water		3 -- Sum of 1 and 2, Total Capacity	B. Average Annual Runoff		C. Divide B from A-3
sq. mi	acre-feet	inches	Acre feet/ year	years	acre feet total years	inches	acre-feet	inches	inches	Precip	inches	Capacity - Inflow (C/I) Ratio
0.69	17.89	0.49	0.10	25	2.5	0.068	15.39	0.420	0.49	20.3	16.09	0.030
0.69	20.39	0.56	0.10	50	5	0.136	15.39	0.420	0.556	20.3	16.09	0.035
0.69	22.89	0.62	0.10	75	7.5	0.20	15.39	0.420	0.624	20.3	16.09	0.039
0.69	25.39	0.69	0.10	100	10	0.273	15.39	0.420	0.692	20.3	16.09	0.043
				6.8								

Santequin Debri Basin 5												
Drainage Area	A. Capacity of Reservoir		1 --Sediment Storage				2 -- Flood Water		3 -- Sum of 1 and 2, Total Capacity	B. Average Annual Runoff		C. Divide B from A-3
sq. mi	acre-feet	inches	Acre feet/ year	years	acre feet total years	inches	acre-feet	inches	inches	Precip	inches	Capacity - Inflow (C/I) Ratio
0.71	14.79	0.39	0.08	25	2	0.053	12.79	0.337	0.39	20.3	15.45	0.025
0.71	16.79	0.44	0.08	50	4	0.106	12.79	0.337	0.443	20.3	15.45	0.029
0.71	18.79	0.50	0.08	75	6	0.16	12.79	0.337	0.496	20.3	15.45	0.032
0.71	20.79	0.55	0.08	100	8	0.211	12.79	0.337	0.548	20.3	15.45	0.036

Santequin Debri Basin 6												
Drainage Area	A. Capacity of Reservoir		1 --Sediment Storage				2 -- Flood Water		3 -- Sum of 1 and 2, Total Capacity	B. Average Annual Runoff		C. Divide B from A-3
sq. mi	acre-feet	inches	Acre feet/ year	years	acre feet total years	inches	acre-feet	inches	inches	Precip	inches	Capacity - Inflow (C/I) Ratio
0.45	14.48	0.60	0.10	25	2.5	0.104	11.98	0.498	0.60	20.3	16.30	0.037
0.45	16.98	0.71	0.10	50	5	0.208	11.98	0.498	0.706	20.3	16.30	0.043
0.45	19.48	0.81	0.10	75	7.5	0.31	11.98	0.498	0.810	20.3	16.30	0.050
0.45	21.98	0.91	0.10	100	10	0.416	11.98	0.498	0.914	20.3	16.30	0.056

ATTACHMENT 4

CONCEPT DRAWINGS



PRELIMINARY NOT FOR CONSTRUCTION	SCALE	WARNING	HORROCKS ENGINEERS	2162 West Grove Parkway Suite 400 Pleasant Grove, UT 84062 (801) 763-5100	SANTAQUIN DEBRIS BASINS	DESIGNED ####	DATE ####	PROJECT NO. PG-1024-1801
REV / DATE / BY / DESCRIPTION	HORIZONTAL 1" = 150'	0 1/2 1				DRAWN ####	DATE ####	SHEET NO. # OF #
REVISIONS	VERTICAL N/A	IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE			BASIN 1 - BELOW GRADE	CHECKED ####	DATE ####	DRAWING NO. P-01

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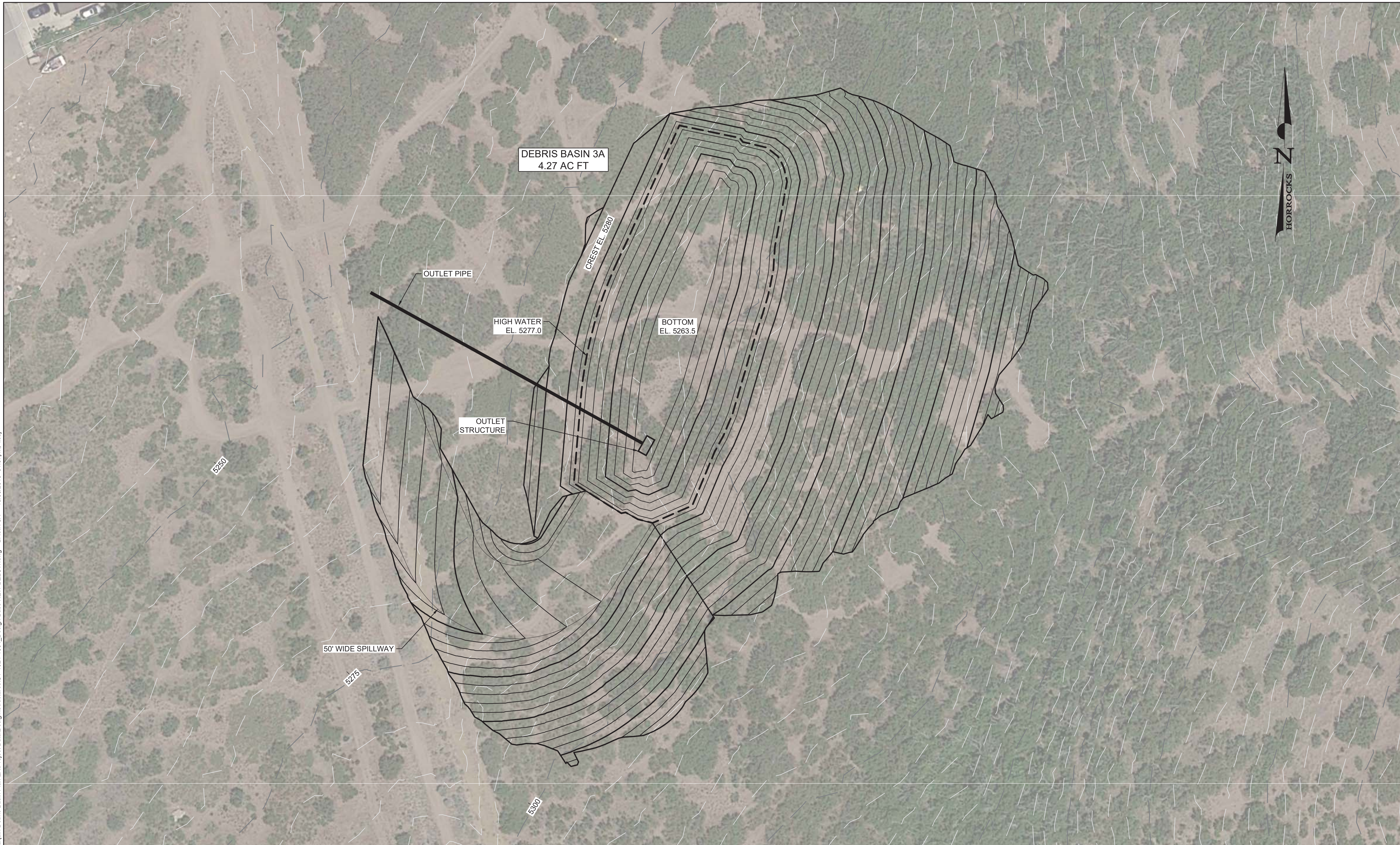

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REV / DATE / BY / DESCRIPTION	HORIZONTAL 1" = 60'	0 1/2 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE			BASIN 3A - BELOW GRADE (WATERSHEDS 2 & 3 COMBINED)	DRAWN ####	DATE ####	SHEET NO. # OF #
REVISIONS	VERTICAL N/A					CHECKED ####	DATE ####	DRAWING NO. P-05

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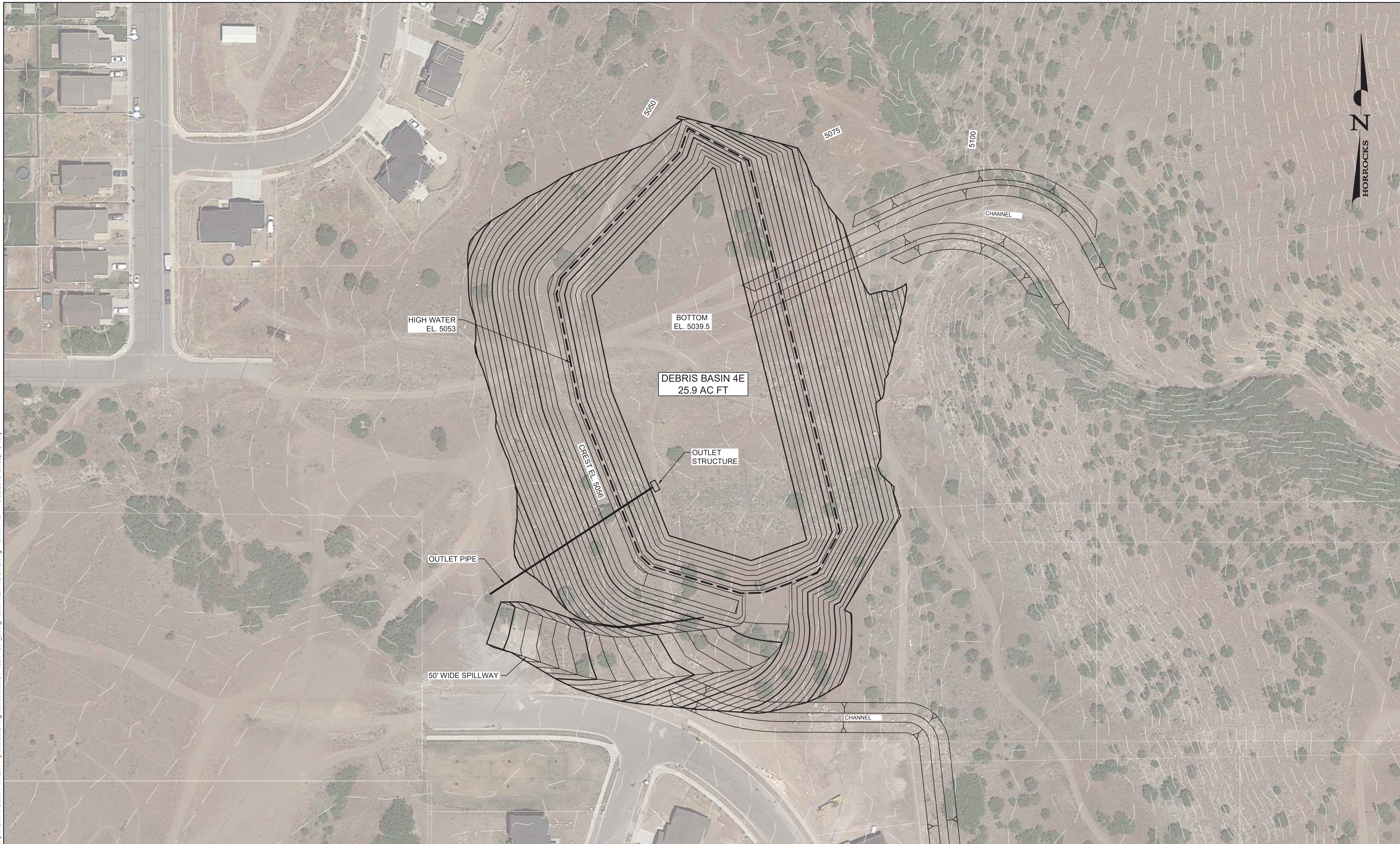

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REV DATE BY DESCRIPTION REVISIONS							PROJECT NO. PG-1024-1801 SHEET NO. 5 OF 12 DRAWING NO. P-05

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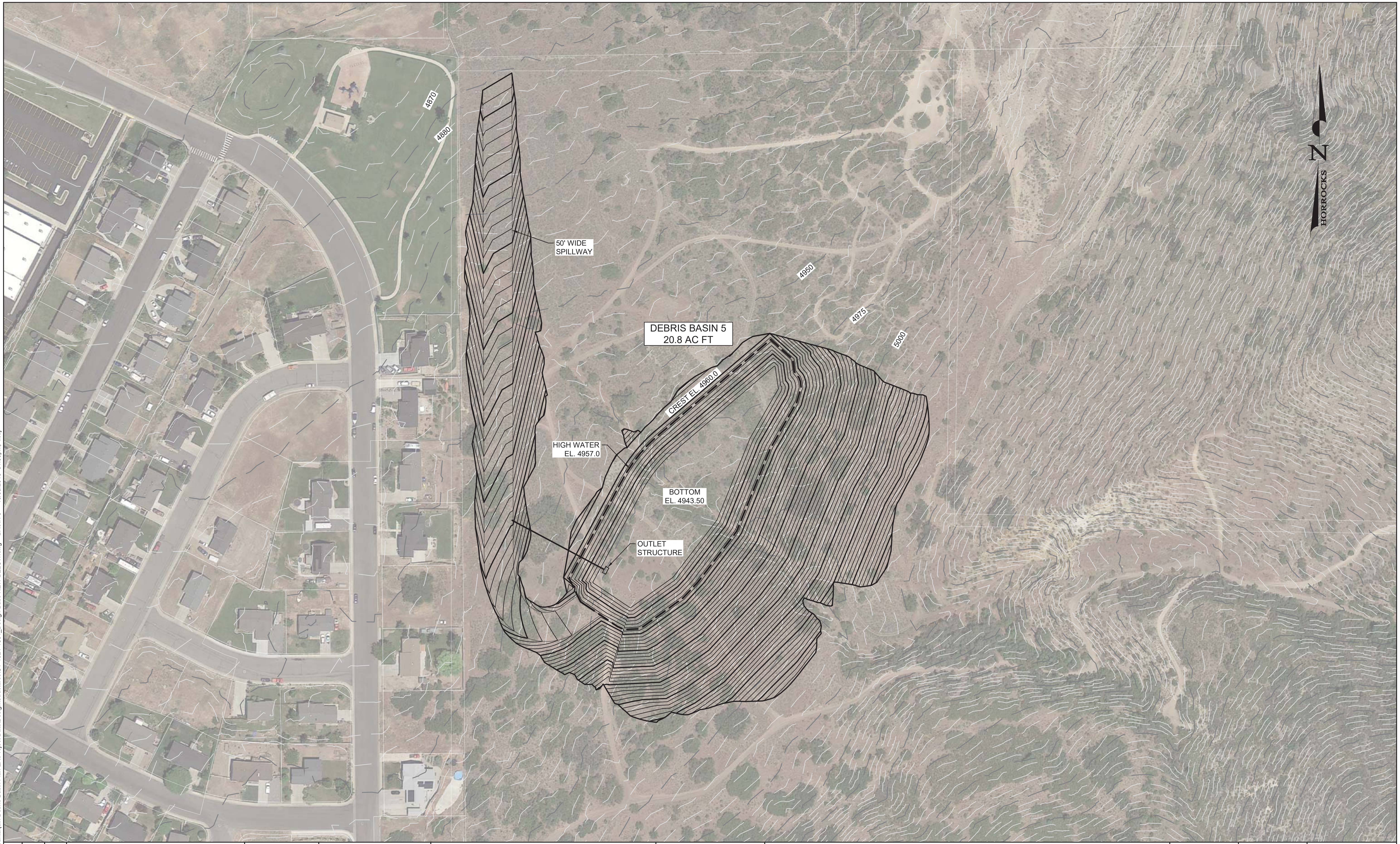

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CHECKED ####	DATE ####	DRAWING NO. P-12

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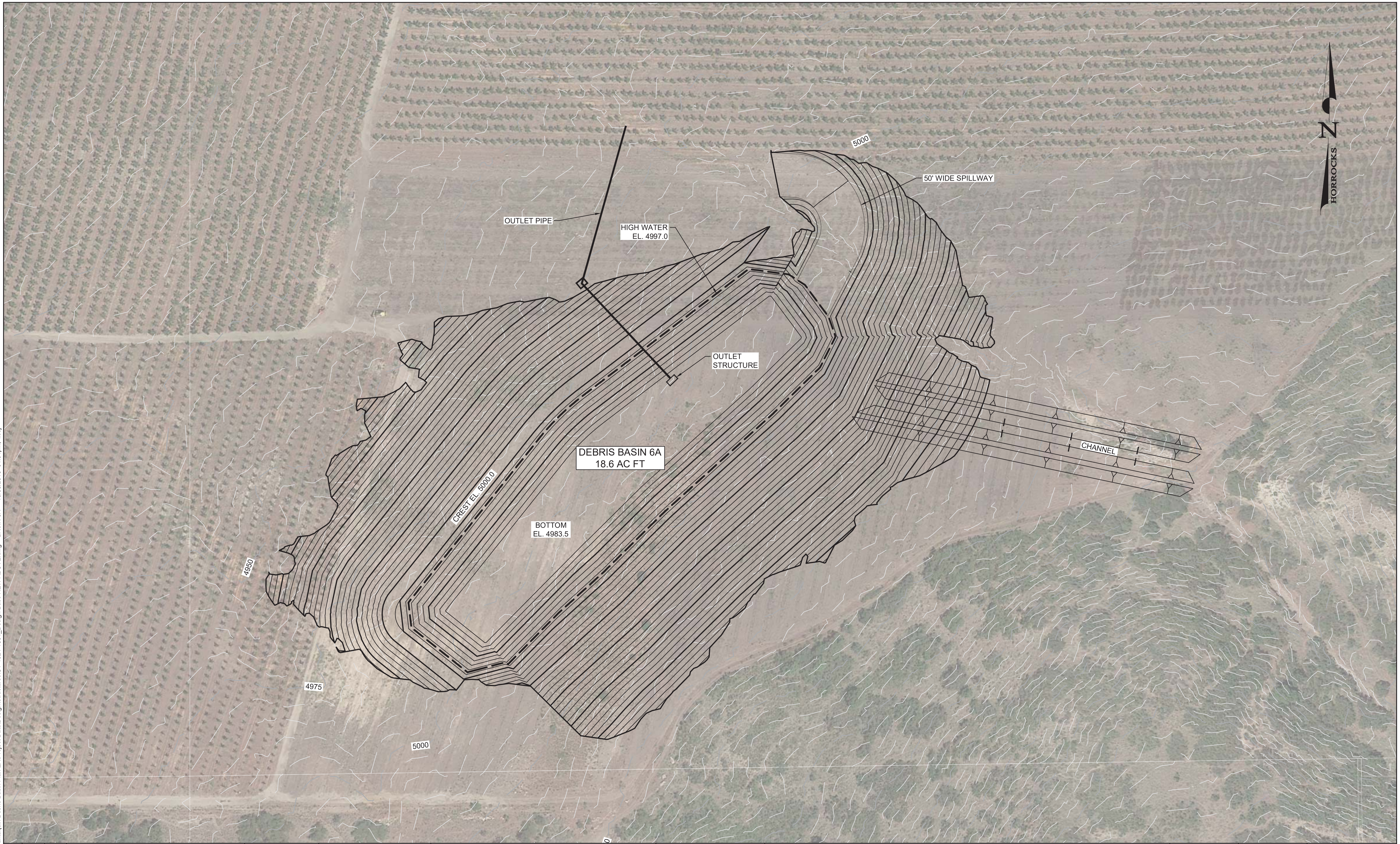

PRELIMINARY NOT FOR CONSTRUCTION REV / DATE / BY / DESCRIPTION REVISIONS	SCALE HORIZONTAL 1" = 100' VERTICAL N/A	WARNING 0 1/2 1 IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE	HORROCKS ENGINEERS	2162 West Grove Parkway Suite 400 Pleasant Grove, UT 84062 (801) 763-5100	SANTAQUIN DEBRIS BASINS BASIN 6A - ABOVE GRADE

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DRAWN ####	DATE ####	SHEET NO. # OF #
CHECKED ####	DATE ####	DRAWING NO. P-07

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ATTACHMENT 5

GEOTECHNICAL REPORT, PRELIMINARY SEISMIC ANALYSIS

GeoStrata

14425 South Center Point Way Bluffdale, Utah 84065
Phone (801) 501-0583 | Fax (801) 501-0584

Preliminary Feasibility Study for 5 Debris Basins
Santaquin, Utah

GeoStrata Job No. 320-013

August 3, 2018

Prepared for:

Horrocks Engineers, Inc.
Attn: Jacob O'Bryant, P.E.
2162 West Grove Parkway Suite 400
Pleasant Grove, Utah 84062

Learn More

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Prepared for:

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Attn: Jacob O'Bryant, P.E.
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Preliminary Feasibility Study for 5 Debris Flow Basins
Santaquin, Utah

GeoStrata Job No. 320-013

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August 3, 2018

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1.0 EXECUTIVE SUMMARY

The purpose of this investigation and report is to provide a preliminary assessment of the debris flow volume of six drainage basins located along the Wasatch Front in Santaquin, Utah in order to provide preliminary recommendations for the size, type and number of check dams that could be constructed within each drainage channel. The work performed for this report was performed in accordance with our proposal, dated April 19, 2018.

GeoStrata completed a site reconnaissance and test pit observations of the alluvial fan deposits on June 26, 2018. GeoStrata completed an additional site reconnaissance of Drainage 2 and Drainage 4 on July 18, 2018. Along with GeoStrata's field observations, geologic mapping of the study area (Solomon, 2010; Witkind and Weiss, 1991) was reviewed by GeoStrata as part of this investigation. Wasatch Front 2013-2014 0.5-meter LiDAR elevation data and 2006 5-meter DEM provided by the State of Utah AGRC were also assessed as part of this investigation to create cross sections along the drainage channels to assess the availability of soil that could ultimately trigger or contribute to a debris-flow event.

Preliminary analysis of the potential debris flow volumes was conducted using a bulking factor applied to the hydrology of each of the canyons and evaluating the available sediment within the channels. A description of the methodology and results of our preliminary analysis are presented is Section 6.0.

Prior to final design of the proposed hazard mitigation structures, a design level evaluation of each of the drainages addressed by this report should be conducted. Debris flow volumes presented in this report should be considered preliminary and should be refined with additional data from the channels in the canyons and from the alluvial fans.

Based on our preliminary engineering analysis of the proposed debris basin sites, the proposed locations are suitable for the proposed construction provided that design level geotechnical evaluations of each of the locations are performed and that recommendations from these studies are incorporated into the final design of the structures.

NOTICE: The scope of services provided within this report are limited to the assessment of the subsurface conditions for the proposed development. This executive summary is not intended to replace the report of which it is part and should not be used separately from the report. The executive summary is provided solely for purposes of overview. The executive summary omits a number of details, any one of which could be crucial to the proper application of this report.

2.0 INTRODUCTION

2.1 PURPOSE AND SCOPE OF WORK

The purpose of this investigation and report is to provide a preliminary assessment of the debris flow volume of six drainage basins located along the Wasatch Front in Santaquin, Utah in order to provide preliminary recommendations for the size, type and number of check dams that could be constructed within each drainage channel. The work performed for this report was performed in accordance with our proposal, dated April 19, 2018.

The recommendations presented by GeoStrata in this preliminary alluvial fan flood hazard report will be specific to the basins located in Santaquin, Utah that were evaluated for this report and are intended to provide geologic data necessary to design mitigation structures to increase the safety of the current and future residences on the alluvial fan associated with these basins.

Our scope of services for the debris-flow/alluvial fan flood hazard assessment for various drainage basins located in Santaquin, Utah included the following:

- Review of available references and maps of the area.
- Stereographic aerial photograph interpretation of aerial photographs covering the site area.
- Review of 2013-2014 0.5-meter LiDAR and 2006 5-meter DEM obtained from the State of Utah AGRC.
- Geologic reconnaissance of the site by an engineering geologist to observe and document pertinent surface features indicative of possible surface rupture fault hazards, alluvial fan flooding hazards or other geologic hazards.
- Subsurface investigation consisting of excavation of test pits on alluvial fans
- Sample collection of subsurface soils
- Laboratory testing:
    - Grain Size Distribution Analysis (ASTM D422)
    - Atterberg Limits Test (ASTM 4318)
- Preliminary assessment of geologic and geotechnical engineering conditions

The preliminary recommendations contained in this report are subject to the limitations presented in the Limitations section of this report.

2.2 PROJECT DESCRIPTION

The project site is located along the Wasatch Front Range in Santaquin, Utah (Plate A-1 Site Vicinity Map). The study area includes six drainage basins, Drainage 1 through Drainage 6, as identified on Plate A-2, Exploration Location Map. Construction of five detention basins are planned to mitigate the alluvial fan flooding hazard of the six drainage basins. Established residential developments are located on alluvial fan deposits and in the alluvial fan flooding paths of Drainage 1 through Drainage 5. An orchard field is located on the alluvial fan deposit and alluvial fan flooding path of Drainage 6.

3.0 GEOLOGIC CONDITIONS

3.1 GEOLOGIC SETTING

The study area and the location of the proposed mitigation structures are located at the base of the Wasatch Front Range in Santaquin, Utah. The geology of the mountains east of Santaquin range from Tertiary to Precambrian age. The bedrock in the Santaquin area has been uplifted and faulted during the Sevier Orogeny and later extensional faulting during late Eocene to middle Miocene. Santaquin is located in Utah Valley, a deep, sediment-filled structural basin of Cenozoic age flanked by uplifted blocks, the Wasatch Range on the east and the Spring Mountains and Western Mountains to the west (Hintze, 1980; Hintze, 1993). The Wasatch Range is the easternmost expression of pronounced Basin and Range extension in north-central Utah.

The near-surface geology of Santaquin is dominated by sediments which were deposited within the last 30,000 years by Lake Bonneville (Scott and others, 1983; Hintze, 1993; Crittenden and Sorensen, 1985). The lacustrine sediments near the mountain front consist mostly of gravel and sand. As the lake receded, streams began to incise large deltas formed at the mouths of major canyons along the Wasatch Range, and the eroded material was deposited in shallow lakes and marshes in the basin and in a series of recessional deltas and alluvial fans. Sediments toward the center of the valley are predominately deep-water deposits of clay, silt and fine sand. However, these deep-water deposits are in places covered by a thin post-Bonneville alluvial cover. Geologic maps of the study area are included with this report (Plate A-3a Site Vicinity Geologic Map; Plate A-4a Site Vicinity 30x60 Geologic Map).

The near-surface geology at the mouth of the drainage basins evaluated as part of this study are mapped by Solomon (2010) as Holocene to Pleistocene age alluvial fan deposits (Qafy, Qaf_{1-5}) overlying Pleistocene age deltaic deposits related to the transgressive phase of the Lake Bonneville cycle. Landslide and colluvial, undivided, deposits (Qmc) are mapped within the drainage basins and along the canyon walls. A Holocene to middle Pleistocene age alluvial and colluvial, undivided, deposit (Qac) is mapped at the base of Drainage 1. Bedrock outcroppings are mapped throughout each drainage basin.

3.2 TECTONIC SETTING

The study area is located on the generally west dipping bench along the western foothills of the Wasatch Mountain Range. The Nephi segment is the southernmost segment of the Wasatch fault zone and is mapped trending north and northwest through the study area. A steeply west dipping scarp or drastic drop in topography trends along the Nephi segment. The Nephi segment extends approximately 20 miles from its southern terminus in Nephi to its northern terminus at the Payson salient. Dry Mountain, Tithing Mountain, and Little Mountain are located south of Payson, Utah and mark the northern extent of the Nephi segment. The Nephi segment includes surface faulting along two strands, the northern strand bounded by Dry Mountain and a southern strand bounded by the Wasatch Range east of Juab Valley (DuRoss and McDonald, 2007). At a paleo-seismic trench excavated in 2005 along the northern strand of the Nephi segment, fault scarps between 10 and 13 feet high were exposed in late Holocene, less than 5,000 years old, alluvial fan deposits. Trench studies indicate that a surface fault rupture event along the northern strand of the Nephi segment has displacement of 10 feet within the last 500 years.

Analysis of the ground shaking hazard along the Wasatch Front suggests that the Wasatch Fault Zone is the single greatest contributor to the seismic hazard in the Salt Lake City region. Each of the faults listed above show evidence of Holocene-age movement and are therefore considered active.

4.0 METHOD OF STUDY

4.1 FIELD INVESTIGATION

Field investigations and observations used to assess the debris flow potential, probability and magnitude can be categorized into three areas of study (Giraud, 2005):

1. Channel Investigation – Studies of debris flows indicate that the majority of material/debris transported onto the alluvial fan comes from existing deposits within the defined drainage channel. The unit volume technique is commonly used to assign applicable debris yield rates (unit volume along distinct reaches of the channel) in order to approximate the potential debris volume.

2. Alluvial Fan Investigation – the thickness of debris deposits measured on the alluvial fan contribute to an understanding of past debris flow magnitude and potential run-out distance.

GeoStrata completed a site reconnaissance and test pit observations of the alluvial fan deposits on June 26, 2018. GeoStrata completed an additional site reconnaissance of Drainage 2 and Drainage 4 on July 18, 2018. Along with GeoStrata's field observations, geologic mapping of the study area (Solomon, 2010; Witkind and Weiss, 1991) was reviewed by GeoStrata as part of this investigation. Wasatch Front 2013-2014 0.5-meter LiDAR elevation data and 2006 5-meter DEM provided by the State of Utah AGRC were also assessed as part of this investigation to create cross sections along the drainage channels to assess the availability of soil that could ultimately trigger or contribute to a debris-flow event.

Six drainage channels were assessed as part of this investigation and aptly named Drainage 1 through Drainage 6. The location of the six drainage basins, test pit locations and profile cross section locations are shown on the Exploration Location Map Plate A-2.

The cross-sectional geometry of the channels within the drainages is variable. It was our objective to produce cross-sections that would be representative of the various geometries that exist in the main channels of the drainages. The following are the drainage basins in order from smallest to largest per area: Drainage 3, Drainage 2, Drainage 6, Drainage 1, Drainage 4 and Drainage 5. Tributary channels within all drainage basins exist but were not evaluated as part of this study. Each drainage is moderately to heavily vegetated within the channel and along the southern slopes of the drainage basins. Vegetation consists mainly of scrub oak and large brush.

A second site reconnaissance was conducted to further evaluate Drainage 2 and Drainage 4. A cross-section was collected in the field within Drainage 2 and Drainage 4 as shown on Plate A-2, Exploration Location Map. The GPS locations of these cross-sections were collected using a Trimble Handheld GeoXT. The cross-sections collected in the field were later compared to cross-sections derived from 2006 5-meter DEM and 2013-2014 0.5-meter LiDAR. Based on our comparison, the area calculated for each cross-section could have an error of ±30-ft^2 for cross-sections derived from 2006 5-meter DEM and ±0.5-ft^2 for cross-sections derived from 2013-2014 0.5-meter LiDAR.

In addition, volumes were calculated based on the assumption that the geometry of the channel remained unchanged along the designated lengths for each cross-section. Lastly, cross-sections were not calculated up the entire drainage due to lack of high resolution elevation data in these areas. The geometry of the final drawn cross-sections was assumed along the remaining length of the drainage. The estimations provided below are part of a preliminary assessment. A more in-depth study including cross-sectional data collected in the field is necessary prior to final design of mitigation structures. The following sections present results of our field and office investigations of the drainage basins assessed as part of this study. Cross section drawings of the channels are included in Appendix B (Plates B-1 to B-12).

4.3 DRAINAGE 1

Drainage 1 is approximately 408.4 acres (0.64 square miles) in size with a total defined channel length of approximately 7,068 feet. The properties of the main drainage channel are variable with some areas containing low to moderate amounts of stored debris and other areas with debris yield rates calculated to be approximately 385 f^3/ft. To estimate potential debris discharge volumes from Drainage 1, GeoStrata produced cross sections in 17 different locations within the drainage channel to estimate the amount of debris currently available for transport. Cross-sections for Drainage 1 were derived from the 2006 5-meter DEM. The approximate locations of profile cross-sections are shown on the Exploration Location Map (Plate A-2).

4.3 DRAINAGE 2

Drainage 2 is approximately 45.1 acres (0.07 square miles) in size with a total defined channel length of approximately 2,397 feet. The properties of the main drainage channel are variable with some areas containing very little debris (exposed bedrock) and other areas where debris yield rates have been estimated to be approximately 250 f^3/ft. To estimate potential debris discharge volumes from Drainage 2, GeoStrata produced cross section in 8 different locations within the drainage channel to estimate the amount of debris currently available for transport. Cross-sections for Drainage 2 were derived from of 2006 5-meter DEM. The approximate locations of profile cross-sections are shown on the Exploration Location Map (Plate A-2). Descriptions of the drainage basin and channel are summarized below.

The channel within Drainage 2 was observed to have shallow banks and to consist of rocks and cobbles approximately 250 feet from the mouth of the drainage. Bedrock exposure along the channel was observed approximately 1,700 feet up the drainage basin. Vegetation was observed to be moderately dense in the channel.

4.4 DRAINAGE 3

Drainage 3 is approximately 34.6 acres (0.05 square miles) in size with a total defined channel length of approximately 1,295 feet. The properties of the main drainage channel are variable with some areas containing low to moderate amounts of stored debris and other areas with debris yield rates calculated to be approximately 7.7 f^3/ft. To estimate potential debris discharge volumes from Drainage 3, GeoStrata produced cross sections in 7 different locations within the drainage channel to estimate the amount of debris currently available for transport. Cross-sections for Drainage 3 were derived from 2013-2014 0.5-meter LiDAR. The approximate locations of profile cross-sections are shown on the Exploration Location Map (Plate A-2).

4.5 DRAINAGE 4

Drainage 4 is approximately 445.8 acres (0.70 square miles) in size with a total defined channel length of approximately 3,828 feet. The properties of the main drainage channel are variable with some areas containing low to moderate amounts of stored debris and other areas with debris yield rates calculated to be approximately 10 f^3/ft. To estimate potential debris discharge volumes from Drainage 4, GeoStrata produced cross sections in 7 different locations within the drainage channel estimate the amount of debris currently available for transport. Cross-sections for Drainage 4 were derived from 2013-2014 0.5-meter LiDAR. The approximate locations of profile cross-sections are shown on the Exploration Location Map (Plate A-2). Descriptions of the drainage basin and channel are summarized below.

The channel within Drainage 4 was observed to have steep banks and a broad, flat channel bottom. Bank cuts were observed to range from approximately 6 to 12 feet high and the channel itself was observed to be broad and U-shaped. Bedrock exposure along the channel was observed at approximately 1,800 feet from the mouth of the drainage. A ramp lined with rip rap on the bottom of the channel to divert the direction of alluvial fan flooding was observed at the mouth of Drainage 4. Vegetation was observed to be moderately dense within the channel.

4.6 DRAINAGE 5

Drainage 5 is approximately 460.6 acres (0.72 square miles) in size with a total defined channel length of approximately 10,670 feet. The properties of the main drainage channel are variable with some areas containing low to moderate amounts of stored debris and other areas with debris yield rates calculated to be approximately 85 f^3/ft. To estimate potential debris discharge volumes from Drainage 6, GeoStrata produced cross sections in 14 different locations within the drainage channel to estimate the amount of debris currently available for transport. Cross-sections for Drainage 5 were derived from 2013-2014 0.5-meter LiDAR. The approximate locations of profile cross-sections are shown on the Exploration Location Map (Plate A-2).

4.7 DRAINAGE 6

Drainage 6 is approximately 292.6 acres (0.46 square miles) in size with a total defined channel length of approximately 5,699 feet. The properties of the main drainage channel are variable with some areas containing low to moderate amounts of stored debris and other areas with debris yield rates calculated to be approximately 112 f^3/ft. To estimate potential debris discharge volumes from Drainage 1, GeoStrata produced cross sections in 8 different locations within the drainage channel to more accurately estimate the amount of debris currently available for transport. Cross-sections for Drainage 3 were derived from 2013-2014 0.5-meter LiDAR. The approximate locations of profile cross-sections are shown on the Exploration Location Map (Plate A-2).

5.0 PRELIMINARY ALLUVIAL FAN INVESTIGATION

The preliminary alluvial fan investigation included the excavation, photographing and logging of six test pits on the alluvial fan deposits of each of the six canyons to observe the near-surface geology and assess the nature and extent of past alluvial fan flooding events across the alluvial fan surface. The logs of these Test Pits are presented on Plates C-1 through C-6. In general, the soils exposed in the test pit excavations consisted of alluvial fan flooding sediments ranging from fluvial to debris flow type deposits that extended the full depth. The approximate locations of the test pits are shown on the Exploration Location Map (Plate A-2). The alluvial fan geomorphology was also assessed using 2013-2014 0.5-meter LiDAR and 2006 5-meter DEM data provided by the State of Utah AGRC (Plate A-5). The following paragraphs provide detailed descriptions of conditions encountered in each test pit.

