Neffs Creek Flood Hazard Assessment

Technical Support Data Notebook

March 2016

Prepared for |

Utah Department of Emergency Management

and

AECOM

LICENSED PROFESSIONAL GEOLOGIST
MICHAEL J. KELLOGG
6111914-2250
03/02/2016
STATE OF UTAH

REGISTERED PROFESSIONAL ENGINEER
No. 9219187-2202
NATHAN BRUCE LOGAN
03/02/2016
STATE OF UTAH

Prepared by|

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

8400 South Kyrene Road, Suite 201
Tempe, AZ 85284
www.jefuller.com

Table of Contents

1.0 INTRODUCTION 1
2.0 METHOD OVERVIEW 2
2.1. Stage 1 2
2.2. Stage 2 3
2.3. Stage 3 3
3.0 DATA SOURCES 4
3.1. NRCS Soils Mapping 4
3.2. Geologic Mapping 8
3.3. Aerial Photography 11
3.3.1. Modern Orthophotography 11
3.3.2. Historical Photography 11
3.4. Topographic Mapping 11
4.0 STAGE 1: RECOGNIZING AND CHARACTERIZING PIEDMONT LANDFORMS 15
4.1. Stage 1 Overview 15
4.2. Composition 15
4.2.1. Soils Mapping Interpretations 15
4.2.2. Surficial Geologic Mapping Interpretations 16
4.2.3. Field Observations 19
4.2.4. Summary 23
4.3. Morphology 23
4.3.1. Location 26
4.3.2. Boundaries 26
4.3.3. Previous Studies 26
4.3.4. Conclusion 27
5.0 STAGE 2: DEFINING ACTIVE VS. INACTIVE ALLUVIAL FAN FLOODING 29
5.1. Overview of Stage 2 Methodology Concepts 29
5.1.1. Age Relationships 30
5.2. Previous Studies 30
5.3. Summary of Stage 2 Analysis 30
6.0 SUMMARY AND RECOMMENDATIONS 32
7.0 STAGE 3 - DEFINING THE 100-YEAR FLOODPLAIN 33
7.1. Alluvial Fan Flood Hazard 33
7.2. Flowpath Uncertainty 33
7.3. Flowpath Uncertainty Modeling 34
7.4. Hydrologic Analysis 35
7.5. Hydraulic Analysis 36
7.5.1. FLO-2D Model Development 36
7.6. Floodplain Mapping 60
7.6.1. Development of Composite Velocities 60
7.7. Floodway Determination 62
7.8. Flood Hazard Profiles 62
8.0 REFERENCES 64

List of Figures

Figure 1. Vicinity map 1
Figure 2. NRCS soils mapping landforms 5
Figure 3. NRCS soils mapping 7
Figure 4. USGS Surficial Geologic Mapping (Van Horn, 1972) 9
Figure 5. USGS Surficial Geologic Mapping (Personius et al., 1992) 10
Figure 6. NAIP orthophotography 12
Figure 7. Historical aerial photograph comparison 13
Figure 8. Digital mapping data 14
Figure 9. Photographs of Neffs Creek diversion near the topographic apex 21
Figure 10. Flow bifurcations 22
Figure 11. Wasatch Range piedmont bajada within the project area 24
Figure 12. Piedmont percent slope 25
Figure 13. Stage 1 landform assessment 28
Figure 14. Stage 2 analysis map 31
Figure 15. FLO-2D model domain boundary 37
Figure 16. Manning's n-values used in the FLO-2D model 39
Figure 17. Typical vegetation density observed in the study area 40
Figure 18. Delineated building footprints 44
Figure 19. Inflow hydrograph location 45
Figure 20. Inflow hydrograph plot 46
Figure 21. Structure locations 47
Figure 22. Outflow grid locations 48
Figure 23. Flowpath uncertainty analysis virtual levees 49
Figure 24. Base condition FLO-2D model for maximum flow depth 51
Figure 25. Maximum flow depth results from the flowpath uncertainty scenario 1 model 52
Figure 26. Maximum flow depth results from the flowpath uncertainty scenario 2 model 53
Figure 27. Maximum flow depth results from the flowpath uncertainty scenario 3 model 54
Figure 28. Maximum flow depth results from the flowpath uncertainty scenario 4 model 55
Figure 29. Maximum flow depth results from the flowpath uncertainty scenario 5 model 56
Figure 30. Maximum flow depth results from the flowpath uncertainty scenario 6 model 57
Figure 31. Maximum flow depth results from the flowpath uncertainty scenario 7 model 58
Figure 32. Maximum flow depth results from the flowpath uncertainty composite model 59
Figure 33. Example of velocity raster clipped to floodplain boundary 61
Figure 34. Proposed revised floodplains 63

List of Tables

Table 1. NRCS soil mapping descriptions 6
Table 2. Available USGS geologic maps 8
Table 3. USGS map unit descriptions 17
Table 4. Neffs Creek estimates discharges (*from HAL, 2007*) 35
Table 5. Manning's n-value assignments 38
Table 6. FLO-2D model simulation times 42
Table 7. Flowpath uncertainty scenario descriptions 50
Table 8. Summary of restudy and remapping efforts 60
Table 9. FEMA-based flood hazard designations associated with delineated floodplains 62

Appendices

Appendix A. AGEC, 2005, Debris Flow Hazard Study Report, Neffs Canyon, Salt Lake County, Utah. Prepared for Hansen, Allen and Luce, Inc.

Appendix B. Floodplain Workmaps

Appendix C. Hansen, Allen & Luce (HAL), 2007, Neffs Canyon Creek Master Plan. Salt Lake County

Appendix D. Annotated DFIRM Maps

Appendix E. Digital Data Submittal

1.0 INTRODUCTION

As part of the Jordan Watershed Risk MAP study for the Utah Division of Emergency Management (UDEM) and the Federal Emergency Management Agency (FEMA) Region VIII, JE Fuller/Hydrology & Geomorphology (JEF) was contracted by AECOM to conduct a geomorphic and flood hazard study for the Neffs Creek watershed located in Salt Lake County, Utah (Figure 1). The effective FEMA regulatory floodplain for Neffs Creek inadequately depicts the flood hazards in this urban, highly developed area as evidenced by historical flooding. The purpose of this study was to assess the 100-year flooding hazard on Neffs Creek within the geomorphic context of the watershed landforms.

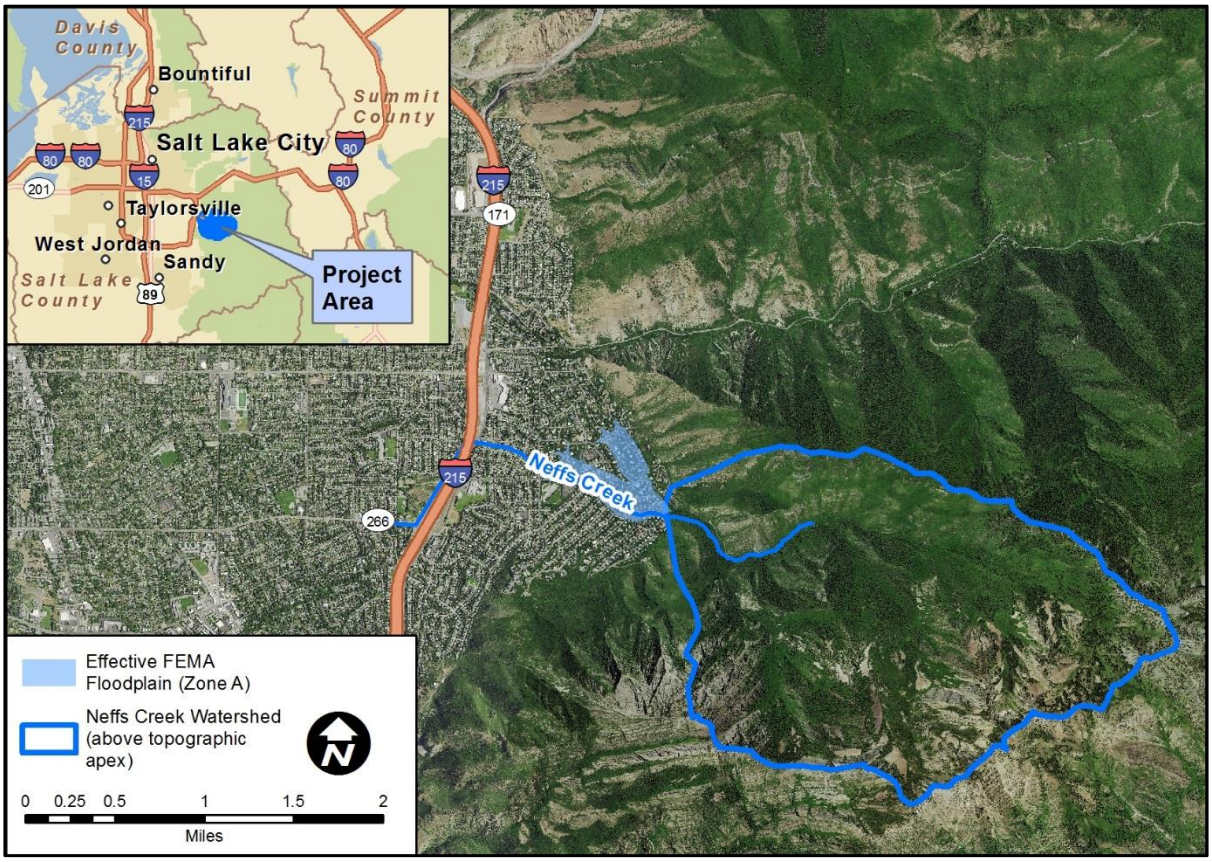


Figure 1. Vicinity map

2.0 METHOD OVERVIEW

The FEMA alluvial fan floodplain delineation methodology is based on a three stage process outlined in the National Research Council's report, *Alluvial Fan Flooding* (NRC, 1996). The National Research Council (NRC) report describes a three stage method used to identify alluvial fan flood hazards, which was later adopted by FEMA and used in developing their *Guidelines and Specifications for Flood Hazard Mapping Partners-Appendix G: Guidance for Alluvial Fan Flooding Analyses and Mapping* (FEMA, 2003), hereafter referred to as the FEMA Guidelines.

The FEMA Guidelines describe the following three stage delineation process intended only for alluvial fan landforms:

- Stage 1: Recognizing and Characterizing Alluvial Fan Landforms
- Stage 2: Defining Active and Inactive Areas of Erosion and Deposition
- Stage 3: Defining the 100-Year Floodplain (for Active Alluvial Fan Landforms)

2.1. Stage 1

Stage 1 of the FEMA alluvial fan methodology is the recognition and characterization of piedmont landforms. The intent of the Stage 1 analysis is to distinguish alluvial fan landforms from riverine, sheet flow, ponding, or coastal landforms.[1] If the landform in question is identified as an alluvial fan landform, then the delineation may proceed using the FEMA Stage 2 and Stage 3 procedures. If the landform is not an alluvial fan landform, then other floodplain delineation procedures should be applied. The Stage 1 delineation relies on the following types of information:

- Composition. Alluvial fans are composed of loose, unconsolidated materials transported by fluvial or debris flow processes (a.k.a., "alluvium").
- Morphology. Alluvial fans have the shape of a partially or fully extended fan as observed on topographic maps or aerial photographs.
- Location. Alluvial fans are usually found at a topographic break where stream channels become less confined than upstream of the break.
- Boundaries. The downstream boundary of an alluvial fan is called the "toe," which is located at an axial stream, lake or landform not formed by alluvial fan flooding processes. The lateral boundaries of the fan are defined by a transition from alluvial fan flooding processes to riverine processes, although an alluvial fan may also coalesce into adjacent alluvial fans to form a bajada.[2]

[1] FEMA Guidelines, p. G-6, 1st paragraph.

[2] A bajada is a low-lying area of confluent pediment slopes and alluvial fans at the base of mountains around a desert.

Data sources for the Stage 1 assessment may include digital topography, National Resource Conservation Service (NRCS) soil surveys, geologic mapping, aerial photography, and hydrologic and hydraulic analyses. These data are used to differentiate piedmont landforms which may include mountains, alluvial fans, and riverine floodplains (both recent and geologically historical). Locations of topographic apices on the landform are also identified in Stage 1. The topographic apex is the extreme upstream extent of an alluvial fan landform, which is often located at the mountain front or within a mountain front embayment. Sudden expansion of flow at a topographic apex causes sediment deposition, uncertain flood flow paths, and uncertain flow distribution below the apex. The complex hydraulics associated with this flow expansion and sediment deposition create significant uncertainties (unpredictability) that "cannot be set aside in the realistic assessment of the flood hazard" (FEMA Guidelines), which is the defining characteristic for alluvial fan flooding.

2.2. Stage 2

Stage 2 of the FEMA alluvial fan methodology consists of defining active and inactive portions of an alluvial fan landform. The FEMA Guidelines define active areas as "that portion of an alluvial fan where deposition, erosion, and unstable flow paths are possible". Active areas on alluvial fans may experience active alluvial flooding defined by "flowpath uncertainty so great that the uncertainty cannot be set aside in realistic assessments of flood risk or in the reliable mitigation of the hazard" (FEMA Guidelines), or other types of flooding where uncertainty can be set aside in mitigating the hazard. Inactive alluvial fan areas are the portions of the alluvial fan where "flow paths with a higher degree of certainty in realistic assessments of flood risk or in the reliable mitigation of the hazard" (FEMA Guidelines) exist.

According to the FEMA Guidelines, a Stage 2 delineation may be completed using a composite-based approach (integrate multiple methods into one result) if the alluvial fan has unique physical characteristics or varying levels of erosion and mitigation activity (*Table G-1* in the FEMA Guidelines). The composite approach can utilize multiple methodologies (hydraulic analytical methods and geomorphic methods) to define the active and inactive areas of the fan landform.

2.3. Stage 3

Stage 3 of the FEMA alluvial fan methodology involves identifying the areas subject to flooding in a 100-year recurrence interval event. Stage 3 methodologies range from probabilistic models such as the FEMA FAN model, to a combination of deterministic models (e.g. two-dimensional hydraulic models) combined with geomorphic interpretations. For this study, a composite of hydraulic modeling and geomorphic methods were used downstream of the topographic apex across the piedmont surface.

3.0 DATA SOURCES

Using the geomorphic approach, surficial stability characteristics were compiled for this analysis and evaluated from the following sources:

- Detailed Soils Mapping. Natural Resource Conservation Service (NRCS) soils maps describe soil composition, soil depth, as well as provide some degree of landform interpretation.

- Surficial Geologic Mapping. The United States Geological Survey (USGS) completed surficial geologic mapping for project area between 1963 and 1965, prior to much of the present development. The USGS map indicates relative surface age and landform type.

- Topographic Mapping. Digital Light Detection and Ranging (LiDAR) mapping (collected 2013) was provided by Salt Lake County and used to assess the surface profile, crenulation index (degree of incision), landform shape, and slope. Topography was also used to help define landform boundaries.

- Vegetation. Vegetation patterns can be used to identify flow paths or areas of more frequent inundation (dense vegetation), sheet flow (uniform vegetation), the degree of soil development, soil material, surface age, and surface boundaries (e.g., vegetation suites change with soil types and landform).

- Drainage Pattern. Inactive fans tend to have tributary drainage patterns with well-defined divides. Active fans tend to have distributary drainage patterns with poorly defined divides and/or perched flow paths.

3.1. NRCS Soils Mapping

The soils data used in this study were derived from the NRCS Soil Survey Geographic (SSURGO) digital soils database for the Salt Lake Area, UT (ut612) and Summit Area, UT (ut613). These detailed soil surveys were developed for use by land planners, farmers, ranchers, agronomists, rangeland managers, community officials, geologists, engineers, developers, builders, home buyers, and watershed and wildlife managers. Figure 2 shows the soil units found within the project area. Landform interpretation information was extracted from the NRCS database and is shown in Table 1. Using the NRCS soils landform information is a valuable first step in the Stage 1 analysis (differentiating alluvial fan landforms from non-fan landforms). Soil descriptions for all soils found within the project area are listed in Table 1 and shown in Figure 3. A more detailed discussion of the soils is included in the Stage 1 analysis (Section 4.0).

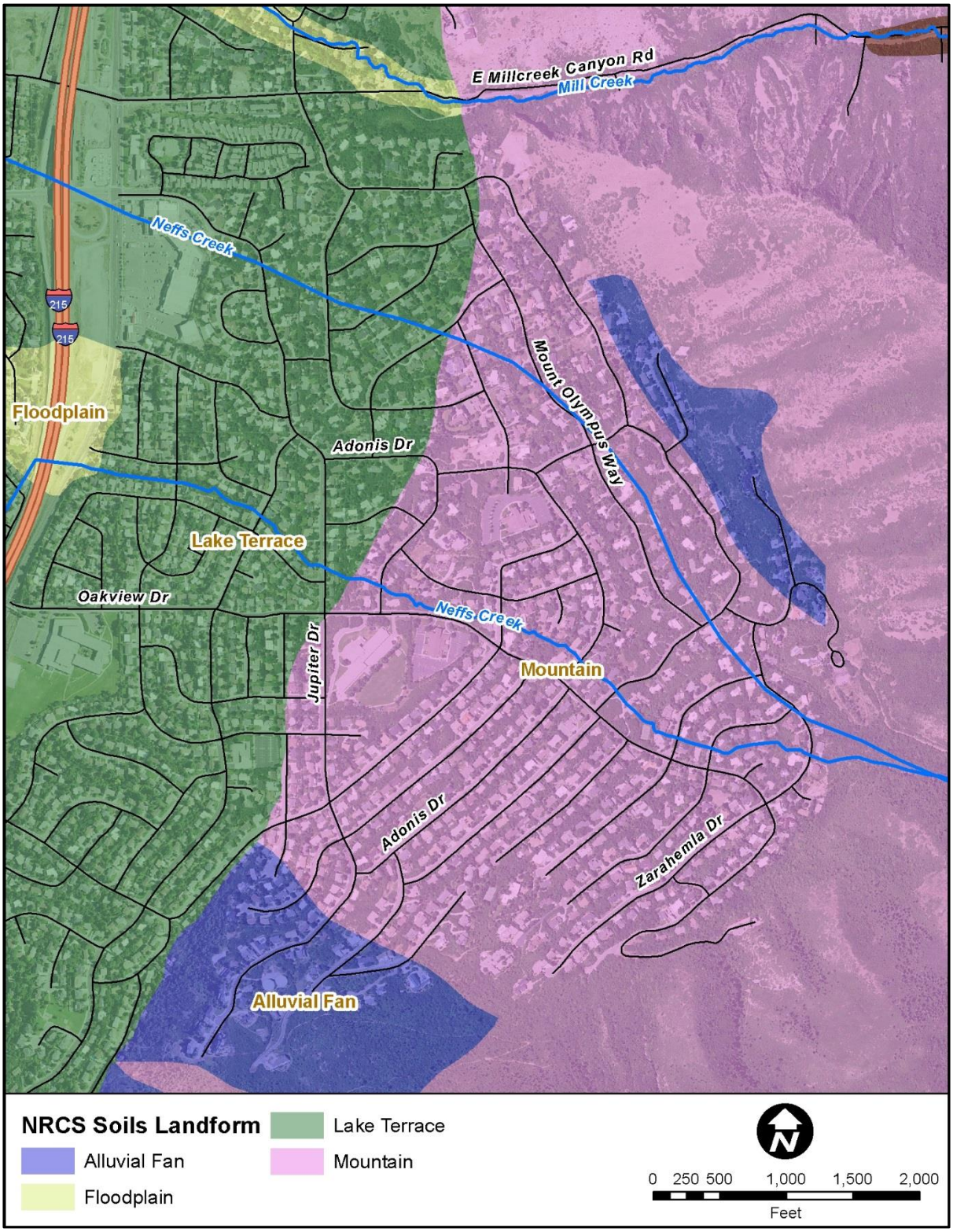


Figure 2. NRCS soils mapping landforms

Table 1. NRCS soil mapping descriptions

Map Symbol	Soil Description	Landform Interpretation
101	Agassiz-Rock outcrop complex, 30 to 70 percent slopes	Mountain
133	Fewkes-Hades complex, 30 to 60 percent slopes	Mountain
136	Hades-Agassiz-Rock outcrop complex, 30 to 70 percent slopes	Mountain
144	Horrocks-Cutoff complex, 15 to 30 percent slopes	Mountain
179	Wanship-Kovich loams, 0 to 3 percent slopes	Terrace
BEG	Bradshaw-Agassiz association, steep	Mountain
BhB	Bingham gravelly loam, 3 to 6 percent slopes	Lake Terrace
EMG	Emigration very cobbly loam, 40 to 70 percent slopes	Mountain
GGG	Gappmayer-Wallsburg association, very steep	Mountain
HHF	Harkers soils, 6 to 40 percent slopes	Alluvial Fan
HtF2	Hillfield-Taylorsville complex, 6 to 30 percent slopes	Lake Terrace
HWF	Horrocks extremely stony loam, 5 to 50 percent slopes	Mountain
KnA	Knutsen coarse sandy loam, 1 to 3 percent slopes	Lake Terrace
SC	Sandy terrace escarpments	Floodplain
SP	Stony terrace escarpments	Lake Terrace
St	Stony alluvial land	Floodplain

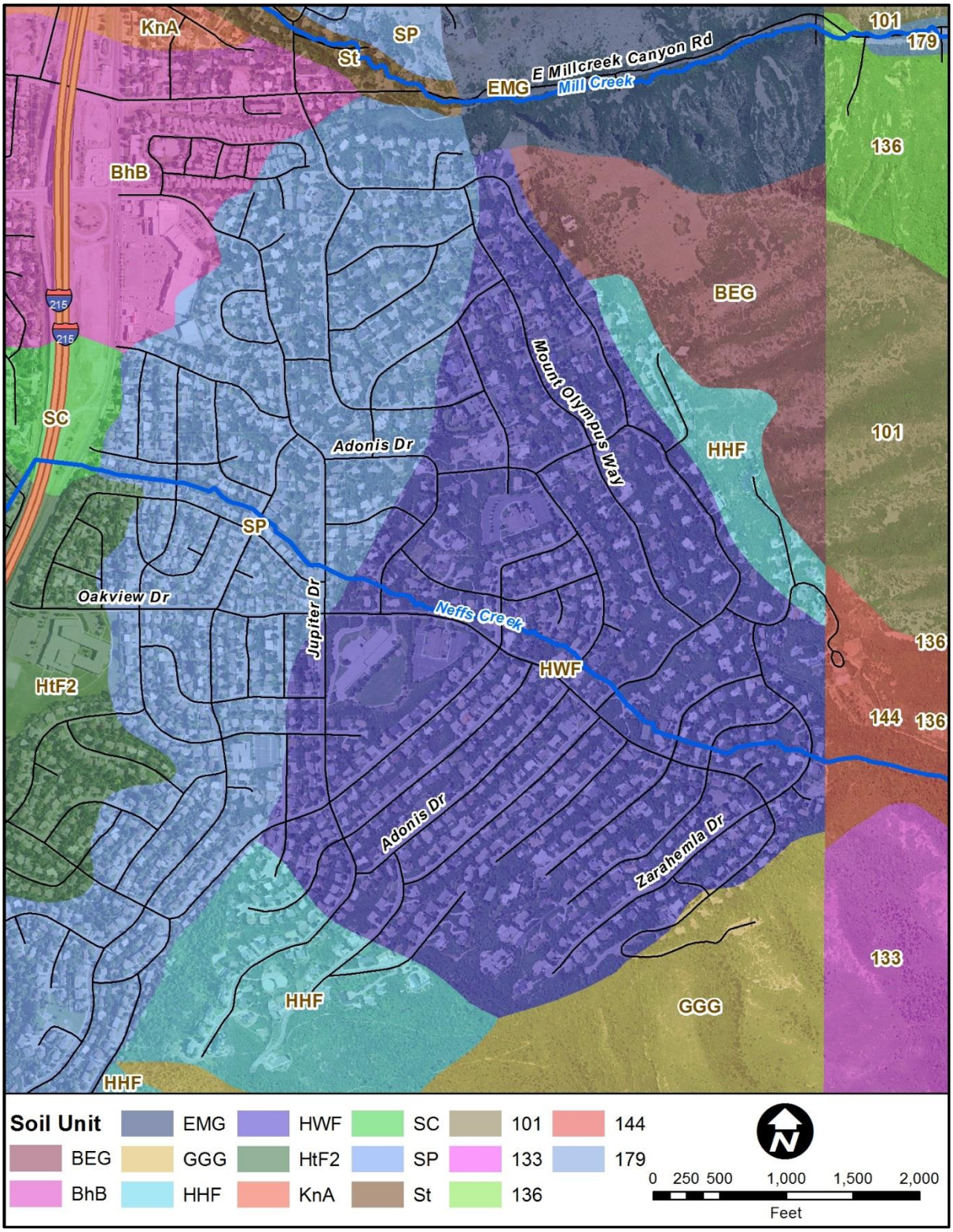


Figure 3. NRCS soils mapping

3.2. Geologic Mapping

The USGS has published surficial and bedrock geologic mapping within the project area as listed in Table 2. Surficial mapping information is invaluable when conducting landform geomorphic investigations. Surficial mapping correlates relative ages of surfaces and helps identify the relative stability of surfaces with respect to flooding potential. Figure 4 shows a 1972 USGS surficial geologic map for the project area and Figure 5 shows a 1992 surficial geologic map. The geologic units in both maps are grouped by geologic composition (alluvium vs. bedrock) and landform type (stream deposit, lake deposit, etc.) which is relevant to the Stage 1 analysis (Section 4.0).

Individual mapped unit descriptions are included in Section 4.0. The USGS mapping was the primary data source for determining the active vs. inactive alluvial fan surfaces (Stage 2). As such, the geologic mapping is discussed in more detail in the Stage 2 analysis (Section 5.0).

Table 2. Available USGS geologic maps

Map Name	Map Format	Scale	Year	Author
Surficial Geologic Map of the Sugar House Quadrangle, Salt Lake County, UT	Raster	1:24,000	1972	Van Horn, R.
Surficial Geologic Map of the Salt Lake City Segment and Parts of Adjacent Segments of the Wasatch Fault Zone, Davis, Salt Lake, and Utah Counties, Utah.	Raster	1:50,000	1992	Personius, S.F., and W.E. Scott

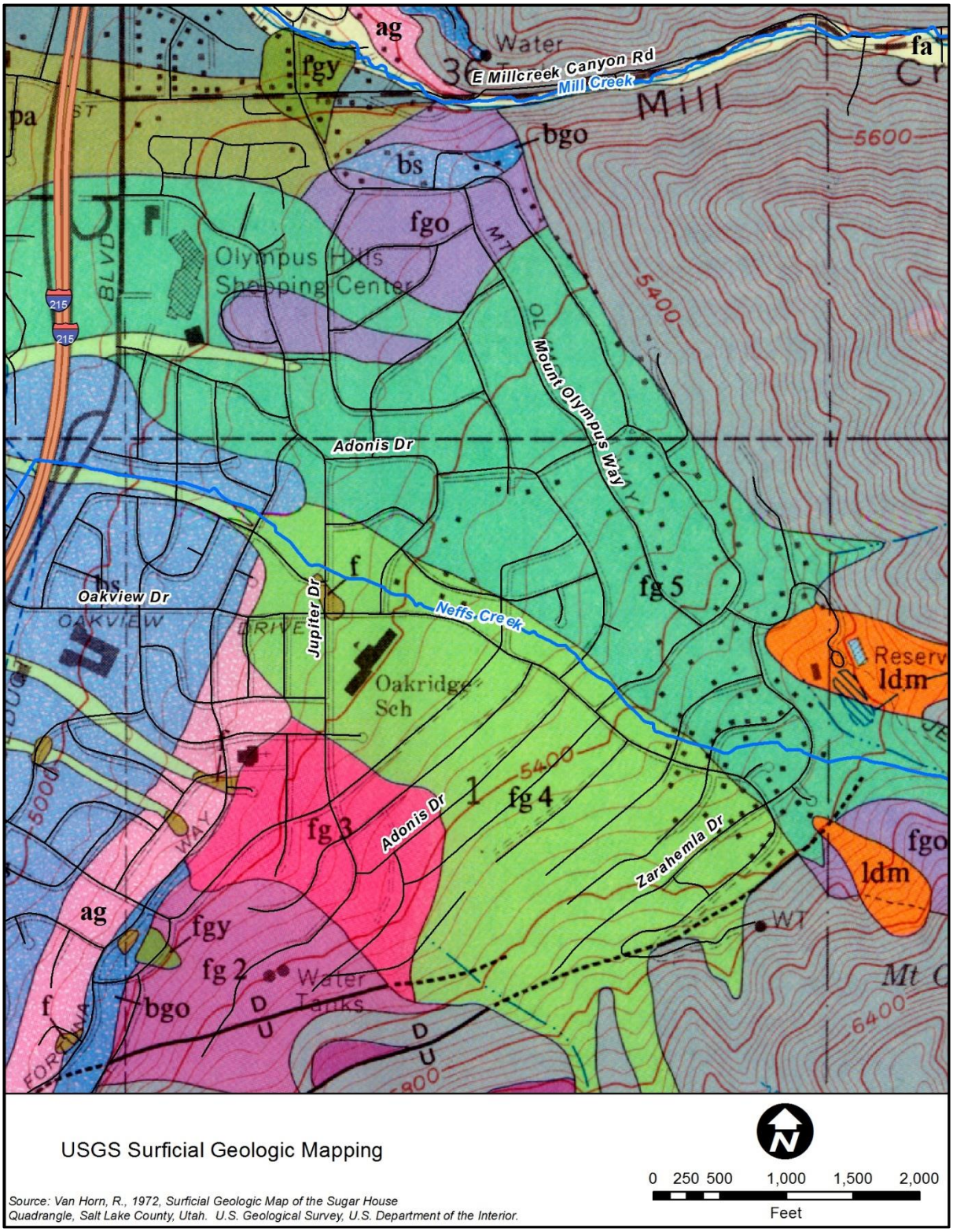


Figure 4. USGS Surficial Geologic Mapping (Van Horn, 1972)

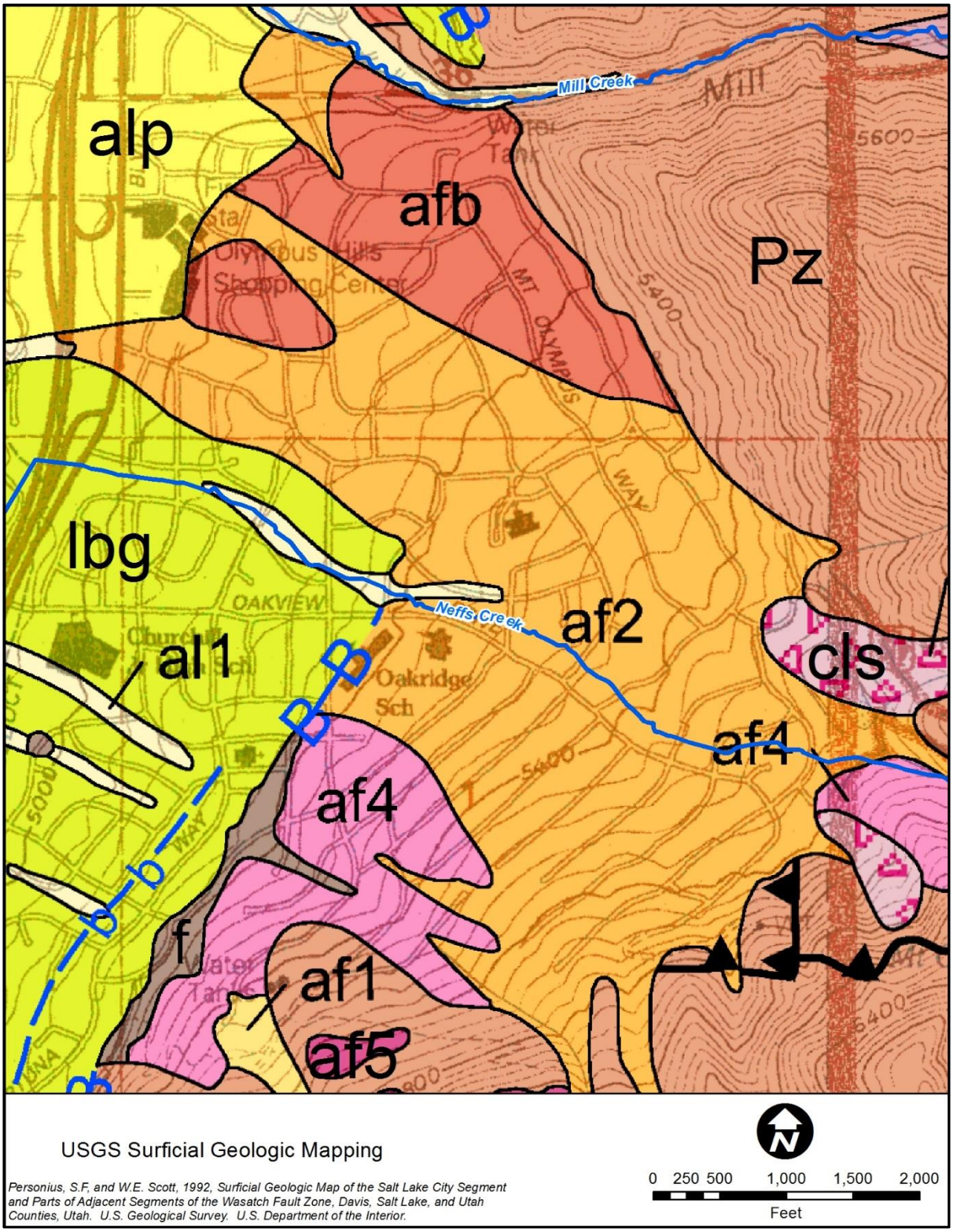


Figure 5. USGS Surficial Geologic Mapping (Personius et al., 1992)

3.3. Aerial Photography

3.3.1. Modern Orthophotography

National Agriculture Imagery Program (NAIP) orthophotography was used for this analysis. NAIP acquires aerial imagery during the agricultural growing seasons in the continental U.S. A primary goal of the NAIP program is to make digital orthophotography available to governmental agencies and the public within a year of acquisition. This analysis used 2014 NAIP orthophotography at a resolution of 1-meter/pixel (Figure 6).

3.3.2. Historical Photography

Historical photographs from 1950 and 1962 were collected and semi-rectified using Geographic Information System (GIS) software tools (Figure 7). The study area is highly urbanized which makes landform identification difficult. Historical photographs that pre-date major development are invaluable when conducting geomorphic investigations.

3.4. Topographic Mapping

The primary mapping source used in this analysis was digital LiDAR data provided by Salt Lake County. The primary purpose of LiDAR data was to provide a source dataset for geospatial analysis and mapping, and the production of high resolution LiDAR derived products such as digital elevation models (DEMs). These classified LiDAR point cloud data were used to create 3D breaklines, hydro-flattened bare earth DEMs, and highest hit DEMs. The LiDAR was collected between November and December 2013. Figure 8 shows the mapping data as both a digital surface and as 10-foot contours.

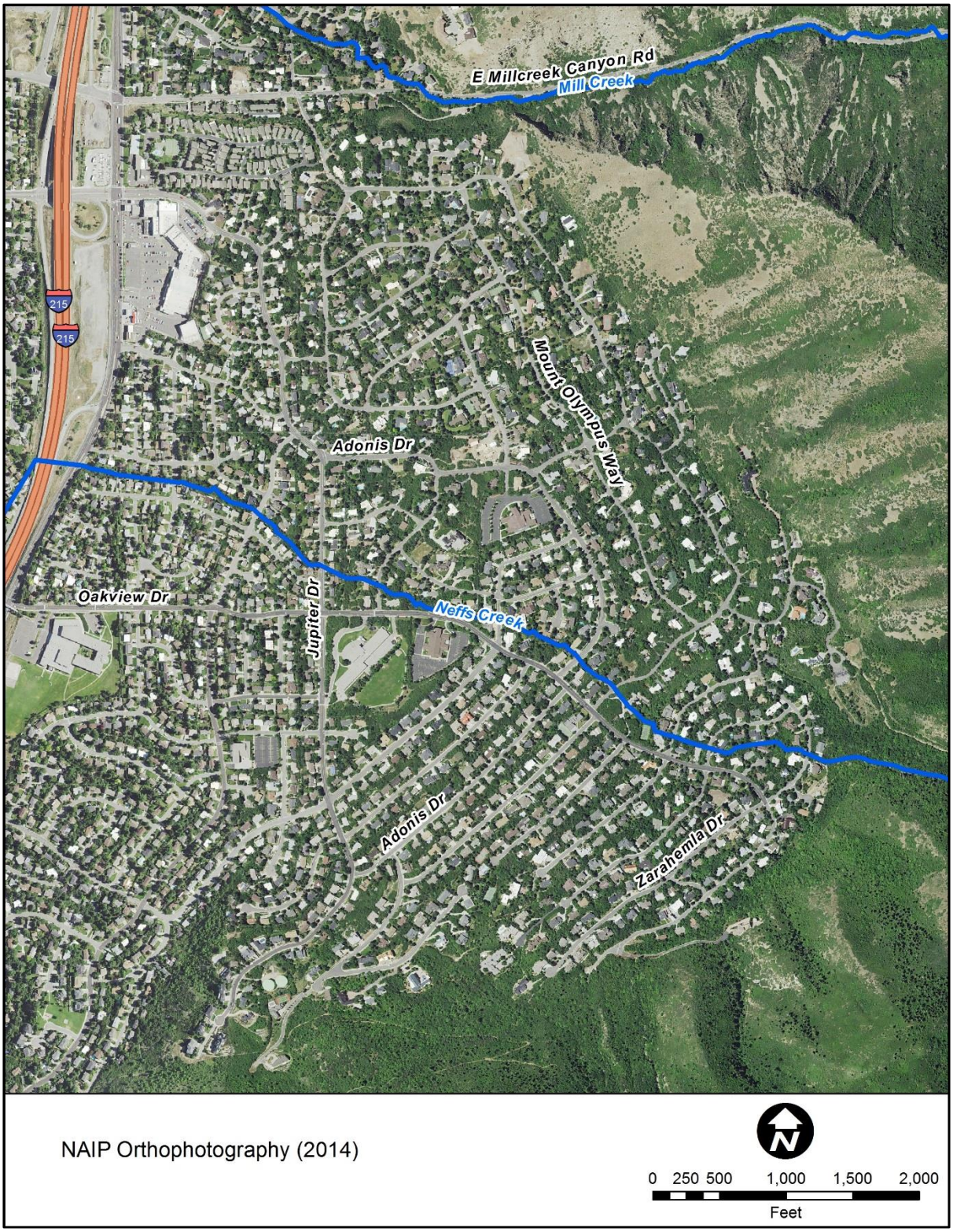


Figure 6. NAIP orthophotography

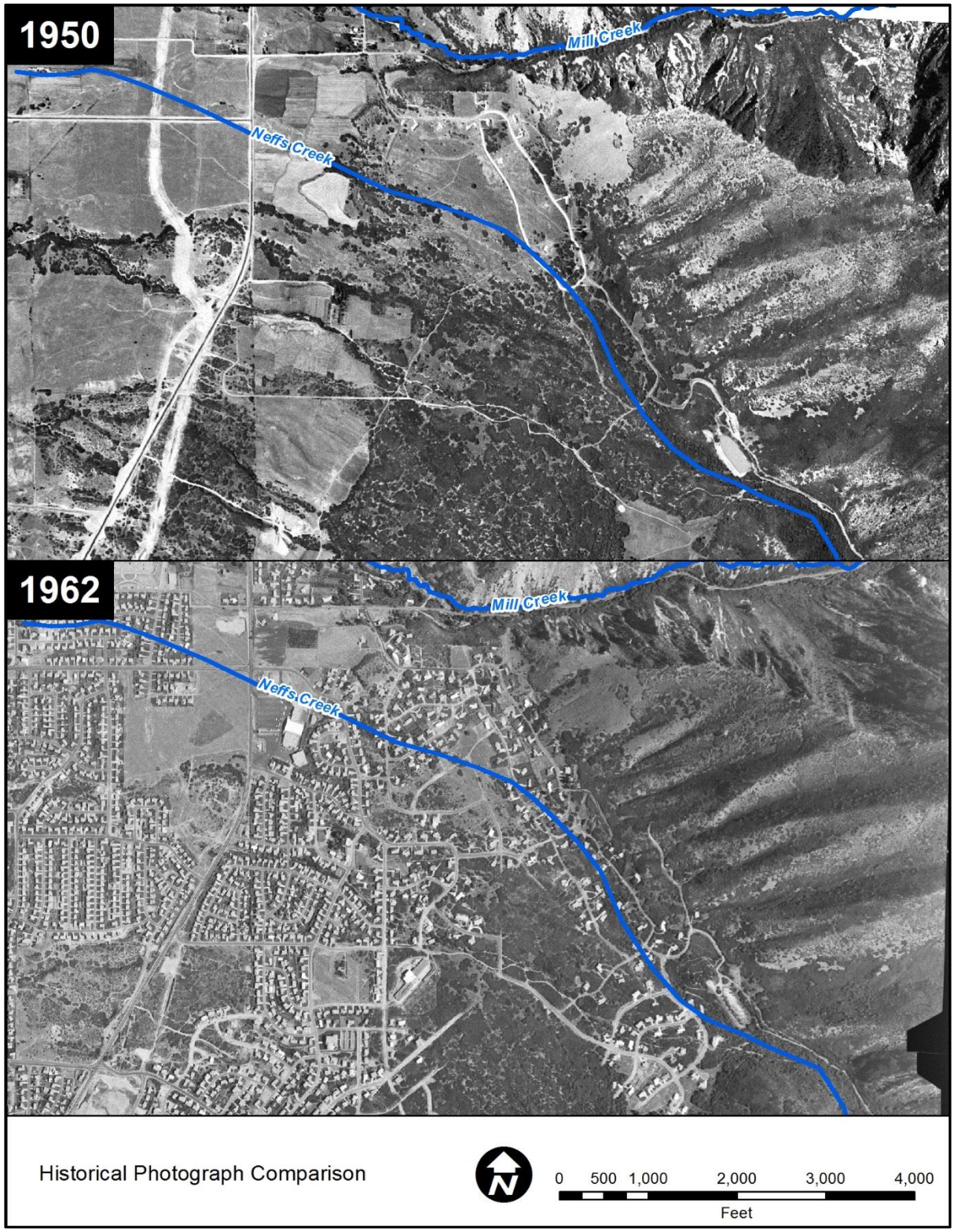


Figure 7. Historical aerial photograph comparison

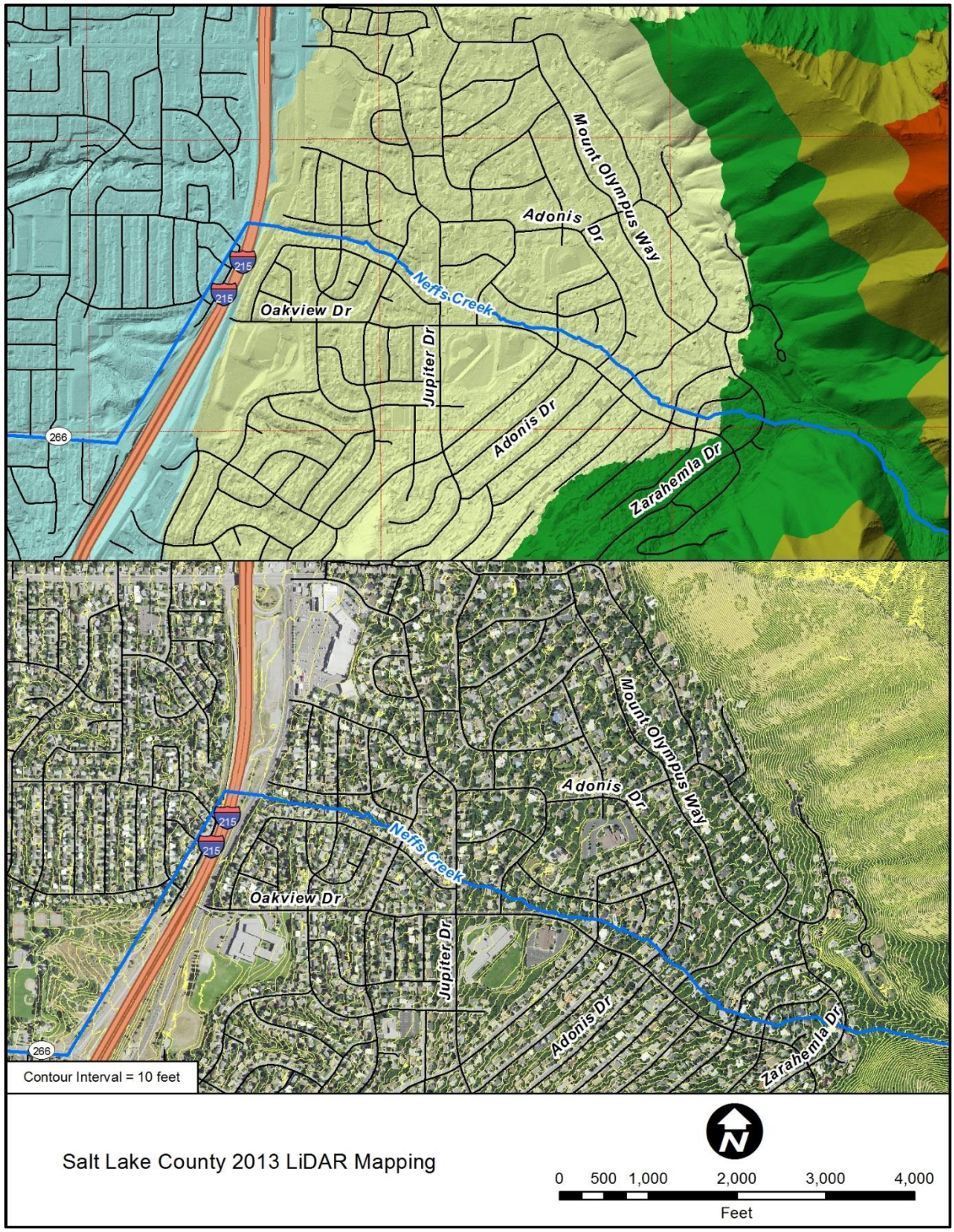


Figure 8. Digital mapping data

4.0 STAGE 1: RECOGNIZING AND CHARACTERIZING PIEDMONT LANDFORMS

4.1. Stage 1 Overview

A Stage 1 alluvial fan delineation was performed for the Neffs Creek project area. Neffs Creek canyon is cut into the western slope of the Wasatch Range within the vicinity of the Mount Olympus Wilderness. The Neffs Canyon headwaters are at approximately 9,500 feet with the canyon mouth at approximately 5,600 feet. The transition from mountain to piedmont is abrupt which is common along much of the western Wasatch Range. Prior to the 1950s, only sparse agricultural development was present on the piedmont. By 1962 urbanization had begun to work its way up the slope toward the mountain front, and by the early 1970s the piedmont was entirely urbanized as it remains today (see Figure 6 and Figure 7).

4.2. Composition

One of the FEMA Guidelines criteria for defining an alluvial fan landform includes composition. Alluvial fans are composed of loose, unconsolidated materials transported by fluvial or debris flow processes (a.k.a., "alluvium").

4.2.1. Soils Mapping Interpretations

Table 1 gives a list and description of the NRCS soil units within the project area and includes the landform classification as found within the soil unit description.

The NRCS soils mapping indicates most of the piedmont is composed of unit HWF (*Horrocks extremely stony loam*) with the lateral limit areas composed of HHF (*Harkers soils*). The soil profile of HWF is cobbly clay loam to a depth of 20 inches, extremely stony sandy loam from 29 inches to 40 inches, and bedrock below 40 inches. It should be noted that this profile is not typical of active alluvial fan surfaces. By definition, alluvial fans are an aggrading landform and thus are generally composed of thick (10s of feet) layers of unconsolidated alluvium. The alluvial composition of active alluvial fans usually result in a soil profile that is characterized by moderate to high rates of precipitation infiltration. The NRCS has developed a series of Hydrologic Soil Groups (HSG) based soil runoff and infiltration characteristics. HSG-A has the highest infiltration rates while HSG-D has the lowest. HSG-D is generally characterized by high percentages of clay and less than 50% sand, which is atypical of active alluvial fans. Alluvial fans are generally classified as HSG-B or HSG-C.

Unit HWF is classified by the NRCS as a mountain slope landform with HSG-D. The relatively thin soil profile of HWF (40 inches) and the HSG-D classification suggests a pediment landform rather than an alluvial fan landform. A pediment is defined as a broadly sloping erosional surface located at the base of a mountain front. The key difference between a pediment and an alluvial fan is a pediment is erosional and an alluvial fan is depositional. Both features are composed of alluvium which is the minimum standard in the FEMA Guidelines in defining an alluvial fan landform.

Unit HHF which is found along the lateral margins of the piedmont is characterized by the NRCS as an alluvial fan landform with a thick alluvial soil profile and a HSG-C classification. This soil description is more typical of what generally defines an alluvial fan landform.

The HWF soil unit is truncated by unit SP (*Stony terrace escarpmen*ts). This soil unit is composed of lacustrine sediments from Lake Bonneville. Lake Bonneville, a prehistoric pluvial lake[3], covered much of northern Utah between approximately 32,000 years BP[4] and 14,500 years BP. Lake Bonneville shoreline evidence is present within the piedmont area and is explained in more detail in the following section. Unit SP is composed of alluvium but is not deposited by alluvial fan flooding processes.

The key fact derived from the NRCS soils mapping with respect to Stage 1 are that the piedmont area is underlain by alluvium that was derived from the Neffs Creek watershed.

4.2.2. Surficial Geologic Mapping Interpretations

Figure 4 and Figure 5 show the USGS surficial geologic mapping for the study area. The figures show the entire piedmont project area is composed of alluvium of either Pleistocene or Holocene in age. Complete descriptions of the surficial geologic units that are provided on the maps are included in Table 3. The importance of the geologic mapping with respect to Stage 1 is to differentiate the alluvial (piedmont units) landform from the non-alluvial (bedrock) and riverine (floodplain) landforms. This differentiation separates the alluvial fan from the non-alluvial fan landforms. The USGS mapped units are described below in order of age youngest to oldest per map:

[3] Pluvial Lake is defined as a closed basin that filled with water during times of glacial climatic conditions.

[4] BP = before present

Table 3. USGS map unit descriptions

Map Label	Unit Description	Unit Type	Age
Van Horn, 1972			
fa	Floodplain alluvium. Cobbly to silty sand, dark-gray at top grading downward to medium- to light-gray sandy to cobbly gravel and sand in lower part; locally bouldery near mountain front; more than 5 feet thick.	Riverine Floodplain	Late Holocene
fg6-fg5	Bouldery to sandy silt at low altitudes and boulder to silty gravel and sand at high altitudes; stones angular to subrounded; dark gray to moderate brown; as much as 20 feet thick. Locally overlies, and at places grades laterally into, lake gravel. Relative age indicated by number. Undifferentiated fan deposits younger than the Bonneville shoreline. All units are subject to sudden and violent flash floods and mudflows.	Fan Deposit	Early to Mid-Holocene
fg4		Fan Deposit	Late Pleistocene
fg3-fg1	Old undifferentiated alluvial fan deposits older than the Bonneville shoreline. Relative age indicated by number. Units fg2 and fg3 are subject to sudden and violent flash floods and mudflows.	Fan Deposit	Early to Mid-Pleistocene
bs	Sand, fine to coarse, slightly silty, light-brown to light-gray, 5-10 feet thick. Deposited in a lake, probably near shore.	Lacustrine Deposit (Lake Bonneville)	Mid- to Late Pleistocene
bgo	Gravel and sand, locally cobbly, gray-to brownish-gray; rounded stones 5-20 feet thick. Locally has a weakly to moderately developed soil formed on it. Deposited as a lakeshore embankment at the Bonneville shoreline.	Lacustrine Deposit (Lake Bonneville)	Mid- to Late Pleistocene
ag	Gravel unit. Cobbly gravel and sand, medium- to light-bluish gray; rounded stones; more than 20 feet thick. Boulders commonly present near base. Upper 10-15 feet commonly moderately to weakly cemented by calcium carbonate. Deposited as a lakeshore embankment at about 5,130 feet above sea level.	Lacustrine Deposit (Alpine Formation)	Late Pleistocene to Early Holocene
fgo	Old undifferentiated alluvial fan that predates the Bonneville shoreline.	Fan Deposit	Pleistocene

Table 3. USGS map unit descriptions

Map Label	Unit Description	Unit Type	Age
ldm	Deposited at the mouth of Neffs Canyon by slow to rapid downslope movement of material forming the slope.	Mudflow Deposit	Quaternary
r	Bedrock	Bedrock	Jurassic to Precambrian
Personius et al., 1992			
al1	Stream alluvium. Sand, silt, and minor clay and gravel along Jordan River and lower reaches of its tributaries. Forms floodplain and terraces less than 5m above modern stream level.	Stream Deposit	Upper Holocene
af2	Fan alluvium. Clast-supported pebble and cobble gravel, locally bouldery, in a matrix of sand and silty sand; poorly sorted; clasts subangular to round. Deposited in perennial and intermittent streams, debris flows, and debris floods graded to modern stream level.	Fan Deposit	Middle Holocene to Uppermost Pleistocene
afb	Fan alluvium related to transgressive phase. Clast-supported pebble and cobble gravel, locally bouldery, in a matrix of sand and silty sand; poorly sorted; clasts subangular to round. Deposited by streams graded to shorelines of the transgressive phase of the Bonneville lake cycle, and forms fans graded to theses shorelines.	Fan Deposit	Upper Pleistocene
lbg	Lacustrine sand and gravel related to transgressive phase. Clast-supported pebble, cobble, and rarely boulder gravel, in a matrix of sand and pebbly sand; locally includes interbedded silt and clay ranging from thin beds and lenses to lagoonal deposits as much as 10m thick. Deposited in beaches, bars, spits, and small deltas and lagoons. Commonly covered by deposits of hillslope colluvium, but typically forms wave-built bench at the Bonneville shoreline and at several less well developed beach berms between the Provo and Bonneville shorelines.	Lacustrine Deposit (Lake Bonneville)	Upper Pleistocene

Table 3. USGS map unit descriptions

Map Label	Unit Description	Unit Type	Age
af4	Fan alluvium. Clast-supported pebble and cobble gravel, locally bouldery, in a matrix of sand and silty sand; poorly sorted; clasts subangular to round. Forms small fans and fan remnants topographically above or cut by the Bonneville shoreline. Correlative deposits probably underlie much of the map area and are buried by younger deposits downslope from the Bonneville shoreline.	Fan Deposit	Upper Middle Pleistocene
cls	Landslide deposits. Grain size and texture character of deposits in source area; usually unsorted, unstratified. Deposited as slides and slump-earthflows on relatively steep slopes in mountains.	Colluvial Deposit	Holocene to Middle Pleistocene

The surficial geologic mapping indicates four basic landform types are found within the vicinity of Neffs Creek: Piedmont (fan, mudflow, and colluvial deposits), Riverine (floodplain deposits), Lake (lacustrine deposits), and Bedrock. Units fg6 though fg1 (Van Horn, 1972) and units af2, af4, and afb (Personius et al., 1992) are identified specifically as alluvial fan deposits on their subsequent surficial geologic maps.

