Report No. UT-XXX

SEISMIC VULNERABILITY OF UDOT LIFELINES IN SALT LAKE COUNTY, UTAH

Prepared For:

Utah Department of Transportation
Research Division

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April 2011

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1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UT- 0(X)-XX	LEAVE BLANK	LEAVE BLANK

4. Title and Subtitle	5. Report Date
SEISMIC VULNERABILITY OF UDOT LIFELINES IN SALT LAKE COUNTY, UTAH	APRIL, 2010
	6. Performing Organization Code UTILIZE WHEN POSSIBLE
7. Author Dr. Steven F. Bartlett, Associate Professor, Dr. Xuesong, Zhou, Assistant Professor, Dr. Aleksandar Stevanovic, Post-Doctorate	8. Performing Organization Report No. UTILIZE WHEN POSSIBLE
9. Performing Organization Name and Address Department of Civil and Environmental Engineering University of Utah 110 Central Campus Dr. Salt Lake City, Utah 84112	10. Work Unit No. PROJECT NUMBER 11. Contract or Grant No. CONTARCT NUMBER
12. Sponsoring Agency Name and Address Utah Department of Transportation 4501 South 2700 West Salt Lake City, Utah 84114-8410	13. Type of Report & Period Covered FINAL, INTERIM, ETC. 14. Sponsoring Agency Code PROJECT ID CODE (PIC) No.

15. Supplementary Notes

Prepared in cooperation with the Utah Department of Transportation or U.S Department of Transportation, Federal Highway Administration

16. Abstract

This report evaluates the damage to the transportation network in Salt Lake City, Utah from two events: (1) M7.0 event on the Salt Lake City segment of the Wasatch fault system, and (2) M6.0 event on the West Valley fault system, both of which are located in the Salt Lake Valley. The evaluations included damage to the transportation system resulting from strong motion (earthquake shaking), liquefaction ground displacement (i.e., lateral spread and settlement) and surface fault rupture. The repair costs for the Salt Lake City traffic network for the M7.0 and M6.0 events are estimated to be $435 M and $71 M (2004 value), respectively. These estimates include infrastructure repair costs, but do not include user losses (i.e., losses due to decreases in the efficiency of the transportation network) and economic losses. It is expected that damage to the network will severely disrupt traffic flows for several months or a few years. The evaluations suggest that the M6.0 scenario event would cause about $65 million in user losses. More significantly, the M7.0 scenario event would cause about $1.3 billion in user losses during a 6-month, post-event window. An adaptive traffic modeling (i.e., Dynamic Traveler Model (Section 6) suggests that the user losses may be about $1.8 to 2 billion for a reconstruction period of 18 months following the M7.0 event.

17. Key Words		18. Distribution Statement		23. Registrant's Seal
Loss assessment, earthquakes, hazard analysis, traffic modeling, REDARS, VISUM, DYNASMART, strong motion, liquefaction, fault rupture		UDOT Research Division 4501 south 2700 West-box 148410 Salt Lake City, Utah 84114		LEAVE BLANK
19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price	
Unclassified	Unclassified	261	LEAVE BLANK	

Acknowledgements

We thank the Research Division of the Utah Department of Transportation (UDOT) for the funding of this project. We would also like to thank Corin Piacenti for developing the NEHRP soil classification map for Salt Lake County.

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Executive Summary

Large earthquakes can cause extensive damage to transportation infrastructure. In addition to replacement and repair costs for the transportation infrastructure, such events can increase time delays and congestion that results from the loss of function of major components of the traffic network. This report describes the methodologies used to perform REDARS (Risks from Earthquake Damage to Roadway Systems) evaluations of urban transportation system in the Salt Lake Valley, Utah from damage resulting from two seismic events. The evaluations were performed using the Hazards System, Component and Economic Modules within the REDARS v.2 software (Chang et al., 2008). This report focuses on the hazards and the component module inputs, analyses and results. Additional system and economic analyses were subsequently calculated outside the REDARS model by Kim et al. (2008) using the expected damage states from this report. These analyses are also presented herein.

