Active Alluvial Fan Landform Inventory

Wasatch Range and Oquirrh Mountains, Utah

September
2017

prepared for | Utah Division of Emergency Management

LICENSED PROFESSIONAL GEOLOGIST
MICHAEL J.
KELLOGG
6111914-2250
STATE OF UTAH

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JE FULLER
8400 S Kyrene Rd, STE 201
Tempe, AZ 85284
www.jefuller.com

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1 PROJECT OVERVIEW

1.1 PROJECT PURPOSE

Alluvial fan landforms pose unique flooding hazards that are not present on non-fan landforms (e.g. rivers, streams, whose flooding hazards are commonly defined through Federal Emergency Management Agency (FEMA) regulatory floodplains). FEMA defines alluvial fan flooding as “Flooding occurring on the surface of an alluvial fan or similar landform which originates at the apex and is characterized by high-velocity flows; active processes of erosion, sediment transport, and deposition; and unpredictable flowpaths. Alluvial fan flooding is depicted on a Flood Insurance Rate Map (FIRM) as Zone AO, with a flood depth and velocity” (FEMA, 2003). Alluvial fans are generally located at a topographic apex between a mountain front and the adjacent piedmont landform. Properly identifying alluvial fan landforms is a critical first step in understanding flood risk to downstream development.

JE Fuller Hydrology & Geomorphology, Inc. (JEF) conducted this study for the Utah Division of Emergency Management (DEM) and the Federal Emergency Management Agency (FEMA) as part of the Risk MAP program.

1.1.1 Active vs. Inactive Alluvial Fan Landforms

Active alluvial fan landforms are defined by location, composition, and flooding characteristics. They are located at a topographic break between a mountain front and the piedmont, they are composed of unconsolidated alluvium, and exhibit flooding characteristics described previously. Inactive alluvial fan landforms are geologically older and are no longer subject to active fan flooding processes. As they age, inactive alluvial fans develop their own internal, tributary drainage networks that exhibit riverine flooding characteristics. Manmade processes can also result in an alluvial fan transition from active to inactive. Construction of dams, debris basins, retention basins near the fan apex, or channelization from the apex downstream across the piedmont are examples of flood mitigation efforts that can effectively remove active alluvial fan flood hazards. The focus of this study was to identify active alluvial fan landforms within the study areas described in the following section.

1.2 STUDY AREAS

The project study areas were limited to 1) the Wasatch Range between the Utah-Idaho border to the north and the Town of Nephi to the south, and 2) the western slopes of the Oquirrh Mountains (Figure 1). Both study areas are characterized by significant development along the mountain-piedmont interface, thus are potentially impacted by active alluvial fan landforms.

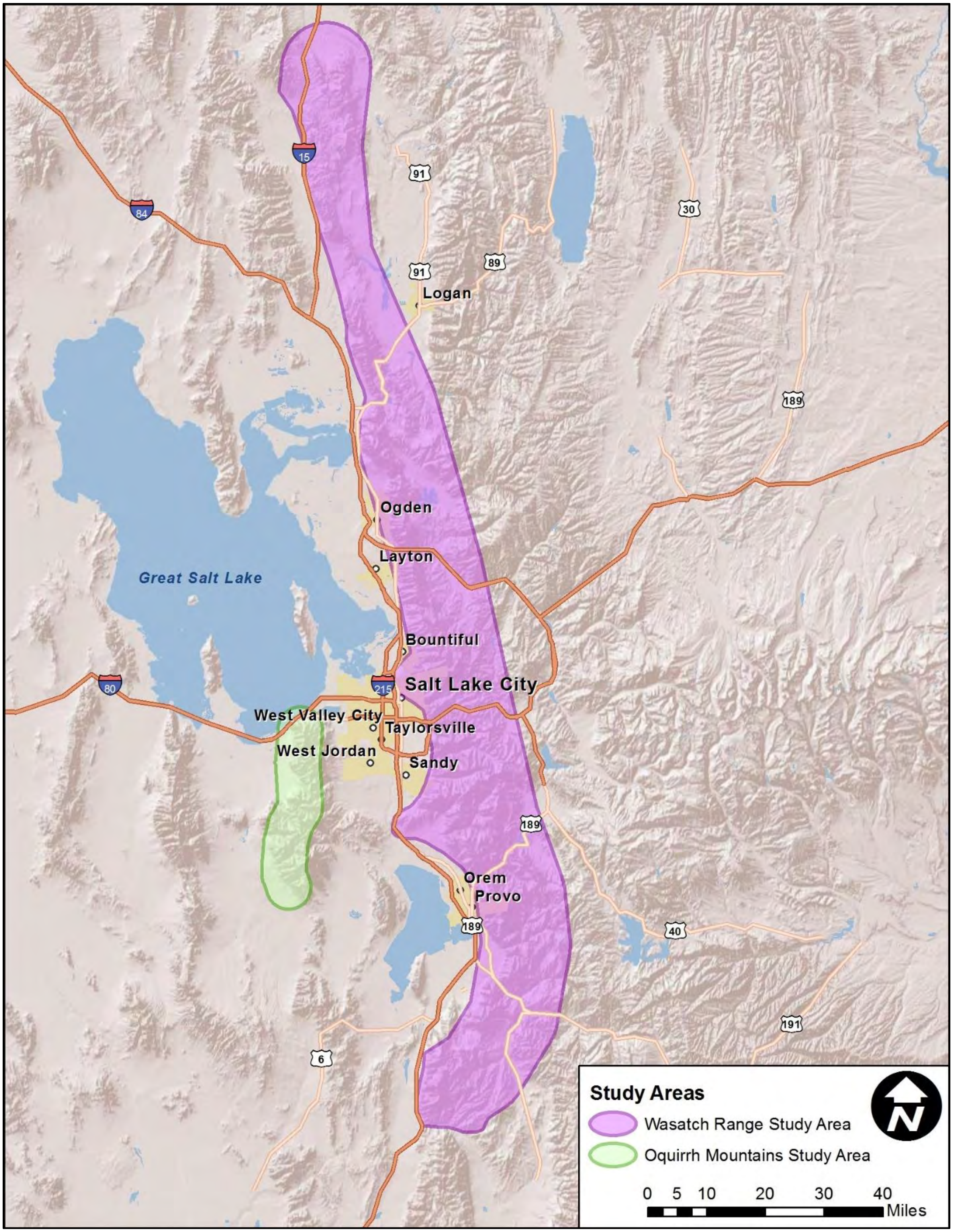

Figure 1. Study Areas

2 DATA SOURCES

2.1 GEOLOGIC MAPPING

The U.S. Geological Survey (USGS) and the Utah Geological Survey (UGS) have completed geologic mapping for much of the study area. Many of the maps include surficial mapping of Quaternary deposits, including alluvial fans. Geologic maps for the study areas were collected and semi-rectified using GIS software tools. Table 1 lists the geologic maps collected for this study.

Table 1. Geologic Maps

Map Title/Scale	Author(s)	Date	Source
Geologic Map of the Stockton Quadrangle, Utah	N/A	N/A	N/A
Geologic Map of the Tooele Quadrangle, Utah	N/A	N/A	N/A
Geologic Map and Sections of the Orem Quadrangle, Utah/24:000	Baker, A.A.	1964	USGS
Geology of the Draper Quadrangle, Utah/24:000	Crittenden, M.D.	1965	USGS
Geology of the Sugar House Quadrangle, Salt Lake County, Utah/24:000	Crittenden, M.D.	1965	USGS
Geologic Map of the Garfield Quadrangle, Salt Lake and Tooele Counties, Utah/24:000	Tooker, E.W, Roberts, R.J.	1971	USGS
Geologic Map of the Springville Quadrangle, Utah County, Utah/24:000	Baker, A.A.	1973	USGS
Geologic Map of the Huntsville Quadrangle, Weber and Cache Counties, Utah/24:000	Sorensen, M.L., Crittenden, M.D.	1979	USGS
Geologic Map of the North Ogden Quadrangle and Part of the Ogden and Plain City Quadrangles, Box Elder and Weber Counties, Utah/24:000	Crittenden, M.D., Sorensen, M.L.	1985	USGS
Geologic Map of the Mantua Quadrangle and Part of the Willard Quadrangle, Box Elder, Weber, and Cache Counties, Utah/24:000	Crittenden, M.D., Sorensen, M.L.	1985	USGS
Geologic Map of the Honey Quadrangle, Cache and Box Elder Counties, Utah/24:000	Oviatt, C.G.	1986	UGS
Geologic Map of the Cutler Dam Quadrangle, Cache and Box Elder Counties, Utah/24:000	Oviatt, C.G.	1986	UGS
Provisional Geologic Map of the Nephi Quadrangle, Juab County, Utah/24:000	Biek, R.F.	1991	UGS
Interim Geologic Map of the Wellsville Quadrangle, Cache County, Utah/24:000	Barker, K.S., Barker, S.W.	1993	UGS
Geologic Map of the Brigham City 7.5-Minute Quadrangle, Box Elder and Cache Counties, Utah/24:000	Jensen, M.E., King, J.K.	1999	UGS
Geologic Map of the Portage Quadrangle, Box Elder and Cache Counties, Utah and Franklin and Oneida Counties, Idaho/24:000	Biek, R.F., Oaks, R.Q., Janecke, S.U., Solomon, B.J., Barry, L.M.S.	2003	UGS
Geologic Map of the Clarkston Quadrangle, Box Elder and Cache Counties, Utah and Franklin and Oneida Counties, Idaho/24:000	Biek, R.F., Oaks, R.Q., Janecke, S.U., Solomon, B.J., Barry, L.M.S.	2003	UGS
Provisional Geologic Map of the Mona Quadrangle, Juab and Utah Counties, Utah/24:000	Felger, T.J., Machette, M.N., and Sorensen, M.L.	2004	UGS