4.2.3. Field Observations

A field visit was conducted on March 10, 2015 and consisted of walking and driving portions of the study area and collecting field photographs. A significant amount of time was spent within the area of the topographic apex to observe and interpret the existing conditions morphology. A man-made ditch was observed near the topographic apex that appeared to be constructed to divert low-flow from the creek (Figure 9). There was no streamflow in either in the main channel or the ditch during the field visit. The ditch diverts flow away from the main channel which is topographically lower and steeper than the ditch. The right bank of the ditch is comprised of a boulder levee between two to three feet in height (Figure 9). The flow capacity of the ditch is significantly less than the main channel. Field evidence indicated the boulder levee had been breached in the recent past (likely due to overtopping) near the diversion point. The ditch diverts flow away from the historical Neffs Creek channel and into a canal system that presently drains to the I-215 highway embankment. The 1950 historical aerial photograph shows the canal making a 90 degree bend near the present alignment of Fortuna Way and draining across a series of agricultural fields. This suggests the canal was constructed to divert Neffs Creek flows for irrigation. There are 10 present road crossings with culverts along the canal system. Each culvert was field verified and their openings were measured during the March 10th visit. That collected data was later used in the hydraulic modeling effort.

The historical photographs indicate many flow bifurcations downstream of the topographic apex. The identification of bifurcations was challenging due to the dense vegetation present in the historical photographs. Although the landform has been substantially altered by the construction of roads and structures, many of the bifurcations are still active as was observed during the field visit. Roads and other structures have changed the relative distribution of flow across the surface, but the hydraulic modeling analysis (discussed later in this report) indicated many of the historical bifurcations are still active during large floods. Bifurcations identified from the 1950 aerial photograph are shown in Figure 10 (also plotted against the 2014 orthophotography).

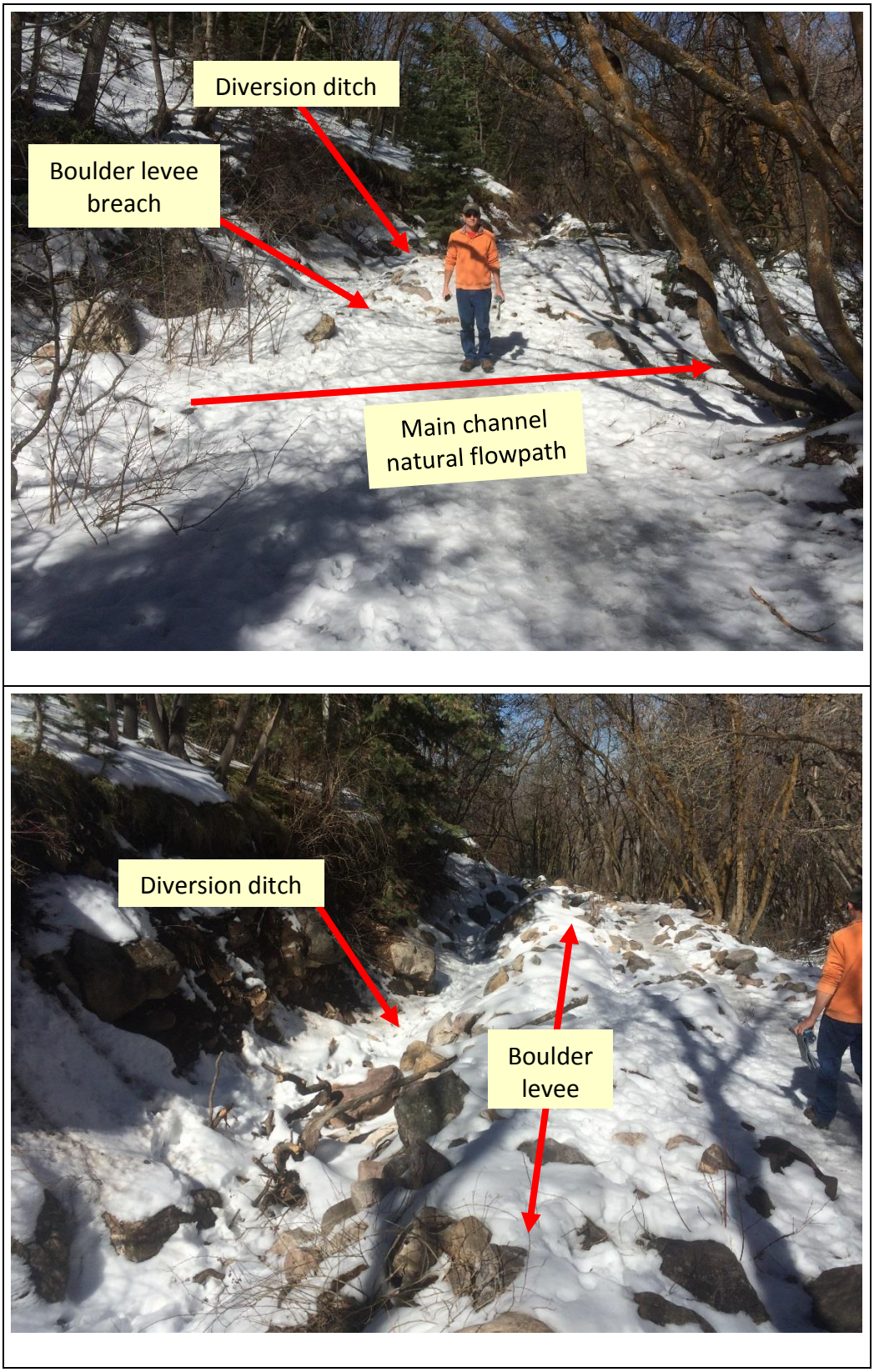


Figure 9. Photographs of Neffs Creek diversion near the topographic apex

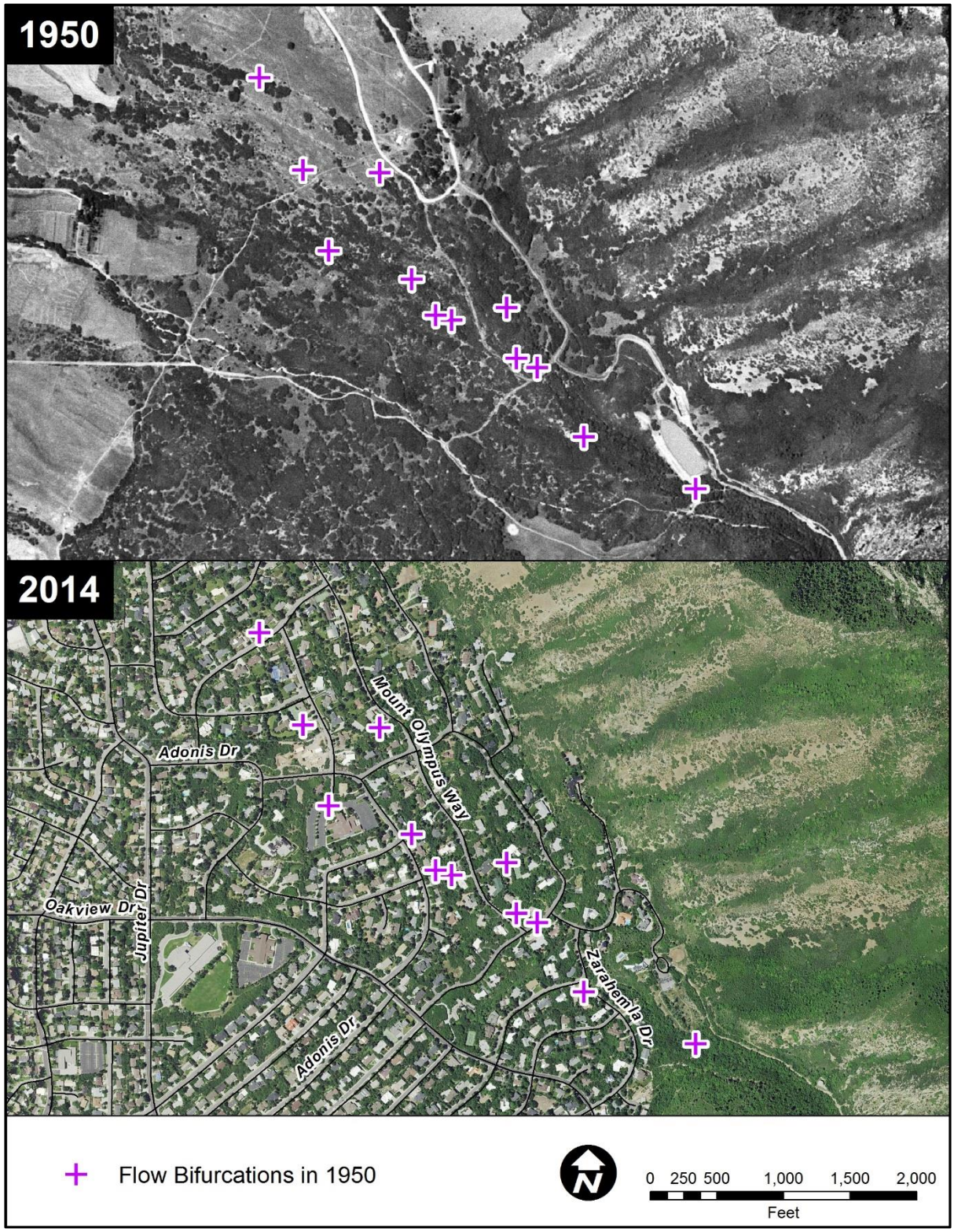


Figure 10. Flow bifurcations

4.2.4. Summary

The NRCS soils mapping, USGS surficial geologic mapping, and field observations all report similar findings regarding the alluvial composition of the Wasatch Range piedmont within the vicinity of Neffs Creek. Therefore, it is concluded that the piedmont is composed of non-consolidated alluvium deposited by fluvial processes, which meets the composition criteria specified in the FEMA Guidelines to classify the surface as an alluvial fan landform.

4.3. Morphology

According to the National Research Council definition (1996), "alluvial fans are landforms that have the shape of a fan, either partly or fully extended." The Wasatch Range piedmont within the project area consists of a series of coalescing landforms each with the shape of a partially extended alluvial fan. These coalescing alluvial fans comprise a bajada which also shows a somewhat distorted, partially extended fan shape which is readily visible on the historical USGS topographic map that pre-dates most of the urbanization of the piedmont (map date: 1952). The USGS map shows smooth contour crenulations and radial lines indicating the degree of fan incision and channel confinement, but uniformly depict a fan shape (Figure 11). Contour radial lines that curve in the downstream direction are indicative of alluvial fan landforms.

Another morphologic feature which supports identifying the piedmont as an alluvial fan landform is the slope. Alluvial fan landforms represent the transition from the steep mountain slopes to the flatter axial valley streams. An analysis of the Wasatch Range piedmont slope indicates a sharp transition from very steep (>20%) in the mountain to between 10% and 20% on the piedmont. The slope transition also indicates a general fan shape of the piedmont (Figure 12). The topographic break at the mountain-piedmont transition is the topographic apex of the alluvial fan.

Based on the analysis of the topographic and morphologic data, it is concluded that the shape of the Neffs Creek piedmont meets the FEMA Guidelines definition of an alluvial fan landform.

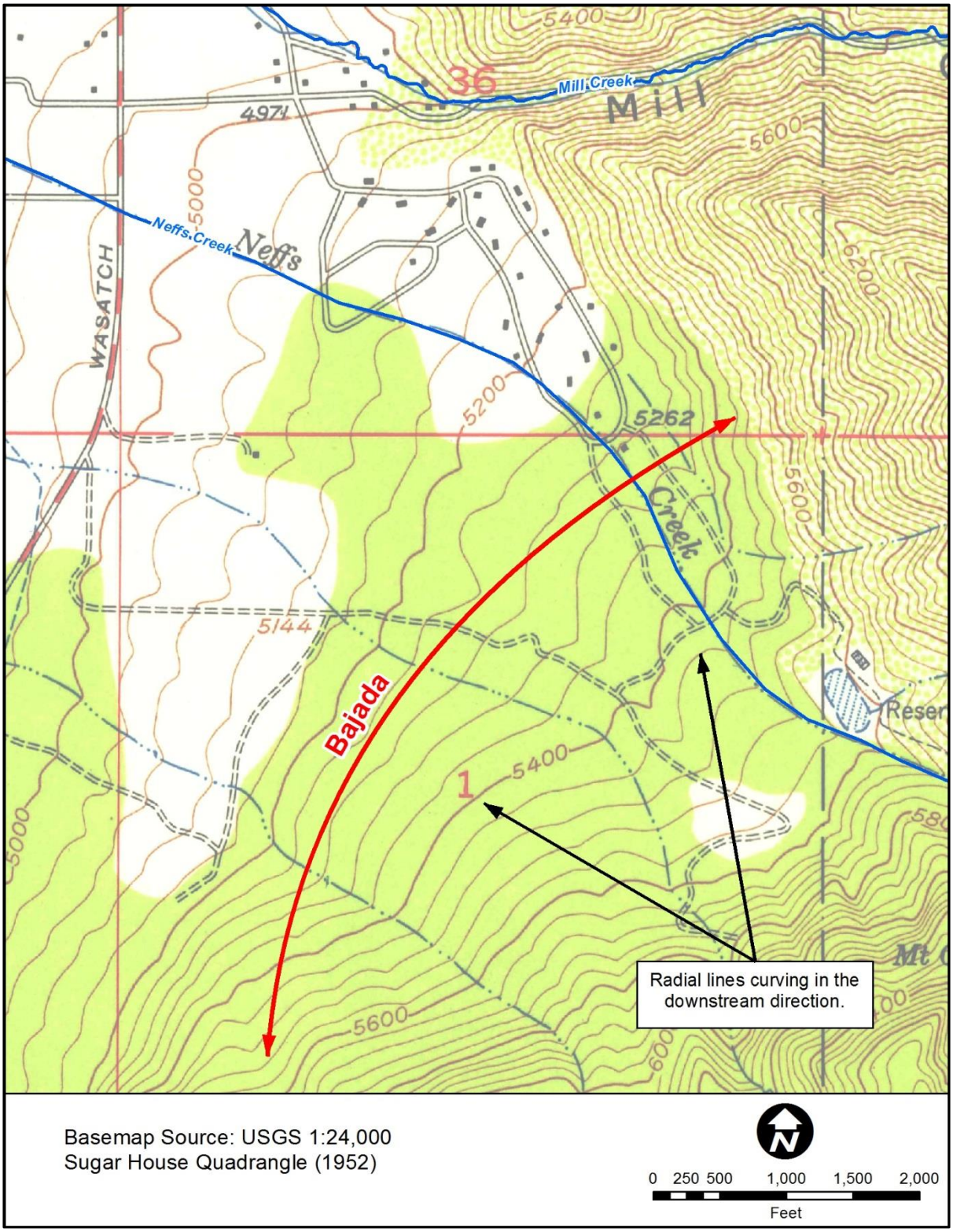


Figure 11. Wasatch Range piedmont bajada within the project area

Figure 12. Piedmont percent slope

4.3.1. Location

The NRC (1996) definition of an alluvial fan landform states that "alluvial fan landforms are located at a topographic break where long-term channel migration and sediment accumulation become markedly less confined than upstream of the break." The piedmont abuts the steep mountain front of the Wasatch Range as indicated by the abrupt change in slope in Figure 12. The mountain front is deeply embayed, which reflects the age and long erosion history of the mountains and creates a linear upstream boundary at the topographic break. At the mountain front, the fluvial environment transitions to one of deposition as indicated by the contour lines (see Figure 11).

4.3.2. Boundaries

The upstream and lateral limits of the piedmont within the project area are defined by the Wasatch Range mountain front, as indicated by the topographic break described previously. The downstream limits of the piedmont were determined from examination of the following:

- NRCS soils. Transition from NRCS interpreted landforms (mountain and alluvial fan to lake terrace).
- USGS surficial geologic mapping. Transition from alluvial stream deposits to lake and river deposits.
- Slope. Transition from steeper slopes (8%-10% = piedmont landform) to shallower slopes (<8% = lake and riverine floodplain landforms).
- Aerial photograph interpretation

4.3.3. Previous Studies

The Utah Geological and Mineral Survey (UGMS) conducted a study in 1974 titled Mt. Olympus Cove Environmental Geology Study. The primary purpose of the study was to address the concerns of the then Salt Lake County Planning Commission on the environmental factors that might have bearing on the future course of development in the Mt. Olympus Cove area. The study was also intended to provide a template for similar assessments in a broader context of the Wasatch Front. The following is an excerpt from the study:

The cove itself is largely an alluvial fan. In the northeast the alluvium of the fan abuts against bedrock with a more or less clear break in slope at the contact, but in the southeast the break in slope is not well defined. The alluvium in the fan consists of intercalated muds, sands, and gravels of great thickness. A complex interfingering exists at depth with better sorted and stratified silts, sands, and gravels that were deposited in Lake Bonneville through the course of multiple regressions and incursions of its shoreline. p.3.

The Mt. Olympus Cove area is referred to as an alluvial fan in several more instances within the 1974 study report.

4.3.4. Conclusion

The NRCS soil mapping, USGS surficial geologic mapping, and field observations clearly show that the Wasatch Range piedmont within the vicinity of Neffs Creek is composed of sedimentary deposits (alluvium). The topographic mapping shows that the piedmont landform is located at the base of a mountain front and has the shape of a partially extended fan, has steep slopes, and radiating contours. Morphologic data, such as the drainage pattern, surface distribution, relief, and channel geometry, are also characteristic of an alluvial fan landform. Finally, the 1974 UGMS study described the Mt. Olympus Cover area as an alluvial fan. From these sources it can be concluded that the Wasatch Range piedmont is an alluvial fan landform and that the FEMA Guidelines for applicability of a Stage 2 assessment apply. Figure 13 shows the Stage 1 landform analysis map.

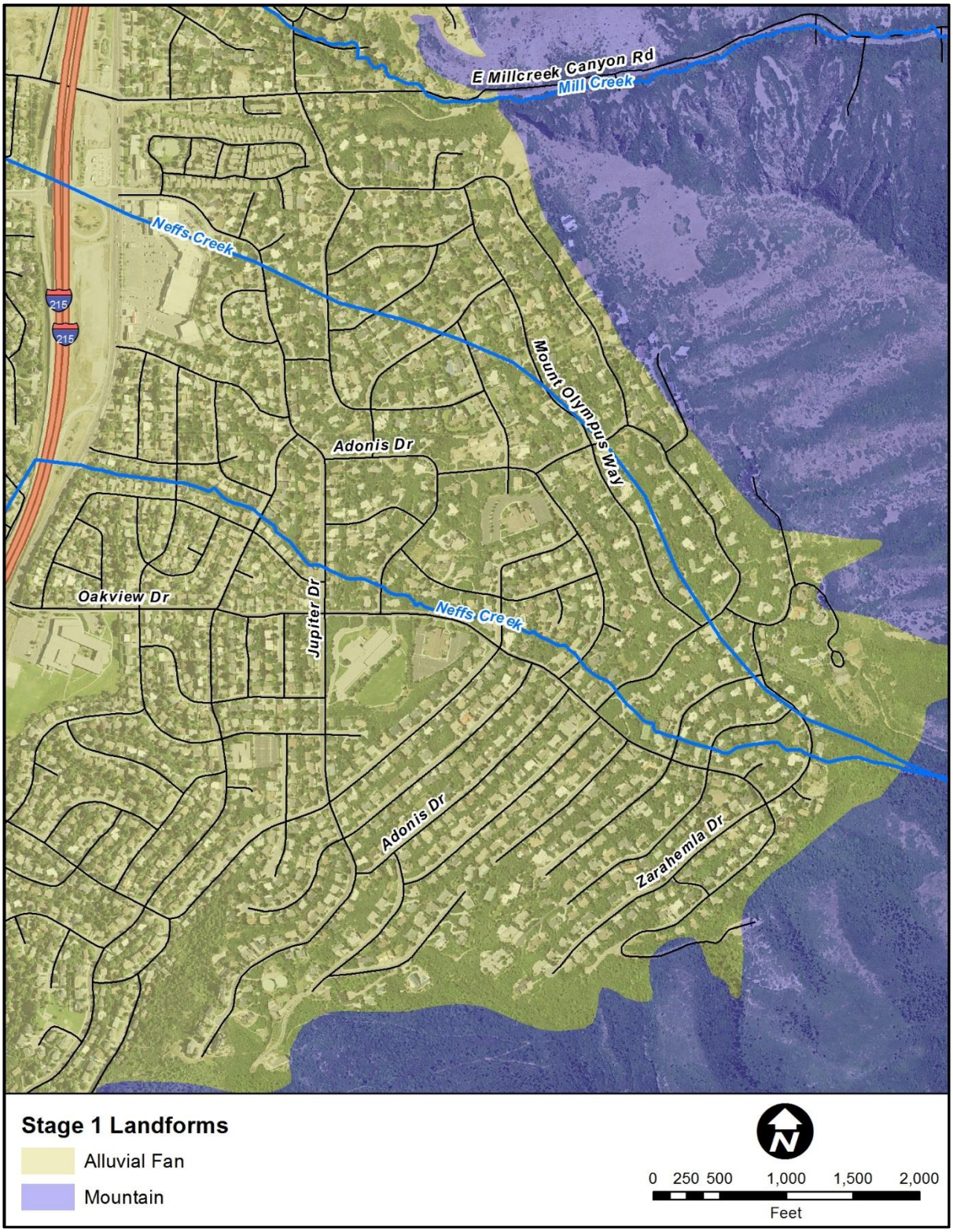


Figure 13. Stage 1 landform assessment

5.0 STAGE 2: DEFINING ACTIVE VS. INACTIVE ALLUVIAL FAN FLOODING

Stage 2 of the FEMA alluvial fan methodology consists of defining active and inactive areas within specific portions of the Wasatch Range piedmont alluvial fan landform, as well as characterizing the nature and types of flooding throughout the landform. Active areas on an alluvial fan consist of those portions of the landform where deposition, erosion, and unstable flow paths are possible. Active areas can experience active alluvial fan flooding (flowpath uncertainty so great that the uncertainty cannot be set aside in realistic assessments of flood risk or in the reliable mitigation of the hazard), in addition to other types of flooding. Inactive alluvial fan areas are the portions of the alluvial fan landform where active fan processes do not occur, but are still subject to flooding hazards.

5.1. Overview of Stage 2 Methodology Concepts

The physical characteristics of a landform provide clues as to its depositional history, existing level of stability, and future flood potential. If a portion of the landform becomes isolated from its original watershed and watercourse, it ceases to receive new deposits and its surface will begin to age and develop specific physical characteristics indicative of its age.

Landform surfaces free from new deposition will also begin to erode due to direct rainfall and the ensuing runoff on the surface. As the surface erodes, new tributary channel networks develop which become more incised and integrated with time. The channels gradually deepen and widen, creating a greater degree of relief between the channel bottoms and the ridges which separate them. The degree of relief can be directly observed in the field or on aerial photographs, but can also be detected by examining the crenulation (curviness) of topographic map contours.

The USGS surficial geology mapping, and to a lesser extent the NRCS soils mapping, differentiate surfaces based on the types of geomorphic characteristics discussed previously. Therefore, the map data also provide information about surface age, stability, and flood potential. Young surfaces are likely to continue to experience flood inundation, sediment deposition, and channel movement. Older surfaces are unlikely to experience such processes, or will experience such processes at a much lower magnitude. Older surfaces tend to be more stable because their soils are more resistant due to the cohesion provided by accumulations of clay, and calcium carbonate as well as due to containment of flow within defined, vegetation-lined channels. That is, the likelihood of the channel changing its location over time is greatly diminished. Conversely, areas with non-cohesive, coarse soil materials and little lateral relief are more susceptible to lateral changes in channel position.

The USGS mapping indicates the Wasatch Range piedmont within the project area is composed of Pleistocene and Holocene-age surfaces. The surfaces increase in age moving south along the mountain front from Neffs Creek. The piedmont surface associated with Neffs Creek is the youngest unit (fg5) in the area and is early Holocene in age. The mapping also indicates the fg5 unit overlays the Bonneville Lake sediments indicating active deposition from Neffs Creek has occurred since the recession of the lake. The piedmont surface units south of Neffs Creek (fg3, fg2) are older than fg5, however their description indicates they

are subject to “sudden and violent flash floods and mudflows” which are characteristic of active alluvial fan flooding.

5.1.1. Age Relationships

The surficial age of the areas of the Neffs Creek portion of the alluvial fan landform identified as active range between 1.8 million years before the present (Pleistocene) to the present (late-Holocene). The areas identified as inactive can be generally described as bedrock and range from 490 million years before present (Cambrian) to 248 million years before present (Permian).

5.2. Previous Studies

A debris flow hazard study for Neffs Creek Canyon was conducted in 2005 (AGEC, 2005). The purpose of the study was to assess the debris flow hazard potential for Neffs Canyon as it related to existing development on the piedmont below the canyon mouth. The study included an assessment of aerial photographs to map the extent of the alluvial fan landform downstream from the topographic apex, specifically looking for distinct debris flow indicators. Their study did not identify discrete debris flow lobes, but their interpretation was that the irregular extent of the distal boundary of the fan suggests a series of discrete flows with variable run-out distances. It was also noted that the fan surface overlies the Lake Bonneville deposits indicating deposition has occurred on the surface within the last 15,000 years. The overall conclusion of the study was that Neffs Canyon is subject to potential debris flows that could reach the alluvial fan. This conclusion suggests that the alluvial fan is potentially subject to active alluvial fan flooding processes. The AGEC report is included in Appendix A.

5.3. Summary of Stage 2 Analysis

Figure 14 shows the limits of the Stage 2 analysis results within the study area. Analysis of all the pertinent data including soils mapping, geologic mapping, topographic mapping, aerial photography, field observations, and previous studies indicate the Neffs Creek piedmont within the study area can be classified as an active alluvial fan per the FEMA Guidelines. The active alluvial fan landform comprises the entire piedmont area that is composed of alluvial sediments derived from erosion of the upper canyon above the topographic apex.

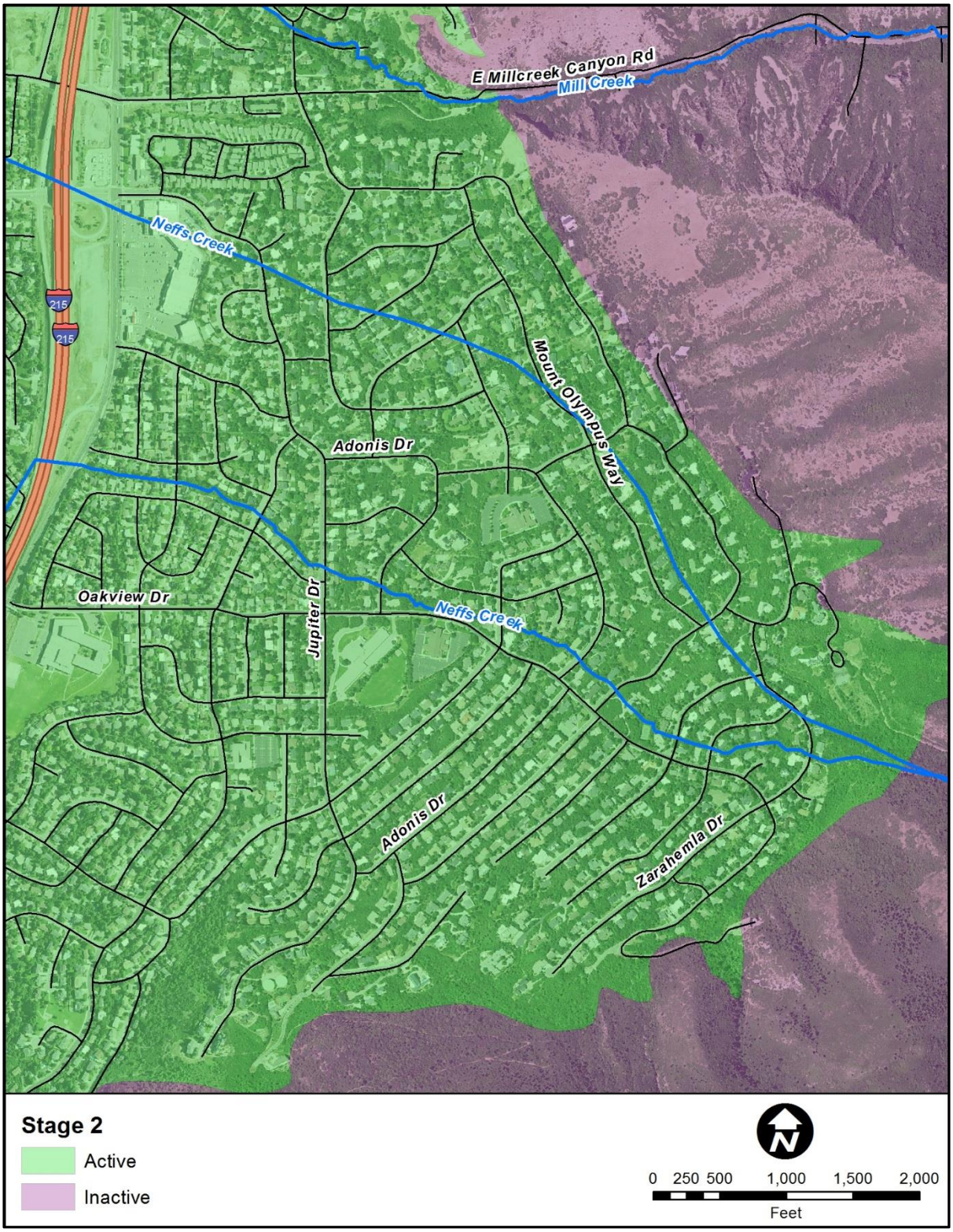


Figure 14. Stage 2 analysis map

6.0 SUMMARY AND RECOMMENDATIONS

The Neffs Creek study area is composed of two primary landforms, 1) Mountains; and 2) Piedmont. A FEMA Appendix G Guidelines assessment was conducted to determine whether the piedmont area could be characterized as an alluvial fan landform (Stage 1). The results of the Stage 1 analysis concluded that the piedmont is an alluvial fan landform, thus necessitating a Stage 2 analysis. The Stage 2 analysis resulted in the findings that the piedmont is subject to active alluvial fan flooding. Based on the results of this analysis a Stage 3 (alluvial fan floodplain delineation) assessment is appropriate.

7.0 STAGE 3 - DEFINING THE 100-YEAR FLOODPLAIN

The 100-year flood hazard assessment is an outgrowth of the information and results identified and generated in Stages 1 and 2. In Stage 1, portions of the project area were identified as part of an alluvial fan landform. In Stage 2, the active portions of the alluvial fan landform were identified. According to the FEMA Guidelines, "the delineated flood prone areas of Stage 2 should approximate the largest possible extent of the 100-year flood." In Stage 3, floodplain limits for the 100-year (1% annual chance) flood are delineated for the active alluvial fan areas characterized by:

- Active Alluvial Fan Flooding. Flowpath uncertainty so great that the uncertainty cannot be set aside in realistic assessments of flood risk or in the reliable mitigation of the hazard. The floodplain in the areas with unstable flowpath flooding downstream of the hydrographic apices were delineated using geomorphic data in conjunction with the Maximum flood hazard hydraulic modeling results.

The Stage 3, 100-year floodplain delineations were incorporated into the Flood Insurance Rate Map (FIRM) Zone delineations described later in this report and are shown on the Floodplain Workmaps included in Appendix B.

7.1. Alluvial Fan Flood Hazard

The FEMA Guidelines state that active alluvial fan flooding hazard is indicated by the following three criteria:

1. Flowpath uncertainty below the hydrographic apex.
2. Abrupt deposition and ensuing erosion of sediment as a stream or debris flow loses its ability to carry material eroded from a steeper, upstream source.
3. An environment where the combination of sediment availability, slope, and topography creates an ultrahazardous condition for which elevation on fill will not reliably mitigate the risk.

The Neffs Creek piedmont exhibits these three criteria within limited portions of the active alluvial fan areas. One of the fundamental challenges with delineating a regulatory 1-percent annual chance floodplain on an active alluvial fan is addressing the actual hazard on any portion of the fan when, by definition, the landform is susceptible to changes both during and following a flood event. The most hazardous areas of an active alluvial fan are generally found near the apex with the flooding and sedimentation hazard generally decreasing in the downstream direction. This is the situation found within the project area.

7.2. Flowpath Uncertainty

An avulsion is the process by which flow is diverted out of an established channel into a new course on the adjacent floodplain (Slingerland & Smith, 2004). Avulsions divert flow from one channel into another, leading to a total or partial abandonment of the previous channel (Field, 2001; Bryant et. al., 1995), or may involve simple flowpath shifts in a braided or sheet flooding system (Slingerland & Smith, 2004). Avulsions are commonly associated with alluvial

fan flooding, but are also known to occur on riverine systems and river deltas (Slingerland & Smith, 2004).

The occurrence of avulsions is what makes an alluvial fan "active." Avulsions give the alluvial fan the ability to distribute water and sediment over the surface of the landform, which results in the radial "fan" shape. Avulsions influence flood hazards on an alluvial fan landform by changing the location, concentration and severity of flooding on the fan surface. That is, an area not previously inundated by flooding (or inundated only by shallow flow) may in a subsequent flood become the locus of flood inundation, sediment deposition, and/or erosion. If an alluvial fan has no risk of avulsion, flood hazard delineation and mitigation become much simpler engineering problems, consisting only of modeling two-dimensional flow and/or normal riverine hydraulic and sedimentation issues.

The occurrence of major avulsions in an alluvial fan drainage system introduces the following complications into an engineering analysis of the flood hazard:

- Uncertain and changing flowpath locations, during and between floods
- Continually changing channel and overbank flowpath topography
- Inundation and/or sedimentation hazards in previously un-flooded areas
- Uncertain and changing flow rate distribution for areas downstream of avulsions
- Uncertain and changing watershed boundaries for areas downstream of avulsions
- Aggrading, net depositional land surfaces and channels with diminishing capacity
- Unsteady, rapidly-varied flow conditions
- High rates of infiltration and flow attenuation across the fan surface

The flowpath uncertainty issue was addressed in this analysis by the use of the Maximum flood hazard two-dimensional hydraulic modeling results. Flowpath uncertainty is caused by abrupt channel avulsions that occur during flood events. The cause of the channel avulsion can vary from channel aggradation (sedimentation) causing a rapid lateral shift in channel position, to overbank flooding carving a new channel, to upstream headcutting resulting in channel piracy. Regardless of the cause, the resulting abrupt change in channel position is something that is generally unpredictable and uncertain. The flowpath uncertainty analysis methodology addresses the channel avulsion potential element of the hazard analysis.

7.3. Flowpath Uncertainty Modeling

The overall objective of flowpath uncertainty modeling was to force flooding in directions that would simulate avulsions, and to estimate maximum depths and velocities over the whole radial width of the Neffs Creek active alluvial fan area by modeling a series of "virtual" levees. The number, geometry, and alignment of the virtual levees were selected to achieve those objectives. Each virtual levee scenario was optimized to direct flow from a bifurcation point to a different area across the width of the alluvial fan. Given the coalescing nature of the alluvial fans, there are multiple scenarios.

The following criteria were considered when developing the virtual levees for the Neffs Creek flowpath uncertainty analysis:

- Levee Length. The virtual levee lengths varied at each location. The lengths were determined based on engineering judgment to achieve the objective of concentrating flows to various target locations downstream.
- Number of Levee Scenarios. The number of virtual levee scenarios modeled were dependent on the surface morphology and the downstream target objectives.
- Alignment. The virtual levees were aligned at moderate angles to the fan axis so that they did not cause a significant "pile up" of flow in the model results.
- Coding. The virtual levees were coded into the model as to not overtop or fail during the model simulations.
- Model Iteration. Multiple modeling integrations were performed to meet the target area objectives. Several virtual levees scenarios can be run within the same hydraulic model if the model results indicate there is no hydrologic inter-mixing of the two scenario results downstream of the virtual levees.
- Final Hazard Delineation. The maximum depth and velocity at each model grid cell from the maximum flood hazard modeling results were used as the final regulatory flood depth and velocity. In other words, the maximum flow depth at each grid cell was computed using the highest depth value considering all the scenarios. This approach was applied to all the grid cells in the model. Additional details on this maximum "composite" approach to the hydraulic modeling results are discussed in the Model Development section of this report.
- Conservative Results. The virtual levee scenario employed for this analysis produces conservative flood depth and velocity results, particularly given the (probable) low frequency of avulsion on fans in Utah, as well as the fact that actual avulsions do not completely divert the entire hydrograph along a particular alignment.

7.4. Hydrologic Analysis

Hydrology used in the analysis was derived from a previous study commissioned and approved by Salt Lake County. The *Neffs Canyon Creek Master Plan* was completed in 2007 and included a complete hydrologic analysis for the 10- and 100-year recurrence interval storm events. Two concentration points were identified and summarized in the analysis:

Table 4. Neffs Creek estimates discharges (*from HAL, 2007*)

Location	Predicted Rainstorm Runoff Flow Rates (cfs)	
	10-year	100-year
Canyon Mouth	70	300
Wasatch Blvd.	90	350

The discharge estimate at the Canyon Mouth is equivalent to the location of the topographic apex for this study. The hydrology for the 2007 study was the approved hydrology for Neffs Creek at the time of this study, thus was adopted as the inflow at the topographic apex. The 2007 study is included in entirety in Appendix C.

7.5. Hydraulic Analysis

Hydraulic analyses performed for the Neffs Creek study was completed using the software package - FLO-2D. FLO-2D is a dynamic two-dimensional hydrologic and hydraulic model that conserves volume as it routes hydrographs over a system of square grid elements. The model routes runoff over the grid using the dynamic wave momentum equation and a central finite difference routing scheme. The floodwave progression is affected by the surface topography and roughness values (Manning's n-values) associated with land use characteristics. The FLO-2D version used for this study is Version 2009.06 Build No. 09-13.05.13, the executable is dated October 29, 2013.

FLO-2D model development was based on the HAL (2007) 100-year hydrograph at the topographic apex. A total of seven (7) FLO-2D models were run to estimate the 100-year composite flood hazard accounting for the flowpath uncertainty scenarios as described previously. The model naming convention is based on the flowpath uncertainty scenario number.

7.5.1. FLO-2D Model Development

7.5.1.1. Model Domain Development

The scope of this project was to consider the flooding impact from Neffs Creek. Although areas outside of Neffs Creek flood inundation limits were mapped as part of the Stage 2 analysis (see Figure 14), the focus of the FLO-2D model development was the Neffs Creek flood inundation area only. The model domain boundary was selected so as to include the area of potential flow from Neffs Creek on the alluvial fan without including much excess area that would significantly increase the size of the model. The domain was developed iteratively by creating a model that was well in-excess of the Neffs Creek flood inundation area. That initial model domain was then modified to exclude significant areas that were not inundated by flows from Neffs Creek. The final selected domain boundary is approximately 0.80 square miles. The downstream domain boundary is Wasatch Blvd. and was selected by a mutual decision between AECOM, JEF, and Salt Lake County. The model domain is shown in Figure 15. It should be noted that areas outside of the model domain may be subject to potential flood hazards from sources outside of Neffs Creek.

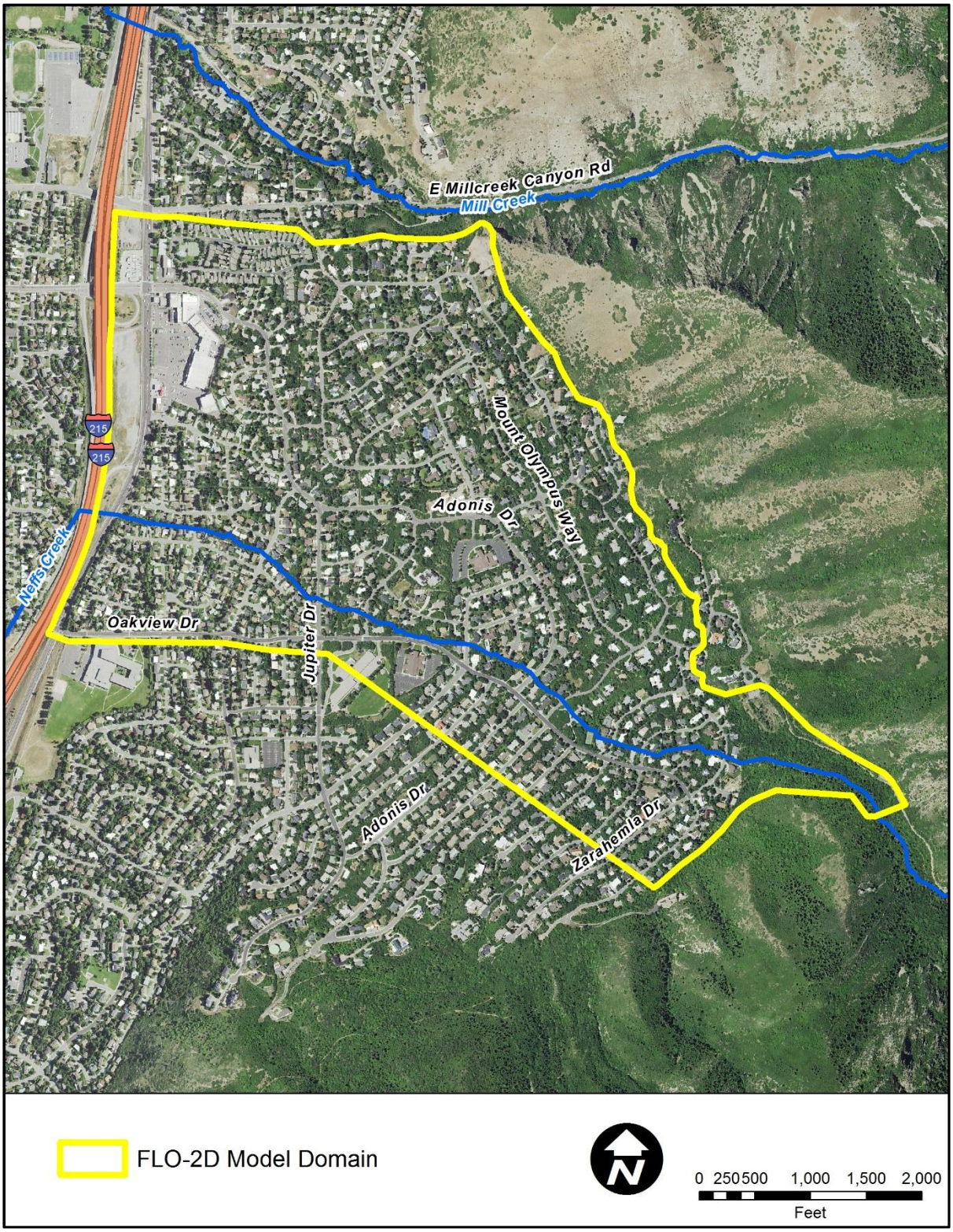


Figure 15. FLO-2D model domain boundary

7.5.1.2. Model Grid Size Development

The watershed surface is represented in FLO-2D as a grid comprised of square elements. The size of the individual grid element is critical to the desired detail of model output and floodplain delineations – the smaller the grid element size, the more defined the model. For example, since the grid element elevation is averaged from the topographic data, large grid elements provide less topographic detail when compared to smaller grid elements. However, although a smaller grid element will provide more detail of the topographic surface data, model run time is significantly impacted by the number of grid elements. A practical grid element size should be selected to achieve the desired detail of the modeling effort while taking into consideration the model run time (number of grid elements). The grid element size selected for this study measures 10'x10'. The total number of grid elements for each FLO-2D model is 223,343.

7.5.1.3. Model Grid Elevation Development

Grid elements measuring 10'x10' were considered detailed enough to capture the topographic relief and man-made features (roads, landscaping, etc.) found within the study area. Grid element elevations were estimated from the Salt Lake County LiDAR mapping data (see Section 3.4) using an ArcGIS (v.10.2.2) routine. The LiDAR was converted to a 10'x10' pixel raster. The conversion procedure averages the elevation within each pixel to a single value assigned to the pixel. The raster was then clipped to the FLO-2D domain boundary.

7.5.1.4. Model Grid Roughness Development

Grid element roughness values (roughness coefficients/Manning's n-values/n-values) were assigned to each grid element based on surface characteristics aerial photograph interpretations, and field reconnaissance. The resulting interpretation was delineated into a GIS dataset (Figure 16) that became the basis for the grid element Manning's n-value assignment. Table 5 lists the n-value assignment based on land cover type. Vegetation observed throughout most of the study area consisted of dense shrub and brush. Figure 17 shows typical vegetation density that was observed during the May 2015 field visit. The selection of Manning's *n* values for the cover types were derived from the Table 1. In the *FLO-2D Reference Manual.*

Table 5. Manning's n-value assignments

Cover Type	Manning's N-Value Assignment
Roads	0.02
Structures	0.06
Vegetation	0.08

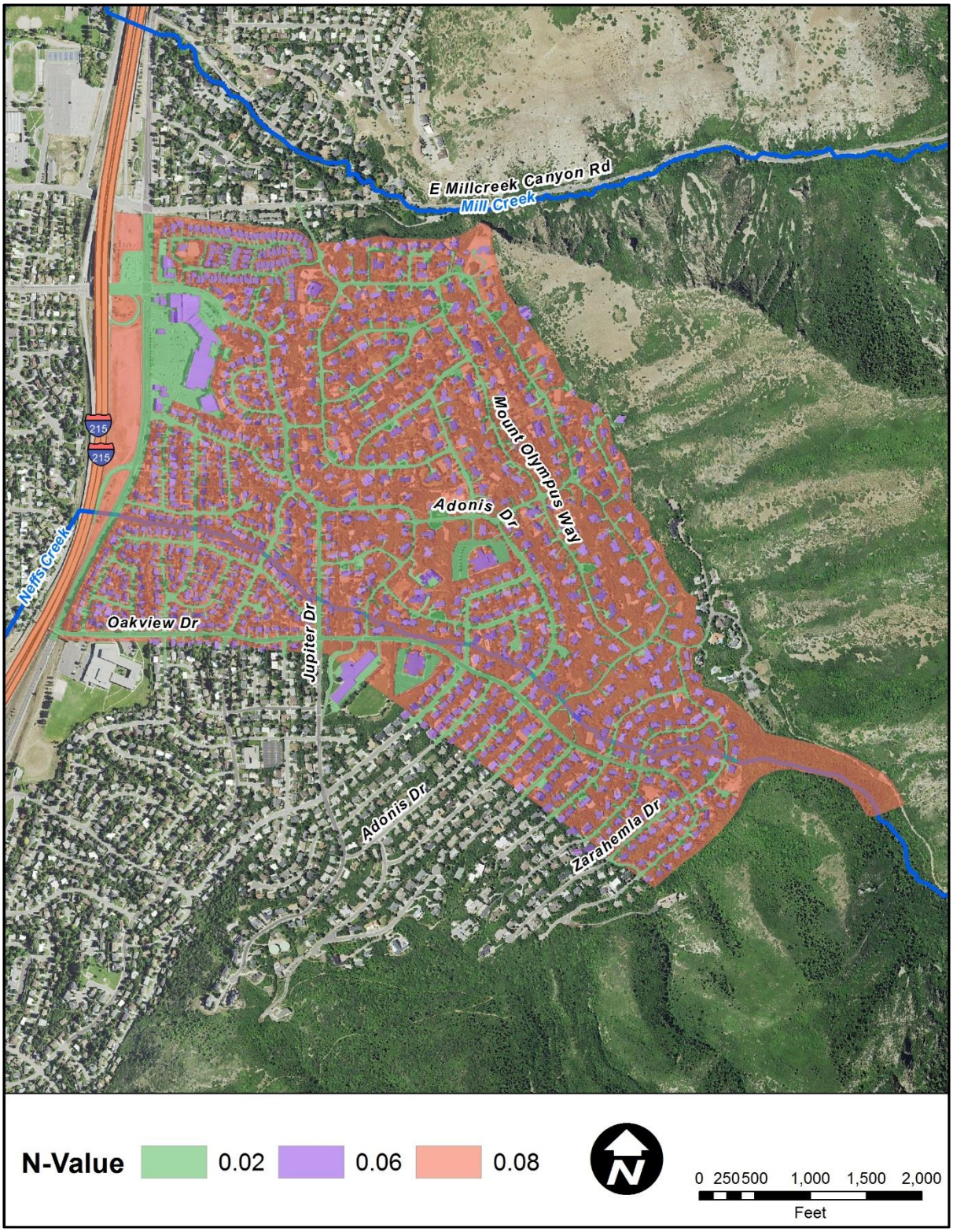


Figure 16. Manning's n-values used in the FLO-2D model

Figure 17. Typical vegetation density observed in the study area

7.5.1.5. Model Grid Aerial Reduction Factor (ARF) Development

An Area Reduction Factor (ARF) was applied to each grid element that had some percentage of area covered by a building structure. The factor reduces the area of a grid cell available for floodplain storage. Structure footprints were delineated based on interpretation of the 2014 orthophotography (Figure 18). Grid elements that were completely blocked by structures were assigned an ARF value of 1.0. All others were assigned an ARF value based on the percentage area of the grid being blocked by the structure.

7.5.1.1. Model Inflow Hydrograph Development

No hydrology was computed in the FLO-2D model. The model was employed for hydraulic routing of flow from the topographic apex. Inflow for the FLO-2D model was extracted from the HAL (2007) study HEC-HMS hydrologic model (filename: NoDebBasin_KinematicU.hms). The outflow hydrograph for the 100-year, 24-hour storm at the Neffs Creek canyon mouth concentration point was used directly as the inflow hydrograph for the FLO-2D model. The inflow location was assigned to grid ID 12629 and is shown on Figure 19, and a plot of the inflow hydrograph is shown in Figure 20.

Given the degree of development of the study area and the resulting extent of impervious area, it was determined that infiltration would not be used in the FLO-2D model. Rainfall-runoff modeling was also not included in the FLO-2D model. The purpose of the model was hydraulic routing only.

7.5.1.2. Model Time Step

The FLO-2D model time step is computed automatically by the model but is limited by the Courant criteria defined in the TOLER.DAT input file. For this analysis, a Courant value of 0.60 was defined for the floodplain as recommended by the model input manual. The model result hydrographs and SUMMARY.OUT output file did not indicate model instability issues, which would justify altering the Courant value.

7.5.1.3. Model Surface Detention

Surface detention is accounted in the model by setting the TOL value in the TOLER.DAT input file. A TOL value of 0.002 feet (0.024 inches) was used for all models.

7.5.1.4. Model Bulking Concentration Factor

Bulking of inflow can be done in the model by adjusting the XCONC variable in the CONT.DAT input file. This is most commonly used to account for sediment load. No bulking factor was used in the modeling for this study.

7.5.1.5. Model Hydraulic Structures

The diversion ditch discussed in Section 4.2.3 contains 11 culvert crossings that were incorporated into the model in the HYSTRUC.DAT input file. Rating curves for each structure were developed using the HY-8 (v.7.2) software program. Culvert sizes were measured in the field and inlet and outlet elevation data was obtained from the LiDAR dataset (Section 3.4). Figure 21 shows the spatial location of the culverts. The HY-8 data files are included in the Appendix E digital data submittal.

Personal communication with Salt Lake County personnel indicated that no other significant drainage infrastructure is present within the study area. This was confirmed during the field investigation.

7.5.1.6. Model Outflow Boundary Conditions

Outflow grids were assigned after selection of the final model domain. The downstream project limit (Wasatch Blvd.) was determined through a mutual decision between AECOM, JEF, and Salt Lake County. Figure 22 shows the location of the outflow grids for the model.