5.1 TEST PIT 1

Test Pit 1 was excavated approximately 10 feet deep. The log of the test pit that shows soil stratigraphy is included in Appendix C as Plate C-1. Test Pit 1 was excavated to a depth to expose alluvial fan sediments that would allow GeoStrata to assess the site for alluvial fan flooding hazard and to evaluate the soil suitability for the construction of a mitigation structure.

The uppermost soils exposed in Test Pit 1 were observed to be approximately 6 inches of A soil Horizon comprised of gravel, silt and sand. Underlying the A soil Horizon and in the upper 1½ to 2 feet were lenses of hyper-concentrated deposit, clast supported subangular pea gravel and gravels up to 2 inches with little to no fines, that were approximately 6 inches to 1 foot thick as shown on Plate E-1. Underlying the hyper-concentrated flows was a matrix supported, brown Silty, Clayey GRAVEL with sand and occasional subangular cobbles. Clasts within this unit were observed to be 2 inches and subangular. Fine roots were observed at a depth of approximately 2 feet into this unit.

5.2 TEST PIT 2

Test Pit 2 was excavated approximately 9 feet deep. The log of the test pit that shows soil stratigraphy is included in Appendix C as Plate C-2. Test Pit 2 was excavated to a depth to expose alluvial fan sediments that would allow GeoStrata to assess the site for alluvial fan flooding hazard and to evaluate the soil suitability for the construction of a mitigation structure.

The uppermost soils exposed in Test Pit 2 was observed to be approximately 6 inches of A soil Horizon. Underlying the A soil Horizon was a matrix supported, brown Silty SAND with gravel. Clasts in this unit were observed to be approximately 2 inches and subangular. A fluvial deposit consisting of Poorly Graded SAND approximately 6 inches thick was observed in the upper 2 ½ feet of this unit as shown on Plate E-2. The unit is comprised of dark-brown Silty SAND with gravel. Roots were observed to extend into the upper 2 feet of this unit.

5.3 TEST PIT 3

Test Pit 3 was excavated approximately 9 feet deep. The log of the test pit that shows soil stratigraphy is included in Appendix C as Plate C-3. Test Pit 3 was excavated to a depth to expose alluvial fan sediments that would allow GeoStrata to assess the site for alluvial fan flooding hazard and to evaluate the soil suitability for the construction of a mitigation structure.

The uppermost soils exposed in Test Pit 3 was observed to be approximately 6 inches of A soil Horizon comprised of gravel, silt and sand. A Silty, Clayey SAND with gravel was observed to underly the A soil Horizon and to extend the depth of the test pit. The upper 3 feet of this unit was observed to be heavily rooted and clast supported, hyper-concentrated to debris flow deposit, with few cobbles; clasts were observed to be subangular as shown on Plate E-3. The lower 6 feet of the test pit was observed to be matrix supported with subangular clasts approximately 2 inches in size.

5.4 TEST PIT 4

Test Pit 4 was excavated approximately 6 feet deep. The log of the test pit that shows soil stratigraphy is included in Appendix C as Plate C-4. Test Pit 4 was excavated to a depth to expose soils to evaluate the soil suitability for the construction of a mitigation structure and to observe potential alluvial fan sediments that would allow GeoStrata to assess the site for alluvial fan flooding hazard. The location of Test Pit 4 is located on the distil margins of the main alluvial fan deposit sourced by Drainage 4.

The uppermost unit in Test Pit 4 was observed to be approximately 6 inches of A soil Horizon. A Clayey GRAVEL with sand was observed to underlie the A soil Horizon and to extend the full depth of the test pit. This unit was observed to be matrix supported and to contain subangular clasts. Large subangular boulders approximately 2 to 3 feet in diameter were observed at the bottom of Test Pit 4.

5.5 TEST PIT 5

Test Pit 5 was excavated approximately 6 feet deep. The log of the test pit that shows soil stratigraphy is included in Appendix C as Plate C-5. Test Pit 5 was excavated to a depth to expose alluvial fan sediments that would allow GeoStrata to assess the site for alluvial fan flooding hazard and to evaluate the soil suitability for the construction of a mitigation structure.

The uppermost unit in Test Pit 5 was observed to be approximately 6 inches of A soil Horizon. The soils observed to underlie the A soil Horizon was observed to consist of a brown Well Graded GRAVEL with silt and sand and occasional cobbles up to approximately 8 inches in size. Clasts predominantly ranged from subangular pea gravel to 2 inches in size. Boulders approximately 1 foot in diameter and subangular were observed at the bottom of Test Pit 5.

5.6 TEST PIT 6

Test Pit 6 was excavated approximately 8 feet deep. The log of the test pit that shows soil stratigraphy is included in Appendix C as Plate C-6. Test Pit 6 was part of a sewer trench that was logged to allow GeoStrata to assess the site for alluvial fan flooding hazard.

The uppermost soils exposed in Test Pit 6 was observed to be approximately 6 inches of A soil Horizon. A matrix supported, brown Silty Gravel with sand and numerous large subangular cobbles up to approximately 2 feet was observed to underlie the A soil Horizon and to extend the full depth of the test pit. Roots were observed to extend approximately 3 feet into this unit.

5.7 LABORATORY TESTING

Geotechnical laboratory tests were conducted on selected soil samples obtained during our field investigation. The laboratory testing program was designed to evaluate the engineering characteristics of onsite earth materials. Laboratory tests conducted during this investigation include:

- Grain Size Distribution Analysis (ASTM D422)
- Atterberg Limits Test (ASTM D4318)
- Moisture Content of Soil Test (ASTM D2216)

The results of laboratory tests are presented on the test pit logs in Appendix C (Plates C-1 to C-6), the Lab Summary Report (Plate D-1), on the test result plates presented in Appendix D (Plates D-2 to D-4).

6.0 PRELIMINARY ESTIMATES OF DEBRIS VOLUME

The prediction of total debris and peak debris-flow volumes is complex and dependent on several factors. Precipitation (rainfall and snowmelt) data is readily available and the addition of moisture is generally viewed as a debris-flow trigger, but this represents only one of the many factors that contribute to debris-flow hazard. Vegetation, root depth, soil gradation, antecedent moisture conditions, and long-term climatic cycles all contribute to the generation of debris and initiation of debris-flows. Events of relatively short duration, such as a fire, can significantly alter a basin's natural resistance to debris-flow mobilization for approximately 5 years (Giraud and Castleton, 2009). These factors are difficult to quantify or predict and vary not only between different watersheds, but also within each sub-area of a drainage basin.

In general, there are two methods by which a debris-flow can be mobilized: 1) when shallow landslides from channel side-slopes are conveyed in existing channels when mixed with water and 2) channel scour where debris is initially mobilized by moving water in a channel and then the mobilized debris continues to assemble and transport downstream sediments. While methods of initiation differ, our observations of the drainage basins and channels lead us to assume that under existing conditions the majority of debris currently available for transport in the subject drainage basins would be mobilized from existing deposits within their developed channel beds and likely only in a post fire condition.

There are several methods available for predicting peak discharge rates and total debris flow volumes associated with debris-flows. The methods used in our preliminary analysis for this investigation are discussed below. Results of each of the methods of analysis are presented in the table below.

Method 1

Analysis of the hydrology of the canyons was performed by the project Civil Engineer (Horrocks) to provide peak flow and total flow data in order to calculate potential debris flow volumes. Stream flow is considered to be debris flow when the concentration by volume of sediment is between 40% and 85% (Keaton, et al., 1991). In order to calculate debris flow volumes, we assumed a 75% bulking rate, meaning that of the total rainstorm runoff, a volume of sediment equal to 3 times the volume of water may be mobilized.

Method 2

The unit-volume analysis method involves measuring and estimating the stored erodible sediment in the channel. Cross-sections are taken at various points along a channel and the geometry of the channel is used to estimate the sediment stored in the channel (Giraud, 2005). Estimating channel sediment volume available for bulking is critical because study of historical debris flows indicates that 80% to 90 % of the debris flow volume comes from the channel (Bowman and Lund, 2016).

All of the cross sections were developed utilizing 0.5-meter Wasatch Front LIDAR Elevation Data 2013 to 2014 and 2006 5-meter DEM data from the National Elevation Data Set. Available debris was estimated from field observations and measurements collected in the vicinity of those cross sections. General descriptions of these cross sections are contained in Section 4 of this report. Debris yield at these cross-sections was then extrapolated beyond investigation locations in order to approximate the potential debris yield for each of the drainages.

Considering alluvial fan flooding event that mobilizes 75% of the sediment stored in the channels and a 25-year burned condition storm event with water runoff volumes as provided by the Civil Engineer for each of the canyons, the table below presents estimated debris flow volumes for each of the subject canyons.

Drainage Basin	Method 1		Method 2		Estimated Total Debris Flow Volume (ac-ft)
	25-yr Burned Condition Runoff Volume (ac-ft)	Estimated Debris Flow Volume (ac-ft)	Estimated Available Streambed Sediment (ac-ft)	Estimated Debris Flow Volume (ac-ft)	
1	10.7	42.8	17.2	23.6	23.6
2	0.9	3.6	6.0	5.4	3.6
3	0.8	3.2	0.3	1.0	1.0
4	10.8	43.2	2.4	12.6	12.6
5	7.8	31.2	9.1	14.6	14.6
6	7.9	31.6	12.7	17.4	17.4

7.0 PRELIMINARY HAZARD MITIGATION RECOMMENDATIONS

7.1 PREFERRED MITIGATION

Methods for reducing debris-flow hazards in order of diminishing effectiveness are: 1) avoidance, 2) source area stabilization, 3) transportation-zone modification and 4) defense measures in the depositional zone (Hungr and others, 1987). Owing to the difficulties associated with equipment and personnel access which would accompany mitigation within the steep mountain drainages (methods 2 and 3) GeoStrata is providing only recommendations for defenses within the depositional zone (the alluvial fan). Other methods, if employed in the source areas and transportation zones within the canyon could further reduce the debris-flow hazard and may be explored if desired. However, this report assumes that mitigation measures will not be constructed within the canyon prior to completion of defense measures within the depositional zone.

Prior to final design of the proposed hazard mitigation structures, a design level evaluation of each of the drainages addressed by this report should be conducted. Debris flow volumes presented in this report should be considered preliminary and should be refined with additional data from the channels in the canyons and from the alluvial fans.

7.2 DEBRIS BASINS

Alluvial fan flooding defenses for the depositional zone recommended in this report may be generally categorized as retention within the depositional zone. Because of the unpredictability of alluvial fan flooding movements within the depositional zone it is generally preferable to locate retention structures as near to the fan apex as possible. Deflection berms or retention structures located to protect individual structures/facilities are useful but will leave other areas of the deposition zone unprotected if and when the alluvial fan flooding creates its own run-out path. In order to provide protection from the potential alluvial fan flooding hazard associated with the various canyons, we recommend that a debris retention basin be constructed as near as possible to the mouth of each canyon and that a spillway and channel be designed and constructed for diversion/direction of flood water flows.

In order to protect existing and proposed development below the canyons, debris detention/retention basins should be designed and constructed to capture and retain the debris flow volumes anticipated to flood flows from each of the canyons.

Based on these results, we recommend that preliminary design of debris detention/retention basins at the mouths of each canyon consider a storage volume of at least the volumes listed in the above table. Some risk associated with this size debris detention/retention basin does exist if a storm event larger than the 25-year burned condition storm event considered in this report were to occur while the canyons were in a post fire condition. Debris detention/retention basins with smaller storage volumes could also be designed with a higher level of risk associated with the smaller storage capacity of the debris detention/retention basins. The final constructed basins should incorporate appropriate outlet works and undergo regular maintenance to preserve design storage capacity. If constructed above grade it becomes a regulated dam and must be designed according to the requirements of the Utah Division of Water Rights, Dam Safety Division. If the basin can be constructed without an embankment (entirely below grade) it will not be regulated by Dam Safety. It is our opinion that debris basin dams can likely be located at or near the mouths of each of the canyons. No geologic or geotechnical features were identified at these locations that would preclude construction of the proposed dams.

Final design of detention/retention structures should consider design guidelines by Prochska, Santi, and Higgins (2008).

7.2 DIVERSION STRUCTURES

As the proposed location of the debris basin for Drainage 4 is located on the distal margins of the main alluvial fan for the canyon, diversion structures will be required to direct debris and flood runoff to the proposed debris basin. Following the debris flows that occurred as a result of the 2002 fire, a diversion berm was constructed to direct flows away from a residential subdivision.

As part of a design level study, an evaluation of the diversion berm should be performed to verify compliance with design guidelines by Prochska, Santi, and Higgins (2008).

8.0 PRELIMINARY ENGINEERING RECOMMENDATIONS

In order to evaluate the engineering properties of the existing soils in the vicinity of the proposed debris basins, a test pit was excavated in the approximate location of proposed debris retention/detention structures. A description of each of the test pits excavated and subsurface conditions encountered in each test pit is presented in Section 5.0 of this report and the test pit locations are shown on Plate A-2, Exploration Location Map.

Deeper subsurface investigations will be required in order to assess excavatability of subsurface soils if basins are to be constructed below the existing site grade or to assess bearing capacity of the subsurface strata if embankments are to be constructed above the existing site grade. Test pits TP-1, TP-2, TP-3, TP-5, and TP-6 were able to be excavated to depths requested for this preliminary investigation with a rubber-tired backhoe while digging was difficult and refusal was encountered in test pit TP-4 on either bedrock or large boulders.

We consider the likelihood of a seismic event occurring while one of the debris basins is loaded to be very low; therefore, seismic design of a fully loaded basin will not be required; however, the Nephi section of the Wasatch Fault Zone lies in close proximity to the proposed debris basin locations. We recommend that an evaluation of the proximity of the fault to each of the proposed debris basin locations be performed as fault rupture could impact the stability and performance of the debris basin embankments/slopes. A preliminary fault study should include examining the footprint of the proposed debris basins compared to the mapped location of the Nephi section of the Wasatch Fault Zone to determine whether further studies will be required, including trenching within the footprint of the proposed debris basins, to clear the sites of faults and/or identify the locations of faults. All fault studies should be completed by a licensed Professional Geologist.

A design level geotechnical investigation should be performed for each of the proposed debris basins including boreholes to sufficient depth to evaluate excavatability and bearing capacity of the subsurface soils, soil strength testing, soil permeability testing, slope stability analysis of proposed cuts and fills, foundation soil bearing capacity, and identification of borrow areas for proposed embankments (as needed).

Based on our preliminary engineering analysis of the proposed debris basin sites, the proposed locations are suitable for the proposed construction provided that design level geotechnical evaluations of each of the locations are performed and that recommendations from these studies are incorporated into the final design of the structures.

9.0 CLOSURE

9.1 LIMITATIONS

Despite the best efforts to quantitatively assess debris-flow hazards, estimating design parameters including peak flows and the subsequent design of mitigation measures has practical limits. As stated by Giraud (2005) “historical records of debris-flows have shown the flows to be highly variable in terms of size, material properties, and travel and depositional behavior.” Predicting the depth of flow, super-elevation, impact forces and location of critical sections should be considered best estimates of intricate natural processes.

The conclusions and recommendations contained in this report which include professional opinions and judgments, are based on the information available to us at the time of our exploration, the results of our field observations, our limited subsurface exploration and our understanding of the proposed site development. The subsurface data used in the preparation of this report were obtained from the explorations made for this investigation. If any conditions are encountered at this site that are different from those described in this report, our firm should be immediately notified so that we may make any necessary revisions to recommendations contained in this report. In addition, if the scope of the proposed mitigation project changes from that described in this report, our firm should also be notified.

This report was prepared in accordance with the generally accepted standard of practice at the time the report was written. No other warranty expressed or implied is made. Development of property on or in the vicinity of alluvial fans involves a certain level of inherent risk.

This report was written for the exclusive use of the above Client and only for the proposed project described herein. It is the Client's responsibility to see that all parties to the project including the Designer, Contractor, Subcontractors, etc. are made aware of this report in its entirety. GeoStrata is not responsible for the technical interpretations by others of the information described or documented in this report.

10.0 REFERENCES CITED

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Appendix A

Legend

Drainage Basins

0 625 1,250 2,500 3,750 5,000 Feet

1 inch = 2,000 feet

Basemap:
2009 1 meter NAIP aerial imagery and hillshades derived from 5 meter Auto-Corrected DEM provided by the State of Utah AGRC.

N

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Geologic Hazards Assessment
Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number: 320-013

Site Vicinity Map

Plate A-1

Legend

Drainage Basins

Approximate Test Pit Location

Cross Section

Feet
0 475 950 1,900 2,850 3,800

1 inch = 1,500 feet

Basemap:
2009 1 meter NAIP aerial imagery and hillshades derived from 5 meter Auto-Corrected DEM provided by the State of Utah AGRC.

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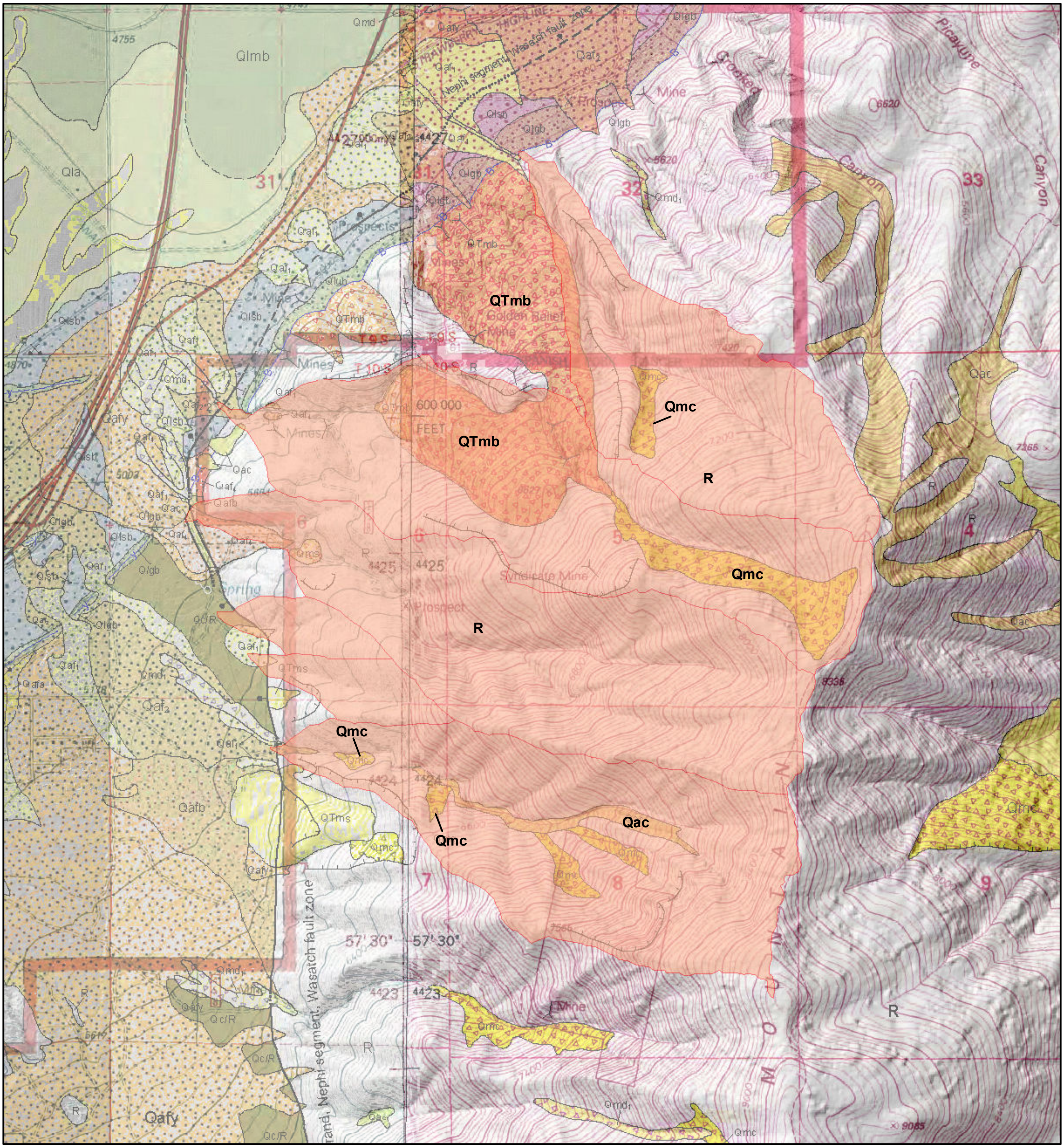
Santaquin, Utah
Project Number: 320-013

Exploration Location Map

Plate A-2



Legend

Drainage Basins

0 625 1,250 2,500 3,750 5,000 Feet

1 inch = 2,000 feet

Basemap:
Interim Geologic Map of Unconsolidated Deposits in the Payson Lakes Quadrangle, Utah County, Utah, Solomon, 2010, Interim Geologic Map of the Santaquin Unconsolidated Deposits in the Payson Lakes Quadrangle, Utah County, Utah, Solomon, 2010 and hillshades derived from 5 meter Auto-Corrected DEM provided by the State of Utah AGRC.

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Horrocks Engineers
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Project Number: 320-013

Site Vicinity Geologic Map

Plate A-3

R **Rock** (Tertiary to Precambrian) – Mapping of bedrock structure and stratigraphy is beyond the scope of this project. Hintze (1962) and Witkind and Weiss (1991) compiled geologic maps of the region that include the Santaquin quadrangle at respective scales of 1:125,000 and 1:100,000, providing valuable overviews of regional geology, although many questions remain regarding stratigraphic relationships and geologic structure. For more information, refer to these maps as well as others cited in the Previous Investigations section of this report. According to these maps, Cretaceous and Tertiary rocks are most common on the east side of Warm Springs Mountain and near Santaquin Canyon; Paleozoic rocks are most common on Goshen Hill, the northern end of Dry Mountain, the west side of Warm Springs Mountain, and in the mountains west and east of Juab Valley; and Precambrian rocks are most common at the base of the western side of Dry Mountain.

QTmb **Megabreccia deposits** (Pleistocene to Pliocene?) – Includes large bedrock blocks, rubble, and younger Quaternary landslide deposits too small to map separately; bedrock blocks are comprised largely of Paleozoic quartzite, dolomite, and limestone on the northwest margin of Dry Mountain, east of Santaquin; mapped by Demars (1956), Hintze (1962), and Witkind and Weiss (1991) as highly faulted and deformed bedrock, but a prominent arcuate main scarp lies to the east of the deposit, which has a more subdued upper surface than surrounding bedrock and lies in an amphitheater at least 150 feet (45 meters) below the scarp; displacement of the deposit is thought to have started in the late Tertiary (possibly Pliocene) and continued intermittently during the Pleistocene as movement along the Wasatch fault zone uplifted the range front relative to the valleys. Thickness as much as 200 feet (60 m).

Qmc **Landslide and colluvial deposits, undivided** (Holocene to middle Pleistocene) – Deposits of landslides (slides and slumps), slopewash, and soil creep that grade into one another in areas of subdued morphology, where mapping colluvium separately from landslides is not possible at map scale; composition and texture depend on local sources; mapped in scattered areas of the Wasatch Range. Thickness less than 40 feet (12 m).

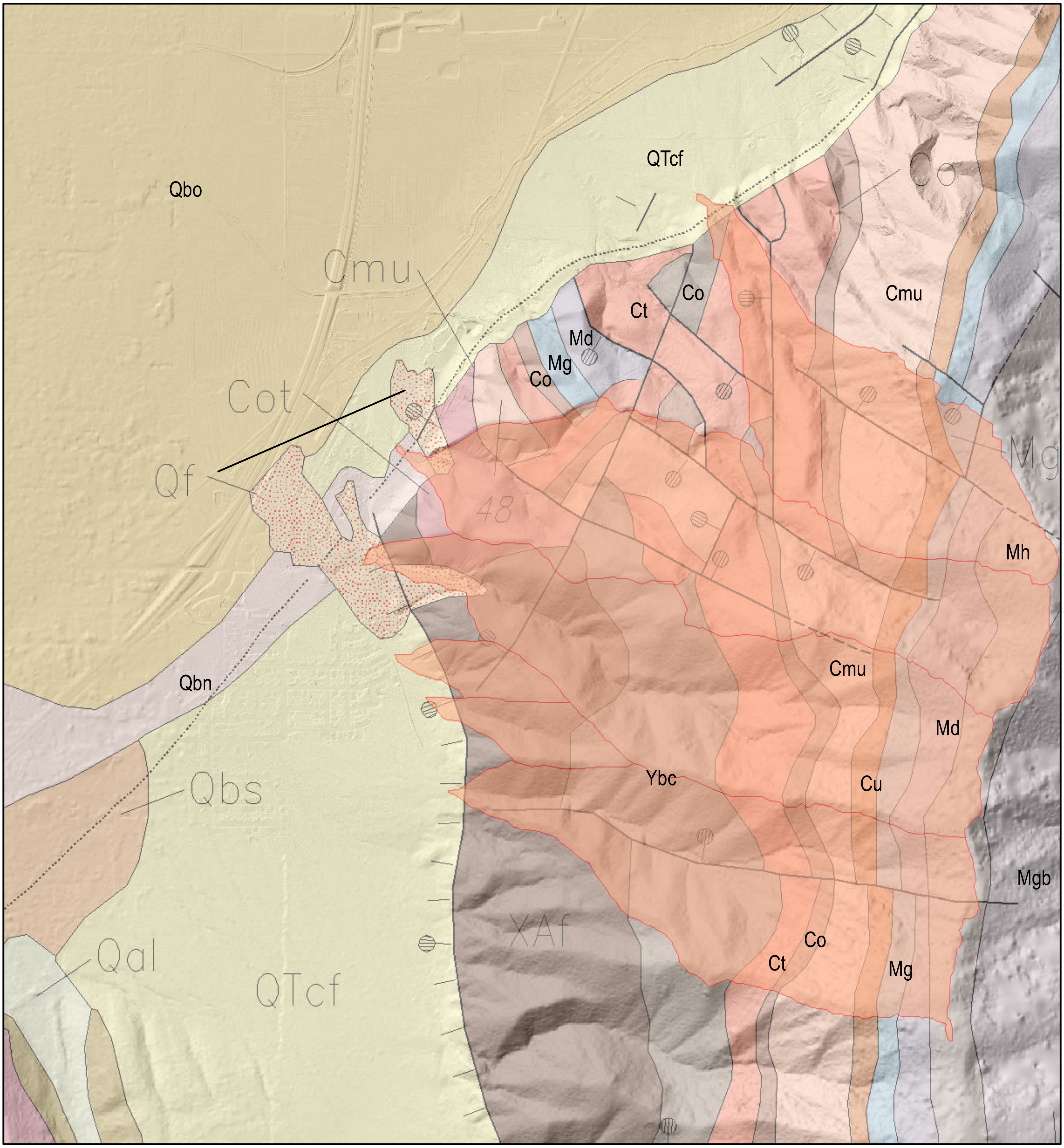
Qac **Alluvial and colluvial deposits, undivided** (Holocene to middle Pleistocene) – Poorly to moderately sorted, generally poorly stratified, clay- to boulder-size, locally derived sediment mapped in drainages scattered throughout the quadrangle that are in bedrock or are underlain by bedrock at shallow depths beneath a veneer of Quaternary deposits, where deposits of alluvium, slopewash, and creep grade into one another; small, unmapped deposits are likely in most small drainages. Thickness less than 10 feet (3 m).

GeoStrata

Geologic Hazards Assessment
Horrocks Engineers
Santaquin, Utah
Project Number: 320-013

Site Vicinity Geologic Map Unit Descriptions

Plate A-3a



Legend

Drainage Basins

0 625 1,250 2,500 3,750 5,000 Feet

1 inch = 2,000 feet

Basemap:
Geologic Map of the Ne[hi 30' x 60' Quadrangle, Carbon, Emery, Juab, Sanpete, Utah, and Wasatch Counties, Utah, Witkind and Weiss, 1991. Hillshades derived from 5 meter Auto-Corrected DEM provided by the State of Utah AGRC.

N

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Site Vicinity 30x60 Geologic Map

Plate A-4

Mgb

Great Blue Limestone (Upper Mississippian)—Light-bluish-gray to bluish-gray limestone and some shale. The limestone is chiefly thick bedded to massive and has been much fractured. About 91 m (300 ft) thick

Md

Deseret Limestone (Upper and Lower Mississippian)—Dark-bluish-gray, thin-bedded limestone that contains abundant interlayered lenticular thin beds of black chert. Chert is characteristic and is found wherever the formation is exposed. Limestone is commonly medium to coarsely crystalline. A few thin shale beds are near base. Includes minor interbedded dolomite. Thickness ranges from 183 to 275 m (600–900 ft) (Rigby and Clark, 1962, p. 19)

Mg

Gardison Limestone (Lower Mississippian)—Dark-bluish-gray, thin-bedded fossiliferous limestone containing minor interleaved dolomite. Highly fossiliferous beds are characteristic. Contains abundant black and light-gray chert as nodules and thin seams. Lower part of formation is marked by scree-covered slopes, upper part forms prominent cliffs and steep slopes. Likely correlative with part of the Madison Limestone of Montana, Wyoming, and northern Utah. Ranges in thickness from 183 to 275 m (600–900 ft) in the southern Wasatch Range (Rigby and Clark, 1962, p. 19)

Ꞓu

Upper Cambrian rocks, undivided—Includes units of the Ajax Dolomite and Opex Formation

Ajax Dolomite—Light-gray to dark-gray, mottled dolomite and minor limestone. About 27 m (90 ft) of Ajax is exposed on Long Ridge. Uncertain if exposed in the southern Wasatch Range (Hintze, 1962, p. 14)

Opex Formation—Dark-bluish-gray dolomite that contains some cherty beds and a few oolite beds. Ranges in thickness from about 30 to 145 m (100–475 ft)

Ꞓmu

Middle Cambrian rocks, undivided—Includes units of the following formations (in descending order): Cole Canyon Dolomite, Bluebird Dolomite, Herkimer Limestone, Dagmar Dolomite, and Teutonic Limestone

Cole Canyon Dolomite—Alternating light- and dark-gray beds of dolomite that locally contain sparse, small twig-like rods. Ranges in thickness from 88 to 152 m (290 to 500 ft) on Long Ridge, and from 70 to 140 m (230–460 ft) in the southern Wasatch Range (Hintze, 1962, p. 13)

Bluebird Dolomite—Dark-bluish-gray dolomite characterized by white, sinuous twig-like rods of dolomite scattered irregularly through the formation. Ranges in thickness from 30 to 52 m (100–170 ft) on Long Ridge, and from 30 to 58 m (100–190 ft) in the southern Wasatch Range

Herkimer Limestone—Bluish-gray limestone characterized by abundant orange-mottled siltstone. Similar in appearance to the Teutonic Limestone but separated from that unit by the white Dagmar Dolomite. Cliff former. About 91 m (300 ft) thick on Long Ridge; ranges in thickness from 70 to 137 m (230–450 ft) in the southern Wasatch Range (Hintze, 1962, p. 12)

Dagmar Dolomite—Light-gray to white, dense, thin-bedded dolomite that contrasts sharply with both the underlying and overlying darker limestone units. About 30 m (100 ft) thick

Teutonic Limestone—Bluish-gray limestone characterized by abundant orange mottled siltstone. Ranges in thickness from about 85 to 145 m (280–475 ft)

Ꞓo

Ophir Formation (Middle Cambrian)—Pale-green to olive-green phyllitic shale. Light-green sandstone beds are interleaved in basal part and light-brown limestone beds are common in the middle. Forms gentle slopes between cliffs and steep slopes formed on underlying Tintic Quartzite (Ꞓt) and overlying Teutonic Limestone (part of unit Ꞓmu). About 91 m (300 ft) thick on Long Ridge and 76 m (250 ft) thick in the southern Wasatch Range (Hintze, 1962, p. 11)

Ꞓt

Tintic Quartzite (Lower Cambrian)—Light-brown to orange-brown, thin- to medium-bedded, fine- to medium-grained quartzite. Grains are coated with limonite. Locally contains basal conglomerate. Forms resistant, steep ledges and slopes. Ranges in thickness from about 275 to 335 m (900–1100 ft) in southern Wasatch Ranage (Hintze, 1962, p. 11)

Ꞓot

Ophir Formation and Tintic Quartzite, undivided (Middle and Lower Cambrian)—Units combined locally for cartographic purposes

MzPzu

Mesozoic and Paleozoic rocks, undivided—Only shown in cross sections. Includes Ankareh Formation (ꞦRa), Thaynes Limestone (ꞦRt), Woodside Formation (ꞦRw), Park City Formation (Ppc), Diamond Creek Sandstone (Pdc), Kirkman Limestone (Pk), Oquirrh Formation (PPo), Manning Canyon Shale (PMmc), Great Blue Limestone (Mgb), Humbug Formation (Mh), Deseret Limestone (Md), Gardison Limestone (Mg), Fitchville Formation (MDf), Upper Devonian rocks of uncertain correlation (Du), Devonian and Ordovician rocks, undivided (DO), Upper Cambrian rocks, undivided (Ꞓu), Middle Cambrian rocks, undivided (Ꞓmu), Ophir Formation (Ꞓo), Diabasic lava flow (Ꞓdf), and Tintic Quartzite (Ꞓt)

PROTEROZOIC AND ARCHEAN METAMORPHIC ROCKS

Ybc

Big Cottonwood Formation (Middle Proterozoic)—Maroon quartzite, arkosic sandstone, and siltstone containing interbedded green, red, brown, and yellowish-green phyllitic shale. Thickness uncertain, possibly as much as 375 m (1230 ft) thick (Metter, 1955, p. 218)

XAf

Farmington Canyon Complex (Early Proterozoic and Archean)—Dark-gray to reddish-gray foliated rocks, chiefly schist, granitoid gneiss, and amphibolite, that have been intruded by dikes of pegmatite and medium-to coarse-grained granite. Thickness unknown

QTcf

Coalesced alluvial-fan deposits (Holocene to Pliocene?)—Brown to dark-brown or gray, unconsolidated to semiconsolidated, thin- to thick-bedded, commonly crossbedded sediments of fluvial origin. Deposits consist of silt, sand, granules, pebbles, cobbles, and sparse boulders. Formed by the overlapping and interfingering of adjacent alluvial fans; forms broad, low, sloping apron at foot of adjacent highlands. Includes Sevier River Formation, which probably ranges in age from Miocene to Pleistocene. Thickness uncertain; possibly as much as 30 m (100 ft) thick locally

DEPOSITS OF THE BONNEVILLE LAKE CYCLE

Qbn

Nearshore deposits of the Bonneville lake cycle (Pleistocene)—Light-gray to gray, moderately well sorted, even-bedded deposits of cross-bedded silt, sand, gravel, and sparse cobbles. Chiefly of deltaic origin. Thickness uncertain; may be as much as 76 m (250 ft) thick

Qf

Alluvial-fan deposits (Holocene)—Light-brown to brown, locally gray, unconsolidated to semiconsolidated, moderately well sorted silt, sand, granules, pebbles, and cobbles at stream mouths. Of fluvial origin. Deposits commonly lobate. Thickness uncertain, probably as much as 15 m (50 ft) locally

GeoStrata

Geologic Hazards Assessment
Horrocks Engineers
Santaquin, Utah
Project Number: 320-013

Site Vicinity 30x60 Geologic Map Unit Descriptions

Plate A-4a

Legend

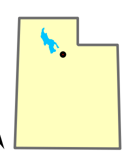
Drainage Basins

0 475 950 1,900 2,850 3,800 Feet

1 inch = 1,500 feet

Basemap:
Hillshades derived from 2013-2014 0.5 meter LiDAR and
5 meter Auto-Corrected DEM provided by the State of Utah AGRC.