Map Title/Scale	Author(s)	Date	Source
Geologic Map of the Ogden 7.5’ Quadrangle, Weber and Davis Counties, Utah/24:000	Yonkee, A., Lowe, M.	2004	UGS
Geologic Map of the Lehi Quadrangle and Part of the Timpanogos Cave Quadrangle, Salt Lake and Utah Counties, Utah/24:000	Biek, R.F	2005	UGS
Geologic Map of the Jordan Narrows Quadrangle, Salt Lake and Utah Counties, Utah/24:000	Biek, R.F.	2005	UGS
Interim Geologic Map of the Plain City Quadrangle, Weber and Box Elder Counties, Utah/24:000	Harty, K.M., Lowe, M.	2005	UGS
Geologic Map of the Spanish Fork Quadrangle, Utah County, Utah/24:000	Solomon, B.J., Clark, D.L., Machette, M.N.	2007	UGS
Surficial Geologic Map of Parts of the Kaysville Quadrangle, Davis County, Utah/24:000	Solomon, B.J.	2007	UGS
Geologic Map of the Provo 7.5’ Quadrangle, Utah County, Utah/24:000	Solomon, B.J., Machette, M.N.	2009	UGS
Geologic Map of the Charleston Quadrangle, Wasatch County, Utah	Biek, R.F., Lowe, M.	2009	UGS
Interim Geologic map of the Unconlolidated Deposits in the Santaquin Quadrangle, Utah and Juab Counties, Utah/24:000	Solomon, B.J.	2010	UGS
Interim Geologic Map of the Unconsolidated Deposits in the Payson Lakes Quadrangle, Utah County, Utah/24:000	Solomon, B.J.	2010	UGS
Geologic Map of the Ophir Quadrangle, Tooele County, Utah/24:000	Kirby, S.M.	2012	UGS
Geologic Map of the Vernon NE Quadrangle, Tooele County, Utah/24:000	Kirby, S.M.	2013	UGS

2.2 TOPOGRAPHIC MAPPING

One of the defining characteristics of an alluvial fan landform is its fan shape in plan-view. By definition, an alluvial fan is an aggrading landform (e.g. receives and accumulates sediment over time). The influx of sediment and variable channel position results in the fan shape which is often expressed as convex, radial contours in topographic data. Two topographic data sources were used in this analysis (Table 2) to aid in identifying alluvial fan landforms and assessing whether they are active or inactive. Figure 2 shows a comparison of the radial contour pattern from the two topographic data sources for Willow Creek (south of Mona) in the Wasatch Range study area. The OpenTopography LiDAR raster datasets were converted to 2-foot digital contours for this analysis using GIS software tools. Figure 3 shows the spatial extent of the LiDAR data.

Table 2. Topographic data sources

Topographic Data Source	Data Type
USGS Quadrangle Maps	1:24,000 scale digital raster graphics (DRG)
OpenTopography LiDAR[1]	0.5-meter resolution raster datasets