This seismic scenarios evaluated by this study were: (1) M7.0 event on the Salt Lake City segment of the Wasatch fault system, and (2) M6.0 event on the West Valley fault system, both of which are located in the Salt Lake Valley. The evaluations included damage to the transportation system resulting from strong motion (earthquake shaking), liquefaction ground displacement (i.e., lateral spread and settlement) and surface fault rupture. The damage estimates calculated by REDARS include bridge and link (i.e., roadway) damage states and total repair costs.

The repair costs for the Salt Lake City traffic network for the M7.0 and M6.0 events are estimated to be $435 M and $71 M (2004 value), respectively. These estimates include infrastructure repair costs, but do not include user losses (i.e., losses due to decreases in the efficiency of the transportation network) and economic losses. In addition, this study suggests that permanent ground displacement from liquefaction and fault rupture for the M7.0 event will be considerable and will be most pronounced on: I-15 (south of I-215), I-215 (west side), I-80 (from the downtown area westward) (Figure 4), and on the valley's east side near the Wasatch fault. For the M6.0 event, liquefaction and fault damage is much more limited and is mainly expected on I-80, near the downtown area, and on the west side of I-215 (Figure 6).

It is expected that damage to the network will severely disrupt traffic flows for several months or a few years. Impacts on road users can be estimated in terms of user costs resulting from travel time delay. This report also evaluates traffic disruption (i.e., user delay costs) resulting from the two scenario events. The VISUM traffic macro-simulation model was used to estimate the delay-based user costs. Road segments, which are vulnerable yet critical to detour traffic following an earthquake have been prioritized for potential rehabilitation. The VISUM evaluations suggest that the M6.0 scenario event would cause about $65 million in user losses. More significantly, the M7.0 scenario event would cause about $1.3 billion in user losses during a 6-month, post-event window. User losses beyond this value may be incurred, depending upon the time required to bring the network back to its original, pre-event capacity, which may require considerable time for the M7.0 scenario event. Adaptive traffic modeling (i.e., Dynamic Traveler Model (Section 6) suggests that the user losses may be about $1.8 to 2 billion for a reconstruction period of 18 months following the M7.0 scenario event.

Links that are susceptible to damage in one scenario, but critical in carrying detour traffic for the other scenario are defined as lifelines. A shortlist of lifelines is provided for each earthquake scenario with detailed information including names, directions and addresses. This list of lifelines may aid UDOT in the planning, operation and emergency response functions of its traffic network prior to a seismic event.

1.0 Introduction

Previous studies have been conducted on the Salt Lake Valley transportation system using earthquake scenarios. King and Kiremidjian (1994) performed a comprehensive seismic hazard and loss estimation study for the Salt Lake Valley using a geographic information systems (GIS) platform. This study considered a M7.5 event on the Salt Lake City segment of the Wasatch fault and evaluated seismic hazards resulting from strong (i.e., earthquake shaking), liquefaction (i.e., severe loss of shear strength from elevated pore pressures), landsliding and surface fault rupture (i.e., fault displacement). Of the 279 bridges analyzed in this study, 264 bridges showed moderate or higher damage. One conclusion from this study was that the damage model overestimated bridge damage and that an improved damage model was needed (King and Kiremidjian, 1994).

A more recent study by the Wasatch Regional Council (WFRC, 2008) is summarized in their Natural Hazard Pre-Disaster Mitigation Plan. This study considered two earthquake scenarios: M7.1 and M5.9 events located in the Salt Lake Valley. The vulnerability and damage to the infrastructure from multiple earthquake hazards was obtained from HAZUS-MH (FEMA, 2005). Out of 698 highway bridges analyzed, 496 showed moderate or higher damage from the M7.1 event, or 71 percent with an estimated repair cost of $469 M (2008 value). For the M5.9 scenario, 126 bridges showed moderate or higher damage, or 18 percent with an estimated repair cost of $82 M (2008 value).