N



GeoStrata

Geologic Hazards Assessment
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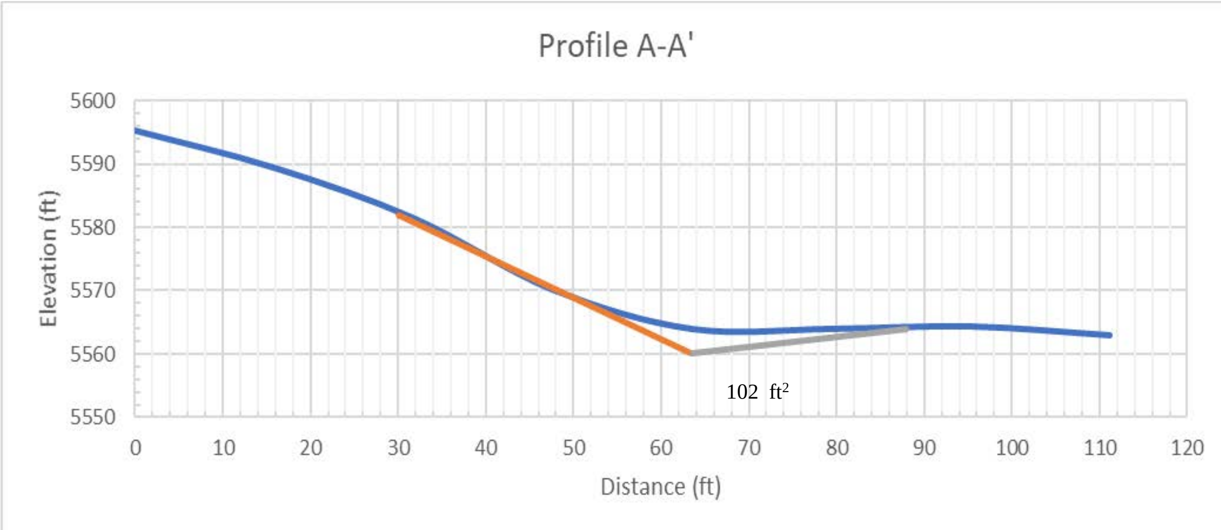
Santaquin, Utah
Project Number: 320-013

Hillshade Map

Plate A-5

Appendix B



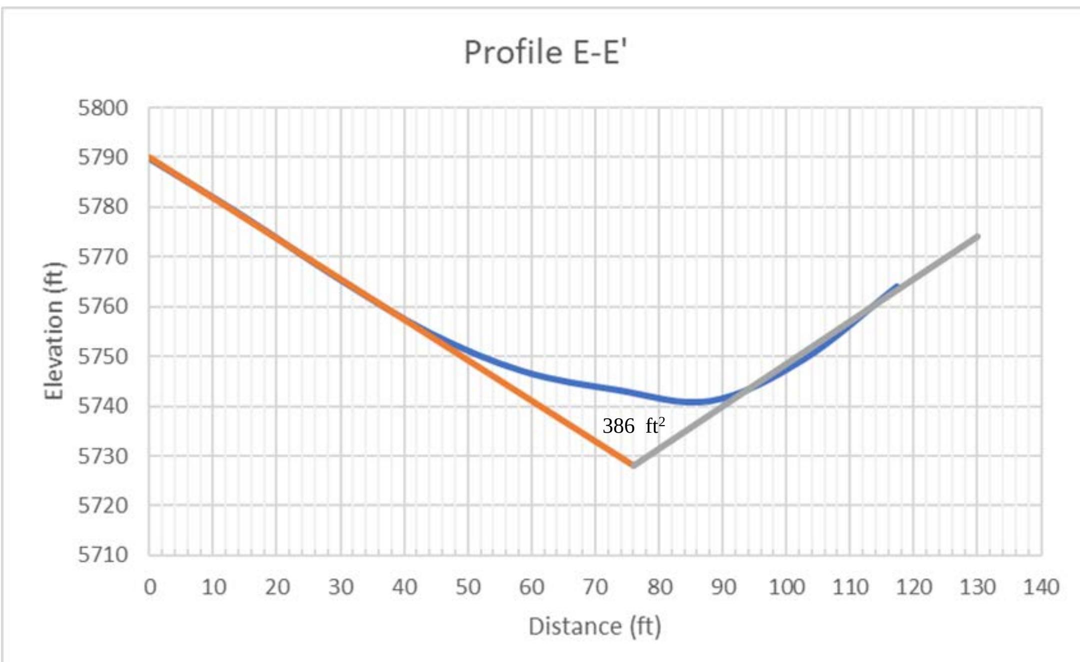
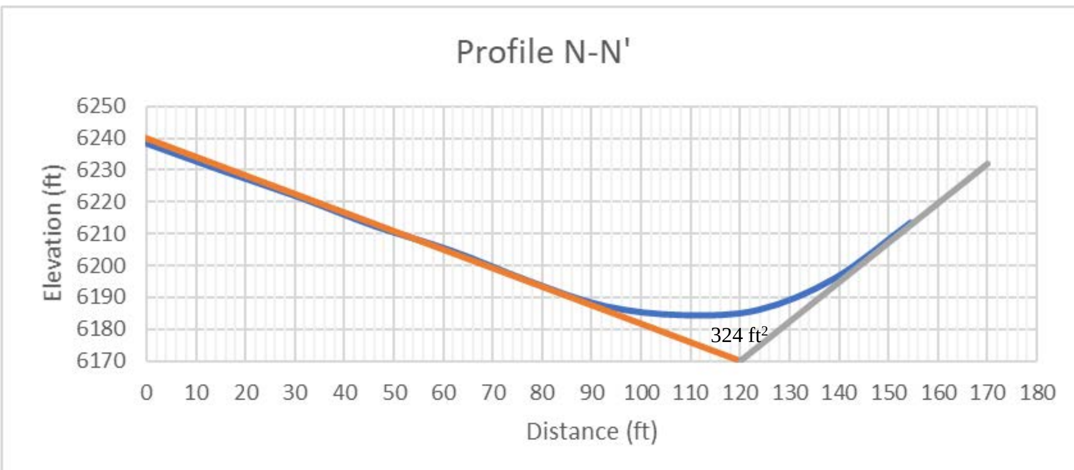


Plate B-1

Horrocks Engineers
Santaquin Debris Basins
Santaquin, Utah
Project Number: 320-013

Drainage 1 Cross-Sections

GeoStrata



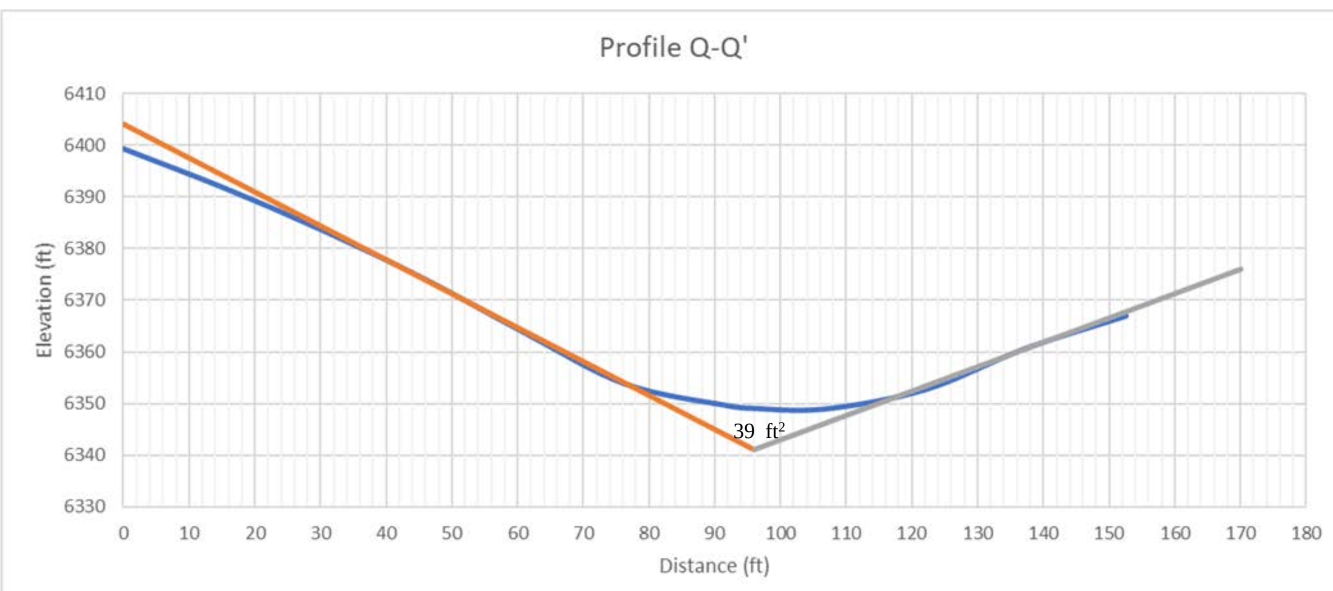


Plate B-2

Horrocks Engineers
Santaquin Debris Basins
Santaquin, Utah
Project Number: 320-013

Drainage 1 Cross-Sections

GeoStrata

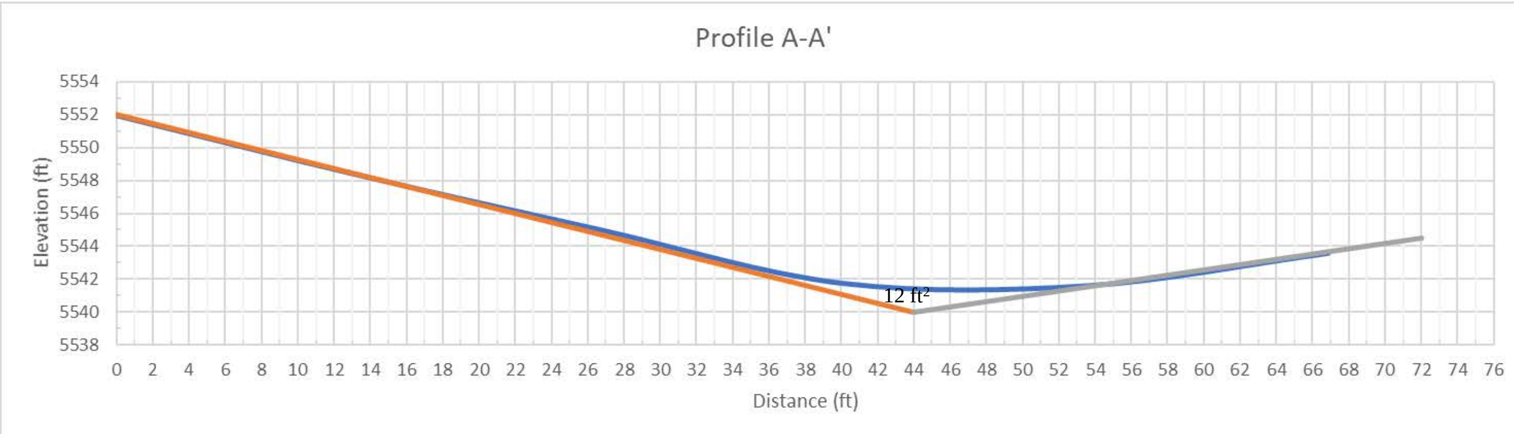


Plate B-3

Horrocks Engineers
Santaquin Debris Basins
Santaquin, Utah
Project Number: 320-013

Drainage 2 Cross-Sections

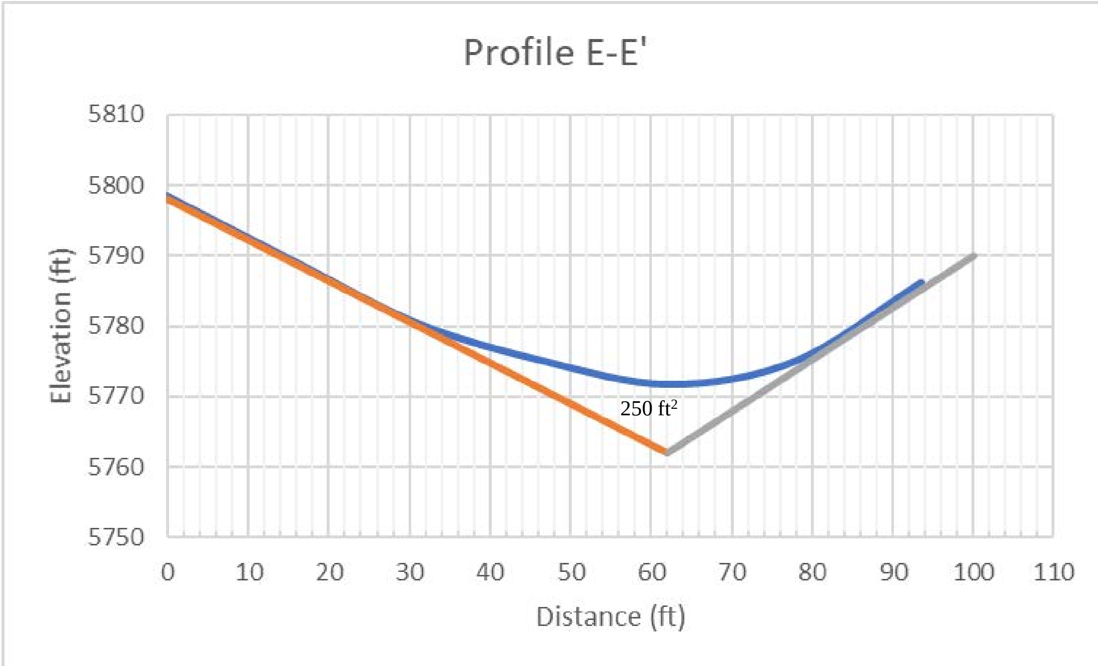
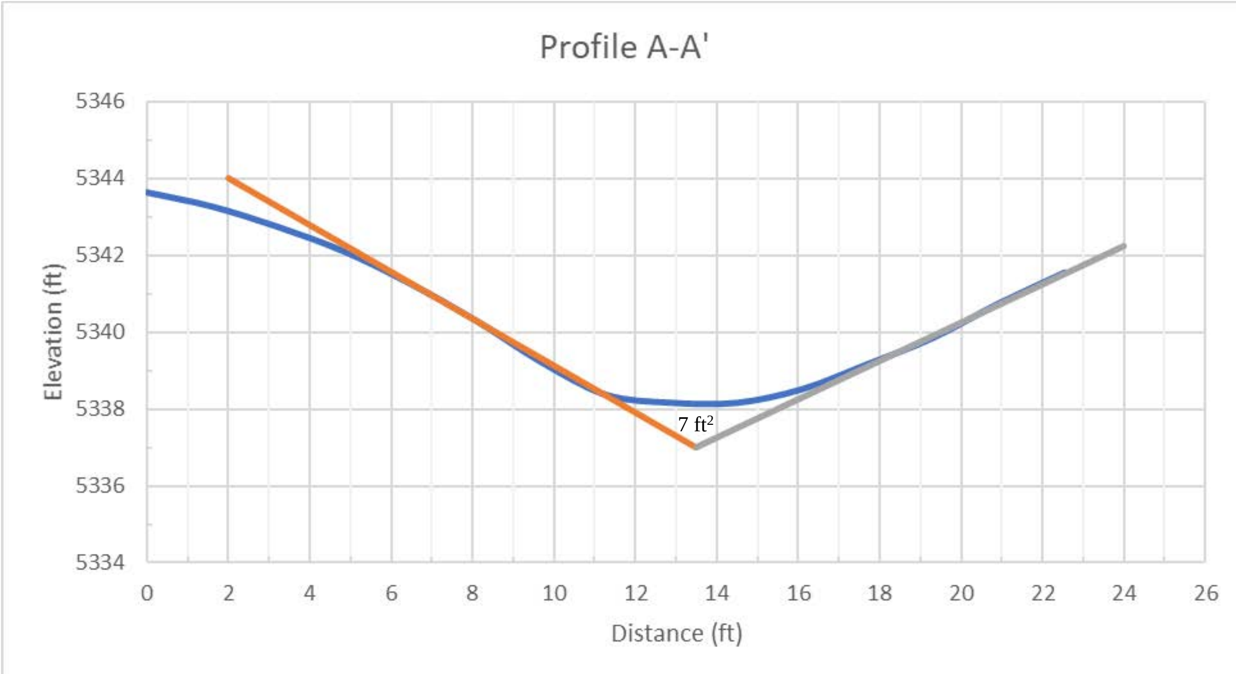


Plate B-4

Horrocks Engineers
Santaquin Debris Basins
Santaquin, Utah
Project Number: 320-013

Drainage 2 Cross-Sections



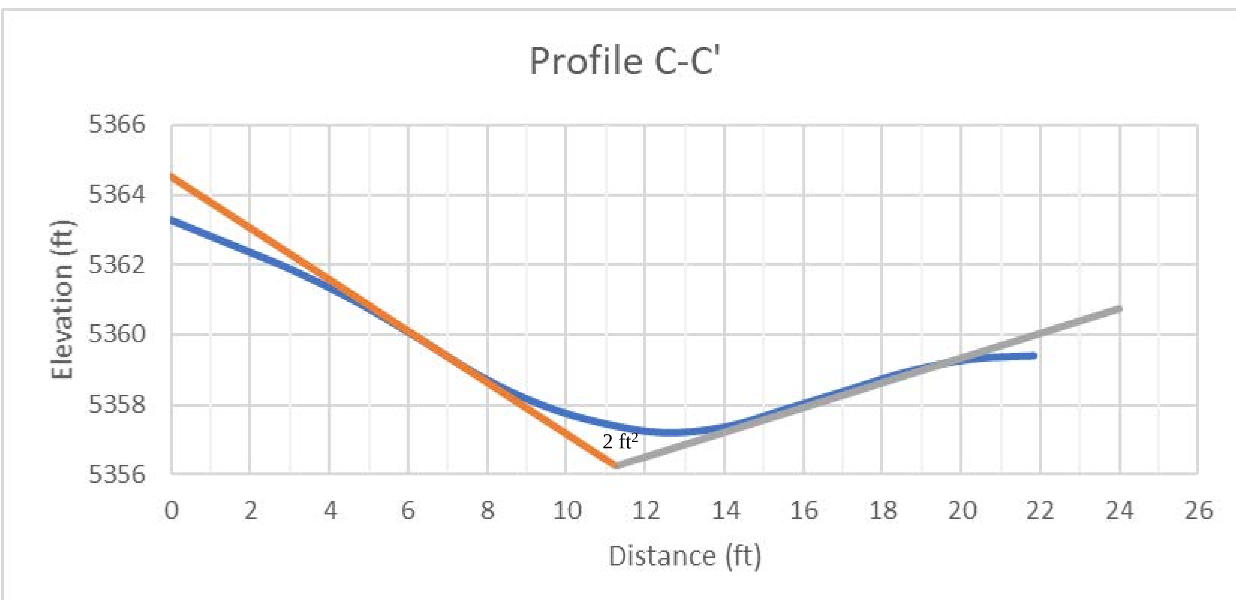


Plate B-5	Horrocks Engineers Santaquin Debris Basins Santaquin, Utah Project Number: 320-013	**Drainage 3 Cross-Sections**	GeoStrata

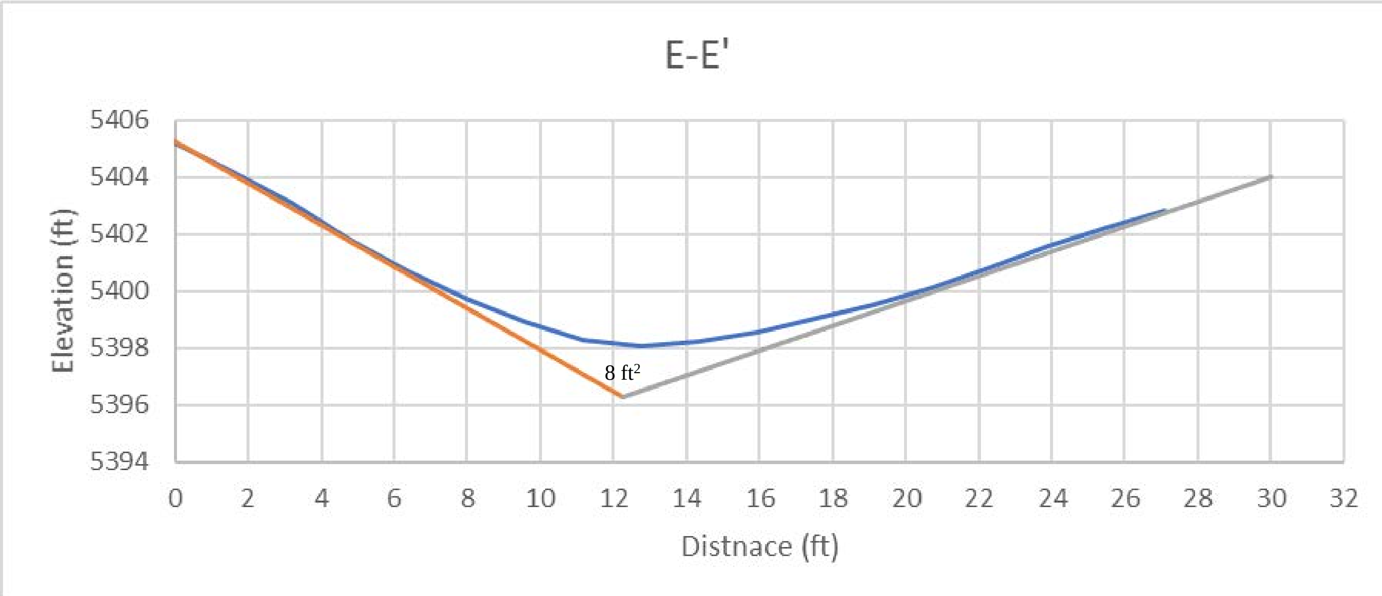
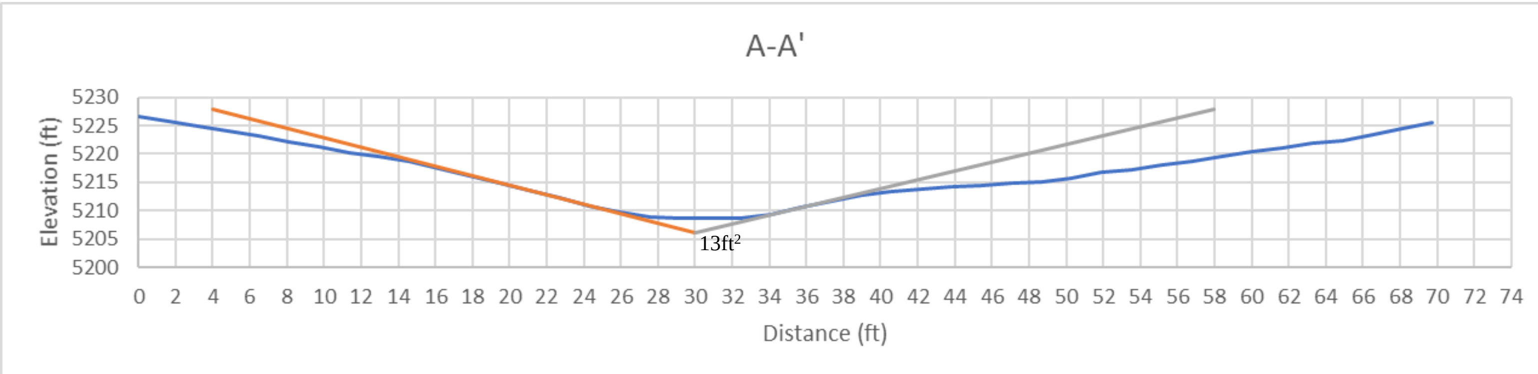


Plate B-6

Horrocks Engineers
Santaquin Debris Basins
Santaquin, Utah
Project Number: 320-013

Drainage 3 Cross-Sections

GeoStrata



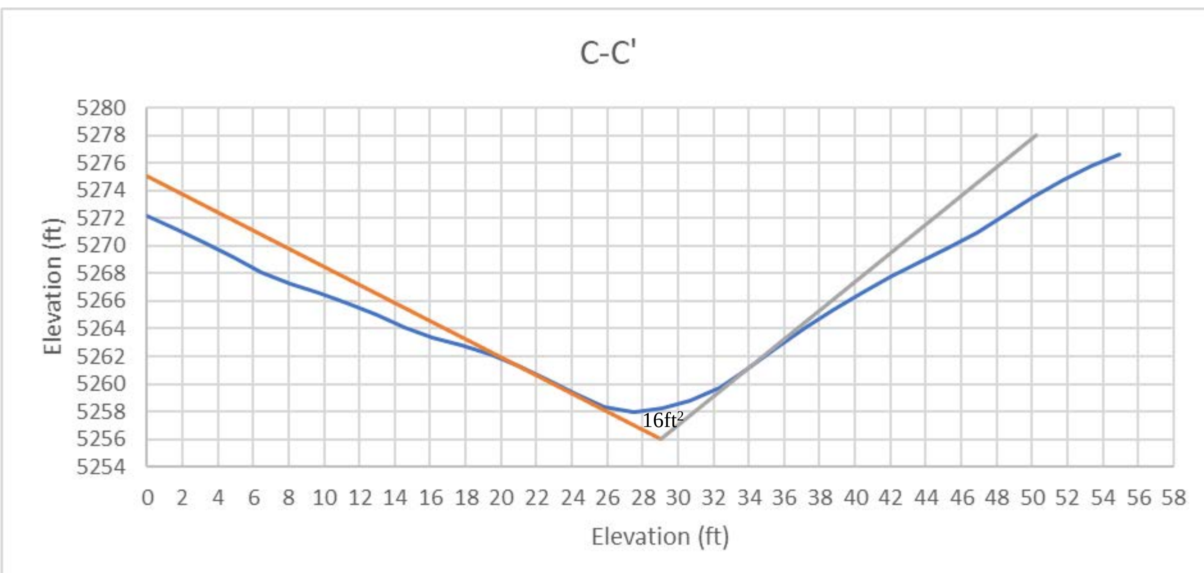


Plate B-7

Horrocks Engineers
Santaquin Debris Basins
Santaquin, Utah
Project Number: 320-013

Drainage 4 Cross-Sections

GeoStrata

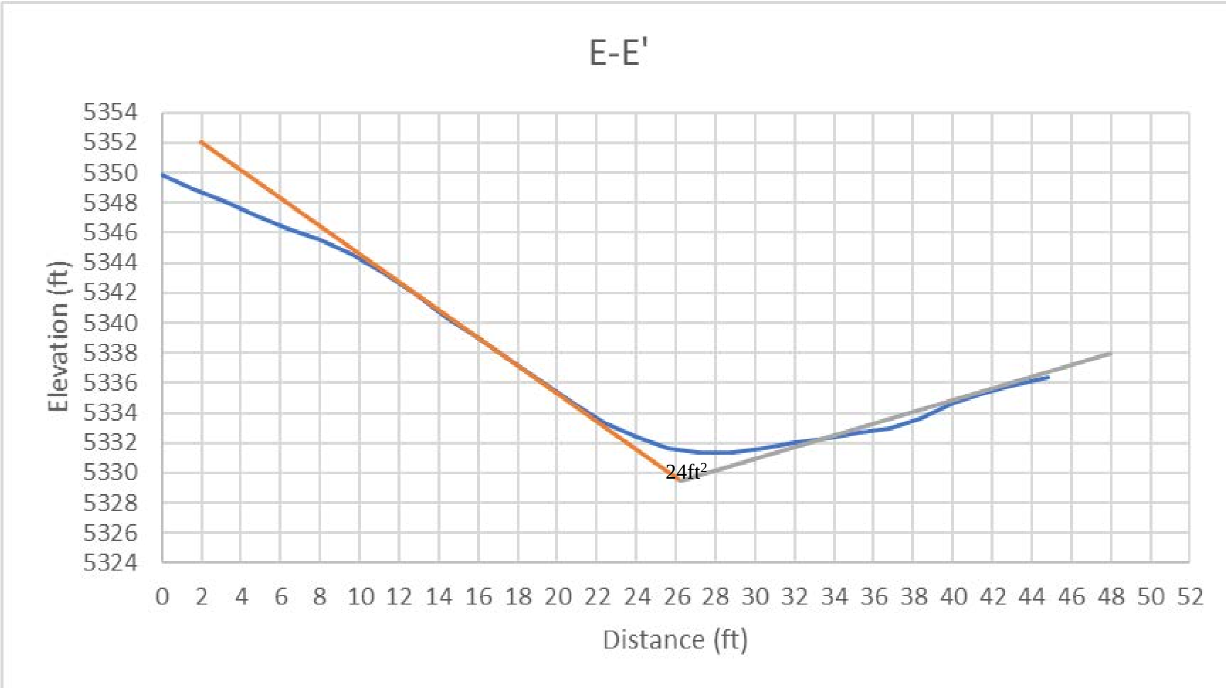
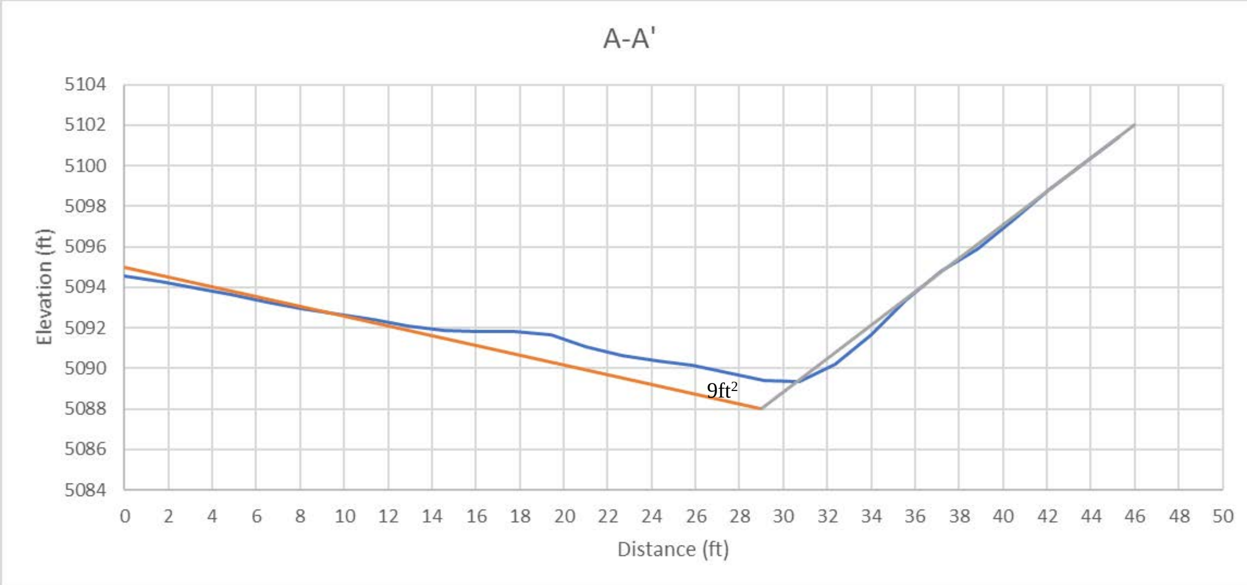


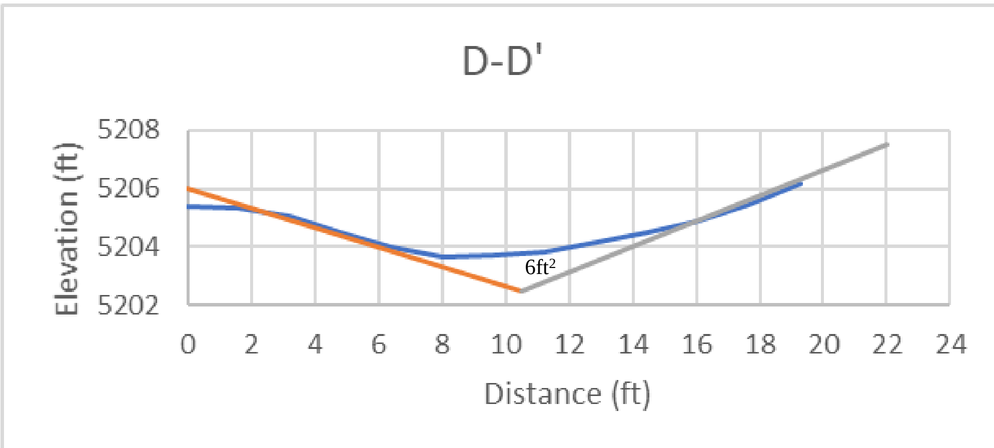
Plate
B-8

Horrocks Engineers
Santaquin Debris Basins
Santaquin, Utah
Project Number: 320-013

Drainage 4 Cross-Sections

GeoStrata





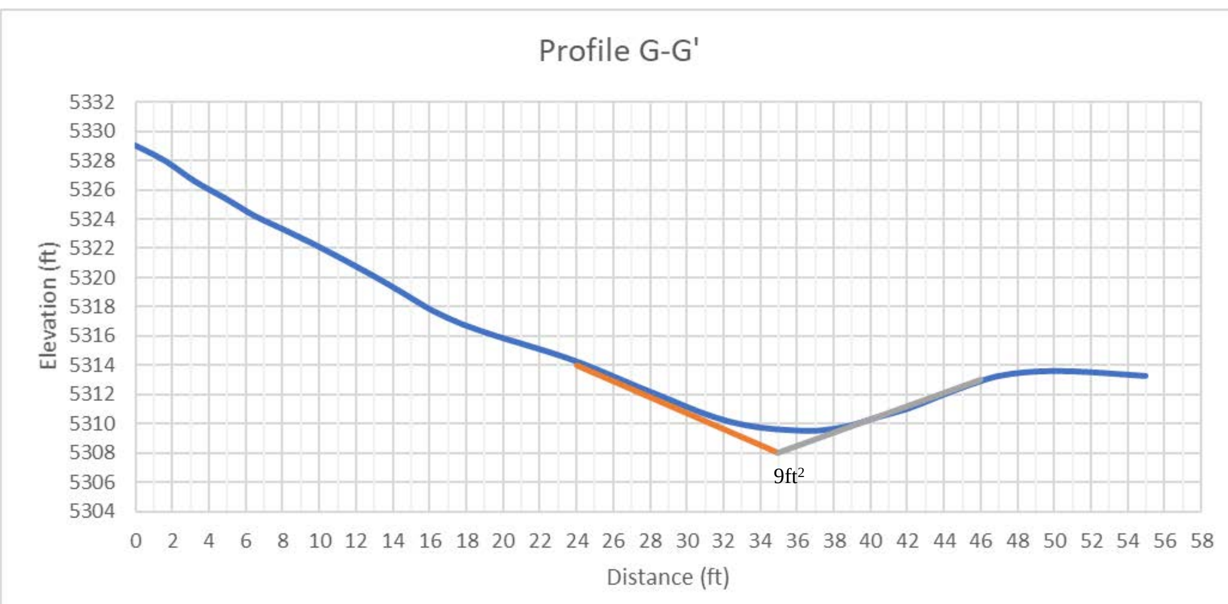
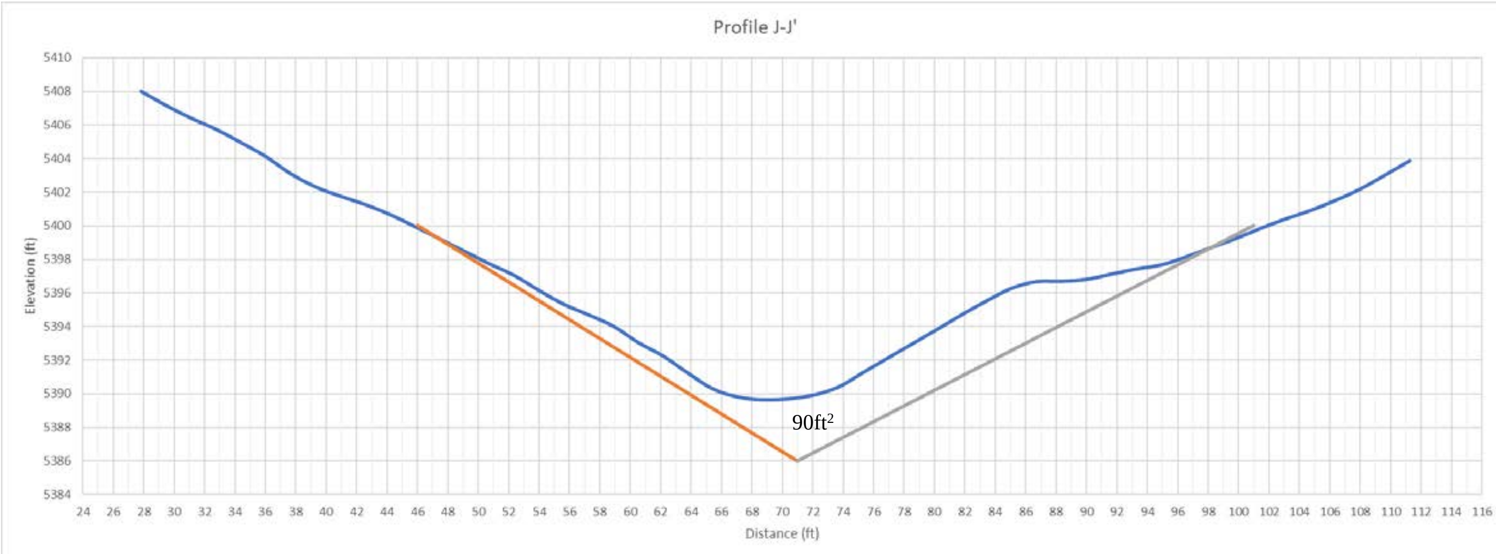