[1] http://opentopo.sdsc.edu/lidar?format=sd&location=Utah

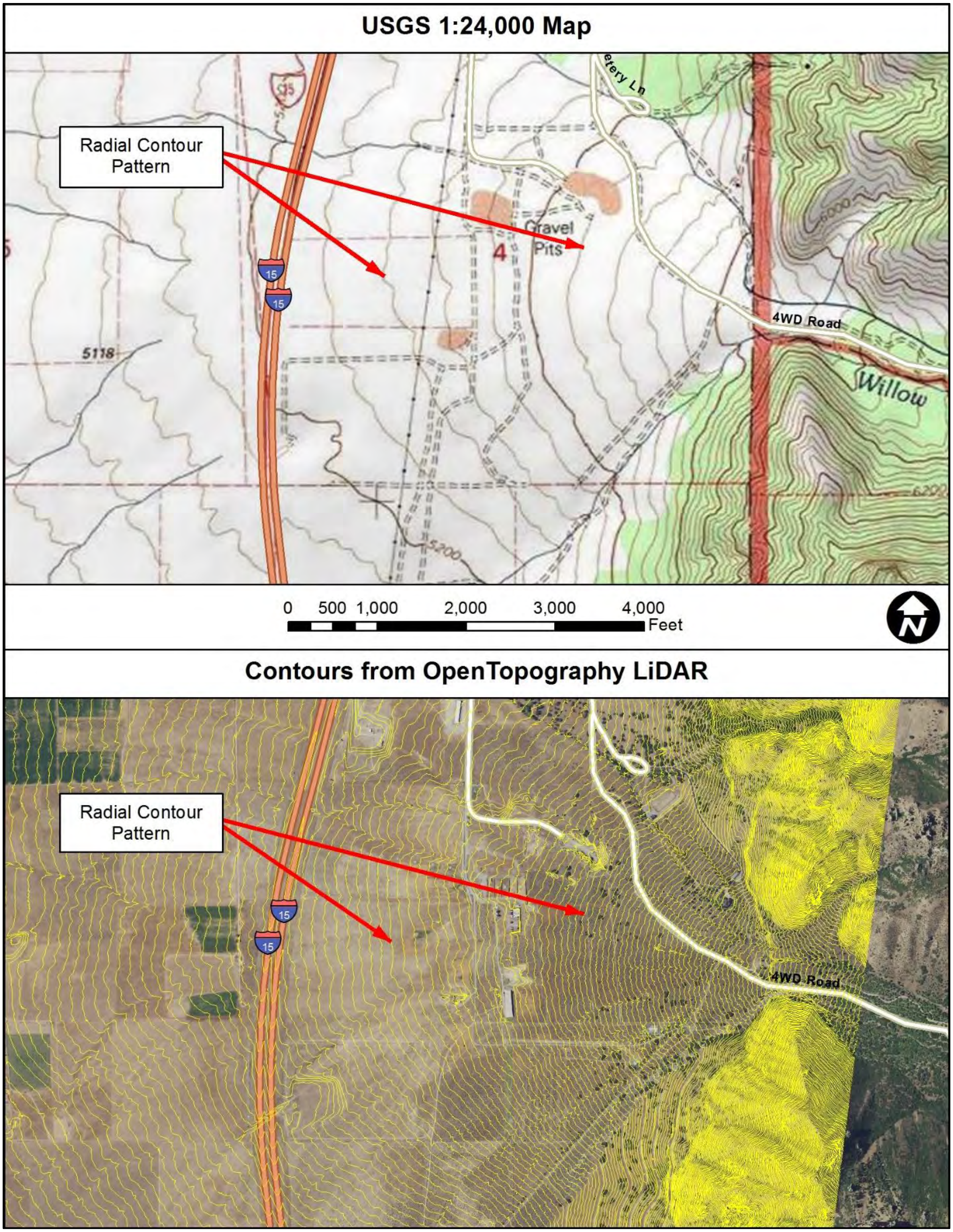

Figure 2. Topographic radial contour patterns

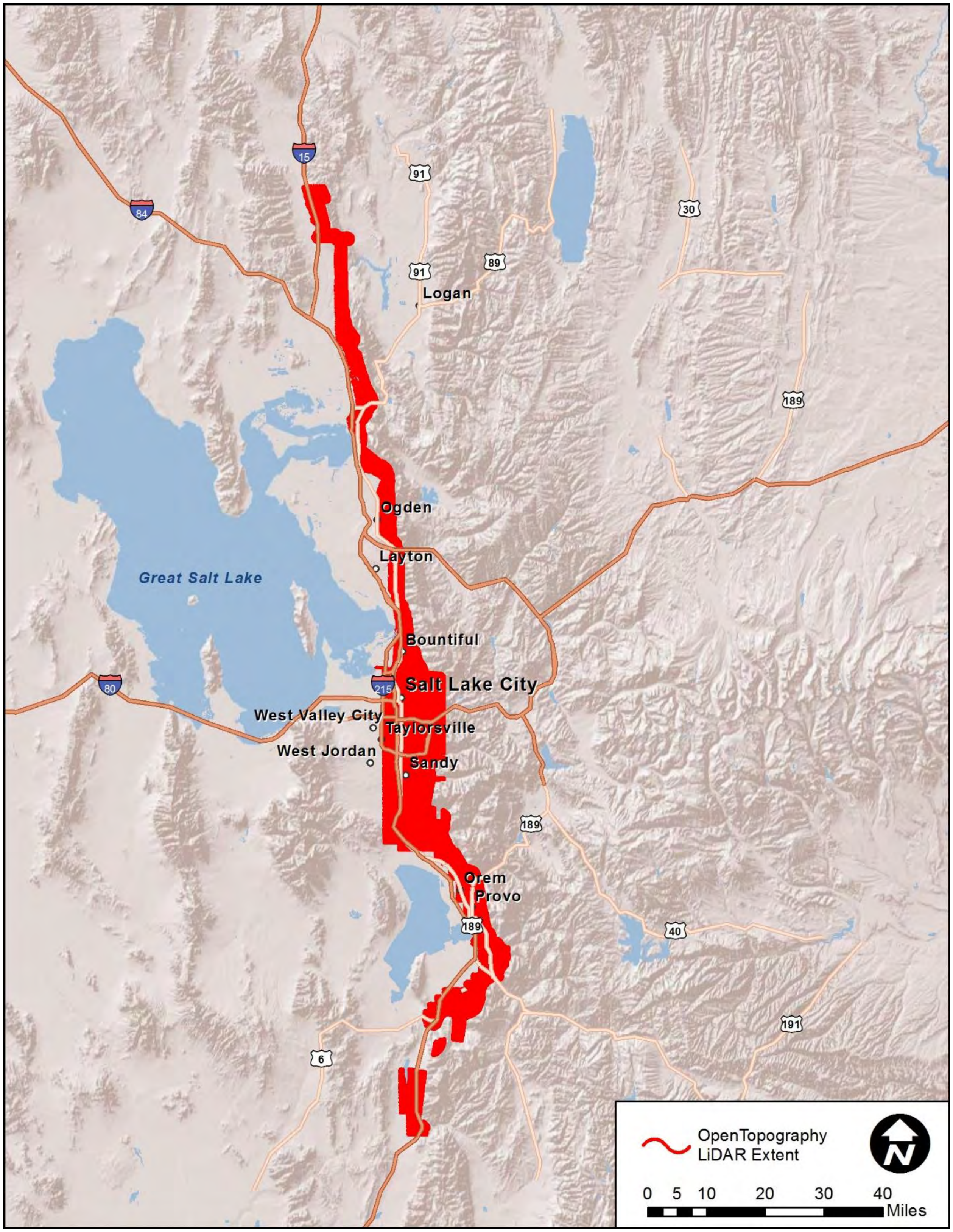

Figure 3. OpenTopography LiDAR extent

The following is a description of the OpenTopography dataset from the website:

> *The State of Utah, including the Utah Automated Geographic Reference Center, Utah Geological Survey, and the Utah Division of Emergency Management, along with local and federal partners, including Salt Lake County and local cities, the Federal Emergency Management Agency, the U.S. Geological Survey, and the U.S. Environmental Protection Agency, have funded and collected over 8380 km2 (3236 mi2) of high-resolution (0.5 or 1 meter) Lidar data across the state since 2011, in support of a diverse set of flood mapping, geologic, transportation, infrastructure, solar energy, and vegetation projects. The datasets include point cloud, first return digital surface model (DSM), and bare-earth digital terrain/elevation model (DEM) data, along with appropriate metadata (XML, project tile indexes, and area completion reports).*
>
> *This 0.5-meter 2013-2014 Wasatch Front dataset includes most of the Salt Lake and Utah Valleys (Utah), and the Wasatch (Utah and Idaho), and West Valley fault zones (Utah).*
>
> *Other recently acquired State of Utah data include the 2011 Utah Geological Survey Lidar dataset covering Cedar and Parowan Valleys, the east shore/wetlands of Great Salt Lake, the Hurricane fault zone, the west half of Ogden Valley, North Ogden, and part of the Wasatch Plateau in Utah.*

2.3 Aerial Photography

Both modern and historical aerial photography were used to aid in identifying alluvial fan landforms and in assessing whether they are active or inactive. Aerial photography is an invaluable tool in any geomorphic assessment.

2.3.1 Modern Aerial Photography

Two primary data sources were used for modern aerial photography: 1) U.S. Department of Agriculture National Agriculture Imagery Program (NAIP), and 2) ESRI World Imagery. The NAIP photography is collected nationwide annually and made available for public use. The most recent set available for the study areas at the time of this study was 2016. The resolution of the NAIP photography is 3-meter/pixel.

The ESRI World Imagery is an online GIS dataset that provides 1-meter or higher aerial and satellite imagery for much of the world. The date of the imagery can vary spatially, but is updated frequently (last updated May 2017).

2.3.2 Historical Aerial Photography

Historical aerial photography is an essential element for most geomorphic assessments. Historical photographs were collected for this study to aid in identifying alluvial fan landforms highly disturbed by development. Such areas are difficult to identify using modern aerial photography. Historical photography can show key landform characteristics that pre-date anthropogenic disturbance. They can also show the evolution of alluvial fan channel patterns and identify avulsions.

Over 2,600 individual historical, digital aerial photographs were collected for this study at varying scales. The date ranges for the photographs are 1937 through 1959. The historical aerial photographs that were applicable to the study areas were semi-rectified using GIS software tools. Figure 4 shows the extent of each set of semi-rectified photographs. All semi-rectified historical aerial photographs are included in Appendix C.

2.4 FEMA Flood Hazard Layer

The latest FEMA Flood Hazard Layer dataset was downloaded from FEMA's website for each county in the study areas. The downloaded dataset is dated May 3, 2017. The purpose of the dataset was to determine if any of the identified alluvial fan landforms had effective FEMA regulatory floodplain delineations. Any identified FEMA floodplains were included as an attribute in the final alluvial fan landform GIS layer. Figure 5 shows the regulatory FEMA flood zones within the study areas.

2.5 Utah Geological Survey Hazard Mapping

The UGS has completed mapping for multiple flood-related hazards within portions of the study areas. The hazards include: 1) Flooding, 2) Landslide/Debris Flow.

2.5.1 Flooding Hazard Mapping

The flooding hazards dataset was generated as part of the Geologic Hazards Program of the UGS (Castleton et al., *in press*). The purpose of the study was to identify areas of potential flood risk by identifying and reviewing existing geologic, hydrologic, and soils information within the area of interest. The flood hazard dataset was designed as an aid for general planning and to indicate areas where detailed, site-specific geologic hazard investigations are recommended. Figure 6 shows the UGS flooding hazard mapping within the study areas.

2.5.2 Landslide/Debris Flow Mapping

The UGS has previously mapped areas of landslide and debris flow deposits, many of which are within the study areas. Landslides and debris flows are often associated with active alluvial fan landforms and can be a primary mechanism for flowpath uncertainty. Figure 6 shows the extent of the UGS landslide and debris flow mapping within the study areas.

The UGS data layers are included in Appendix C.

2.6 Field Investigation

Following the identification of the alluvial fan landforms within the study areas using the data sources described previously, JEF staff conducted a field investigation for a selected number of locations. The purpose of the investigation was to:

- Verify geomorphic characteristics and features that were observed in the aerial photography.
- Observe, record, and photograph the existing conditions of the landforms.
- Observe and interpret geomorphic characteristics that indicated whether the landforms were active or inactive.

The field investigation was conducted on May 22-26, 2017. Budget constraints for the study necessitated prioritizing the more than 400 identified alluvial fan landforms to a selected number that could be realistically visited within the time constraint. A total of 37 sites were selected and sent to Utah Department of Emergency Management (UDEM) staff for prioritization prior to the field visits. All but a few of the selected field sites were accessible. The non-accessible sites were located on private land with no public access. Over 170 georeferenced field photographs were collected and are included in Appendix A along with a location map of each photograph. Figure 7 shows the visited field investigation sites.