In contrast to these general loss estimation tools, REDARS was developed to more specifically evaluate the damage impacts to a region's traffic system resulting from an earthquake event. It estimates reconstruction, travel and economic losses associated with this damage. REDARS v. 1 (Werner et al. 2000; 2003) was developed jointly in 2000 by MCEER (Multidisciplinary Center for Earthquake Engineering Research) and the FHWA (Federal Highway Administration) as part of FHWA-MCEER Project 106. This earlier version of the software was tested for a pre-earthquake traffic network for Shelby County, Tennessee (Werner et al. 2000). After this, the software was used make a pre-event evaluation of the Los Angeles, California area highway system (Werner et al. 2006a). The software package that was implemented for this study is REDARS v.2, which is the most current version (Werner et al. 2006b).

REDARS v. 2 has four modules that are used in performing an assessment: (1) component, (2) hazards, (3) system and (4) economic. The component module consists of inputting component attributes (e.g., bridge and roadway attributes – Section 2.1) and the subsequent REDAR analyses that determine each component's post-event damage state (e.g., collapsed, severely damaged, no damage, etc.) and the post-event traffic state (i.e., full or partial closure for repairs) and the cost and duration of the repairs. The hazards module is used to determine the spatial distribution of strong motion, location of fault rupture and amount of liquefaction-induced ground failure and requires earthquake, fault geometry and soil inputs. The system module consists of input data (Section 2.1) and models for determining the seismic performance of the highway system at different elapsed times following the earthquake. Lastly, the economic model is used for estimating anticipated repair costs (Section 4) and economic losses induced by the increase in travel times and reduced trip demands (Section 5). This study focuses on implementing the first two modules to the Salt Lake Valley traffic network and earthquake hazards. A summary of how our results were used in subsequent system and economic analyses is also given.

2.0 Modeling Inputs

2.1 Component Module

The component module estimates the seismic performance of the system components for a given scenario earthquake. The required inputs are: NHPN, HPMS, NBI and OD files and a map of the NEHRP (National Earthquake Hazard Reduction Program) soil classifications for the study area (Figure 1, see also Appendix 1). The NHPN (National Highway Planning Network) file is maintained by the FHWA and contains the transportation network (i.e., interstates, principal arterials and minor arterials.) The HPMS (Highway Performance and Monitoring System) data file is a nationwide inventory distributed by the FHWA that includes the condition, performance, use and operating characteristics of a roadway. The FHWA National Bridge Inventory (NBI) includes the location, structural type, year built and number of bridge lanes for each bridge in the transportation system. The Origin Destination (OD) data includes travel origins and destinations based on periodic public surveys. The NEHRP soil map used in the Hazard Component (Section 2.2) was developed for this study from surficial geologic mapping and soils data available for the Salt Lake Valley.

These input files are normally imported into the REDARS software using its import wizard and are subsequently processed and placed into tabular form before the hazard analysis can be performed. However, we did not use the REDARS import wizard due to incompatibility issues that REDARS has with the current format of the NHPN and HPMS files. Following the release of REDARS v. 2 in 2006, the formats of these files have changed, thus making them incompatible with the REDARS import wizard. Instead the raw data from these files was placed directly in Microsoft Access™ tables, which entailed a significant effort for the project team. Future improvements to REDARS should consider modifications to its current import wizard.

The transportation network we considered was not obtained from the FHWA NHPN; instead a more extensive transportation network was obtained from the Wasatch Front Regional Council and manually imported into REDARS. The WFRC network is more extensive than that of the NHPN and the WFRC network has been used in several traffic modeling studies performed by the University of Utah for UDOT and other agencies. This network consists of 1,407 bridges and

18,601 links in Salt Lake Valley. An overview map of the interstate corridors, primary highways and major roads for the study area is shown in Figure 1. In short, the traffic system consists of four major freeways. Interstate 15 runs north-south just west of downtown. Interstate 80 enters close to the airport and merges with I-15 west of downtown and then heads east through the residential areas. State Route 201 runs east-west and bisects I-15 and I-80 at a major interchange in the northeastern part of the valley near the downtown area. Interstate 215 is a beltway that transverses the northwest and west neighborhoods and encircles the southern part of Salt Lake City.

2.2 Hazards Module

The hazards module is used to estimate seismic hazards and their impacts to the transportation network. It contains models for calculating the seismic hazards (i.e., strong motion, liquefaction damage and surface fault rupture) imposed on the traffic network. The earthquake event can be defined in three different ways: a) point source (magnitude and epicenter location), b) walkthrough file (multiple events including earthquake magnitude and fault geometry) and c) United State Geological Survey (USGS) ShakeMap™ file, which is currently found at: (http://earthquake.usgs.gov/eqcenter/shakemap/).