Plate B-9

Horrocks Engineers
Santaquin Debris Basins
Santaquin, Utah
Project Number: 320-013

Drainage 5 Cross-Sections

GeoStrata



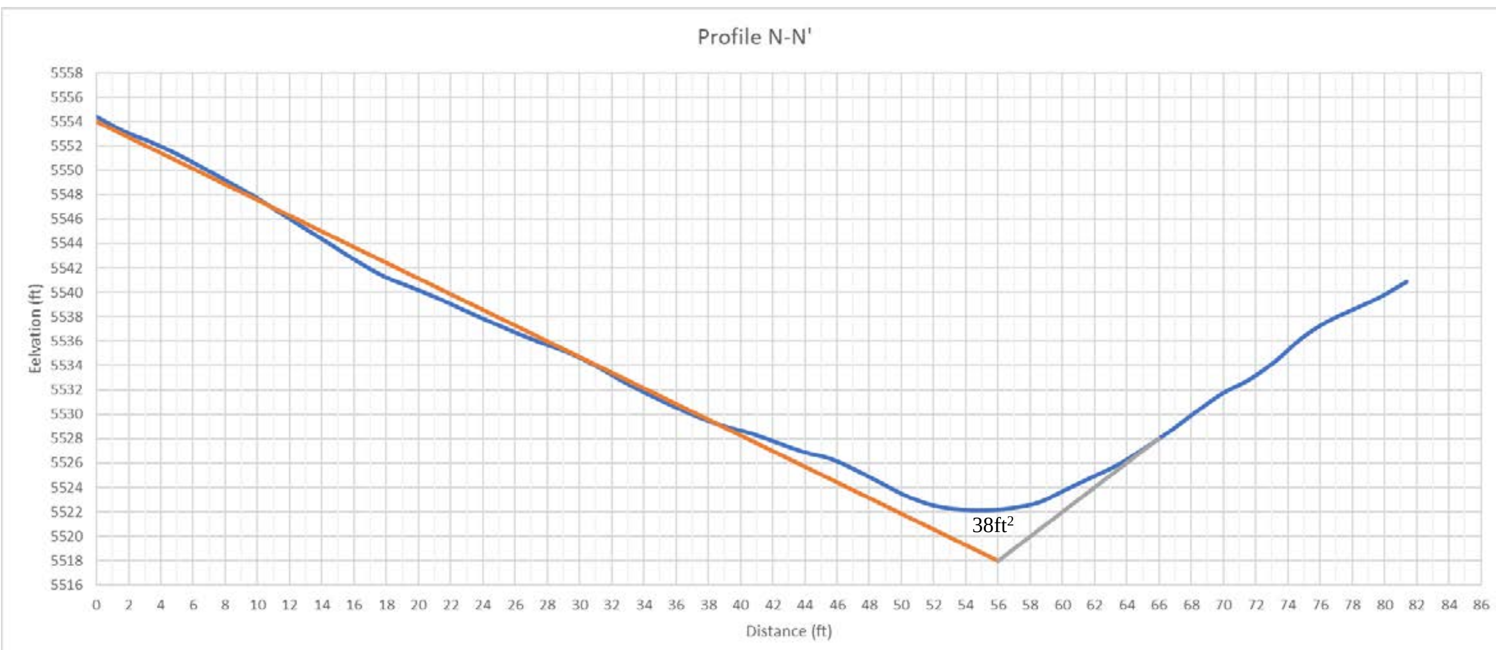
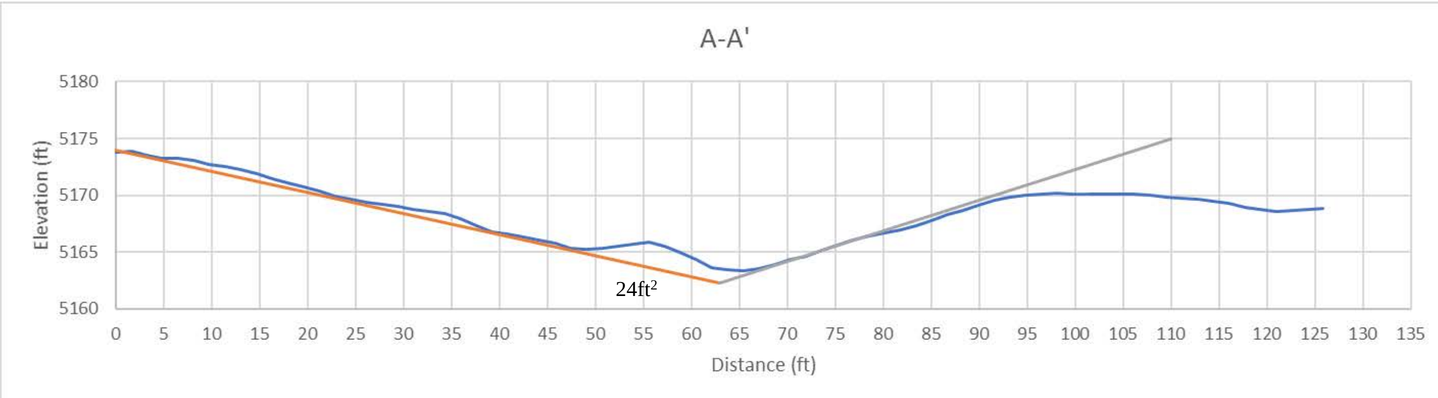


Plate B-10	Horrocks Engineers Santaquin Debris Basins Santaquin, Utah Project Number: 320-013	**Drainage 5 Cross-Sections**



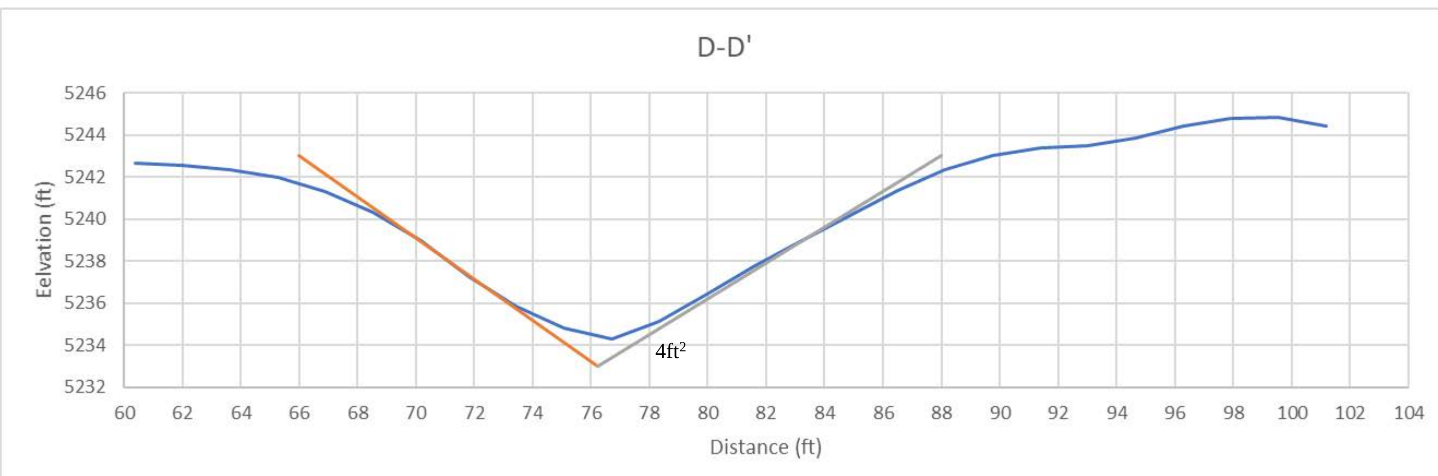


Plate B-11

Horrocks Engineers
Santaquin Debris Basins
Santaquin, Utah
Project Number: 320-013

Drainage 6 Cross-Sections

GeoStrata

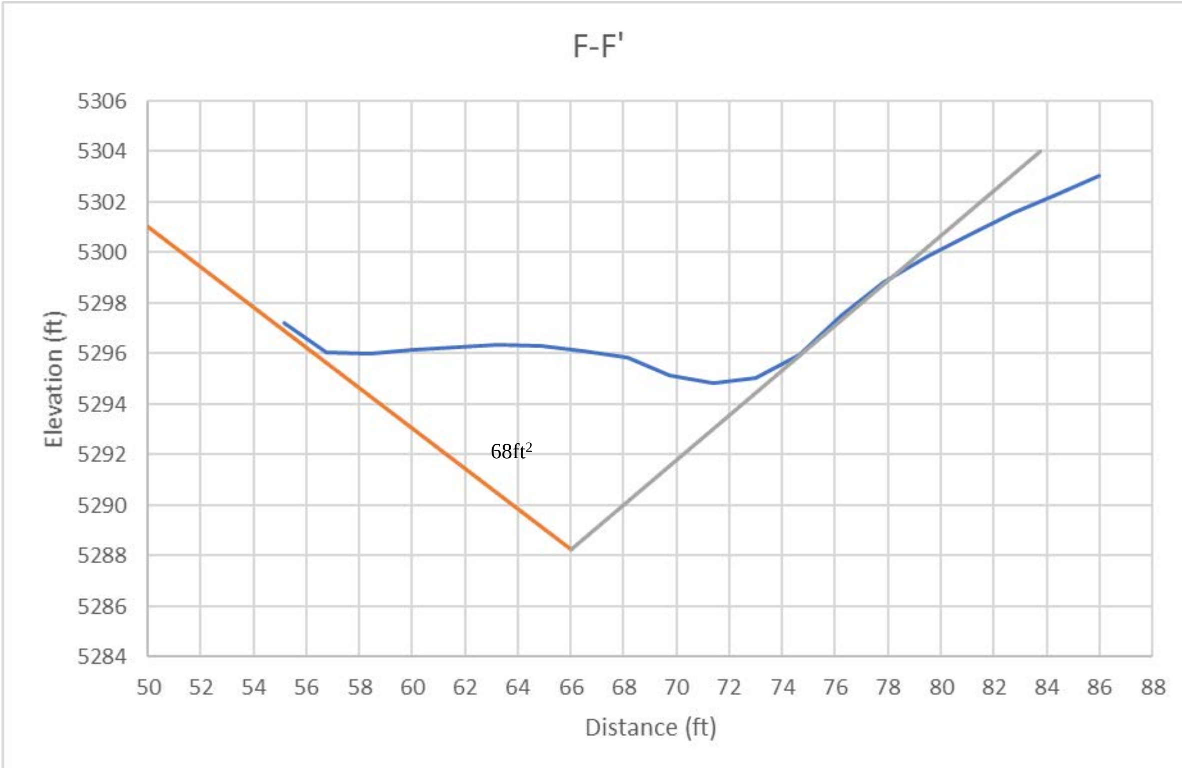


Plate B-12

Horrocks Engineers
Santaquin Debris Basins
Santaquin, Utah
Project Number: 320-013

Drainage 6 Cross-Sections

GeoStrata

Appendix C

DATE		
STARTED:	6/26/18	
COMPLETED:	6/26/18	
BACKFILLED:	6/26/18	

Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number 320-013

GeoStrata Rep: SA
Rig Type: Backhoe

TEST PIT NO:
TP-1
Sheet 1 of 1

LOCATION

NORTHING | EASTING | ELEVATION

Moisture Content and Atterberg Limits

Plastic Limit | Moisture Content | Liquid Limit

10 20 30 40 50 60 70 80 90

DEPTH METERS	DEPTH FEET	SAMPLES	WATER LEVEL	GRAPHICAL LOG	UNIFIED SOIL CLASSIFICATION	MATERIAL DESCRIPTION	Dry Density(pcf)	Moisture Content %	Percent minus 200	Liquid Limit	Plasticity Index
0	0					TOPSOIL - silt, sand, gravel, brown, slightly moist, fine roots.					
					GC-GM	Silty Clayey GRAVEL with sand - dense, slightly moist, brown, clasts subangular, matrix supported, clast supported pea gravel in the upper 1½ to 2 feet					
	5	▯				- boulders up to 2 feet, subangular		2.2	13.0	24	6
						- lenses of pea gravel, 2 feet thick					
1											
2											
3											

Bottom of Test Pit @ 10 Feet

SAMPLE TYPE
▯ - GRAB SAMPLE
▮ - 3" O.D. THIN-WALLED HAND SAMPLER

WATER LEVEL
▼ - MEASURED
▽ - ESTIMATED

NOTES:

Plate C-1

DATE		
STARTED:	6/26/18	
COMPLETED:	6/26/18	
BACKFILLED:	6/26/18	

Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number 320-013

GeoStrata Rep: SA
Rig Type: Backhoe

TEST PIT NO:
TP-2
Sheet 1 of 1

LOCATION
NORTHING EASTING ELEVATION

MATERIAL DESCRIPTION

DEPTH (METERS)	DEPTH (FEET)	SAMPLES	WATER LEVEL	UNIFIED SOIL CLASSIFICATION	MATERIAL DESCRIPTION	Dry Density(pcf)	Moisture Content %	Percent minus 200	Liquid Limit	Plasticity Index
0	0				TOPSOIL - silt, sand, gravel, brown, slightly moist, fine roots.					
				SM	Silty SAND with gravel - medium dense, moist, brown, matrix supported, subangular gravel 2 to 3 inches					
					- lenses of Poorly Graded SAND (SP)					
1										
	5	Grab sample			- increase in fines, less gravel, cobbles and boulders, subangular clasts		2.6	12.2	NP	NP
2										
					Bottom of Test Pit @ 9 Feet					
3										

Moisture Content and Atterberg Limits

Plastic Limit — Moisture Content — Liquid Limit

10 20 30 40 50 60 70 80 90

SAMPLE TYPE
- GRAB SAMPLE
- 3" O.D. THIN-WALLED HAND SAMPLER

WATER LEVEL
- MEASURED
- ESTIMATED

NOTES:

Plate

C-2

DATE		
STARTED:	6/26/18	
COMPLETED:	6/26/18	
BACKFILLED:	6/26/18	

Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number 320-013

GeoStrata Rep: SA
Rig Type: Backhoe

TEST PIT NO:
TP-3
Sheet 1 of 1

LOCATION

NORTHING | EASTING | ELEVATION

DEPTH METERS	DEPTH FEET	SAMPLES	WATER LEVEL	GRAPHICAL LOG	UNIFIED SOIL CLASSIFICATION	MATERIAL DESCRIPTION	Dry Density(pcf)	Moisture Content %	Percent minus 200	Liquid Limit	Plasticity Index	Moisture Content and Atterberg Limits (Plastic Limit / Moisture Content / Liquid Limit) 10 20 30 40 50 60 70 80 90
0	0					TOPSOIL - silt, sand, gravel, brown, slightly moist, fine roots.						
					SC-SM	Silty Clayey SAND with gravel - medium dense, moist, brown, matrix supported, lenses of Poorly GRADED SAND (SP), occassional large subangular boulders in upper 3 feet						
1												
	5	▯						3.2	16.1	24	5	● H
2												
						Bottom of Test Pit @ 9 Feet						
3												

SAMPLE TYPE
▯ - GRAB SAMPLE
☒ - 3" O.D. THIN-WALLED HAND SAMPLER

WATER LEVEL
▼ - MEASURED
▽ - ESTIMATED

NOTES:

Plate C-3

DATE		
STARTED:	6/26/18	
COMPLETED:	6/26/18	
BACKFILLED:	6/26/18	

Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number 320-013

GeoStrata Rep: SA
Rig Type: Backhoe

TEST PIT NO:
TP-4
Sheet 1 of 1

LOCATION
NORTHING EASTING ELEVATION

MATERIAL DESCRIPTION

DEPTH METERS	DEPTH FEET	SAMPLES	WATER LEVEL	GRAPHICAL LOG	UNIFIED SOIL CLASSIFICATION	MATERIAL DESCRIPTION	Dry Density(pcf)	Moisture Content %	Percent minus 200	Liquid Limit	Plasticity Index
0	0					TOPSOIL - silt, sand, gravel, brown, slightly moist, fine roots.					
					GC	Clayey GRAVEL with sand - dense, slightly moist, brown, matrix supported, subangular clasts.					
1											
	5	Grab sample						3.4	15.4	26	13
2											
						- subangular boulders 2 to 3 feet in diameter, refusal.					
						Bottom of Test Pit @ 8 Feet					
3											

Moisture Content and Atterberg Limits
Plastic Limit — Moisture Content — Liquid Limit
10 20 30 40 50 60 70 80 90

SAMPLE TYPE
- GRAB SAMPLE
- 3" O.D. THIN-WALLED HAND SAMPLER

WATER LEVEL
- MEASURED
- ESTIMATED

NOTES:

Plate
C-4

DATE		
STARTED:	6/26/18	
COMPLETED:	6/26/18	
BACKFILLED:	6/26/18	

Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number 320-013

GeoStrata Rep: SA
Rig Type: Backhoe

TEST PIT NO:
TP-5
Sheet 1 of 1

LOCATION
NORTHING EASTING ELEVATION

MATERIAL DESCRIPTION

DEPTH (METERS)	DEPTH (FEET)	SAMPLES	WATER LEVEL	GRAPHICAL LOG	UNIFIED SOIL CLASSIFICATION	MATERIAL DESCRIPTION	Dry Density(pcf)	Moisture Content %	Percent minus 200	Liquid Limit	Plasticity Index
0	0					TOPSOIL - silt, sand, gravel, brown, slightly moist, fine roots.					
					GW	Well-Graded GRAVEL with silt and sand - dense, slightly moist, brown, matrix supported, clasts range from pea gravel to 2 inches in diameter and subangular.					
1	5	Grab				- subangular boulders 1 foot in diameter.		2.4	11.0	NP	NP
2						Bottom of Test Pit @ 6 Feet					
3											

Moisture Content and Atterberg Limits
Plastic Limit — Moisture Content — Liquid Limit
10 20 30 40 50 60 70 80 90

SAMPLE TYPE
- GRAB SAMPLE
- 3" O.D. THIN-WALLED HAND SAMPLER

WATER LEVEL
- MEASURED
- ESTIMATED

NOTES:

Plate C-5

DATE		
STARTED:	6/26/18	
COMPLETED:	6/26/18	
BACKFILLED:	6/26/18	

Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number 320-013

GeoStrata Rep: SA
Rig Type: Backhoe

TEST PIT NO:
TP-6
Sheet 1 of 1

LOCATION
NORTHING EASTING ELEVATION

MATERIAL DESCRIPTION

DEPTH METERS	DEPTH FEET	SAMPLES	WATER LEVEL	UNIFIED SOIL CLASSIFICATION	MATERIAL DESCRIPTION	Dry Density(pcf)	Moisture Content %	Percent minus 200	Liquid Limit	Plasticity Index
0	0				TOPSOIL - silt, sand, gravel, brown, slightly moist, fine roots.					
				GM	Silty GRAVEL with sand - dense, slightly moist, brown, matrix supported, subangular cobbles up to 1 foot in diameter.					
	5						2.1	15.9	NP	NP
					Bottom of Test Pit @ 8 Feet					

Moisture Content and Atterberg Limits
Plastic Limit — Moisture Content — Liquid Limit
10 20 30 40 50 60 70 80 90

GeoStrata

SAMPLE TYPE
- GRAB SAMPLE
- 3" O.D. THIN-WALLED HAND SAMPLER

WATER LEVEL
- MEASURED
- ESTIMATED

NOTES:

Plate C-6

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			USCS SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS (More than half of material is larger than the #200 sieve)	GRAVELS (More than half of coarse fraction is larger than the #4 sieve)	CLEAN GRAVELS WITH LITTLE OR NO FINES	GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
			GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES WITH LITTLE OR NO FINES
		GRAVELS WITH OVER 12% FINES	GM	SILTY GRAVELS, GRAVEL-SILT-SAND MIXTURES
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SANDS (More than half of coarse fraction is smaller than the #4 sieve)	CLEAN SANDS WITH LITTLE OR NO FINES	SW	WELL-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
			SP	POORLY-GRADED SANDS, SAND-GRAVEL MIXTURES WITH LITTLE OR NO FINES
		SANDS WITH OVER 12% FINES	SM	SILTY SANDS, SAND-GRAVEL-SILT MIXTURES
			SC	CLAYEY SANDS SAND-GRAVEL-CLAY MIXTURES
FINE GRAINED SOILS (More than half of material is smaller than the #200 sieve)	SILTS AND CLAYS (Liquid limit less than 50)		ML	INORGANIC SILTS & VERY FINE SANDS, SILTY OR CLAYEY FINE SANDS, CLAYEY SILTS WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
			OL	ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS (Liquid limit greater than 50)		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILT
			CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
			OH	ORGANIC CLAYS & ORGANIC SILTS OF MEDIUM-TO-HIGH PLASTICITY
HIGHLY ORGANIC SOILS			PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

LOG KEY SYMBOLS

BORING SAMPLE LOCATION

TEST-PIT SAMPLE LOCATION

WATER LEVEL (level after completion)

WATER LEVEL (level where first encountered)

CEMENTATION

DESCRIPTION	DESCRIPTION
WEAKELY	CRUMBLES OR BREAKS WITH HANDLING OR SLIGHT FINGER PRESSURE
MODERATELY	CRUMBLES OR BREAKS WITH CONSIDERABLE FINGER PRESSURE
STRONGLY	WILL NOT CRUMBLE OR BREAK WITH FINGER PRESSURE

OTHER TESTS KEY

C	CONSOLIDATION	SA	SIEVE ANALYSIS
AL	ATTERBERG LIMITS	DS	DIRECT SHEAR
UC	UNCONFINED COMPRESSION	T	TRIAXIAL
S	SOLUBILITY	R	RESISTIVITY
O	ORGANIC CONTENT	RV	R-VALUE
CBR	CALIFORNIA BEARING RATIO	SU	SOLUBLE SULFATES
COMP	MOISTURE/DENSITY RELATIONSHIP	PM	PERMEABILITY
CI	CALIFORNIA IMPACT	-200	% FINER THAN #200
COL	COLLAPSE POTENTIAL	Gs	SPECIFIC GRAVITY
SS	SHRINK SWELL	SL	SWELL LOAD

MODIFIERS

DESCRIPTION	%
TRACE	<5
SOME	5 - 12
WITH	>12

MOISTURE CONTENT

DESCRIPTION	FIELD TEST
DRY	ABSENCE OF MOISTURE, DUSTY, DRY TO THE TOUCH
MOIST	DAMP BUT NO VISIBLE WATER
WET	VISIBLE FREE WATER, USUALLY SOIL BELOW WATER TABLE

STRATIFICATION

DESCRIPTION	THICKNESS	DESCRIPTION	THICKNESS
SEAM	1/16 - 1/2"	OCCASIONAL	ONE OR LESS PER FOOT OF THICKNESS
LAYER	1/2 - 12"	FREQUENT	MORE THAN ONE PER FOOT OF THICKNESS

GENERAL NOTES

1. Lines separating strata on the logs represent approximate boundaries only. Actual transitions may be gradual.
2. No warranty is provided as to the continuity of soil conditions between individual sample locations.
3. Logs represent general soil conditions observed at the point of exploration on the date indicated.
4. In general, Unified Soil Classification designations presented on the logs were evaluated by visual methods only. Therefore, actual designations (based on laboratory tests) may vary.

APPARENT / RELATIVE DENSITY - COARSE-GRAINED SOIL

APPARENT DENSITY	SPT (blows/ft)	MODIFIED CA. SAMPLER (blows/ft)	CALIFORNIA SAMPLER (blows/ft)	RELATIVE DENSITY (%)	FIELD TEST
VERY LOOSE	<4	<4	<5	0 - 15	EASILY PENETRATED WITH 1/2-INCH REINFORCING ROD PUSHED BY HAND
LOOSE	4 - 10	5 - 12	5 - 15	15 - 35	DIFFICULT TO PENETRATE WITH 1/2-INCH REINFORCING ROD PUSHED BY HAND
MEDIUM DENSE	10 - 30	12 - 35	15 - 40	35 - 65	EASILY PENETRATED A FOOT WITH 1/2-INCH REINFORCING ROD DRIVEN WITH 5-LB HAMMER
DENSE	30 - 50	35 - 60	40 - 70	65 - 85	DIFFICULT TO PENETRATED A FOOT WITH 1/2-INCH REINFORCING ROD DRIVEN WITH 5-LB HAMMER
VERY DENSE	>50	>60	>70	85 - 100	PENETRATED ONLY A FEW INCHES WITH 1/2-INCH REINFORCING ROD DRIVEN WITH 5-LB HAMMER

CONSISTENCY - FINE-GRAINED SOIL

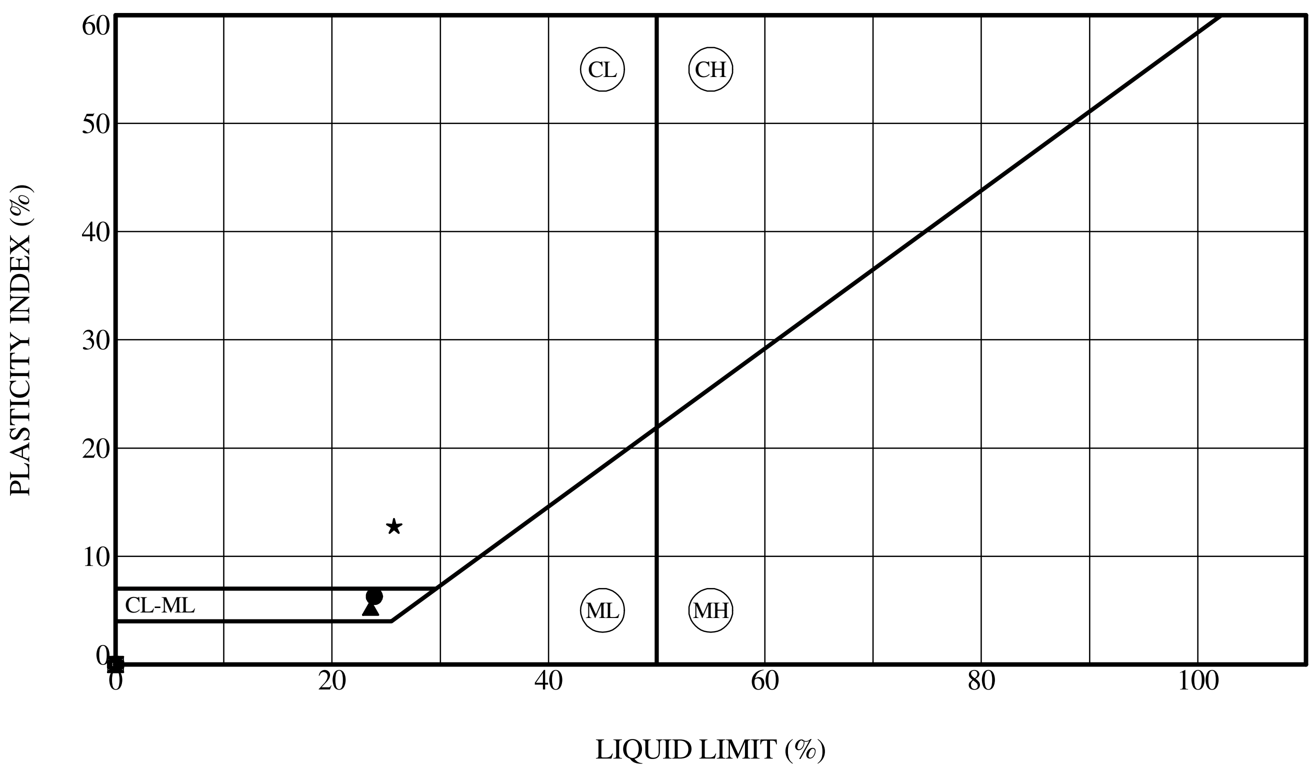
CONSISTENCY	SPT (blows/ft)	TORVANE UNTRAINED SHEAR STRENGTH (tsf)	POCKET PENETROMETER UNCONFINED COMPRESSIVE STRENGTH (tsf)	FIELD TEST
VERY SOFT	<2	<0.125	<0.25	EASILY PENETRATED SEVERAL INCHES BY THUMB. EXUDES BETWEEN THUMB AND FINGERS WHEN SQUEEZED BY HAND.
SOFT	2 - 4	0.125 - 0.25	0.25 - 0.5	EASILY PENETRATED ONE INCH BY THUMB. MOLDED BY LIGHT FINGER PRESSURE.
MEDIUM STIFF	4 - 8	0.25 - 0.5	0.5 - 1.0	PENETRATED OVER 1/2 INCH BY THUMB WITH MODERATE EFFORT. MOLDED BY STRONG FINGER PRESSURE.
STIFF	8 - 15	0.5 - 1.0	1.0 - 2.0	INDENTED ABOUT 1/2 INCH BY THUMB BUT PENETRATED ONLY WITH GREAT EFFORT.
VERY STIFF	15 - 30	1.0 - 2.0	2.0 - 4.0	READILY INDENTED BY THUMBNAIL.
HARD	>30	>2.0	>4.0	INDENTED WITH DIFFICULTY BY THUMBNAIL.

GeoStrata

Appendix D

Test Pit No.	Sample Depth (feet)	USCS Soil Classification	Natural Moisture Content (%)	Gradation			Atterberg	
				Gravel (%)	Sand (%)	Fines (%)	LL	PI
TP-1	5	GC	2.2	63.7	23.3	13	24	6
TP-2	5	SM	2.6	30.8	54.1	12.2	NP	NP
TP-3	5	SC-SM	3.2	27.3	56.6	16.1	22	4
TP-4	5	GC	3.4	49.3	24.6	15.4	26	10
TP-5	5	GW	2.4	46.7	37.9	11	NP	NP
TP-6	5	GM	2.1	54.3	23.8	15.9	NP	NP

GeoStrata



	Sample Location	Depth (ft)	LL (%)	PL (%)	PI (%)	Fines (%)	Classification
●	**TP-1**	**5.0**	**24**	**18**	**6**		**Silty Clayey GRAVEL with sand**
⊠	**TP-2**	**5.0**	**NP**	**NP**	**NP**		**Silty SAND with gravel**
▲	**TP-3**	**5.0**	**24**	**18**	**6**		**Silty Clayey SAND with gravel**
★	**TP-4**	**5.0**	**26**	**13**	**13**		**Clayey GRAVEL with sand**
⊙	**TP-5**	**5.0**	**NP**	**NP**	**NP**		**Well-Graded GRAVEL with silt and sand**
✿	**TP-6**	**5.0**	**NP**	**NP**	**NP**		**Silty GRAVEL with sand**

GeoStrata

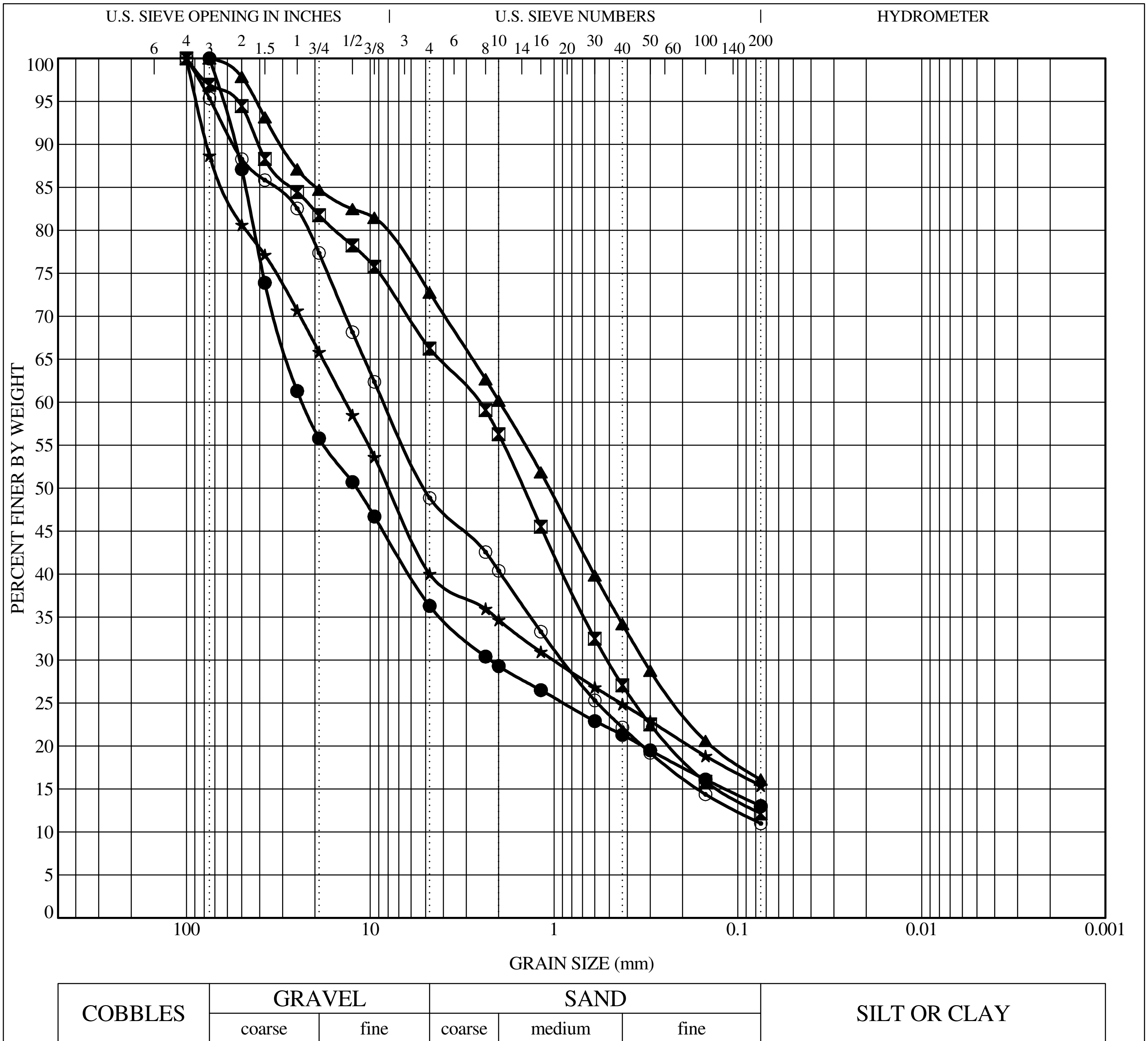
ATTERBERG LIMITS' RESULTS - ASTM D 4318

Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number: 320-013

Plate

D - 2

D_ATTERBERG EXPLORATION LOGS.GPJ GEOSTRATA.GDT 8/3/18



	Sample Location	Depth	Classification	LL	PL	PI	Cc	Cu
●	**TP-1**	**5.0**	**Silty Clayey GRAVEL with sand**	**24**	**18**	**6**		
⊠	**TP-2**	**5.0**	**Silty SAND with gravel**	**NP**	**NP**	**NP**	**2.03**	**51.59**
▲	**TP-3**	**5.0**	**Silty Clayey SAND with gravel**	**24**	**18**	**6**		
★	**TP-4**	**5.0**	**Clayey GRAVEL with sand**	**26**	**13**	**13**		
⊙	**TP-5**	**5.0**	**Well-Graded GRAVEL with silt and sand**	**NP**	**NP**	**NP**	**1.55**	**137.52**

	Sample Loctaion	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**TP-1**	**5.0**	**75**	**23.43**	**2.222**		**63.7**	**23.3**	**13.0**	
⊠	**TP-2**	**5.0**	**100**	**2.58**	**0.512**		**30.9**	**54.1**	**12.2**	
▲	**TP-3**	**5.0**	**75**	**1.978**	**0.325**		**27.3**	**56.7**	**16.1**	
★	**TP-4**	**5.0**	**100**	**13.616**	**1.008**		**49.3**	**24.6**	**15.4**	
⊙	**TP-5**	**5.0**	**100**	**8.413**	**0.893**		**46.8**	**37.9**	**11.0**	