7.5.1.7. Model Limiting Froude Number

It is a standard of practice to set the limiting Froude to 0.9 or 0.95 in the CONT.DAT input file. A value of 0.9 was used for this study. FLO-2D adjusts the Manning's *n* value for stability. To determine the total number of grid elements and the magnitude of change in *n* values, a shapefile was generated using data from the ROUGH.OUT output file for each model scenario. The results indicated that *n* values for 5,110 grid elements out of 223,343 (2%) were adjusted by the model. Most of those adjustments were for grid elements within the main flow corridors. The *n* value adjustments result in conservative flow depths.

7.5.1.8. Model Simulation Time

Model simulation times are listed in Table 6.

Table 6. FLO-2D model simulation times

FLO-2D Model	Simulation Time (hours)
BASE	9.3
SCENARIO 1	7.0
SCENARIO 2	6.1
SCENARIO 3	8.5
SCENARIO 4	6.2
SCENARIO 5	5.0
SCENARIO 6	6.1
SCENARIO 7	5.2

7.5.1.9. Model Flowpath Uncertainty Development

While a base conditions FLO-2D model depicts the existing, fixed-bed condition of an X-year flood hazard event, it does not predict the full flood hazard associated within the active alluvial fan flooding and should not be the only scenario used to compute flow depths. To account for flowpath uncertainty, avulsion scenarios were developed and simulated within the model to account for the possibility of avulsions that would adversely affect (increase the inflow discharge) downstream.

The flowpath uncertainty scenarios were developed by reviewing existing flow bifurcations observed in aerial photography, topography, field reconnaissance, and the base FLO-2D model. In locations where avulsions appeared likely or evidence of prior avulsions was observed, avulsions were simulated by adding berm-like features to redirect flow along an avulsion path (Figure 23).

The flowpath uncertainty scenarios were modeled by redirecting flow with a hard barrier accomplished using the LEVEE.DAT input file within FLO-2D. These barriers were given an arbitrary height well-above the ground elevation to ensure no overtopping. The barriers essentially were aligned to direct all the flow in the avulsion direction.

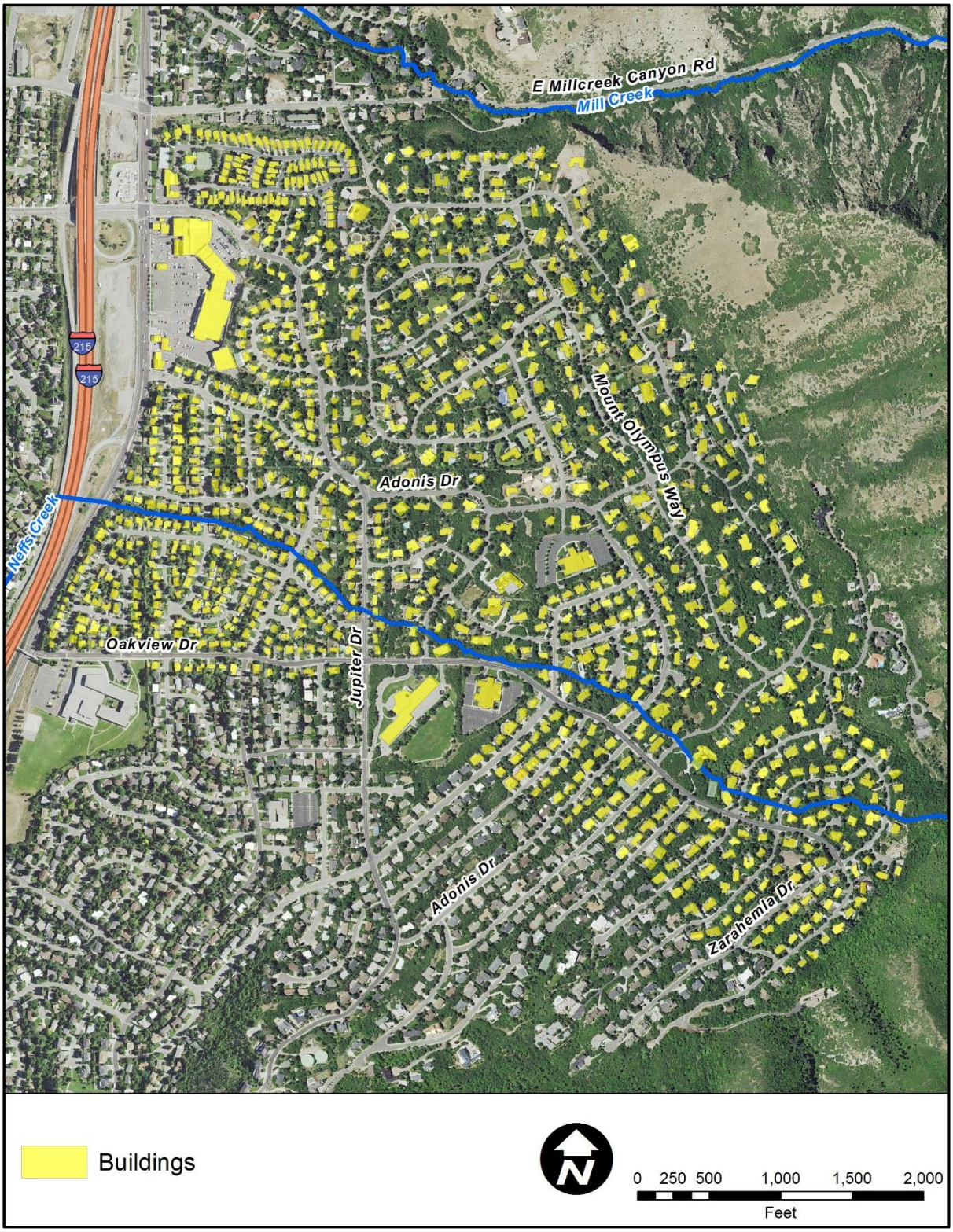


Figure 18. Delineated building footprints

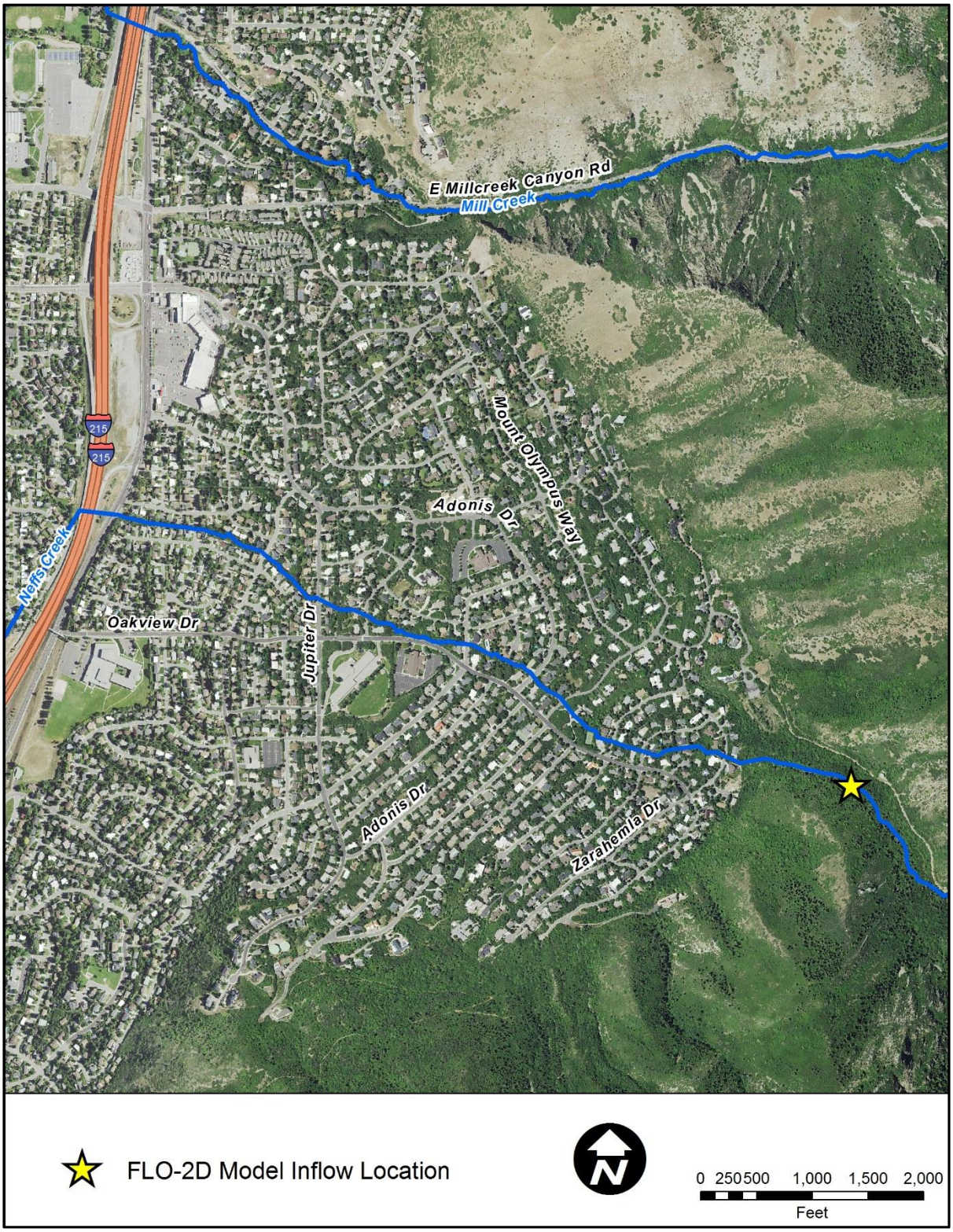


Figure 19. Inflow hydrograph location

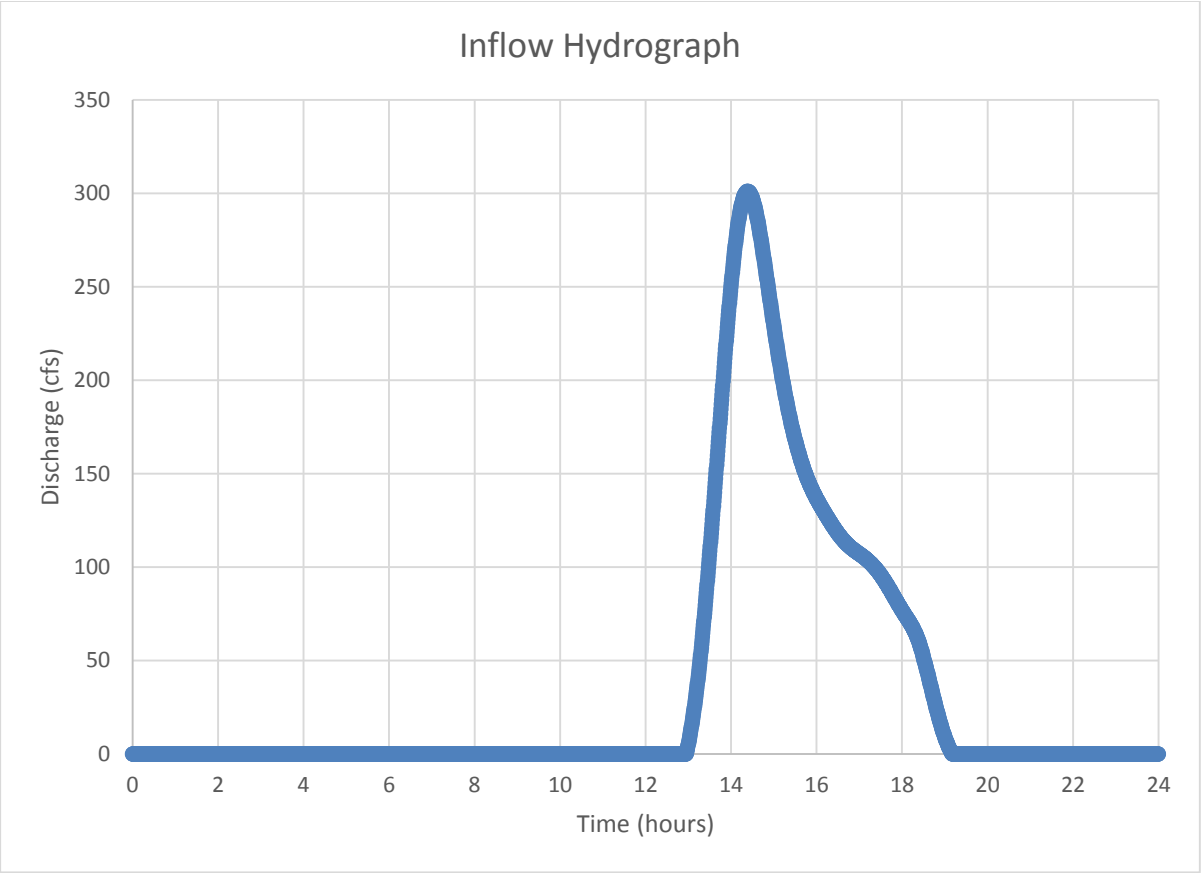


Figure 20. Inflow hydrograph plot

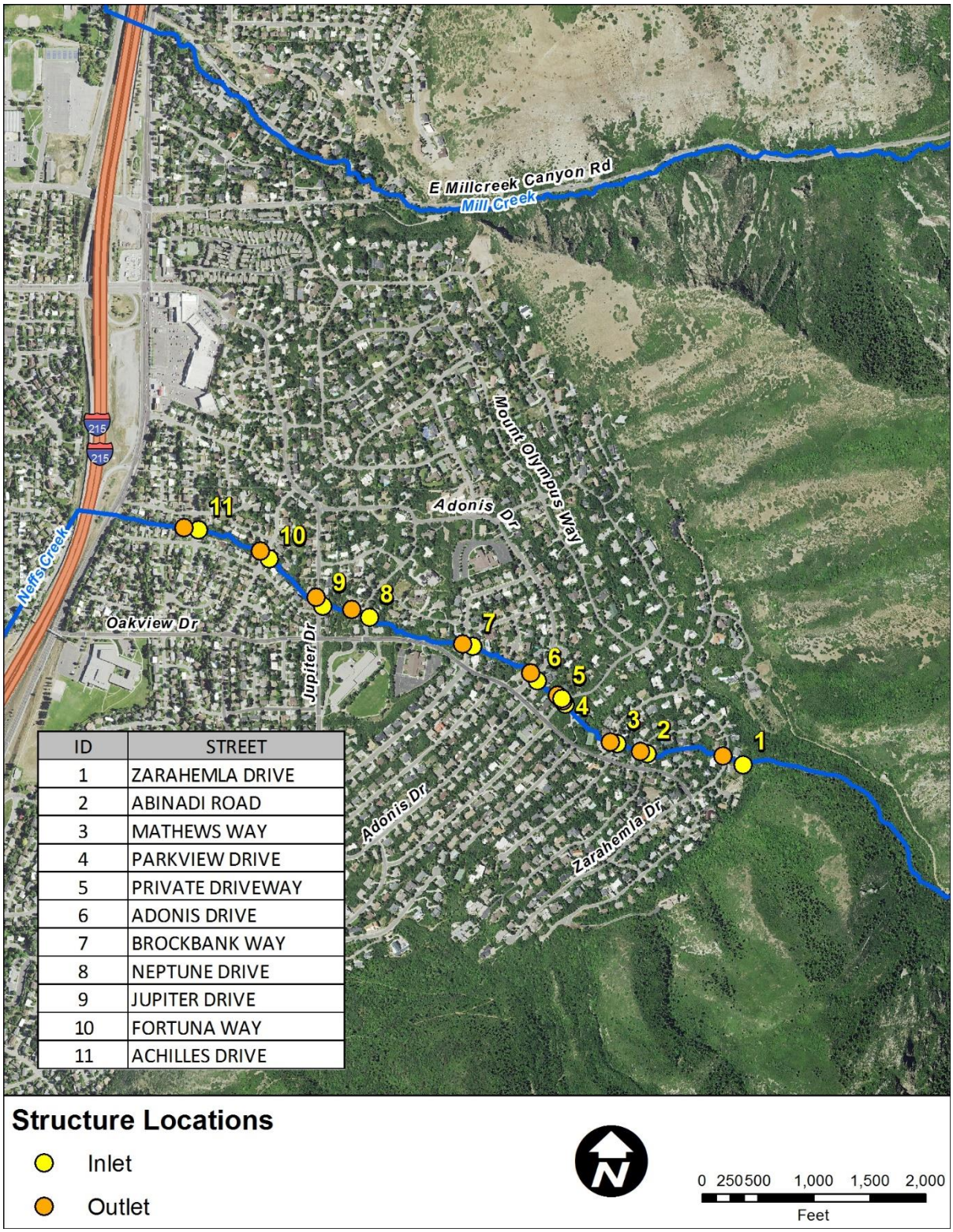


Figure 21. Structure locations

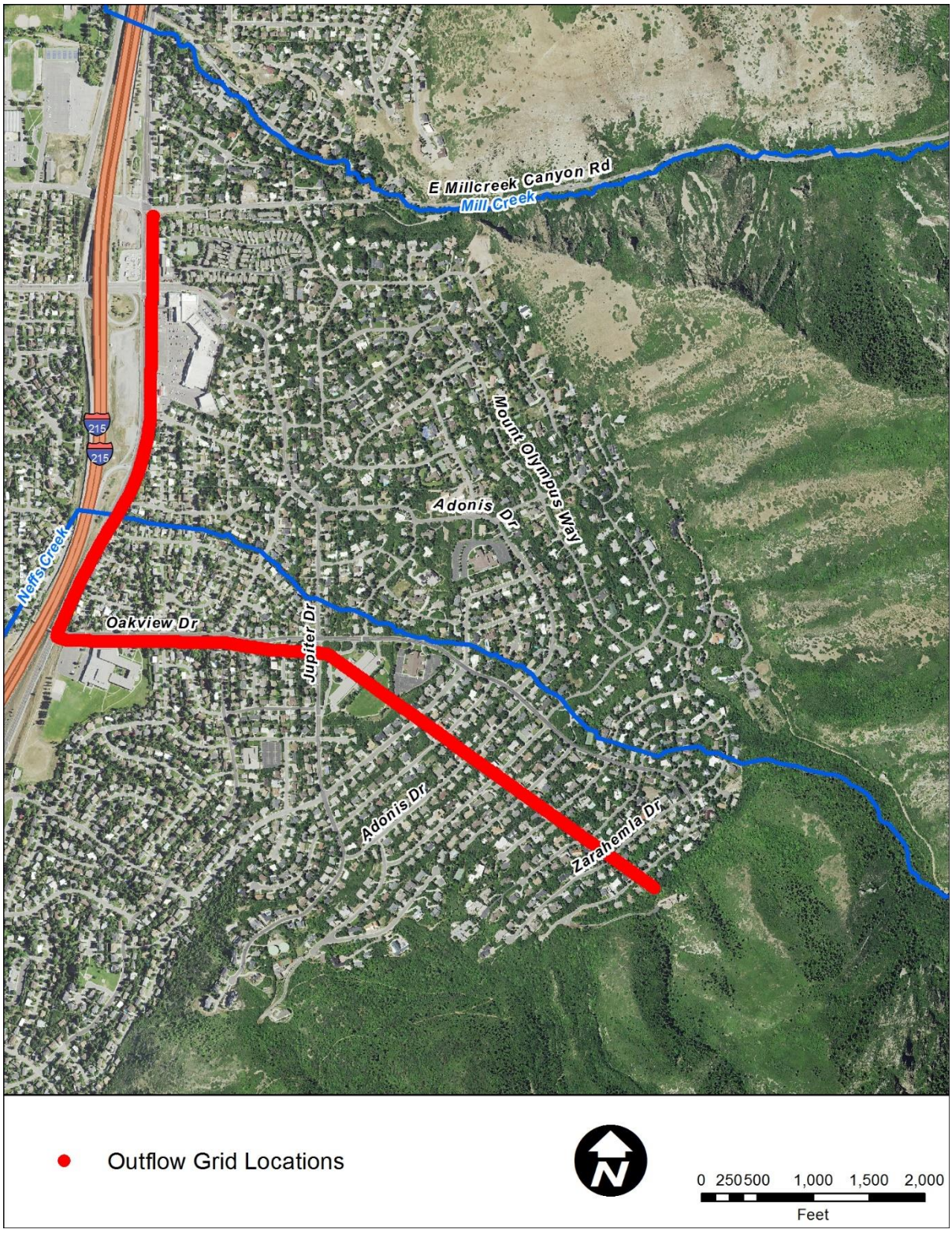


Figure 22. Outflow grid locations

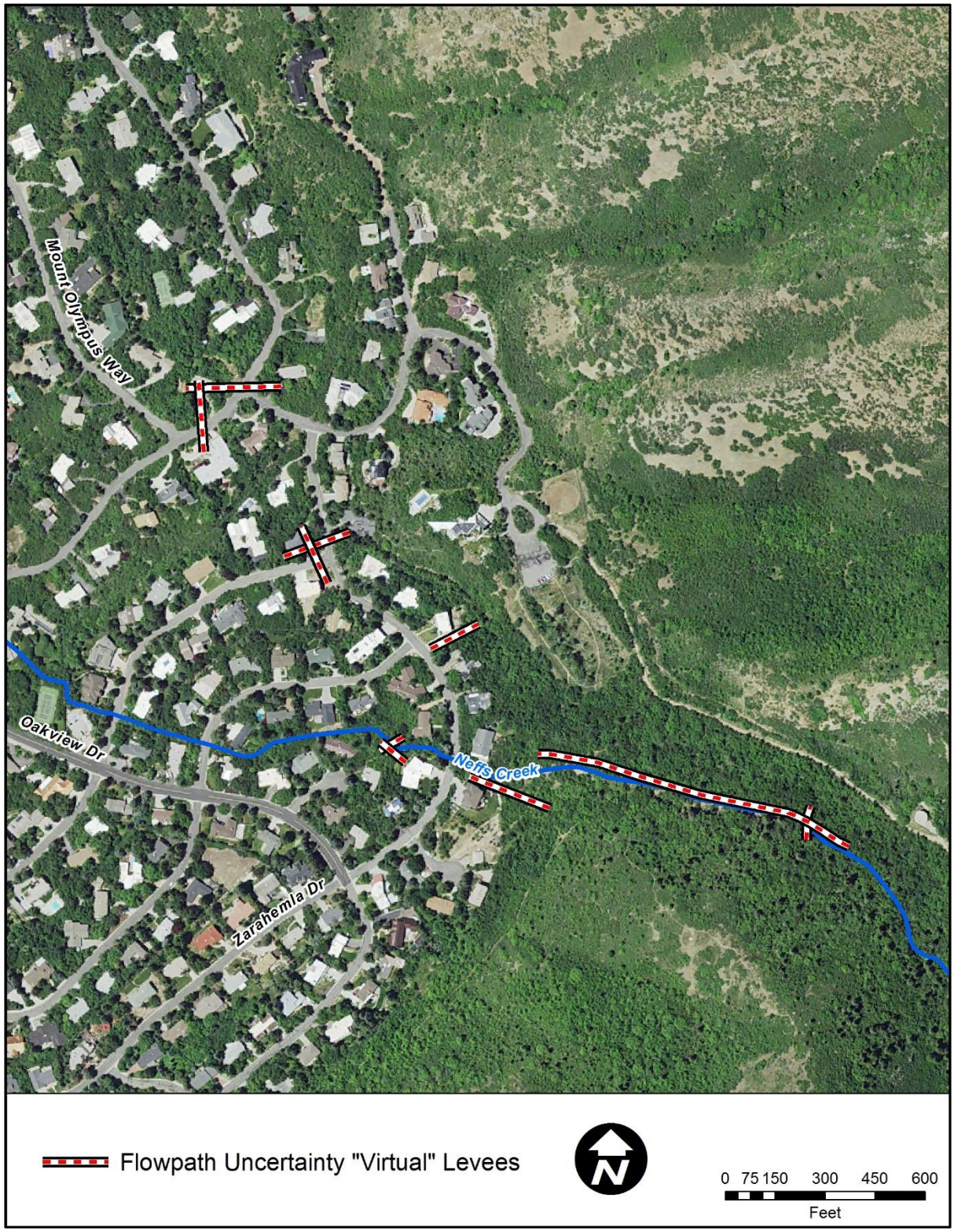


Figure 23. Flowpath uncertainty analysis virtual levees

7.5.1.10. FLO-2D Composite Flow Depth Modeling Results

Given the immense density/quantity of output data associated with two-dimensional modeling (such as FLO-2D modeling), modeling results are best depicted graphically in figures, exhibits, maps, etc. Therefore, the composite (Maximum) flood hazard condition is depicted graphically for the 100-year storm event. Figure 25 through Figure 31 depicts all the maximum flow depth flowpath uncertainty scenarios modeled. Figure 24 depicts the maximum flow depth Base Condition FLO-2D model results for reference. Note that flow depths less than 0.5 feet (6 inches) are not displayed in the figures. Flow depth less than 1 foot are generally not regulated by FEMA and the National Flood Insurance Program (NFIP) since the inundation risk is low.

It is important for the reader to distinguish, for the purpose of this study, the difference between flowpath uncertainty flood scenarios and composite flood hazard conditions. Each of the seven FLO-2D maximum flow depth models is considered a flowpath uncertainty flood scenario. Composite flood hazard conditions (maximum flow depth) were determined by compiling the flowpath uncertainty scenario rasters using ArcGIS software tools to extract the highest value for each pixel (combined maximum values), then convert those values to a single output raster grid. The output raster represent the potential composite flood hazard condition per model grid element. The maximum flow depth (composite flood hazard conditions) for the 100-year event is shown spatially below in Figure 32. A description of each flowpath uncertainty scenario is listed in Table 7.

Table 7. Flowpath uncertainty scenario descriptions

Flowpath Uncertainty Scenario	Description
Base Condition	Existing conditions. No virtual levees were used.
Scenario 1	Virtual levees were placed to direct flow toward the northern portion of the project area.
Scenario 2	Virtual levees were places to direct flow toward the central portion of the project area.
Scenario 3	Virtual levees were placed to split the flow between the northern and southern portions of the study area.
Scenario 4	Virtual levees were places to direct flow toward the southern portion of the project area.
Scenario 5	Virtual levees were places to direct all the flow into the diversion ditch channel.
Scenario 6	Virtual levees were places to direct flow toward the southern fan apex area.
Scenario 7	Virtual levees were places to direct flow toward the central fan apex area.

Figure 24. Base condition FLO-2D model for maximum flow depth

Figure 25. Maximum flow depth results from the flowpath uncertainty scenario 1 model

Figure 26. Maximum flow depth results from the flowpath uncertainty scenario 2 model

Figure 27. Maximum flow depth results from the flowpath uncertainty scenario 3 model

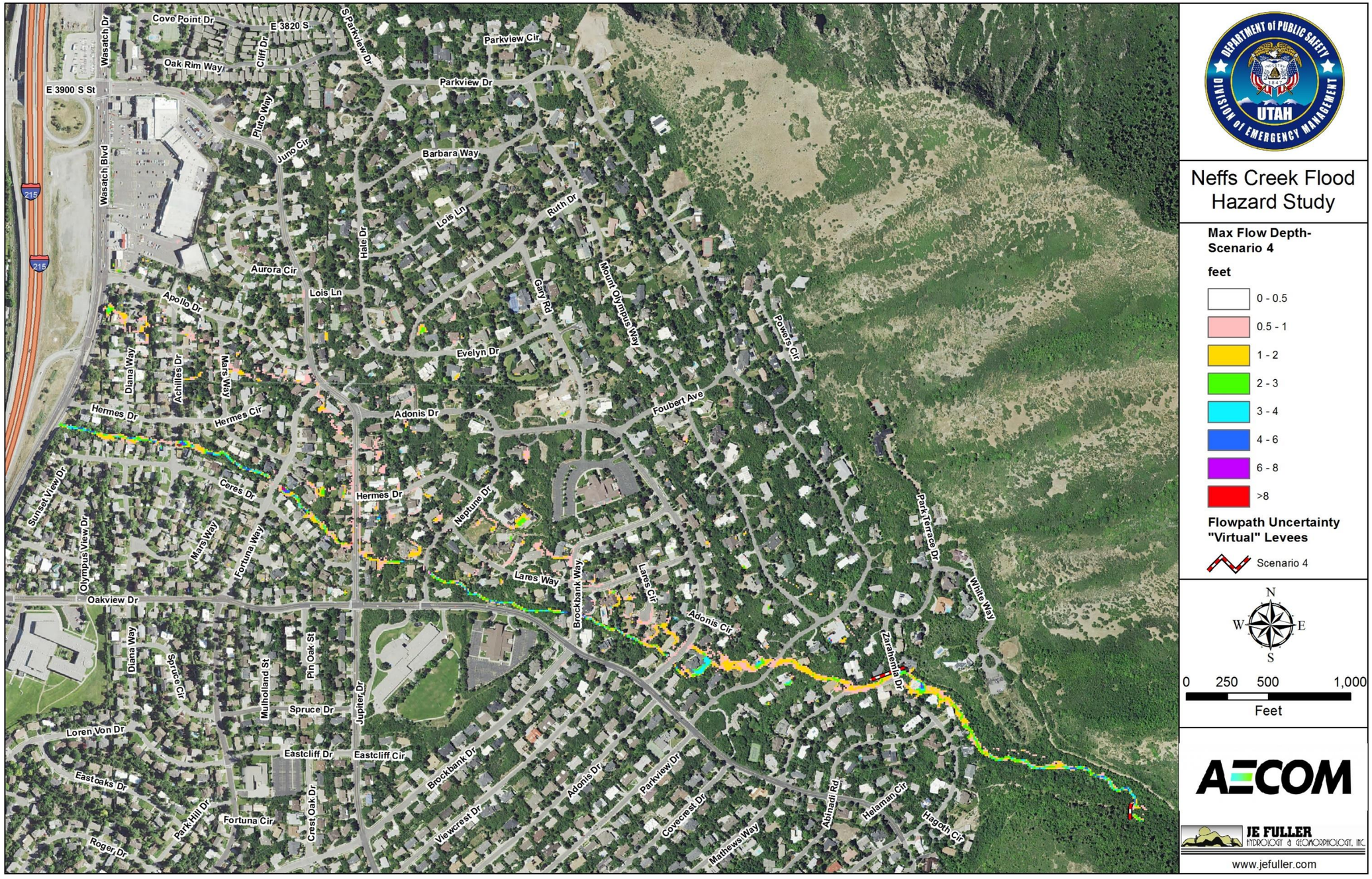


Figure 28. Maximum flow depth results from the flowpath uncertainty scenario 4 model

Figure 29. Maximum flow depth results from the flowpath uncertainty scenario 5 model

Figure 30. Maximum flow depth results from the flowpath uncertainty scenario 6 model

Figure 31. Maximum flow depth results from the flowpath uncertainty scenario 7 model

Figure 32. Maximum flow depth results from the flowpath uncertainty composite model

7.6. Floodplain Mapping

The ultimate objective of this study was to remap the currently effective FEMA floodplain for Neffs Creek based on updated geomorphic and hydraulic analyses. At the time of this study the effective FEMA floodplain was designated as Zone A (Basic Study). A summary of the restudy and remapping efforts is provided in Table 8.

Table 8. Summary of restudy and remapping efforts

	Zone A (Basic Study)	Zone AO (Enhanced/Detailed Study)	Shaded X (Enhanced/Detailed Study)
Area of Currently Effective Floodplain	0.16 Sq. Mi.	N/A	N/A
Approximate Area Updated Floodplain	0.04 Sq. Mi.	0.14 Sq. Mi.	0.19 Sq. Mi.

For developed and undeveloped portions of the study area, proposed floodplain boundaries delineated as part of this restudy are based on 100-year maximum flow depths (according to composite flood hazard conditions) as discussed in Section 7.5.1. In addition to maximum flow depths, geomorphic and topographic characteristics of the flood source were considered in determining limits of inundation.

Floodplain delineations are shown in Figure 34 and on the Floodplain Workmaps provided in Appendix B. Floodplain delineations are also shown on annotated DFIRM panels located in Appendix D. The annotated DFIRMs can be used to evaluate differences between effective floodplains (effective at the time of this study) and proposed delineations.

FEMA-based flood hazard designations associated with the delineated floodplains are listed below in Table 9. Further discussion regarding typical selection of FEMA-based flood hazard designations is provided below.

7.6.1. Development of Composite Velocities

The velocity designations for the FEMA Zones were developed using the same methodology as the composite flow depth analysis (Section 7.5.1.10). The maximum velocity rasters for each scenario were combined to create a composite maximum velocity raster for the entire study area. The composite maximum velocity raster was then clipped using the flood zone dataset. The average velocity value for each of the clipped raster segments was extracted and assigned to the corresponding flood zone. Figure 33 is an example of a velocity raster segment clipped to a flood zone boundary.

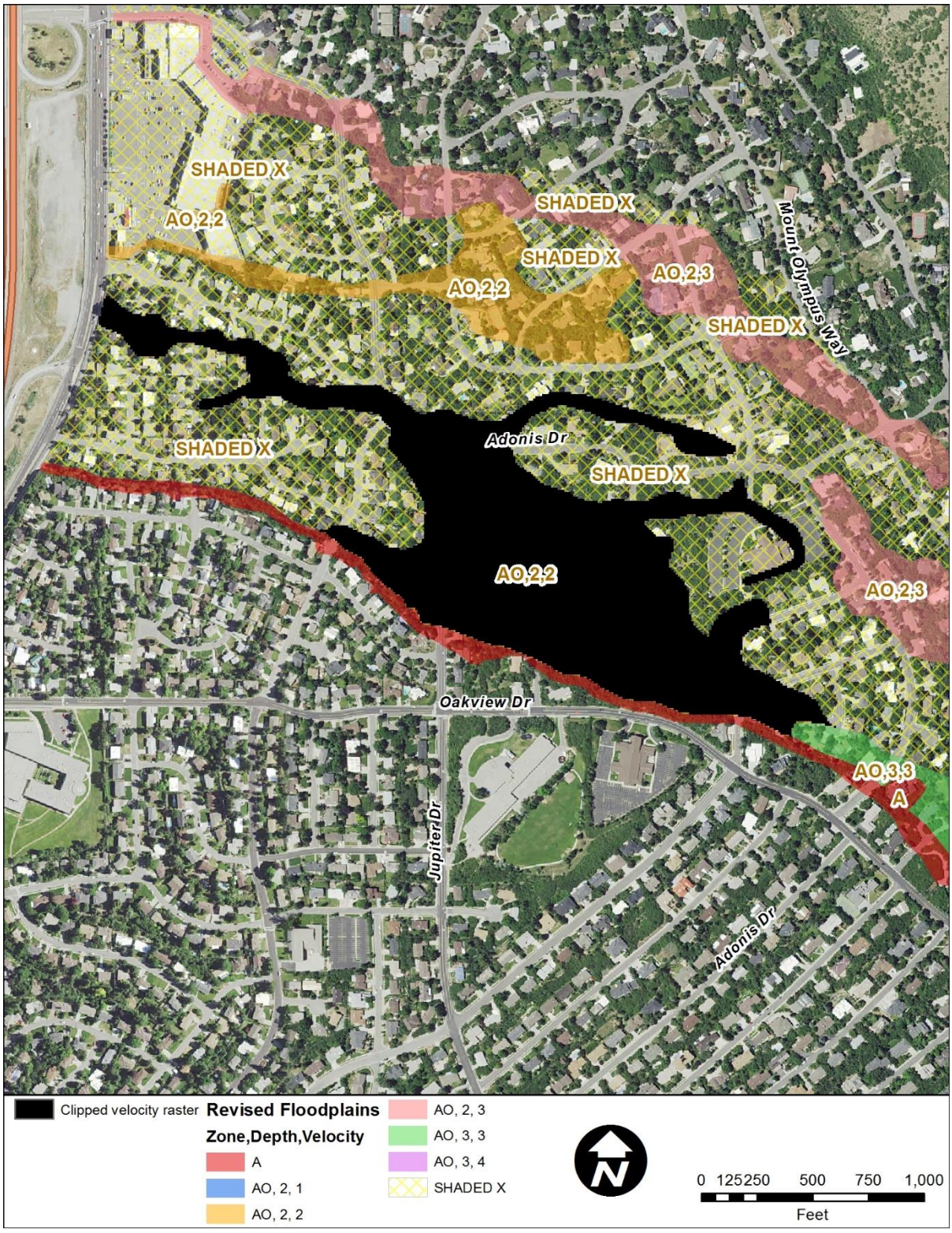


Figure 33. Example of velocity raster clipped to floodplain boundary

Table 9. FEMA-based flood hazard designations associated with delineated floodplains

FEMA-Based Flood Hazard Designation	Notes
Zone X (shaded)	100-year flow depth between 0.5’ and 1.0’.
Zone A	Ultrahazardous zone near the alluvial fan topographic apex. Area subject to the highest degree of flowpath uncertainty. In other areas where the average flow depths are greater than 3 feet. Approximate 100-year floodplain.
Zone AO2,1	100-year flow depth between 1.5 foot and 2.5 feet. Average flow velocities of 1 foot/second.
Zone AO2,2	100-year flow depth between 1.5 feet and 2.5 feet. Average flow velocities of 2 feet/second.
Zone AO2,3	100-year flow depth between 1.5 feet and 2.5 feet. Average flow velocities of 3 feet/second.
Zone AO3,3	100-year flow depth between 2.5 feet and 3.0 feet. Average flow velocities of 3 feet/second.
Zone AO3,4	100-year flow depth between 2.5 feet and 3.0 feet. Average flow velocities of 4 feet/second.

7.7. Floodway Determination

No floodways were determined in this analysis.

7.8. Flood Hazard Profiles

Given that the floodplains delineated for this study are designated as either Zone A or Zone AO, development of flood hazard profiles is not required.

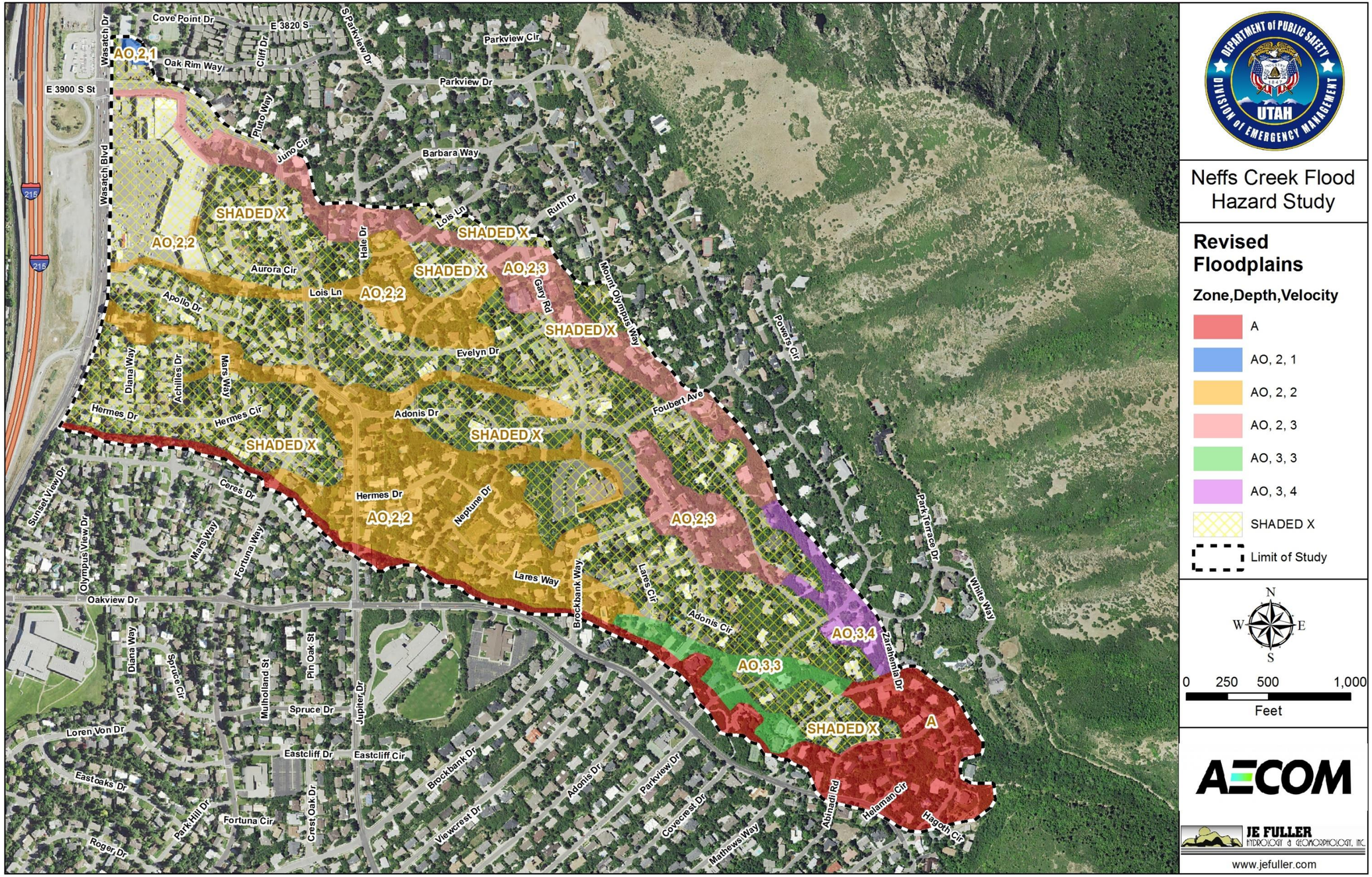


Figure 34. Proposed revised floodplains

8.0 REFERENCES

1. AGEC, 2005, Debris Flow Hazard Study Report, Neffs Canyon, Salt Lake County, Utah. Prepared for Hansen, Allen and Luce, Inc.

2. Dohrenwend, J.C., 1987, Basin and Range, in Graf, W.L., ed., Geomorphic systems in North America: Geological Society of America, Centennial Special Volume 2, p. 303-342.

3. FEMA, 2003, Guidelines and Specifications for Flood Hazard Mapping Partners – Appendix E: Guidance for Shallow Flooding Analyses and Mapping, April 2003. Available on-line at http://www.fema.gov/mit/tsd/FT_alfan.htm.

4. FEMA, 2003, Guidelines and Specifications for Flood Hazard Mapping Partners – Appendix G: Guidance for Alluvial Fan Flooding Analyses and Mapping, April, 2003. Available on-line at http://www.fema.gov/mit/tsd/FT_alfan.htm.

5. Field, John, 2001, "Channel avulsion on alluvial fans in southern Arizona," Geomorphology, Vol. 37, p. 93-104.

6. Hansen, Allen & Luce (HAL), 2007, Neffs Canyon Creek Master Plan. Salt Lake County.

7. Kalister, B.N., 1974, *Mt. Olympus Cove Environmental Geology Study*. Utah Geological and Mineral Survey Report of Investigation No. 86.

8. National Research Council, 1996, Alluvial Fan Flooding: Washington, D.C., National Academy Press, 172 p.

9. Personius, S.F, and W.E. Scott, 1992, Surficial Geologic Map of the Salt Lake City Segment and Parts of Adjacent Segments of the Wasatch Fault Zone, Davis, Salt Lake, and Utah Counties, Utah. U.S. Geological Survey. U.S. Department of the Interior.

10. Slingerland, R and Smith, N.D., 2004, River Avulsions and Their Deposits, Annual Review of Earth and Planetary Science, Vol. 32:257-285.

11. Van Horn, R., 1972, Surficial Geologic Map of the Sugar House Quadrangle, Salt Lake County, Utah. U.S. Geological Survey. U.S. Department of the Interior.

APPENDIX A

AGEC, 2005, Debris Flow Hazard Study Report, Neffs Canyon, Salt Lake County, Utah. Prepared for Hansen, Allen and Luce, Inc.

Applied Geotechnical Engineering Consultants, P.C.

DEBRIS FLOW HAZARD STUDY REPORT

NEFFS CANYON

SALT LAKE COUNTY, UTAH

PREPARED FOR:

HANSEN, ALLEN AND LUCE, INC.
6771 SOUTH 900 EAST
MIDVALE, UTAH 84047

ATTENTION: GREG POOLE

PROJECT NO. 1050097

AUGUST 10, 2005

600 West Sandy Parkway • Sandy, Utah 84070 • (801) 566-6399 • FAX (801) 566-6493

TABLE OF CONTENTS

SCOPE . . . . . Page 1

GEOLOGIC AND SEISMOTECTONIC SETTING . . . . . Page 1
- A. Regional Geology . . . . . Page 1
- B. Tectonic Setting . . . . . Page 2
- C. Structure . . . . . Page 3
- D. Stratigraphy . . . . . Page 3

SITE CONDITIONS . . . . . Page 4

OFFICE METHODS OF INVESTIGATION . . . . . Page 5

FIELD METHODS OF INVESTIGATION . . . . . Page 9

DEBRIS FLOW EVENT PREDICTION . . . . . Page 11

MITIGATION OPTIONS . . . . . Page 16

LIMITATIONS . . . . . Page 17

REFERENCES . . . . . Page 18

FIGURES

MAP OF PROJECT AREA	FIGURE 1
BEDROCK GEOLOGY OF PROJECT AREA	FIGURE 2
SURFICIAL GEOLOGY OF PROJECT AREA	FIGURE 3
NEFFS CANYON CHANNEL 1 AND 2 PROFILES	FIGURE 4
NEFFS CANYON CHANNEL 2a AND 3 PROFILES	FIGURE 5
NEFFS CANYON CHANNEL 3a, 3b AND ALLUVIAL FAN PROFILES	FIGURE 6
MAP OF CHANNEL SEGMENT DRAINAGE AREAS	FIGURE 7

SCOPE

This report presents the results of a debris flow hazard study for Neffs Canyon in Salt Lake County, Utah. The drainage encompasses an area of approximately 2,386 acres that drain into eastern Salt Lake County. The Neffs Canyon drainage basin, along with the approximate extent of the younger part of the alluvial fan, is shown on Figure 1.

The study was conducted to evaluate the debris flow hazard potential for Neffs Canyon as it relates to existing development on the alluvial fan (Olympus Cove area). The study included a review of geologic literature, an evaluation of aerial photographs, field reconnaissance, and analysis.

The geology of the site was reviewed and much of the drainage basin was observed by a geologist from AGEC. Subsurface exploration of the alluvial fan produced by Neffs Canyon was not performed for this study due to extensive development on the fan. Geologic literature was reviewed, and our interpretation of the site geologic and hydrogeologic conditions was used to evaluate the quantity of debris that may be produced from the Neffs Canyon drainage basin.

The study was performed in general accordance with our proposal dated January 31, 2005. This report has been prepared to summarize the data obtained during the study and to present our conclusions.

GEOLOGIC AND SEISMOTECTONIC SETTING

A. Regional Geology

Salt Lake County is located on the eastern edge of the Basin and Range Province. The province is made up of north/south elongated mountain blocks and valleys. The

Salt Lake Valley is one of the valleys in the province with the Oquirrh and Wasatch Mountains partially bounding the valley on the west and east, respectively.

Neffs Canyon drains westward into the Salt Lake Valley. The valley was once occupied by a large lake known as Lake Bonneville during the Wisconsin Glacial period of the Pleistocene age. The present-day Great Salt Lake is a remnant of ancient Lake Bonneville. Stillstands of Lake Bonneville formed benches along the Wasatch Front. The highest level of Lake Bonneville is marked by a bench, the Bonneville Shoreline, at approximate elevation 5,200 feet. The lake remained at this high level from approximately 17 to 15 thousand years before present (bp), until it dropped approximately 350 feet during a catastrophic flood known as the Bonneville Flood (Currey and Oviatt, 1985; Jarrett and Malde, 1987). Two lower stillstands of Lake Bonneville are the Provo and Gilbert levels, which formed at approximate elevations 4,850 and 4,250 feet, respectively.

The mouth of Neffs Canyon is situated approximately 400 feet above the Bonneville Shoreline. The Neffs Canyon alluvial fan extends out onto and coalesces with Lake Bonneville deposits.

Neffs Canyon was formed by erosion of the Wasatch mountain block, which has undergone repeated uplift due to faulting. The geology of Neffs Canyon is dominated by north-northwest dipping beds of quartzite and limestone (see Figure 2). Particularly in the southern drainage basin area, drainage is controlled by exposed bedrock slabs that form steep tributaries.

B. Tectonic Setting

The site is located on the east side of the Salt Lake Valley along the Wasatch Front, which is a prominent mountain front escarpment extending approximately 240 miles from near Malad, Idaho to the vicinity of Fayette, Utah. The prominent west facing

steep escarpment of the Wasatch Mountain Front is the result of repeated normal fault displacements which have taken place over the last several million years. The system of normal faults which makes up this escarpment is known collectively as the Wasatch Fault. Relatively recent fault movements are evidenced by offsets in Lake Bonneville sediments and more recent alluvial and colluvial deposits.

The Wasatch Fault is considered to be made up of several segments, each segment acting relatively independently (Machette et al., 1992). Neffs Canyon is located near the northern end of the Salt Lake City segment of the Wasatch Fault, which is a segment approximately 23 miles in length that extends from North Salt Lake to Draper, Utah.

C. Structure

Crittenden (1965a, 1965b) mapped the bedrock geology of the project area at a 1:24,000 scale. The bedrock in this area consists of a series of tilted Pennsylvanian- and Mississippian-aged quartzites and limestones overlying Cambrian- and Precambrian-aged quartzites exposed on the northern side of Mount Olympus. Bedrock units generally strike east/northeast in the project area. The bedrock geology of the project area based on mapping by Crittenden (1965a, 1965b) is presented on Figure 2.

D. Stratigraphy

The stratigraphy of the geologic units in the project area generally consists of the above-described limestone and quartzite rocks overlain in part by surficial (Quaternary) deposits of talus, colluvium, alluvium and glacial till (Van Horn, 1972). The surficial geology of the western portion of Neffs Canyon is presented on Figure 3. Quaternary alluvial deposits are mapped primarily along the lower main drainage channels and lower Norths Fork channel. From near the convergence of the

unnamed drainage east of Norths Fork with the main channel, glacial till and outwash deposits are mapped along the main channel and covering much of the tributary basin. Figure 3 also shows the fan mapped by Van Horn (1972) to consist of undifferentiated fan deposits younger than the Bonneville shoreline. Van Horn indicates that these units are subject to sudden and violent flash floods and mudflows.

SITE CONDITIONS

The Neffs Canyon drainage basin consists almost entirely of Wasatch National Forest land. The drainage basin covers an area of approximately 3.7 square miles. The general topography of the drainage basin is presented on Figure 1. Elevation of the canyon mouth is approximately 5600 feet. The canyon crest reaches an elevation of approximately 9776 feet. Based on USGS topography, the main channel of Neffs Canyon is approximately 15,000 feet long and begins at approximate elevation 8760 feet. Tributaries from the south flow into the main channel at approximate elevations of 6260 and 5880 feet. The gradient of the main channel is as low as approximately 6 to 8 degrees in portions of the lower channel up to approximately 21 degrees in the upper reaches of the channel. Two steeper tributaries south of the main channel are Norths Fork and an unnamed tributary east of Norths Fork. Norths Fork drainage consists of at least three tributaries with gradients ranging from approximately 16 to 31 degrees. The unnamed drainage east of Norths Fork consists of two major tributaries with gradients ranging from approximately 4 to 40 degrees.

A water tank is located near the mouth of the canyon on the north side. An unpaved dirt road extends along the northern side approximately 2000 feet into the canyon. From there, the road narrows to an unpaved trail that generally follows the main stream channel of Neffs Canyon. Various other trails are located in the lower drainage area and in the Norths Fork drainage.

Vegetation in the canyon consists of scrub oak and maple brush and pine and aspen trees with distributions typical to Wasatch Front canyons. Although vegetation is generally very thick on the north-facing slopes, much of the southern drainage basin area consists of broad, steeply dipping slabs of quartzite bedrock with a small amount of vegetation.

At the time of our field study, water was flowing in each of the canyon tributaries. Streamflow near the canyon mouth in the lower drainage basin has been diverted away from the natural channel to a man-made ditch channel along the southern canyon wall. In places, the water elevation in the current channel is significantly higher than the natural channel.

The drainage basin is bounded on the north and east by the Mill Creek Canyon drainage basin, and on the south by Mount Olympus. The Olympus Cove neighborhood is located east of the canyon mouth on the alluvial fan.

OFFICE METHODS OF INVESTIGATION

Debris flow hazard of Neffs Canyon was evaluated in the office by review of geologic literature, an evaluation of aerial photographs, and comparisons of debris production from reported debris flow events in other areas. Aerial photographs used during the study include photograph numbers AAL-6K-124 through 126, dated September 3, 1952, at an approximate scale of 1 inch equals 950 feet, and photograph numbers 10-AAL4-58, 59, 60, 89 and 90, dated September 21, 1937, at an approximate scale of 1 inch equals 1640 feet. The 1937 photographs predate most of the development on the Neffs Canyon alluvial fan and within the Olympus Cove area. Several of the roads and houses on the alluvial fan existed at the time of the 1952 photographs.

Giraud (2005) describes debris flows as fast-moving flow-type landslides composed of a slurry of rock, mud, organic matter, and water that move down drainage-basin channels onto alluvial fans. They generally have a very high concentration of sediment in relation to

water. Debris flows generally initiate on steep slopes or in channels by the addition of water from intense rainfall or rapid snowmelt, and incorporate additional sediment and vegetation as they travel downstream. When flows reach an alluvial fan and lose channel confinement or where channel gradients are sufficiently low (generally 10 degrees or less), they spread laterally and deposit entrained sediment (Giraud, 2005).