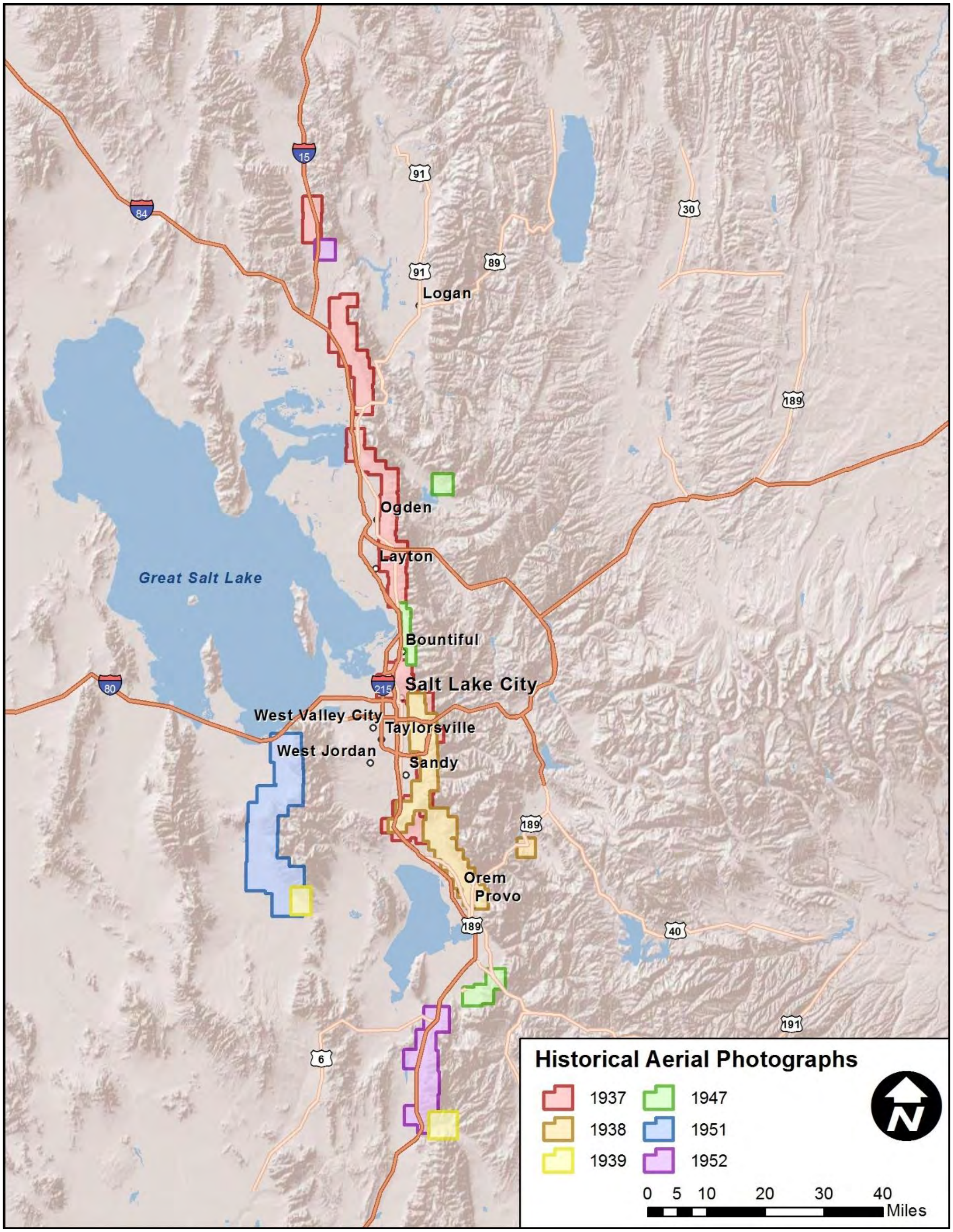

Figure 4. Semi-rectified historical aerial photography extents

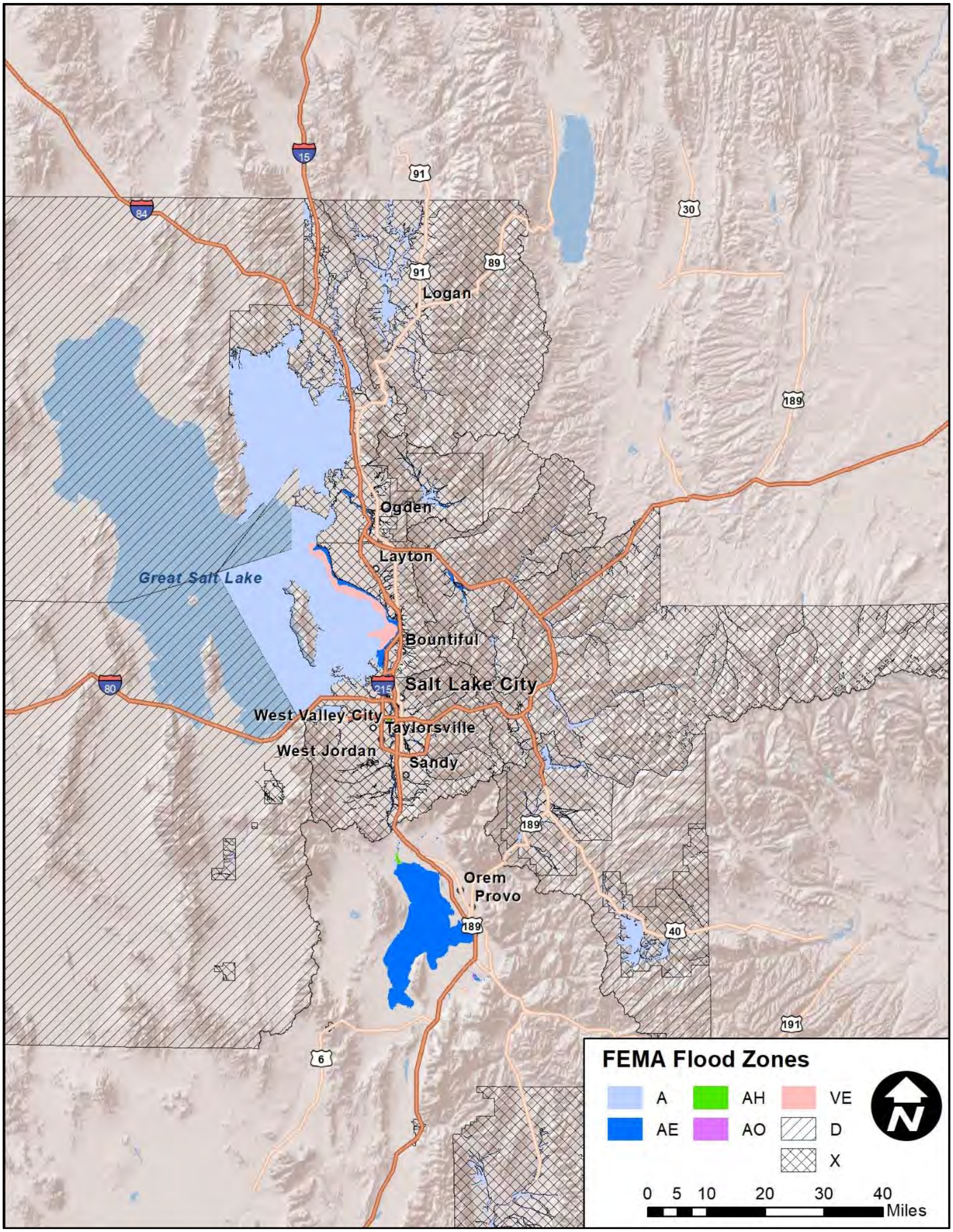

Figure 5. Effective FEMA flood zones within the study areas

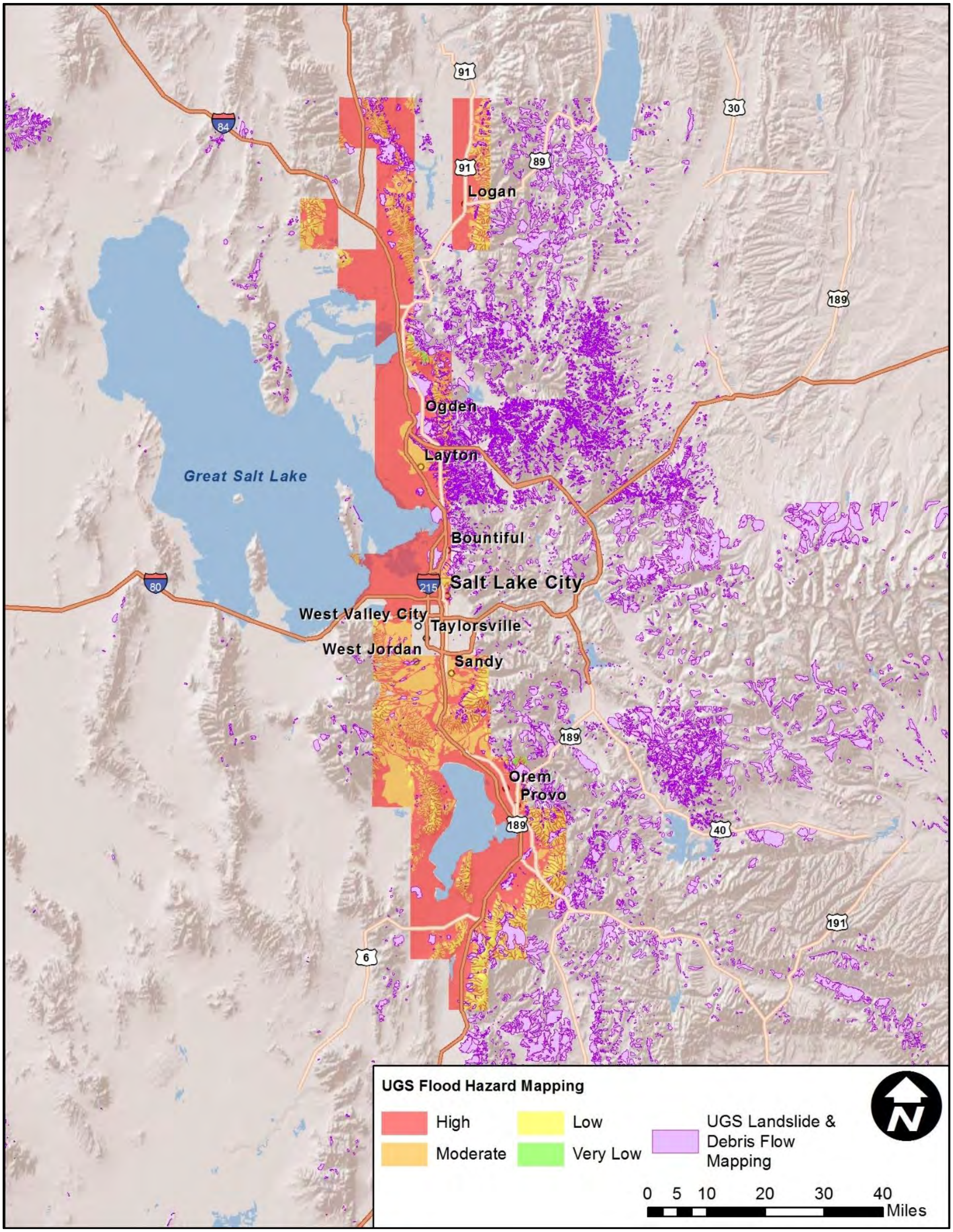

Figure 6. Utah Geological Survey hazard mapping

Figure 7. Field investigation sites

3 ALLUVIAL FAN LANDFORMS

3.1 INITIAL IDENTIFICATION

Initial identification of the alluvial fan landforms within the study areas was conducted using GIS software tools and the data sources listed in Section 2. Over 400 individual landforms were initially identified. That number was reduced following the field investigation and additional GIS analyses.