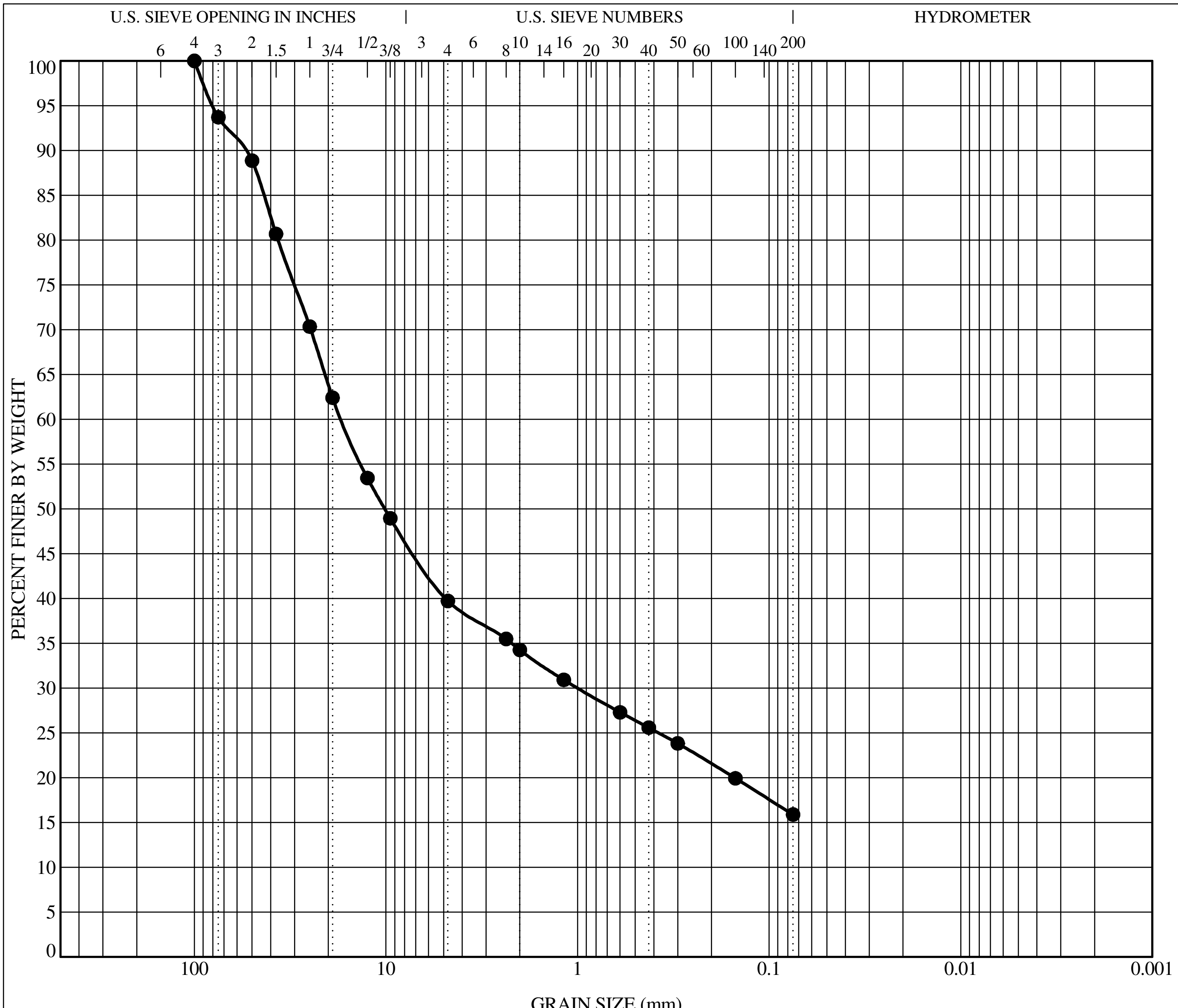
GeoStrata

GRAIN SIZE DISTRIBUTION - ASTM D422

Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number: 320-013

Plate

D - 3



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Sample Location	Depth	Classification	LL	PL	PI	Cc	Cu
●	**TP-6**	**5.0**	**Silty GRAVEL with sand**	**NP**	**NP**	**NP**		

	Sample Loctaion	Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**TP-6**	**5.0**	**100**	**16.983**	**0.995**		**54.3**	**23.8**	**15.9**	

D_GSD EXPLORATION LOGS.GPJ GEOSTRATA.GDT 8/3/18

GeoStrata

GRAIN SIZE DISTRIBUTION - ASTM D422

Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number: 320-013

Plate

D - 4

Appendix E

TEST PIT 1 EAST WALL

North **South**

Plate E-1

Geologic Hazards Investigation
Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number: 320-013

GeoStrata

TEST PIT 2 EAST WALL

North **South**

Plate E-2

Geologic Hazards Investigation
Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number: 320-013

GeoStrata

TEST PIT 3 EAST WALL

Plate
E-3

Geologic Hazards Investigation
Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number: 320-013

TEST PIT 5 EAST WALL

North **South**

Plate E-4

Geologic Hazards Investigation
Horrocks Engineers
Santaquin Debris Basin
Santaquin, Utah
Project Number: 320-013

GeoStrata

GeoStrata 14425 S Center Point Way, Bluffdale, Utah 84065
T: (801) 501-0583 ~ F: (801) 501-0584

To: **Horrocks Engineers**
Attn: Mr. Jacob O'Bryant
2162 West Grove Parkway, Suite 400
Pleasant Grove, Utah 84062

From: **Daniel J. Brown, P.E.**
Senior Geotechnical Engineer

PROFESSIONAL ENGINEER
6/10/2019
No. 10186640
DANIEL J. BROWN
STATE OF UTAH

Date: **June 10, 2019**

Subject: **Preliminary Embankment Slope Stability**
Santaquin Debris Basins
Santaquin, Utah
GeoStrata Job No. 320-013

Mr. O'Bryant;

At your request, GeoStrata has completed a preliminary slope stability assessment of the five proposed embankments to be constructed at the mouths of six drainages in Santaquin, Utah. The proposed embankments are intended to mitigate debris flow hazard for the properties downstream and on the alluvial fan deposits of these drainages. Based on our understanding, the embankments are to consist of reworked native soils and have a maximum steepness of 3H:1V, a maximum height of 16 feet, and a top width of 12 feet.

Soils at the locations of each of the proposed debris basins were observed in test pits excavated for the *Preliminary Feasibility Study of 5 Debris Basins, Santaquin, Utah* report prepared by GeoStrata dated August 3, 2018. Based on laboratory testing completed on soil samples collected from these test pits, the soils consist of Silty, Clayey GRAVEL with sand, Silty SAND with gravel, Silty, Clayey SAND with gravel, Clayey GRAVEL with sand, Well-Graded GRAVEL with silt and sand, and Silty GRAVEL with sand. No soil strength testing was completed as part of the August 2018 preliminary feasibility study; however, for the purpose of this preliminary slope stability assessment, we have assumed soil strength parameters based on Table 2-6 of Bowles' Foundation Analysis and Design (1996) of a friction angle of 32 degrees and cohesion of 50 psf for the undisturbed native soil and a friction angle of 33 degrees and cohesion of 50 psf for the compacted embankment material.

Seismic design parameters were assessed for each of the proposed debris basin locations using the IBC 2015 Seismic Ground Motion Values maps. The table below summarizes seismic design parameters for these locations.

Drainage	1	2+3	4	5	6
Lat	39.9662	39.9705	39.9757	39.9817	39.9912
Long	-111.7585	-111.7603	-111.7646	-111.7613	-111.7443
S_S	1.303	1.32	1.341	1.355	1.362
S_1	0.48	0.484	0.489	0.494	0.503
S_{MS}	1.303	1.32	1.341	1.355	1.362
S_{M1}	0.730	0.734	0.739	0.744	0.755
S_{DS}	0.869	0.880	0.894	0.903	0.908
S_{D1}	0.486	0.489	0.493	0.496	0.503
F_a	1	1	1	1	1
F_v	1.52	1.516	1.511	1.506	1.5
PGA	0.591	0.598	0.607	0.613	0.615
F_{PGA}	1	1	1	1	1
PGA_M	0.591	0.598	0.607	0.613	0.615

Based on the seismic design data obtained from the IBC 2015 as summarized in the above table, a design PGA of 0.615g was utilized in our seismic slope stability analysis.

Slope stability modeling was completed using Slide, a computer program which incorporates Bishop's method of slope analysis. Analyses were completed using both full and empty basins, conservatively assuming the full basin contains only water. The full condition was assumed to have at least 2 feet of freeboard to the crest of the embankment.

Our rapid drawdown analysis used effective stresses but accounted for the pore pressure conditions created during such an event by using the B-bar method of analysis. The B-bar method calculates the change in pore pressure due to loading or unloading by multiplying the change in vertical pressure by B-bar. B-bar is usually a value from 0 to 1, with free draining soils having a value of 0. In our analysis we assumed a B-bar value of 1.0.

A deformation analysis for pseudo static conditions was completed on the embankment using the Bray and Travasarou method (2007). Our results indicate that during a seismic event, the embankment may experience total deformation of only approximately 1.9 inches if a seismic event were to occur during a time period when the embankment holds water with 2 feet of freeboard.

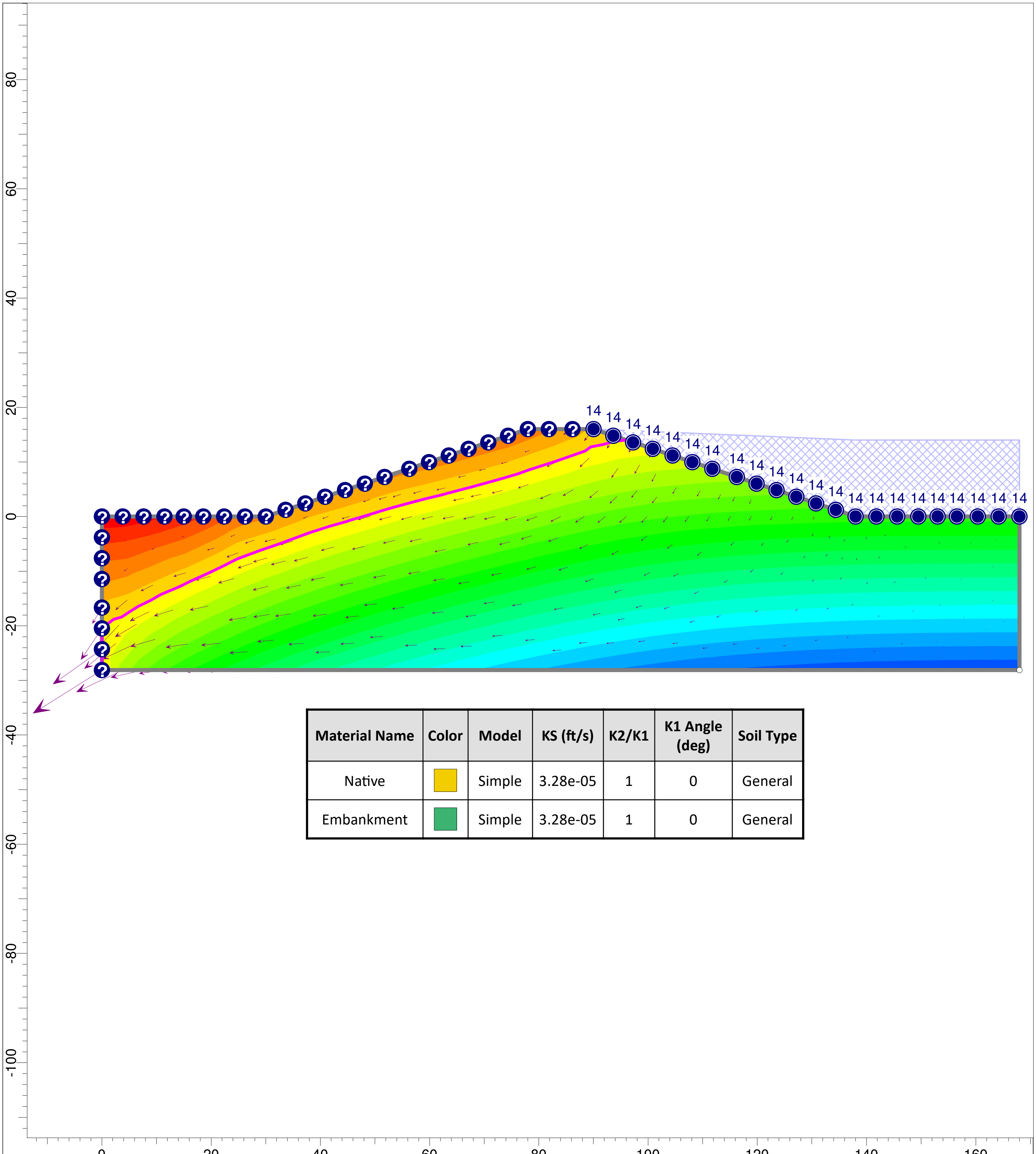
Results for our slope stability modeling are attached to this letter (Plate 1 to Plate 7). The results of the seepage analysis are presented on Plate 1. Based on our analysis, the proposed 3H:1V slopes constructed with the proposed native borrow material meets the minimum design standards. Our calculated safety factors are listed on the following table;

Analysis Type	Minimum Factor of Safety
Full – Static	2.307
Full – Pseudo Static	1.048
Rapid Drawdown	2.477
Dry – Static	2.477
Dry – Pseudo Static	1.181

Closure

The conclusions and recommendations contained in this memorandum which include professional opinions and judgments, are based on the information available to us at the time of our evaluation, the results of our field observations, our limited subsurface exploration and our understanding of the proposed site development. This memorandum was prepared in accordance with the generally accepted standard of practice at the time the report was written. No other warranty, expressed or implied, is made.

This memorandum was written for the exclusive use of Horrocks Engineers and only for the proposed project described herein. It is the Client's responsibility to see that all parties to the project including the Designer, Contractor, Subcontractors, etc. are made aware of this memorandum in its entirety. We are not responsible for the technical interpretations by others of the information described or documented in this memorandum. The use of information contained in this memorandum for bidding purposes should be done at the Contractor's option and risk.



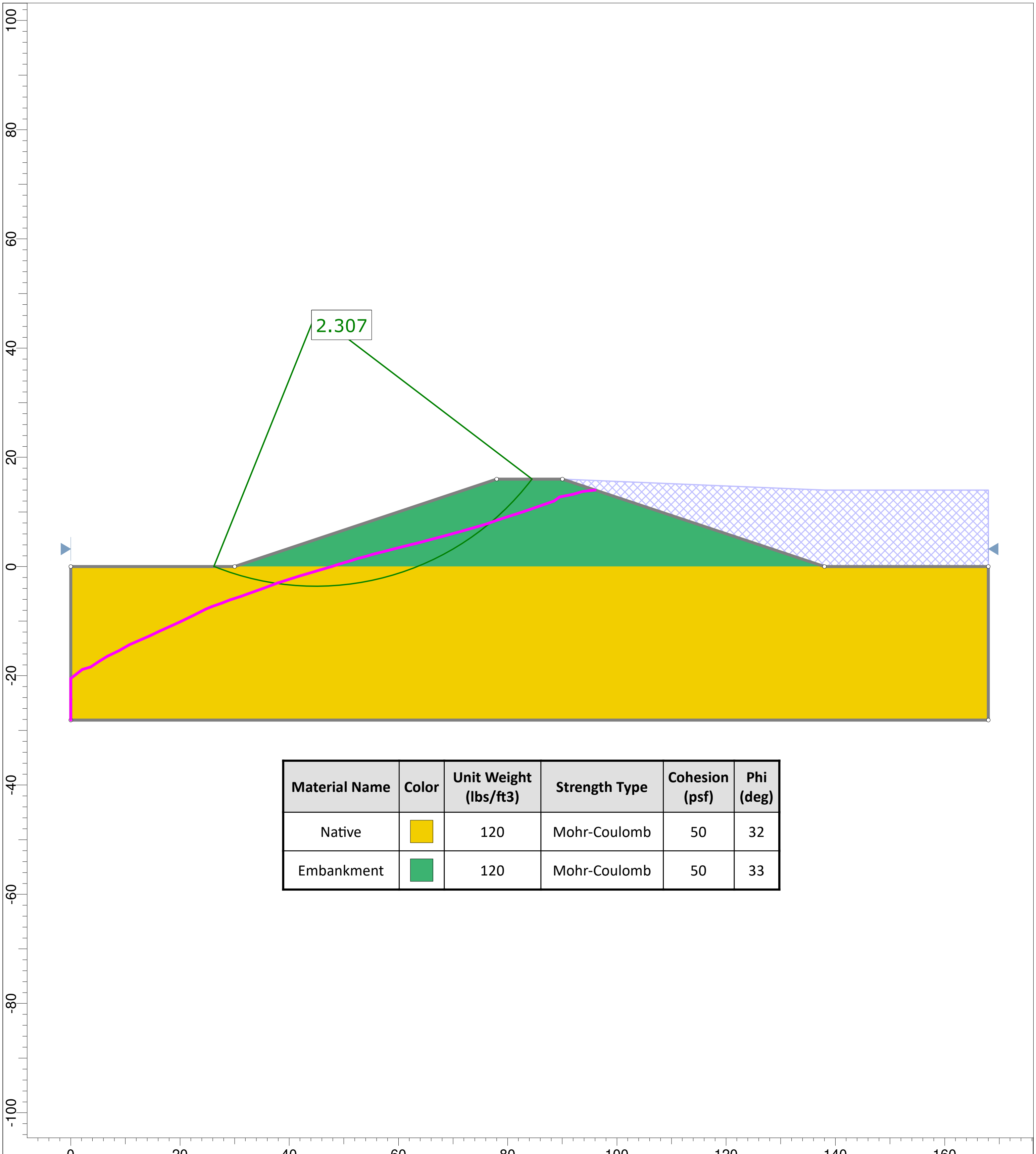
Material Name	Color	Model	KS (ft/s)	K2/K1	K1 Angle (deg)	Soil Type
Native		Simple	3.28e-05	1	0	General
Embankment		Simple	3.28e-05	1	0	General

GeoStrata

Seepage Model

Horrocks Engineers
Santaquin Debris Basins
Santaquin, UT
Project Number: 320-013

Plate 1



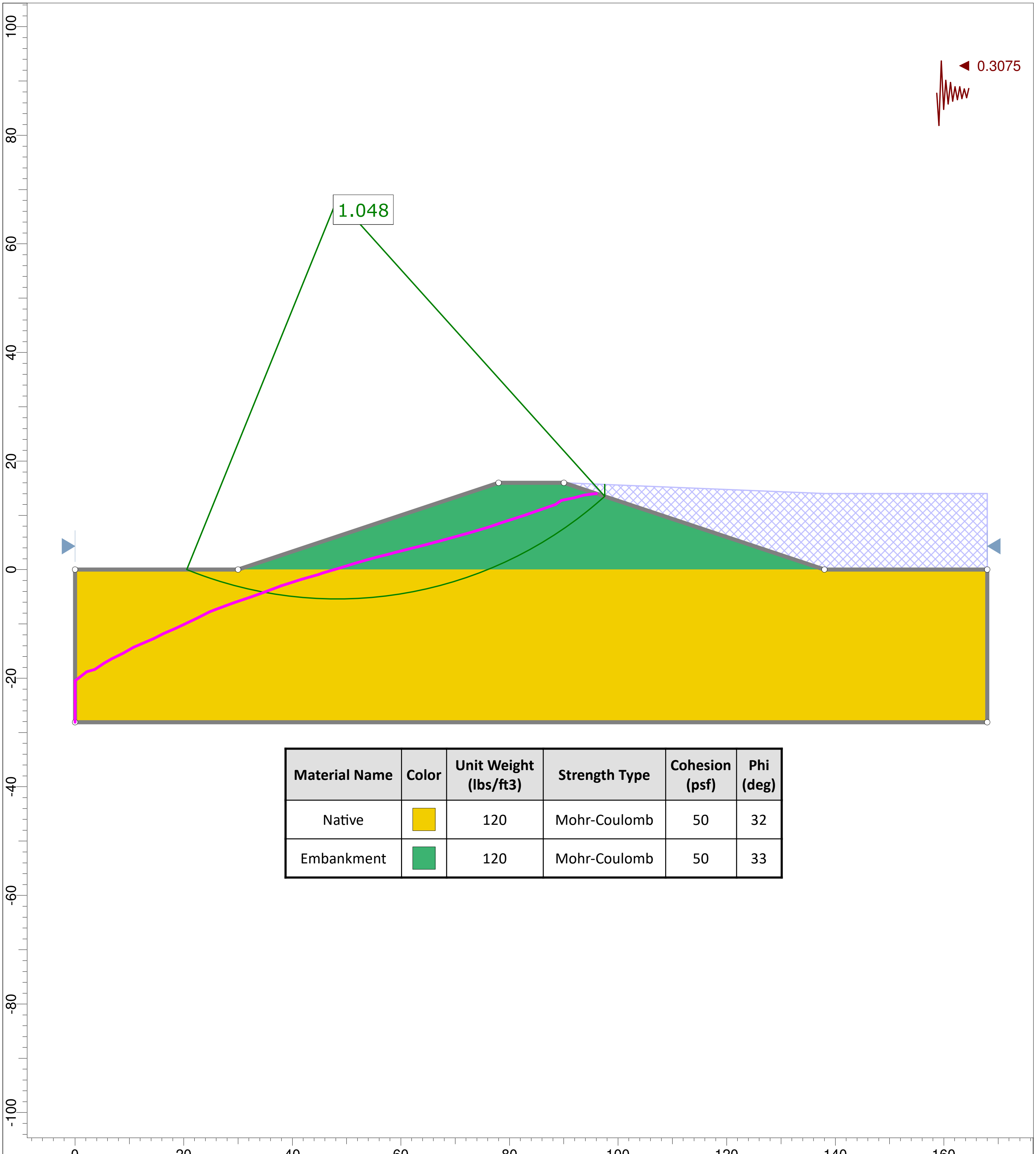
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Native		120	Mohr-Coulomb	50	32
Embankment		120	Mohr-Coulomb	50	33

GeoStrata

Static Slope Stability

Horrocks Engineers
Santaquin Debris Basins
Santaquin
Project Number: 320-013

Plate 2



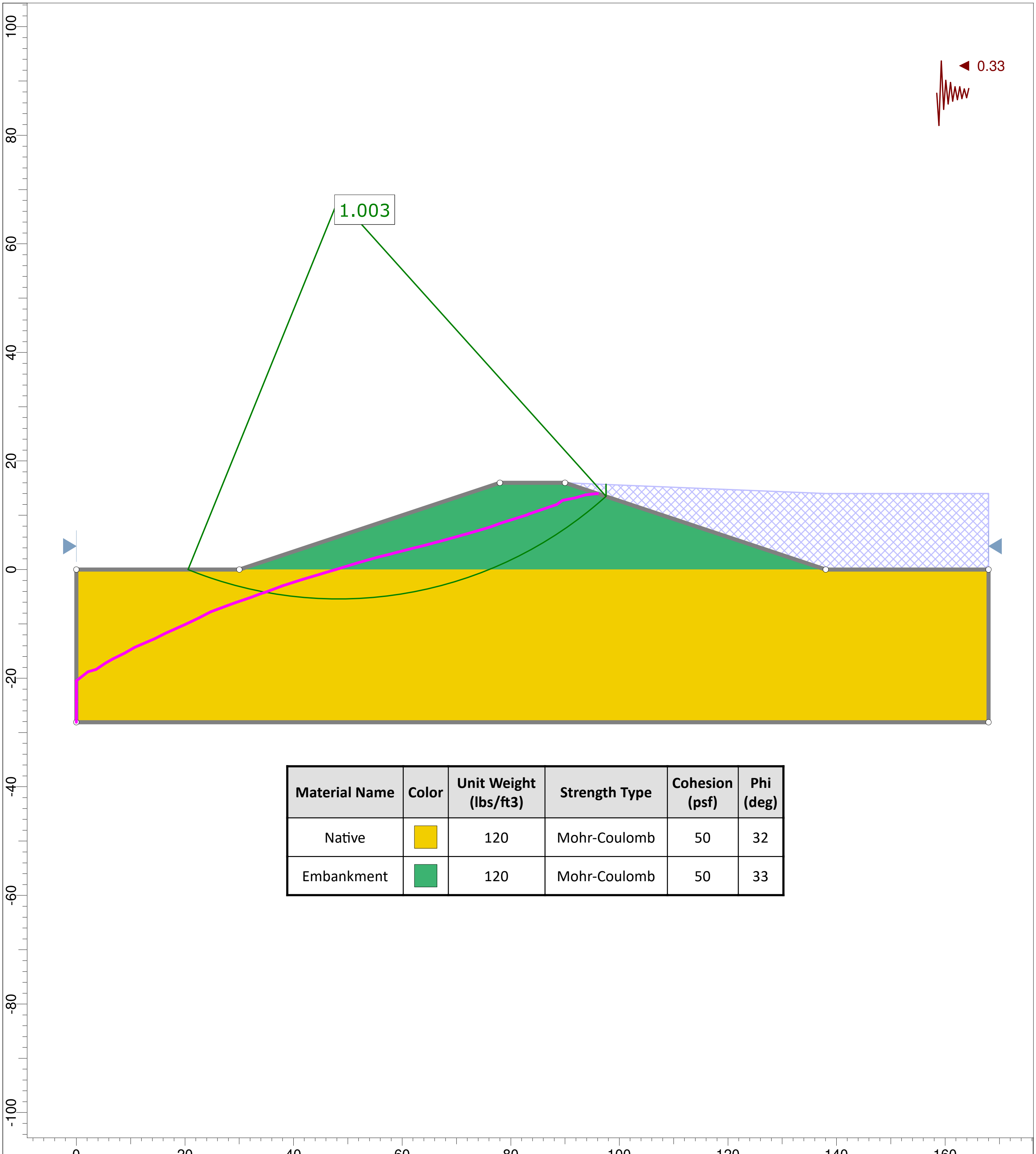
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Native		120	Mohr-Coulomb	50	32
Embankment		120	Mohr-Coulomb	50	33

GeoStrata

Pseudo Static Slope Stability

Horrocks Engineers
Santaquin Debris Basins
Santaquin
Project Number: 320-013

Plate 3



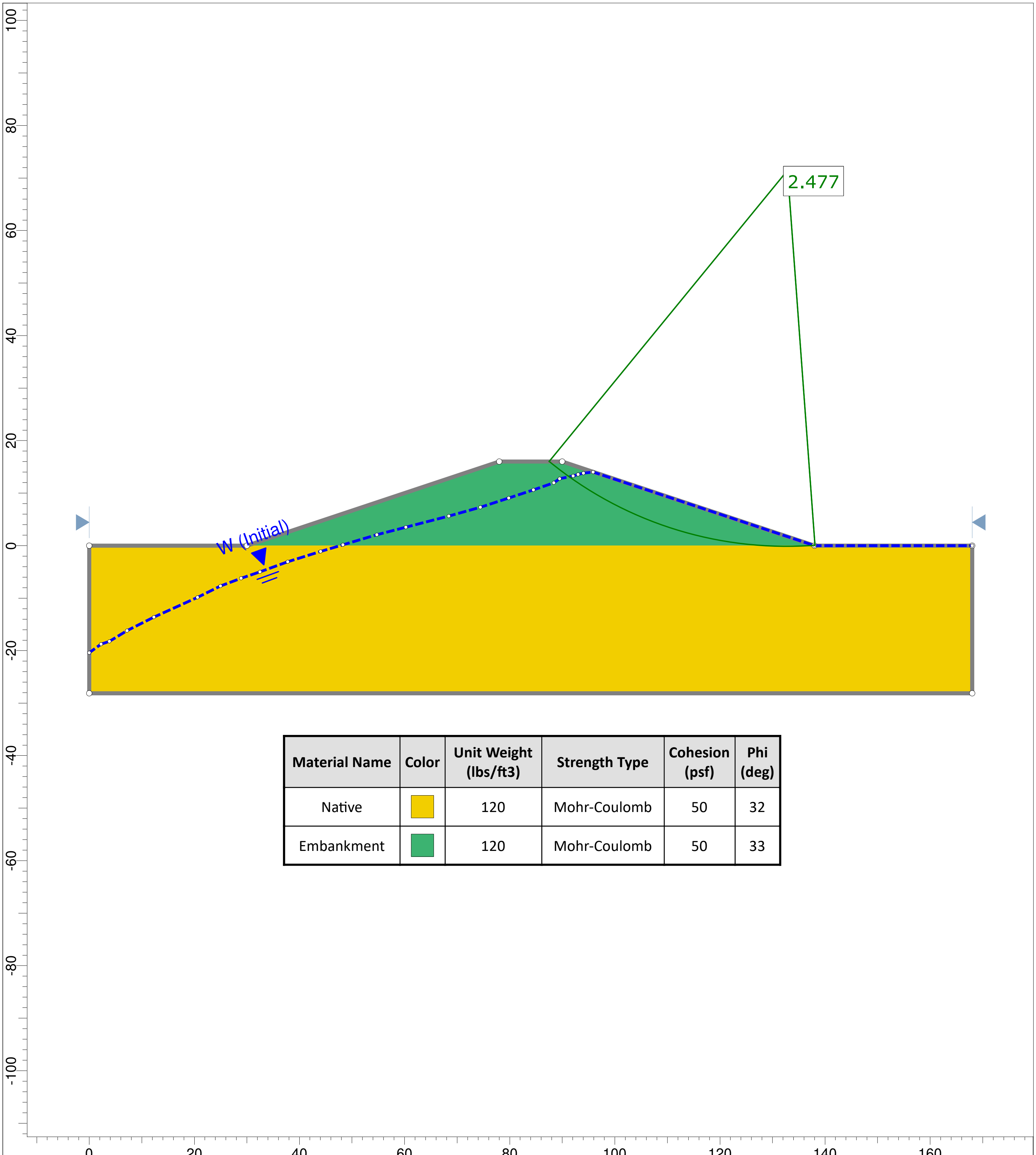
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Native		120	Mohr-Coulomb	50	32
Embankment		120	Mohr-Coulomb	50	33

GeoStrata

Yield Acceleration

Horrocks Engineers
Santaquin Debris Basins
Santaquin, UT
Project Number: 320-013

Plate 4



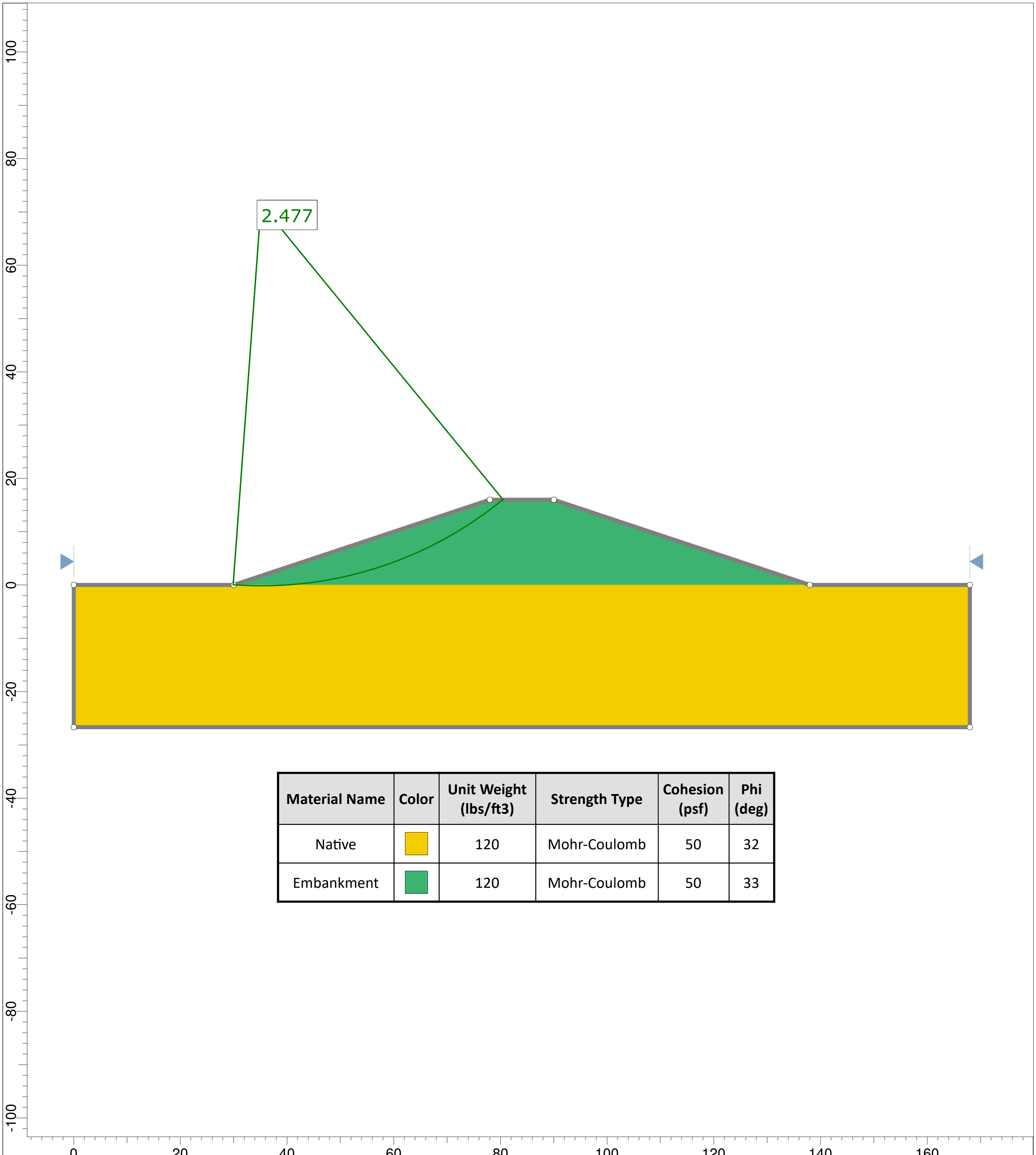
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Native		120	Mohr-Coulomb	50	32
Embankment		120	Mohr-Coulomb	50	33

GeoStrata

Rapid Drawdown

Horrocks Engineers
Santaquin Debris Basins
Santaquin
Project Number: 320-013

Plate 5



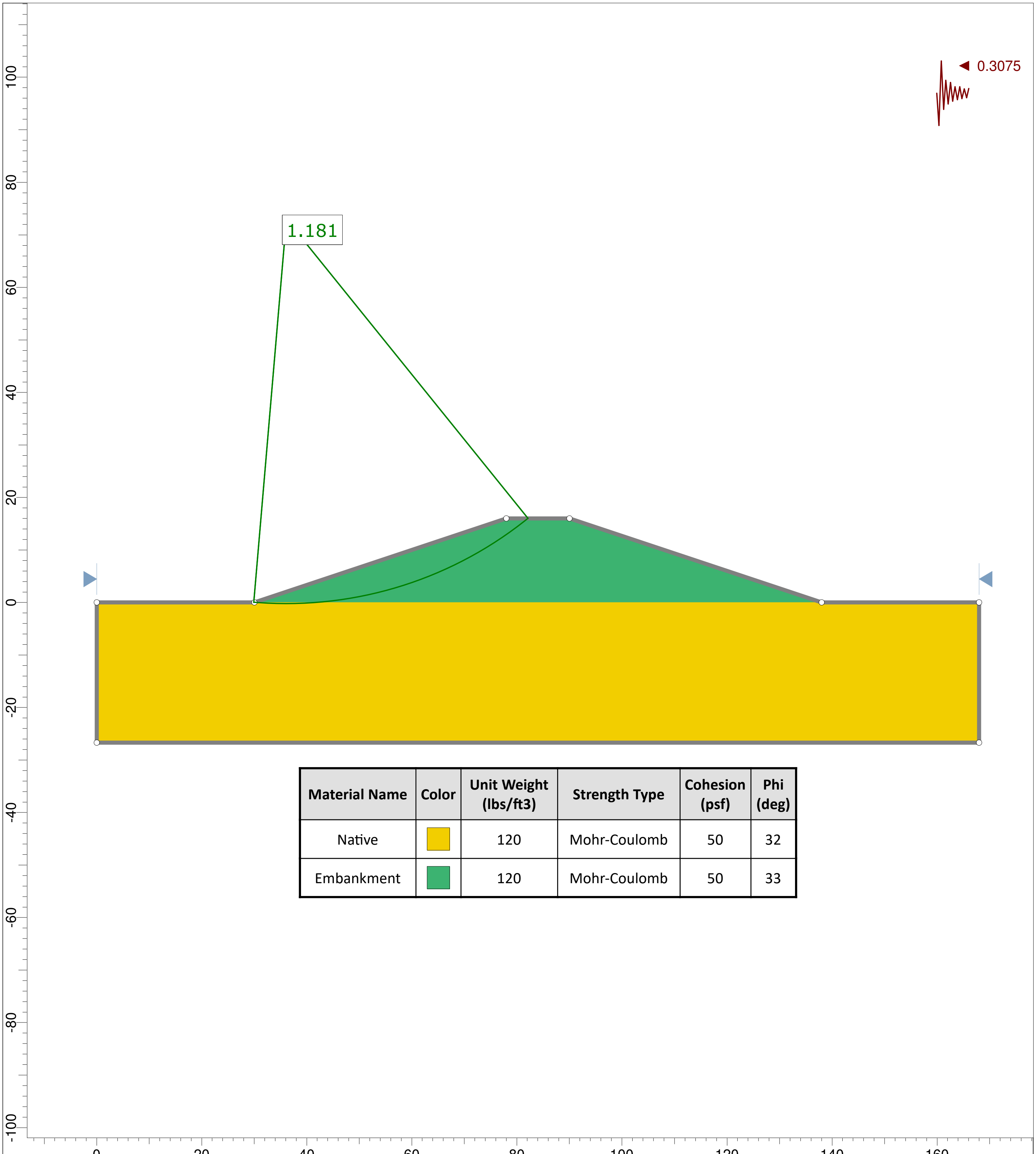
Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Native		120	Mohr-Coulomb	50	32
Embankment		120	Mohr-Coulomb	50	33