Several geomorphic indicators of debris flow potential are discussed in the literature. One general rule is that watersheds smaller than about 2 square miles with gradients steeper than approximately 15 degrees are likely to have debris-flow potential (Jakob, 2005). Neffs Canyon drainage basin is roughly double the upper size limit given by Jakob; however, slopes frequently exceed 15 degrees. Another common rule of thumb follows that fans at least partially formed by debris flow have a fan gradient greater than 4 degrees (Jakob, 2005). However, correlation of fan gradient to the dominant geomorphic fan-forming process is problematic in that regional fan gradient thresholds cannot readily be transferred to other regions (Jakob, 2005). The Neffs Canyon alluvial fan gradient is approximately 7 degrees in the proximal fan area to approximately 5 degrees in the distal portions of the fan.

Alluvial Fan

Generally, a debris flow hazard evaluation includes investigation of both the alluvial fan and the drainage basin/feeder channel. Subsurface investigation of the fan aids in identifying the dominant fan-building processes, whether stream flow, hyperconcentrated flow (intermediate between stream flow and debris flow), or debris flow. In this study, subsurface investigation of the fan was not conducted due to urban development of the fan surface. Therefore, aerial photograph observation and review of previous geologic mapping were primarily used to evaluate the fan.

Aerial photographs were used to map the extent of the alluvial fan which appears to represent geologically the more recent sediment deposition from Neffs Canyon and cover Lake Bonneville deposits. The mapped extent of the alluvial fan is shown on Figure 1. The

extent of the mapped alluvial fan is fairly consistent with surficial geologic mapping by Van Horn (1972) and Personius and Scott (1992). Study of the aerial photographs did not identify discrete debris flow lobes on the fan. However, the distal portion of the fan is irregular in extent, which may be interpreted as a series of discrete flows with variable run-out distances. The mapped fan surface overlies the Lake Bonneville deposits, indicating that deposition of this portion of the fan has occurred in the last approximately 15,000 years. Van Horn (1972) mapped the alluvium as fg5 overlying fg4 in the southern portion of Olympus Cove. Personius and Scott (1992) map the area of the Neffs Canyon alluvial fan as af2, which is assigned the age of middle Holocene to uppermost Pleistocene (> 5000 years old).

Drainage Basin

Review of the drainage basin on the aerial photographs did not identify evidence of relatively recent debris flow or shallow landslide activity. No documentation of historic debris flows occurring in Neffs Canyon was found in the literature.

Debris flows along the Wasatch Front are typically initiated by intense rainfall or rapid snowmelt. Triggering mechanisms for debris flow events are generally storm-induced erosion on denuded areas, or landslides. Measurement of sediment production from the source areas show that their debris contribution is usually less than 20% of the total and in many cases is negligible (Williams and Lowe, 1990). In evaluation of the numerous 1983 debris flows along the Wasatch Range, Wieczorek and others (1983) noted that most of the landslides that mobilized as debris flows occurred in areas underlain by the bedrock of the Farmington Canyon complex found in Davis County. The gneiss and schist that constitute most of this unit commonly decompose into zones of clayey material prone to landslides. Landslides typically do not form in limestone and quartzite, which is the bedrock underlying Neffs Canyon, indicating that this debris flow triggering mechanism would be less likely than storm-induced erosion on denuded areas.

The southern reaches of the Neffs Canyon drainage basin contain abundant exposed bedrock, which promotes rapid surface-water runoff that could help generate a debris flow. However, these north-facing slopes also contain large areas of dense brush and trees that act to inhibit mobilization of slope colluvium.

In the case of a wildfire that partially or completely burns the Neffs Canyon drainage basin, increased runoff and erosion conditions would increase the potential for a debris flow to occur. Cannon and Gartner (2005) describe two primary processes for the initiation of fire-related debris flows: runoff-dominated erosion by surface overland flow, and infiltration-triggered failure and mobilization of a discrete landslide mass. During the drought years of 1999-2004 in Utah, 26 debris flows occurred in seven wildfire areas, including repeated flows from different drainages during the same storm pattern (Giraud, 2005). The potential for debris flow would be increased if a significant portion of the drainage is burned.

Historic Debris Flow Events

Information reported by the Utah Geological Survey on two recent debris flow events along the Wasatch Front was used to evaluate potential sediment production from Neffs Canyon. Drainage basin size, geology, channel gradient and the ratio of debris production per foot of channel length from these two events were compared to Neffs Canyon.

A 1991 debris flow in North Ogden deposited approximately 26,000 cubic yards of material (Mulvey and Lowe, 1991). The debris flow was produced by an approximately 0.27 square mile drainage basin with channel gradients ranging from approximately 16 to 30 degrees. The canyon is mostly underlain by Tintic Quartzite, which is also widely exposed in Neffs Canyon. The quartzite forms high cliffs that extend up to the ridgeline. Talus and colluvium cover the slopes below the high cliffs. Based on the reported debris flow volume and the total affected channel length (approximately 6200 feet), roughly 4.2 cubic yards of debris per foot of channel length was produced during this event.

McDonald and Giraud (2002) described the 2002 fire-related debris flows east of Santaquin and Spring Lake in Utah County. These events included major debris flows from five tributaries that deposited debris on alluvial fans west of Dry Mountain. The drainage basins range in size from approximately 0.56 to 0.75 square miles. Channel gradients range from approximately 11 degrees up to approximately 32 degrees and appear to be relatively consistent between each drainage. Dry Mountain is composed of generally east-dipping Precambrian quartzite, sandstone, siltstone, schist, gneiss and amphibolite locally intruded by pegmatite and granite dikes. These rocks are overlain by Mississippian limestone and shale, and Quaternary alluvium, colluvium, talus and mass-movement deposits (McDonald and Giraud, 2002). Based on the reported debris flow volume and channel length of each tributary (ranging from approximately 6300 to 9600 feet in length), the debris produced from the five tributaries ranged from 0.18 to 2.2 cubic yards per foot of channel length. The average sediment production during this event was 1.3 cubic yards per foot of channel length.

Both examples indicate sediment production rates much lower than the average sediment bulking rate of 12 cubic yards per foot of channel length reported for the canyons of Davis County (Williams and Lowe, 1990). The Farmington Canyon complex bedrock tends to weather deeply into clayey material, whereas the predominantly quartzite bedrock in Neffs Canyon (and in the 1991 North Ogden debris flow event) appears to weather to granular material, most likely at a slower rate. It follows that sediment production, as well as the amount of sediment available for entrainment, is greater in Davis County when compared with the project area.

FIELD METHODS OF INVESTIGATION

The geology of the site was reviewed and much of the drainage basin was observed by a geologist from AGEC. Since subsurface investigation of the alluvial fan was not considered feasible, the field study focused on drainage basin and channel evaluation. The basin and

channel reconnaissance included observations of vegetation cover, volume and gradation of sediment that could be incorporated into a debris flow, potential slope instability that could initiate an event, and the presence or absence of geomorphic evidence of past debris flow events.

The basin slopes and channel banks are generally densely vegetated. A vast majority of slopes are north-facing and thus have dense brush and tree cover. Sediment depth to bedrock appears to be relatively deep particularly on the north-facing slopes where increased moisture has led to well-developed soil cover. The fine-grained portion of sediments was observed to be predominantly silty. However, upslope of these areas in much of the basin are massive, tilted quartzite or limestone slabs that concentrate surface run-off into the tributaries. Very little bedrock was exposed along the main channel, although roughly 10 percent bedrock exposure was observed in Norths Fork drainage. Bedrock exposure generally increased with elevation. Reconnaissance of the drainage indicates that the main channel and its tributaries are in relatively stable condition. There are no significant signs of erosion in the channel or along the slopes above the channel. Possible geomorphic evidence of past debris flow activity was observed in the lower reach of Norths Fork tributary, where boulder trains and levees were observed between roughly parallel channels on either side of the drainage. The boulders were partially buried. No apparent scouring of channel sediment was observed. The area above approximate elevation 7000 feet in Norths Fork drainage was inaccessible, as well as most of the unnamed drainage east of Norths Fork.

Reconnaissance of the main channel indicates that although the lower drainage channel is relatively broad it contains an incised channel that would act to partially confine a debris flow.

DEBRIS FLOW EVENT PREDICTION

Based on USGS topography, the gradient of the lower main channel varies from approximately 6 to 11 degrees. Hungr et al. (1984) estimate deposition angles of 8 to 12 degrees for channeled debris flows. It is often assumed in the literature that deposition begins at slopes of 10 degrees (Rickenmann, 2005). Based on the data obtained from this study, deposition is conservatively assumed in our analysis to occur along channels with slopes less than 10 degrees. Profiles of the main channel and tributary channels were developed and are presented on Figures 4 through 6. The channels are numbered 1, 2, 2a, 3, 3a and 3b as shown on Figure 1.

Debris Flow Volume

Hungr and others (1984) discuss estimation of event magnitude, or total volume of coarse and fine debris material transported to the fan during a single event, using a channel debris yield rate. The rate is applied to the length of channel (including any major tributaries) upstream of the depositional area to the point of origin. Based on rock type and weathering characteristics, we anticipate that the channel debris yield rate for Neffs Canyon would be significantly lower than the reported sediment bulking rate of 12 cubic yards per foot of channel length for the canyons of Davis County (Williams and Lowe, 1990). Close comparisons of drainage basin size (when considering the numerous smaller tributaries within Neffs Canyon), channel gradient (particularly in the upper tributaries in the southern Neffs Canyon area), and rock type indicate that Neffs Canyon could produce a similar channel debris yield rate to the 1991 North Ogden debris flow, which averaged approximately 4.2 cubic yards per foot of contributing channel length.

Varying channel debris yield rates were selected for channel segments based on channel types described by Hungr and others (1984) based on the criteria of channel gradient, bed material, side slopes, and the stability condition of the drainage area. Consideration was also given to the amount of vegetative cover and/or bedrock exposed within the contributing

drainage area. The channel segments, as well as the drainage area contributing to each channel segment, are shown on Figure 7. The criteria for channel types A, B and C (Hungr and others, 1984) is listed below.

Channel Type	Gradient (deg.)	Bed Material	Side Slopes	Stability Condition	Channel Debris Yield Rate (yd^3/ft)
A	20-35	bedrock	nonerodible	stable, practically bare of soil cover	0-2
B	10-20	thin debris or loose soil over bedrock	nonerodible (bedrock)	stable	2-4
C	10-20	deep talus or moraine	less than 16 feet high	stable	4-6

Two methods were used to calculate the potential debris flow volume for each channel segment. Method A is the direct relationship of the channel length multiplied by the channel debris yield rate (Hungr and others, 1984). Method B incorporates the size of the drainage area tributary to the channel segment under consideration in the equation:

$$V = A^{1/2}Le$$

where V is magnitude, or volume in cubic meters, A is the drainage area measured in square kilometers, L is the channel segment length in meters, and e is the channel erodibility coefficient with the dimensions of $m^3/m \cdot km^2$ (Hungr and others, 1984).

The channel debris yield rate selected for each channel segment and the debris flow volumes calculated using Methods A and B are listed in the following table. Reference Figure 1 for the locations of Channels 1, 2, 2a, 3, 3a and 3b.

Channel No. - Segment No.	Approximate Channel Segment Elevation*	Selected Channel Debris Yield Rate (yd^3/ft)	Debris Flow Volume (yd^3/ft)	
			Method A	Method B
1	Above 6800 feet	5	35,000	58,600
2-1	8920 to 8400 feet	3	5,100	2,500
2-2	8400 to 7800 feet	5	11,500	6,300
2-3	7720 to 6240 feet	5	24,000	23,200
2a-1	8800 to 8200 feet	2	1,900	400
2a-2	8200 to 6480 feet	5	27,000	19,300
3-1	8440 to 7800 feet	3	4,200	2,000
3-2	7800 to 5880 feet	5	26,000	27,900
3a-1	8280 to 8000 feet	1	500	100
3a-2	8000 to 7240 feet	3	4,500	1,400
3a-3	7240 to 7050 feet	5	2,500	400
3b-1	7480 to 7200 feet	3	1,500	1,500
3b-2	7200 to 6320 feet	5	11,000	4,600

* Gap in elevation represents channel gradient below 10 degrees.

The total volume of debris flow calculated using Methods A and B is 154,700 cubic yards and 148,200 cubic yards, respectively. The portion of the Neffs Canyon drainage below approximate elevation 6800 feet has a gradient suggesting deposition rather than erosion and would decrease the volume of sediment reaching the canyon mouth. However, the channel is relatively narrow and confined until it reaches the canyon mouth. Assuming a channel width of 15 feet, a deposition thickness of 3 feet, and a channel length of 8,000 feet, a sediment volume of 13,000 cubic yards could be deposited through this flatter reach of the drainage.

There may also be some loss in flow energy and resulting deposition of a part of the debris mass where tributaries intersect the main channel since there will be a change in flow direction and some runup of sediment at these intersecting points.

Based on the large drainage basin area and the observed site conditions, we assume that the volume of material produced from a point of initiation would be negligible compared with the channel sediment contribution of a debris flow that reaches the alluvial fan. Therefore, our analysis does not consider the contribution of debris from the point of initiation.

A debris flow volume on the order of 150,000 cubic yards appears to be similar or slightly greater than estimated debris flow volumes of events along the northern Wasatch Front reported by Wieczorek and others (1983). One of largest magnitude events occurred in Parrish Creek, Davis County, in 1930. This debris flow deposited roughly 300,000 cubic yards of material based on a description of the event. The Parrish Creek drainage basin is approximately 2 square miles. A majority of the reported debris flow volumes were estimated to be between 75,000 and 210,00 cubic yards (Wieczorek and others,1983).

Debris Flow Potential

Limited information on historic debris flows and other types of flooding and sedimentation events in Utah has been compiled by Butler and Marsell (1972). Several events have been documented as occurring within Salt Lake County, although in many cases debris flows are not consistently distinguished from hyper-concentrated floods or water floods (Wieczorek and others, 1989). Butler and Marsell (1972) report possible debris flows occurring within City Creek, Parleys Canyon, and several other canyons in Salt Lake County. No debris flow events were described for Neffs Canyon. Woolley (1946) describes a debris flow issuing from City Creek Canyon on September 11, 1864.

Overall, it is clear from the literature that debris flows have occurred in the past more commonly in Davis County than Salt Lake County. The drainages that produce these events

are typically much smaller than Neffs Canyon. Smaller drainages tend to have higher gradients, such as those that produced the 1991 North Ogden and 2002 Santaquin debris flows. Unlike the main channel in Neffs Canyon, relatively high channel gradients (above approximately 20 degrees) are found in Channels 2, 2a, 3, 3a and 3b. However, even if a debris flow were to be initiated within one or more of these channels, historic records suggest that during unusually wet cycles or heavy rainfall events, the likelihood of a flow traveling down-channel and reaching the alluvial fan is low relative to Davis County, in particular.

When considering debris flow potential, initiation of a fire-related debris flow in a partially or fully denuded basin represents the most significant threat. Burned areas typically exhibit reduced infiltration, increased runoff, and increased soil erodibility. Numerous studies have documented an increased occurrence of debris flows following wildfire (Cannon and Gartner, 2005). Very little data exists in the literature comparing debris flow volumes produced in burned and non-burned conditions. Thus, in designing for a fire-related debris flow event it is most important to consider the increased probability, or higher potential, of one or more debris flow events occurring.

The predicted debris flow volumes of 154,700 and 148,200 cubic yards represent an event that occurs over the entire Neffs Canyon drainage basin. The potential for a smaller flow to occur within one of the tributary channels, or within tributary channels in a portion of the canyon, is greater than the potential for debris flows to occur simultaneously within the entire basin. Further, many of these smaller flows may be deposited before reaching the canyon mouth due to the low gradient of the main channel below approximate elevation 6800 feet.

MITIGATION OPTIONS

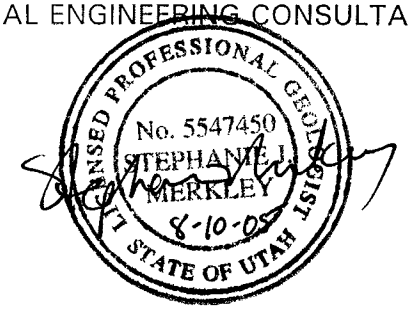
Potential debris flow mitigation options for Neffs Canyon include building a catch basin near the mouth of the canyon, or diverting flow to an area where deposition is acceptable. The second option may not be feasible due to constraints within the Olympus Cove area. A combination of these options could also be used.

In the literature, active and passive debris flow mitigation measures are discussed by Huebl and Fiebiger (2005). Event management is the active mitigation practice of manipulating a debris flow by measures such as debris flow breakers, permanent or temporary debris deposition under controlled conditions within the drainage area, deflection to an area of low consequence, or an organic debris rake (Huebl and Fiebiger, 2005). In addition to mitigation measures designed for retaining or diverting flow at the mouth of the canyon or at locations along the channel, several methods of disposition management, or the practice of changing the probability of occurrence of a debris flow, are discussed (Huebl and Fiebiger, 2005). Disposition management includes measures that act to decrease runoff and erosion. However, these alternative measures may be more appropriate in cases where debris flow potential is considered high and debris flow constitutes a recurring problem for development.

LIMITATIONS

The analysis and report findings are based on review of geologic literature, review of aerial photographs, and site reconnaissance. Geologic related conclusions are based on currently accepted geologic interpretation of this information. The volume of debris estimated is only a rough approximation based on the literature reviewed and geologic conditions observed at the site. The potential for and timing of debris flow events is greatly influenced by climatic conditions and changes to the drainage such as from fires. Those who will determine the need for and possible methods of debris flow mitigation for Neffs Canyon should consider the potential wide range in debris flow volume and event occurrence.

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, P.C.



Stephanie J. Merkley, P.G.

Reviewed by Douglas R. Hawkes, P.E., P.G.

SJM/sc

REFERENCES

Black, B.D., Lund, W.R., Schwartz, D.P., Gill, H.B., and Mayes, B.H.; Paleoseismic investigation on the Salt Lake City segment of the Wasatch Fault Zone at the South Fork Dry Creek and Dry Gulch sites, Salt Lake County, Utah, 1996, Utah Geological Survey, Special Study 92.

Cannon, S.H. and Gartner, J.E., 2005; Wildfire-related debris flow from a hazards perspective *in* Jakob, M. and Hungr, O., eds., Debris-flow hazards and related phenomena: Chichester, United Kingdom, Praxis Publishing Ltd, p. 363-381.

Crittenden, M.D., 1965a; Geology of the Mount Aire Quadrangle, Salt Lake County, Utah, U.S. Geological Survey Map GQ-379.

Crittenden, M.D., 1965b; Geology of the Sugar House Quadrangle, Salt Lake County, Utah, U.S. Geological Survey Map GQ-380.

Currey, D.R. and Oviatt, F.G., 1985; Durations, average rates and probable cause of Lake Bonneville expansion, Stillstands and contractions during the last deep-lake cycle 32,000 to 10,000 years ago *in* Diaz, H.F., eds. Problems of and prospects for predicting Great Salt Lake levels, Proceedings for NOAA conference; center for Public Affairs and Administration, University of Utah, Salt Lake City, Utah.

Giraud, R.E., 2005; Guidelines for the Geologic Evaluation of Debris-Flow Hazards on Alluvial Fans in Utah, Utah Geological Survey MP 05-6.

Hungr, O., Morgan, G.C., and Kellerhals, R., 1984, Quantitative analysis of debris torrent hazards for design of remedial measures: Canadian Geotechnical Journal, v. 21, p. 663-677.

Jakob, M., 2005; Debris-flow hazard analysis *in* Jakob, M. and Hungr, O., eds., Debris-flow hazards and related phenomena: Chichester, United Kingdom, Praxis Publishing Ltd, p. 411-443.

Jarrett, R.D. and Malde, H.E., 1987; Paleodischarge of the late Pleistocene Bonneville Flood, Snake River, Idaho, computed from new evidence; Geological Society of America Bulletin, v. 99, p. 127-134.

Machette, M.N. and Personius, S.F. and Nelson, A.R., 1992; Paleoseismology of the Wasatch Fault Zone: A Summary of Recent Investigations, Interpretations, and Conclusions; U.S. Geological Survey Professional Paper 1500-A-J, p A1 - A71.

McDonald, G.N. and Giraud, R.E., 2002; September 12, 2002, Fire-related debris flows east of Santaquin and Spring Lake, Utah County, Utah, Utah Geological Survey.

Mulvey, W.E. and Lowe, M., 1991; 1991 Cameron Cove Debris Flow, North Ogden, Utah, Utah Geological Survey.

Personius, S.F., and Scott, W.E., 1992; Surficial Geologic Map of the Salt Lake City Segment and Parts of Adjacent Segments of the Wasatch Fault Zone, Davis, Salt Lake and Utah Counties, Utah, U.S. Geological Survey Map I-2106.

Rickenmann, D., 2005; Runout prediction methods *in* Jakob, M. and Hungr, O., eds., Debris-flow hazards and related phenomena: Chichester, United Kingdom, Praxis Publishing Ltd, p. 305-324.

Salt Lake County aerial photograph collection, copies from the National Archives, photograph numbers 10-AAL 4-58 through 4-60 and 4-88 through 4-90, dated September 21, 1937.

U. S. Department of Agriculture, Aerial photographs obtained from Field Office, Salt Lake City, Utah, photograph numbers AAL-6K-124 through AAL-6K-126, dated September 3, 1952.

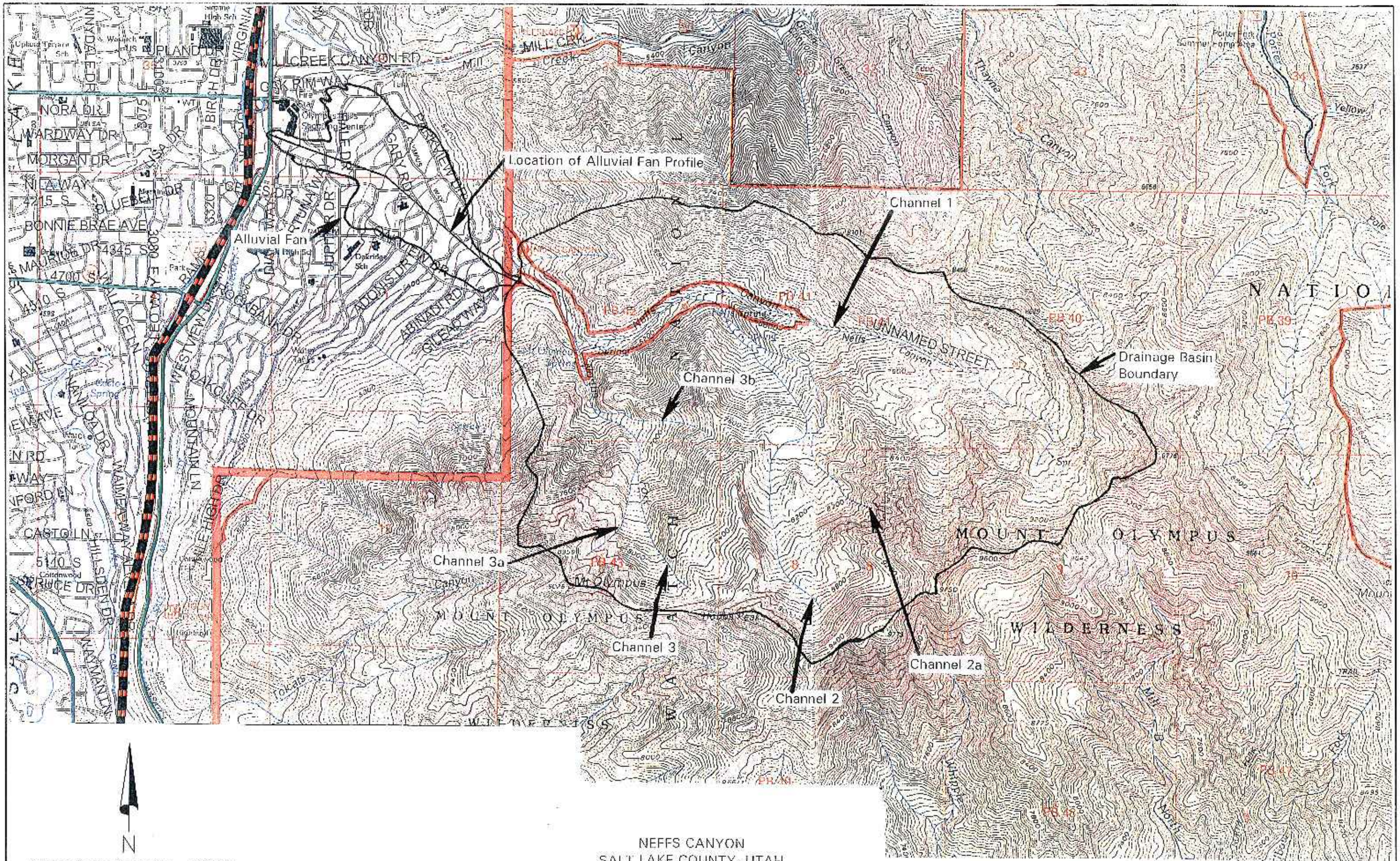
Van Horn, R., 1972; Surficial Geologic Map of the Sugar House Quadrangle, Salt Lake County, Utah, U.S. Geological Survey Map I-766-A.

Wieczorek, G.F., Lips, E.W., and Ellen, S.D, 1989; Debris flows and hyperconcentrated floods along the Wasatch Front, Utah, 1983 and 1984: Bulletin of the Association of Engineering Geologists, Vol. XXVI No. 2, 1989, p. 191-208.

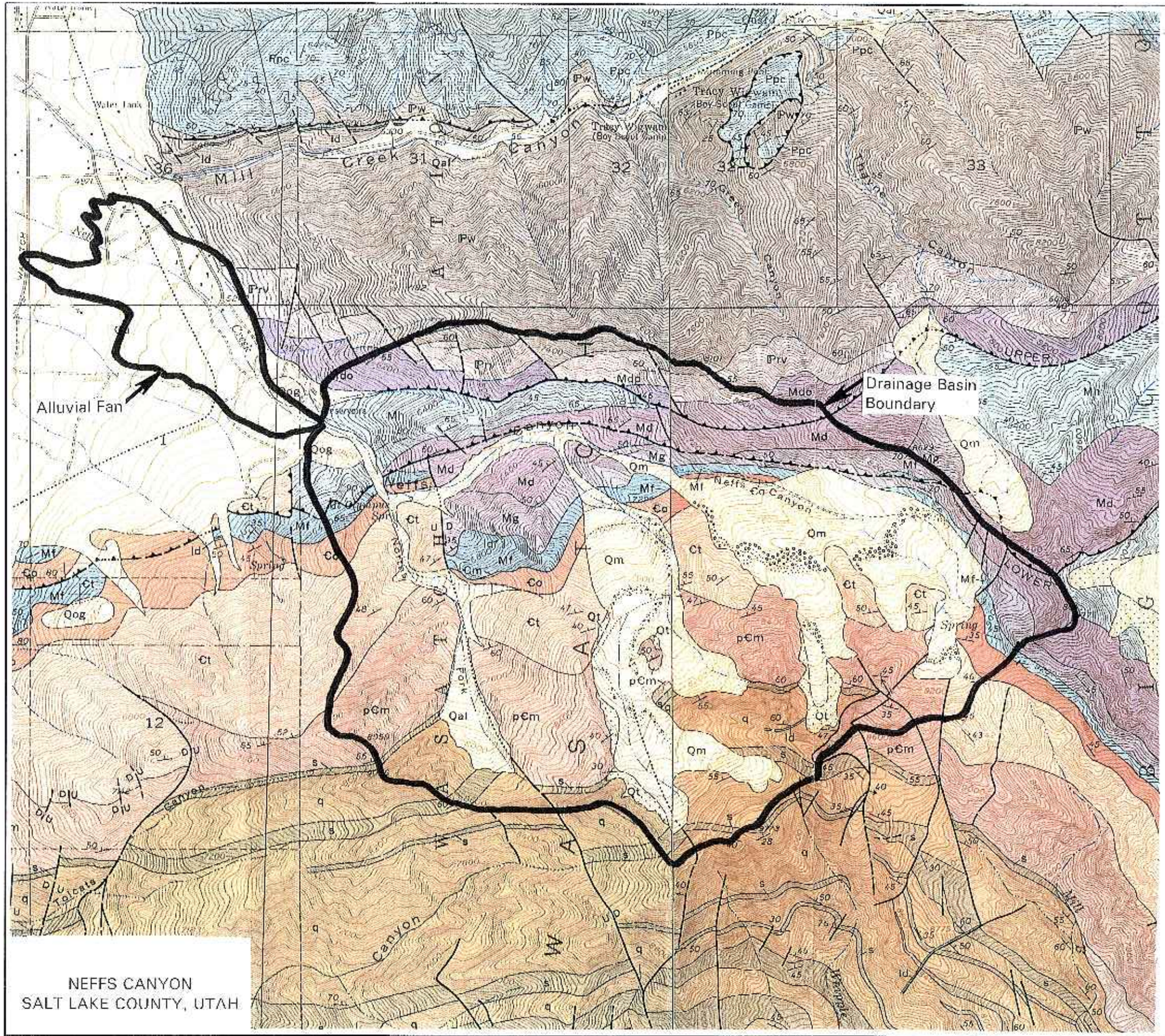
Wieczorek, G.F., Ellen, S., Lips, E.W., Cannon, S.H., an d Short, D.N., 1983; Potential for debris flow and debris flood along the Wasatch Front between Salt Lake City and Willard, Utah, and measures for their mitigation: U. S. Geological Survey Open-File Report 83-635.

Williams, S.R. and Lowe, M., 1990; Process Based Debris-Flow Prediction Method: International Symposium of the Hydraulics/Hydrology of Arid Lands, July 30 - August 3, 1990, San Diego, CA.

Woolley, R.R., 1946; Cloudburst floods in Utah, 1850-1938: U.S. Geological Survey Water Supply Paper 994, 128 p.



1050097	AGEC	Map of Project Area	Figure 1



NEFFS CANYON
SALT LAKE COUNTY, UTAH

BEDROCK GEOLOGY OF PROJECT AREA

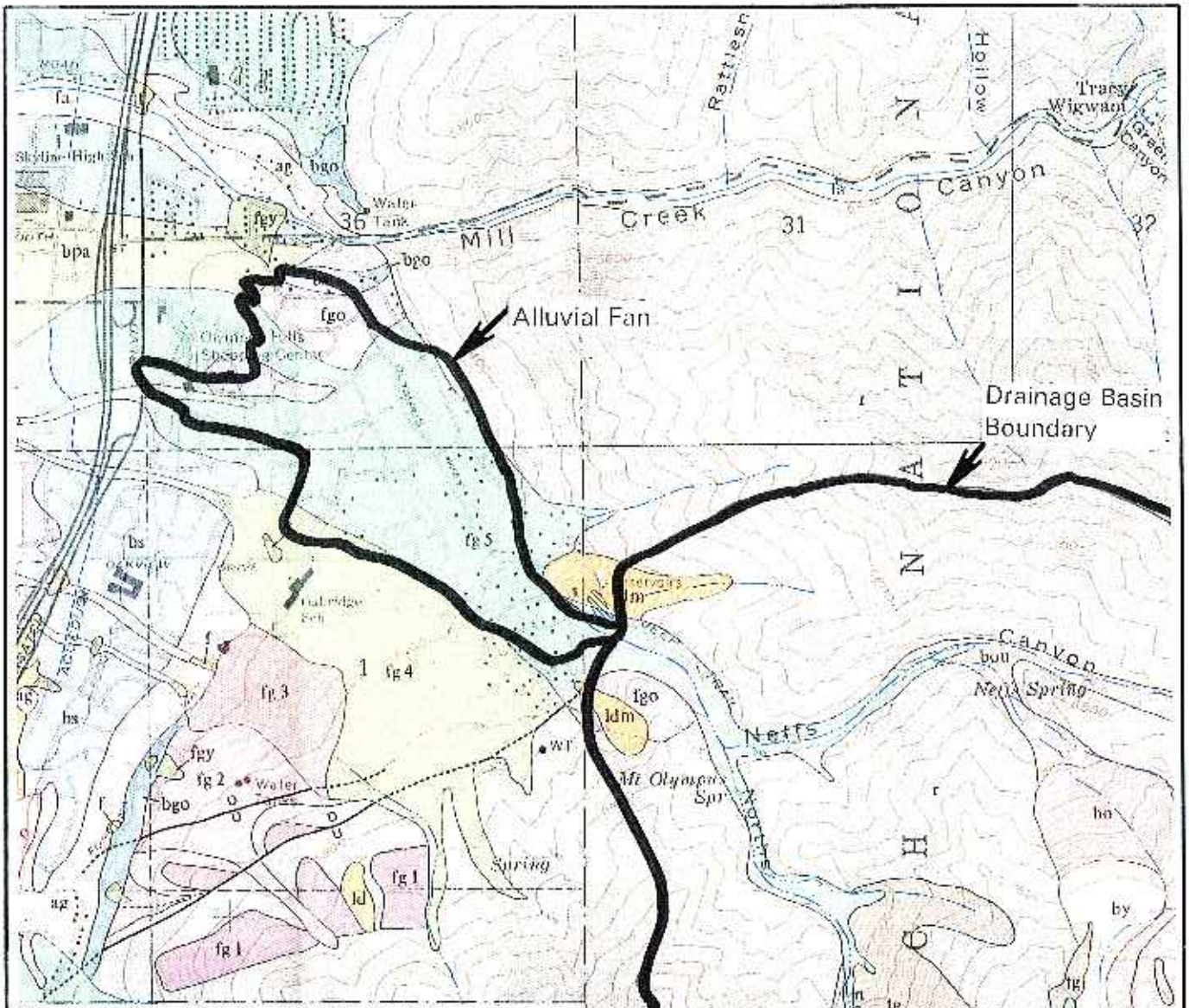
Qal	Alluvial Deposits -	Stream gravel and valley fill (Quaternary)
Qu	Alluvial Deposits -	Undifferentiated alluvium (Quaternary)
Qog	Older Gravel -	Gravel covered benches (Quaternary)
Qm	Glacial Deposits -	(Quaternary)
Pw	Weber Quartzite -	Tan weathering quartzite and limy sandstone (Pennsylvanian)
Prv	Round Valley Limestone -	Limestone containing sparse modules of chert and silicified fossils (Pennsylvanian)
Mdo	Doughnut Formation -	Fine-grained fossiliferous silty limestone (Mississippian)
Mh	Humbug Formation -	Limestone inter bedded with tan weathering sandstone (Mississippian)
Md	Deseret Limestone	Limestone and dolomite with lenses and thin beds of chert (Mississippian)
Mg	Gardison Limestone -	Fossiliferous limestone and dolomite (Mississippian)
Mf	Fitchville Formation -	Massive dolomite with bed of white dolomite on upper part, and bed of coarse-grained sandstone on lower part (Mississippian)
Co	Ophir Formation -	Upper is shaley limestone, middle is light gray limestone, lower worm tracked shale (Cambrain)
Ct	Tintic Quartzite	Coarse-grained vitreous quartzite (Cambrain)
pCm	Mutual Formation	Shale and quartzite grading into grit and coarse boulder conglomerate (Pre-Cambrain)
q,s	Big Cottonwood Formation -	q, Quartzite unit; s, Shale or siltstone unit (Pre-Cambrain)

N

Approximate Scale
1" = 2,000'

Modified from Crittenden (1965a, 1965b)

1050097	AGEC	Bedrock Geology of Project Area	Figure 2



SURFICIAL GEOLOGY OF PROJECT AREA

Alluvial Fan Deposits

fg5, fg4	Undifferentiated alluvial fan deposits younger than Bonneville Shoreline (Pleistocene)
fgo, fg3, fg2, fg1	Undifferentiated alluvial fan deposits older than Bonneville Shoreline (Pleistocene)

Landslide Deposits

ld	Landslide deposit (Quarternary)
ldm	Mudflow (Quarternary)

tg - Talus; loose angular rock fragments (Quarternary)

Bull Lake Glaciation - Till; boulders, cobbles, sand and silt (Pleistocene)

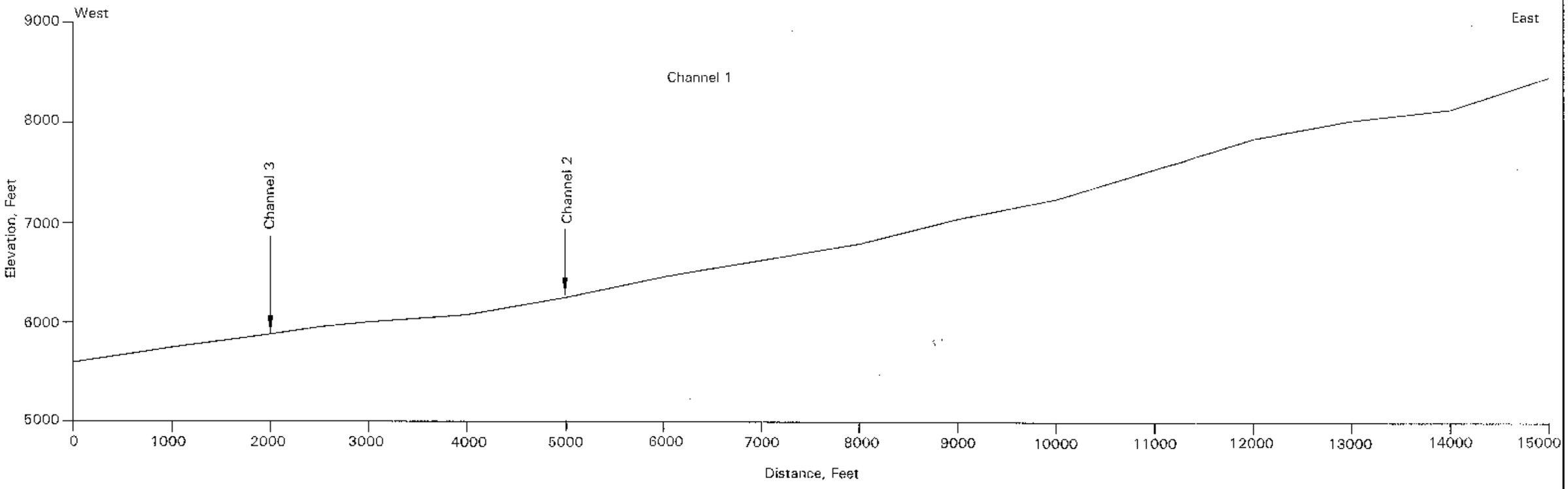
bo	Older till
by	Younger till
bou	Outwash, bouldery to silty gravel and sand (Pleistocene)
r	Bedrock (Jurassic to Precambrian)

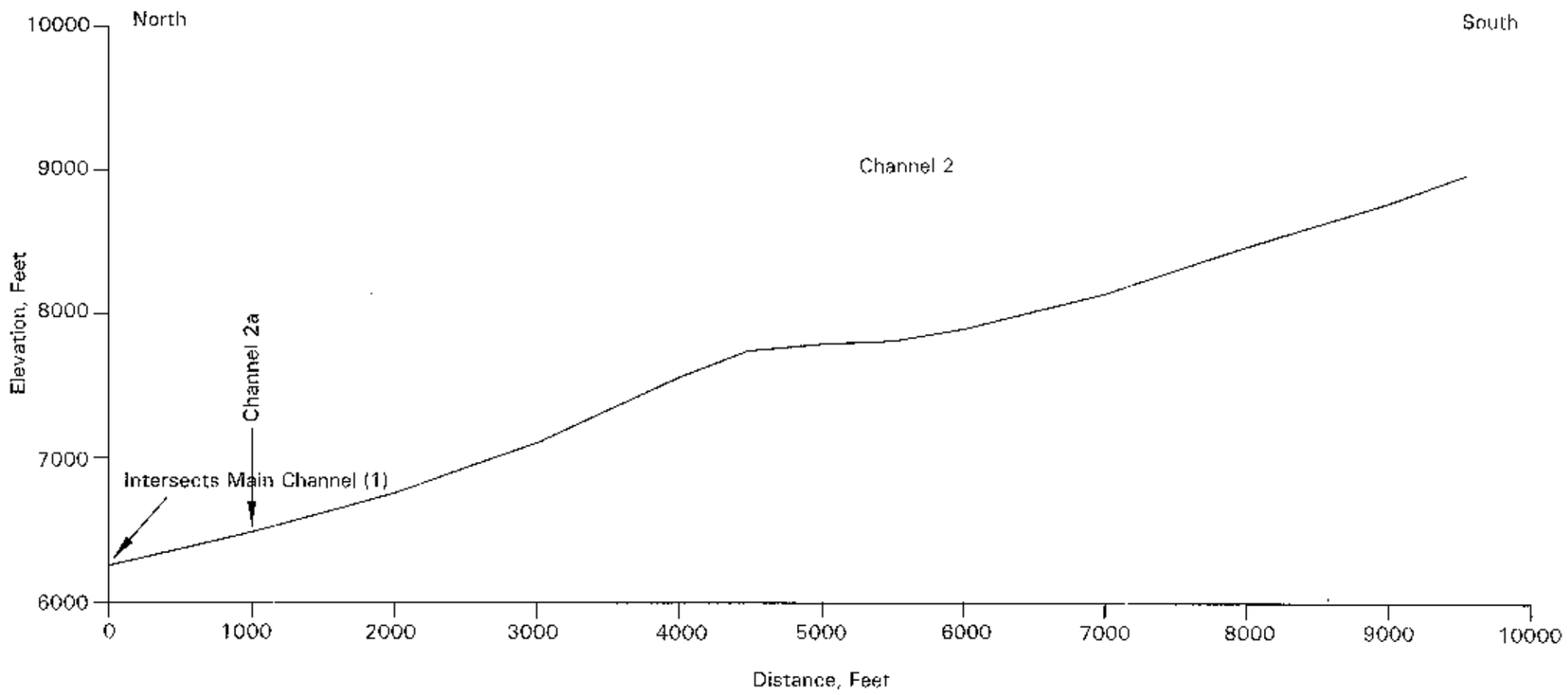
NEFFS CANYON
SALT LAKE COUNTY, UTAH

Approximate Scale
1" = 2,000'

modified from Van Horn (1972)

1050097	AGEC	Surficial Geology of Project Area	Figure 3





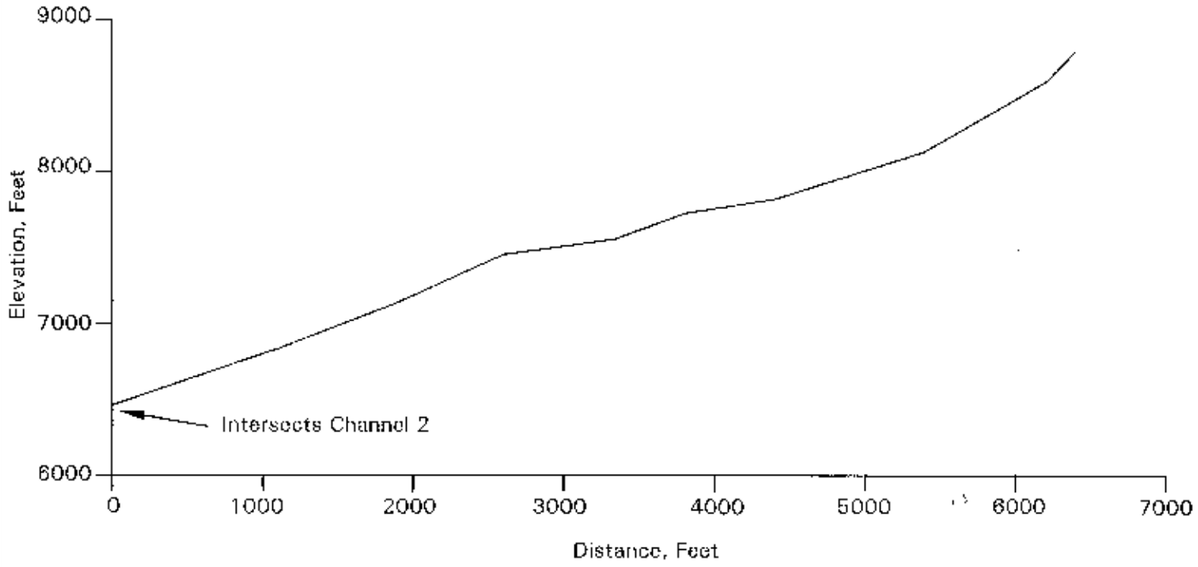
See Figure 1 for Locations of Channels

1050097	AGEC	Neffs Canyon Channels 1 and 2 Profiles	Figure 4

Channel 2a

Northwest

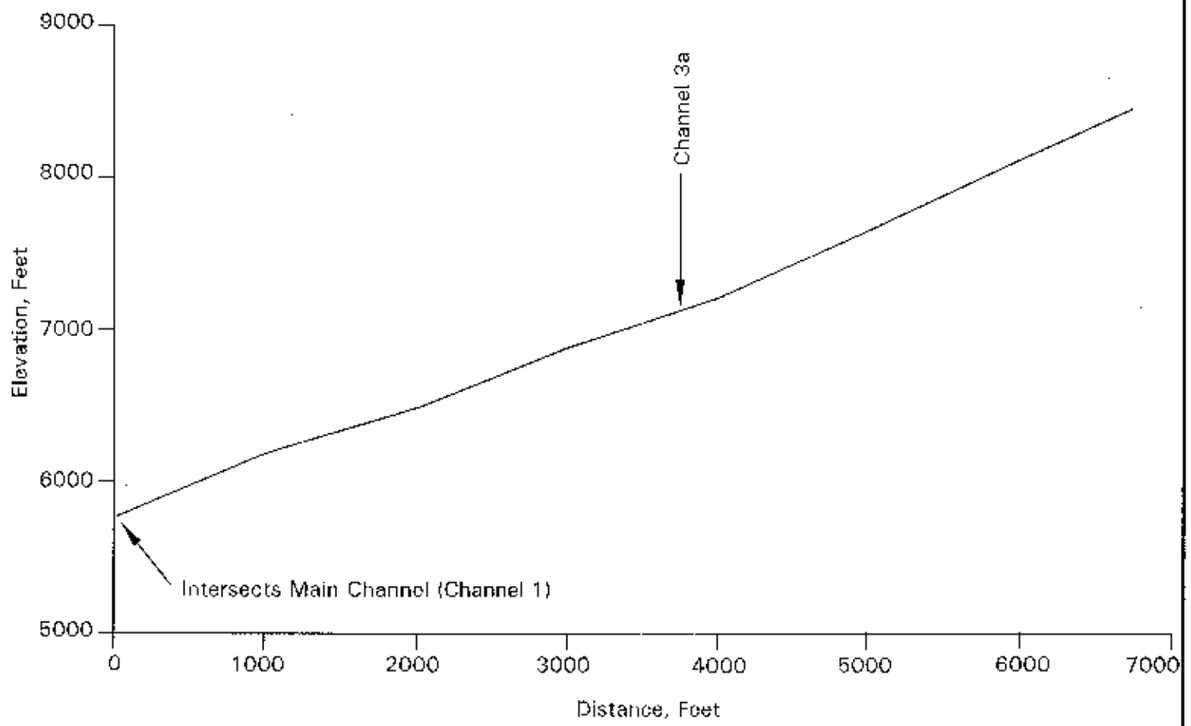
Southeast



Channel 3

North

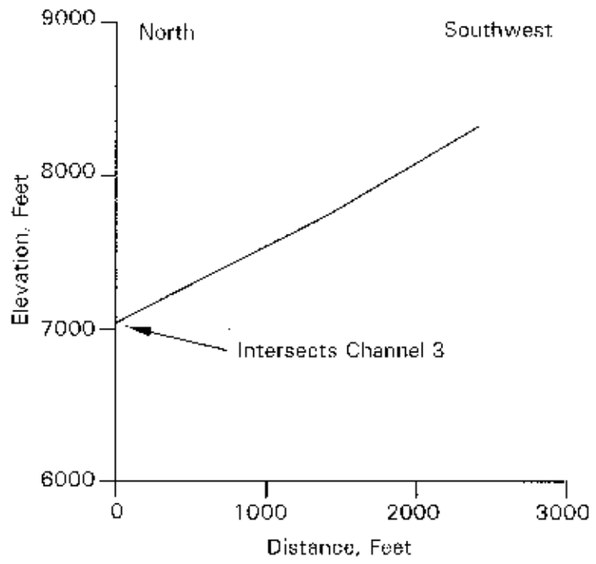
South



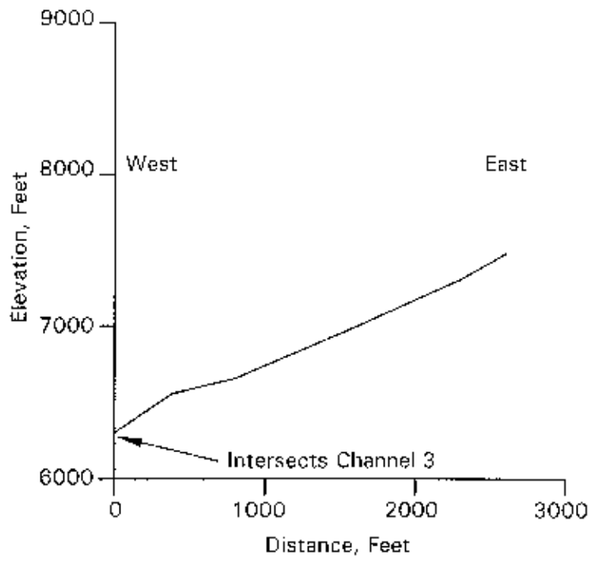
See Figure 1 for Locations of Channels

1050097	AGEC	Neffs Canyon Channels 2a and 3 Profiles	Figure 5

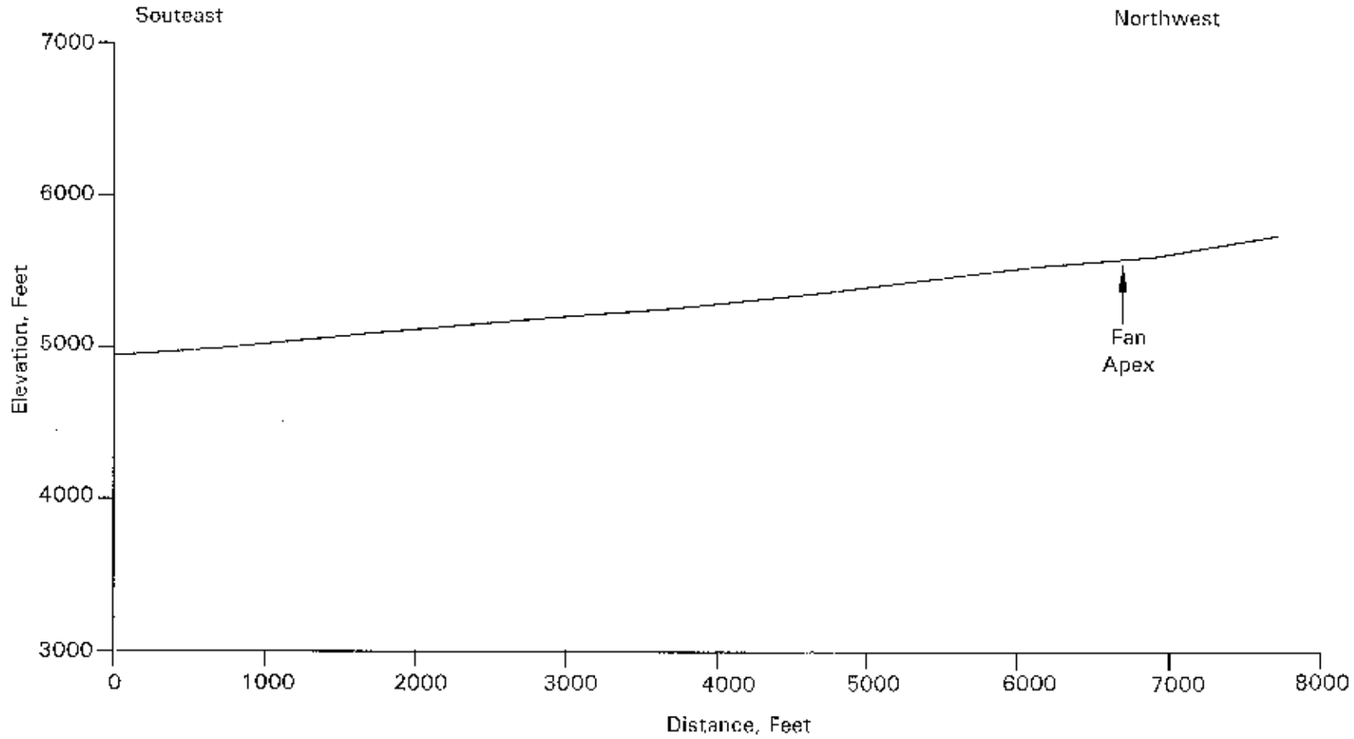
Channel 3a



Channel 3b

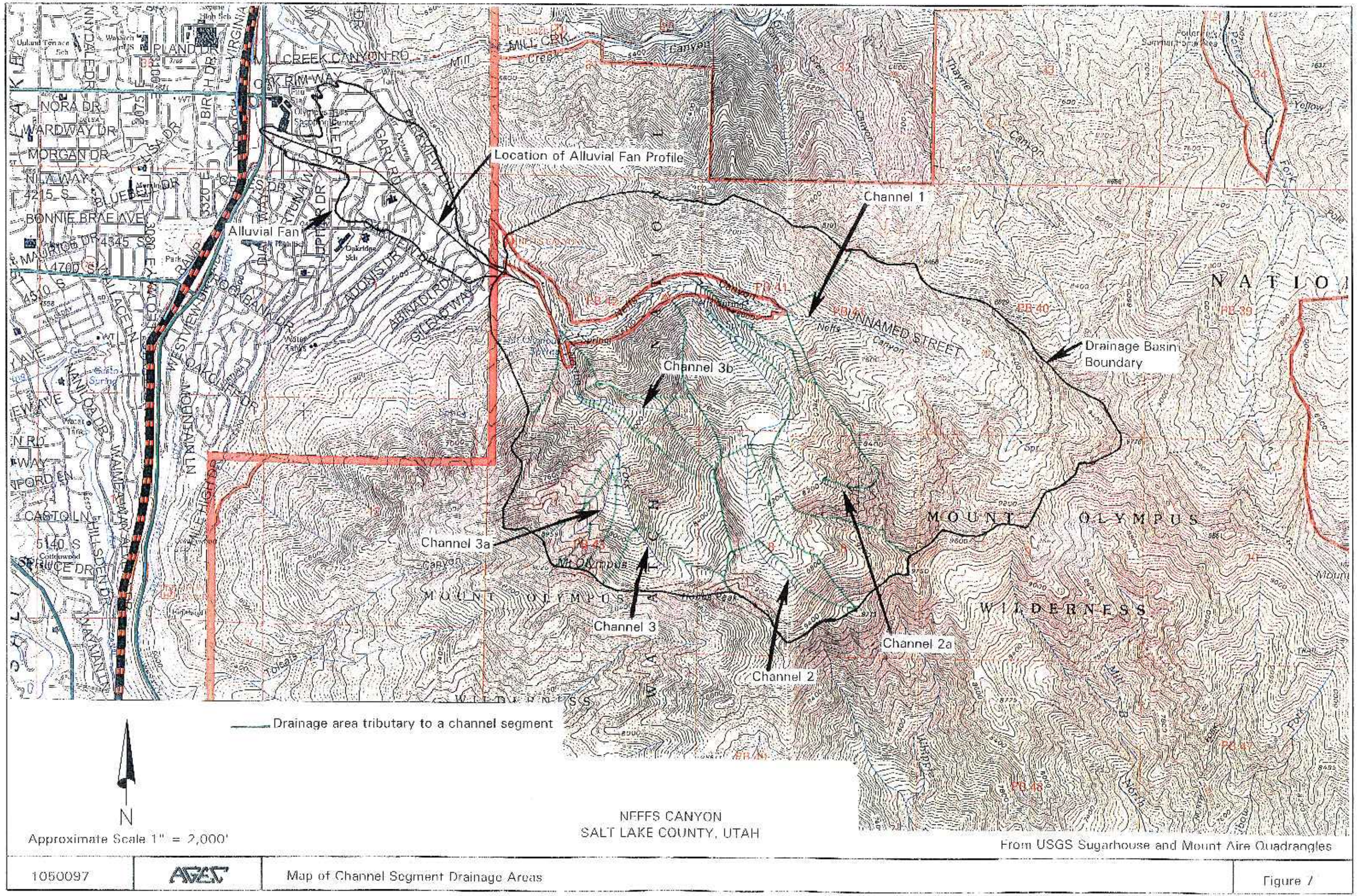


Neffs Canyon Alluvial Fan Profile



See Figure 1 for Locations of Channels

1050097	AGEC	Neffs Canyon Channels 3a, 3b and Alluvial Fan Profiles	Figure 6



Approximate Scale 1" = 2,000'

NEFFS CANYON
SALT LAKE COUNTY, UTAH

From USGS Sugarhouse and Mount Aire Quadrangles

1050097	AGEC	Map of Channel Segment Drainage Areas	Figure 1

APPENDIX B

Floodplain Workmaps

1110 State Office Building
Salt Lake City, UT 84114-1710

Neffs Creek Flood Hazard Assessment

LEGEND

- Limit of Study
- 2-Foot Contour Topography

Revised Floodplains

Zone,Depth,Velocity

- A
- AO, 2, 1
- AO, 2, 2
- AO, 2, 3
- AO, 3, 3
- AO, 3, 4
- SHADED X

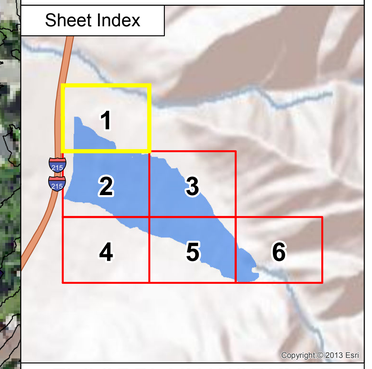
N W E S

0 50 100 200

Feet

NOTES:
1. Base imagery: NAIP 2014 Orthophotography
2. 2-foot contour topography generated from Salt Lake County LiDAR mapping.