3.2 FIELD VERIFICATION

The field verification resulted in a number of identified landforms being removed from the final dataset due to a number of possible situations:

- A debris or retention basin constructed at the fan apex. These structures remove the sedimentation and flowpath uncertainty elements of alluvial fan flooding. The landforms downstream of the basins are no longer active.
- Geomorphic characteristics observed within the watershed or near the apex indicated the landform was no longer active.
- The landform initially identified as an alluvial fan was determined to be a non-fan landform.

3.3 RELATIVE HAZARD CLASSIFICATION

The final alluvial fan landforms identified for this study were assigned a relative hazard classification. The purpose of this classification is to identify which landforms may pose a higher risk of alluvial fan flooding, and provide a relative priority for future detailed studies. Two relative hazard classifications were assigned: 1) Moderate, and 2) High. Below are the criteria used for the High classification.

- Manmade structures were present within the alluvial fan landform delineation boundary. (Note: the type of structure was not identified.)
- The landform delineation intersected the UGS landslide and debris flow mapping layer.
- Field evidence indicated the landform posed a high hazard to downstream development.

All remaining landforms within the dataset were assigned a relative hazard classification of Moderate. Appendix B shows the final alluvial fan landform GIS layer symbolized by relative hazard classification.

4 RESULTS

This study resulted in the initial identification of over 400 alluvial fan landform areas within the project study areas. Identification of the landforms was conducted using the best available data from multiple sources. A subset (37) of the identified landforms were selected for field investigation and verification. The field investigation resulted in the removal of several identified alluvial fan landforms from the final dataset. The data sources used in the landform identification were incorporated into the final alluvial fan GIS layer. Table 3 described the attributes incorporated into the final GIS layer. Table 4 is a summary count of the alluvial fan landforms by jurisdiction. Figure 8 through Figure 14 shows the final alluvial fan landform GIS layer symbolized by relative hazard classification by county.

Table 3. GIS layer attributes for the alluvial fan landform layer

GIS Layer Attribute Field	Description
WATERCOURSE	Watercourse name (if applicable).
GEOLOGIC_MAP_DESCRIPTION	USGS or UGS geologic map unit description.
GEOLOGIC_MAP_UNIT	USGS or UGS geologic map unit.
MUNICIPALITY	Municipality within which the alluvial fan landform delineation is located.
COUNTY	County within which the alluvial fan landform delineation is located.
FEMA_FLOOD_ZONE	FEMA regulatory flood zone that intersects the alluvial fan delineation.
UGS_FLOOD_HAZARD	The UGS flood hazard layer that intersects the alluvial fan delineation (see Figure 6).
UGS_LANDSLIDE_DESCRIPTION	The UGS landslide/debris flow layer description that intersects the alluvial fan delineation (see Figure 6).
UGS_LANDSLIDE_MOVE_TYPE	The UGS landslide/debris flow layer movement type that intersects the alluvial fan delineation (see Figure 6).
RELATIVE_HAZARD	The relative hazard classification assigned from this study. See Section 3.3 for the classification criteria.
FIELD_NOTES	General notes for the sites visited during the field investigation.

Table 4. Active alluvial fan landform count summary

Municipality	No. Fan Landforms Moderate Hazard	No. Fan Landforms High Hazard
Alpine	1	13
Bountiful	-	2
Brigham City	-	2
Cottonwood Heights	-	7
Deweyville	9	3
Draper City	6	4
Elk Ridge	-	1
Farmington	-	3
Fruit Heights	4	2
Highland	1	-
Holladay City	-	3
Honeyville City	3	6
Kaysville	2	-
Layton	-	10
Lehi	3	-
Lindon	-	2
Mapleton	8	4
Mendon	-	1
Nephi City	-	3
North Ogden City	-	5
Ogden City	-	17
Orem	1	4
Payson	-	8
Perry City	-	5
Pleasant View	-	2
Plymouth	-	1
Provo	2	7
Rocky Ridge Town	-	1
Salem	1	4

Municipality	No. Fan Landforms Moderate Hazard	No. Fan Landforms High Hazard
Sandy City	-	4
Santaquin City	-	9
South Weber	-	3
Springville	-	6
Stockton	6	-
Tooele	5	1
Uintah	-	3
Willard City	-	6
Unincorporated Box Elder County	21	43
Unincorporated Cache County	1	6
Unincorporated Davis County	-	1
Unincorporated Juab County	23	14
Unincorporated Salt Lake County	-	7
Unincorporated Tooele County	37	11
Unincorporated Utah County	10	11
Unincorporated Weber County	-	9