We evaluated options b) and c) above. However, regarding option c), we found that when the ShakeMap™ option is used in REDARS 2, liquefaction and surface fault rupture effects are not calculated. This programming oversight is a serious shortfall for the Salt Lake Valley; because liquefaction ground failure is expected in many parts of the central part of the valley (Olsen et al., 2007). In addition, option c) does not include surface fault rupture effects, so it was not used.

Ultimately, we chose to use option b) because it estimates strong motion, fault rupture and liquefaction effects; thus it is the most comprehensive option from a seismic hazard standpoint. Option b) can include multiple earthquake scenarios and requires data that characterizes the known active fault system(s) or random earthquake sources. Strong motion estimates for the Salt Lake Valley were calculated by REDARS using the Abrahamson and Silva (1997) attenuation relation. (Unfortunately, the Next Generation of Ground-Motion Attenuation (NGA) models

(Powers et al. 2008) are not available in REDARS 2, which would be an improvement to its current methodology.)

We considered two faulting scenarios for the Salt Lake Valley: a characteristic M7.0 event on the Salt Lake City segment of the Wasatch fault (Wong et al., 2002) and a M6.0 event on the West Valley fault system. The Salt Lake City segment is the primary seismic threat to the Salt Lake Valley transportation system. It is a normal fault at the eastern most edge of the Basin and Range Province that is approximately 46 km long and is bounded to the east by the Wasatch Mountain Range (Figure 2). This fault has an average recurrence interval of 1,200–1,300 years (Lund 2005) and is capable of generating peak ground acceleration values between 0.3 to 1.0 g throughout the valley (Wong et al. 2002). The West Valley fault zone (Figure 2) is antithetic to the Salt Lake City segment and may or may not be linked to rupture on the Wasatch fault. Based on its mapped surface length, this fault was assigned a M6.0 event using empirical relations of Wells and Coppersmith (1994). The information needed by REDARS 2 for option b) is summarized in Table 1 for these faults.

The fault geometry for the Salt Lake City segment of the Wasatch fault was assumed to be a polygon consisting of four points (Table 1) (Figure 2). The depth of the fault was estimated to be 20 km and that the fault dips westward at an angle of 45 degrees. The actual depth and dip of faulting are unknown, but a 20 km depth and dip of 45 degrees is commonly used in evaluations of the Wasatch fault. In addition, because this is a normal fault, all fault movement was assigned in the dip direction. The hypocenter was approximated at the center of the fault plane (Table 1), and the center of energy release location was approximated as halfway between the fault's base and its hypocenter location.

Nonlinear behavior of soft and deep soil deposits at relatively high levels of strong ground motion is of particular interest to Utah's transportation network because much of its urban population and infrastructure is located within 10 km of the Wasatch fault, where future peak ground acceleration (pga) is expected to be 0.3 g to 1.0 g, depending on the site conditions and proximity to the Wasatch fault (Wong et al. 2002). In addition, the Salt Lake Valley, which contains approximately 50 percent of the State's population, is a relatively deep intermontane basin filled with interbedded alluvium and lacustrine deposits that extend to considerable depths. For example, Arnow et al. (1970) (see also Wong et al. (2002)) estimate that the thickness of unconsolidated Quaternary sediments is about 100 to 360 m near downtown Salt Lake City and such sediments extend to a depth of over 600 m, just north of the downtown area. In addition, late-Pleistocene and Holocene surficial sediments deposited by the Pleistocene-age Lake Bonneville and the present Great Salt Lake are soft, compressible and typically classify as soft to medium consistency clays. Undoubtedly, soft soil effects will play a significant role in modifying the strong motion in the Salt Lake Valley.