Sheet Index



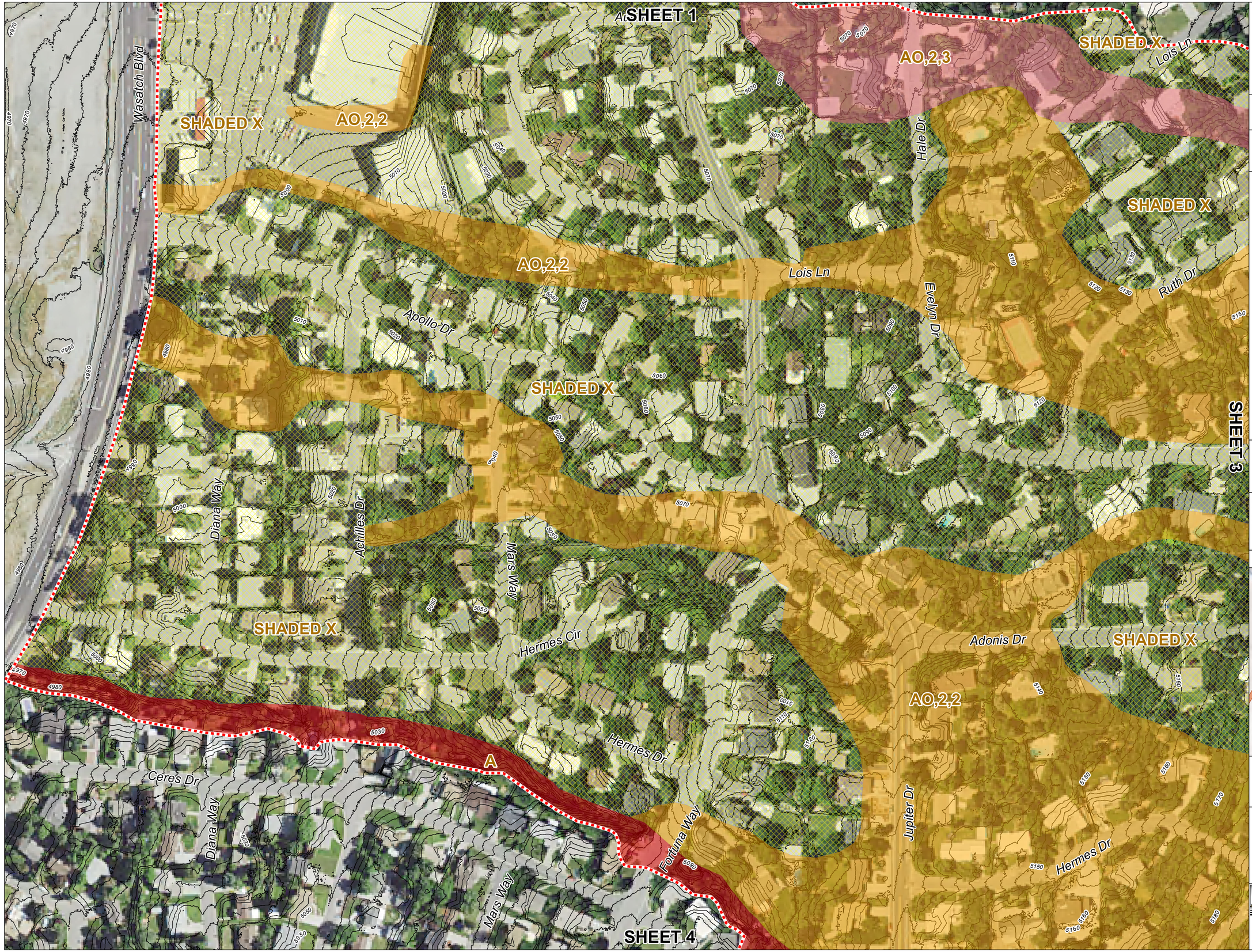
FLOODPLAIN WORKMAP

SHEET 1 OF 6

REGISTERED PROFESSIONAL ENGINEER
No. 8219199-2202
NATHAN BRUCE LOGAN
03/02/2016
STATE OF UTAH

LICENSED PROFESSIONAL GEOLOGIST
MICHAEL J. KELLOGG
6111914-2250
03/02/2016
STATE OF UTAH

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.
8400 South Kyrene Road, Suite 201
Tempe, AZ 85284
Phone: 480.752.2124



1110 State Office Building
Salt Lake City, UT 84114-1710

Neffs Creek Flood Hazard Assessment

LEGEND

- Limit of Study
- 2-Foot Contour Topography

Revised Floodplains

Zone,Depth,Velocity

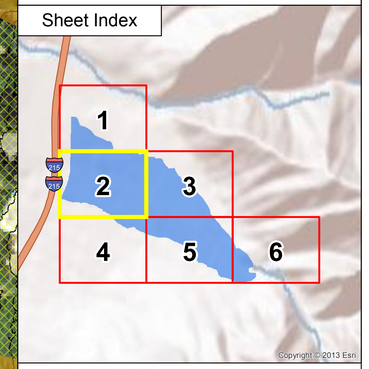
- A
- AO, 2, 1
- AO, 2, 2
- AO, 2, 3
- AO, 3, 3
- AO, 3, 4
- SHADED X

N W E S

0 50 100 200
Feet

NOTES:
1. Base imagery: NAIP 2014 Orthophotography
2. 2-foot contour topography generated from Salt Lake County LiDAR mapping.

Sheet Index



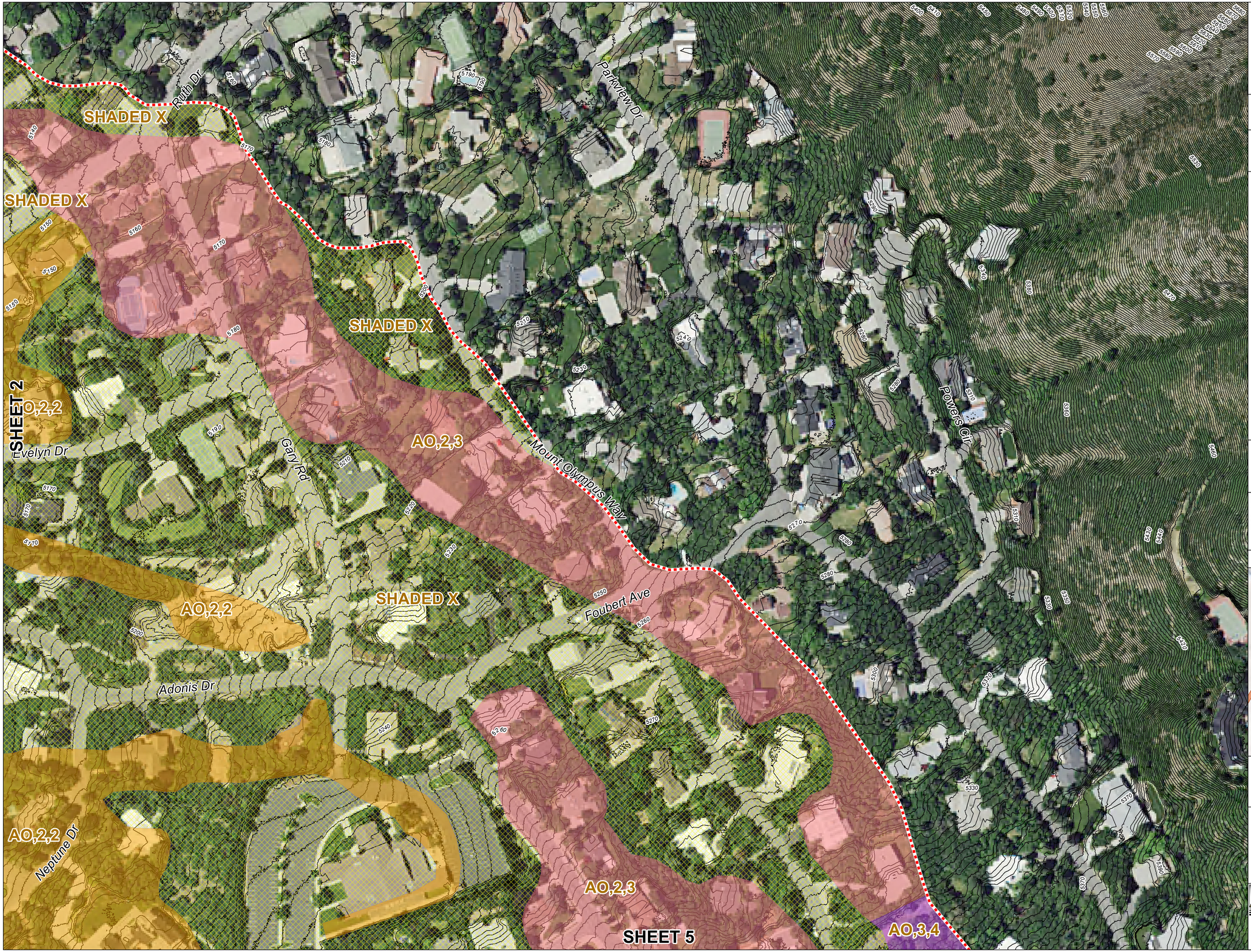
FLOODPLAIN WORKMAP

SHEET 2 OF 6

REGISTERED PROFESSIONAL ENGINEER
NO. 8219199-2202
NATHAN BRUCE LOGAN
03/02/2016
STATE OF UTAH

LICENSED PROFESSIONAL GEOLOGIST
MICHAEL J. KELLOGG
6111914-2250
03/02/2016
STATE OF UTAH

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.
8400 South Kyrene Road, Suite 201
Tempe, AZ 85284
Phone: 480.752.2124



1110 State Office Building
Salt Lake City, UT 84114-1710

Neffs Creek Flood Hazard Assessment

LEGEND

Limit of Study

2-Foot Contour Topography

Revised Floodplains

Zone,Depth,Velocity

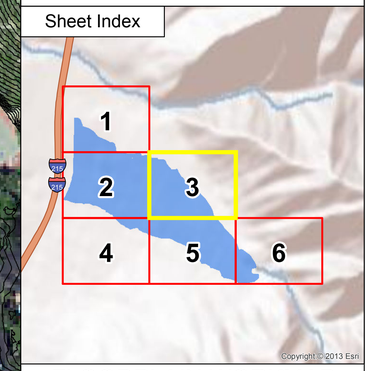
- A
- AO, 2, 1
- AO, 2, 2
- AO, 2, 3
- AO, 3, 3
- AO, 3, 4
- SHADED X

N W E S

0 50 100 200
Feet

NOTES:
1. Base imagery: NAIP 2014 Orthophotography
2. 2-foot contour topography generated from Salt Lake County LiDAR mapping.

Sheet Index



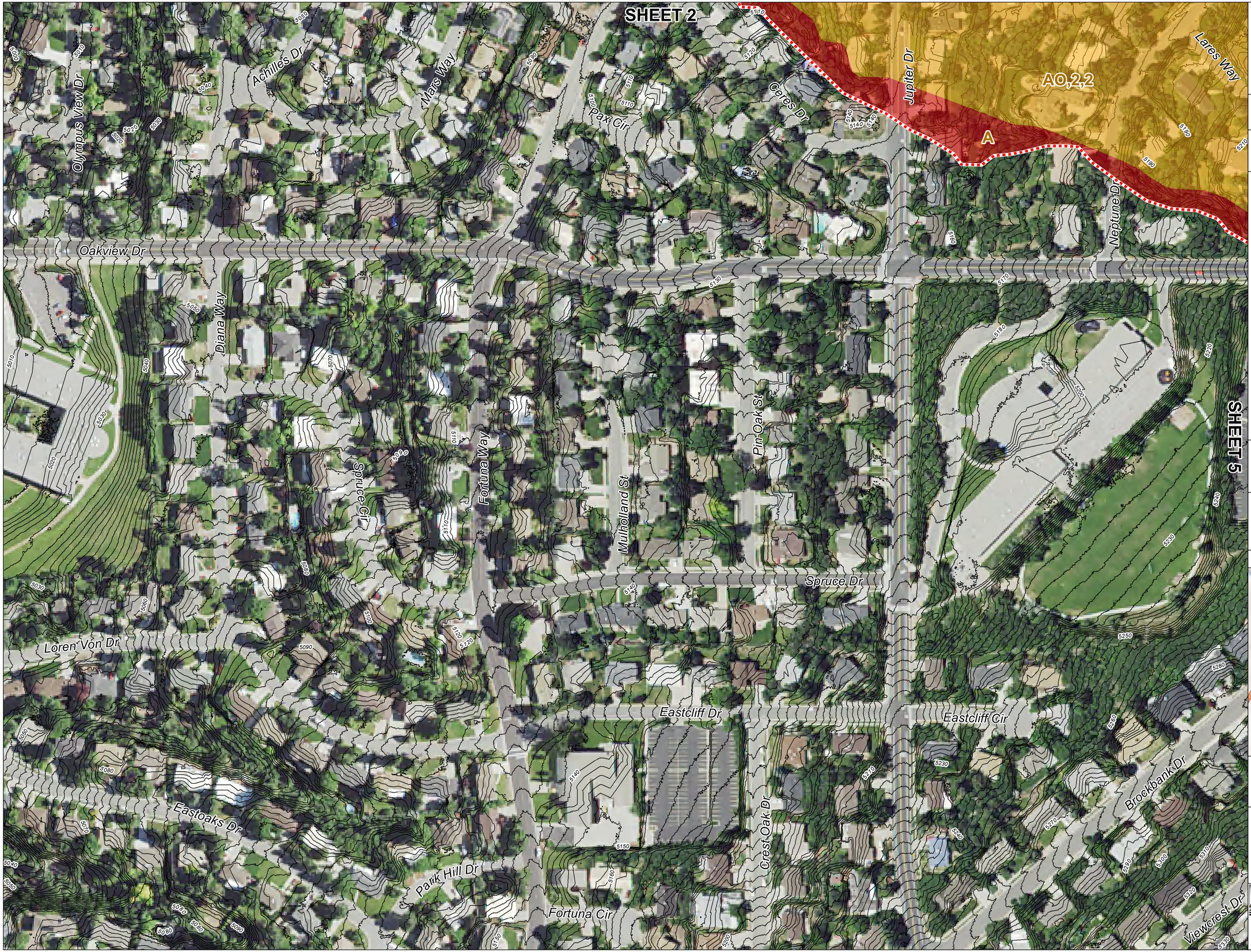
FLOODPLAIN WORKMAP

SHEET 3 OF 6

REGISTERED PROFESSIONAL ENGINEER
No. 9219187-2202
NATHAN BRUCE LOGAN
03/02/2016
STATE OF UTAH

LICENSED PROFESSIONAL GEOLOGIST
MICHAEL J. KELLOGG
6111914-2250
03/02/2016
STATE OF UTAH

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.
8400 South Kyrene Road, Suite 201
Tempe, AZ 85284
Phone: 480.752.2124



1110 State Office Building
Salt Lake City, UT 84114-1710

Neffs Creek Flood Hazard Assessment

LEGEND

- Limit of Study
- 2-Foot Contour Topography

Revised Floodplains

Zone,Depth,Velocity

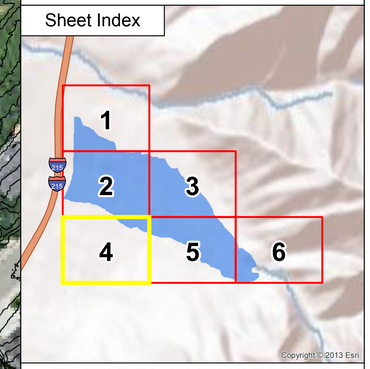
- A
- AO, 2, 1
- AO, 2, 2
- AO, 2, 3
- AO, 3, 3
- AO, 3, 4
- SHADED X

N W E S

0 50 100 200
Feet

NOTES:
1. Base imagery: NAIP 2014 Orthophotography
2. 2-foot contour topography generated from Salt Lake County LiDAR mapping.

Sheet Index



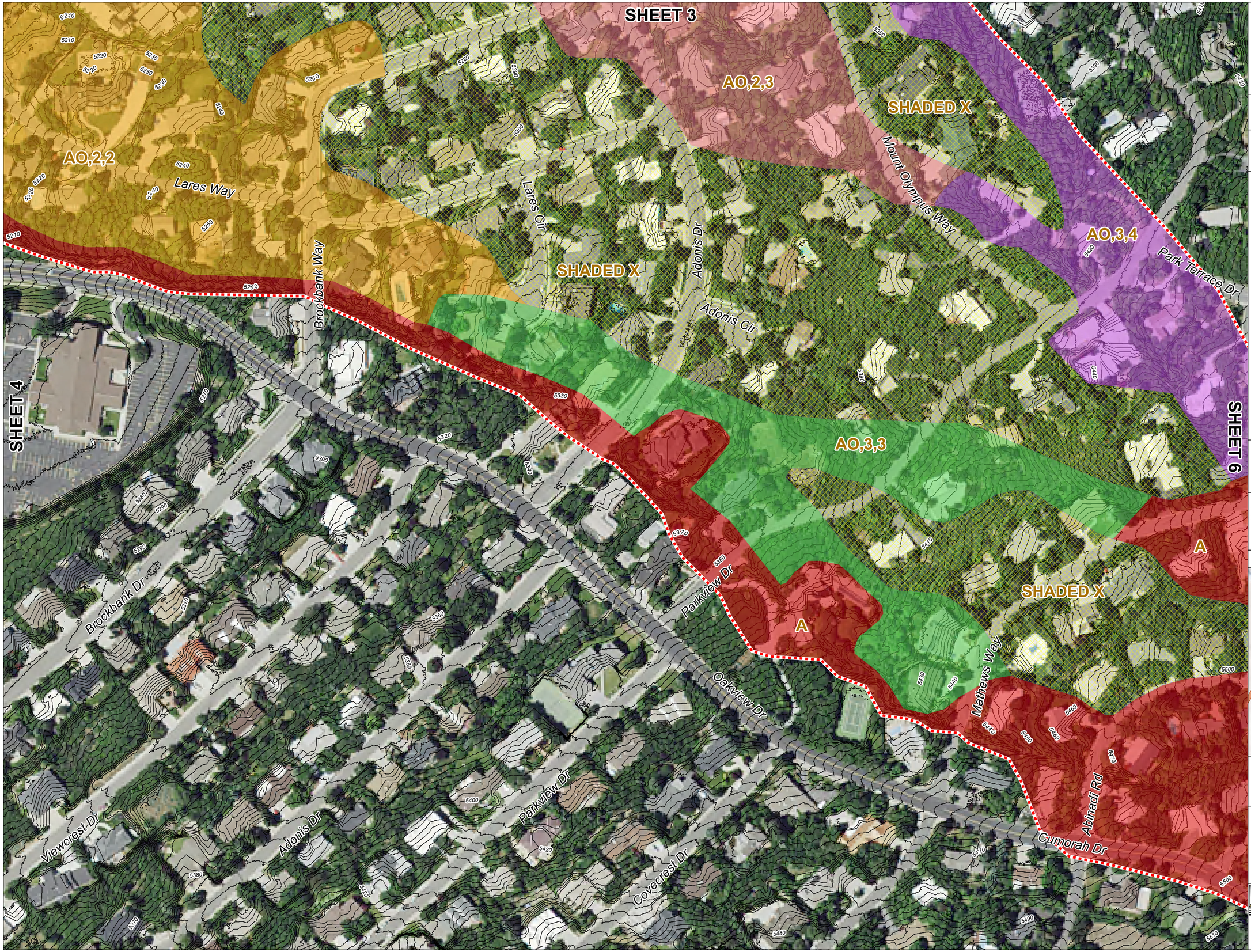
FLOODPLAIN WORKMAP

SHEET 4 OF 6

REGISTERED PROFESSIONAL ENGINEER
No. 8219199-2202
NATHAN BRUCE LOGAN
03/02/2016
STATE OF UTAH

LICENSED PROFESSIONAL GEOLOGIST
MICHAEL J KELLOGG
6111914-2250
03/02/2016
STATE OF UTAH

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.
8400 South Kyrene Road, Suite 201
Tempe, AZ 85284
Phone: 480.752.2124



1110 State Office Building
Salt Lake City, UT 84114-1710

Neffs Creek Flood Hazard Assessment

LEGEND

- Limit of Study
- 2-Foot Contour Topography

Revised Floodplains

Zone,Depth,Velocity

- A
- AO, 2, 1
- AO, 2, 2
- AO, 2, 3
- AO, 3, 3
- AO, 3, 4
- SHADED X

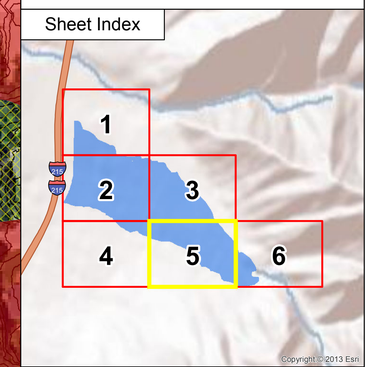
N W E S

0 50 100 200

Feet

NOTES:
1. Base imagery: NAIP 2014 Orthophotography
2. 2-foot contour topography generated from Salt Lake County LiDAR mapping.

Sheet Index



FLOODPLAIN WORKMAP

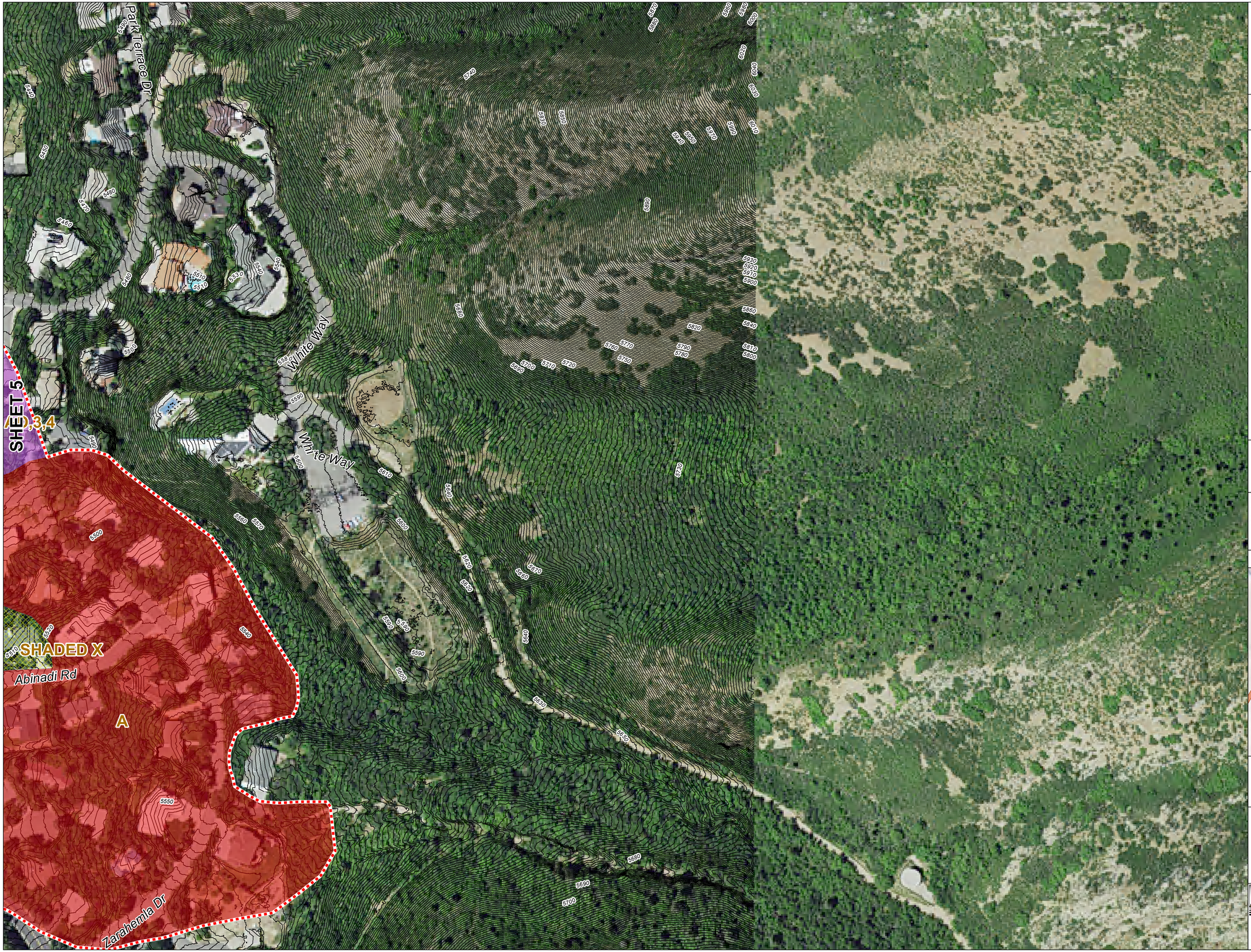
SHEET 5 OF 6

REGISTERED PROFESSIONAL ENGINEER
No. 6219197-2202
NATHAN BRUCE COGAN
03/02/2016
STATE OF UTAH

LICENSED PROFESSIONAL GEOLOGIST
MICHAEL J. KELLOGG
6111914-2250
03/02/2016
STATE OF UTAH

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.

8400 South Kyrene Road, Suite 201
Tempe, AZ 85284
Phone: 480.752.2124



1110 State Office Building
Salt Lake City, UT 84114-1710

Neffs Creek Flood Hazard Assessment

LEGEND

- Limit of Study
- 2-Foot Contour Topography

Revised Floodplains

Zone,Depth,Velocity

- A
- AO, 2, 1
- AO, 2, 2
- AO, 2, 3
- AO, 3, 3
- AO, 3, 4
- SHADED X

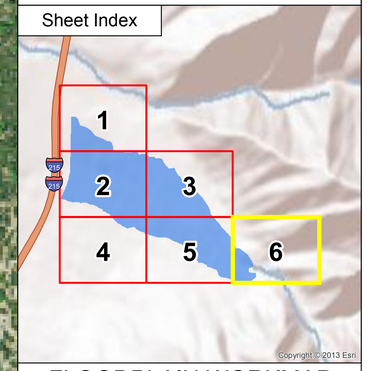
N W E S

0 50 100 200

Feet

NOTES:
1. Base imagery: NAIP 2014 Orthophotography
2. 2-foot contour topography generated from Salt Lake County LiDAR mapping.

Sheet Index



FLOODPLAIN WORKMAP

SHEET 6 OF 6

REGISTERED PROFESSIONAL ENGINEER
NATHAN BRUCE LOGAN
NO. 8219199-2202
03/02/2016
STATE OF UTAH

LICENSED PROFESSIONAL GEOLOGIST
MICHAEL J. KELLOGG
6111914-2250
03/02/2016
STATE OF UTAH

JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.
8400 South Kyrene Road, Suite 201
Tempe, AZ 85284
Phone: 480.752.2124

APPENDIX C

Hansen, Allen & Luce (HAL), 2007, Neffs Canyon Creek Master Plan. Salt Lake County

SALT LAKE COUNTY

NEFFS CANYON CREEK MASTER PLAN

(HAL Project No.: 014.10.100)

FINAL REPORT

December 2007

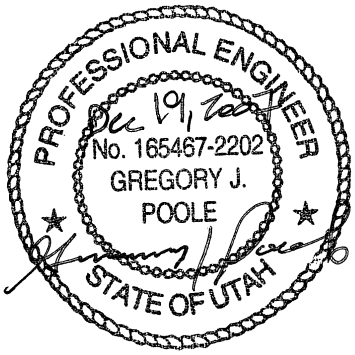
HANSEN ALLEN & LUCE INC
ENGINEERS

SALT LAKE COUNTY

NEFFS CANYON CREEK MASTER PLAN

(HAL Project No.: 014.10.100)

FINAL REPORT



Project Manager

HANSEN ALLEN & LUCE inc
ENGINEERS
6771 South 900 East
Midvale, Utah 84047
(801) 566-5599

December 2007

ACKNOWLEDGMENTS

Successful completion of this study was made possible by the cooperation and assistance of many individuals, including the Salt Lake County Public Works Engineering, Flood Control Division , as shown below. We sincerely appreciate the cooperation and assistance provided by these individuals.

Salt Lake County Public Works Engineering, Flood Control

Neil Stack
Brent Beardall

Mount Olympus Community Council

North Area:
Jeff Silvestrini
Judy Keane
Darrel French

Central Area:
Ken Smith
Warren Davis
Shonnie Hayes

South Area:
Nick Powell
Pat English
Carol Morgan
Tom Brown

Merrill Ridd

HAL PROJECT TEAM

Gregory J. Poole, Principal-in-Charge
David E. Hansen, Quality Assurance
Ben Miner, Hydraulics
Gordon Jones, Hydrology

TABLE OF CONTENTS

INTRODUCTION I-1
- BACKGROUND AND PURPOSE I-1
- OBJECTIVES I-1
- SCOPE I-1
- AUTHORIZATION I-1

HYDROLOGY II-1
- DRAINAGE BASIN CHARACTERISTICS II-1
  - Subbasin Area II-1
  - Hydrologic Soil Group II-1
  - Percentage of Impervious Area II-1
  - SCS Curve Number II-2
  - Basin Lag Time II-2
  - Conveyance System Routing II-2
- MOUNTAIN AREAS II-3
- URBAN AREAS II-3
- DESIGN RAINSTORM II-4
  - Storm Duration Sensitivity Analysis II-5
  - Storm Distribution II-5
  - Aerial Reduction II-6
  - Rainfall Adjustment II-7
- TRANSMISSION LOSSES II-7
- DESIGN FLOWS II-7
- SNOW MELT II-8

DEBRIS FLOW HAZARD STUDY III-9

EXISTING CONVEYANCE SYSTEM DESCRIPTION AND CAPACITY IV-1

ALTERNATIVE EVALUATION V-1
- DEBRIS FLOW MITIGATION ALTERNATIVES V-1
- DEBRIS BASIN ALTERNATIVES V-1
  - Upper Debris Basin V-2
  - Lower Debris Basin V-2
- URBAN AREA FLOOD CONVEYANCE SYSTEM ALTERNATIVES V-2
- DESIGN FLOWS VI-1

APPENDIX
A GLOSSARY AND ABBREVIATIONS
B HYDROLOGY
C HYDRAULICS
D COST ESTIMATES
COMPACT DISK (Debris Flow Hazard Study (AGEC), HEC-HMS files, and HEC-RAS files)

LIST OF TABLES

NO.	TITLE	PAGE
TABLE II-1	NEFFS CANYON SUBBASIN CHARACTERISTICS FOR MOUNTAIN AREAS	II-3
TABLE II-2	NEFFS CANYON SUBBASIN CHARACTERISTICS FOR URBAN AREAS	II-4
TABLE II-3	COMPARISON OF TRC 1999 AND NOAA 14 RAINFALL DEPTHS	II-4
Table II-4	AREAL REDUCTION FACTORS	II-6
Table II-5	ADJUSTED PRECIPITATION VALUES FOR 100-YEAR DURATION	II-7
Table II-6	NEFFS CANYON CREEK – DESIGN FLOW RATES	II-8
Table II-7	ESTIMATED SNOW MELT FLOW RATES	II-8
TABLE IV-I	ESTIMATED CAPACITY OF EXISTING CULVERTS	IV-1
TABLE V-1	NEFFS CANYON CREEK CONVEYANCE ALTERNATIVES COMPARATIVE MATRIX	V-3
Table VI-1	NEFFS CANYON CREEK – DESIGN FLOW RATES	VI-1
Table VI-2	ESTIMATED SNOW MELT FLOW RATES	VI-1

LIST OF FIGURES

NO.	TITLE	AFTER PAGE
Figure II-1	DRAINAGE SUBBASIN BOUNDARIES	II-1
Figure IV-1	EXISTING NEFFS CREEK CAHNNEL ALIGNMENT	IV-1
Figure IV-2	CURRENT NEFFS CHANNEL AND CANYON THALWEG	IV-1
Figure V-1	ALTERNATIVE DEBRIS BASIN LOCATIONS	V-1
Figure V-2	UPPER DEBRIS BASIN ALTERNATIVE	V-2
Figure V-3	LOWER DEBRIS BASIN ALTERNATIVE	V-2
Figure V-4	CONVEYANCE SYSTEM ALTERNATIVES	V-2
Figure IV-2	NEFFS CREEK CONVEYANCE IMPROVEMENTS	VI-2

CHAPTER I

INTRODUCTION

BACKGROUND AND PURPOSE

Neffs Creek is directly tributary to a residential development at the Canyon mouth. The 2002 Flood Insurance Study identified flooding associated with Neffs Creek affecting approximately 150 homes (see Flood Insurance Rate Map panels 49035C0316E and 49035C0317E). Currently normal Neffs Creek flows are conveyed to a storm drain system in Wasatch Boulevard.

The Neffs Canyon conveyance system was constructed prior to the inception of the Federal Flood Insurance Program. A key purpose of Salt Lake County Flood Control is to plan drainage improvements to better protect County residents from flooding and bring the system up to the requirements of the Federal Flood Insurance Program.

OBJECTIVES

Define the 100-year flood flows.

Evaluate debris flow hazard.

Identify means for flood and debris flow hazard mitigation.

SCOPE

The scope of the Neffs Canyon Creek Master Plan included the following:

Documentation and review of the existing Neffs Canyon Creek conveyance system,

Hydrologic analyses to define design stream flows.

Debris flow hazard evaluation.

Develop alternatives for mitigating flood hazards to residences.

Participate in public meetings to receive public input on flood hazard mitigation alternatives.

Prepare Master Plan Document.

AUTHORIZATION

The Neffs Canyon Creek Master Plan has been completed in accordance with a contract approved on April 7, 2005 between Salt Lake County and Hansen, Allen, & Luce, Inc.

CHAPTER II

HYDROLOGY

DRAINAGE BASIN CHARACTERISTICS

A drainage basin is an area where all precipitation that falls within it will collect to a common point. Another name for a drainage basin is watershed or catchment. Subbasins are located within a larger drainage basin. Drainage subbasin boundaries depend upon both the topography and the location of storm drainage facilities. The delineated Neffs Creek drainage basin and subbasin boundaries are shown on Figure II-1.

Subbasin characteristics were developed based on field observations and the GIS mapping supplied by Salt Lake County. Important subbasin characteristics discussed in this report include:

- Subbasin Area
- Hydrologic Soil Group
- Percentage of Impervious Area
- SCS Curve Number
- Basin Lag Time
- Conveyance System Routing

Subbasin Area

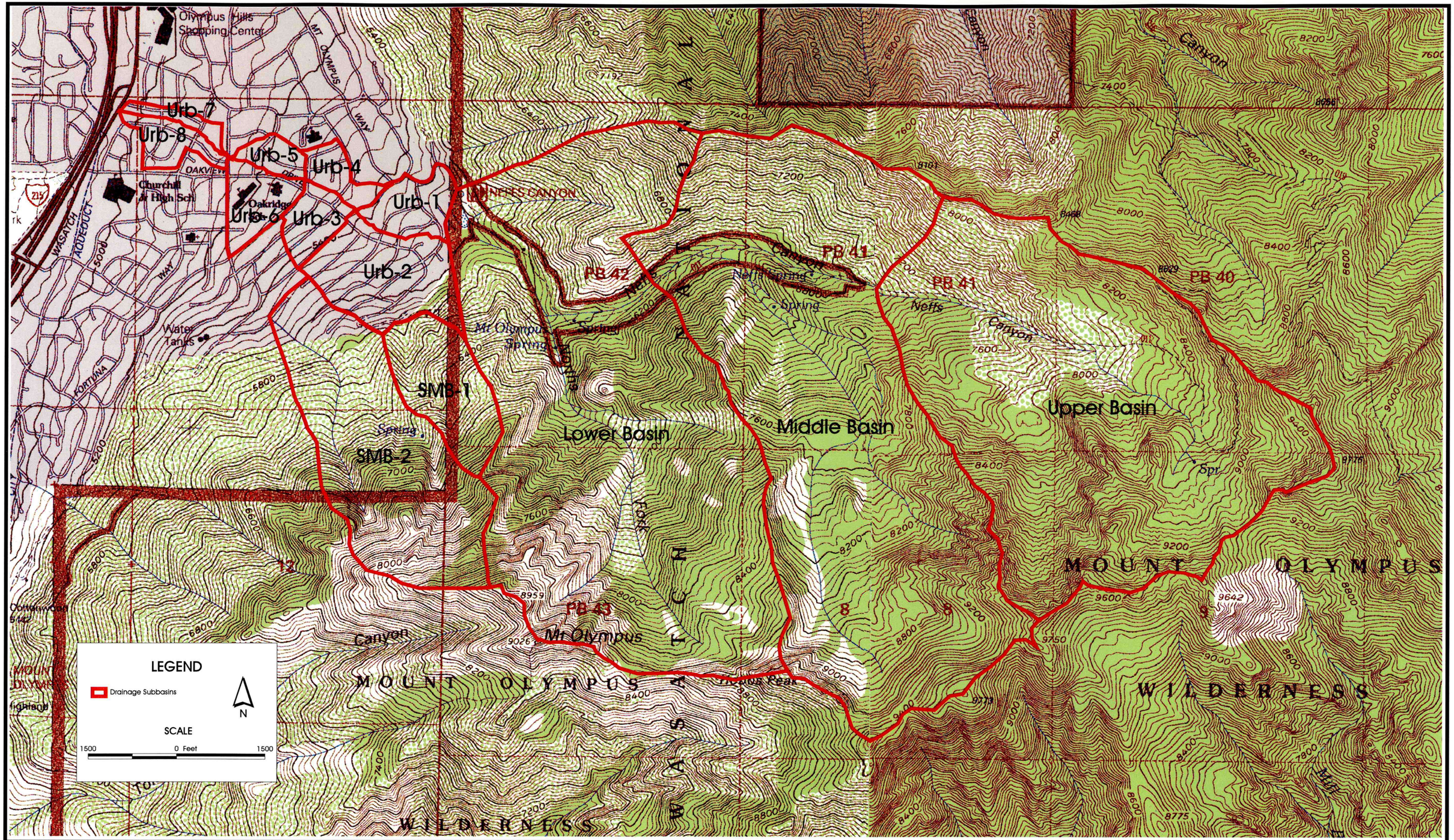
Subbasins were delineated within ArcView GIS using USGS Topographic Quadrangle maps and the locations of storm drainage facilities. Mountain watersheds were divided into subbasins where distinct vegetation, soil type and precipitation characteristics were found.

Hydrologic Soil Group

Hydrologic soil group is a indication of the soil's minimum infiltration rate. Soils are assigned a hydrologic group of A, B, C, or D by the Natural Resource Conservation Service (NRCS, formerly know as the Soil Conservation Service, SCS). Soils of hydrologic soil group A have the highest infiltration rate, and therefore produce the least amount of runoff. Soils of hydrologic soil group D have the lowest infiltration rate, and therefore produce the highest amount of runoff. Soil maps were obtained from the Natural Resources Conservation Service (NRCS) Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/app/).

Percentage of Impervious Area

Impervious areas within each urban subbasin were estimated using the GIS model. The impervious area was divided into two components: directly connected impervious areas and unconnected impervious areas. Directly connected impervious areas provide a direct path for runoff from the impervious area to a conveyance such as a pipe, gutter, or channel. Directly connected impervious areas include roadways, parking lots, driveways, and sometimes the roofs of buildings. Runoff from unconnected impervious areas include sidewalks that are not



HANSEN ALLEN & LUCE inc ENGINEERS	SALT LAKE COUNTY PUBLIC WORKS NEFFS CANYON CREEK MASTER PLAN	DRAINAGE SUBBASIN BOUNDARIES	FIGURE II-1

adjacent to the curb, patios, sheds, and usually some portion of the roof of the house or structure. Unconnected impervious area is combined with the pervious area of a subbasin resulting in a weighted curve number for unconnected area.

SCS Curve Number

The SCS curve number methodology is described in the NRCS publication TR-55. A curve number is determined based on several factors described in the manual. These factors include: hydrologic soil group, cover type, treatment and hydrologic condition. The hydrologic soil groups were discussed earlier in the hydrologic soil group section. The cover type is the kind of vegetation prominent in that area. Urban areas were assumed to have a normal mix of grasses and shrubs common in residential yards. Vegetation cover types were delineated using aerial photography and the NRCS soils map. Vegetation cover types were verified through site reconnaissance. The mountain vegetation cover types are described following.

Herbaceous. This complex includes a mixture of grass, weeds, and low-growing brush, with brush being the minor element. This cover was found on the ridges and more exposed areas.

Pinyon-Juniper. This cover type includes pinyon, juniper or both with a grass understory.

Oak-Aspen. This vegatative cover consists of mountain brush mixture of oak brush, aspen, mountain mohogany, bitter brush, maple, and other brush. This is only found on the high north-facing slopes.

The drainage subbasin composite curve numbers were calculated by an area weighting method.

Basin Lag Time

The basin lag time for mountain areas was calculated using the regression equation outlined in the article entitled “Lag Time Characteristics for Small Watersheds in the U.S.” by M.J. Simas and R.H. Hawkins. The equation relies on basin area, slope, and curve number characteristics. The regression equation follows:

$$T_{lag} = .0051 \times width^{.594} \times slope^{-.15} \times S_{nat}^{.313}$$

where

width = Watershed Area / Watershed Length
slope = Maximum Elevation difference / Longest Flow Path
S_{nat} = 1000/CN - 10

Conveyance System Routing

Mountain area runoff enters Neffs Canyon Creek via sheet flow, shallow concentrated flow and stream flow. In urban locations runoff is routed to Neff’s Creek through storm drain pipes or road

side drainage ditches. The shape and roughness of these conveyance systems were estimated based on site visits and engineering judgment.

MOUNTAIN AREAS

Subbasin hydrologic characteristics for the mountain area conditions are summarized in Table II-1. Required hydrologic characteristics for use in modeling storm water runoff with the Soil Conservation Service Curve Number (CN) and Unit Hydrograph technique include drainage area, Curve Number, and Lag Time.

TABLE II-1
NEFFS CANYON SUBBASIN CHARACTERISTICS FOR MOUNTAIN AREAS

Subbasin ID	Area (Acres)	Area Weighted CN	Lag Time (hr)
Upper Basin	723	63	1.32
Middle Basin	822	67	1.18
Lower Basin	840	66	1.25
SMB1	73	65	0.12
SMB2	235	65	0.16
TOTAL:	2693		

URBAN AREAS

Hydrologic characteristics for urban areas in the model are presented in Table II-2. Urban hydrologic characteristics for use in modeling storm water runoff with the SCS Curve Number and Unit Hydrograph technique include drainage area, percent of the subbasin which is covered by impervious area, percent of the subbasin which is directly connected impervious area, composite curve number representing the portion of the subbasin which includes the pervious area plus the impervious areas which are unconnected (that is runoff off these areas flows across pervious surfaces prior to entering the conveyance system), and time of concentration.

TABLE II-2
NEFFS CANYON SUBBASIN CHARACTERISTICS FOR URBAN AREAS

Subbasin ID	Area (Acres)	% Impervious Area	% Directly Connected Impervious Area	CN Pervious + Unconnected Impervious	Time of Concentration (minutes)
Urb-1	31	32	14	65.6	42
Urb-2	81	35	17	66.0	43
Urb-3	24	38	19	66.6	18
Urb-4	18	38	19	66.5	17
Urb-5	13	32	16	64.8	18
Urb-6	30	45	29	66.0	28
Urb-7	10	42	25	66.3	15
Urb-8	21	53	36	68.0	16
TOTAL:	207				

DESIGN RAINSTORM

Precipitation depth-duration return period information provided in the"Rainfall Intensity Duration Analysis Salt Lake County, Utah" (TRC North American Weather Consultants, 1999) (hereinafter referred to as TRC 1999) and from National Oceanic and Atmospheric Administration Atlas 14 (NOAA 14) found on the website http://hdsc.nws.noaa.gov/hdsc/pfds were compared. The TRC 1999 depth-duration return period maps cover the urban portion of the study area. The following table provides a comparison between the predicted 100-year rainfall depths for the urban area taken from the two sources.

TABLE II-3
COMPARISON OF TRC 1999 AND NOAA 14 RAINFALL DEPTHS (INCHES)
OLYMPUS COVE URBAN AREA

RETURN PERIOD - DURATION	TRC 1999	NOAA 14
100-YEAR 30-MINUTE	1.24	1.49
100-YEAR 1-HOUR	1.62	1.84
100-YEAR 6-HOUR	2.38	2.33
100-YEAR 24-HOUR	3.46	3.53

Because the TRC 1999 depth-duration return period maps do not cover the mountain watersheds, it was decided to use the NOAA 14 data for consistency. The precipitation values used were dependent upon the general elevation and location of the different sub-basins. The precipitation values were assigned to general zones which include: Upper Neffs Canyon, Middle Neffs Canyon, Lower Neffs Canyon, and the Urban Area.

Storm Duration Sensitivity Analysis

The storm duration that will produce the highest peak runoff flow rate is dependent on rainfall-duration relationships, the characteristics of the basin, and upon the level of detention storage. Generally speaking, the longer runoff takes to flow through a drainage basin or detention basin, the longer the critical storm duration. A duration sensitivity analysis of the hydrologic study area was performed by successive model runs using 1-hour, 3-hour, 6-hour, 12-hour, and 24-hour storm durations. The 24-hour storm duration was found to produce the largest peak and was used as the basis for Neffs Canyon design flows.

Storm Distribution

Critical runoff events from urban areas along the Wasatch Front are caused by cloudburst type storms, characterized by short periods of high intensity rainfall. During the 1960's and early 1970's, Dr. Eugene E. Farmer and Dr. Joel E. Fletcher completed a major study of the precipitation characteristics for storms in northern Utah based on data from two rainfall gage networks located in central and north-central Utah. These gage networks are referred to as the Great Basin Experimental Area (GBEA) and the Davis County Experimental Watershed (DCEW) respectively. This effort has become the definitive source for rainfall distributions appropriate for the Wasatch Front area. Because this study applied to short duration storms, it was not applied to durations exceeding the 6-hour event.

Thirteen separate gaging stations in the Great Basin Experimental Area (ranging in elevation from 5,500 feet to over 10,000 feet) were maintained for varying periods of time from 1919 to 1965. Fifteen gaging stations were maintained in the Davis County Experimental Watershed (ranging in elevation from 4,350 to 9,000 feet) for varying periods of time between 1939 and 1968. After completing their analyses of the data, Farmer and Fletcher found that “more than 50 percent of the storm rainfall depth occurs in 25 percent of the storm periods;” and that “usually more than half of the total depth of rain is delivered as burst rainfall.” Farmer and Fletcher developed design storm distributions which have become accepted by governmental entities including Salt Lake County and Davis County as the characteristic distributions for storms in Utah of short duration (generally less than six hours).

The work of Farmer and Fletcher was expanded in 1985 to develop a 24-hour rainfall distribution from the GBEA data (VHA, 1985). For the derivation of the design 24-hour rainfall event, a storm was defined “as a period of continuous or intermittent precipitation delivering at least 0.1 inches of rainfall during which time dry periods without rainfall did not exceed four hours.” Storms having durations ranging from 20 hours to 28 hours were accepted to be representative of a 24-hour storm duration. The 24-hour duration storms were then screened to include only storms

which contained rainfall meeting the burst criteria of having over 50 percent of the precipitation occurring in less than 25 percent of the time. Storms meeting the burst criteria were further categorized in accordance with which quartile of the storm the burst had occured (i.e. the first, second, third or fourth quarter of the storm period). Identified storms were used to develop a 24-hour design storm distribution for use in Utah.

A sensitivity analysis for all storm distributions developed shows the 3rd quartile storm distribution to produce the higher runoff peaks. The SCS Type II distribution is an extreme distribution which includes a very intense burst of rainfall with over 35 percent of the 24-hour total rainfall occurring within a half hour. The GBEA 3rd Quartile storm distribution developed in 1985 includes a burst of rainfall with an approximate 10 percent of the 24-hour total rainfall falling within a half hour period. In a similar comparison, the SCS Type II distribution allows approximately 62 percent of the total precipitation to occur within the same period.

Because the distribution was developed based on local data, the GBEA distribution is believed to be the best available storm distribution for Utah for storms lasting between 6 and 24 hours. For the same reason, the Farmer-Fletcher distribution is the best available storm distribution for durations of less than 6 hours. Comparisons of the predicted runoff peaks from the GBEA storm distribution and from the Farmer Fletcher storm distribution reveal good agreement for a 6-hour duration storm.

Aerial Reduction

Aerial reduction factors were applied to the model based on the Salt Lake City Hydrology Manual. These factors were developed to compensate for the aerial differences associated with different storm durations and drainage basin area. The total area for the combined sub-basins is 4.52 square miles which results in an aerial reduction factor of 0.96 or an equivalent precipitation depth reduction of 4% for the 24-hour event. The respective areal reduction amounts shown in Table II-4 were applied to each of the precipitation depths obtained from the NOAA 14 Atlas.