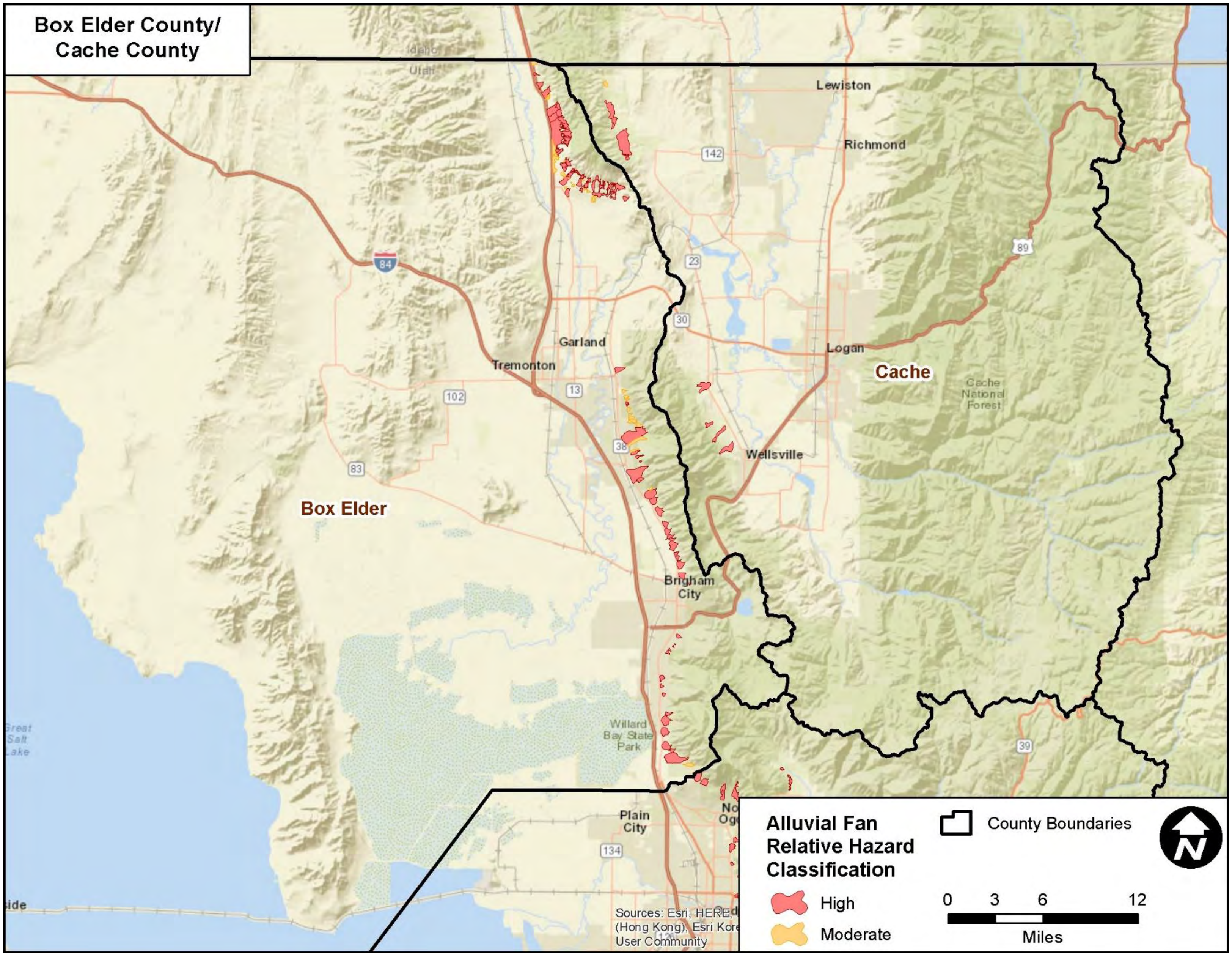

Figure 8. Alluvial fan landforms within Box Elder and Cache Counties

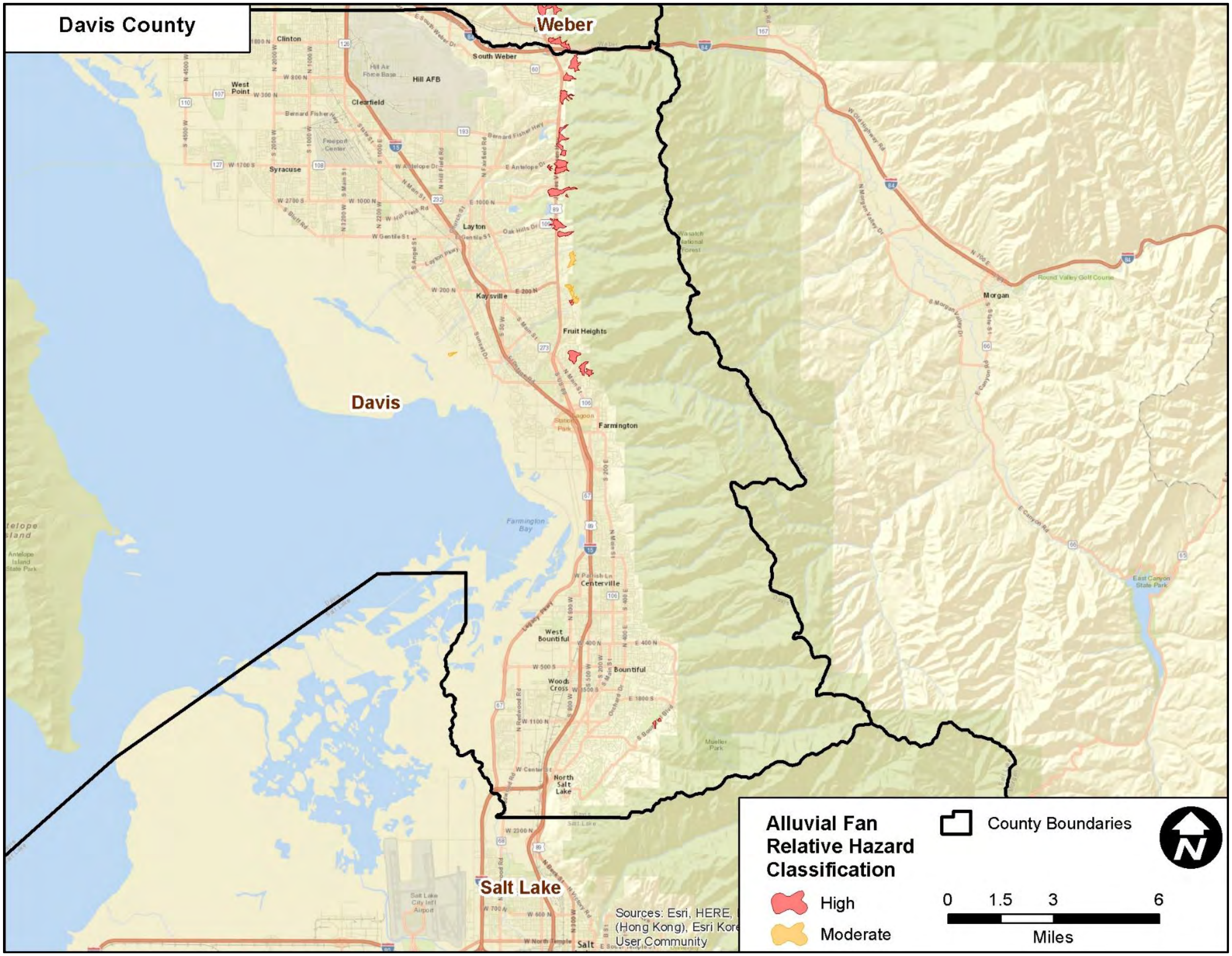

Figure 9. Alluvial fan landforms within Davis County

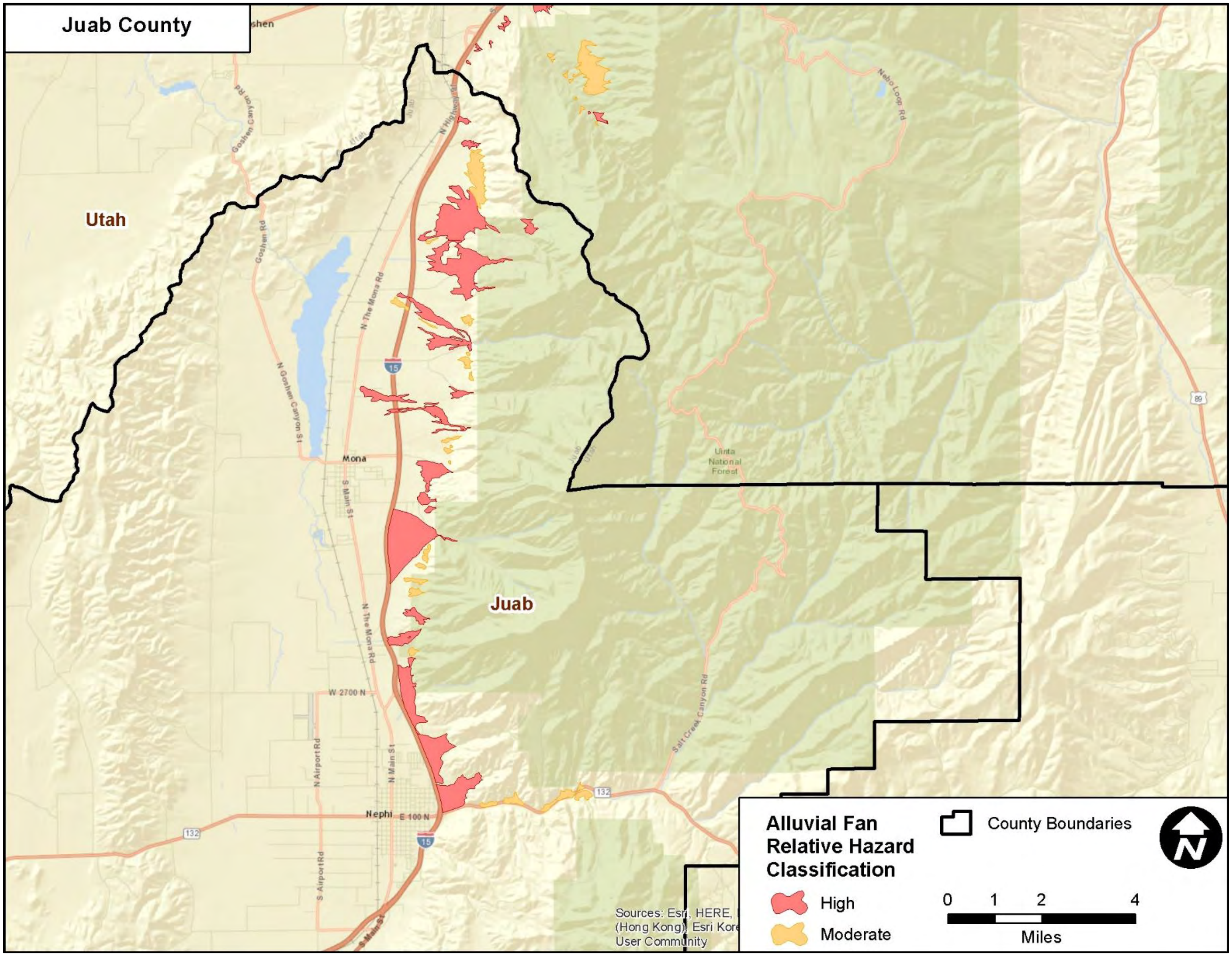

Figure 10. Alluvial fan landforms within Juab County

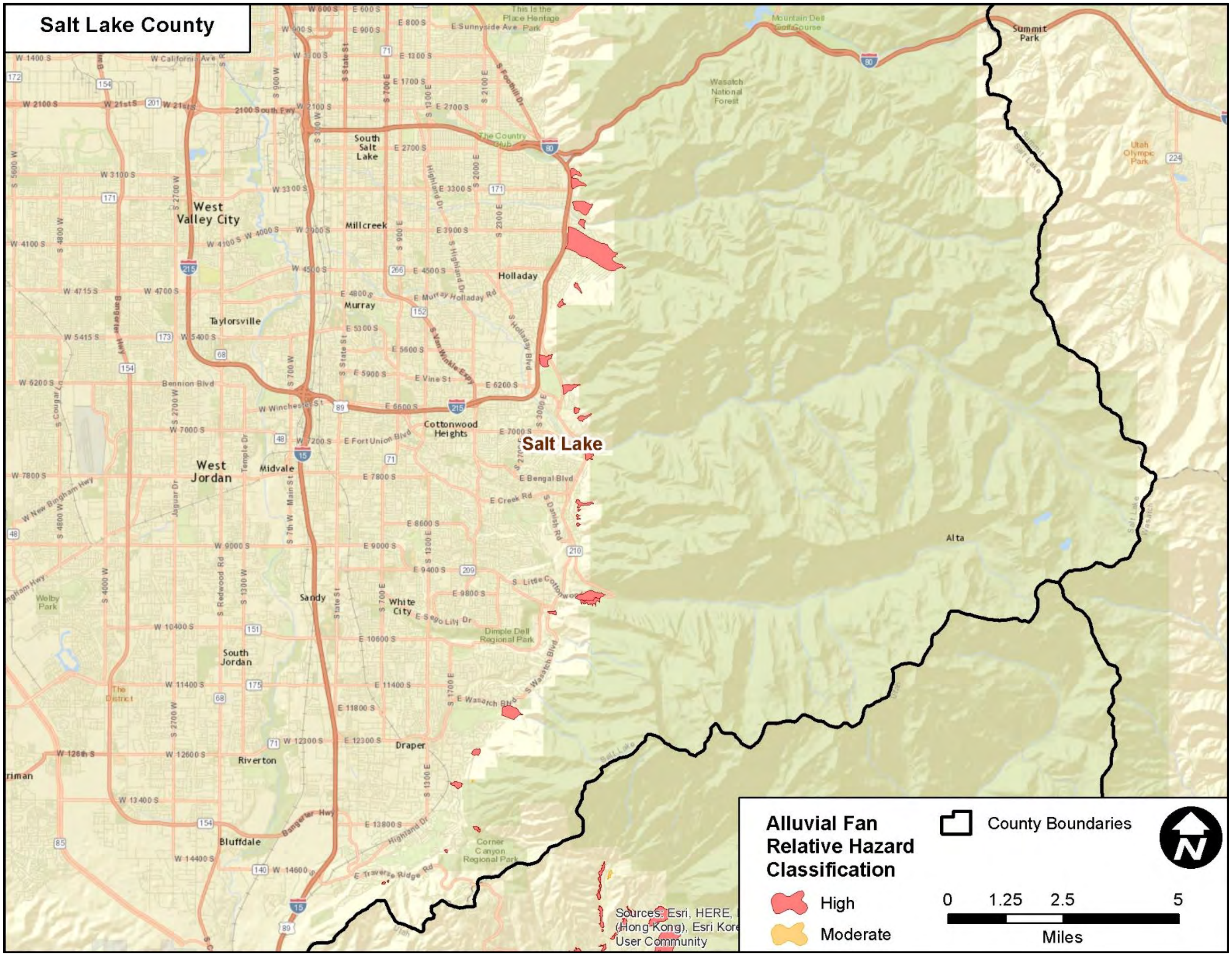

Figure 11. Alluvial fan landforms within Salt Lake County

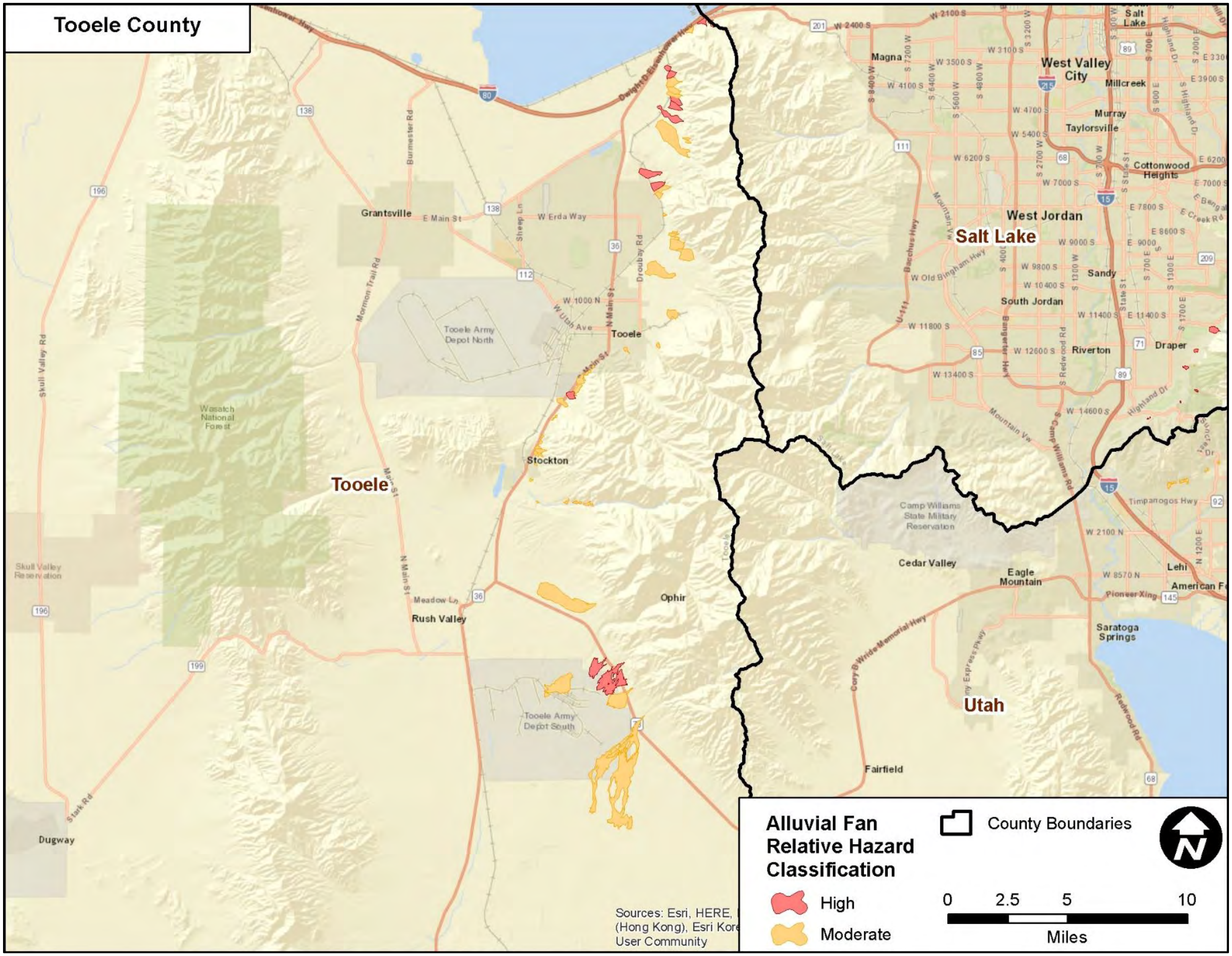

Figure 12. Alluvial fan landforms within Tooele County

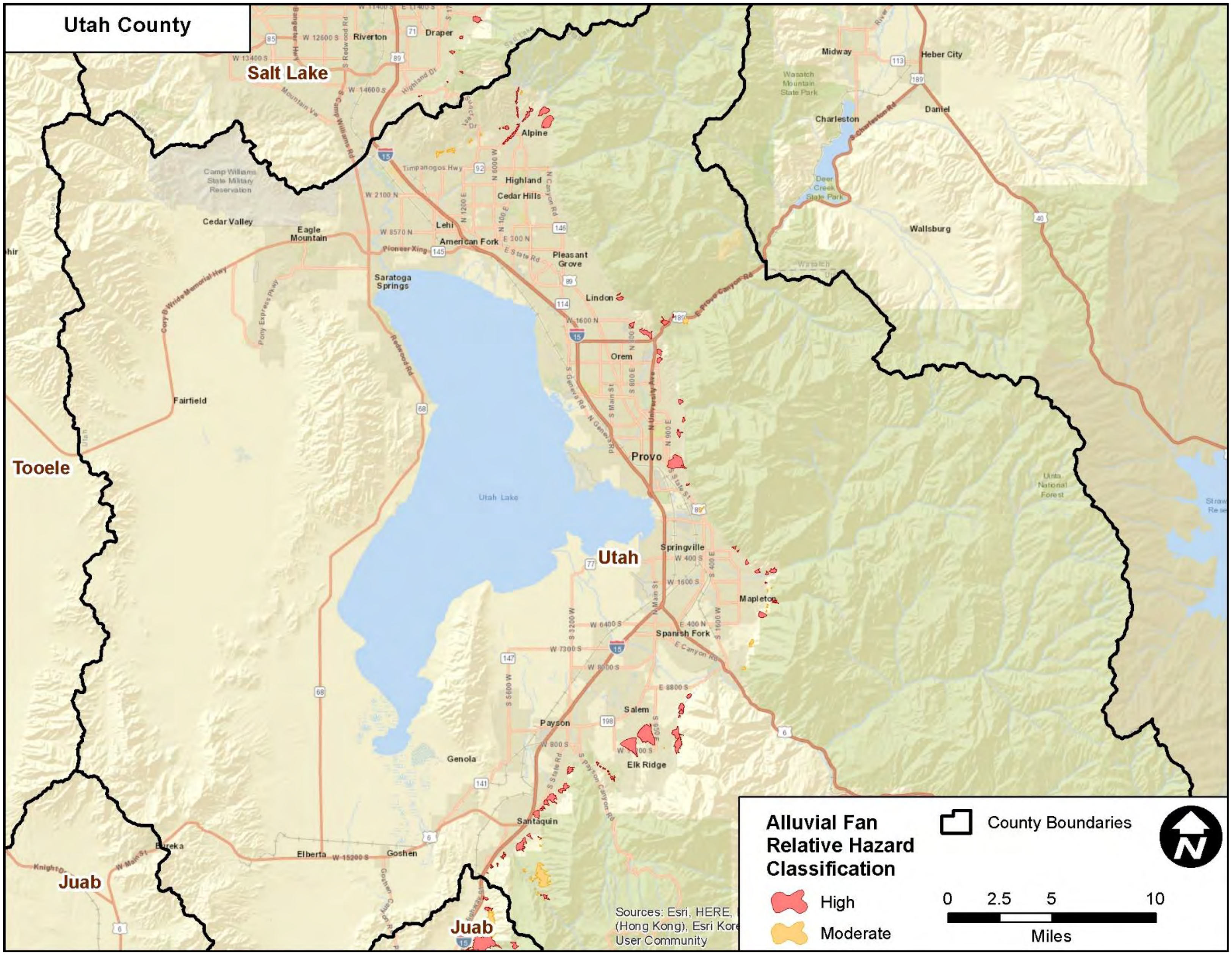

Figure 13. Alluvial fan landforms within Utah County

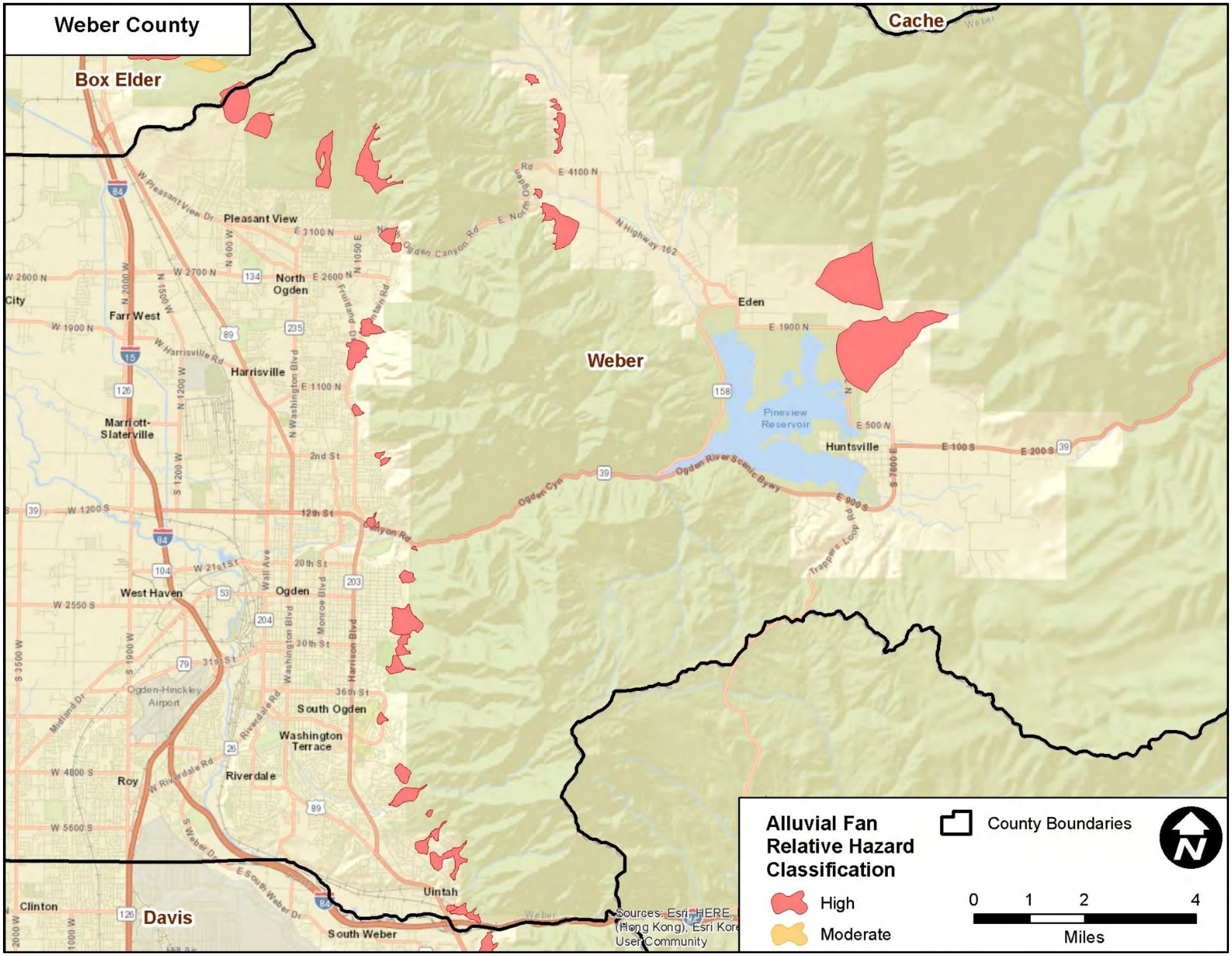

Figure 14. Alluvial fan landforms within Weber County

5 SUMMARY

Alluvial fan landforms pose a unique flooding hazard that is not found on non-fan landforms. FEMA requires special procedures when performing regulatory floodplain delineations on alluvial fans. Communities with active alluvial fan landforms should be aware of the unique hazards posed by alluvial fan landforms, and should take proper steps to assess those hazards.