REDARS v. 2 adjusts the strong motion estimates for soil effects using maps that use the NEHRP soil classification system (NEHRP, 1997). In implementing the Abrahamson and Silva (1997) attenuation relation, soil classes A, B and C are considered to be rock sites and are not adjusted; NEHRP soil classes D and E are considered to be soil sites and their ground motion estimates are adjusted. We developed a NEHRP site class map for the Salt Lake Valley, Utah (Figure 1) using geologic mapping and geophysical data (Figure 2) (Table 2). To produce this map, SH-wave velocities at 140 locations in the Salt Lake Valley were compiled from conventional downhole, crosshole and surface geophysical techniques. These Vs measurements were obtained from Ashland and Rollins (1999) and from Bischoff (2005) and entered into the GIS database by Bartlett et al. (2005). The average shear wave velocity of the upper 30 m of the soil profile, Vs_{30}, was calculated and superimposed on a surficial geological map (Figure 2). The geologic mapping for the Salt Lake Valley was acquired from two main sources: a surficial geologic map of the Salt Lake City segment of the Wasatch fault zone (Personius and Scott, 1992) for the eastern side of the valley and several quadrangle maps (Biek et al., 2004 and Biek, 2005) that cover the remainder of the valley. All the geospatial data was entered in the North American Datum (NAD) 1983 projected coordinate system data. The geologic data and the major roads were clipped at the Salt Lake County boundaries. These maps and Vs data were combined to produce a NEHRP site class map of the entire valley (Figure 1, see also Appendix 1). For units where shear wave velocity measurements were not available, the type and age of the deposit was used to infer the site class. Figure 1 shows that the central portion of the valley, near the Jordan River, is predominantly Site Class E ($Vs_{30} < 180$ m/s); however some Site Class F soils may exist, due to the possibility of liquefaction. Sites located outside of recent river and stream deposits, but still in the central part of the valley floor, are underlain by lacustrine silts and clays and typically classify as Site Class D (Vs_{30} 180–360 m/s). At higher elevations, denser sand and gravel deposits of terrace, fan, delta and glacial origin generally have Vs_{30} values greater than 360 m/s and classify as Site Class C (Vs_{30} 360–760 m/s). There was insufficient data to map site class F soils; thus, all such soils were categorized as site class E in this map. However, we recommend that the potential for site class F soils should be determined by site-specific investigations using geotechnical data, as was done for potentially liquefiable soils in this study, as described in the next section. In addition, the Magna Tailings impoundment was labeled as "Special Study Area;" because of the special characteristics of these tailing slimes.

Table 1 Walkthrough file input for the Salt Lake Valley scenario earthquakes

	Fault/Earthquake Data	Salt Lake City Segment	West Valley Fault System
Type	Description/Units		
Moment Magnitude	----	7	6
Fault Style	1 = strike-slip fault, 2= reverse fault, 3 = normal fault, 4 = other)	3	3
Fault Number	Random sources are numbered "0"	0	0
Fault Name	----	Salt Lake City	West Valley
No. of End-End Segments	----	1	1
defining Fault Rupture			
Fault Rupture Plane End-Point Latitudes, Longitudes	End Point 1 along Top of Fault Plane, deg (Location – Figure 2)	40.83629, -111.88340 (1)	40.808299, -111.981866 (5)

	End Point 2 along Top of Fault Plane, deg (Location – Figure 2)	40.476133, -111.832781 (2)	40.661203, -111.945364 (6)
	End Point A along Base of Fault Plane, deg (Location – Figure 2)	40.821367, -112.121896 (3)	40.820401, -111.890608 (7)
	End Point B along Base of Fault Plane, deg (Location – Figure 2)	40.44092, -112.07136 (4)	40.673826, -111.855856 (8)
Fault Plane Orientation	Dip Angle, deg	45	45
	Azimuth of Dipping Plane of Fault, deg	264	80
EQ Hypocenter Depth	Km	10	3.855
Total Width of Fault Plane	Km	28.28427	10.9
EQ Epicenter Coordinates	Latitude and Longitude, deg	40.6, -111.9	40.7468, -111.9173
EQ Seismogenic Zone	Depth to Rupture Plane, km	0	0
EQ Center of Energy Release	Depth from ground surface, km	15	5.78
	Latitude and Longitude, deg	40.65, -112.03	40.7437, -111.9005