Table II-4
AREAL REDUCTION FACTORS

Storm Duration	Areal Reduction Factor
30-minute	0.82
1-hour	0.86
3-hour	0.91
6-hour	0.93
12-hour	0.95
24-hour	0.96

Rainfall Adjustment

Rainfall is assumed to produce the peak runoff for Neffs Canyon Creek. The NOAA Atlas 14 did not include an update to the May-October rainfall amounts included in NOAA Atlas 2. The precipitation values found in NOAA Atlas 14 are based on the complete data set (full year including snow). In order to predict the rainfall values based on the NOAA Atlas 14, a ratio was calculated using the NOAA Atlas 2 May-October rainfall versus the full year precipitation from NOAA Atlas 2. This ratio was applied to the NOAA Atlas 14 full year precipitation values to produce design storm rainfall amounts. The precipitation values from NOAA 14 with areal and rainfall adjustments are shown in Table II-5.

Table II-5
ADJUSTED PRECIPITATION VALUES FOR 100-YEAR DURATION

Zone	30-min	1-hour	3-hour	6-hour	12-hour	24-hour
Upper Neffs Canyon	1.20	1.58	1.98	2.32	3.10	3.97
Middle Neffs Canyon	1.20	1.56	1.95	2.26	3.01	3.77
Lower Neffs Canyon	1.16	1.51	1.86	2.12	2.74	3.32
Urban Area	1.14	1.49	1.80	2.04	2.60	3.12

TRANSMISSION LOSSES

Transmission losses result from infiltration along the drainage channel reaches and are calculated using methodology presented in the "National Engineering Handbook , Section 4 - Hydrology, Chapter 19 - Transmission Losses." These losses apply to ephemeral streams in semiarid regions typical of the Neffs Canyon area. The losses are calculated using regression equations based on the effective hydraulic conductivity.

A gaining stream is defined as a stream that receives groundwater discharge. The upper reaches of Neffs Canyon upstream of about 7,400 feet and tributary channels were assumed to be gaining, therefore, no losses were applied to those reaches.

DESIGN FLOWS

A storm rainfall runoff model was prepared for the Neffs Canyon watershed using the U.S. Army Corps of Engineers Hydrologic Modeling System (HEC-HMS) software. A summary of the design creek flow rates for a 10-Year and a 100-Year return period (a 100-year return period event has a 1% chance of being equaled or exceeded in any given year) are provided in Table VI-1. A duration sensitivity analysis was performed and the 24-hour storm was found to govern both the 10-year and 100-year events.

Table II-6
NEFFS CANYON CREEK – DESIGN FLOW RATES

Location	Predicted Rainstorm Runoff Flow Rates (cfs)	
	10-Year	100-Year
Canyon Mouth	70	300
Wasatch Blvd	90	350

SNOW MELT

Historical snowmelt peak flows are not available for Neffs Canyon. Regression equations developed by Gingery and Associates ("Hydrology Report, Flood Insurance Studies, 20 Utah Communities, F.I.A. Contract H-4790", 1979) were used to estimate snowmelt runoff. The equations rely on the size of the basin area and the return period for the snowmelt event. Table II-7 gives a summary of expected snowmelt flows at the canyon mouth.

Table II-7
ESTIMATED SNOW MELT FLOW RATES

Location	Predicted Snowmelt Flow Rates (cfs)		
	10-Year	50-Year	100-Year
Mouth of Canyon	50	70	75

CHAPTER III

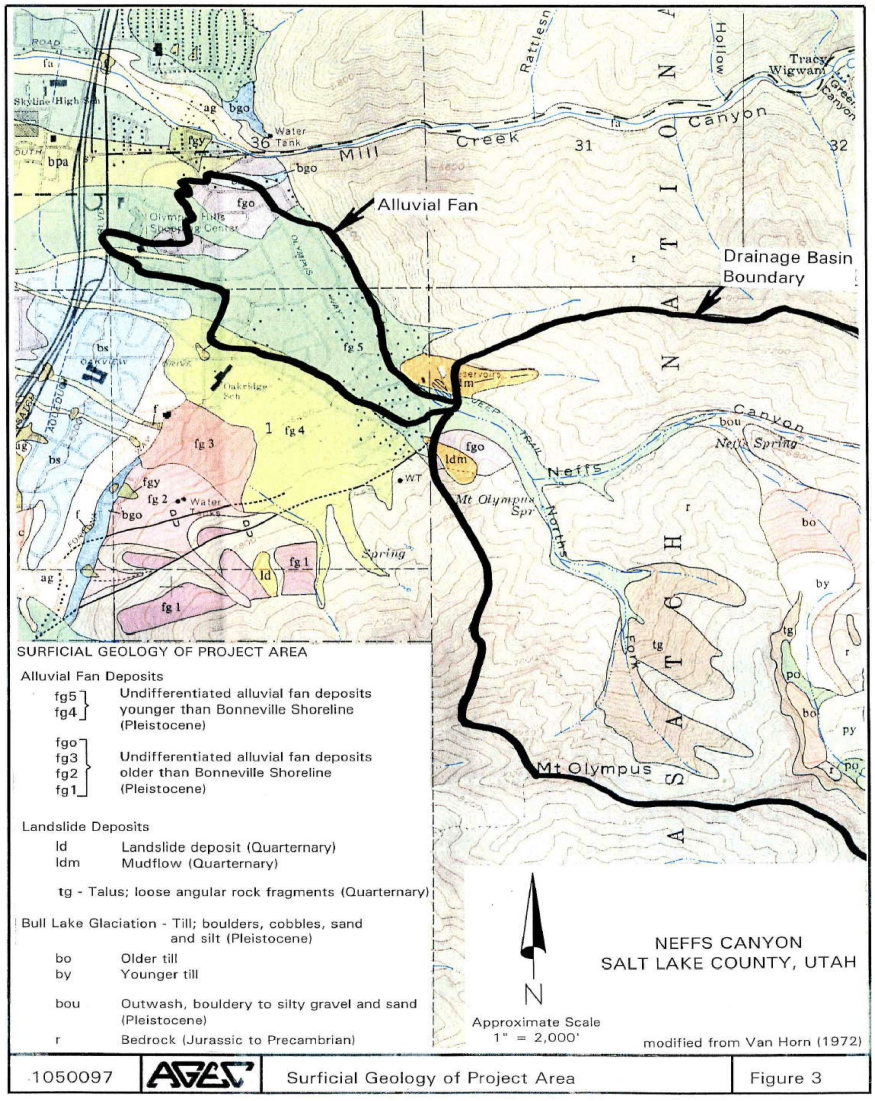
DEBRIS FLOW HAZARD STUDY

An evaluation of the debris flow hazard potential for Neffs Canyon was completed by Applied Geotehcinal Engineering Consultants (AGEC), P.C. (Project No. 1050097, August 10, 2005, see copy on CD in appendix). The debris flow hazard study included a review of geologic literature, an evaluation of aerial photographs, filed reconnaissance, and analysis. AGEC findings are summarized below.

- "The mouth of Neffs Canyon is situated approximately 400 feet above the Bonneville Shoreline. The Neffs Canyon Alluvial fan extends out onto and coalesces with Lake Bonneville deposits."

- "Study of the aerial photographs did not identify discrete debris flow lobes on the fan. However, the distal portion of the fan is irregular in extent, which may be interpreted as a series of discrete flows with variable run-out distances."

- "Personius and Scott (1992) map the area of the Neffs Canyon alluvial fan as af2, which is assigned the age of middle Holocene to uppermost Pleistocene (> 5000 years old)."



- "Landslides typically do not form in limestone and quartzite, which is the bedrock underlying Neffs Canyon, indicating that this debris flow triggering mechanism would be less likely than storm-induced erosion on denuded areas."

- "The southern reaches of the Neffs Canyon drainage basin contain abundant exposed bedrock, which promotes rapid surface-water runoff that could help generate a debris flow. However, these north-facing slopes also contain large areas of dense brush and trees that act to inhibit mobilization of slope colluviaum."

- "The potential for debris flow would be increased if a significant portion of the drainage is burned."

- "Possible geomorphic evidence of past debris flow activity was observed in the lower reach of Norths Fork tributary, where boulder trains and levees were observed between roughly parallel channels on either side of the drainage."

- "... although the lower drainage channel is relatively broad it contains an incised channel that would act to partially confine a debris flow."

- Two methods were used to calculate the potential debris flow volume for each channel segment. The total volume of debris flow calculated is 154,700 cubic yards and 148,200 cubic yards for the different methods.

- "The portion of the Neffs Canyon drainage below approximate elevation 6800 feet has a gradient suggesting deposition rather than erosion and would decrease the volume of sediment reaching the canyon mouth. The potential deposition in this reach is estimated at 13,000 cubic yards."

- "Overall, it is clear from the literature that debris flows have occurred in the past more commonly in Davis County than Salt Lake County. The drainages that produce these events are typically much smaller than Neffs Canyon."

- "The predicted debris flow volumes ... represent an event that occurs over the entire Neffs Canyon drainage basin. The potential for a smaller flow to occur within one of the tributary channels, or within tributary channels in a portion of the canyon, is greater than the potential for debris flows to occur simultaneously within the entire basin. Further, many of these smaller flows may be deposited before reaching the canyon mouth due to the low gradient of the main channel below approximate elevation 6800 feet."

It is difficult to assign a probability to the potential debris flow events. In discussion with the geologist and Salt Lake County, it was decided that taking the average of the predicted debris flow from the largest channel segment, upper Neffs Canyon, [(35,000 + 58,600)/2] = 46,800 cubic yards and subtracting the estimated deposition in the lower reach (13,000 cubic yards) provides an estimated debris flow volume (33,800 cubic yards) which may be an appropriate design volume for facilities with the objective of providing protection to developed ares below the canyon mouth. The design debris flow volume (33,800 cubic yards) is about 21 acre-feet.

CHAPTER IV

EXISTING CONVEYANCE SYSTEM DESCRIPTION AND CAPACITY

The existing Neffs Canyon Creek conveyance system consists of open channels and culverts. The existing channel alignment is shown on Figure IV-1. The conveyance system flows through the Olympus Cove subdivision. The Olympus Cove subdivision was constructed in about 1958. The Forest Service boundary defines the east border of the Olympus Cove subdivision. After development of the subdivision, the area was identified as an active alluvial fan, with significant flood and debris flow risk. This condition is exacerbated because the Neffs Creek low flows currently are delivered to the subdivision from a channel which is higher than the thalweg (lowest part) of the canyon. The higher channel appears to be the result of a past diversion (possibly for irrigation purposes). In places the water elevation in the current channel is significantly higher than the lower thalweg. The alignment of the current channel and the thalweg are shown on Figure IV-2.

The diversion to the current channel from the Neffs Canyon thalweg occurs about 1300 feet east of the homes. The diversion is somewhat fragile and storm runoff often spills into the lower thalweg.

The capacity of the existing conveyance system through the residential area was estimated by surveying the culverts (inlet flow line, outlet flow line, and available headwater elevation at the inlet) and surveying typical channel cross sections. A HEC-RAS model was prepared of the conveyance system and culvert capacities were estimated (see Appendix). Culvert capacities are provided in the following table.

TABLE IV-I
ESTIMATED CAPACITY OF EXISTING CULVERTS

LOCATION	DISTANCE UPSTREAM OF WASATCH Blvd. (feet)	LENGTH (feet)	DIAMETER (feet)	ESTIMATED CAPACITY (CFS)
Zarahemla Dr.	6375	175	2.5	50
Abinadi Rd	5476	59	3	100
Mathews Way	5192	60	4	130
Parkway Dr.	4597	29	3	50
Adonis Dr.	4232	70	3	55
Brockbank Dr.	3543	68	5	230

N

0 250 500

SCALE IN FEET

FILE DATE: 2.6.2007 13:38:28 (JDB)

FILE NAME: 014\10.100\CADFILES\FIGURES\FIG IV-1.DWG

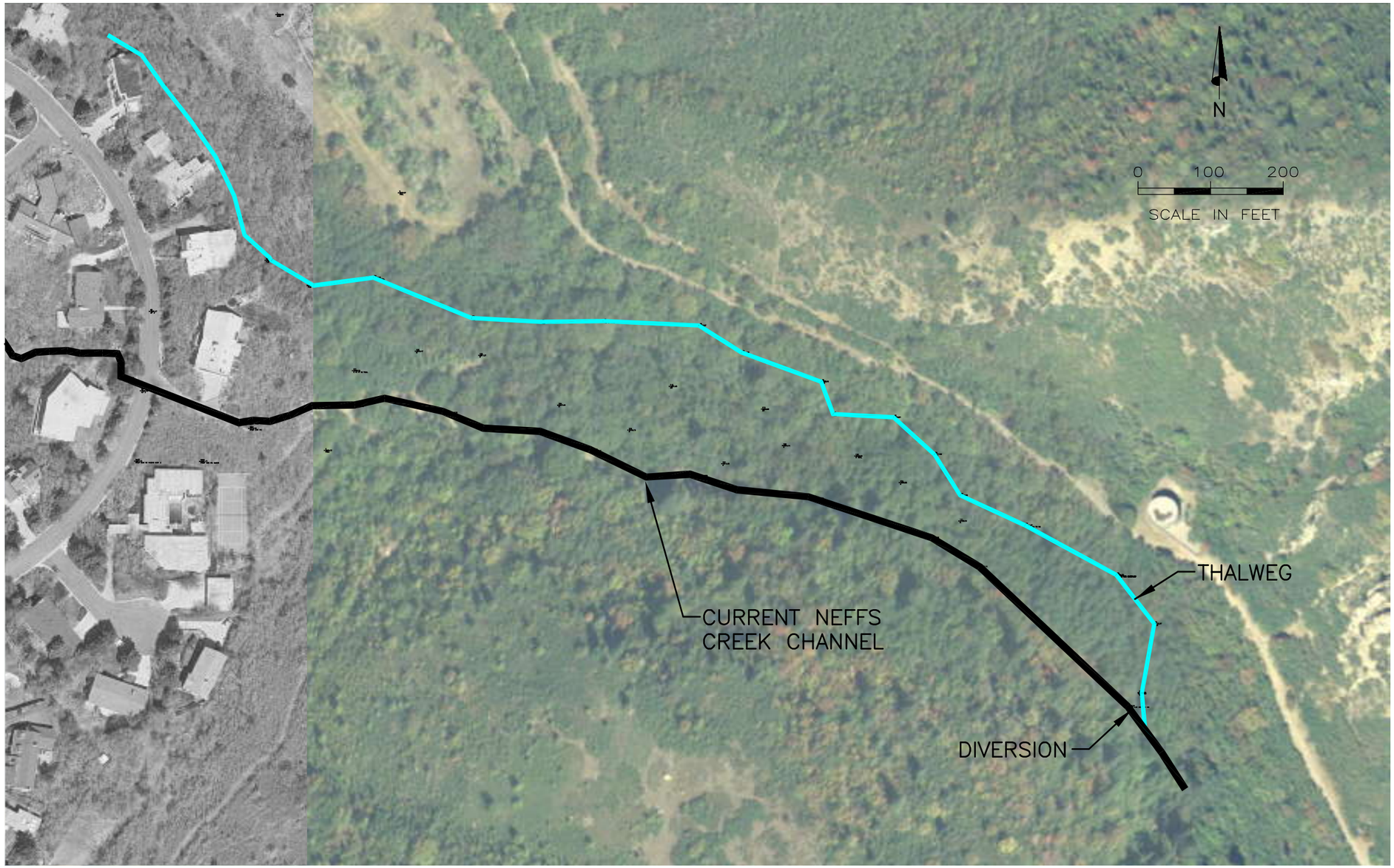
3/2024

HANSEN ALLEN & LUCE inc ENGINEERS

SALT LAKE COUNTY
NEFFS CANYON CREEK

EXISTING NEFFS CREEK CHANNEL ALIGNMENT

FIGURE
IV–1



FILE DATE:

FILE NAME:

3/04

HANSEN ALLEN & LUCE inc
ENGINEERS

SALT LAKE COUNTY
NEFFS CANYON CREEK

CURRENT NEFFS CHANNEL AND CANYON THALWEG

FIGURE
IV–2

LOCATION	DISTANCE UPSTREAM OF WASATCH Blvd. (feet)	LENGTH (feet)	DIAMETER (feet)	ESTIMATED CAPACITY (CFS)
Neptune Dr.	2505	166	5	160
Jupiter Dr.	2099	93	5	138
Fortuna Way	1408	95	5	140
Achillies Dr.	715	45	5	150

Existing channel capacities vary significantly through the Olympus Cove subdivision. The existing channel between Abinadi Road and Zarahemla Drive has an estimated bank full channel capacity of less than 200 cfs (assuming no backwater effects from the culvert at Abinadi Road). The smallest existing channel capacity is located adjacent to Helaman Circle below Zarahemla Drive and has an estimated bank full capacity of about 120 cfs. The safe carrying capacity is much less than the bank full carrying capacity due to high erosion potential with higher flows on the steep channel slopes. The channel adjacent to Helaman Circle has a safe carrying capacity of less than 70 cfs (due to the risk to a berm).

The channel below Abinadi Road generally has sufficient capacity (in excess of the 100-year event assuming that the backwater effects are eliminated by replacing the culverts), but there is a high erosion potential and risk that the channel will move affecting existing buildings.

CHAPTER V

ALTERNATIVE EVALUATION

A key master plan study objective is to identify means for flood and debris flow hazard mitigation. The Federal Emergency Management Agency in "Guidelines for Determining Flood Hazards on Alluvial Fans" (FEMA, 2000) states: "Active alluvial fan flooding occurs only on alluvial fans and is characterized by flow path uncertainty so great that this uncertainty cannot be set aside in realistic assessments of flood risk or in the reliable mitigation of the hazard." Alternative mitigation methods have been investigated for debris flow and conveyance system flooding.

DEBRIS FLOW MITIGATION ALTERNATIVES

Mitigation measures for debris flows can be categorized into three types: debris basin, deflection, and watershed treatments.

Debris Basin. A debris basin positioned to intercept debris flows prior to reaching the residential area provides an embankment designed to stop the debris flow allowing the soilds portion of the debris flow to deposit in the debris basin and the liquid portion to flow through the basin outlet facilities. Debris basins have been used for years and have provided a reliable means of mitigating debris flow hazards.

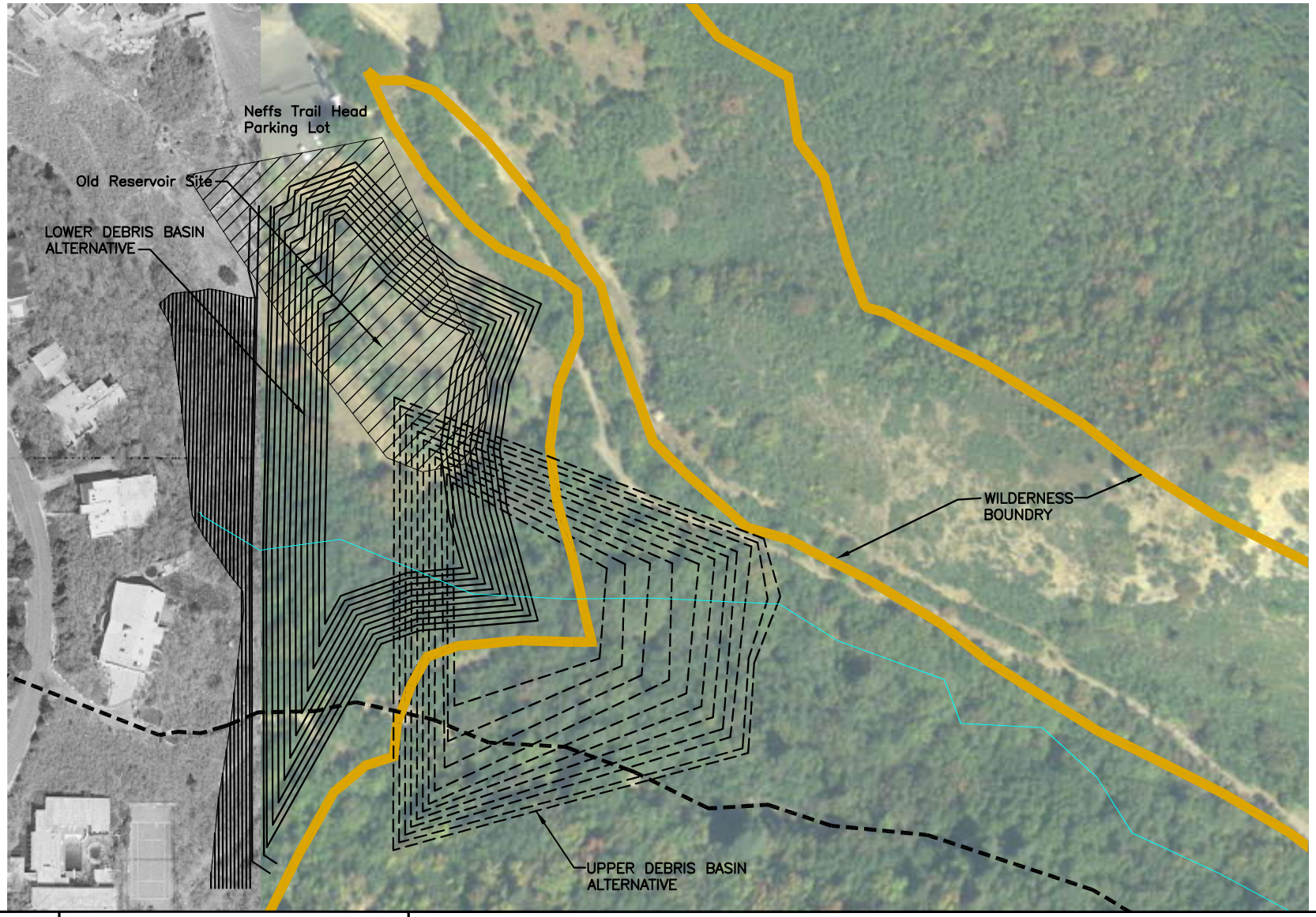
Deflection. Deflection utilizes an armored embankment to deflect debris flows away from homes. A suitable location to receive the deflected debris flows does not exist at the mouth of Neffs Canyon, therefore this alternative was eliminated.

Watershed Treatments. Watershed treatments include several different types of measures which are implemented in the watershed. These measures include construction of temporary measures such as silt fences, organic debris rakes, and matting. More permanent type measures include earth retaining structures to stabilize potential trigger areas. Because these measures would need to be implemented within the designated Wilderness Area, equipment for construction of these treatments would be limited to hand tools. Measures which could be constructed with hand tools would be temporary and not sufficiently durable to provide sufficient debris flow mitigation to remove the homes from the hazard. These measures could be effective in providing short term protection such as during the re-vegetation period after a fire.

Of the debris flow mitigation alternatives, only the debris basin was found to sufficiently reduce the debris flow hazard to the homes.

DEBRIS BASIN ALTERNATIVES

Two alternative debris basin locations have been identified: Upper Debris Basin (located partially in the Wilderness Area), and Lower Debris Basin (located below the Wilderness Area). The alternative debris basin locations are shown on Figure V-1.



FILE DATE:

FILE NAME:

3/04

HANSEN ALLEN & LUCE, Inc. ENGINEERS

SALT LAKE COUNTY
NEFFS CANYON CREEK

ALTERNATE DEBRIS BASIN LOCATIONS

FIGURE
V–1

Upper Debris Basin

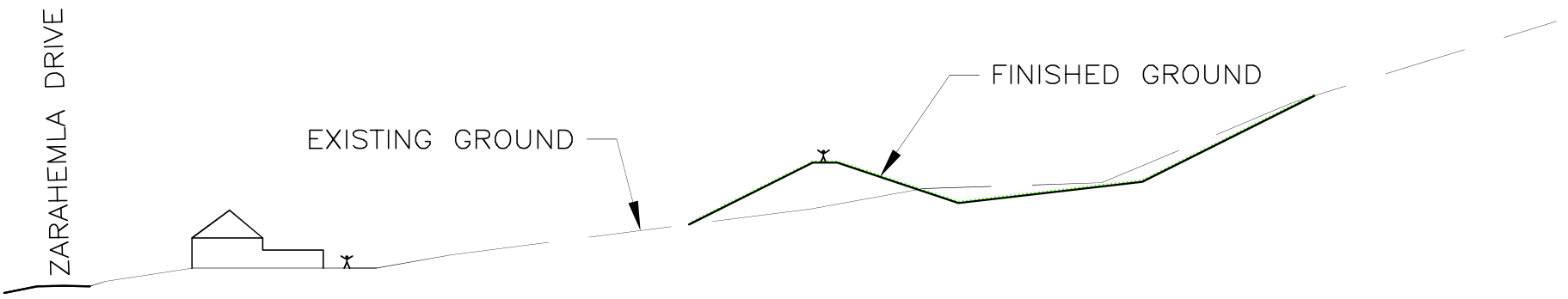
The Upper Debris Basin alternative is located partially within the wilderness area and would conceptually have a top of dam elevation of 5610 feet. For reference, the existing parking lot and the top of the old reservoir embankment are at about 5600 feet. This alternative would allow maintaining a portion of the existing trees between the homes and the embankment. A action of the U.S. Congress would be required to authorize construction and maintenance within the wilderness area. A typical cross section through the Upper Debris Basin is shown on Figure V-2.

Lower Debris Basin

The Lower Debris Basin alternative is located on U.S. Forest Service property between the wilderness area and the homes. The conceptual top of dam elevation is 5595 feet (about five feet lower than the top of the existing old reservoir embankment). A typical cross section through the Lower Debris Basin is shown on Figure V-3.

URBAN AREA FLOOD CONVEYANCE SYSTEM ALTERNATIVES

Conveyance system improvements without the debris basin discussed above are believed to be insufficient to remove the homes from the flood hazard designation. Four alternatives have been identified for improving the conveyance system through the residential area between Zarahemla Drive and Wasatch Blvd. Three of the alternatives (riprap channel, composite channel, and concrete low flow channel) assume that the existing under-capacity culverts (see Table IV-1) are replaced. The fourth alternative replaces the existing culverts and channels with a storm drain pipe. Conceptual cross sections of the alternatives are shown on Figure V-4. The alternatives are compared on Table V-1. An option for the composite channel alternative is included which does not include grade control structures.



UPPER DEBRIS BASIN ALTERNATIVE
CROSS SECTION TAKEN WEST TO EAST

FILE NAME: 014\10.100\CADFILES\FIGURES\FIG V-2.DWG
FILE DATE: 12.17.2007 10:02:22 (JVH)

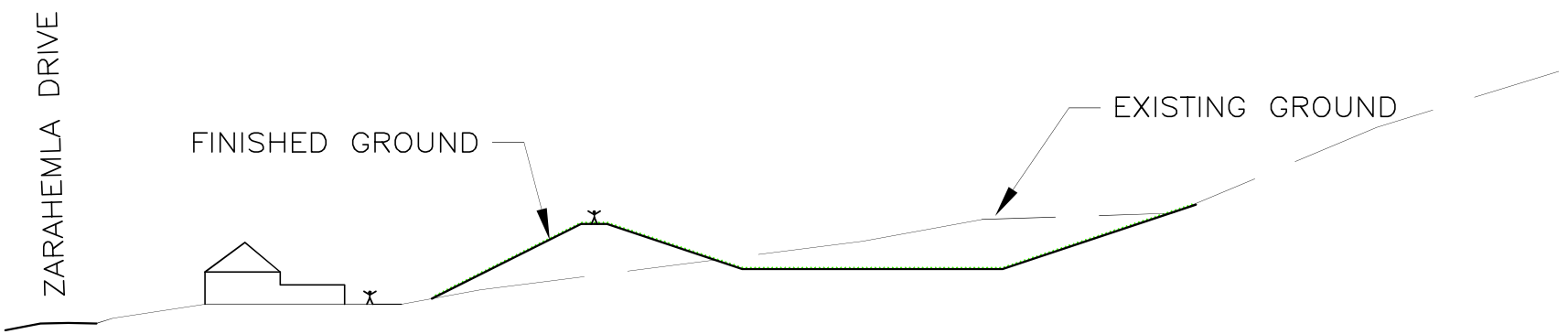
HANSEN ALLEN & LUCE inc ENGINEERS

SALT LAKE COUNTY
NEFFS CANYON CREEK

UPPER DEBRIS BASIN ALTERNATIVE

FIGURE
V-2

10/07



LOWER DEBRIS BASIN ALTERNATIVE
CROSS SECTION TAKEN WEST TO EAST

FILE NAME: 014\10.100\CADFILES\FIGURES\FIG V-3.DWG
FILE DATE: 12.17.2007 10:02:42 (JVH)

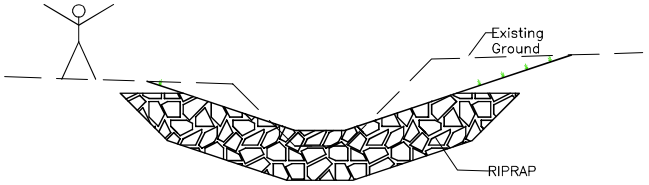
HANSEN ALLEN & LUCE inc ENGINEERS

SALT LAKE COUNTY
NEFFS CANYON CREEK

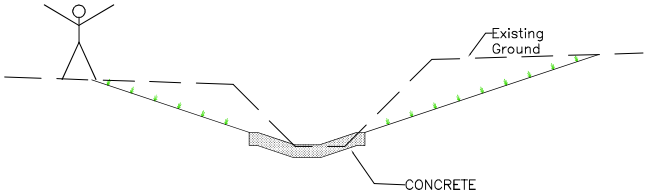
LOWER DEBRIS BASIN ALTERNATIVE

FIGURE
V-3

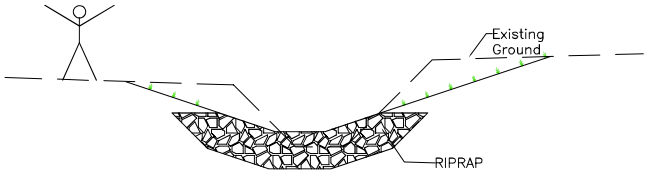
10/07



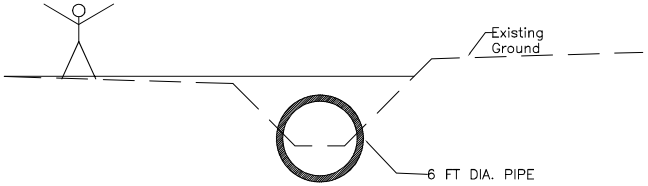
1. RIPRAP CHANNEL



3. CONCRETE LOWFLOW
& GRASS/MATT CHANNEL



2. COMPOSITE
RIPRAP & GRASS/MATT CHANNEL



4. PIPE ALTERNATIVE

FILE DATE:

FILE NAME:

3/04

HANSEN ALLEN & LUCE inc ENGINEERS

SALT LAKE COUNTY
NEFFS CANYON CREEK

CONVEYANCE SYSTEM ALTERNATIVES

FIGURE
V–4

TABLE V-1
NEFFS CANYON CREEK
CONVEYANCE ALTERNATIVES COMPARATIVE MATRIX

CONVEYANCE ALTERNATIVE (Description/Location)	DESIGN FLOW & Criteria	COMMENT	COMPARE COST PER FOOT
1. RIPRAP CHANNEL	300 cfs SF=1 70 cfs SF=1.5	Likely the least maintenance costs.	$400
2A. COMPOSITE CHANNEL	50 cfs riprap lowflow 300 cfs w/ SF=1 on matt So = 7.0%, GSBD 5' height	The drops will affect the width of the improvements and will increase potential for conflict with existing structures.	$550
2B. COMPOSITE CHANNEL	50 cfs riprap lowflow Mat side slopes, but no drops	Potential for extensive erosion in higher flows.	$250
3. CONCRETE LOW FLOW CHANNEL with MAT PROTECTED GRASS CHANNEL	50 cfs low flow with concrete channel depth for sequent depth matt lined channel above to total 300 cfs sequent depth	Safety and aesthetics issues. Potential for extensive erosion in higher flows.	$240
4. PIPE ALTERNATIVE	300 cfs; min. depth to pipe flowline = sequent depth	Concerns over maintenance and integrity of pipeline without a debris basin.	$340

Note: The comparative cost per foot does not include costs for elements common to all alternatives. For example the road repair costs are not included and are considered equivalent for all alternatives and therefore not needed to compare conveyance alternatives.

CHAPTER VI

SUMMARY

A key purpose of Salt Lake County Flood Control is to plan drainage improvements to better protect County residents from flooding and bring the system up to the requirements of the federal Flood Insurance Program. An analysis of Neffs Canyon Creek flooding hazard mitigation has been completed for the subdivision located between the mouth of Neffs Canyon and Wasatch Blvd. The analysis and potential mitigation measures are summarized below.

DESIGN FLOWS

A storm rainfall runoff model was prepared for the Neffs Canyon watershed using the U.S. Army Corps of Engineers Hydrologic Modeling System (HEC-HMS) software (please see Chapter II above). A summary of the design creek flow rates for a 10-Year and a 100-Year return period (a 100-year return period event has a 1% chance of being equaled or exceeded in any given year) are provided in Table VI-1. The snow melt flood flows were estimated using regional regression equations (see estimated snow melt flow rates in Table VI-2).

Table VI-1
NEFFS CANYON CREEK – DESIGN FLOW RATES

Location	Predicted Rainstorm Runoff Flow Rates (cfs)	
	10-Year	100-Year
Canyon Mouth	70	300
Wasatch Blvd	90	350

Table VI-2
ESTIMATED SNOW MELT FLOW RATES

Location	Predicted Snowmelt Flow Rates (cfs)		
	10-Year	50-Year	100-Year
Mouth of Canyon	50	70	75

DEBRIS FLOW HAZARD

A debris flow flooding hazard associated with an alluvial fan has been identified for areas located downstream of the mouth of Neffs Canyon (see Chapter III). The design debris flow volume (33,800 cubic yards) is about 21 acre-feet.

EXISTING CONVEYANCE SYSTEM

Neffs Creek low flows currently are delivered to the Olympus Cove subdivision from a channel which is higher than the thalweg (lowest part) of the canyon. The alignment of the current channel and the thalweg are shown on Figure IV-2. The diversion to the current channel from the Neffs Canyon thalweg occurs about 1300 feet east of the homes. The diversion is somewhat fragile and storm runoff often spills into the lower thalweg.

The existing channel and culvert system which conveys Neffs Canyon flood flows through the subdivision to Wasatch Blvd. has capacity for about the 10-year snow melt event (about 50 cfs). There is risk of flooding of homes for events exceeding the 10-year snow melt event. In addition, the existing channel is steep and there is risk of rapid bank erosion during a major event.

DEBRIS FLOW AND FLOODING MITIGATION ALTERNATIVES

The recommended alternative for providing protection to developed areas below the canyon mouth is the construction of a debris basin for a design debris flow volume of 21 acre-feet. Alternative debris basin locations are shown on Figure V-1.

It is recommended that the conveyance system through the subdivision be improved to convey the 100-year flood event. It is recognized that without the debris basin recommended above, flooding risk to homes cannot be mitigated through conveyance system improvements alone.

Proposed Neffs Creek conveyance improvements are shown on Figure VI-1. Alternative channel cross section improvements are discussed in Chapter V (see Figure V-4) with a cost comparison (see Table V-1).

N

0 200 400

SCALE IN FEET

FILE DATE:

FILE NAME:

3/04

HANSEN ALLEN & LUCE inc ENGINEERS

SALT LAKE COUNTY
NEFFS CANYON CREEK

NEFFS CREEK CONVEYANCE IMPROVEMENTS

FIGURE
VI–1

REFERENCES

Farmer, E. E. and Joel E. Fletcher. 1972. *Distribution of Precipitation in Mountainous Areas*. Geilo Symposium, Norway.

National Oceanic and Atmospheric Administration (NOAA) website. 2006. http://hdsc.nws.noaa.gov/hdsc/pfds. Point Precipitation Frequency Estimates for Utah.

National Oceanic and Atmospheric Administration (NOAA). 1972. *NOAA Atlas 2 Precipitation-Frequency Atlas of the Western United States, Volume VI-Utah*.

Natural Resource Conservation Service (NRCS) Website. 2005. http://soildatamart.nrcs.usda.gov/. Soil Survey Geographic (SSURGO) Database for Salt Lake County, Utah.

RS Means. 2007. *Heavy Construction Cost Data*. RS Means Inc. Kingston, MA.

TRC North American Weather Consultants. 1999. "*Rainfall Intensity Duration Analysis Salt Lake County, Utah*"

U.S. Army Corps of Engineers (USACE). 2006. *User's Manual - HEC-HMS Version 3.0.1*. Davis, California.

U.S. Soil Conservation Service (SCS). 1972. *SCS National Engineering Handbook - Section 5 Hydrology*. United States Department of Agriculture, Washington, D.C.

U.S. Soil Conservation Service (SCS). 1986. *Urban Hydrology for Small Watersheds - Technical Release No. 55*. United States Department of Agriculture, Washington, D.C.

APPENDIX A
GLOSSARY AND ABBREVIATIONS

GLOSSARY

10-year storm - The storm event that has a 10% (1 in 10) chance of being equaled or exceeded in any given year.

100-year storm - The storm event that has a 1% (1 in 100) chance of being equaled or exceeded in any given year.

Cross drainage structures - Cross drainage structures convey storm drainage flows from one side of the street to the other and normally consist of storm drains or culverts.

Design Rainstorm - A rainfall event, defined by storm frequency and storm duration, that is used to design drainage structures or conveyance systems.

Detention Basin - An impoundment structure designed to reduce peak runoff flowrates by retaining a portion of the runoff during periods of peak flow and then releasing the runoff at lower flowrates.

HEC-HMS - A Hydrologic Modeling System developed by the U.S. Army Corps of Engineers.

Initial storm drainage system - The drainage system which provides for conveyance of the storm runoff from minor storm events. The initial drainage system usually consists of curb and gutter, storm drains, and local detention facilities. The initial drainage system should be designed to reduce street maintenance, control nuisance flooding, help create an orderly urban system, and provide convenience to urban residents.

Major storm drainage system - The drainage system that provides protection from flooding of homes during a major storm event. The major storm drainage system may include streets (including overtopping the curb onto the lawn area), large conduits, open channels, and regional detention facilities.

Major storm event - Generally accepted as the 100-year storm. Typically homes should be protected from flooding in storm events up to a 100-year event.

Minor storm event - Storm event which is less than or equal to a 10-year storm.

Probable Maximum Flood - A flood event with a very low probability, usually less than 0.2%, of being exceeded in any given year. This flood event is used as a design storm when failure of the structure could cause loss of life.

Retention Basin - An impoundment structure designed to contain all of the runoff from a design storm event. Retention basins usually contain the runoff until it evaporates or infiltrates into the ground.

Storm Duration - The length of time that defines the rainfall depth or intensity for a given frequency.

Storm Frequency - A measure of the relative risk that the precipitation depth for a particular design storm will be equaled or exceeded in any given year. This risk is usually expressed in years. For example, a storm with a 100-year frequency will have a 1% chance of being equaled or exceeded in a given year.

thalweg (täl'veg) - The line defining the lowest points along the length of a river bed or valley.
A subterranean stream. "The American Heritage® Dictionary of the English Language, Fourth Edition Copyright © 2005, 2000 by Houghton Mifflin Company. Updated 2005."

ABBREVIATIONS

ac-ft	acre-feet
cfs	cubic feet per second (ft^3/s)
cmp	corrugated metal pipe
DB	detention basin
Det	detention
E	East
ft	foot or feet
GIS	Geographic Information System
gw	groundwater
HAL	Hansen, Allen & Luce, Inc.
in	inches
N	North
Q10	peak storm water flow in a 10-year event
Q100	peak storm water flow in a 100-year event
S	South
W	West
w/	with
w/o	without

APPENDIX B
HYDROLOGY

TABLE OF CONTENTS

ITEM	No. Of Pages
POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14	4
PRECIPITATION VALUES FOR NEFFS CANYON FROM NOAA ATLAS II	1
NOAA 14 DATA ADJUSTED FOR SEASONAL AND AREAL REDUCTION	2
MOUNTAIN WATERSHED CURVE NUMBER SUMMARY	1
LAG TIME COMPUTATIONS - MOUNTAIN SUBBASINS	2
TRANSMISSION LOSSES AT BOTTOM OF NEFFS CANYON	1
URBAN SUBBASINS CHARACTERISTICS	2
HEC-HMS PRINTOUTS	3
SNOWMELT CALCULATIONS FOR NEFFS CANYON	1

Top of Nett's Canyon

1/4

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

Utah 40.66428 N 111.73556 W 9038 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 1, Version 3
G.M. Bonnin, D. Todd, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2003

Extracted: Thu Jun 16 2005

Confidence Limits | Seasonality | Location Maps | Other Info. | Grids | Maps | Help | Docs

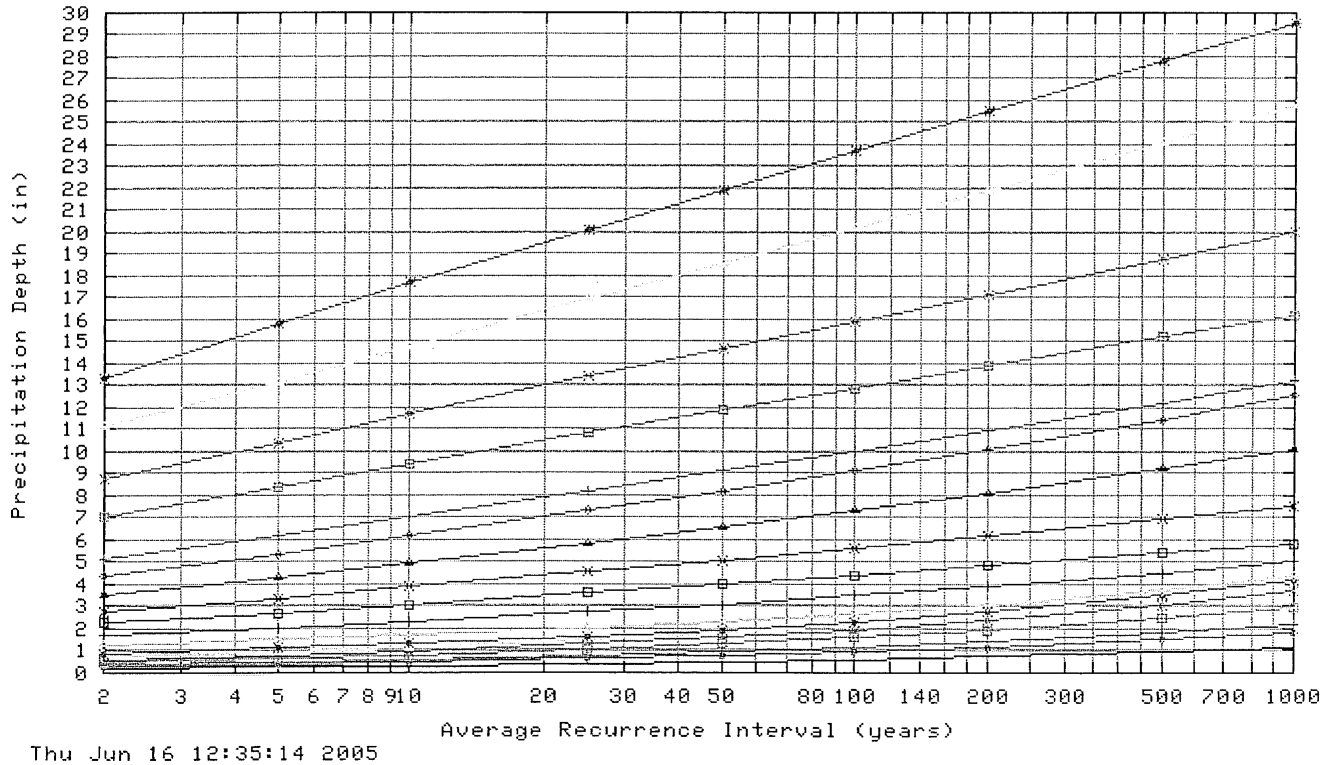
Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.19	0.28	0.35	0.47	0.58	0.76	0.90	1.25	1.67	2.25	2.80	3.52	4.40	5.11	7.04	8.77	11.11	13.33
5	0.25	0.38	0.48	0.64	0.79	0.97	1.11	1.49	1.99	2.70	3.38	4.29	5.36	6.17	8.40	10.42	13.15	15.77
10	0.31	0.48	0.59	0.79	0.98	1.18	1.32	1.71	2.29	3.07	3.86	4.94	6.17	7.04	9.47	11.71	14.79	17.67
25	0.41	0.63	0.78	1.05	1.30	1.52	1.64	2.05	2.73	3.58	4.52	5.86	7.30	8.20	10.85	13.41	16.95	20.11
50	0.51	0.77	0.96	1.29	1.60	1.83	1.94	2.33	3.08	3.98	5.05	6.58	8.19	9.10	11.88	14.68	18.59	21.92
100	0.62	0.94	1.17	1.57	1.95	2.21	2.32	2.65	3.48	4.40	5.59	7.35	9.14	10.02	12.90	15.93	20.24	23.71
200	0.75	1.15	1.42	1.92	2.37	2.66	2.77	3.05	3.90	4.82	6.15	8.14	10.11	10.96	13.91	17.16	21.89	25.48
500	0.97	1.48	1.83	2.47	3.06	3.39	3.51	3.68	4.51	5.39	6.92	9.25	11.47	12.22	15.21	18.77	24.10	27.78
1000	1.18	1.79	2.23	3.00	3.71	4.05	4.19	4.34	5.00	5.84	7.52	10.13	12.56	13.21	16.21	19.98	25.82	29.54

Text version of table

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.
Please refer to the documentation for more information. NOTE: Formatting forces estimates near zero to appear as zero.

Partial duration based Point Precipitation Frequency Estimates Version: 3
40.66428 N 111.73556 W 9038 ft



Thu Jun 16 12:35:14 2005

Duration			
5-min		48-hr	30-day
10-min	3-hr	4-day	
15-min		7-day	60-day
30-min	12-hr	10-day	
60-min	24-hr	20-day	

Middle of Neff's Canyon

2/4

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

Utah 40.66848 N 111.753 W 7660 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 1, Version 3
G.M. Bonnin, D. Todd, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2003

Extracted: Thu Jun 16 2005

Confidence Limits | Seasonality | Location Maps | Other Info. | Grids | Maps | Help | Docs

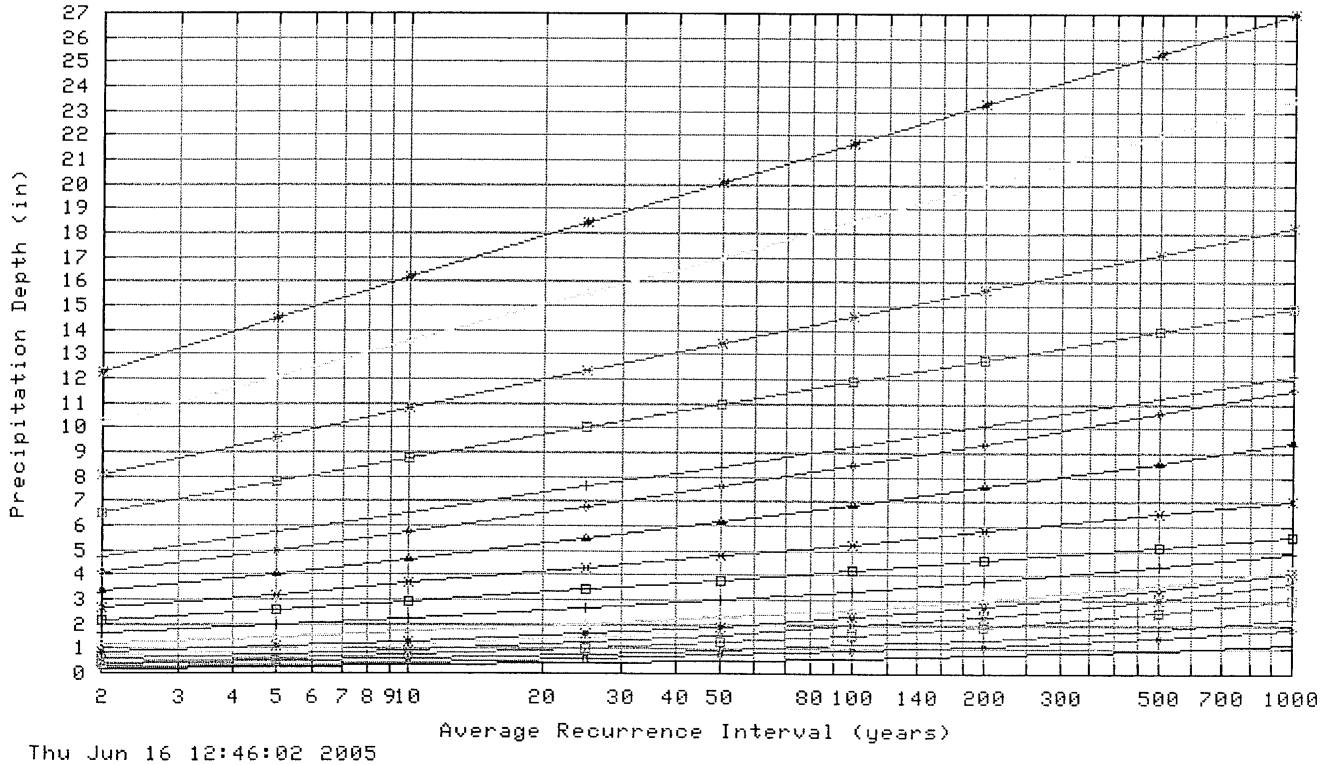
Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.18	0.28	0.35	0.47	0.58	0.75	0.89	1.22	1.61	2.15	2.65	3.31	4.11	4.75	6.52	8.08	10.20	12.24
5	0.25	0.38	0.47	0.64	0.79	0.96	1.09	1.45	1.93	2.57	3.19	4.03	4.99	5.73	7.77	9.59	12.07	14.47
10	0.31	0.47	0.58	0.79	0.97	1.17	1.29	1.68	2.22	2.93	3.65	4.63	5.74	6.53	8.74	10.76	13.57	16.21
25	0.41	0.63	0.78	1.04	1.29	1.50	1.61	2.00	2.64	3.41	4.27	5.48	6.78	7.60	10.01	12.30	15.53	18.44
50	0.50	0.77	0.95	1.28	1.58	1.81	1.90	2.28	2.99	3.79	4.76	6.15	7.60	8.42	10.95	13.46	17.01	20.09
100	0.61	0.94	1.16	1.56	1.93	2.19	2.28	2.59	3.38	4.18	5.26	6.86	8.47	9.27	11.88	14.59	18.51	21.71
200	0.75	1.14	1.41	1.90	2.36	2.63	2.72	2.97	3.79	4.59	5.79	7.59	9.37	10.12	12.80	15.70	20.00	23.31
500	0.97	1.47	1.82	2.46	3.04	3.35	3.45	3.58	4.38	5.13	6.50	8.61	10.61	11.27	13.99	17.15	21.99	25.39
1000	1.17	1.78	2.21	2.98	3.69	4.02	4.12	4.23	4.86	5.55	7.06	9.42	11.59	12.16	14.89	18.23	23.52	26.97

Text version of table

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval. Please refer to the documentation for more information. NOTE: Formatting forces estimates near zero to appear as zero.