This study resulted in the identification of nearly 400 potentially active alluvial fan landforms on the Wasatch Range and Oquirrh Mountains, with 254 classified as a High hazard and 144 as a Moderate hazard.

5.1 HOW TO USE THE DATA FROM THIS STUDY

The alluvial fan landform GIS layer is the primary deliverable for this study. It is recommended that the data be used by regulatory officials (state, county, and local) when evaluating flooding hazards in their jurisdictions. If future Flood Insurance Studies (FIS), or revisions to existing effective studies include watercourses that have alluvial fan landform delineations from this study, it is recommended that the FIS sponsoring agency conduct a more detailed assessment of the landform and associated watercourse and determine whether they meet the criteria for a FEMA alluvial fan assessment (per FEMA, 2003).

The alluvial fan landform delineations should not be considered FEMA regulatory alluvial fan floodplains. The purpose of the delineations is to identify landforms that will potentially require additional analysis to determine the actual flood risk.

6 REFERENCES

Castleton, J.J., B.A. Erickson, and E.J. Kleber, *in press*, *Flood Hazard Mapping of the Wasatch Front and Cache Valley, Utah*. Utah Geological Survey. Utah Department of Natural Resources.

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.

APPENDIX A

Field Photographs


Logan
Brigham City
Ogden
Roy
Clearfield
Layton
Kaysville
Bountiful
Salt Lake City
Magna
West Valley City
Canyon Rim
Millcreek
East Millcreek
Taylorsville
Holladay
Kearns
Murray
Oquirrh
Union
Cottonwood West
West Jordan
Cottonwood Heights
Sandy
South Jordan
Riverton
American Fork
Orem
Provo
Springville
Field Photo Locations and Photo ID
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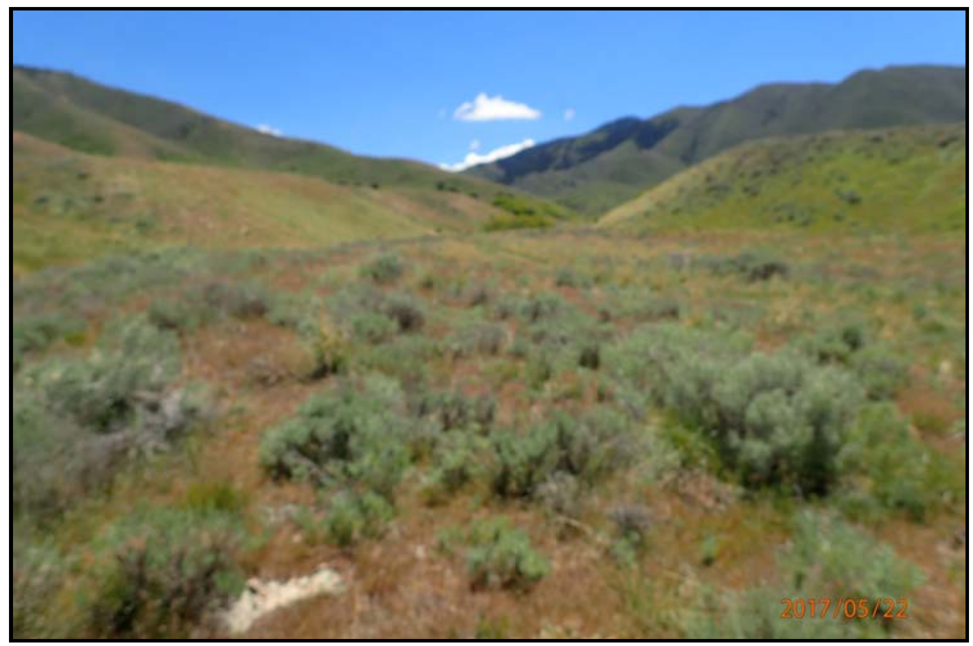

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APPENDIX B

Alluvial Fan Landform Delineations


Relative Hazard Classification
High
Moderate
Municipalities
County Boundaries
0 2.5 5 10 15 20
Miles
Box Elder
Cache
Rich
Weber
Morgan
Davis
Summit
Salt Lake
Tooele
Wasatch
Utah
Duchesne
Juab
Sanpete

APPENDIX C

Digital Data Submittal