GeoStrata

Dry Static Slope Stability

Horrocks Engineers
Santaquin Debris Basins
Santaquin
Project Number: 320-013

Plate 6



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
Native		120	Mohr-Coulomb	50	32
Embankment		120	Mohr-Coulomb	50	33

GeoStrata

Dry Pseudo Static Slope Stability

Horrocks Engineers
Santaquin Debris Basins
Santaquin
Project Number: 320-013

Plate 7

ATTACHMENT 6

COST ESTIMATES

Basin 1 - Below Grade
Hillside Debris Basins

Item	Description	Quantity	Units	Unit Cost	Cost
1	Mobilization	1	LS	----	$200,190.00
2	15 Inch Storm Drain	0	LF	$55.00	$0.00
3	18 Inch Storm Drain	0	LF	$60.00	$0.00
4	21 Inch Storm Drain	0	LF	$65.00	$0.00
5	24 Inch Storm Drain	0	LF	$70.00	$0.00
6	30 Inch Storm Drain	300	LF	$75.00	$22,500.00
7	36 Inch Storm Drain		LF	$95.00	$0.00
8	42 Inch Storm Drain	0	LF	$125.00	$0.00
9	48 Inch Storm Drain	0	LF	$155.00	$0.00
10	Spillway Cut	9,087	CY	$8.00	$72,696.00
11	Spillway Structure and Riprap	1	EA	$45,000.00	$45,000.00
11	Outlet works	1	EA	$35,000.00	$35,000.00
12	Excavation (cut)	217,813	CY	$8.00	$1,742,504.00
13	Embankment (fill)	55	CY	$0.00	$0.00
14	Sediment Basin Additional Cut	0	CY	$0.00	$0.00
15	Liner/internal Cutoff Earthwork	0	CY	$8.00	$0.00
16	Manholes/Inlets/Structures	1	EA	$8,000.00	$8,000.00
17	Toe Drain	1	LS	$55,000.00	$55,000.00
18	Class "A" Road Repair	0	SF	$6.00	$0.00
19	Class "D" Field Repair	-	SF	$0.25	$0.00
20	Revegetation	21.2	Acres	$1,000.00	$21,200.00
21	Imported Fill	0	CY	$10.00	$0.00
22	Railroad and Canal Crossing	0	LS	$108,000.00	$0.00
23	State Road Crossing	0	LS	$220,000.00	$0.00
24	Traffic Control	0	LS	$675.00	$0.00
25	Utility Relocation (20% of pipe cost)	0	LS	$4,500.00	$0.00
	Sub Total (Construction)				$2,202,090.00
	Contingencies	20%			$440,418.00
	Land	462,000	SF	$2.00	$924,000.00
	Right of Way	-	SF	$1.00	$0.00
	Total (Construction)				$3,566,508.00
	Environmental	0%			$0.00
	Design and Construction Engineering	20%			$440,418.00
	Administration, Legal, and Bond Counsel	1%			$22,020.90
	Total (Professional Services)				$462,438.90
	Grand Total				**$4,028,946.90**

Basin 3A - Below Grade
Hillside Debris Basins

Item	Description	Quantity	Units	Unit Cost	Cost
1	Mobilization	1	LS	----	$43,191.90
2	15 Inch Storm Drain	0	LF	$55.00	$0.00
3	18 Inch Storm Drain	0	LF	$60.00	$0.00
4	21 Inch Storm Drain	0	LF	$65.00	$0.00
5	24 Inch Storm Drain	0	LF	$70.00	$0.00
6	30 Inch Storm Drain	300	LF	$75.00	$22,500.00
7	36 Inch Storm Drain	0	LF	$95.00	$0.00
8	42 Inch Storm Drain	0	LF	$125.00	$0.00
9	48 Inch Storm Drain	0	LF	$155.00	$0.00
10	Trench Earthwork	0	LF	$0.00	$0.00
11	Spillway	1	EA	$35,000.00	$35,000.00
12	Outlet works	1	EA	$20,000.00	$20,000.00
13	Excavation (cut)	39836	CY	$ 8.00	$318,688.00
14	Embankment (fill)	0	CY	$0.00	$0.00
15	Imported Fill	0	CY	$9.00	$0.00
16	Cutoff Excavation and Backfill	0	CY	$10.00	$0.00
17	Sediment Basin Additional Cut	0	CY	$5.00	$0.00
18	Toe Drain	1	LS	$25,000.00	$25,000.00
19	Manholes/Inlets/Structures	1	EA	$6,500.00	$6,500.00
20	Class "A" Road Repair	0	SF	$6.00	$0.00
21	Class "D" Field Repair	3,150	SF	$0.25	$787.50
22	Revegetation	3.44	Acre	$1,000.00	$3,443.53
23	Railroad and Canal Crossing	0	LS	$108,000.00	$0.00
24	State Road Crossing	0	LS	$220,000.00	$0.00
25	Traffic Control	0	LS	$675.00	$0.00
	Utility Relocation (20% of pipe cost)	0	LS	$4,500.00	$0.00
	Sub Total (Construction)				$475,110.93
	Contingencies	20%			$95,022.19
	Land	150,000	SF	$2.00	$300,000.00
	Right of Way	-	SF	$1.00	$0.00
	Total (Construction)				$870,133.11
	Environmental	0%			$0.00
	Design and Construction Engineering	20%			$95,022.19
	Administration, Legal, and Bond Counsel	1%			$4,751.11
	Total (Professional Services)				$99,773.30
	Grand Total				**$969,906.41**

Basin 4 - Above Grade, Single Watershed (4E)
Hillside Debris Basins

Item	Description	Quantity	Units	Unit Cost	Cost
1	Mobilization	1	LS	----	$80,308.99
2	15 Inch Storm Drain	0	LF	$55.00	$0.00
3	18 Inch Storm Drain	0	LF	$60.00	$0.00
4	21 Inch Storm Drain	0	LF	$65.00	$0.00
5	24 Inch Storm Drain	0	LF	$70.00	$0.00
6	30 Inch Storm Drain	200	LF	$75.00	$15,000.00
7	36 Inch Storm Drain	0	LF	$95.00	$0.00
8	42 Inch Storm Drain	0	LF	$125.00	$0.00
9	48 Inch Storm Drain		LF	$155.00	$0.00
10	60 Inch Pipe or Box Culvert (from upstream channel)	550	LF	$250.00	$137,500.00
11	Spillway Cut	8500	CY	$6.00	$51,000.00
12	Spillway Structure and Riprap	1	EA	$50,000.00	$50,000.00
13	Outlet works	1	EA	$30,000.00	$30,000.00
14	Excavation (cut)	67050	CY	$6.00	$402,300.00
15	Embankment (fill)	26600	CY	$0.00	$0.00
16	Imported Fill	0	CY	$9.00	$0.00
17	Cutoff Excavation and Fill	6028	CY	$10.00	$60,280.00
18	Sediment Basin Additional Cut	0	CY	$5.00	$0.00
19	Manholes/Inlets/Structures	1	EA	$8,000.00	$8,000.00
20	Toe Drain	1	EA	$40,000.00	$40,000.00
21	Class "A" Road Repair	0	SF	$6.00	$0.00
22	Class "D" Field Repair	-	SF	$0.25	$0.00
23	Revegetation	8	Acre	$1,000.00	$8,034.89
24	Imported Backfill	0	TON	$12.00	$0.00
25	Railroad and Canal Crossing	0	LS	$108,000.00	$0.00
26	State Road Crossing	0	LS	$220,000.00	$0.00
27	Traffic Control	1	LS	$225.00	$225.00
28	Utility Relocation (5% of pipe cost)	1	LS	$750.00	$750.00
	Sub Total (Construction)				$883,398.88
	Contingencies	20%			$176,679.78
	Land	350,000	SF	$2.00	$700,000.00
	Right of Way	-	SF	$1.00	$0.00
	Total (Construction)				$1,760,078.66
	Environmental	0%			$0.00
	Design and Construction Engineering	20%			$176,679.78
	Administration, Legal, and Bond Counsel	1%			$8,833.99
	Total (Professional Services)				$185,513.77
	Grand Total				**$1,945,592.43**

Basin 5 (Below/hybrid)
Hillside Debris Basins

Item	Description	Quantity	Units	Unit Cost	Cost
1	Mobilization	1	LS	----	$193,505.00
2	15 Inch Storm Drain	0	LF	$55.00	$0.00
3	18 Inch Storm Drain	0	LF	$60.00	$0.00
4	21 Inch Storm Drain	0	LF	$65.00	$0.00
5	24 Inch Storm Drain	0	LF	$70.00	$0.00
6	30 Inch Storm Drain	200	LF	$75.00	$15,000.00
7	36 Inch Storm Drain	0	LF	$95.00	$0.00
8	42 Inch Storm Drain	0	LF	$125.00	$0.00
9	48 Inch Storm Drain	0	LF	$155.00	$0.00
10	Spillway and Channel Cut	23000	CY	$8.00	$184,000.00
11	Spillway Structure and Riprap	1	EA	$50,000.00	$50,000.00
12	Outlet works	1	EA	$35,000.00	$35,000.00
13	Excavation (cut)	197100	CY	$8.00	$1,576,800.00
14	Embankment (fill)	150	CY	$0.00	$0.00
15	Imported Fill		CY	$9.00	$0.00
16	Cutoff Excavation and Fill	1100	CY	$20.00	$22,000.00
17	Sediment Basin Additional Cut	0	CY	$5.00	$0.00
18	Manholes/Inlets/Structures	1	EA	$6,500.00	$6,500.00
19	Toe Drain	1	EA	$45,000.00	$45,000.00
20	Class "A" Road Repair	0	SF	$6.00	$0.00
21	Class "D" Field Repair	-	SF	$0.25	$0.00
22	Revegetation	-	Acre	$1,000.00	$0.00
22	Imported Backfill	0	TON	$12.00	$0.00
23	Railroad and Canal Crossing	0	LS	$108,000.00	$0.00
24	State Road Crossing	0	LS	$220,000.00	$0.00
25	Traffic Control	0	LS	$450.00	$0.00
26	Utility Relocation (5% of pipe cost)	1	LS	$750.00	$750.00
	Sub Total (Construction)				$2,128,555.00
	Contingencies	20%			$425,711.00
	Land		SF	$2.00	$0.00
	Right of Way*	581,000	SF	$0.10	$58,100.00
	Total (Construction)				$2,612,366.00
	Environmental	0%			$0.00
	Design and Construction Engineering	20%			$425,711.00
	Administration, Legal, and Bond Counsel	1%			$21,285.55
	Total (Professional Services)				$446,996.55
	Grand Total				**$3,059,362.55**

*Administrative costs, based on land swap with the Forest Service

Basin 6
Hillside Debris Basins

Item	Description	Quantity	Units	Unit Cost	Cost
1	Mobilization	1	LS	----	$95,868.72
2	15 Inch Storm Drain	0	LF	$55.00	$0.00
3	18 Inch Storm Drain	0	LF	$60.00	$0.00
4	21 Inch Storm Drain	0	LF	$65.00	$0.00
5	24 Inch Storm Drain	0	LF	$70.00	$0.00
6	30 Inch Storm Drain	350	LF	$75.00	$26,250.00
7	36 Inch Storm Drain	0	LF	$95.00	$0.00
8	42 Inch Storm Drain	0	LF	$125.00	$0.00
9	48 Inch Storm Drain	0	LF	$155.00	$0.00
10	Spillway Cut	12560	EA	$6.00	$75,360.00
11	Spillway Structure and Riprap	1	EA	$50,000.00	$50,000.00
12	Outlet works	1	EA	$35,000.00	$35,000.00
13	Excavation (cut)	89100	CY	$6.00	$534,600.00
14	Embankment (fill)	29091	CY	$0.00	$0.00
15	Imported Fill	6209	CY	$10.00	$62,088.40
16	Cutoff Excavation and Fill	6193	CY	$10.00	$61,930.00
17	Sediment Basin Additional Cut	0	CY	$5.00	$0.00
18	Toe Drain	1	EA	$45,000.00	$45,000.00
19	Manholes/Inlets/Structures	2	EA	$8,000.00	$16,000.00
20	Class "A" Road Repair	0	SF	$6.00	$0.00
21	Class "D" Field Repair	3,675	SF	$0.25	$918.75
22	Revegetation	9.04	Acre	$1,000.00	$9,045.00
22	Imported Backfill	3476	TON	$12.00	$41,707.56
23	Railroad and Canal Crossing	0	LS	$108,000.00	$0.00
24	State Road Crossing	0	LS	$220,000.00	$0.00
25	Traffic Control	1	LS	$787.50	$787.50
26	Utility Relocation (20% of pipe cost)	0	LS	$5,250.00	$0.00
	Sub Total (Construction)				$1,054,555.93
	Contingencies	20%			$210,911.19
	Land	394,000	SF	$2.00	$788,000.00
	Right of Way	-	SF	$1.00	$0.00
	Total (Construction)				$2,053,467.12
	Environmental	0%			$0.00
	Design and Construction Engineering	20%			$210,911.19
	Administration, Legal, and Bond Counsel	1%			$10,545.56
	Total (Professional Services)				$221,456.75
	Grand Total				**$2,274,923.86**

ATTACHMENT 7

CPA-52 ENVIRONMENTAL EVALUATION

U.S. Department of Agriculture Natural Resources Conservation Service **ENVIRONMENTAL EVALUATION WORKSHEET**	NRCS-CPA-52 6/2010	**A. Client Name:** Santaquin City, Utah **B. Conservation Plan ID #** (as applicable): Santaquin Storm Drain **Program Authority** (optional): WFPO Program 2017 Funding
D. Client's Objective(s) (purpose): The purpose of the project is to prevent flooding and debris flow from storm events in the hills above Santaquin.		**C. Identification #** (farm, tract, field #, etc as required):

E. Need for Action:	**G. Alternatives**		
	No Action √ if RMS ☐	***Alternative 1*** √ if RMS ☐	***Alternative 2*** √ if RMS ☐
Wildfires in 2001 led to debris flows in 2002 and later in the hills above Santaquin. These debris flows have impacted residences and other public infrastructure. The need of the project is to prevent further debris flows.	Typical maintenance of existing storm drainage facilities will be continued	The project will construct five debris/water retention basins as well as installing pipelines and/or ditches to carry stormwater away from the hillsides to a safe outfall.	The project will construct three debris/water retention basins as well as installing pipelines and/or ditches to carry stormwater away from the hillsides to a safe outfall.

Resource Concerns

In Section "F" below, analyze, record, and address concerns identified through the Resources Inventory process. (See FOTG Section III - Resource Quality Criteria for guidance).

F. Resource Concerns and Existing / Benchmark Conditions (Analyze and record the existing/benchmark conditions for each identified concern)	**H. Effects of Alternatives** — ***No Action*** Amount, Status, Description (short and long term)	√ if does NOT meet QC	***Alternative 1*** Amount, Status, Description (short and long term)	√ if does NOT meet QC	***Alternative 2*** Amount, Status, Description (short and long term)	√ if does NOT meet QC
SOIL						
Erosion (Streambank) Erosion is not a concern for the project.	Streambank erosion is not expected.	☐ NOT meet QC	No erosional impacts are expected.	☐ NOT meet QC	No erosional impacts are expected.	☐ NOT meet QC
Erosion (Sheet and Rill) Erosion and debris flows are major concerns.	Heavy storm events may cause additional debris flows near and through residential neighborhoods in eastern Santaquin.	☐ NOT meet QC	The threat of debris flows will be greatly lessened through control of storm water.	☐ NOT meet QC	The threat of debris flows will be greatly lessened through control of storm water. Two areas where debris flows have not yet, but could in the future, occur would not be protected.	☐ NOT meet QC
WATER						
Quantity (Excessive Runoff, Flooding, or Ponding) Excessive runoff and flooding is currently an issue in the project area.	Heavy storm events may cause additional flooding and/or debris flows near and through residential neighborhoods in eastern Santaquin.	☐ NOT meet QC	The project will allow the capture of water and its diversion to a safe outfall.	☐ NOT meet QC	The project will allow the capture of water and its diversion to a safe outfall.	☐ NOT meet QC
Quality (Surface Water: Excessive Susp. Sedmt & Turbidity) There are no impaired waters in the study area.	No changes in water quality are expected.	☐ NOT meet QC	No changes in water quality are expected.	☐ NOT meet QC	No changes in water quality are expected.	☐ NOT meet QC

F. Resource Concerns and Existing / Benchmark Conditions (Analyze and record the existing/benchmark conditions for each identified concern)	**H. (continued)** *No Action* Amount, Status, Description (short and long term)	√ if does NOT meet QC	*Alternative 1* Amount, Status, Description (short and long term)	√ if does NOT meet QC	*Alternative 2* Amount, Status, Description (short and long term)	√ if does NOT meet QC
AIR						
Quality [Particulate Matter < 10µm diameter ("PM 10")] No Effect	No Effect	NOT meet ☐ QC	Short term: fugitive dust expected during construction activities; Long term: no effect	NOT meet ☐ QC	Short term: fugitive dust expected during construction activities; Long term: no effect	NOT meet ☐ QC
PLANTS						
Other Vegetation consists primarily of low sage, bunch grasses, and Gambel oak.	No effect.	☐ meet QC	Short term: Removal of some vegetation during construction activities. Long term: some areas would be converted to debris/retention basins.	☐ meet QC	Short term: Removal of some vegetation during construction activities. Long term: some areas would be converted to debris/retention basins.	☐ meet QC
Condition (Noxious and Invasive Plants) Utah County uses the Utah State Noxious Weed list.	No change to existing management policies.	NOT ☐ QC	Short term: Disturbed areas would be temporarily exposed to some invasive weed growth. Long term: No effect.	NOT ☐ QC	Short term: Disturbed areas would be temporarily exposed to some invasive weed growth. Long term: No effect.	NOT ☐ QC
ANIMALS						
Fish and wildlife (Impacts to Endangered or Threatened Animals) State listed threatened or endangered species: Canada lynx, yellow-billed cuckoo, June sucker. (Ref. IPaC, accessed 17Aug17)	No effect.	☐ NOT meet QC	There is no critical habitat for any state sensitive species in the project area or proximity.	☐ NOT meet QC	There is no critical habitat for any state sensitive species in the project area or proximity.	☐ NOT meet QC
HUMAN - Economic and Social Considerations						
Public Health and Safety Debris flows and flooding threaten health and safety of area residents.	Residential neighborhoods will continue to be threatened by flooding and debris flows.		The threat of flooding and debris flows will be greatly reduced.		The threat of flooding and debris flows will be greatly reduced.	

Special Environmental Concerns: Environmental Laws, Executive Orders, policies, etc.

In Section "I" complete and attach applicable Environmental Procedures Guide Sheets for documentation. Items with a "●" may require a federal permit or consultation/coordination between the lead agency and another government agency. In these cases, effects may need to be determined in consultation with another agency. Planning and practice implementation may proceed for practices not involved in consultation.

I. Special Environmental Concerns (Document compliance with Environmental Laws, Executive Orders, policies, etc.)	**J. Impacts to Special Environmental Concerns**					
	No Action		***Alternative 1***		***Alternative 2***	
	Status and progress of compliance. (Complete and attach Guide Sheets as applicable)	√ if needs further action	Status and progress of compliance. (Complete and attach Guide Sheets as applicable)	√ if needs further action	Status and progress of compliance. (Complete and attach Guide Sheets as applicable)	√ if needs further action
●Clean Air Act No effect.	Upon Review, No Action Needed		Upon Review, No Effect		Upon Review, No Effect	
●Clean Water Act / Waters of the U.S.	Upon Review, No Action Needed		Upon Review, No Effect		Upon Review, No Effect	
●Coastal Zone Management	Upon Review, Not Applicable		Upon Review, Not Applicable		Upon Review, Not Applicable	
Coral Reefs	Upon Review, Not Applicable		Upon Review, Not Applicable		Upon Review, Not Applicable	
●Cultural Resources / Historic Properties	Upon Review, No Effect		Other Two non-eligible historic trash scatters have been previously recorded near one of the pipelines. A pipeline would also cross 42UT473, the Strawberry Highline Canal.	√	Other Two non-eligible historic trash scatters have been previously recorded near one of the pipelines. A pipeline would also cross 42UT473, the Strawberry Highline Canal.	
●Endangered and Threatened Species	See Attached Documentation		Upon Review, No Effect There is no critical habitat for any state sensitive species in the project area or proximity.	√	Upon Review, No Effect There is no critical habitat for any state sensitive species in the project area or proximity.	√
Environmental Justice	Upon Review, No Action Needed		Upon Review, Not Present		Upon Review, Not Present	
●Essential Fish Habitat	Upon Review, Not Applicable		Upon Review, Not Applicable		Upon Review, Not Applicable	
Floodplain Management	Upon Review, Not Applicable		Upon Review, No Effect There is no flood map printed for the project area.		Upon Review, No Effect There is no flood map printed for the project area.	
Invasive Species	Upon Review, No Effect There would be no change to invasive species.		Other Disturbed areas will be replanted-reseeded per agency consult.	√	Other Disturbed areas will be replanted-reseeded per agency consult.	
●Migratory Birds/Bald and Golden Eagle Protection Act	Upon Review, No Action Needed		Upon Review, No Action Needed The IpAC database has shown the potential for migratory birds to be present; however, any removal of mature trees or shrubs during the bird nesting season (Feb 1-Aug31) would be surveyed prior by a qualified biologist. If any nesting birds are in the area or its proximity, USFWS guidance on temporal and spatial buffers will be followed.		Upon Review, No Action Needed The IpAC database has shown the potential for migratory birds to be present; however, any removal of mature trees or shrubs during the bird nesting season (Feb 1-Aug31) would be surveyed prior by a qualified biologist. If any nesting birds are in the area or its proximity, USFWS guidance on temporal and spatial buffers will be followed.	
Prime and Unique Farmlands No effect	Upon Review, Not Applicable		Upon Review, Not Applicable		Upon Review, Not Applicable	
Riparian Area	Upon Review, Not Present		Upon Review, Not Present		Upon Review, Not Present	
●Wetlands No effect	Upon Review, Not Present		Upon Review, Not Present		Upon Review, Not Present	
●Wild and Scenic Rivers Virgin River is the only designated Wild & Scenic River in Utah.	Upon Review, Not Applicable		Upon Review, Not Applicable		Upon Review, Not Applicable	

K. Other Agencies and Broad Public Concerns	***No Action***	***Alternative 1***	***Alternative 2***
Easements, Permissions, Public Review, or Permits Required and Agencies Consulted.	None needed	USFWS: T&E species; UDWaterRts: Stream Alt Permit; SHPO: Cultural Resources. Native American consultation. ACOE 401 WQ/NPDES Cert: To be completed before construction.	

K. (continued) Other Agencies and Broad Public Concerns		No Action	Alternative 1	Alternative 2
Cumulative Effects Narrative (Describe the cumulative impacts considered, including past, present and known future actions regardless of who performed the actions)		Residential areas will continue to be threatened by debris flow and flooding, potentially leading to lower property values and increased danger.	Residential areas will be safer from debris flows and flooding.	
L. Mitigation		None		
M. Preferred Alternative	√ preferred alternative	☐	☑	☐
	Supporting reason	Does not fit the purpose and need for EWP.	Consistent with WFPO program as it provides for flood protection.	Consistent with WFPO program as it provides for flood protection.
N. Context (Record context of alternatives analysis)		local	local	local

The significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected region, the affected interests, and the locality.

O. Determination of Significance or Extraordinary Circumstances

Intensity: Refers to the severity of impact. Impacts may be both beneficial and adverse. A significant effect may exist even if the Federal agency believes that on balance the effect will be beneficial. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts.

If you answer ANY of the below questions "yes" then contact the State Environmental Liaison as there may be extraordinary circumstances and significance issues to consider and a site specific NEPA analysis may be required.

Yes	No	
☐	☑	• Is the preferred alternative expected to cause significant effects on public health or safety?
☐	☑	• Is the preferred alternative expected to significantly effect unique characteristics of the geographic area such as proximity to historic or cultural resources, park lands, prime farmlands, wetlands, wild and scenic rivers, or ecologically critical areas?
☐	☑	• Are the effects of the preferred alternative on the quality of the human environment likely to be highly controversial?
☐	☑	• Does the preferred alternative have highly uncertain effects or involve unique or unknown risks on the human environment?
☐	☑	• Does the preferred alternative establish a precedent for future actions with significant impacts or represent a decision in principle about a future consideration?
☐	☑	• Is the preferred alternative known or reasonably expected to have potentially significant environment impacts to the quality of the human environment either individually or cumulatively over time?
☐	☑	• Will the preferred alternative likely have a significant adverse effect on ANY of the special environmental concerns? Use the Evaluation Procedure Guide Sheets to assist in this determination. This includes, but is not limited to, concerns such as cultural or historical resources, endangered and threatened species, environmental justice, wetlands, floodplains, coastal zones, coral reefs, essential fish habitat, wild and scenic rivers, clean air, riparian areas, natural areas, and invasive species.
☐	☑	• Will the preferred alternative threaten a violation of Federal, State, or local law or requirements for the protection of the environment?

P. The information recorded above is based on the best available information:

In the case where a non-NRCS person (i.e. a TSP) assists with planning they are to sign the first signature block and then NRCS is to sign the second block as the responsible federal agency for the planning action.

Signature (TSP if applicable)	**Title**	**Date**
Signature (NRCS)	**Title**	**Date**

The following sections are to be completed by the Responsible Federal Official (RFO)

Q. NEPA Compliance Finding (check one)

The preferred alternative:		**Action required**
☐	1) is **not a federal action** where the agency has control or responsibility.	Document in "R.1" below. No additional analysis is required
☐	2) is a federal action that is **categorically excluded** from further environmental analysis **and** there are no extraordinary circumstances.	Document in "R.2" below. No additional analysis is required
☐	3) is a federal action that has been **sufficiently analyzed** in an existing Agency state, regional, or national NEPA document **and** there are no predicted significant adverse environmental effects or extraordinary circumstances.	Document in "R.1" below. No additional analysis is required.
☐	4) is a federal action that has been sufficiently analyzed in another Federal agency's NEPA document (EA or EIS) that addresses the proposed NRCS action and its' effects **and has been formally adopted by NRCS**. NRCS is required to prepare and publish the agency's own Finding of No Significant Impact for an EA or Record of Decision for an EIS when adopting another agency's EA or EIS document. **Note: This box is not applicable to FSA.**	Contact the State Environmental Liaison for list of NEPA documents formally adopted and available for tiering. Document in "R.1" below. No additional analysis is required
☐	5) is a federal action that has **NOT** been sufficiently analyzed or may involve predicted significant adverse environmental effects or extraordinary circumstances and may require an EA or EIS.	Contact the State Environmental Liaison. Further NEPA analysis required.

R. Rationale Supporting the Finding

R.1 Findings Documentation	
R.2 Applicable Categorical Exclusion(s) (more than one may apply)	

I have considered the effects of the alternatives on the Resource Concerns, Economic and Social Considerations, Special Environmental Concerns, and Extraordinary Circumstances as defined by Agency regulation and policy.

S. Signature of Responsible Federal Official:

Signature	**Title**	**Date**

Additional notes

Instructions for Completing the Environmental Evaluation Worksheet (Form NRCS-CPA-52),

INTRODUCTION

The Environmental Evaluation (EE) is "a concurrent part of the planning process in which the potential long-term and short-term impacts of an action on people, their physical surroundings, and nature are evaluated and alternative actions explored" (NPPH-Amendment 4, March 2003). This form provides for the documentation of that part of the planning process, and was designed to assist the conservation planner with compliance requirements for applicable Federal laws, regulations, Executive Orders, and policy. The form also provides a framework for documenting compliance with applicable State and local requirements.

NRCS is required to conduct an EE on all actions to determine if there is a need for an Environmental Assessment (EA) or an Environmental Impact Statement (EIS). The EE process results in a "Finding" or conclusion (see guidance for "Q" below) that, either further NEPA analysis is required (EA or EIS) or that no EA or EIS is required because: 1) There is no federal action; 2) The action is categorically excluded; or 3) There is an existing NRCS or NRCS-adopted NEPA document that has sufficiently analyzed the effects of this action. The EE applies to all assistance provided by NRCS (GM190, Part 410.5). The CPA-52 form is used by NRCS to document the results of the evaluation and show compliance with NRCS regulations implementing NEPA at 7 CFR Part 650.

A copy of the NRCS-CPA-52 must be included in the administrative file. Supporting documentation, including the applicable Special Environmental Concerns Evaluation Procedure Guide Sheets, must be retained and should be included with the NRCS-CPA-52 to relay specific compliance information.

Attach additional sheets or assistance notes if more documentation space is needed beyond the form NRCS-CPA-52, including any state-specific worksheets.

COMPLETING THE NRCS-CPA-52

A. **Client Name**

B. **Conservation Plan ID #** (as applicable)

Program Authority (optional)**:** Identifying the program authority (EQIP, WRP, etc.) can help lead the planner to the appropriate NRCS NEPA document the planner may tier to as addressed later in section "R. Rational Supporting the Finding".

C. **Identification #:** Record any other relevant client identification # (farm, tract, field #, etc.).

D. **Client's Objective(s) (purpose):** Briefly summarize the client's stated objective(s) [synonymous to "Purpose" under NEPA]. Refer to Step 2 of the NRCS planning process found in the NPPH, Part 600.22 for help, if needed. "Purpose" refers to a goal being pursued in the process of meeting the "Need", such as keeping the operation economically viable or meeting TMDL requirements. Clearly articulated purposes become the decision factors used to decide between the action alternatives.

E. **Need for Action:** Describe the underlying need being met. Why is the action being proposed? The underlying need will define and shape the alternatives; therefore it is important to accurately articulate the need(s) based on the identified resource concerns and the landowner objectives. The chosen alternative should clearly address the underying need(s). A *"need"* is usually the improvement of the condition of a natural resource(s), for example the quality of runoff water from a farm does not meet State standards, or inadequate forage supply and/or grazing strategies are resulting in poor livestock performance. Use information from Step 3 of the Conservation Planning Process (Resource Inventory) to help define the need. Identify here which Resource Concerns need to be addressed in the plan.

F. Resource Concerns and Existing / Benchmark Conditions:

Resource Concerns Analyze and record resource concerns from the current list in your state's eFOTG Section III that have been identified through the Resources Inventory process as a concern that needs to be addressed. The Resource Quality Criteria will also be helpful in considering potential environmental effects and comparing alternatives. Include all resource concerns that apply, adding additional sheets as necessary.

Documenting Existing/Benchmark Conditions Analyze and record the existing (benchmark) conditions for each relevant concern using state-specific tools and protocols available. For example, "the current soil erosion rate = 6T" (or note where this information can be found in the conservation plan). This information will inform the final decision by allowing a comparative effects analysis of all alternatives (including the "no action" alternative). (Note: States often choose to include protocols here to assist the field planner with identification and descriptions of Resource Concerns, as well as other state-specific worksheets.) Optional: If desired, planners can include specific land use designations here.

Human - Economic and Social Considerations Below are some examples for what to consider when addressing the Human - Economic and Social Considerations.

Land use:

- Is the present land use suitable for the proposed alternative?
- Will land use change after practice(s) installation?
- How will a change affect the operation? (e.g., Feed and Forage Balance Sheet)
- Will the action affect resources on which people depend for subsistence, employment or recreation?
- Will land be taken in or out of production?

Capital:

- Does the producer have the funds or ability to obtain the funds needed to implement the proposed alternative?
- What are the impacts of the cost of the initial investment for this alternative?
- What are the impacts of any additional annual costs for Operation and Maintenance?
- What possible impact does implementing this alternative have on the client's future eligibility for farm programs?

Labor:

- Does the client understand the amount and kind of labor needed to implement, operate and maintain the proposed practice(s)?
- Does the client have the skills and time to carry out the conservation practice(s) or will they have to hire someone?

Management level:

- Does the client understand the inputs needed to manage the practice(s) and the client's responsibility in obtaining these inputs?
- Does the client understand their responsibility to maintain practice(s) as planned and implemented?
- Is it necessary for the client to obtain additional education, or hire a technical consultant, to operate and/or maintain the practice(s)?

Profitability:

- Profitability describes the relative benefits and costs of the farm or ranch operation, and is often measured in dollars. An activity is profitable if the benefits are greater than the costs.
- Is the proposed alternative needed and feasible?
- Do the benefits of improving the current operation outweigh the installation and maintenance costs (positive benefit/cost ratio)?
- Is there a reasonable expectation of long-term profitability/benefits for the operation if implemented?
- Will crop, livestock, or wildlife yield increase/decrease?

Risk:
- Adverse risk is the potential for monetary loss, physical injury, or damage to resources or the environment.
- Will the proposed alternative aid/risk client participation in USDA programs?
- What are the possible impacts due to a change in yield?
- Is there flexibility in modifying the conservation plan at a future date?
- What issues are involved with the timing of installation and maintenance?
- What are the cash flow requirements of this alternative?
- What, if any, are the hazards involved?

Public Health and Safety:
- What effect (both positive or negative) will the action have on the client and community with regard to public health and safety?
- What are the off-site effects?

G. **Alternatives:** ***Describe Alternatives*** Briefly summarize the practice/system of practices being proposed. The no action and RMS alternatives are required. (NPPH Part 600.41) Alternatives should be formulated to *meet the underlying need.* Note that the no action alternative may not meet the underlying need and is still required to be evaluated and compared to other alternatives (see below). To the extent possible, the alternatives should also prevent additional problems from occurring and take advantage of available opportunities. *If there are unresolved conflicts concerning alternative uses of resources, appropriate alternatives that meet the underlying need must be developed.*

"No Action": Include a brief summary of the activities that would be implemented in the absence of USDA asistance (financial or technical). Unless a change in management direction or intensity will be undertaken, record effects of existing activities. The "No Action" alternative requires the same level of analysis as other alternatives. It should answer the question of what impacts are likely to occur (or what the predicted future condition of the identified resource concerns might be) under the landowner's current and planned management strategies without implementation of a federally assisted action.

"Alternatives 1,2,etc.": List here the practices or system of practices being proposed for each alternative. At least one of the alternatives should contain the practices that NRCS has determined best address all of the identified resource concerns (i.e., RMS alternative). Indicate if the alternative meets RMS criteria based on your State's requirements. One or more other alternatives may be evaluated to aid in the decision-making process or at the request of the client. Use additional sheets if necessary.
Under guidance in the NPPH Part 600.11(f) and the GM 180 Part 409.1(a)(2), at least one alternative that meets RMS criteria should be developed, evaluated, and discussed with the client.

It is important to define the differences between each alternative, including the "No Action" alternative. See "Helpful Tips" in the NECH, Part 610.67 for guidance on narrowing the scope of your analysis when considering alternatives.