Partial duration based Point Precipitation Frequency Estimates Version: 3
40.66848 N 111.753 W 7660 ft



Thu Jun 16 12:46:02 2005

Duration			
5-min		48-hr	30-day
10-min	3-hr	4-day	
15-min		7-day	60-day
30-min	12-hr	10-day	
60-min	24-hr	20-day	

Bottom of Neff's Canyon

3/4

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

Utah 40.67666 N 111.77477 W 5593 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 1, Version 3
G.M. Bonnin, D. Todd, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2003

Extracted: Thu Jun 16 2005

Confidence Limits | Seasonality | Location Maps | Other Info. | Grids | Maps | Help | Docs

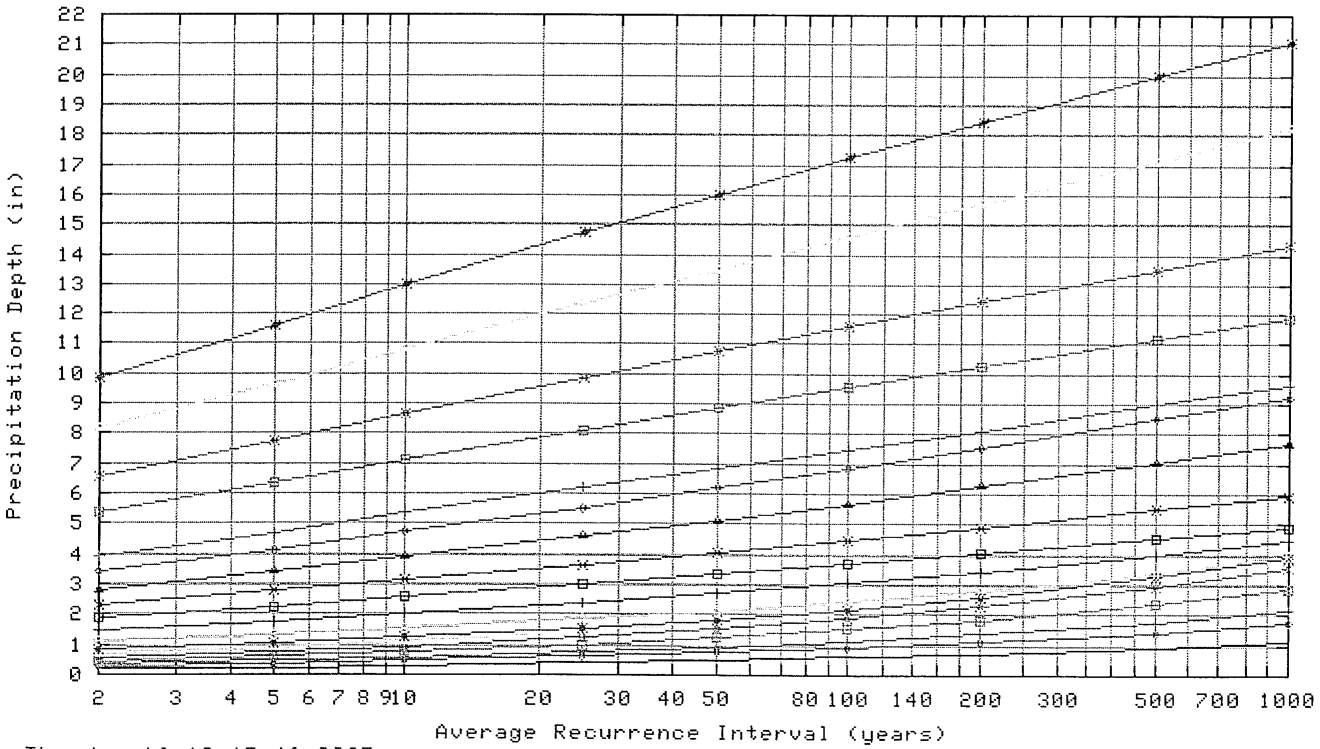
Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.18	0.27	0.33	0.45	0.56	0.71	0.83	1.13	1.46	1.90	2.30	2.81	3.42	3.93	5.35	6.55	8.20	9.87
5	0.24	0.37	0.45	0.61	0.76	0.92	1.03	1.34	1.75	2.27	2.76	3.40	4.14	4.70	6.35	7.74	9.66	11.62
10	0.30	0.45	0.56	0.76	0.94	1.12	1.23	1.55	2.01	2.58	3.14	3.89	4.73	5.34	7.13	8.66	10.83	12.98
25	0.40	0.60	0.75	1.01	1.25	1.44	1.53	1.86	2.40	3.01	3.66	4.58	5.55	6.18	8.13	9.86	12.34	14.72
50	0.49	0.74	0.92	1.24	1.53	1.74	1.80	2.13	2.72	3.34	4.07	5.12	6.20	6.82	8.87	10.74	13.47	15.99
100	0.60	0.91	1.12	1.51	1.87	2.10	2.17	2.42	3.07	3.68	4.49	5.69	6.88	7.47	9.59	11.60	14.59	17.22
200	0.73	1.11	1.37	1.85	2.29	2.53	2.59	2.77	3.45	4.03	4.91	6.26	7.56	8.13	10.30	12.44	15.69	18.43
500	0.94	1.43	1.77	2.38	2.95	3.23	3.29	3.34	3.99	4.51	5.49	7.07	8.51	8.99	11.19	13.51	17.12	19.96
1000	1.14	1.73	2.15	2.89	3.58	3.87	3.93	3.97	4.44	4.87	5.93	7.69	9.25	9.64	11.85	14.29	18.20	21.09

Text version of table

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.
Please refer to the documentation for more information. NOTE: Formatting forces estimates near zero to appear as zero.

Partial duration based Point Precipitation Frequency Estimates Version: 3
40.67666 N 111.77477 W 5593 ft



Thu Jun 16 13:15:46 2005

Duration			
5-min		48-hr	30-day
10-min	3-hr	4-day	
15-min		7-day	60-day
30-min	12-hr	10-day	
60-min	24-hr	20-day	

Middle of Urban Area (Below Neff's Canyon)

4/4

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

Utah 40.67949 N 111.78674 W 5180 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 1, Version 3
G.M. Bonnin, D. Todd, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2003

Extracted: Fri May 6 2005

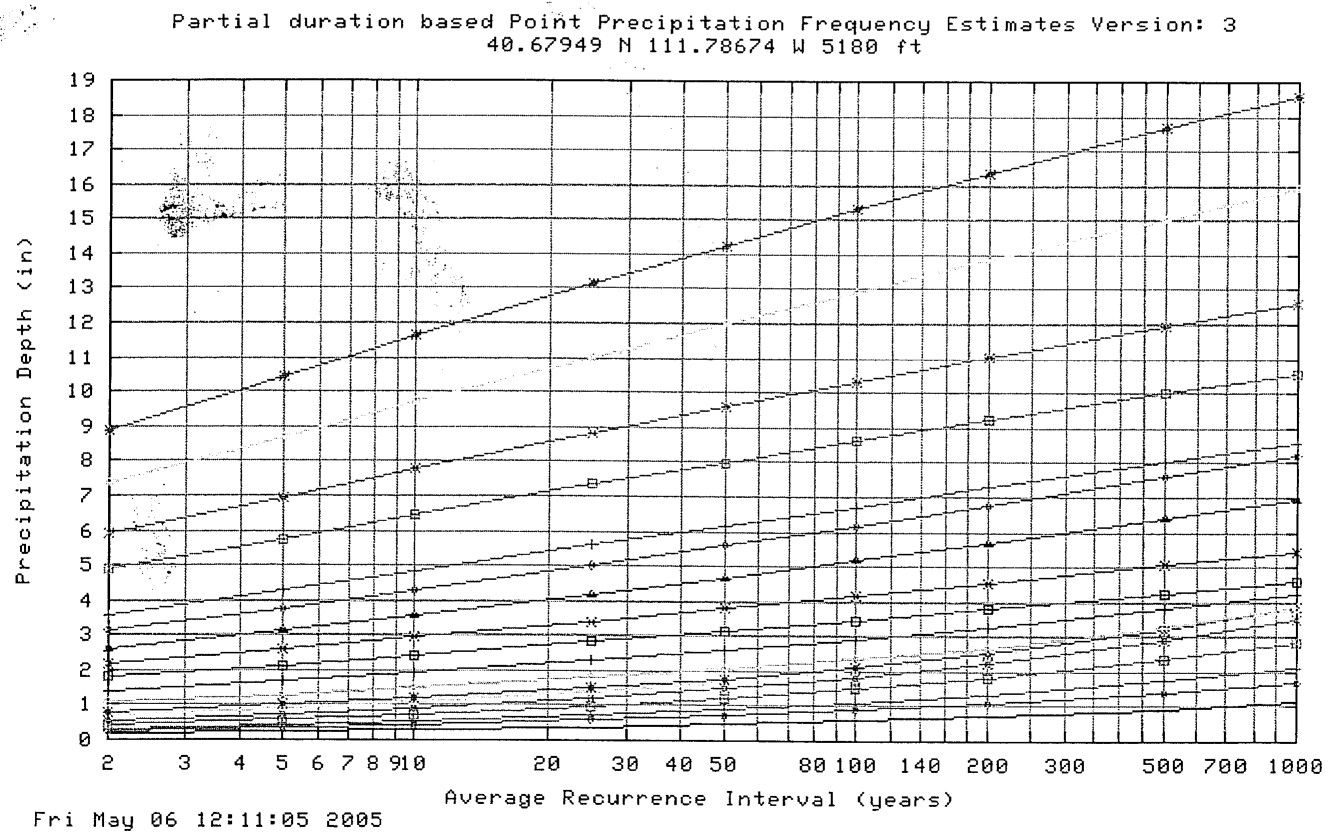
Confidence Limits | Seasonality | Location Maps | Other Info. | Grids | Maps | Help | Docs

Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	60 day
2	0.17	0.26	0.32	0.44	0.54	0.70	0.81	1.08	1.38	1.79	2.16	2.60	3.13	3.58	4.86	5.91	7.36	8.87
5	0.23	0.36	0.44	0.59	0.74	0.90	1.00	1.29	1.66	2.14	2.58	3.13	3.77	4.27	5.76	6.96	8.66	10.43
10	0.29	0.44	0.55	0.74	0.92	1.09	1.19	1.49	1.91	2.43	2.93	3.57	4.30	4.84	6.44	7.77	9.68	11.63
25	0.39	0.59	0.73	0.99	1.22	1.41	1.49	1.79	2.28	2.83	3.40	4.19	5.02	5.58	7.33	8.81	11.00	13.16
50	0.48	0.73	0.90	1.21	1.50	1.70	1.76	2.04	2.58	3.14	3.78	4.67	5.59	6.14	7.98	9.59	11.97	14.26
100	0.58	0.89	1.10	1.49	1.84	2.06	2.11	2.33	2.92	3.46	4.15	5.17	6.18	6.71	8.62	10.33	12.93	15.33
200	0.71	1.08	1.34	1.81	2.24	2.48	2.53	2.68	3.27	3.79	4.53	5.68	6.78	7.27	9.22	11.04	13.86	16.36
500	0.92	1.40	1.74	2.34	2.90	3.17	3.21	3.25	3.80	4.23	5.05	6.39	7.59	8.01	9.99	11.94	15.04	17.65
1000	1.12	1.70	2.11	2.84	3.51	3.80	3.84	3.85	4.23	4.57	5.45	6.93	8.22	8.56	10.55	12.59	15.91	18.58

Text version of table

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval. Please refer to the documentation for more information. NOTE: Formatting forces estimates near zero to appear as zero.



PRECIPITATION VALUES FOR NEFFS CANYON FROM NOAA ATLAS II
GJP 2006

ANNUAL DATA SERIES
UPPER NEFFS CANYON

Return Period (Years)	6 (hr)	24 (hr)
10	1.80	3.00
100	2.60	4.40

CENTRAL NEFFS CANYON

Return Period (Years)	6 (hr)	24 (hr)
10	1.79	2.90
100	2.55	4.21

LOWER NEFFS CANYON

Return Period (Years)	6 (hr)	24 (hr)
10	1.70	2.80
100	2.45	4.05

SEASONAL (MAY - OCT) DATA SERIES
UPPER NEFFS CANYON

Return Period (Years)	6 (hr)	24 (hr)
10	1.60	2.60
100	2.40	4.00

CENTRAL NEFFS CANYON

Return Period (Years)	6 (hr)	24 (hr)
10	1.60	2.58
100	2.30	3.90

LOWER NEFFS CANYON

Return Period (Years)	6 (hr)	24 (hr)
10	1.51	2.40
100	2.25	3.80

RATIO SEASONAL/ANNUAL
UPPER NEFFS CANYON

Return Period (Years)	6 (hr)	24 (hr)
10	0.89	0.87
100	0.92	0.91

CENTRAL NEFFS CANYON

Return Period (Years)	6 (hr)	24 (hr)
10	0.89	0.89
100	0.90	0.93

LOWER NEFFS CANYON

Return Period (Years)	6 (hr)	24 (hr)
10	0.89	0.86
100	0.92	0.94

Summary: Ratio seasonal/annual varies from 0.90 to 0.94 for 100-year; and 0.86 to 0.89 for 10-year.
Conclusion: Use a factor of 0.94 for 100-year and 0.89 for 10-year.

NOAA 14 DATA ADJUSTED FOR SEASONAL AND AREAL REDUCTION

Seasonal adjustment 0.94
Areal reduction See Areal Reduction Sheet

Precipitation Zones and Depths for 100-year Storm Event

Zone	30 min (in)	1 hr (in)	3 hr (in)	6 hr (in)	12 hr (in)	24 hr (in)
Upper Neffs Canyon	1.20	1.58	1.98	2.32	3.10	3.97
Middle Neffs Canyon	1.20	1.56	1.95	2.26	3.01	3.77
Lower Neffs Canyon	1.16	1.51	1.86	2.12	2.74	3.32
Urban	1.14	1.49	1.80	2.04	2.60	3.12

Seasonal adjustment 0.89
Areal reduction See Areal Reduction Sheet

Precipitation Zones and Depths for 10-year Storm Event

Zone	30 min (in)	1 hr (in)	3 hr (in)	6 hr (in)	12 hr (in)	24 hr (in)
Upper Neffs Canyon	0.57	0.75	1.07	1.42	1.93	2.62
Middle Neffs Canyon	0.57	0.74	1.04	1.39	1.87	2.50
Lower Neffs Canyon	0.55	0.72	1.00	1.28	1.70	2.20
Urban	0.54	0.70	0.96	1.23	1.61	2.08

AREAL REDUCTION
Calculated by GLJ on 3/10/2006

Based on the Salt Lake Hydrology Model

Total Area **4.54** mi^2

Duration	Areal Reduction
30-min	0.82
1-hr	0.86
3-hr	0.91
6-hr	0.93
12-hr	0.95
24-hr	0.96

Neff's Canyon Mountain Watershed Curve Number Summary
Computed - GLJ
July 26, 2005

Lower Basin

SOILTYPE	GROUP	VEGETATION	CONDITION	CN	AREA_ACRES	RATIO	COMPOSITE CN
Dromedary-Rock Outcrop Complex, 30 to 70%	D	Pinyon-Juniper	Good	71	235.491	0.280	19.9
Fewkes-Hades Complex, 30 to 60% Slopes	C	Oak-Aspen	Fair	57	41.152	0.049	2.8
ParkCity-Dromedary Gravelly Loams, 30 to 70%	B	Pinyon-Juniper	Good	41	158.983	0.189	7.8
Rock Outcrop	D	Herbaceous	Poor	93	29.818	0.035	3.3
Horrocks-Cutoff Complex, 15 to 30%	B	Oak-Aspen	Fair	48	31.371	0.037	1.8
Hades-Agassiz-Rock Outcrop Complex, 30 to 70%	D	Pinyon-Juniper	Good	71	34.739	0.041	2.9
Rock Outcrop	D	Herbaceous	Poor	93	99.873	0.119	11.1
Rock Outcrop	D	Oak-Aspen	Fair	63	76.552	0.091	5.7
Agassiz-Rock Outcrop Complex, 30 to 70% Slopes	D	Oak-Aspen	Fair	63	32.182	0.038	2.4
Agassiz-Rock Outcrop Complex, 30 to 70% Slopes	D	Oak-Aspen	Poor	79	22.990	0.027	2.2
Agassiz-Rock Outcrop Complex, 30 to 70% Slopes	D	Oak-Aspen	Fair	63	77.133	0.092	5.8
			TOTAL		840.284	1.000	65.6

Middle Basin

SOILTYPE	GROUP	VEGETATION	CONDITION	CN	AREA_ACRES	RATIO	COMPOSITE CN
Hades-Agassiz-Rock Outcrop Complex, 30 to 70%	D	Oak-Aspen	Fair	63	97.039	0.118003	7.4
Dromedary-Rock Outcrop Complex, 30 to 70%	D	Pinyon-Juniper	Good	71	191.104	0.232389	16.5
ParkCity-Dromedary Gravelly Loams, 30 to 70%	B	Pinyon-Juniper	Good	41	239.543	0.291292	11.9
Rock Outcrop	D	Herbaceous	Poor	93	199.488	0.242584	22.6
Dromedary-Rock Outcrop Complex, 30 to 70%	D	Oak-Aspen	Fair	63	1.729	0.002103	0.1
Agassiz-Rock Outcrop Complex, 30 to 70% Slopes	D	Oak-Aspen	Poor	79	40.187	0.048869	3.9
Agassiz-Rock Outcrop Complex, 30 to 70% Slopes	D	Oak-Aspen	Fair	63	52.972	0.064416	4.1
			TOTAL		822.062	1.000	66.5

Upper Basin

SOILTYPE	GROUP	VEGETATION	CONDITION	CN	AREA_ACRES	RATIO	COMPOSITE CN
Hades-Agassiz-Rock Outcrop Complex, 30 to 70%	D	Oak-Aspen	Fair	63	89.693	0.124003	7.8
ParkCity-Dromedary Gravelly Loams, 30 to 70%	B	Pinyon-Juniper	Good	41	243.009	0.335966	13.8
Rock Outcrop	D	Herbaceous	Poor	93	184.889	0.255614	23.8
Rock Outcrop - Starley Family Complex, 30 to 70%	D	Oak-Aspen	Fair	63	198.614	0.274589	17.3
Dromedary-Rock Outcrop Complex, 30 to 70%	D	Oak-Aspen	Fair	63	3.812	0.005270	0.3
Dromedary-Rock Outcrop Complex, 30 to 70%	D	Oak-Aspen	Fair	63	1.183	0.001636	0.1
Dromedary-Rock Outcrop Complex, 30 to 70%	D	Oak-Aspen	Fair	63	0.901	0.001246	0.1
Dromedary-Rock Outcrop Complex, 30 to 70%	D	Oak-Aspen	Fair	63	1.213	0.001677	0.1
			TOTAL		723.314	1.000	63.3

Regression Equation — $Lag = .0051 \times width^{.594} \times slope^{-.15} \times S_{nat}^{.313}$

$width = \frac{\text{Watershed Area}}{\text{Watershed Length}}$

$Slope = \frac{\text{max Elev. dif}}{\text{longest flow path}}$

$S_{nat} = \frac{1000}{CN} - 10$

From "Lag Time Characteristics for Small Watersheds in the U.S." by M.J. Simas & R.H. Hawkins

Lower Basin — Watershed Area = 36610472.3 ft²
Watershed Length = 10,850 ft

$Width = \frac{Area}{Length} = 3374$ ft

$Slope = \frac{9400 - 5560}{10,850} = .35$ ft/ft

$S_{nat} = \frac{1,000}{65.6} - 10 = 5.2$ in

$Lag = .0051 \times 3,374^{.594} \times .35^{-.15} \times 5.2^{.313}$

$= 1.24$ hours

$= \boxed{74.8 \text{ minutes}}$

HANSEN ALLEN & LUCE inc
ENGINEERS

CLIENT Salt Lake County
PROJECT Neffs Canyon
FEATURE Lag Time - Regression
PROJECT NO 014.10.100

SHEET 2 OF 2
COMPUTED gli
CHECKED
DATE 12/27/05

Middle Basin -

Watershed Area = 35,823,659.2 ft^2
Watershed Length = 11,800 ft

$$\text{Width} = \frac{\text{Area}}{\text{Length}} = 3{,}036 \text{ ft}$$

$$\text{Slope} = \frac{9{,}770 - 6{,}100}{11{,}800} = .31 \text{ ft/ft}$$

$$S_{nat} = \frac{1000}{66.5} - 10 = 5.04 \text{ in}$$

$$\text{Lag} = .0051 \times 3{,}036^{.594} \times .31^{-.15} \times 5.04^{.313}$$

$$= 1.18 \text{ hrs}$$

$$= \boxed{70.9 \text{ minutes}}$$

Upper Basin -

Watershed Area = 31,507,800.6 ft^2
Watershed Length = 9,400 ft

$$\text{Width} = \frac{\text{Area}}{\text{Length}} = 3{,}352 \text{ ft}$$

$$\text{Slope} = \frac{9{,}680 - 6{,}840}{9{,}400} = .30 \text{ ft/ft}$$

$$S_{nat} = \frac{1000}{63.3} - 10 = 5.8 \text{ in}$$

$$\text{Lag} = .0051 \times 3{,}352^{.594} \times .30^{-.15} \times 5.8^{.313}$$

$$= 1.32 \text{ hrs}$$

$$= \boxed{78.9 \text{ minutes}}$$

Transmission Losses @ Bottom of Neffs Canyon
100 Year - 24 Hour Event

"National Engineering Handbook", Section 4 - Hydrology, Chapter 19 - Transmission Losses

D = duration (hours)
P = inflow volume (acre-feet)

$a(D) = -0.00465KD$
$k(D,P) = -1.09\ln[1.0 - 0.0545KD/P]$

D = 24 Hours
K = 4 in/hr

P = 156.92 acre-feet

a = -0.44640 acre-feet
k = 0.003640 $(ft\text{-}mi)^{-1}$

b = regression slope for unit channel

b = 0.996366

$b(x,w) = e^{-kxw}$

x = length of reach (miles)
w = average width of flow (feet)

x = 2 miles
w = 10 feet

b(x,w) = 0.930

$a(x,w) = a / 1 - b\ [1-b(x,w)]$

a(x,w) = -8.63 acre-feet

$P_o(x,w) = -a(x,w)/b(x,w)$

P_o = 9.28 acre-feet

P = inflow volume (acre-feet)

P = 156.92 acre-feet

Q(x,w) = 137.3 acre-feet

$q(x,w) = 12.1/D*(a(x,w) - [1-b(x,w)]P) + b(x,w)p$
p = peak rate of inflow (cfs)

p = 335 cfs

q(x,w) = 302 cfs

The losses in cfs per 1000 feet of reach length

L = 3.17 cfs/1000ft

SALT LAKE COUNTY
NEFFS CANYON CREEK MASTER PLAN
URBAN SUBBASINS
Time of Concentration

1/2

	SHEET FLOW						SHALLOW CONCENTRATED FLOW				CHANNEL FLOW					TIME OF C	Tlag (MIN (minutes)
	L	S (ft/ft)	n	P2	Tt (hrs)	Tt (min)	L	S (ft/ft)	V (fps)	T (min)	L	S (ft/ft)	N	V (fps)	T (min)		
Urb-1	400	0.16	0.4	1.79	0.63	37.5	0				2200	0.13	0.016	9	4.1	41.6	25.0
Urb-2	400	0.16	0.4	1.79	0.63	37.5	0				2700	0.11	0.016	8	5.6	43.2	25.9
Urb-3	250	0.26	0.24	1.79	0.24	14.2	0				1700	0.12	0.016	8.5	3.3	17.5	10.5
Urb-4	400	0.16	0.13	1.79	0.25	15.3	0				413	0.02	0.016	4	1.7	17.0	10.2
Urb-5	400	0.15	0.13	1.79	0.26	15.8	0				405	0.01	0.016	3	2.3	18.1	10.8
Urb-6	400	0.15	0.24	1.79	0.43	25.8	0				960	0.06	0.016	7	2.3	28.1	16.9
Urb-7	224	0.13	0.13	1.79	0.18	10.7	175	0.11	6.5	0.448718	2000	0.05	0.04	8.5	3.9	15.0	9.0
Urb-8	244	0.11	0.13	1.79	0.20	12.2	0				1430	0.07	0.016	7	3.4	15.6	9.4

KINEMATIC WAVE PARAMETERS

	PLANE 2 - Imp & Unnconected			% of Area	PLANE 1 - Directly C		% of Area	SubCollector				Collector					
	L	S (ft/ft)			L	S (ft/ft)		L	S (ft/ft)	% Area		L	S (ft/ft)		b	z	n
Urb-1	400	0.16	0.4	86.1%	30	0.035	13.9%	900	0.10	0.33	0.015984	900	0.11	channel	4	2	0.04
Urb-2	400	0.16	0.4	83.2%	30	0.035	16.8%	1300	0.06	0.166667	0.021094	1700	0.1	road	2	50	0.016
Urb-3	250	0.26	0.24	80.9%	30	0.035	19.1%	1000	0.06	0.333333	0.0125	900	0.1		2	50	0.016
Urb-4	400	0.16	0.13	80.6%	30	0.035	19.4%	800	0.11	0.4	0.01125	400	0.04		2	50	0.016
Urb-5	400	0.15	0.13	84.1%	30	0.035	15.9%	800	0.11	0.4	0.008125	600	0.05		2	50	0.016
Urb-6	400	0.15	0.24	71.1%	200	0.065	28.9%					1400	0.1		2	50	0.016
Urb-7	224	0.13	0.13	74.9%	30	0.035	25.1%					1000	0.07		2	50	0.016
Urb-8	244	0.11	0.13	64.3%	30	0.035	35.7%	300	0.015	0.5	0.016406	1300	0.07		2	50	0.016

SALT LAKE COUNTY
NEFFS CANYON CREEK MASTER PLAN
URBAN SUBBASINS

	AREA (sq miles)	AREA	No. of Homes		Units/Acre	% Impervi	Impervious Are	OVERALL Composite CN	DIRECTLY CONNECTED ROADS	LOTS	DIRECTLY Connected Imper (acres)	% Directly Cc	UnConnec Impervious (acres)	Area Perv + unconnected	Pervious + Unconnected COMPOSITE CN
Urb-1	0.0484	31	41		1.32	32	9.92	70.1	2.7	2.4	4.3	13.9%	5.6	26.7	65.6
Urb-2	0.1266	81	137		1.69	35	28.35	71.4	5.7	7.9	13.6	16.8%	14.8	67.4	66.0
Urb-3	0.0375	24	45		1.88	38	9.12	72.6	2.0	2.6	4.6	19.1%	4.5	19.4	66.6
Urb-4	0.0281	18	34		1.89	38	6.84	72.6	1.5	2.0	3.5	19.4%	3.4	14.5	66.5
Urb-5	0.0203	13	17		1.31	32	4.16	70.1	1.1	1.0	2.1	15.9%	2.1	10.9	64.8
Urb-6	0.0469	30	29	+ school &	0.97	44.6	13.4	75.3	2.3	6.4	8.7	28.9%	4.7	21.3	66.0
Urb-7	0.0156	10	26		2.60	42	4.2	74.2	1.0	1.5	2.5	25.1%	1.7	7.5	66.3
Urb-8	0.0328	21	81		3.86	53	11.13	78.7	2.8	4.6	7.5	35.7%	3.6	13.5	68.0

school 103879.5 29497.77 3.06192 impervious acres
church 122402.15 2.80997 impervious acres

SOILS

		HSGroup
SP	Stony terrace escarpments	na
HWF	Horrocks extremely stony loam	C
HHF	Harkers soils	D

soils are mostly HWF, therefore use C

Pervious Area Cover

Oak-Aspen, Type C, Good co	CN=	57
Impervious	CN=	98

SALT LAKE COUNTY
NEFFS CANYON CREEK MASTER PLAN
URBAN SUBBASINS
Time of Concentration

	SHEET FLOW						SHALLOW CONCENTRATED FLOW				CHANNEL FLOW					TIME	Tlag
	L	S (ft/ft)	n	P2	Tt (hrs)	Tt (min)	L	S (ft/ft)	V (fps)	T (min)	L	S (ft/ft)	N	V (fps)	T (min)	OF C (MIN	(minutes)
Urb-1	400	0.16	0.4	1.79	0.63	37.5	0				2200	0.13	0.016	9	4.1	41.6	25.0
Urb-2	400	0.16	0.4	1.79	0.63	37.5	0				2700	0.11	0.016	8	5.6	43.2	25.9
Urb-3	250	0.26	0.24	1.79	0.24	14.2	0				1700	0.12	0.016	8.5	3.3	17.5	10.5
Urb-4	400	0.16	0.13	1.79	0.25	15.3	0				413	0.02	0.016	4	1.7	17.0	10.2
Urb-5	400	0.15	0.13	1.79	0.26	15.8	0				405	0.01	0.016	3	2.3	18.1	10.8
Urb-6	400	0.15	0.24	1.79	0.43	25.8	0				960	0.06	0.016	7	2.3	28.1	16.9
Urb-7	224	0.13	0.13	1.79	0.18	10.7	175	0.11	6.5	0.448718	2000	0.05	0.04	8.5	3.9	15.0	9.0
Urb-8	244	0.11	0.13	1.79	0.20	12.2	0				1430	0.07	0.016	7	3.4	15.6	9.4

KINEMATIC WAVE PARAMETERS

	PLANE 2 - Imp & Unnconected			% of Area	PLANE 1 - Directly C		% of Area	SubCollector				Collector					
	L	S (ft/ft)			L	S (ft/ft)		L	S (ft/ft)	% Area		L	S (ft/ft)		b	z	n
Urb-1	400	0.16	0.4	86.1%	30	0.035	13.9%	900	0.10	0.33	0.015984	900	0.11	channel	4	2	0.04
Urb-2	400	0.16	0.4	83.2%	30	0.035	16.8%	1300	0.06	0.166667	0.021094	1700	0.1	road	2	50	0.016
Urb-3	250	0.26	0.24	80.9%	30	0.035	19.1%	1000	0.06	0.333333	0.0125	900	0.1		2	50	0.016
Urb-4	400	0.16	0.13	80.6%	30	0.035	19.4%	800	0.11	0.4	0.01125	400	0.04		2	50	0.016
Urb-5	400	0.15	0.13	84.1%	30	0.035	15.9%	800	0.11	0.4	0.008125	600	0.05		2	50	0.016
Urb-6	400	0.15	0.24	71.1%	200	0.065	28.9%					1400	0.1		2	50	0.016
Urb-7	224	0.13	0.13	74.9%	30	0.035	25.1%					1000	0.07		2	50	0.016
Urb-8	244	0.11	0.13	64.3%	30	0.035	35.7%	300	0.015	0.5	0.016406	1300	0.07		2	50	0.016

SALT LAKE COUNTY
NEFFS CANYON CREEK MASTER PLAN
URBAN SUBBASINS

	AREA (sq miles)	AREA	No. of Homes		Units/Acre	% Impervi	Impervious Are	OVERALL Composite CN	DIRECTLY CONNECTED ROADS	DIRECTLY CONNECTED LOTS	DIRECTLY Connected Imper (acres)	% Directly C	UnConnec Impervious (acres)	Area Perv + unconnected	Pervious + COMPOSI
Urb-1	0.0484	31	41		1.32	32	9.92	70.1	2.7	2.4	4.3	13.9%	5.6	26.7	65.6
Urb-2	0.1266	81	137		1.69	35	28.35	71.4	5.7	7.9	13.6	16.8%	14.8	67.4	66.0
Urb-3	0.0375	24	45		1.88	38	9.12	72.6	2.0	2.6	4.6	19.1%	4.5	19.4	66.6
Urb-4	0.0281	18	34		1.89	38	6.84	72.6	1.5	2.0	3.5	19.4%	3.4	14.5	66.5
Urb-5	0.0203	13	17		1.31	32	4.16	70.1	1.1	1.0	2.1	15.9%	2.1	10.9	64.8
Urb-6	0.0469	30	29	+ school &	0.97	44.6	13.4	75.3	2.3	6.4	8.7	28.9%	4.7	21.3	66.0
Urb-7	0.0156	10	26		2.60	42	4.2	74.2	1.0	1.5	2.5	25.1%	1.7	7.5	66.3
Urb-8	0.0328	21	81		3.86	53	11.13	78.7	2.8	4.6	7.5	35.7%	3.6	13.5	68.0

school	103879.5	29497.77	3.06192	impervious acres
church		122402.15	2.80997	impervious acres

SOILS

		HSGroup	
SP	Stony terrace escarpments	na	
HWF	Horrocks extremely stony loam	C	soils are mostly HWF, therefore use C
HHF	Harkers soils	D	

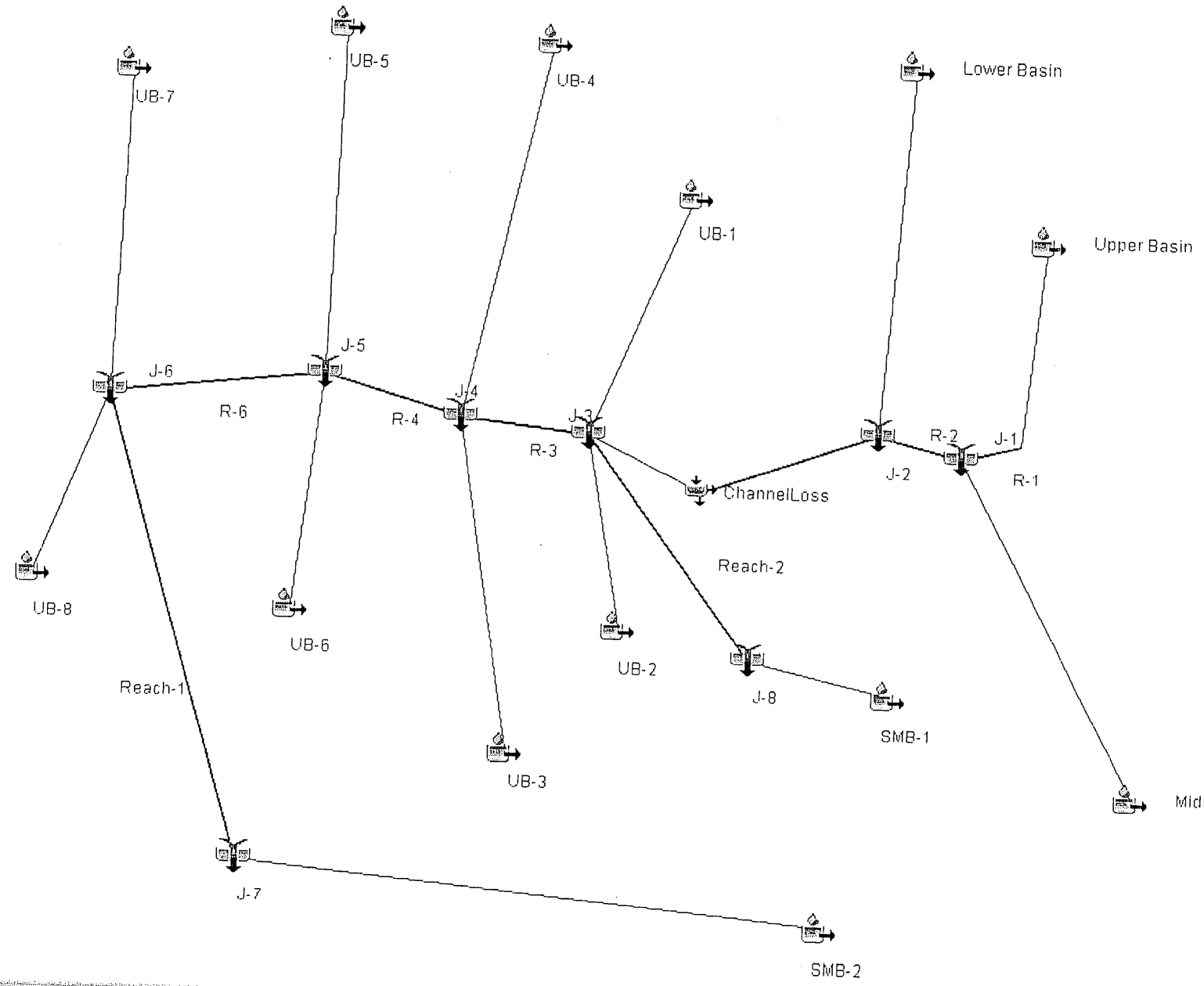
Pervious Area Cover

Oak-Aspen, Type C, Good co	CN=	57
Impervious	CN=	98

2/2

Components Parameters Compute Results Tools Help

Basin Model [NeffCanyon] Current Run [100yr-24hr-New]



Alpha: 2.8257 m: 1.3334

Project: NoDebBasin_KinematicU Simulation Run: 100yr-24hr-New

Start of Run: 01Aug2005, 12:00 Basin Model: NeffCanyon
End of Run: 02Aug2005, 18:00 Meteorologic Model: 100yr-24hr
Compute Time: 21Dec2007, 12:09:24 Control Specifications: 24hr

Volume Units: AC-FT

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (AC-FT)
ChannelLoss	3.7280	300.7	02Aug2005, 04:47	136.8
J-1	2.4150	241.8	02Aug2005, 04:38	122.3
J-2	3.7280	336.1	02Aug2005, 04:43	170.4
J-3	4.0168	317.7	02Aug2005, 04:43	149.8
J-4	4.0824	321.7	02Aug2005, 04:45	153.5
J-5	4.1496	326.1	02Aug2005, 04:47	157.7
J-6	4.5654	348.0	02Aug2005, 04:46	174.2
J-7	0.3674	31.7	02Aug2005, 03:33	12.9
J-8	0.1138	9.9	02Aug2005, 03:32	4.0
Lower Basin	1.3130	94.4	02Aug2005, 04:42	48.1
Middle Basin	1.2850	135.1	02Aug2005, 04:31	67.1
R-1	1.1300	107.9	02Aug2005, 04:48	55.3
R-2	2.4150	241.8	02Aug2005, 04:43	122.3
R-3	4.0168	317.7	02Aug2005, 04:45	149.8
R-4	4.0824	321.7	02Aug2005, 04:48	153.5
R-5	3.7280	336.1	02Aug2005, 04:47	170.4
R-6	4.1496	326.1	02Aug2005, 04:52	157.7
Reach-1	0.3674	31.7	02Aug2005, 03:39	12.9
Reach-2	0.1138	9.9	02Aug2005, 03:36	4.0
SMB-1	0.1138	9.9	02Aug2005, 03:32	4.0
SMB-2	0.3674	31.7	02Aug2005, 03:33	12.9
UB-1	0.0484	4.6	02Aug2005, 03:31	2.3
UB-2	0.1266	12.9	02Aug2005, 03:31	6.7
UB-3	0.0375	4.3	02Aug2005, 03:31	2.1
UB-4	0.0281	3.2	02Aug2005, 03:30	1.6

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (AC-FT)
UB-5	0.0203	2.0	02Aug2005, 03:31	1.0
UB-6	0.0469	6.0	02Aug2005, 03:30	3.2
UB-7	0.0156	1.9	02Aug2005, 03:30	1.0
UB-8	0.0328	4.9	02Aug2005, 03:31	2.6
Upper Basin	1.1300	107.9	02Aug2005, 04:43	55.3

Snowmelt Calculations for Neffs Canyon
Client: Salt Lake County
Project #: 014.10.100
Computed: GLJ

Basin Size = 3.73 mi^2

$$Q_{10} = 14.13A^{0.94} \quad \text{where R = 0.84}$$
$$Q_{50} = 20.44A^{0.92} \quad \text{where R = 0.84}$$
$$Q_{100} = 22.57A^{0.91} \quad \text{where R = 0.84}$$

R = Correlation Coefficient
A = Drainage Area in Square Miles
Q = Discharge in Cubic Feet per Second

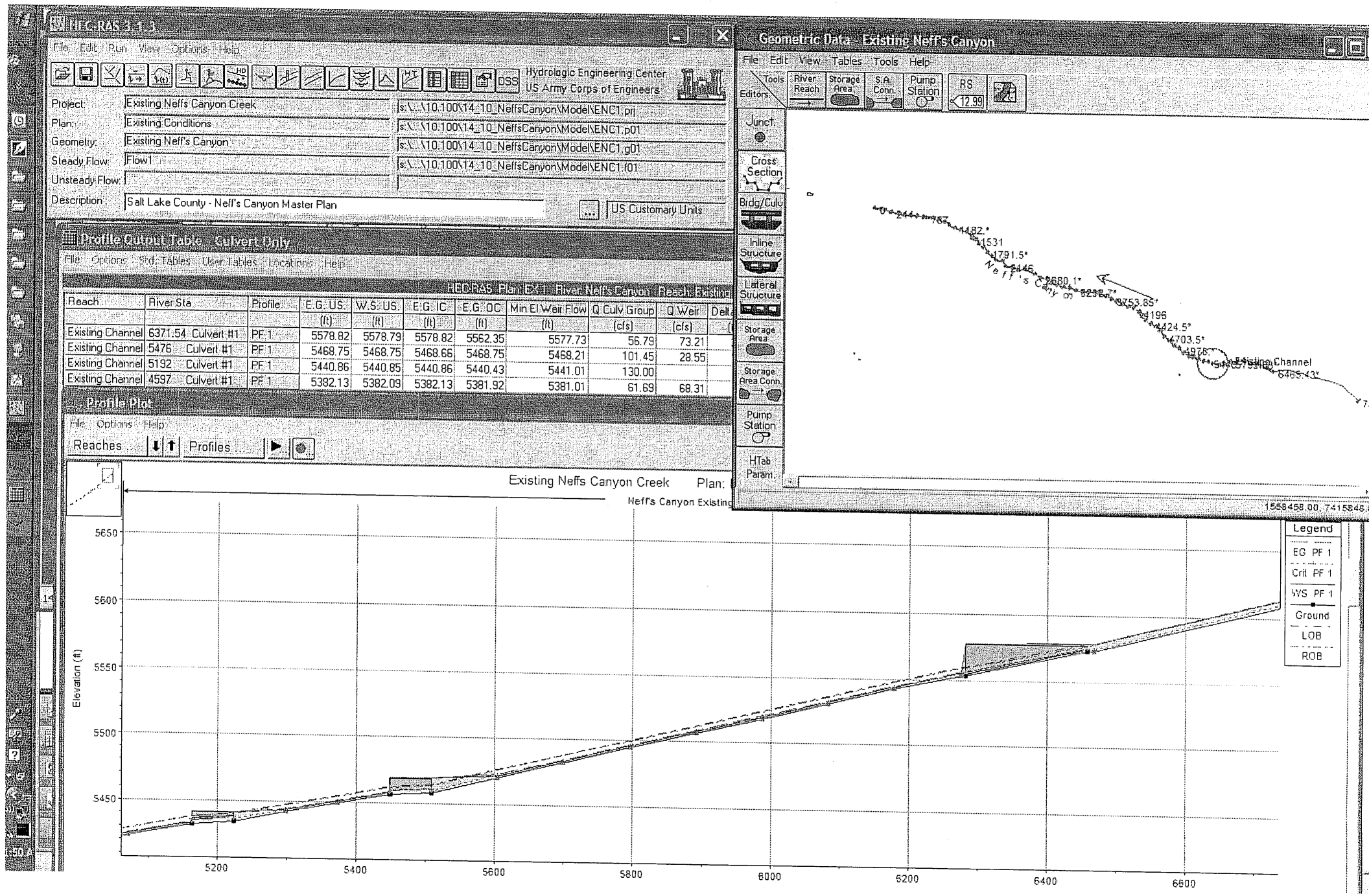
Q_{10} = 49 cfs
Q_{50} = 69 cfs
Q_{100} = 75 cfs

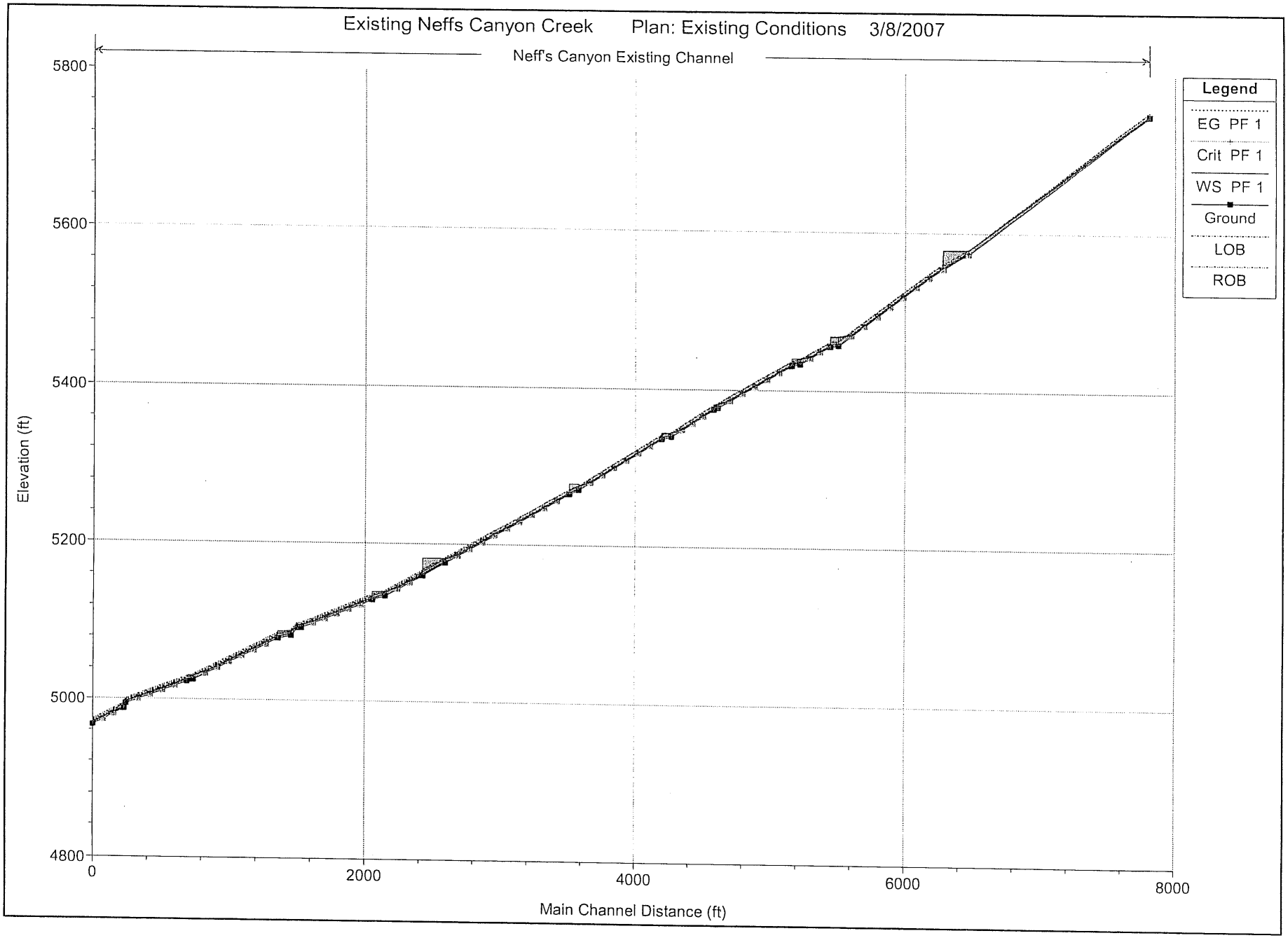
REFERENCE: "Hydrology Report, Flood Insurance Studies, 20 Utah Communities, F.I.A. Contract H-4790", Gingery and Associates, 1979.

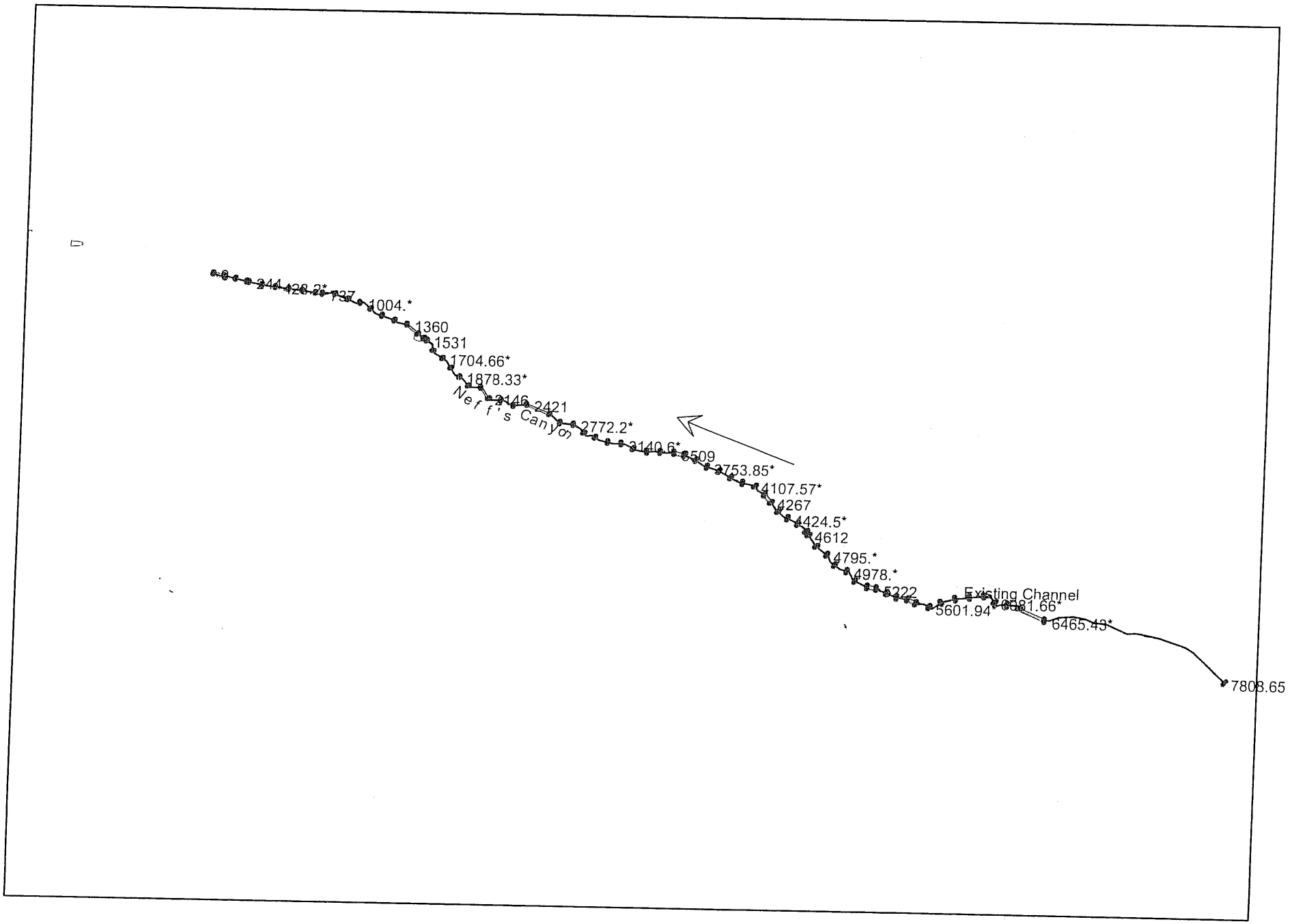
APPENDIX C
HYDRAULICS

TABLE OF CONTENTS

ITEM	No. Of Pages
HEC-RAS MODEL PRINTOUTS – EXISTING NEFFS CREEK CONVEYANCES	9
HDS-5 CULVERT INLET CONTROL PRINTOUTS	1
ALTERNATIVE CHANNEL ANALYSIS	4
PIPE ALTERNATIVE ANALYSIS	1


HEC-RAS 4.1.0
File Edit Run View Options Help
Hydrologic Engineering Center
US Army Corps of Engineers
Project: Existing Neffs Canyon Creek
Plan: Existing Conditions
Geometry: Existing Neff's Canyon
Steady Flow: Flow1
Unsteady Flow:
Description: Salt Lake County - Neff's Canyon Master Plan
US Customary Units
Profile Output Table - Culvert Only
File Options Std. Tables User Tables Locations Help
HECRAS Plan: EX1 River: Neff's Canyon Reach: Existing
Reach | River Sta | Profile | E.G. US. | W.S. US. | E.G. IC | E.G. OC | Min El Weir Flow | Q Culv Group | Q Weir | Delt
(ft) | (ft) | (ft) | (ft) | (ft) | (cfs) | (cfs)
Existing Channel | 6371.54 Culvert #1 | PF 1 | 5578.82 | 5578.79 | 5578.82 | 5562.35 | 5577.73 | 56.79 | 73.21
Existing Channel | 5476 Culvert #1 | PF 1 | 5468.75 | 5468.75 | 5468.66 | 5468.75 | 5468.21 | 101.45 | 28.55
Existing Channel | 5192 Culvert #1 | PF 1 | 5440.86 | 5440.85 | 5440.86 | 5440.43 | 5441.01 | 130.00
Existing Channel | 4597 Culvert #1 | PF 1 | 5382.13 | 5382.09 | 5382.13 | 5381.92 | 5381.01 | 61.69 | 68.31
Profile Plot
File Options Help
Reaches... Profiles...
Existing Neffs Canyon Creek Plan:
Neff's Canyon Existing
Elevation (ft)
5650
5600
5550
5500
5450
5200
5400
5600
5800
6000
6200
6400
6600
Legend
EG PF 1
Crit PF 1
WS PF 1
Ground
LOB
ROB
Geometric Data - Existing Neff's Canyon
File Edit View Tables Tools Help
Tools
Editors
River Reach
Storage Area
S.A. Conn.
Pump Station
RS
12.99
Junct.
Cross Section
Brdg/Culv
Inline Structure
Lateral Structure
Storage Area
Storage Area Conn.
Pump Station
HTab Param.
Existing Channel
1558458.00, 7415846.