H. **Effects of Alternatives:**

Under "Amount, Status, Description", record the effect of each alternative on the concerns listed, quantifying where possible. *It is important to consider and document both short-term and long-term consequences, as appropriate, for direct, indirect, and cumulative effects (described below).* If a change to the concern is predicted, then estimate the amount. Professional judgement should be used where Quality Criteria or other tools are not avialable.

Analyze effects based on the combined effect of all practices on the resource concern. For example, if one proposed practice may impact the water quality of an adjacent stream, but another proposed practice such as a buffer may reduce or eliminate the impact, the overall effect is the one that should be recorded here. As mentioned above, one or more "Other Alternative(s)" may be evaluated to aid in the decision-making process or at the request of the client. Use additional sheets if necessary.

"No Action": Record the impacts that are likely to occur (or what the predicted future condition of the identified resource concerns might be) under the landowner's planned management strategies without implementation of a federally assisted action. Address impacts to each identified resource concern, quantifying where possible. If this information is found elsewhere in the conservation plan, simply provide a summary here.

"Alternatives 1,2, etc.": Record the impacts that are likely to occur under each alternative scenario. Document impacts to each identified resource concern, quantifying where possible. If this information is found elsewhere in the conservation plan, simply provide a summary here. Include both short and long-term consequences in the analysis.

Categories of Effects to Consider- There are three categories of effects that must be considered when predicting short- and long-term effects of an alternative on concerns:

Direct effects are caused by the alternative and occur at the same time and place.

Indirect effects are caused by the alternative and are later in time or farther removed in distance, but are still reasonably foreseeable (e.g., "downstream" effects).

Cumulative effects are those that result from all past, present, and reasonably foreseeable future actions. They can result from individually minor but collectively significant actions taking place over a period of time. Cumulative effects are most appropriately analyzed on a watershed or area-wide level. *Cumulative Impacts ideally consider "...all actions in the area of potential effect, REGARDLESS of what agency (Federal or non-Federal) or person undertakes such other actions." (CEQ 1508.7)*

The NECH, Part 610.70, "Effects Analysis," provides important information on describing effects so that an adequate analysis can be made when the proposed alternative has adverse effects.

Resource Concerns Use your state's eFOTG Section III Quality Criteria or other tools where possible which are the established threshold levels for identified resource concerns. Professional judgement should be used where Quality Criteria or other tools are not available. Place a check in the "NOT meet QC" box for each resource concern to indicate when FOTG Section III Quality Criteria will not be met (i.e., where additional measures are needed to meet QC).

I. Special Environmental Concerns

For guidance in addressing special environmental concerns, see NECH Subpart B and the Special Environmental Concern Evaluation Procedure Guide Sheets for specific information applicable to each concern. Where consultation with another federal agency is required (e.g., USFWS or NMFS) to determine potential environmental effects, follow established State protocols or contact the appropriate NRCS State Specialist for guidance. Document any additional State and/or local special environmental concerns in "K. Other Agencies and Broad Public Concerns". Attach additional documentation if needed.

J. Impacts to Special Environmental Concerns: Briefly describe the status and/or description of effects on any of the Special Environmental Concerns, and include other notes as needed. Complete applicable Evaluation Procedure Guide Sheets or other state specific documentation as needed and include them in the client's administrative file. If the Special Environmental Concern is not present in the project area then there is no need to attach the Guide Sheet. Completion of Guide Sheets is not mandatory, but appropriate documentation should be provided. Check your own States' guidance for compliance and planning requirements.

Place a check in the "needs action " box when effects have not been fully determined or when additional procedural action is needed, such as the need for a permit or completing required consultation with regulatory agencies. Practice implementation should not occur until all required consultations and coordination with the appropriate agency have been completed and all necessary permits provided. Planning and practice implementation may continue for practices not involved in required consultation/coordination efforts.

K. **<u>Other Agencies and Broad Public Concerns:</u>** List any necessary easements, permissions, or permits (e.g., Clean Water Act Section 404, Rivers and Harbors Act Section 10, Endangered Species Act Section 10, wetland mitigation easements, state or county permits) required to implement the alternatives. *<u>Remember that identifying needed permits for ALL alternatives may be an important decision criteria between alternatives and should be considered during the planning process.</u>*

Relay public concerns related to land-use, demographics, landscape characteristics, or other Federal, Tribal, State, and local laws/regulations. Document the impacts of each alternative on these issues. Responses will impact the selection of an alternative as well as issues surrounding "significance." Document contact and communications with USFWS, NOAA-NMFS, COE, EPA, SWCD's, NRCS State Office, state/local environmental agencies, etc., and others consulted, including public participation activities. The NECH, Part 610.68 provides important information on public participation requirements.

Cumulative Effects Refer to NECH Part 610.70. A cumulative impact is defined as "the impact on the environment which results from the incremental impact of the action when added to other past, present and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.70). Cumulative effects include the direct and indirect effects of a project together with the effects from reasonably foreseeable future actions of others. For a project to be reasonably foreseeable, it must have advanced far enough in the planning process that its implementation is likely. Reasonably foreseeable future actions are not speculative, are likely to occur based on reliable resources and are typically characterized in planning documents. Add additional pages as needed.

L. **<u>Mitigation:</u>** Include here any mitigation measures that are NOT already incorporated in the alternatives that will offset any adverse impacts. Briefly describe or reference all mitigation efforts that may be applied at the time of the decision. Mitigation actions to be applied must be included in the conservation plan.

As referenced in CEQ regulations Section 1508.20 and NECH Part 610.71, Mitigation includes:

- Avoiding the impacts altogether by not taking a certain action or parts of an action.
- Minimizing impacts by limiting the degree of magnitude of the action and its implementation.
- Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
- Reducing or eliminating impact over time by preservation/maintenance operations during action life.
- Compensating for the impact by replacing or providing substitute resources or environments.

M. **<u>Preferred Alternative:</u>** Record which alternative was agreed upon by the client and agency and why. The decision should clearly address the underlying need(s) as identified in "E". The Objective(s) (Purpose) stated in "D" serves as the decision factors between alternatives.

N. **<u>Context:</u>** Record the context used in the alternatives analysis. Significance varies with the setting of the proposed action. For instance, in the case of a site-specific action, significance would usually depend upon the effects in the locale rather than in the world as a whole. Both short- and long-term effects are relevant.

O. **<u>Determination of Significance or Extraordinary Circumstances:</u>** This section is a very important part of the evaluation process. Many of our actions have been analyzed in one of the National/Regional Programmatic NEPA documents and will only require documentation as detailed in Q-3 below. However, site-specific circumstances (existence of federally listed species, important cultural resources, high degree of controversy, etc.) may be such that a more detailed analysis may be needed to determine, through an EA, that impacts would be non-significant, or through a more detailed EIS if we feel that impacts are likely to significantly or adversely affect the quality of the human environment. The questions in this section list those considerations that, if associated with implementation of the proposed action, may result in a determination of “significance.”

Categorical Exclusions: On the other hand, it may be the case that the action we are proposing falls under one of USDA or NRCS' lists of "categorical exclusions." Before documenting the use of one of these categorical exclusions, it is important to read Section 610.46 of the NECH. This section provides a list of all categorical exclusions that apply to actions as well as more detailed considerations and requirements for their use. In order for an action to be categorically excluded, appropriate documentation must be made on the NRCS-CPA-52 indicating that the proposed action does not meet any of the criteria for "significance," as discussed above. These criteria are also known as "extraordinary circumstances" when discussing categorical exclusions. If a proposed plan involves any actions that are NOT on the list of allowable categorical exclusions, the entire action can NOT be categorically excluded from review under NEPA. Also, if actions are interdependent, they can NOT be segmented into smaller component parts to avoid the requisite and appropriate level of environmental review under NEPA.

To complete the determination on the NRCS-CPA-52, check "yes" or "no" for each of the questions. If you are not sure about the answer, contact your State Environmental Liaison for assistance. The NRCS-CPA-52 must provide evidence to conclude that the activity will not result in significant adverse environmental effects or extraordinary circumstances on the quality of the human environment, either individually or cumulatively. If any of the extraordinary circumstances are found to apply to the proposed action, then you should determine whether the proposal can be modified to mitigate the adverse effects and prevent the extraordinary circumstances. If this can be done and the client agrees to any necessary change(s) in the proposed action to avoid significant adverse impacts, then the proposed action is to be modified and implemented. If the proposed action cannot be modified or the proponent refuses to accept a proposed change, then Item 5 in Section "Q" must be checked for the NRCS NEPA Compliance Finding to indicate that additional analysis and documentation is needed.

P. <u>**Signature (planner):**</u> The individual completing Parts A thru P of the CPA-52 must sign and date to indicate they have used the best available information. This may or may not be the same person as the agency RFO. In cases wher the planner is not a NRCS employee they will sign the first signature area and then the NRCS will also need to sign to confirm and validate the information as the responsible agency.

Parts "Q" thru "S" must be completed by the Responsible Federal Official (RFO).
For NRCS applications this is the NRCS employee responsible for NEPA compliance at the state or field office level. For NRCS the State Conservationist is the RFO and may delegate that authority to a designated agency representative.

Q. <u>**NEPA Compliance Finding (check one):**</u> This finding will determine the appropriate NEPA action required. Instructions below correspond to the option numbers in Section "Q" of the Form. In Section "R" document the rationale for your Finding.

1) Federal actions do NOT include situations in which NRCS (or any other federal agency) provides technical assistance (CTA) only. The agency cannot control what the client ultimately does with that assistance. Non-Federal actions include, but are not limited to:
   - NRCS makes HEL or wetland conservation determinations.
   - NRCS provides technical designs where there is <u>**no**</u> federal financial assistance.
   - NRCS provides planning assistance or other technical assistance and information to individuals, organizations, States, or local governments where there is no federal financial assistance or other control of the decision or action.
2) Categorically excluded (CE) actions are a category of actions which do not individually or cumulatively have a significant effect on the human environment, therefore, neither an environmental assessment nor an environmental impact statement is required. First determine whether the proposed action is a categorically excluded action as identified in NRCS or USDA regulations implementing NEPA. Note that there may be overarching or CE-specific side boards that must be met in order to apply a CE. If the proposed action is listed as a CE action, then assess whether there are any applicable extraordinary circumstances which would prevent the action from being eligible as a CE. Check this box only if the action is categorically excluded **AND** there are no EXTRAORDINARY CIRCUMSTANCES involved or affected by the proposed action. USDA and NRCS categorical exclusions are listed in the NECH, Part 610.46.

3) Check this box if there is an existing NRCS NEPA document that has sufficiently analyzed the action being proposed. A number of NRCS National Programmatic NEPA documents have analyzed effects of many practices planned under nationwide conservation programs. There may also be Regional, State, or area wide Programmatic NEPA documents that can be referred to. For information about "Tiering" to existing NRCS NEPA documents see the NECH Part 610.81.

   Keep in mind that Programmatic EA's and EIS's are not site-specific so they do not attempt to describe every possible type of effect resulting from actions that could be taken. Thus, you must use your knowledge of site-specific conditions to decide if additional analysis is needed. Network diagrams illustrating general effects of conservation practices can be found that are associated with national or state EA's or EIS's. These diagrams may help in analyzing effects of practices.

   Authorized planners and RFOs should conduct their own analyses in a similar manner to assess site-specific environmental impacts. Impacts to other resources protected by Executive Orders, laws, and policies (i.e., the Special Environmental Concerns such as cultural resources, endangered species, and riparian areas) must be evaluated separately unless an existing NEPA document analyzes those impacts for the same geographic area and at the same site-specific scale covered by the selected alternative. Potentially significant adverse impacts requiring consultation under other applicable environmental laws and Executive Orders may require preparation of a site-specific EA or EIS. The State Environmental Liaison should be consulted in such cases to assist in determining whether a site-specific EA or EIS is required.

   Copies of NRCS national programmatic NEPA documents may be viewed on NRCS' Environmental Compliance web page.

4) It is possible to tier to NEPA documents prepared by other Federal agencies if they have undergone a formal "adoption" process by NRCS as outlined in the NECH 610.83 and CEQ regulations 40 CFR-1506.3. NRCS must have prepared and published the agency's own Finding of No Significant Impact (FONSI) for an EA or Record of Decision for an EIS in order for a NEPA document to be "adopted". For information about "Tiering" to NEPA documents see the NECH Section 610.81.

5) *<u>If 1), 2), 3), or 4) do not apply, the action may cause a significant effect on the quality of the human environment and an EA or EIS may be required.</u> Additional analysis may be required to comply with NEPA.* Contact the State Environmental Liaision or equivalent for guidance on completing this analysis and provide them with a copy of the NRCS-CPA-52 and supporting documentation.

R. **<u>Rationale Supporting the Finding:</u>** Explain the reasons for making the "Finding" in "R".

<u>If "Q 1)" was selected,</u> explain why the action is NOT a federal action subject to NRCS regulations implementing NEPA.
<u>If "Q 2)" was selected,</u> document the categorical exclusion that covers the proposed action **and** indicate that there are no extraordinary circumstances.
<u>If "Q 3)" was selected,</u> identify any applicable NRCS NEPA document. Record the citation of the NRCS NEPA document you are tiering to.
<u>If "Q 4)" was selected,</u> identify any applicable NRCS NEPA document that was officially adopted from another agency. Record the citation of the NRCS adopted NEPA document you are tiering to.
<u>If " Q 5)"was selected,</u> document your analysis and provide this information (NRCS-CPA-52 and supporting ducuments) to your State Environmental Liaison or equivalent.

S. **<u>Signature of Responsible Federal Official(RFO):</u>** The appropriate agency RFO must sign and date. The RFO should wait to make the finding until all consultations, permits, etc., are finalized. This signature certifies that the proposed action/plan complies with all NRCS policies implementing NEPA and all other applicable Federal, State, and local laws/Executive Orders.

CLEAN AIR ACT
NECH 610.21
Evaluation Procedure Guide Sheet

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

Check all that apply to this Guide Sheet review: ☑ Alternative 1 ☐ Alternative 2 ☐ Other

NOTE: STEPS 1 and 2 help determine whether construction permitting is needed for the planned action or activity. STEP 3 help determines whether the opportunity for emissions reduction credits exist. STEP 4 help determines whether any other permitting, record keeping, reporting, monitoring, or testing requirements are applicable. Each of these steps should be updated with more specific language as needed, since air quality permitting and regulatory requirements are different for each state. In each step, if more information is needed or there is a question as to whether there are air quality requirements that need to be met, the planner or client should contact the appropriate air quality regulatory agency with permitting jurisdiction for the site to determine what air quality regulatory requirement must be met prior to implementing the planned action or activity.

STEP 1.

Is the proposed action or alternative expected to increase the emission rate of any regulated air pollutant? **NOTE:** The definition of a "regulated air pollutant" differs depending on the air quality regulations in effect for a given site. For a federal definition of "regulated air pollutant," please refer to the 40 CFR 70.2. Other definitions for "regulated air pollutant" found in state or local air quality regulations may be different. *States should tailor this question to the State air quality regulations and definitions since those will include any Federal requirements.*

☑ No — If "No," it is likely that no permitting or authorization is necessary to implement the proposed action or alternative. Document the finding on form NRCS-CPA-52 and advise the client to contact the appropriate air quality regulatory agency with permitting jurisdiction for the site to either verify that no permitting or authorization is necessary or to determine what requirements must be met prior to implementing the planned action or activity. Go to step 3.

☐ Yes — If "Yes," go to Step 2.

STEP 2.

Can the proposed action or alternative be modified to eliminate or reduce the increase in emission rate of the regulated air pollutant(s)? **NOTE:** This Step is to prompt the planner to review the planned action or activity to see if there is an opportunity to either eliminate the emission rate increase (possibly remove a permitting requirement) or reduce the emission rate increase (possibly move to less stringent permitting).

☐ No — If "No," it is likely that permitting or authorization from the appropriate air quality regulatory agency will be required prior to implementing the planned action or activity. Document the finding on form NRCS-CPA-52 and advise the client to contact the appropriate air quality regulatory agency with permitting jurisdiction for the site to either verify that no permitting or authorization is necessary or to determine what requirements must be met prior to implementing the proposed action or alternative. Go to Step 3.

☐ Yes — If "Yes," modify the proposed action or alternative and repeat Step 1.

STEP 3.

Is the proposed action or alternative expected to result in a decrease in the emission rate of any criteria air pollutant for which the area in which the site is located in an EPA designated nonattainment area for that criteria air pollutant? NOTE: For an explanation of criteria air pollutants and nonattainment areas, refer to Section 610.81 of the NECH. Further information regarding nonattainment areas can also be found on the U.S. EPA nonattainment area webpage at http://www.epa.gov/oar/oaqps/greenbk/.

CLEAN AIR ACT (continued)

☑ No — If "No," go to Step 4.

☐ Yes — If "Yes," the opportunity for obtaining non-attainment pollutant emission credits may exist. Document the finding on form NRCS-CPA-52 and advise the client of that potential opportunity. If the client is interested in registering nonattainment pollutant emission credits, advise him/her to contact the appropriate air quality regulatory agency with permitting jurisdiction for the site to determine if and how credits can be documented and/or registered for potential sale. Go to Step 4.

STEP 4.

Is the site or proposed action or alternative subject to any other federal (i.e., New Source Performance Standards, National Emissions Standards for Hazardous Air Pollutants, etc.), state, or local air quality regulation (including odor, fugitive dust, or outdoor burning)? **NOTE:** Refer to Section 610.81 of the NECH for a further discussion of air quality regulations.

☑ No — If "No," no additional requirements are likely needed prior to implementing the proposed action or alternative. Document finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," additional permitting, authorization, or control requirements may be needed prior to implementing the proposed action or alternative. Document the finding on form NRCS-CPA-52, and advise the client to contact the appropriate air quality regulatory agency with permitting jurisdiction for the site to determine what requirements must be met prior to implementing the proposed action or alternative.

Notes:

CLEAN WATER ACT/WATERS of the U.S.
NECH 610.22
Evaluation Procedure Guide Sheet

Check all that apply to this Guide Sheet review: ☑ Alternative 1 ☐ Alternative 2 ☐ Other

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

NOTE: This guide sheet should be tailored to meet the specific needs of individual State and/or local regulatory/permitting requirements. It is important for each state to coordinate with their individual State and Federal regulatory agencies to tailor state-specific protocols in order to prevent significant delays in processing permit applications.

Complete both sections of this guide sheet in order to address Federal as well as State administered regulatory requirements of the Clean Water Act.

SECTION I

Federally Administered Regulatory Program - Section 404 of the CWA

STEP 1.

Will the proposed action or alternative involve or likely result in the discharge of dredged or fill material or other pollutants into "waters of the United States?" *More detailed information regarding "Waters of the U.S.", and federal permitting programs under CWA is found in the NECH 610.82.*

☑ No — If "No," document this on form NRCS-CPA-52 and proceed with Section II below.

☐ Yes — If "Yes," go to Step 2.

☐ Unknown — If "Unknown," refer to your FOTG or contact your NRCS Environmental Liaison for assistance. Inform the client early on that they may need to contact the appropriate U.S. Army Corps of Engineers (COE) office to determine if the proposed action or alternative will require a permit. Repeat Step 1.

STEP 2.

Has the client obtained a Section 404 permit (Individual, Regional, or Nationwide) or a determination of an exemption from the appropriate COE office?

☐ No — If "No," determine if the client has applied for a permit. If a permit has not been applied for, the client will need to do so. If a permit has been applied for, document this, and continue the planning process in consultation with the client and the regulatory agencies. The permit authorization should be reflected in the final plan and documentation. Continue planning, but a permit is required prior to implementation. Complete Section II below.

☐ Yes — If "Yes," document on form NRCS-CPA-52 and complete Section II below. The final plan should not be contrary to the provisions of the permit authorization or exemption. Changes made during the planning process that may impact the applicability of the permit, such as amount or location of fills or discharges of pollutants should be coordinated with the COE.

☐ Unknown — If "Unknown," meaning that you do not know if authorization has been obtained or applied for, consult with the client and repeat Step 2.

Notes:

CLEAN WATER ACT/WATERS of the U.S. (continued)

SECTION II

State Administered Regulatory Programs, Sections 303(d) and 402 of CWA

STEP 1

Is the proposed action or alternative located in proximity to waters listed by the State as "impaired" under Section 303(d) of the CWA?

- [x] No — If "No," document this on form NRCS-CPA-52 and proceed to Step 2.
- [ ] Yes — If "Yes," review and comply with any existing TMDLs or associated Watershed Action Plans that have been established by the State for that stream segment. However, even if TMDLshave not been established by the State for that stream segment, ensure that the action will not contribute to further degradation of that stream segment. Proceed to Step 2.
- [ ] Unknown — If "Unknown," refer to FOTG for information regarding State designation of "impaired" stream segments, or contact your NRCS Environmental Liaison for assistance. Repeat Step 1.

STEP 2

Will the proposed action or alternative likely result in point-source discharges from developments, construction sites, or other areas of soil disturbance, or sewer discharges (e.g. projects involving stormwater ponds or point-source pollution including CAFOs for which CNMPs are being developed)? *Section 402 of the CWA requires a permit for these activities through the National Pollutant Discharge Elimination System (NPDES) program which the States administer.*

- [ ] No — If "No," document this on form CPA-52 and proceed with planning.
- [x] Yes — If "Yes," go to Step 3.
- [ ] Unknown — If "Unknown," refer to your FOTG for additional information or contact your NRCS Environmental Liaison for assistance. Inform the client early on that they may need to contact the appropriate State regulatory office to determine if the proposed action or alternative will require a NPDES permit. Repeat Step 2.

STEP 3

Has the client obtained a National Pollutant Discharge Elimination System (NPDES) permit or a determination of an exemption from the appropriate State regulatory office?

- [x] No — If "No," determine if the client has applied for any necessary permits. If a permit has not been applied for, the client will need to do so. If they have applied, document this, and continue the planning process in consultation with the client and the regulatory agency. Continue the planning process in consultation with the client and the regulatory agencies. The permit authorization should be reflected in the final plan and documentation. Continue planning, but a permit is required prior to implementation.
- [ ] Yes — If "Yes, document this on form NRCS-CPA-52 and proceed with planning. The final NRCS conservation plan should not be contrary to the provisions of the permit authorization or exemption. Changes made during the planning process that may impact the applicability of the permit should be coordinated with the appropriate State regulatory agency.
- [ ] Unknown — If "Unknown," meaning that you do not know if authorization has been obtained or applied for, consult with the client and repeat Step 3.

Notes:

COASTAL ZONE MANAGEMENT AREAS
NECH 610.23
Evaluation Procedure Guide Sheet

Check all that apply to this Guide Sheet review:
- [x] Alternative 1
- [ ] Alternative 2
- [ ] Other

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

STEP 1.

Is the proposed action or alternative in an officially designated "Coastal Zone Management Area"?

- [x] No — If "No," additional evaluation is not needed concerning coastal zones. Document the finding on form NRCS-CPA-52 and proceed with planning.
- [ ] Yes — If "Yes," go to Step 2.
- [ ] Unknown — If "Unknown," consult Section II of the FOTG for information regarding Coastal Zone Management Programs in your area and repeat Step 1.

Is the proposed action or alternative "consistent" with the goals and objectives of the State's Coastal Zone Management Program (as required by Section 307 of the Coastal Zone Management Act)?

- [ ] No — If "No," go to Step 3.
- [ ] Yes — If "Yes," no additional evaluation is needed concerning coastal zones. Document the finding, including the reasons, on form NRCS-CPA-52 and proceed with planning.
- [ ] Unknown — If "Unknown," consult with your designated State specialist for CZMA and repeat Step 2.

Is NRCS providing financial assistance or otherwise controlling the action?

- [ ] No — If "No," go to Step 4.
- [ ] Yes — If "Yes," the NRCS District Conservationist or an NRCS State Office employee must contact the State's Coastal Zone Program Office before the action is implemented to discuss possible modifications to the proposed action. NRCS shall not provide assistance if the proposed action or alternative would result in a violaton of a State's Coastal Zone Management Plan. NRCS shall provide a consistency determination to the State agency no later than 90 days before final approval of the activity. When consultation is complete, document the agreed to items and reference or attach them to the NRCS-CPA-52.

STEP 4.

Will a Federal agency OTHER than NRCS provide funding or otherwise control implementation of the action?

- [ ] No — If "No," NRCS should provide the landowner with relevant information regarding any local/state compliance requirements and protocols (permitting, etc) in Special Management Areas as appropriate to comply with local Coastal Zone Management Programs. Document on the NRCS-CPA-52 and proceed with planning.
- [ ] Yes — If "Yes," recommend that the funding or controlling agency consult with the State Coastal Zone Management Office before the action is implemented. Proceed with planning.

Notes:

CORAL REEFS
NECH 610.24
Evaluation Procedure Guide Sheet

Check all that apply to this Guide Sheet review: ☑ Alternative 1 ☐ Alternative 2 ☐ Other

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

STEP 1.

Are coral reefs or associated water bodies (e.g. embayment areas) present in or near the planning area?

☑ No — If "No," additional evaluation is not needed concerning coral reefs. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 2. **Note:** If there are any endangered or threatened species of coral inhabiting the coral reef ecosystem you must also fill out the Endangered and Threatened Species Guide Sheet.

STEP 2.

Is there a potential for the proposed action or alternative to degrade the conditions of the coral reef ecosystem? (Refer to www.coralreef.gov/ for Local Action Strategies in your area.)

☐ No — If "No," additional evaluation is not needed concerning coral reefs. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 3.

STEP 3.

Can the action or alternative be modified to reduce or avoid degradation to the coral reef ecosystem?

☐ No — If "No," identify the component(s) of the system which will cause the potential impacts. Document the effects, including the reasons, on form NRCS-CPA-52. Go to Step 4.

☐ Yes — If "Yes," modify the action or alternative and repeat Step 2.

STEP 4.

Is NRCS providing financial assistance or otherwise controlling the action?

☐ No — If "No," go to Step 5.

☐ Yes — If "Yes," the significance of the impacts must be determined. An Environmental Assessment (EA) or Environmental Impact Statement (EIS) may be required. Contact your State Office for assistance and, if you are the RFO, select option 4) in Section S of the form NRCS-CPA-52.

STEP 5.

Will a Federal agency other than NRCS provide funding or otherwise control implementation of the action?

☐ No — If "No," and degradation of the reefs is unavoidable, provide the client with information regarding the current status of U.S. coral reefs and the documented causes of degradation (including sedimentation and nutrient runoff), and the beneficial aspects of maintaining coral reefs.

☐ Yes — If "Yes," the significance of the impacts must be determined. An Environmental Assessment (EA) or Environmental Impact Statement (EIS) may be required. Document this on the NRCS-CPA-52, with a description of the potential impacts, and provide a copy of the form to the Federal agency providing funding or controlling the action. Inform the client and proceed with planning.

Notes:

CULTURAL RESOURCES / HISTORIC PROPERTIES NECH 610.25
Evaluation Procedure Guide Sheet

Check all that apply to this Guide Sheet review: ☑ Alternative 1 ☐ Alternative 2 ☐ Other

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

NOTE: This guidesheet provides general guidance to field planners and managers. States may need to tailor this Evaluation Procedure Guide Sheet to reflect State Level Agreements (SLA's) with SHPOs or Tribal consultation protocols or operating procedures pertinent to your state, and/or other state specific protocols that reflect the terms of the current National Programmatic Agreement among NRCS, the Advisory Council on Historic Preservation, and the National Conference of SHPOs. For additional information regarding compliance with Section 106 of the NHPA and NRCS cultural resource policy refer to the General Manual Title 420 Part 401 Cultural Resources; for current operating procedures see Title 190 Part 601, the National Cultural Resource Procedures Handbook (NCRPH).

NOTE regarding consultations: When dealing with undertakings with the potential to affect cultural resources/historic properties, it is important to follow NRCS's policy and the regulations that implement Section 106 and complete consultation with mandatory (SHPOs, THPOs, federally recognized tribes) and identified consulting parties during the course of planning. This consultation is not documented on this guidesheet but would occur with Steps 2, 3, 4, and 6 and these must be conducted in accordance with NRCS State Office operating procedures to ensure appropriate oversight by Cultural Resources Specialists who meet the Secretary of Interior's Qualification Standards.

STEP 1.

Is the proposed action or alternative funded in whole or part or under the control of NRCS? To make this determination, answer the following:

Is technical assistance carried out by or on behalf of NRCS?	☐ No	☑ Yes	☐ Unknown
Is it carried out with NRCS financial assistance?	☐ No	☑ Yes	☐ Unknown
Does it require Federal approval with NRCS as the lead federal agency (permit, license, approval, etc.)?	☑ No	☐ Yes	☐ Unknown
Is it a joint project with another Federal, State, or local entity with NRCS functioning as lead federal agency?	☑ No	☐ Yes	☐ Unknown

- If all of your responses are "No," document decision on the NRCS-CPA-52 and proceed with planning.
- If any responses are "Yes," go to Step 2.
- If "Unknown," consult with your State Cultural Resources Coordinator or Specialist (CRC/CRS) to determine if this is an action/undertaking that requires review and then complete Step 1.

STEP 2.

Is the proposed action(s) or alternative(s) identified as an "undertaking" (as defined in the NCRPH and GM) with the potential to cause effects to cultural resources/historic properties?

☐ No — If "No," document this finding on the NRCS-CPA-52 and proceed with planning.

☑ Yes — If "Yes," go to Step 3.

STEP 3.

Has the undertaking's Area of Potential Effect (APE) been determined? **NOTE:** Include all areas to be altered or affected, directly or indirectly: access and haul roads, equipment lots, borrow areas, surface grading areas, locations for disposition of sediment, streambank stabilization areas, building removal and relocation sites, disposition of removed concrete, as well as the area of the actual conservation practice. Consultation is essential during determination of the APE so that all historic properties (buildings, structures, sites, landscapes, objects, and properties of cultural or religious importance to American Indian tribal governments and native Hawaiians) are included.

☑ No
☐ Unknown — If "No," or "Unknown," consult with your state specific protocols or the CRC/CRS to determine the APE.
☐ Yes — If "Yes," go to Step 4.

CULTURAL RESOURCES (continued)

STEP 4.

Have the appropriate Records (National, State and local registers and lists) been checked and/or interviews conducted to determine whether any known cultural or historic resources are within or in close proximity to the proposed APE/project area? **Note:** This record checking does not substitute for mandatory consultation with SHPO, THPO, tribes and other identified consulting parties.

	No	Yes	Unknown
National Register of Historic Places?	☐	☑	☐
State Register of Historic Places?	☐	☑	☐
The SHPO's statewide inventory/data base?	☐	☑	☐
Local/county historical society and/or commission lists?	☐	☑	☐
Client knowledge of existing artifacts, historic structures or cultural features?	☐	☑	☐

- If any responses are "No" or "Unknown," work with your CRC/CRS to be sure these files are checked (sometimes the SHPO will let only the CRS or CRC review the files). Follow all other operating procedures as required by NRCS policy and procedures, State Level Agreement (SLA), and Tribal consultation protocols or operating procedures, as appropriate.
- If all responses are "Yes," and **NRCS providing technical assistance only,** then use any known information, notify the landowner of any potential affects, and provide recommendations for consideration. Document this on the NRCS-CPA-52 and proceed with planning. If NRCS is providing more that technical assistance go to Step 5.

STEP 5.

Did STEP 4 reveal the existence of any known or potential cultural resources in the APE, and/or were any cultural resource indicators observed during the field inspection of the APE? **NOTE:** Field inspections or cultural resource survey will need to be conducted by qualified personnel in your state. Check with you State Cultural Resource Specialist to determine qualification criteria.

☐ No	If "No," document this finding on the NRCS-CPA-52 and proceed with planning.
☑ Yes	If "Yes," contact the CRC/CRS. Do NOT proceed with finalizing project design or project implementation until the final CRS response is received. Go to Step 6.

STEP 6.

Can the proposed action(s) or alternative(s) be modified to avoid effects on the known cultural resources?

☐ No	If "No," go to Step 7.
☑ Yes	If "Yes," modify the planned action(s) or activity(ies) and proceed according to CRS guidance and document this on the NRCS-CPA-52 and continue with planning.

STEP 7.

Has consultation with appropriate and interested parties been completed and documented? **NOTE:** The field planner completing the NRCS-CPA-52 generally does not do the consultation unless it is the CRS or CRC. Refer to the appropriate specialist for the documentation information.

☑ No	If "No" refer to State CRC or CRS for further consultation and recommendations to the State Conservationist.
☐ Yes	If "Yes," and all necessary historic preservation activities of identification, evaluation, and treatment have been completed, document any consultation and proceed with planning.

Notes:

ENDANGERED AND THREATENED SPECIES, NECH 610.26
Evaluation Procedure Guide Sheet

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

Check all that apply to this Guide Sheet review: ☐ Alternative 1 ☐ Alternative 2 ☐ Other

If species listing/status changes prior to implementation, go back and analyze the affects in the appropriate section as dictated in Step 1.

Note Regarding Candidate Species: As per GM Title 190, Part 410.22, NRCS shall contact the Services, State agencies, and Tribal governments to identify Federal candidate, State and Tribal designated species, and NRCS actions which have the greatest potential to affect those species and their habitats. NRCS shall determine which candidate species and species of concern are to be considered during planning and implementation of NRCS actions. When NRCS concludes that a proposed action "may adversely affect" Federal candidate species, NRCS will recommend only alternative conservation treatments that will avoid adverse effects, and to the extent practicable, provide long-term benefit to the species. If the species becomes

STEP 1.

Are there any endangered or threatened species, designated critical habitat(s), proposed species/habitats, or sState/Tribal species of concern protected by law or regulation present, or potentially present, in the area of potential effect?

☑ No — If "No," additional evaluation is not needed. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Unknown — If "Unknown," consult Section II of the FOTG for a listing of threatened and endangered species and associated critical habitats, and State species of concern, then repeat Step 1. If you are still uncertain about the status of threatened, endangered, proposed, or species of concern in the planning area, ask your State Biologist or contact the FWS/NMFS Fisheries, as appropriate.

☐ Yes — **If "Yes," then proceed to the applicable section(s) listed below:**

- Federally listed **endangered or threatened** species/habitats. **Go to Step 2.**
- Federally listed **proposed** species/habitats. **Go to Step 5.**
- **State/Tribal species of concern** protected by law or regulation. **Go to Step 9.**

Federally endangered or threatened species/habitats

STEP 2.

What are the short and long-term impacts of the proposed action or alternative on endangered or threatened species or their designated critical habitat? If more than one may apply, then differentiate in the "Notes" section below.

☐ No effect — If "No effect," additional evaluation is not needed concerning endangered and threatened species or designated critical habitat. Document the finding, including the reasons for your determination on form NRCS-CPA-52 and proceed with planning.

☐ May Affect but not likely to adversely affect (e.g. beneficial affect) — If "May affect but not likely to adversely affect," document the finding, including the reasons, on form NRCS-CPA-52. This determination may require concurrence from FWS/NMFS Fisheries. Go to Step 3.

Federally endangered or threatened species/habitats (continued)

☐ May adversely affect — If "May adversely affect," modify the action if possible to avoid adverse effects. If the action can be modified, repeat Step 2. If the action can not be modified, go to Step 3.

☐ Effects are unknown — If "Effects are unknown," contact the NRCS State Biologist for assistance and repeat Step 2.

STEP 3.

Will a Federal agency other then NRCS provide funding or otherwise control implementation of the action?

☐ No — If "No," go to Step 4.

☐ Yes — If "Yes," ensure that potential adverse effects are avoided to the extent feasible, document and describe the effects on form NRCS-CPA-52. Include both short-term and long-term effects. Document the need for the lead Federal agency to consult (if listed species or habitat may be affected beneficially or adversely) with the FWS/NMFS Fisheries, as appropriate. Inform the client and continue planning. However, make the client aware that the action can not be implemented without first attaining the appropriate concurrence.

STEP 4.

Is NRCS providing financial assistance or otherwise controlling the action?

☐ No — **If "No," and your answer in Step 2 was, "May affect but not likely to adversely affect"** and there is no possibility of any short-term or long-term adverse effects then continue with planning but ensure the client is aware of the effects.