Existing Neffs Canyon Creek Plan: Existing Conditions 3/8/2007
Neff's Canyon Existing Channel
Legend
EG PF 1
Crit PF 1
WS PF 1
Ground
LOB
ROB
Elevation (ft)
5800
5600
5400
5200
5000
4800
0
2000
4000
6000
8000
Main Channel Distance (ft)


1004.*
1360
1531
1704.66*
1878.33*
Neff's Canyon
2421
2772.2*
3753.85*
4107.57*
4267
4424.5*
4612
4795.*
4978.*
Existing Channel
5601.94
6465.43*
7808.65

HEC-RAS Plan: EX 1 River: Neff's Canyon Reach: Existing Channel Profile: PF 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Existing Channel	7808.65	PF 1	130.00	5749.00	5750.68	5750.68	5751.38	0.082008	6.70	19.41	14.13	1.01
Existing Channel	6465.43*	PF 1	130.00	5573.20	5578.79	5574.87	5578.82	0.000858	1.31	99.61	25.99	0.12
Existing Channel	6371.54		Culvert									
Existing Channel	6273.55*	PF 1	130.00	5553.93	5555.61	5555.61	5556.31	0.081337	6.68	19.47	14.14	1.00
Existing Channel	6177.60*	PF 1	130.00	5542.59	5543.94	5544.27	5545.12	0.177140	8.72	14.90	13.12	1.44
Existing Channel	6081.66*	PF 1	130.00	5530.45	5532.06	5532.13	5532.83	0.095262	7.05	18.43	13.92	1.08
Existing Channel	5985.71*	PF 1	130.00	5518.31	5519.67	5519.99	5520.82	0.170379	8.61	15.10	13.16	1.42
Existing Channel	5889.77*	PF 1	130.00	5506.17	5507.77	5507.85	5508.55	0.098062	7.12	18.25	13.88	1.09
Existing Channel	5793.83*	PF 1	130.00	5494.02	5495.40	5495.70	5496.52	0.164756	8.51	15.28	13.20	1.39
Existing Channel	5697.88*	PF 1	130.00	5481.88	5483.47	5483.56	5484.27	0.100420	7.18	18.10	13.84	1.11
Existing Channel	5601.94*	PF 1	130.00	5469.74	5471.13	5471.42	5472.23	0.159955	8.42	15.43	13.24	1.38
Existing Channel	5506	PF 1	130.00	5457.60	5468.75	5459.28	5468.75	0.000066	0.53	244.04	26.30	0.03
Existing Channel	5476		Culvert									
Existing Channel	5446	PF 1	130.00	5456.30	5457.98	5457.98	5458.68	0.081841	6.69	19.43	14.13	1.01
Existing Channel	5371.33*	PF 1	130.00	5448.87	5450.37	5450.55	5451.28	0.121298	7.66	16.96	13.59	1.21
Existing Channel	5296.66*	PF 1	130.00	5441.43	5443.10	5443.11	5443.81	0.082771	6.72	19.35	14.12	1.01
Existing Channel	5222	PF 1	130.00	5434.00	5440.85	5435.68	5440.86	0.000384	0.99	130.98	26.30	0.08
Existing Channel	5192		Culvert									
Existing Channel	5161	PF 1	130.00	5431.70	5433.38	5433.38	5434.08	0.081840	6.69	19.43	14.13	0.08
Existing Channel	5069.5*	PF 1	130.00	5422.62	5424.12	5424.30	5425.03	0.121022	7.66	16.98	13.59	1.21
Existing Channel	4978.*	PF 1	130.00	5413.53	5415.21	5415.21	5415.91	0.082602	6.71	19.37	14.12	1.01
Existing Channel	4886.5*	PF 1	130.00	5404.45	5405.96	5406.13	5406.86	0.119790	7.63	17.04	13.61	1.20
Existing Channel	4795.*	PF 1	130.00	5395.37	5397.04	5397.05	5397.75	0.083198	6.73	19.32	14.11	1.01
Existing Channel	4703.5*	PF 1	130.00	5386.28	5387.79	5387.96	5388.69	0.118844	7.61	17.08	13.62	1.20
Existing Channel	4612	PF 1	130.00	5377.20	5382.09	5378.88	5382.13	0.001542	1.62	80.45	23.93	0.16
Existing Channel	4597		Culvert									
Existing Channel	4582	PF 1	130.00	5375.00	5376.68	5376.68	5377.38	0.081337	6.68	19.47	14.14	1.00
Existing Channel	4503.25*	PF 1	130.00	5366.15	5367.54	5367.83	5368.64	0.158589	8.40	15.48	13.25	1.37
Existing Channel	4424.5*	PF 1	130.00	5357.30	5358.97	5358.98	5359.68	0.083716	6.74	19.28	14.10	1.02
Existing Channel	4345.75*	PF 1	130.00	5348.45	5349.86	5350.13	5350.92	0.152711	8.29	15.68	13.30	1.35
Existing Channel	4267	PF 1	130.00	5339.60	5345.09	5341.28	5345.12	0.000964	1.36	95.47	25.62	0.12
Existing Channel	4232		Culvert									
Existing Channel	4196	PF 1	130.00	5336.80	5338.48	5338.48	5339.18	0.081841	6.69	19.43	14.13	1.01
Existing Channel	4107.57*	PF 1	130.00	5327.29	5328.72	5328.97	5329.75	0.144490	8.14	15.98	13.37	1.31
Existing Channel	4019.14*	PF 1	130.00	5317.77	5319.44	5319.45	5320.15	0.083112	6.73	19.32	14.11	1.01
Existing Channel	3930.71*	PF 1	130.00	5308.26	5309.70	5309.94	5310.71	0.140758	8.06	16.12	13.40	1.30
Existing Channel	3842.28*	PF 1	130.00	5298.74	5300.40	5300.42	5301.12	0.084761	6.77	19.19	14.08	1.02
Existing Channel	3753.85*	PF 1	130.00	5289.23	5290.68	5290.91	5291.67	0.137630	8.00	16.25	13.43	1.28
Existing Channel	3665.42*	PF 1	130.00	5279.71	5281.37	5281.39	5282.09	0.086271	6.81	19.08	14.06	1.03

HEC-RAS Plan: EX 1 River: Neff's Canyon Reach: Existing Channel Profile: PF 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Existing Channel	3577	PF 1	130.00	5270.20	5275.57	5271.88	5275.60	0.001059	1.41	92.37	25.41	0.13
Existing Channel	3543		Culvert									
Existing Channel	3509	PF 1	130.00	5264.50	5266.18	5266.18	5266.88	0.081924	6.69	19.42	14.13	1.01
Existing Channel	3416.9*	PF 1	130.00	5255.63	5257.22	5257.37	5258.11	0.112197	7.56	17.20	13.16	1.17
Existing Channel	3324.8*	PF 1	130.00	5246.75	5248.55	5248.55	5249.28	0.082132	6.87	18.92	13.07	1.01
Existing Channel	3232.7*	PF 1	130.00	5237.88	5239.59	5239.74	5240.52	0.110933	7.73	16.82	12.14	1.16
Existing Channel	3140.6*	PF 1	130.00	5229.00	5230.94	5230.94	5231.71	0.082617	7.06	18.42	12.04	1.01
Existing Channel	3048.5*	PF 1	130.00	5220.13	5221.99	5222.14	5222.96	0.109793	7.90	16.46	11.15	1.15
Existing Channel	2956.4*	PF 1	130.00	5211.26	5213.36	5213.36	5214.18	0.084616	7.29	17.84	11.02	1.01
Existing Channel	2864.3*	PF 1	130.00	5202.38	5204.44	5204.57	5205.44	0.106689	8.01	16.22	10.23	1.12
Existing Channel	2772.2*	PF 1	130.00	5193.51	5195.81	5195.81	5196.69	0.086636	7.51	17.30	10.04	1.01
Existing Channel	2680.1*	PF 1	130.00	5184.63	5186.95	5187.05	5187.97	0.103559	8.10	16.05	9.36	1.09
Existing Channel	2588	PF 1	130.00	5175.76	5181.09	5178.31	5181.20	0.004818	2.62	49.70	14.33	0.25
Existing Channel	2505		Culvert									
Existing Channel	2421	PF 1	130.00	5159.46	5161.35	5162.02	5163.48	0.277425	11.71	11.10	7.77	0.25
Existing Channel	2329.33*	PF 1	130.00	5150.83	5153.39	5153.39	5154.32	0.089895	7.76	16.76	9.11	1.01
Existing Channel	2237.66*	PF 1	130.00	5142.19	5144.69	5144.75	5145.68	0.098467	8.02	16.21	8.99	1.05
Existing Channel	2146	PF 1	130.00	5133.56	5138.89	5136.11	5139.00	0.004818	2.62	49.70	14.33	0.25
Existing Channel	2099		Culvert									
Existing Channel	2052	PF 1	130.00	5128.46	5130.71	5131.02	5132.04	0.144937	9.24	14.06	8.50	0.25
Existing Channel	1965.16*	PF 1	130.00	5122.34	5124.96	5124.89	5125.83	0.081357	7.48	17.39	9.25	0.96
Existing Channel	1878.33*	PF 1	130.00	5116.23	5119.08	5118.79	5119.77	0.059745	6.67	19.49	9.69	0.83
Existing Channel	1791.5*	PF 1	130.00	5110.11	5112.70	5112.67	5113.60	0.085130	7.60	17.10	9.19	0.98
Existing Channel	1704.66*	PF 1	130.00	5103.99	5106.87	5106.54	5107.54	0.057223	6.57	19.80	9.76	0.81
Existing Channel	1617.83*	PF 1	130.00	5097.88	5100.44	5100.44	5101.37	0.089895	7.76	16.76	9.11	1.01
Existing Channel	1531	PF 1	130.00	5091.76	5095.80	5094.32	5096.05	0.015150	4.01	32.46	12.08	0.43
Existing Channel	1507	PF 1	130.00	5091.76	5094.32	5094.32	5095.25	0.089830	7.76	16.76	9.11	1.01
Existing Channel	1456	PF 1	130.00	5081.96	5087.29	5084.52	5087.40	0.004818	2.62	49.70	14.33	0.25
Existing Channel	1408		Culvert									
Existing Channel	1360	PF 1	130.00	5078.56	5081.09	5081.12	5082.05	0.093889	7.88	16.49	9.05	0.25
Existing Channel	1271.*	PF 1	130.00	5070.83	5073.43	5073.38	5074.32	0.084407	7.58	17.15	9.20	0.98
Existing Channel	1182.*	PF 1	130.00	5063.10	5065.66	5065.66	5066.59	0.089442	7.74	16.79	9.12	1.01
Existing Channel	1093.*	PF 1	130.00	5055.37	5057.97	5057.93	5058.86	0.084048	7.57	17.18	9.20	0.98
Existing Channel	1004.*	PF 1	130.00	5047.65	5050.21	5050.20	5051.14	0.089442	7.74	16.79	9.12	1.01
Existing Channel	915.*	PF 1	130.00	5039.92	5042.52	5042.48	5043.41	0.083988	7.57	17.18	9.21	0.98
Existing Channel	826.*	PF 1	130.00	5032.19	5034.75	5034.75	5035.68	0.089830	7.76	16.76	9.11	1.01
Existing Channel	737	PF 1	130.00	5024.46	5029.79	5027.02	5029.90	0.004818	2.62	49.70	14.33	0.25
Existing Channel	715		Culvert									
Existing Channel	692	PF 1	130.00	5022.19	5025.08		5025.74	0.056192	6.52	19.93	9.78	0.81

HEC-RAS Plan: EX 1 River: Neff's Canyon Reach: Existing Channel Profile: PF 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Existing Channel	602.4*	PF 1	130.00	5016.42	5019.10	5018.98	5019.92	0.075707	7.28	17.85	9.35	0.93
Existing Channel	512.8*	PF 1	130.00	5010.66	5013.60	5013.21	5014.23	0.053098	6.39	20.35	9.87	0.78
Existing Channel	423.2*	PF 1	130.00	5004.89	5007.52	5007.45	5008.38	0.081357	7.48	17.39	9.25	0.96
Existing Channel	333.6*	PF 1	130.00	4999.13	5002.12	5001.69	5002.72	0.049270	6.21	20.93	9.99	0.76
Existing Channel	244	PF 1	130.00	4993.36	4995.91	4995.91	4996.85	0.090219	7.77	16.74	9.11	1.01
Existing Channel	230	PF 1	130.00	4986.86	4988.19	4989.42	4993.45	0.978004	18.41	7.06	6.65	3.15
Existing Channel	153.333*	PF 1	130.00	4980.09	4982.65	4982.65	4983.58	0.089830	7.76	16.76	9.11	1.01
Existing Channel	76.6666*	PF 1	130.00	4973.33	4975.89	4975.89	4976.82	0.089765	7.75	16.77	9.11	1.01
Existing Channel	0	PF 1	130.00	4966.56	4969.05	4969.13	4970.06	0.099635	8.06	16.14	8.97	1.06

HEC-RAS Plan: EX 1 River: Neff's Canyon Reach: Existing Channel Profile: PF 1

Reach	River Sta	Profile	E.G. US.	W.S. US.	E.G. IC	E.G. OC	Min El Weir Flow	Q Culv Group	Q Weir	Delta WS	Culv Vel US	Culv Vel DS
			(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft)	(ft/s)	(ft/s)
Existing Channel	6371.54 Culvert #1	PF 1	5578.82	5578.79	5578.82	5562.35	5577.73	56.79	73.21	23.18	11.57	26.60
Existing Channel	5476 Culvert #1	PF 1	5468.75	5468.75	5468.66	5468.75	5468.21	101.45	28.55	10.77	14.35	14.35
Existing Channel	5192 Culvert #1	PF 1	5440.86	5440.85	5440.86	5440.43	5441.01	130.00		7.46	10.35	13.96
Existing Channel	4597 Culvert #1	PF 1	5382.13	5382.09	5382.13	5381.92	5381.01	61.69	68.31	5.40	8.73	14.14
Existing Channel	4232 Culvert #1	PF 1	5345.12	5345.09	5345.12	5344.66	5344.11	66.94	63.06	6.61	9.47	11.78
Existing Channel	3543 Culvert #1	PF 1	5275.60	5275.57	5275.11	5275.60	5278.61	130.00		9.39	9.58	17.49
Existing Channel	2505 Culvert #1	PF 1	5181.20	5181.09	5180.67	5181.20	5181.81	130.00		19.08	9.58	19.61
Existing Channel	2099 Culvert #1	PF 1	5139.00	5138.89	5138.58	5139.00	5139.11	130.00		7.61	9.58	15.45
Existing Channel	1408 Culvert #1	PF 1	5087.40	5087.29	5087.03	5087.40	5087.61	130.00		6.17	9.58	13.33
Existing Channel	715 Culvert #1	PF 1	5029.90	5029.79	5029.49	5029.90	5030.01	130.00		4.71	9.58	14.27

HEC-RAS Plan: EX 1 River: Neff's Canyon Reach: Existing Channel Profile: PF 1

Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
			(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Existing Channel	7808.65	PF 1	5751.38	5750.68	0.70	3.80	0.20		130.00		14.13
Existing Channel	6465.43*	PF 1	5578.82	5578.79	0.03				130.00		25.99
Existing Channel	6371.54		Culvert								
Existing Channel	6273.55*	PF 1	5556.31	5555.61	0.69	7.83	0.00		130.00		14.14
Existing Channel	6177.60*	PF 1	5545.12	5543.94	1.18	11.13	0.05		130.00		13.12
Existing Channel	6081.66*	PF 1	5532.83	5532.06	0.77	12.17	0.12		130.00		13.92
Existing Channel	5985.71*	PF 1	5520.82	5519.67	1.15	11.97	0.04		130.00		13.16
Existing Channel	5889.77*	PF 1	5508.55	5507.77	0.79	12.17	0.11		130.00		13.88
Existing Channel	5793.83*	PF 1	5496.52	5495.40	1.12	11.99	0.03		130.00		13.20
Existing Channel	5697.88*	PF 1	5484.27	5483.47	0.80	12.16	0.10		130.00		13.84
Existing Channel	5601.94*	PF 1	5472.23	5471.13	1.10	12.00	0.03		130.00		13.24
Existing Channel	5506	PF 1	5468.75	5468.75	0.00				130.00		26.30
Existing Channel	5476		Culvert								
Existing Channel	5446	PF 1	5458.68	5457.98	0.70	6.09	0.00		130.00		14.13
Existing Channel	5371.33*	PF 1	5451.28	5450.37	0.91	7.37	0.02		130.00		13.59
Existing Channel	5296.66*	PF 1	5443.81	5443.10	0.70	7.41	0.06		130.00		14.12
Existing Channel	5222	PF 1	5440.86	5440.85	0.02				130.00		26.30
Existing Channel	5192		Culvert								
Existing Channel	5161	PF 1	5434.08	5433.38	0.70				130.00		14.13
Existing Channel	5069.5*	PF 1	5425.03	5424.12	0.91	9.02	0.02		130.00		13.59
Existing Channel	4978.*	PF 1	5415.91	5415.21	0.70	9.07	0.06		130.00		14.12
Existing Channel	4886.5*	PF 1	5406.86	5405.96	0.90	9.02	0.02		130.00		13.61
Existing Channel	4795.*	PF 1	5397.75	5397.04	0.70	9.06	0.06		130.00		14.11
Existing Channel	4703.5*	PF 1	5388.69	5387.79	0.90	9.03	0.02		130.00		13.62
Existing Channel	4612	PF 1	5382.13	5382.09	0.04				130.00		23.93
Existing Channel	4597		Culvert								
Existing Channel	4582	PF 1	5377.38	5376.68	0.69	6.43	0.00		130.00		14.14
Existing Channel	4503.25*	PF 1	5368.64	5367.54	1.10	8.70	0.04		130.00		13.25
Existing Channel	4424.5*	PF 1	5359.68	5358.97	0.71	8.85	0.12		130.00		14.10
Existing Channel	4345.75*	PF 1	5350.92	5349.86	1.07	8.71	0.04		130.00		13.30
Existing Channel	4267	PF 1	5345.12	5345.09	0.03				130.00		25.62
Existing Channel	4232		Culvert								
Existing Channel	4196	PF 1	5339.18	5338.48	0.70	7.21	0.00		130.00		14.13
Existing Channel	4107.57*	PF 1	5329.75	5328.72	1.03	9.39	0.03		130.00		13.37
Existing Channel	4019.14*	PF 1	5320.15	5319.44	0.70	9.51	0.10		130.00		14.11
Existing Channel	3930.71*	PF 1	5310.71	5309.70	1.01	9.40	0.03		130.00		13.40
Existing Channel	3842.28*	PF 1	5301.12	5300.40	0.71	9.51	0.09		130.00		14.08
Existing Channel	3753.85*	PF 1	5291.67	5290.68	0.99	9.41	0.03		130.00		13.43
Existing Channel	3665.42*	PF 1	5282.09	5281.37	0.72	9.51	0.08		130.00		14.06
Existing Channel	3577	PF 1	5275.60	5275.57	0.03				130.00		25.41
Existing Channel	3543		Culvert								
Existing Channel	3509	PF 1	5266.88	5266.18	0.70	7.50	0.00		130.00		14.13
Existing Channel	3416.9*	PF 1	5258.11	5257.22	0.89	8.74	0.02		130.00		13.16
Existing Channel	3324.8*	PF 1	5249.28	5248.55	0.73	7.60	0.00		130.00		13.07
Existing Channel	3232.7*	PF 1	5240.52	5239.59	0.93	8.74	0.02		130.00		12.14
Existing Channel	3140.6*	PF 1	5231.71	5230.94	0.77	7.66	0.00		130.00		12.04
Existing Channel	3048.5*	PF 1	5222.96	5221.99	0.97	8.73	0.02		130.00		11.15
Existing Channel	2956.4*	PF 1	5214.18	5213.36	0.82	7.82	0.00		130.00		11.02
Existing Channel	2864.3*	PF 1	5205.44	5204.44	1.00	8.72	0.02		130.00		10.23
Existing Channel	2772.2*	PF 1	5196.69	5195.81	0.88	8.03	0.00		130.00		10.04
Existing Channel	2680.1*	PF 1	5187.97	5186.95	1.02	8.71	0.01		130.00		9.36
Existing Channel	2588	PF 1	5181.20	5181.09	0.11				130.00		14.33
Existing Channel	2505		Culvert								
Existing Channel	2421	PF 1	5163.48	5161.35	2.13				130.00		7.77
Existing Channel	2329.33*	PF 1	5154.32	5153.39	0.93	8.24	0.00		130.00		9.11
Existing Channel	2237.66*	PF 1	5145.68	5144.69	1.00	8.62	0.01		130.00		8.99
Existing Channel	2146	PF 1	5139.00	5138.89	0.11				130.00		14.33
Existing Channel	2099		Culvert								
Existing Channel	2052	PF 1	5132.04	5130.71	1.33				130.00		8.50
Existing Channel	1965.16*	PF 1	5125.83	5124.96	0.87	6.02	0.05		130.00		9.25
Existing Channel	1878.33*	PF 1	5119.77	5119.08	0.69	6.14	0.02		130.00		9.69
Existing Channel	1791.5*	PF 1	5113.60	5112.70	0.90	6.00	0.07		130.00		9.19
Existing Channel	1704.66*	PF 1	5107.54	5106.87	0.67	6.15	0.03		130.00		9.76
Existing Channel	1617.83*	PF 1	5101.37	5100.44	0.93	2.64	0.21		130.00		9.11
Existing Channel	1531	PF 1	5096.05	5095.80	0.25	0.73	0.07		130.00		12.08
Existing Channel	1507	PF 1	5095.25	5094.32	0.93	0.65	0.25		130.00		9.11
Existing Channel	1456	PF 1	5087.40	5087.29	0.11				130.00		14.33
Existing Channel	1408		Culvert								
Existing Channel	1360	PF 1	5082.05	5081.09	0.96				130.00		9.05
Existing Channel	1271.*	PF 1	5074.32	5073.43	0.89	7.73	0.00		130.00		9.20
Existing Channel	1182.*	PF 1	5066.59	5065.66	0.93	7.71	0.01		130.00		9.12
Existing Channel	1093.*	PF 1	5058.86	5057.97	0.89	7.71	0.00		130.00		9.20
Existing Channel	1004.*	PF 1	5051.14	5050.21	0.93	7.71	0.01		130.00		9.12
Existing Channel	915.*	PF 1	5043.41	5042.52	0.89	7.73	0.00		130.00		9.21

HEC-RAS Plan: EX 1 River: Neff's Canyon Reach: Existing Channel Profile: PF 1 (Continued)

Reach	River Sta	Profile	E.G. Elev	W.S. Elev	Vel Head	Frctn Loss	C & E Loss	Q Left	Q Channel	Q Right	Top Width
			(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Existing Channel	826.*	PF 1	5035.68	5034.75	0.93	1.13	0.25		130.00		9.11
Existing Channel	737	PF 1	5029.90	5029.79	0.11				130.00		14.33
Existing Channel	715		Culvert								
Existing Channel	692	PF 1	5025.74	5025.08	0.66	5.81	0.02		130.00		9.78
Existing Channel	602.4*	PF 1	5019.92	5019.10	0.82	5.64	0.06		130.00		9.35
Existing Channel	512.8*	PF 1	5014.23	5013.60	0.63	5.82	0.02		130.00		9.87
Existing Channel	423.2*	PF 1	5008.38	5007.52	0.87	5.58	0.08		130.00		9.25
Existing Channel	333.6*	PF 1	5002.72	5002.12	0.60	5.84	0.03		130.00		9.99
Existing Channel	244	PF 1	4996.85	4995.91	0.94	1.25	0.01		130.00		9.11
Existing Channel	230	PF 1	4993.45	4988.19	5.26	2.97	0.43		130.00		6.65
Existing Channel	153.333*	PF 1	4983.58	4982.65	0.93	16.22	1.30		130.00		9.11
Existing Channel	76.6666*	PF 1	4976.82	4975.89	0.93				130.00		9.11
Existing Channel	0	PF 1	4970.06	4969.05	1.01	6.85	0.00		130.00		8.97

HDS 5 Nomograph Calculator
Dr. William S Grenney

1/2

Headwater Depth for Concrete Pipe Culverts with Inlet Control

- ○ Square Edge with Headwall
- ◉ Groove End with Headwall
- ○ Groove End Projecting

		Calc — Critical Depth (ft)
		Critical Velocity (ft/s)
	300	Q = Discharge (cfs)
	.06	Culvert Barrel Slope (ft/ft)
	6	Culvert diameter (ft)
	7.547	Headwater (ft)

Calc

Units
◉ English ○ Metric

Headwater Depth for Concrete Pipe Culverts with Inlet Control

- ○ Square Edge with Headwall
- ◉ Groove End with Headwall
- ○ Groove End Projecting

		Critical Depth (ft)
Calc		Critical Velocity (ft/s)
	350	Q = Discharge (cfs)
	.06	Culvert Barrel Slope (ft/ft)
	6	Culvert diameter (ft)
	8.734	Headwater (ft)

Calc

Units
◉ English ○ Metric

SALT LAKE COUNTY
NEFFS CANYON CREEK
ALTERNATIVE CHANNEL ANALYSIS
JANUARY 2007

Data

Design flowrates	100-year	300	cfs
	10-year	70	cfs
	Low Flow	50	cfs
Channel slopes	0.12	ft/ft max	
	0.06	ft/ft min	

Alternatives:

Trapezoidal riprap channel
Composite trapezoidal channel (riprap lowflow with erosion control mat on upper slopes)
Concrete low flow channel
Pipe

RIPRAP CHANNEL

3 horizontal to 1 side slopes

Bottom W	Normal D	Channel D	riprap D50	
4	2.1	3	2	feet

Use Erosion control Mat & vegetation to total depth on slope

	Slope (ft/ft)	Flow (cfs)	Bottom W (ft)	Yo (ft)	Velocity (fps)	P (ft)	A (ft2)	T (ft)	Froude No.	Eo	AY^	M
Normal Depth	0.1	300	4	1.93	15.9	7.9	18.9	15.58	2.5	3.9	15.2	163.1
Sequent Depth		300	4	**4.2**	4.3	5.7	69.7	29.2	0.5	0.3	125.2	165.3
Normal Depth	0.07	300	4	2.11	13.8	8.2	21.8	16.66	2.1	2.9	19.2	147.4
Sequent Depth		300	4	**3.9**	4.9	4.0	61.2	27.4	0.6	0.4	101.9	147.6

SALT LAKE COUNTY
NEFFS CANYON CREEK
ALTERNATIVE CHANNEL ANALYSIS (CONTINUED)
JANUARY 2007

COMPOSITE CHANNEL (riprap lowflow and erosion control mat on upper slopes)

Riprap Low Flow channel (70 cfs capacity with 0.5 foot freeboard) NO DROPS

3 horizontal to 1 side slopes

Slope range	Bottom W	Normal D	Channel D	riprap D50
0.07 to 0.10	4	1.3	1.5	2 feet

riprap volume (Area with D + riprap thickness) - A channel

Area Channel = by + my^2 — 12.75 ft2

Area with D + riprap thickness

riprap thickness = D50 x 2 = 4

D + riprap thickness = 5.5

AREA = by + my^2 = 112.75 ft2

Reduce for edge adjustment 108.75 ft2

riprap volume 96.0 ft3/ft

3.6 cy/ft

Erosion Control Mat on side slope

North American Green calculator:

Maximum channel slope 8% using the P550 mat

Yo= 2.44' Calculated shear stress 11.8 psf

Allowable shear stress 12 psf

At 10% slope **NOT STABLE**

Calculated shear stress 16.2

	Slope (ft/ft)	Flow (cfs)	Bottom W (ft)	Yo (ft)	Velocity (fps)	P (ft)	A (ft2)	T (ft)	Froude No.	Eo	AY^	M
Normal Depth	0.1	300	4	2.44	10.9	8.9	27.6	18.64	1.6	1.8	28.3	129.5
Sequent Depth		300	4	**3.5**	5.9	4.0	50.8	25	0.7	0.5	75.5	130.6
Normal Depth	0.07	300	4	2.51	10.4	9.0	28.9	19.06	1.5	1.7	30.5	127.1
Sequent Depth		300	4	**3.4**	6.2	8.0	48.3	24.4	0.8	0.6	69.7	127.6

COMPOSITE CHANNEL (riprap lowflow and erosion control mat on upper slopes) (CONTINUED)

For conceptual design assume design slope of 0.07 ft/ft between drops

Normal depth	2.5	feet
Channel Depth	4	feet
Calculated shear stress	10.8	
Allowable shear stress	12	

Riprap Low Flow channel (70 cfs capacity)

3 horizontal to 1 side slopes

Bottom W	Normal D	Channel D	riprap D50	
4	1.2	1.5	1.5	feet

riprap volume (Area with D + riprap thickness) - A channel

Area Channel = by + my^2 12.75 ft2

Area with D + riprap thickness

riprap thickness = D50 x 2 =	3	
D + riprap thickness =	4.5	
AREA = by + my^2 =	78.75	ft2
Reduce for edge adjustment	74.75	ft2

riprap volume **54.2 ft3/ft**

2.0 cy/ft

Drop analysis

Avg slope from Zarahemla to Wasatch

Delta Z	587.37	feet
Length	6275.7	feet
Avg Slope	0.093594	ft/ft

Assume 5' drop in grouted sloping boulder drops

Length of Drop

Slope	0.25	ft/ft	4:1
Slope L	20	ft	
Basin L	15	ft - flat	
Overall slc	0.142857	ft/ft	
Drop overall slope - channel slope	0.07285714	ft/ft	
Actual Delta z due to drop	2.55	feet	

Drops needed = (total channel drop - channel L x slope)/actual delta z due to drop

58

Avg spacing = length x number of drops

108 feet

ALTERNATIVE CHANNEL ANALYSIS (CONTINUED)
JANUARY 2007

CONCRETE LOW FLOW CHANNEL

			Bottom Wi	Depth	Side slope above low flow						
Concrete Low Flow channel			2	1	3 H : 1 V						
	0 horizontal to 1 side slopes										
	Slope (ft/ft)	Flow (cfs)	Bottom W (ft)	Yo (ft)	Velocity (fps)	P (ft)	A (ft2)	T (ft)	Froude No.	Eo	AY^	M
Normal Depth	0.07	50	2	0.72	16.7	6.6	3.0	6.32	4.3	4.3	0.9	26.8
USE 1' lowflow channel depth (with footing?) and 3:1 side slopes above lowflow channel												
Normal Depth	0.07	70	2	0.87	17.5	7.5	4.0	7.22	4.1	4.7	1.4	39.4
Normal Depth	0.07	300	2	2.08	17.5	15.2	17.1	14.48	2.8	4.8	13.3	176.4
Sequent Depth		300	2	**4.91**	3.7	33.1	82.1	31.46	0.4	0.2	142.5	176.5
Normal Depth	0.12	300	2	1.8	22.5	13.4	13.3	12.8	3.9	7.9	9.1	218.9
Sequent Depth		300	2	**5.45**	3.0	33.1	100.0	34.7	0.3	0.1	191.6	219.5
NAG calculator == SF<1 for P550												
Normal Depth	0.1	300	2	1.89	20.7	14.0	14.5	13.34	3.5	6.7	10.3	203.1
Sequent Depth		300	2	**5.26**	3.2	33.1	93.5	33.56	0.3	0.2	173.2	203.1

Use 10% max channel slope – check of the existing average channel slope between culverts indicates that using culverts to make up the differ
works except between Zarahemla and Abinadi; where an additional 5' drop will be needed.

PIPE ALTERNATIVE

Culvert 6 feet diameter
8 feet min. headwater depth at inlet

Pipe alternative (without debris basin) – reduce size to 5 feet diameter (see attached spread sheet)
Use minimum manhole and inlet depths of 9 feet to accomodate sequent depth
Based on conceptual pipe layout estimate 40 manholes
9 feet deep
TOTAL LENGTH downstream of Zarahemla 6120 feet

CLIENT: SALT LAKE COUNTY
PROJECT: NEFFS CANYON
PIPE ALTERNATIVE ANALYSIS
10% Slope

PIPE	DESIGN FLOW (CFS)	SLOPE (ft/ft)	DIAMETER (FT)	MANNINGS N	DEPTH (FT)	COMPUT FLOW (CFS)	FLOW AREA (FT2)	VELOCITY (FPS)	Hv (feet)	FROUDE NO.	2nd Moment of Flow Area	Momentum	Sequent Depth (feet)	
6 ft pipe alt	300	0.1	**6**	0.013	1.93	301	7.86	38.28	22.8	5.70	6.3	362.1		
Full pipe Momentum	300		6	0.013	6	301	28.27	10.64	1.8	0.00	84.8	183.7	higher than top of pipe	
	Q (cfs)		B (ft)	q (cfs/ft)	y try									
Assume rectangular MH	300		6	50	8.91							362.4	9	
Assume rectangular MH	300		8	37.5	8.94							362.1	9	

PIPE	DESIGN FLOW (CFS)	SLOPE (ft/ft)	DIAMETER (FT)	MANNINGS N	DEPTH (FT)	COMPUT FLOW (CFS)	FLOW AREA (FT2)	VELOCITY (FPS)	Hv (feet)	FROUDE NO.	2nd Moment of Flow Area	Momentum	Sequent Depth (feet)	
5 ft pipe alt	300	0.1	**5**	0.013	2.085	300	7.75	38.72	23.3	5.44	6.8	367.3		
Full pipe Momentum	300	0	5	0.013	4	300	16.84	17.83	4.9	1.53	30.6	196.6	higher than top of pipe	
	Q (cfs)		B (ft)	q (cfs/ft)	y try									
Assume rectangular MH	300		6	50	8.95							367.1	9	
Assume rectangular MH	300		8	37.5	8.985							367.5	9	

PIPE	DESIGN FLOW (CFS)	SLOPE (ft/ft)	DIAMETER (FT)	MANNINGS N	DEPTH (FT)	COMPUT FLOW (CFS)	FLOW AREA (FT2)	VELOCITY (FPS)	Hv (feet)	FROUDE NO.	2nd Moment of Flow Area	Momentum	Sequent Depth (feet)	
4.5 ft pipe alt	300	0.1	**4.5**	0.013	2.2	300	7.73	38.83	23.4	5.22	7.2	368.9		
Full pipe Momentum	300	0	4.5	0.013	4.5	300	15.90	18.87	5.5	0.00	35.8	211.5	higher than top of pipe	
	Q (cfs)		B (ft)	q (cfs/ft)	y try									
Assume rectangular MH	300		6	50	8.965							368.9	9	
Assume rectangular MH	300		8	37.5	9							369.4	9	

APPENDIX D
COST ESTIMATES

TABLE OF CONTENTS

ITEM	No. Of Pages
ALTERNATIVE CHANNEL ANALYSIS CONSTRUCTION COST ESTIMATE	2
DEBRIS BASIN CONCEPTUAL EARTHWORK ESTIMATES	2

SALT LAKE COUNTY
NEFFS CANYON CREEK
ALTERNATIVE CHANNEL ANALYSIS
CONSTRUCTION COST ESTIMATE
January 2007

channel L	5591	feet
Existing culv	860	feet
New culvert	340	feet

RIPRAP CHANNEL ALTERNATIVE

DESCRIPTION	QUANTITY	Units	UNIT PRICE	TOTAL	Comparative cost per foot
RIPRAP CHANNEL (2' D50, 4.3 cy/ft)	24,083	cy	$70	$ 1,685,790	
Erosion Mat & Seed	7,455	sy	$5	$ 37,273	
CULVERTS (6' Dia., 8' depth)	1,025	ft	$343	$ 351,575	
INLET STRUCTURES	11	each	$8,000	$ 88,000	
Outlet Energy Structure & dissipation	11	each	$12,000	$ 132,000	
TOTAL COMPARATIVE COST				**$ 2,294,638**	$338 per foot

COMPOSITE CHANNEL (riprap lowflow and erosion control mat on upper slopes)
WITH DROP STRUCTURES to limit provide SF=1 during 100-year on side slopes

DESCRIPTION	QUANTITY	Units	UNIT PRICE	TOTAL
RIPRAP CHANNEL low flow (1.5' D50, 2 cy/ft)	7,182	cy	$70	$ 502,740
Erosion Mat & Seed	11,182	sy	$8	$ 89,456
Drop Structures	50	each	$50,000	$ 2,500,000
CULVERTS (6' Dia., 8' depth)	1,025	ft	$343	$ 351,575
INLET STRUCTURES	11	each	$8,000	$ 88,000
Outlet Energy Structure & dissipation	11	each	$12,000	$ 132,000
TOTAL COMPARATIVE COST				**$ 3,663,771**

$540 per foot

COMPOSITE CHANNEL (riprap lowflow and erosion control mat on upper slopes) (Continued)

WITH OUT DROP STRUCTURES – ALLOW EROSION DURING 100-YEAR

DESCRIPTION	QUANTITY	Units	UNIT PRICE	TOTAL	
RIPRAP CHANNEL low flow (2' D50, 3.6 cy/ft)	20,128	cy	$70	$ 1,408,932	
Erosion Mat & Seed	7,858	sy	$8	$ 62,863	
CULVERTS (6' Dia., 8' depth)	50	ft	$343	$ 17,150	
INLET STRUCTURES	11	each	$8,000	$ 88,000	
Outlet Energy Structure & dissipation	11	each	$12,000	$ 132,000	
TOTAL COMPARATIVE COST				**$ 1,708,945**	$252 per foot

PIPE ALTERNATIVE

DESCRIPTION	QUANTITY	Units	UNIT PRICE	TOTAL	
INLET STRUCTURE	1	each	$15,000	$ 15,000	
PIPE (5' DIA., 9' DEPTH)	6460	feet	317	$ 2,047,820	
Manholes (9' depth 8' diameter)	40	each	6050	$ 242,000	
TOTAL COMPARATIVE COST				**$ 2,304,820**	$339 per foot

CONCRETE LOW FLOW CHANNEL

DESCRIPTION	QUANTITY	Units	UNIT PRICE	TOTAL	
Concrete channel (4' B x 4.5 ft deep, assume 8" t)	4,431	cy	$400	$ 1,772,554	
Channel Excavation	7,455	cy	$5	$ 37,273	
Drop Structures (one between Zarahemla & Abina	1	each	$50,000	$ 50,000	
Erosion Mat & Seed	17,394	sy	$8	$ 139,154	
CULVERTS (6' Dia., 8' depth)	1,025	ft	$343	$ 351,575	
INLET STRUCTURES	11	each	$8,000	$ 88,000	
Outlet Energy Structure & dissipation	11	each	$8,000	$ 88,000	
TOTAL COMPARATIVE COST				**$ 2,526,556**	$372 per foot

SALT LAKE COUNTY
NEFFS CANYON
UPPER DEBRIS BASIN ALTERNATIVE (LOCATED IN WILDERNESS AREA)
EARTHWORK - CONCEPTUAL ESTIMATE May 2006

Cross Section		AREA CUT	AVG AREA	DELTA VOLUME		AREA FILL		
0	246.77	0.0				0.0		
toe_West	333.3	876.3	438	37,911		1,392.0	696	60,225
Toe_East	419.4	3,711.8	2,294	197,517		1,558.1	1,475	127,002
FL B	451.5	3,094.5	3,403	109,241		817.2	1,188	38,124
Toe_East	511.4	2,350.1	2,722	163,063		386.9	602	36,064
Toe_West	561.1	8,059.2	5,205	258,670		197.2	292	14,516
0	707.8	0.0	4,030	591,142		0	99	14,465
TOTAL (FT3)				1,357,543				290,395
TOTAL (CY)				**50,279**	CUT			**10,755** FILL

2/2

SALT LAKE COUNTY
NEFFS CANYON
LOWER DEBRIS BASIN ALTERNATIVE
(LOCATED ON FOREST SERVICE PROPERTY BELOW THE WILDERNESS AREA)
EARTHWORK - CONCEPTUAL ESTIMATE March 2006

Cross Section	AREA **CUT**	AVG AREA	DELTA VOLUME		AREA **FILL**	AVG AREA	DELTA VOLUME	
0	0				0			
64	939	470	30,048		93	46	2,960	
180.76	4,030	2,485	290,107		746	419	48,974	
298.59	2,698	3,364	396,402		1,878	1,312	154,627	
420.36	2,681	2,690	327,502		814	1,346	163,919	
479.04	2,427	2,554	149,882		93	454	26,621	
707.76	0	1,214	277,609		0	47	10,664	
TOTAL (FT3)			1,471,550				407,766	
TOTAL (CY)			**54,502**	CUT			**15,102**	FILL

APPENDIX D

Annotated FIRM Maps

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevation** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevation (BFEs) shown on this map apply only landward of 0.0' North American Vertical Datum (NAVD). Users of this FIRM should be aware that coastal flood elevations may also be provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this community. Elevations shown in the Summary of Stillwater Elevations table should be used for construction, and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures.** Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures in this jurisdiction.

The **projection** used in the preparation of this map is Universal Tranverse Mercator (UTM) zone 12. The **horizontal datum** is NAD83, GRS1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of the FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum.** For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

Spatial Reference System Division
National Geodetic Survey, NOAA
Silver Spring Metro Center
1315 East-West Highway
Silver Spring, Maryland 20910
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242,** or visit their website at www.ngs.noaa.gov.

Base map information shown on this FIRM was provided in digital format by the Salt Lake County Planning Department.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

An accompanying Flood Insurance Study report, Letters of Map Revision or Letters of Map Amendment revising portions of this panel, and digital versions of this PANEL may be available. Contact the **FEMA Map Service Center** at the following phone numbers and Internet address for information on all related products available from FEMA:

Phone: 800-358-9616
FAX: 800-358-9620
http://msc.fema.gov/

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1-877-FEMA-MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip/

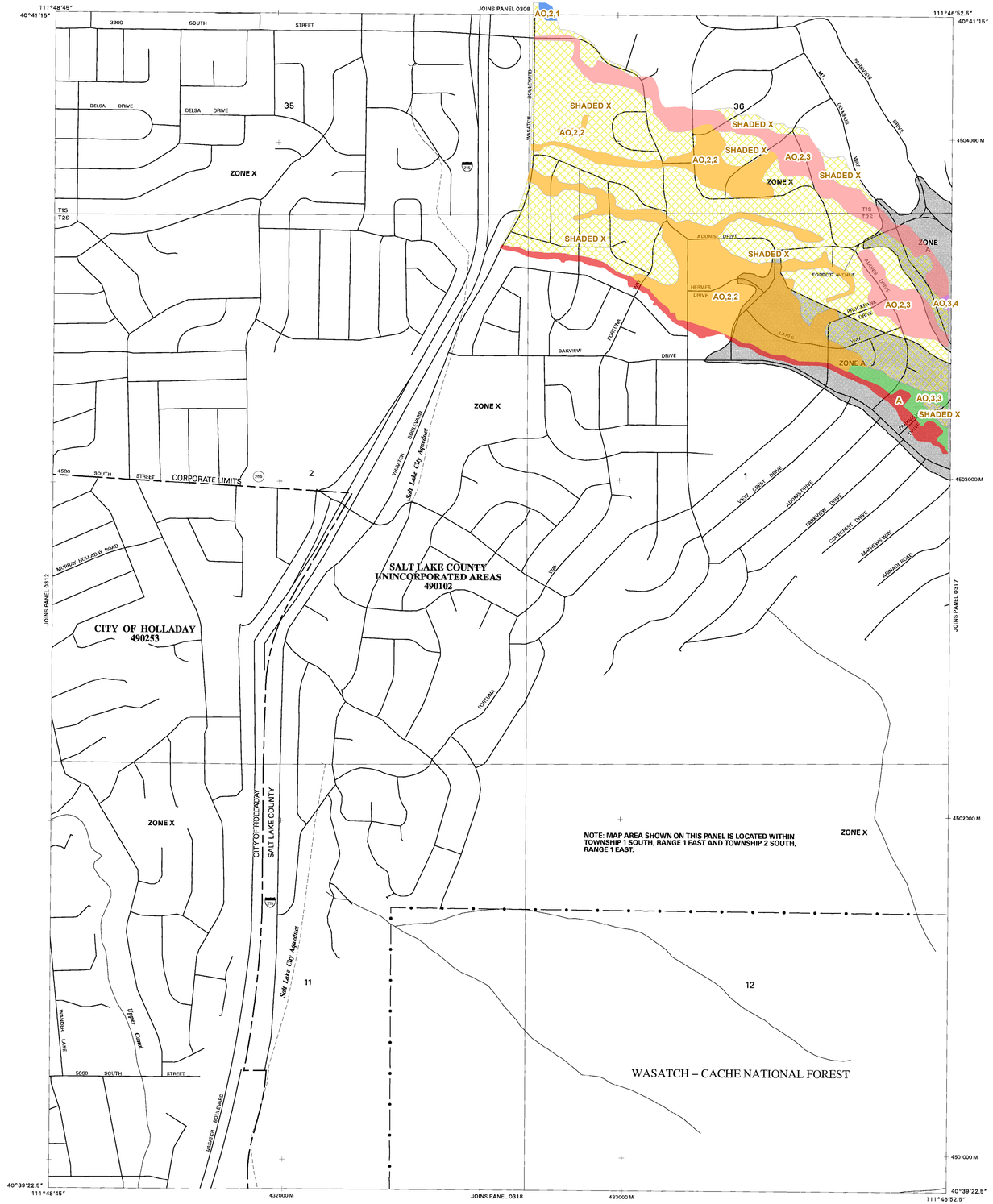
This map reflects more detailed and up-to-date stream channel configurations than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study report may reflect stream channel distances that differ from what is shown on this map.

Legend

Revised Floodplains

Zone,Depth,Velocity

- A
- AO, 2, 1
- AO, 2, 2
- AO, 2, 3
- AO, 3, 3
- AO, 3, 4
- SHADED X



LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD EVENT

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water surface elevation of the 1% annual chance flood.

ZONE A No base flood elevations determined.

ZONE AE Base flood elevations determined.

ZONE AH Flood depths of 1 to 3 feet (usually areas of ponding); base flood elevations determined.

ZONE AO Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.

ZONE AR Area of special flood hazard formerly protected from the 1% annual chance flood event by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood event.

ZONE A99 Area to be protected from 1% annual chance flood event by a Federal flood protection system under construction; no base flood elevations determined.

ZONE V Coastal flood zone with velocity hazard (wave action); no base flood elevations determined.

ZONE VE Coastal flood zone with velocity hazard (wave action); base flood elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X Areas determined to be outside the 0.2% annual chance floodplain.

ZONE D Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

- Floodplain boundary
- Floodway boundary
- Zone D boundary
- CBRS and OPA boundary
- Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or velocities.
- 513 — Base Flood Elevation line and value; elevation in feet*
- (EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

- (A)—(A) Cross Section Line
- (23)- - -(23) Transect Line
- 97°07'30", 32°22'30" Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
- 4276000M 1000-meter Universal Transverse Mercator grid values, zone 12
- 600000 FT 5000-foot grid ticks
- DX5510 × Bench mark (see explanation in Notes to Users section of this FIRM panel).
- M1.5 River Mile

MAP REPOSITORY
Refer to Repository Listing on Index Map

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP
SEPTEMBER 21, 2001

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

MAY 15, 2002
SEPTEMBER 25, 2009: to update corporate limits, to change base flood elevations, to add base flood elevations, to add special flood hazard areas, to change special flood hazard areas, to update map format, to add roads and road names, to reflect updated topographic information, and to incorporate previously issued letters of map revision.

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at (800) 638-6620.

MAP SCALE 1" = 500'
250 0 500 1000 FEET
150 0 150 300 METERS

PANEL 0316G

FIRM
FLOOD INSURANCE RATE MAP

SALT LAKE COUNTY,
UTAH
AND INCORPORATED AREAS

PANEL 316 OF 625

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
SALT LAKE COUNTY, UNINCORPORATED AREAS	490102	0316	G
HOLLADAY CITY, CITY OF	490253	0316	G

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
49035C0316G

MAP REVISED:
SEPTEMBER 25, 2009

Federal Emergency Management Agency

PRELIMINARY
NOT VALID FOR CONSTRUCTION OR FLOODPLAIN MANAGEMENT

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevation** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevation (BFEs) shown on this map apply only landward of 0.0' North American Vertical Datum (NAVD). Users of this FIRM should be aware that coastal flood elevations may also be provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this community. Elevations shown in the Summary of Stillwater Elevations table should be used for construction, and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures.** Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures in this jurisdiction.

The **projection** used in the preparation of this map is Universal Tranverse Mercator (UTM) zone 12. The **horizontal datum** is NAD83, GRS1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of the FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum.** For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

Spatial Reference System Division
National Geodetic Survey, NOAA
Silver Spring Metro Center
1315 East-West Highway
Silver Spring, Maryland 20910
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242,** or visit their website at www.ngs.noaa.gov.

Base map information shown on this FIRM was provided in digital format by the Salt Lake County Planning Department.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

An accompanying Flood Insurance Study report, Letters of Map Revision or Letters of Map Amendment revising portions of this panel, and digital versions of this PANEL may be available. Contact the **FEMA Map Service Center** at the following phone numbers and Internet address for infomation on all related products available from FEMA:

Phone: 800-358-9616
FAX: 800-358-9620
http://msc.fema.gov/

If you have **questions about this map** or questions concerning the National Flood Insurance Program in general, please call **1-877-FEMA-MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip/

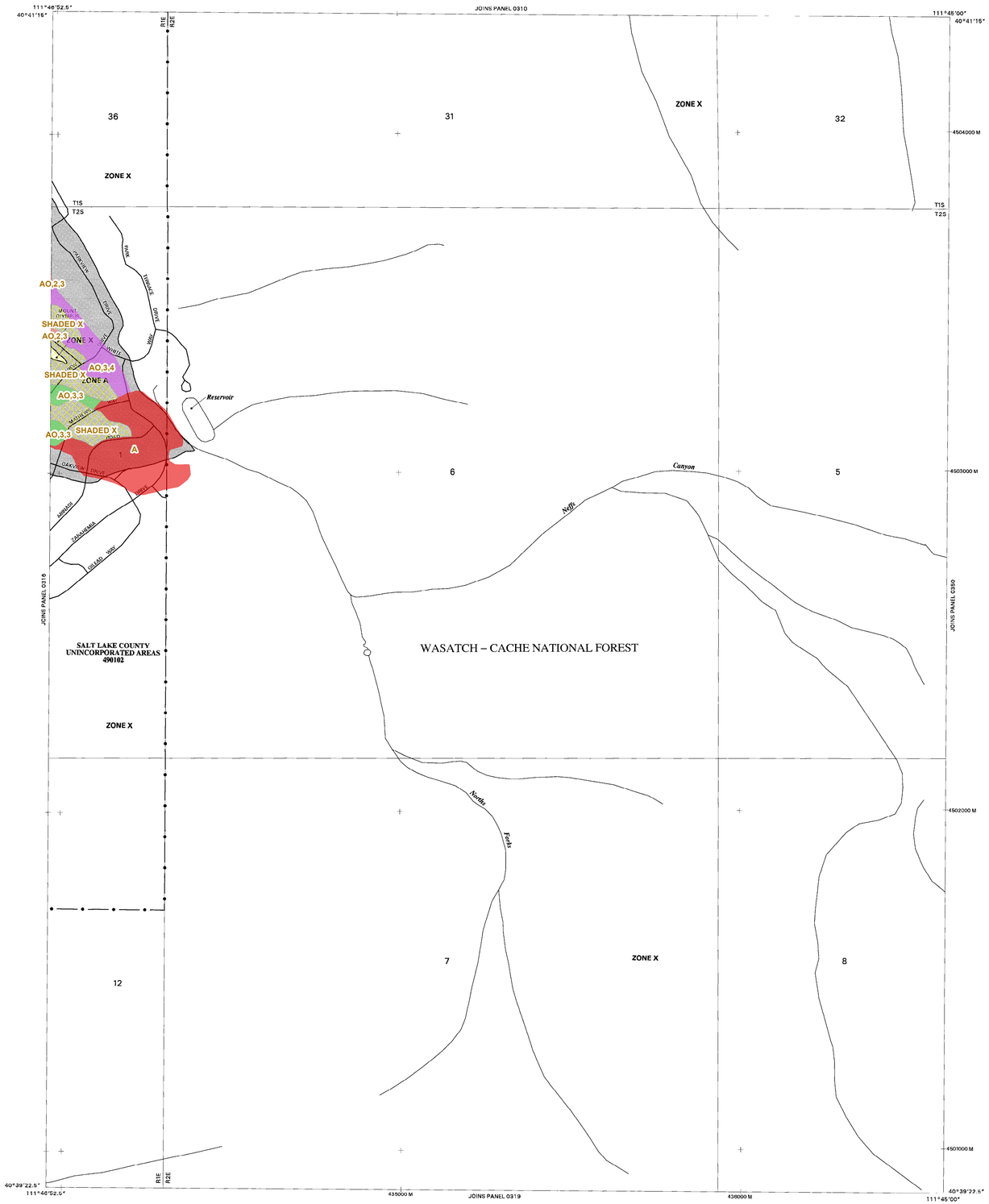
This map reflects more detailed and up-to-date stream channel configurations than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study report may reflect stream channel distances that differ from what is shown on this map.

Legend

Revised Floodplains

Zone,Depth,Velocity

- A
- AO, 2, 1
- AO, 2, 2
- AO, 2, 3
- AO, 3, 3
- AO, 3, 4
- SHADED X



LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD EVENT

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water surface elevation of the 1% annual chance flood.

ZONE A No base flood elevations determined.

ZONE AE Base flood elevations determined.

ZONE AH Flood depths of 1 to 3 feet (usually areas of ponding); base flood elevations determined.

ZONE AO Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.

ZONE AR Area of special flood hazard formerly protected from the 1% annual chance flood event by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood event.

ZONE A99 Area to be protected from 1% annual chance flood event by a Federal flood protection system under construction; no base flood elevations determined.

ZONE V Coastal flood zone with velocity hazard (wave action); no base flood elevations determined.

ZONE VE Coastal flood zone with velocity hazard (wave action); base flood elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X Areas determined to be outside the 0.2% annual chance floodplain.

ZONE D Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

- Floodplain boundary
- Floodway boundary
- Zone D boundary
- CBRS and OPA boundary
- Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or velocities.
- 513 — Base Flood Elevation line and value; elevation in feet*
- (EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

- (A) — (A) Cross Section Line
- (23) — (23) Transect Line
- 97°07'30", 32°22'30" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83)
- 4276000M — 1000-meter Universal Transverse Mercator grid values, zone 12
- 600000 FT — 5000-foot grid ticks
- DX5510 × — Bench mark (see explanation in Notes to Users section of this FIRM panel).
- M1.5 — River Mile

MAP REPOSITORY
Refer to Repository Listing on Index Map

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP
SEPTEMBER 21, 2001

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

MAY 15, 2002
SEPTEMBER 25, 2009: to update corporate limits, to change base flood elevations, to add base flood elevations, to add special flood hazard areas, to change special flood hazard areas, to update map format, to add roads and road names, to reflect updated topographic information, and to incorporate previously issued letters of map revision.

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at (800) 638-6620.

MAP SCALE 1" = 500'

250 0 500 1000 FEET
150 0 150 300 METERS

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0317G

FIRM
FLOOD INSURANCE RATE MAP

SALT LAKE COUNTY,
UTAH
AND INCORPORATED AREAS

PANEL 317 OF 625

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
SALT LAKE COUNTY, UNINCORPORATED AREAS	490102	0317	G

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

MAP NUMBER
49035C0317G

MAP REVISED:
SEPTEMBER 25, 2009

Federal Emergency Management Agency