☐ No — **If "No," and your answer in Step 2 was, "May adversely affect,"** then inform the client of NRCS's policy concerning endangered and threatened species and the need to use alternative conservation treatments to avoid adverse effects on these species or their habitat. Further NRCS assistance will be provided only if one of the conservation alternatives is selected that avoids adverse effects (then repeat from Step 2) or the landowner obtains a "take" permit from the FWS/NMFS Fisheries, as appropriate. Refer the client to USFWS/NMFS Fisheries to address their responsibilities under Sections 9 & 10 of the ESA, for Federally listed species.

☐ Yes — **If "Yes," and your answer in Step 2 was either, "May affect but not likely to adversely affect"**, or,**"May adversely affect,"** then inform client that the NRCS must consult on listed species with FWS/NMFS Fisheries, as appropriate. The action will only be implemented according to the terms of the consultation. When consultation is complete, reference or attach the consultation documents to NRCS-CPA-52 and proceed with planning.

Notes for Federally endangered or threatened species/habitats:

Federally proposed species/habitats

For proposed species and their proposed critical habitats the action agency (NRCS) has the responsibility of determining that "activities will not jeopardize the continued existence of or destroy or adversely modify designated or proposed critical habitat for listed or proposed species" [190 GM Part 410.22(f)(5)(i)(B)]. Also see Chapter 6 in the ESA Section 7 Consultation Handbook for more information.

STEP 5.

What are the short and long-term impacts of the proposed action or alternative on proposed species or their proposed critical habitat? If more than one may apply, then differentiate in the "Notes" section below.

☐ No adverse effect	If “No adverse effect," additional evaluation is not needed concerning proposed species or proposed critical habitat. Document finding, including the reasons for your determination on form NRCS-CPA-52 and proceed with planning.
☐ Potential adverse effect	If "Potential adverse effect," go to Step 6.
☐ Effects unknown	If "Effects unknown," contact the NRCS State Biologist for assistance and then repeat Step 5.

STEP 6.

Will a Federal agency other then NRCS provide funding or otherwise control implementation of the action?

☐ No	If "No," go to Step 7.
☐ Yes	If “Yes,” ensure that potential adverse effects that are likely to jeopardize the continued existence of the proposed species or destroy or adversely modify proposed critical habitat are avoided. Coordinate with the lead Federal agency and provide any assistance needed for them to make the required "jeopardy" determination. Document on form NRCS-CPA-52 the potential need for the lead Federal agency to conference with the FWS/NMFS Fisheries, as appropriate. Inform the client and continue planning. However, make the client aware that the action can not be implemented without first attaining the appropriate concurrence.

STEP 7.

Is NRCS providing financial assistance or otherwise controlling the action?

☐ No	If "No," inform client of NRCS policy for proposed species and the need to use alternative conservation treatments to avoid adverse effects that are likely to jeopardize the continued existence of the proposed species or destroy or adversely modify proposed critical habitat. **Contact NRCS State Biologist to make the affects determination** then go to Step 8.
☐ Yes	If “Yes,” then inform the client that the NRCS must conference on proposed species with FWS/NMFS Fisheries, as appropriate. The action will only be implemented according to the terms of the conference. When conference is complete, reference or attach the conference documents to form NRCS-CPA-52 and proceed with planning.

STEP 8.

Upon guidance from NRCS State Biologist, has it been determined that the proposed action or alternative is likely to jeopardize the proposed species or destroy or adversely modify proposed critical habitat?

☐ No	If "No," document the finding on the NRCS-CPA-52 and proceed with planning.
☐ Yes	If “Yes,” further NRCS assistance will be provided only if one of the conservation alternatives is selected that avoids that level if adverse effects (then repeat from Step 5). If the client is unwilling to modify the action, NRCS assistance must be discontinued. Although a "take" permit is not required for proposed species, there may be cases where the proposed species/habitats becomes formally listed as endangered/threatened or critical habitat is designated prior to project implementation. In this case, advise the client that a "take" permit from the USFWS/NMFS Fisheries would be needed prior to project implementation if it is determined that the action may have an adverse affect on the listed species/habitat.

Notes for Federally proposed species/habitats:

State / Tribal species of concern protected by law or regulation

STEPS 9-11 ADDRESS "STATE/Tribal SPECIES OF CONCERN" ONLY. Consult Section II of your State's FOTG for a listing of State/Tribal Species of Concern that are protected by law or regulation that may need to be evaluated, or ask your State Biologist for assistance.

STEP 9.

What are the short and long-term impacts of the proposed action or alternative on the State/Tribal Species of Concern? If more than one may apply, then differentiate in the "Notes" section below.

☐ No adverse effect — If "No adverse effect," additional evaluation is not needed concerning State species of concern, unless otherwise specified by State procedures or the State Biologist. Document the finding, including the reasons for your determination, on form NRCS-CPA-52 and proceed with planning.

☐ May adversely affect — If "May adversely affect," modify the action if possible to avoid adverse effects. If the action can be modified, repeat Step 9. If the action can not be modified, go to Step 10.

☐ Effects are unknown — If "Effects are unknown," contact the NRCS State Biologist for assistance and repeat Step 9.

STEP 10.

Will a Federal agency other then NRCS provide funding or otherwise control implementation of the action?

☐ No — If "No," go to Step 11.

☐ Yes — If "Yes," ensure that potential adverse effects are avoided to the extent possible, document and describe the effects on form NRCS-CPA-52. Include both short-term and long-term effects. Document on form NRCS-CPA-52 the need for the lead Federal agency to address State/Tribal species of concern as appropriate under State land Tribal aws and regulations. Inform the client and continue planning.

STEP 11.

Is NRCS providing financial assistance or otherwise controlling the action?

☐ No — **If "No," and your answer in Step 9 was, "May adversely affect",** inform the client of NRCS's policy regarding State and Tribal species of concern and the need to use alternative conservation treatments to avoid adverse effects on species. Provide alternative measures to client for consideration. Advise the client to contact the appropriate State or tribal resource agency for additional guidance to avoid any penalties applicable under State or Tribal law, and continue planning.

☐ Yes — **If "Yes," and your answer in Step 9 was, "May adversely affect,"** inform the client of NRCS's policy concerning State species of concern and the need to use alternative conservation treatments to avoid adverse effects on species. Follow policy and procedures in your state for addressing State and Tribal species of concern. Consultation with the appropriate State wildlife resource agency may be needed.

Notes for State species of concern:

ENVIRONMENTAL JUSTICE
NECH 610.27
Evaluation Procedure Guide Sheet

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

Check all that apply to this Guide Sheet review: ☐ Alternative 1 ☐ Alternative 2 ☐ Other

STEP 1.

In the area affected by the NRCS action, are there low-income populations, minority populations, Indian tribes, or other specified populations that would be adversely impacted by environmental effects resulting from the proposed action or alternative?

☑ No — If "No," additional evaluation is not needed concerning environmental justice. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 2.

☐ Unknown — If "Unknown," consult your State Environmental Specialist, or equivalent, and/or Tribal Liaison for additional guidance. NOTE: The USDA Departmental Regulations on Environmental Justice (DR 5600-002) provides detailed "determination procedures" for NEPA as well as non-NEPA activities and suggests social and economic effects for considerations.

STEP 2.

Is the proposed action or alternative the type that might have a disproportionately adverse environmental or human health effect on any population?

☐ No — If "No," additional evaluation is not needed concerning environmental justice. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," initiate community outreach or Tribal consultation to affected and interested parties that are categorized as low-income, minority, or as Indian Tribes. The purpose is to encourage participation and input on the proposed program or activity and any alternatives or mitigating options. Participation of these populations may require adaptive or innovative approaches to overcome linguistic, institutional, cultural, economic, historic, or other potential barriers to effective participation. If assistance is needed with this process, contact your State Public Affairs Specialist or Tribal Liaison. Go to Step 3.

STEP 3.

Considering the results of the outreach initiative together with other information gathered for the decision-making process, will the proposed action or alternative have a disproportionately high and adverse effect on the human health or the environment of the minority, low-income, or Indian populations?

☐ No — If "No," notify interested and affected parties of agency decision.

☐ Yes — If "Yes," consider the feasibility and appropriateness of the proposed alternatives and their effects and the possiblity of developing additional alternatives or a mitigation alternative and repeat Step 4. Document results of these early scoping sessions on the NRCS-CPA-52. If it is felt that there remains a potentially high and/or adverse effect on human health or the environment, or the project/action carries a high degree of controversy, check "Q 5)" in Q of the NRCS-CPA-52 and refer the action to the State Environmental Liaison for further analysis. An EA may be required to determine if the action is "significant." If it is known that the "action will have significant effects on the quality of the human environment," and EIS will be required (NECH 610.44 and 610.45).

Notes:

ESSENTIAL FISH HABITAT
NECH 610.28
Evaluation Procedure Guide Sheet

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

Check all that apply to this Guide Sheet review: ☐ Alternative 1 ☐ Alternative 2 ☐ Other

STEP 1.

Is the proposed action or alternative in an area designated as Essential Fish Habitat (EFH) or in an area where effects could indirectly or cumulatively affect EFH?

☑ No — If "No," additional evaluation is not needed concerning EFH. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 2.

☐ Unknown — If "Unknown," consult Section II of the FOTG for a list or the location of EFH areas and repeat Step 1. **Note:** Additional information regarding EFH Descriptions and Identifications can be found on NOAA's web site, http://www.nmfs.noaa.gov/habitat/habitatprotection/efh/index.htm

STEP 2.

Will the proposed action or alternative result in short-term or long-term disruptions or alterations that may result in an "adverse effect" to EFH? [16 U.S.C. 1855(b)(2); MSA Section 305(b)(2)]

☐ No — If "No," consultation with NOAA Fisheries and further evaluation is not needed concerning EFH unless otherwise specified by the State Biologist. Document the finding on form NRCS-CPA-52 or equivalent and proceed with planning.

☐ Yes — If "Yes," GO TO Step 3.

☐ Unknown — If "Unknown," consult with your State Biologist and repeat Step 2.

STEP 3.

Can the proposed action or alternative be modified to avoid the potential adverse effect?

☐ No — If "No," document the effects, including the reasons, on form NRCS-CPA-52. Go to Step 4.

☐ Yes — If "Yes," modify the action or activity and repeat Step 2.

STEP 4.

Is NRCS providing assistance that would result in the funding, authorization, or undertaking of the proposed action or alternative? [MSA Section 305(b)]

☐ No — If "No," go to Step 5.

☐ Yes — If "Yes," inform the client that the NRCS District Conservationist or NRCS State Biologist must consult with NOAA Fisheries before further action or activity can proceed [MSA, Section 305(b)(2)]. **Note:** For specific information regarding consultation for EFH, see NOAA's "Essential Fish Habitat Consultation Guidance," April 2004, available at http://www.nmfs.noaa.gov/habitat/habitatprotection/efh/index.htm

ESSENTIAL FISH HABITAT (continued)

STEP 5.

Is a Federal agency other than NRCS providing assistance that would result in the funding, authorization, or undertaking of the proposed action or alternative?

☐ No — If "No," an alternative conservation system that avoids the adverse effect must be identified as the proposed action or NRCS must discontinue assistance. If assistance is terminated, indicate the circumstances in the Remarks section of the NRCS-CPA-52 or contact the NRCS State Office for assistance. (GM 190, Part 410.3)

☐ Yes — If "Yes," document on the NRCS-CPA-52 that the lead Federal agency should consult with NOAA Fisheries before the action is implemented. Inform the client and proceed with planning.

Notes:

FLOODPLAIN MANAGEMENT
NECH 610.29
Evaluation Procedure Guide Sheet

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

Check all that apply to this Guide Sheet review: ☐ Alternative 1 ☐ Alternative 2 ☐ Other

NOTE: This Guide Sheet is intended for evaluation of non-project technical and financial assistance only (individual projects). For project assistance criteria (those assisting local sponsoring organizations), consult GM-190, Part 410.25.

STEP 1.

Is the project area in or near a 100-year floodplain?

☑ No — If "No," additional evaluation is not needed. Record "N/A" on NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 2.

☐ Unknown — If "Unknown", review the HUD/FEMA flood insurance maps and/or other available data. If still "Unknown", contact the appropriate field or hydraulic engineer. Repeat Step 1.

STEP 2.

Is the planning area in the floodplain an agricultural area that has been used to produce food, fiber, feed, forage or oilseed for at least 3 of the last 5 years before the request for assistance?

☐ No — If "No," go to Step 4.

If "Yes," document the agricultural use history and go to Step 3.

STEP 3.

Is the floodplain's agricultural production in accordance with official state or designated area water quality plans?

☐ No — If "No," advise the client of conservation practices or other measures that will bring the land into accordance with water quality plans and incorporate these into the conservation plan. Go to Step 4.

☐ Yes — If "Yes," document and go to Step 4.

STEP 4.

Over the short or long term, will this proposed action or alternative likely result in an increased flood hazard, incompatible development, or other adverse effect to the existing natural and beneficial values of the floodplain or lands adjacent or downstream from the floodplain?

☐ No — If "No," document your finding on the NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," modify the action if possible to avoid adverse effects. Inform landuser of the hazards of locating actions in the floodplain and discuss alternative methods of achieving the objective and/or alternative locations outside the 100-year floodplain. If the action can be modified, describe the modification on the NRCS-CPA-52 and repeat Step 4. If the action can not be modified to eliminate adverse effects, go to Step 5.

FLOODPLAIN MANAGEMENT (continued)

STEP 5.

Is one or more of the alternative methods or locations practical?

☐ No

If "No," the District Conservationist will carefully evaluate and document the potential extent of the adverse effects and any increased flood risk before making a determination of whether to continue providing assistance. Go to Step 6.

☐ Yes

If your answer is "Yes, **and client agrees** to implement the alternative methods or locations outside the floodplain, document the agreed upon actions, including the reasons, on form NRCS-CPA-52 or equivalent and proceed with planning.

If your answer is "Yes," **and client does not agree** to implement the alternative methods or locations, advise the client that NRCS may not continue to provide technical and/or financial assistance where there are practicable alternatives. Go to Step 6.

STEP 6.

Will assistance continue to be provided?

☐ No

If "No," provide written notification of the decision to terminate assistance to the client and the local conservation district, if one exists. Document the decision, including the reasons, on NRCS-CPA-52 and proceed with planning.

☐ Yes

If "Yes," the District Conservartionist should design or modify the proposed action or alternative to minimize the adverse effects to the extent possible. Circulate a written public notice locally explaining why the action is proposed to be located in the 100-year floodplain. Document the decision, including the reasons, on form NRCS-CPA-52 and proceed with planning.

Notes:

INVASIVE SPECIES
NECH 610.30
Evaluation Procedure Guide Sheet

Check all that apply to this Guide Sheet review:	☐ Alternative 1 ☐ Alternative 2	☐ Other	Client/Plan Information: Santaquin City, Utah Santaquin Storm Drain WFPO Program 2017 Funding

NOTE: The GM 190, Part 414 states that "NRCS shall not authorize, fund, or carry out actions that it believes are likely to cause or promote the introduction and spread of invasive species in the U.S. or elsewhere."

STEP 1.

Is the proposed action or alternative in an area where invasive species are known to occur or where risk of an invasion exists? **NOTE:** Executive Order 13112 (1999) directs Federal agencies to "prevent the introduction of invasive species, provide for their control, and to minimize the economic, ecological, and human health impacts that invasive species cause."

☐ No — If "No," additional evaluation is not needed concerning invasive species. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 2.

☐ Unknown — If "Unknown", consult Section II of the FOTG for a listing of invasive species in the area and/or the appropriate technical specialist to determine the potential for introduction of new invasive species into the area.

STEP 2.

Conduct an inventory of the invasive species and identify areas at risk for future invasions (GM 190, Part 414.30). Delineate these areas on the conservation plan map and document management considerations in the plan or assistance notes. Have all appropriate tools, techniques, management strategies, and risks for invasive species prevention, control, and management been considered in the planning process?

☐ No — If "No," you must consider and include all appropriate factors relating to the existing and potential invasive species for the planning area and repeat Step 2.

☐ Yes — If "Yes," describe strategies, techniques, and reasons on NRCS-CPA-52 and go to Step 3.

STEP 3.

Is the proposed action or alternative consistent with the E.O. 13112, the National Invasive Species Management Plan (http://www.invasivespeciesinfo.gov/laws/execorder.shtml), and/or an applicable State or local Invasive Species Management Plan?

☐ No — If "No," modify the action and repeat Step 3. If the client is unwilling to modify the proposed action, NRCS must discontinue assistance. Document the circumstances on the NRCS-CPA-52 and in the case file.

☐ Yes — If "Yes," describe strategies, techniques, and reasons, on the NRCS-CPA-52 and proceed with planning.

Notes:

MIGRATORY BIRDS, BALD AND GOLDEN EAGLE PROTECTION ACT, NECH 610.31
Evaluation Procedure Guide Sheet

Check all that apply to this Guide Sheet review:	☐ Alternative 1 ☐ Alternative 2 ☐ Other	Client/Plan Information: Santaquin City, Utah Santaquin Storm Drain WFPO Program 2017 Funding

NOTE: This guide sheet includes evaluation guidance for compliance with both the Migratory Birds Treaty Act, Executive Order 13186 (2001), and the Bald and Golden Eagle Protection Act. Both sections must be completed if eagles are identified within the area of potential effect.

MIGRATORY BIRDS TREATY ACT

In the lower 48 states, all species except the house sparrow, rock pigeon, common starling, and non-migratory game birds like pheasants, gray partridge, and sage grouse, are protected.

STEP 1.

Could the proposed action or alternative result in a "take" (intentionally or unintentionally) to any migratory bird, nest or egg? **"Take"** means to pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to pursue, hunt, shoot, wound, kill, trap, capture, or collect (50 CFR 10.12). **NOTE:** The MBTA does not contain any prohibition that applies to the destruction of a migratory bird nest alone (without birds or eggs) provided that no possession occurs during the destruction (USFWS, Migratory Bird Memorandum, MBPM-2, April 2003).

☐ No — If "No," additional evaluation is not needed concerning migratory birds. Document the finding, including the reasons, on form CPA-52 and proceed with planning.

☑ Yes — If "Yes," go to Step 2.

STEP 2.

Is it the purpose of the proposed action or alternative to intentionally "take" a migratory bird or any part, nest or egg (such as, but not limited to: controlling depredation by a migratory bird, or removal of occupied nests of nuisance migratory birds)? **NOTE:** Take of migratory game birds is exempt, as provided for under state and Federal hunting regulations.

☑ No — If "No," go to Step 3.

☐ Yes — If "Yes," document the effects, including the reasons, on form NRCS-CPA-52. Inform the client that they must obtain a permit from USFWS and any required state permit before the action is implemented.

STEP 3.

Have adverse effects on migratory birds been mitigated (avoided, reduced, or minimized) to the maximum practicable extent?

☐ No — If "No," modify the alternative and repeat Step 1. If client is unwilling to modify the action then NRCS must discontinue assistance until issue has been resolved with USFWS.

☑ Yes — If "Yes," document mitigation measures and go to Step 4.

MIGRATORY BIRDS TREATY ACT / BALD AND GOLDEN EAGLE PROTECTION ACT (continued)

STEP 4.

Will unintentional take of migratory birds, either individually or cumulatively, result in a measurable negative effect on a migratory birds population?

☑ No — If "No," additional evaluation is not needed concerning migratory birds. Document the finding, including the reasons, on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," additional principles, standards and practices shall be developed in coordination with USFWS to further lessen the amount of unintentional take (EO 13186(3)(e)(9)). Repeat Step 1 or indicate which of the following options is pursued by the client:

- The client will obtain a permit from USFWS before the action is implemented; OR
- NRCS may need to terminate assistance. Contact the NRCS State Environmental Specialist or Wildlife Biologist.

Notes:

BALD & GOLDEN EAGLE PROTECTION ACT

STEP 1.

Will the proposed action or alternative result in the take, possession, sale, purchase, barter, or offer to sell, purchase, or barter, export or import "of any bald or golden eagle, alive or dead, including any part, nest, or egg, unless allowed by permit?" **"Take"** is defined as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb" a bald or golden eagle. The term "disturb" under this Act means to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available; 1) injury to an eagle; 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or; 3) nest abandonement, by substantially interfering with normal breeding, feeding, or sheltering behavior.

☑ No — If "No," additional evaluation is not needed. Document the finding, including the reasons, on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 2.

STEP 2.

Can the proposed action or alternative be modified to avoid the adverse effect?

☐ No — If "No," document the finding, including the reasons, on form NRCS-CPA-52. Contact the NRCS State Biologist or appropriate NRCS official about working with the client and USFWS to permit the action or finding another alternative action to avoid adverse effects prior to providing final designs or implementing the proposed action or alternative. No permit authorizes the sale, puchase, barter, trade, importation, or exportation of eagles, or their parts or feathers. The regulations governing eagle permits can be found in 50 CFR Part 22 (Eagle Permits).

☐ Yes — If "Yes," modify the alternative and repeat Step 1.

Notes:

PRIME AND UNIQUE FARMLANDS
NECH 610.32
Evaluation Procedure Guide Sheet

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

Check all that apply to this Guide Sheet review: ☐ Alternative 1 ☐ Alternative 2 ☐ Other

STEP 1.

Using the criteria found in the FPPA Rule (7 CFR Part 658.5), does the proposed action or alternative convert farmland to a nonagricultural use? NOTE: Conversion does not include construction of on-farm structures necessary for farm operations. Also, form AD-1006 entitled "Farmland Conversion Impact Rating" and form NRCS-CPA-106 entitled "Farmland Conversion Impact Rating for Corridor Type Projects" are used to document effects of proposed projects that may convert farmland.

☑ No — If "No," additional evaluation is not needed concerning prime and unique farmland. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 2.

☐ Unknown — If "Unknown," consult Section II of the FOTG and FPPA Rule and repeat Step 1. If you are still uncertain about the effects of prime and unique farmlands in your planning area, consult your State Soil Scientist.

STEP 2.

Are prime or unique farmlands or farmlands of statewide or local importance present in or near the area that will be affected by the proposed action or alternative?

☐ No — If "No," additional evaluation is not needed concerning prime and unique farmland. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 3.

STEP 3.

Can the pproposed action or alternative be modified to avoid adverse effects or conversion?

☐ No — If "No," document the adverse effects on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," modify and repeat Step 2 or contact the State Soil Scientist for further assistance.

Notes:

RIPARIAN AREA
NECH 610.33
Evaluation Procedure Guide Sheet

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

Check all that apply to this Guide Sheet review: ☐ Alternative 1 ☐ Alternative 2 ☐ Other

STEP 1.

Is a riparian area present in or near the planning area? (Definition can be found in the GM 190, Part 411.)

☑ No — If "No," additional evaluation is not needed concerning riparian areas. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 2.

STEP 2.

Does the proposed action or alternative conflict with the conservation values/functions of the riparian area?

☐ No — If "No," go to Step 3.

☐ Yes — If "Yes," explain the values/functions of riparian areas to the client, including their contribution to floodplain function, streambank stability and integrity, nutrient cycling, pollutant filtering, sediment retention, biological diversity, and present alternatives that will resolve the conflict (GM 190, Part 411.03). Then, go to Step 3.

☐ Unknown — If "Unknown," refer to your state specific protocols to determine the current status of ecological function of the riparian area and project future conditions if the practice is implemented. If further assistance is required, contact your State Biologist.

STEP 3.

Does the proposed action or alternative maintain or improve water quality and quantity benefits provided by the riparian area?

☐ No — If "No," alternatives must be developed which maintain or improve water quality and quantity benefits (GM 190, Part 411.03). When alternatives have been developed and discussed with the client, go to Step 4.

☐ Yes — If "Yes," no additional evaluation is needed concerning Riparian Areas. Document the finding on form NRCS-CPA-52 and proceed with planning.

STEP 4.

Is the client willing to modify the proposed action or alternative so that water quality and quantity benefits provided by the riparian area are maintained or improved?

☐ No — If "No," inform the client that NRCS policy requires that the conservation plan must maintain or improve water quality and quantity benefits of riparian areas where they exist (GM 190, Part 411.03). If the client remains unwilling to modify the proposed action, NRCS must discontinue assistance on those portions of the plan impacting riparian areas. If assistance is terminated, indicate the circumstances in the Remarks section of the NRCS-CPA-52. Be sure to also document in the case file that the values of riparian areas were explained to the client and alternatives were provided, but the client declined to modify the proposed action.

☐ Yes — If "Yes," no additional evaluation is needed concerning Riparian Areas. Document the finding along with any mitigation actions or modifications on the NRCS-CPA-52 and proceed with planning.

Notes:

WETLANDS
NECH 610.34
Evaluation Procedure Guide Sheet

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

Check all that apply to this Guide Sheet review: ☐ Alternative 1 ☐ Alternative 2 ☐ Other

This guide sheet addresses policy relative to the Food Security Act of 1985, GM 190, Part 410.26, E.O. 11990 "Protection of Wetlands," and the NRCS Wetland Technical Assistance Policy 7 CFR Part 650.26. Use the Clean Water Act guide sheet for addressing wetland concerns relating to the Clean Water Act.

STEP 1.

Are wetlands present in or near the planning area? **NOTE:** This includes ALL wetlands except those artificial wetlands created by irrigation water. Thus, areas determined as Prior Converted (PC) per the 1985 Food Security Act and non-irrigation induced artificial wetlands (AW), which retain wetland characteristics, are wetlands as they relate to the Wetland Protection Policy.

☑ No — If "No," document this on the NRCS-CPA-52. (If the area could qualify as an "other water of the U.S." such as lakes, streams, channels, or other impoundment or conveyances, a Clean Water Act Section 404 or River and Harbors Act Section 10 permit may be required from the Corps of Engineers. Refer to the Clean Water Act Guide sheet.)

☐ Yes — If “Yes,” document and go to Step 2.

STEP 2.

Will the proposed action or alternative impact any wetland areas (this includes changing wetland types when considering wetland restoration projects)?

☐ No — If "No," document this on the form NRCS-CPA-52, along with any additional supporting evidence, and proceed with planning.

☐ Yes — If “Yes,” describe (on the NRCS-CPA-52) the effects of the proposed activity on the wetland area. Proceed to Step 3.

STEP 3.

Do practicable actions or alternatives exist which either enhance wetland functions and values, or avoid or minimize harm to wetlands?

☐ No — If "No," a "minimal effects determination" will need to be conducted. (For State-specific protocols, consult with your State Wetland Specialist.) If it is determined that impacts to wetlands are likely to be minimal, proceed with planning. **If it is determined that the action will likely exceed minimal effects, NRCS can provide assistance only if an adequate compensatory mitigation plan is provided.** NRCS can assist with the development of a compensatory mitigation plan for the functions and values that were lost. Prior to or concurrent with NRCS, the client should obtain all necessary permits or approvals related to work in the wetland. Document on NRCS_CPA-52 and proceed with planning.

☐ Yes — If “Yes,” inform the client and advise them of the available option(s). (If there is a practicable action or alternative that will avoid impacts, the client MUST choose the alternative. HOWEVER, under Swampbuster, if the participant wants to convert a wetland the statute affords the mitigation exemptions without question.) Proceed to Step 4.

WETLANDS (continued)

STEP 4.

Does the client wish to pursue an identified practicable action or alternative that will enhance wetland functions and values, or avoid/minimize harm to wetlands?

☐ No — If "No," advise the client regarding eligibility criteria under the FSA as amended, and that the NRCS may assist with the development of acceptable associated mitigation plan for swampbuster, but can not offer further technical or financial assistance for the wetland conversion activity itself. Prior to or concurrent with NRCS assistance, the client should obtain all necessary permits or approvals related to work in wetlands. Document on the NRCS-CPA-52.

☐ Yes — If "Yes," continue with planning and technical assistance for the activity, and, if applicable, the development of an associated mitigation plan. Prior to or concurrent with NRCS assistance, the client should obtain all necessary permits or approvals related to work in wetlands (including those required under the Clean Water Act). Document effects on the NRCS-CPA-52.

Notes:

WILD AND SCENIC RIVERS
NECH 610.35
Evaluation Procedure Guide Sheet

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

Check all that apply to this Guide Sheet review: ☐ Alternative 1 ☐ Alternative 2 ☐ Other

STEP 1.

Could the proposed action or alternative have an effect on the natural, cultural and recreational values of any nearby river(s)?

☑ No — If "No," additional evaluation is not needed concerning Wild and Scenic Rivers. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," analyze the potential effects and develop alternatives, as necessary, that would mitigate potential adverse effects, then go to Step 2.

STEP 2.

Is there a Federal or State designated Wild, Scenic, or Recreational River segment or a river listed in the National River Inventory in or near the planning area?

☑ No — If "No," additional evaluation is not needed concerning Wild and Scenic Rivers. Document the finding on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," and there is still potential for effect consult your State Environmental Liaison to assist with determining significance. Go to Step 3. **Note:** The State Office may request the National Park Service to assist you in developing appropriate avoidance/mitigation measures. (Remember that if an action/activity has not been sufficiently analyzed to determine if it may be significant (either beneficial or adverse), an EA or EIS may be required)

☐ Unknown — If "Unknown," consult Section II of the FOTG for a list or the location of Wild, Scenic, or Recreational Rivers of river segments (or see the NPS list of Wild and Scenic Rivers and the "Nationwide Rivers Inventory") and repeat Step 2.

STEP 3.

Upon further analysis, could the proposed action or alternative have an **adverse effect or have the effects been found to be significant** on the natural, cultural and recreational values of the Wild, Scenic, or Recreational River segment?

☐ No — If "No," document the finding, including the reasons, on form NRCS-CPA-52 and proceed with planning.

☐ Yes — If "Yes," go to Step 4.

STEP 4.

Is NRCS providing financial assistace or otherwise controlling the proposed action or alternative?

☐ No — If "No," go to Step 5.

☐ Yes — If "Yes," an environmental assessment (EA) or, if the effects are significant, an environmental impact statement (EIS) must be prepared. Check "Q 5)" on the NRCS-CPA-52 and provide documentation regarding the action/activity to you State Environmental Liaison for further analysis.

WILD AND SCENIC RIVERS (continued)

STEP 5.

Will a Federal agency other than NRCS provide funding or otherwise control implementation of the action?

☐ No — If "No," inform the client that a permit may be required for their activities and they should consult with the NPS. The permit authorization should be reflected in the final plan and documentation.

☐ Yes — If “Yes,” indicate on the NRCS-CPA-52, that the lead agency should consult with the NPS.

Notes:

RESOURCE CONSIDERATIONS (Optional)

Field Inventory Guide Sheet

Identify the resource concern(s) that need to be addressed and the assessment tool(s) used for the evaluation.

Client/Plan Information:
Santaquin City, Utah
Santaquin Storm Drain
WFPO Program 2017 Funding

SOIL

Erosion

- ☐ Sheet and Rill
- ☐ Wind
- ☐ Ephemeral Gully
- ☐ Classic Gully
- ☐ Streambank
- ☐ Shoreline
- ☐ Irrigation Induced
- ☐ Mass Movement
- ☐ Road, Road Sides & Construction Sites
- ☐ Other:
- ☐ Other:

Condition

- ☐ Organic Matter Depletion
- ☐ Rangeland Site Stability
- ☐ Compaction
- ☐ Subsidence
- ☐ Contaminants-Salts & Other Chemicals
- ☐ Contaminants-Animal Waste & Other Organics
- ☐ Contaminants-Commercial Fertilizer
- ☐ Contaminants-Residual Pesticides
- ☐ Damage from Soil Deposition

Assessment tools, Problems & Notes:

WATER

Quantity

- ☐ Excessive Seepage
- ☐ Excessive Runoff, Flooding, or Ponding
- ☐ Excessive Subsurface Water
- ☐ Drifted Snow
- ☐ Inadequate Outlets
- ☐ Inefficient Water Use on Irrigated Land
- ☐ Inefficient Water Use on Non-irrigated Land
- ☐ Reduced Capacity of Conveyances by Sediment Deposition
- ☐ Reduced Storage of Water Bodies by Sediment Accumulation
- ☐ Aquifer Overdraft
- ☐ Insufficient Flows in Water Courses
- ☐ Rangeland Hydrologic Cycle
- ☐ Other:

Quality

- ☐ Harmful Levels of Pesticides in Groundwater
- ☐ Excessive Nutrients and Organics in Groundwater
- ☐ Excessive Salinity in Groundwater
- ☐ Harmful Levels of Heavy Metals in Groundwater
- ☐ Harmful Levels of Pathogens in Groundwater
- ☐ Harmful Levels of Petroleum in Groundwater
- ☐ Harmful Levels of Pesticides in Surface Water
- ☐ Excessive Nutrients and Organics in Surface Water
- ☐ Excessive Suspended Sediment & Turbidity in Surface Water
- ☐ Excessive Salinity in Surface Water
- ☐ Harmful Levels of Heavy Metals in Surface Water
- ☐ Harmful Temperatures of Surface Water
- ☐ Harmful Levels of Pathogens in Surface Water
- ☐ Harmful Levels of Petroleum in Surface Water

Assessment tools, Problems & Notes:

AIR

Quality

- ☐ Particulate matter less than 10 micrometers in diameter
- ☐ Particulate matter less than 2.5 micrometers in diameter
- ☐ Excessive Ozone
- ☐ Excessive Greenhouse Gas - CO_2
- ☐ Excessive Greenhouse Gas - N_2O
- ☐ Excessive Greenhouse Gas - CH_4
- ☐ Ammonia (NH_3)
- ☐ Chemical Drift
- ☐ Objectionable Odors
- ☐ Reduced Visibility
- ☐ Undesirable Air Movement
- ☐ Adverse Air Temperature
- ☐ Other:
- ☐ Other:

Assessment tools, Problems & Notes:

PLANTS

- ☐ Plants are not adapted or suited

Condition

- ☐ Impared Forage Quality and Palatability
- ☐ Threatened or Endangered Species
- ☐ Declining Species, Species of Concern
- ☐ Productivity, Health and Vigor
- ☐ Noxious and Invasive Plants
- ☐ Wildfire Hazard
- ☐ Other:

Assessment tools, Problems & Notes:

ANIMALS

Fish and Wildlife

- ☐ Inadequate Food
- ☐ Inadequate Water
- ☐ Inadequate Cover/Shelter
- ☐ Inadequate Space
- ☐ Plant Community Fragmentation
- ☐ Imbalance Among and Within Populations
- ☐ Threatened and Endangered Species
- ☐ Declining Species, Species of Concern

Domestic Animals

- ☐ Inadequate Quantities and Quality of Feed & Forage
- ☐ Inadequate Shelter
- ☐ Inadequate Stock Water
- ☐ Stress and Mortality
- ☐ Other:
- ☐ Other:

Assessment tools, Problems & Notes:

ADDENDUM 1
INDIVIDUAL DEBRIS BASIN BENEFIT ANALYSIS

This addendum is included in response to the following request made during the Final EA review:

Input the benefits per structure as part of incremental analysis for the aggregated NED. This incremental analysis should be add on Appendix D. Individual benefits shall be known in the unlikely event that all the debris basins are not constructed. If the state cannot add the incremental analysis then a justification shall be submit to NHQ of why the request cannot be done.

The Santaquin Watershed Project in Utah calls for five debris basins to control flooding. The original plan did not rank the basins on cfs control or average annual benefits. The table below displays this information. The total estimated average annual benefits are $478,600. Flow rates from each watershed are shown without and with the basin to demonstrate the amount of flow rate captured by each proposed debris basin and to estimate a corresponding benefit.

The ranking is provided so that if total funding is not available all at once, prioritization can occur. Some local opinion may differ on the ranking of basin six, as it is the northernmost basin and controls primarily agricultural land, however it does provide a great deal of control as opposed to ranks 4 and 5. Note that while other storm events were analyzed, the basins control analysis is only for the storms listed in the table.

Table 1. Rank of Funding for Basins

	100-yr			200-yr			500-yr						
Watershed	**Existing Flow**	**Plan Flow**	**Control**	**Existing Flow**	**Plan Flow**	**Control**	**Existing Flow**	**Plan Flow**	**Control**	**Total Control**	**Pct. Of Total**	**Estimated Average Annual Benefits**	**Rank**
1	301	17	284	404	95	309	570	344	226	819	0.27	$ 127,174	1
2&3	77	4	73	105	22	83	152	80	72	228	0.07	$ 35,313	5
4	292	17	275	396	107	289	564	361	202	767	0.25	$ 118,979	2
5	210	15	195	296	96	200	438	305	133	528	0.17	$ 82,020	4
6	263	13	250	353	78	275	502	286	217	742	0.24	$ 115,114	3
										3083	1.00	$ 478,600	