Fault Plane Widths on Either Side of Fault Plane	Integer named ZD (=1 if user specified input fault widths are provided; =2 if default values are used)	0	0
Zone of Deformation (ZD) Widths	Units of m; Ignored if ZD=0	---	---

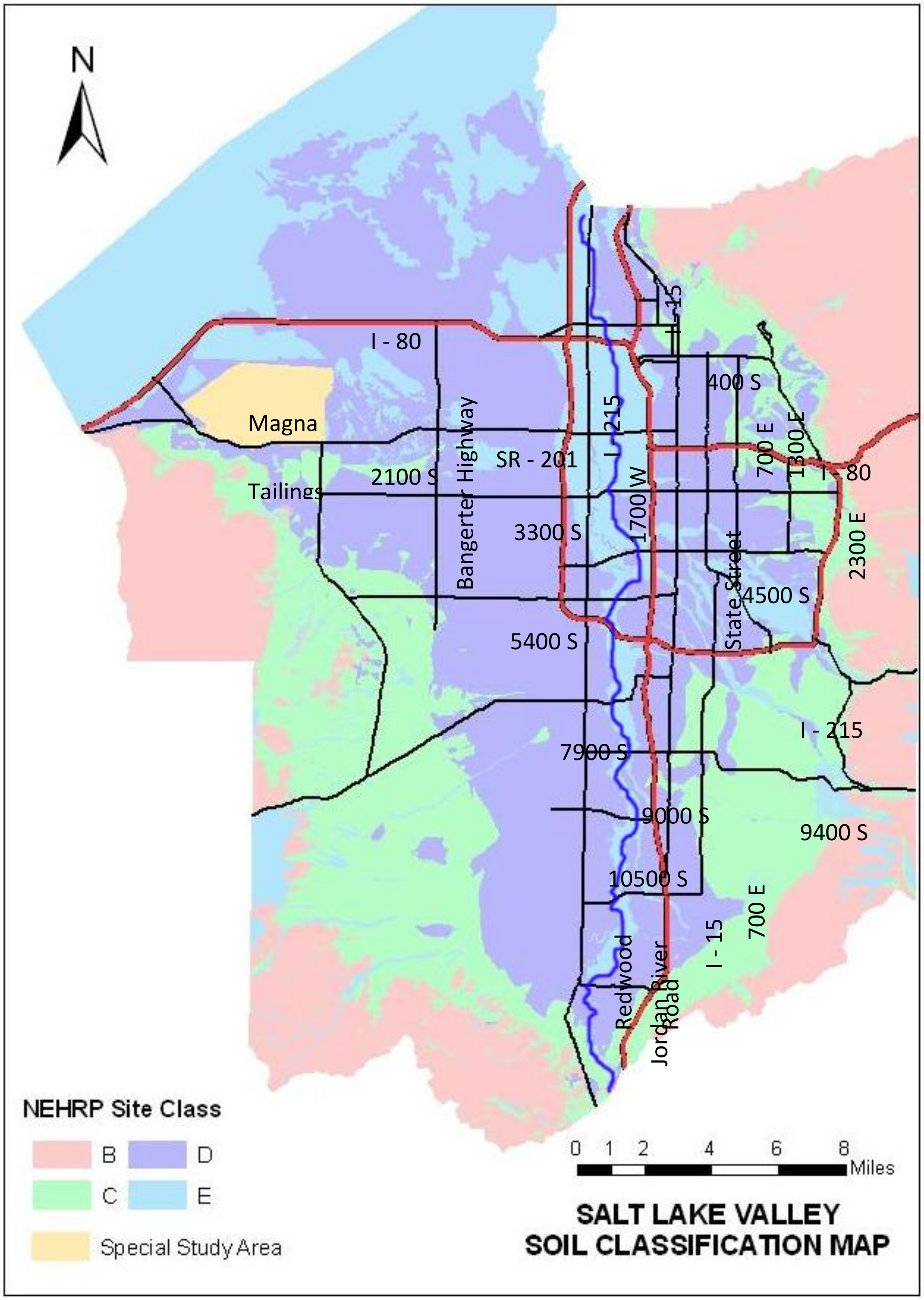

Figure 1 NEHRP site classification map and major route locations for Salt Lake County, Utah

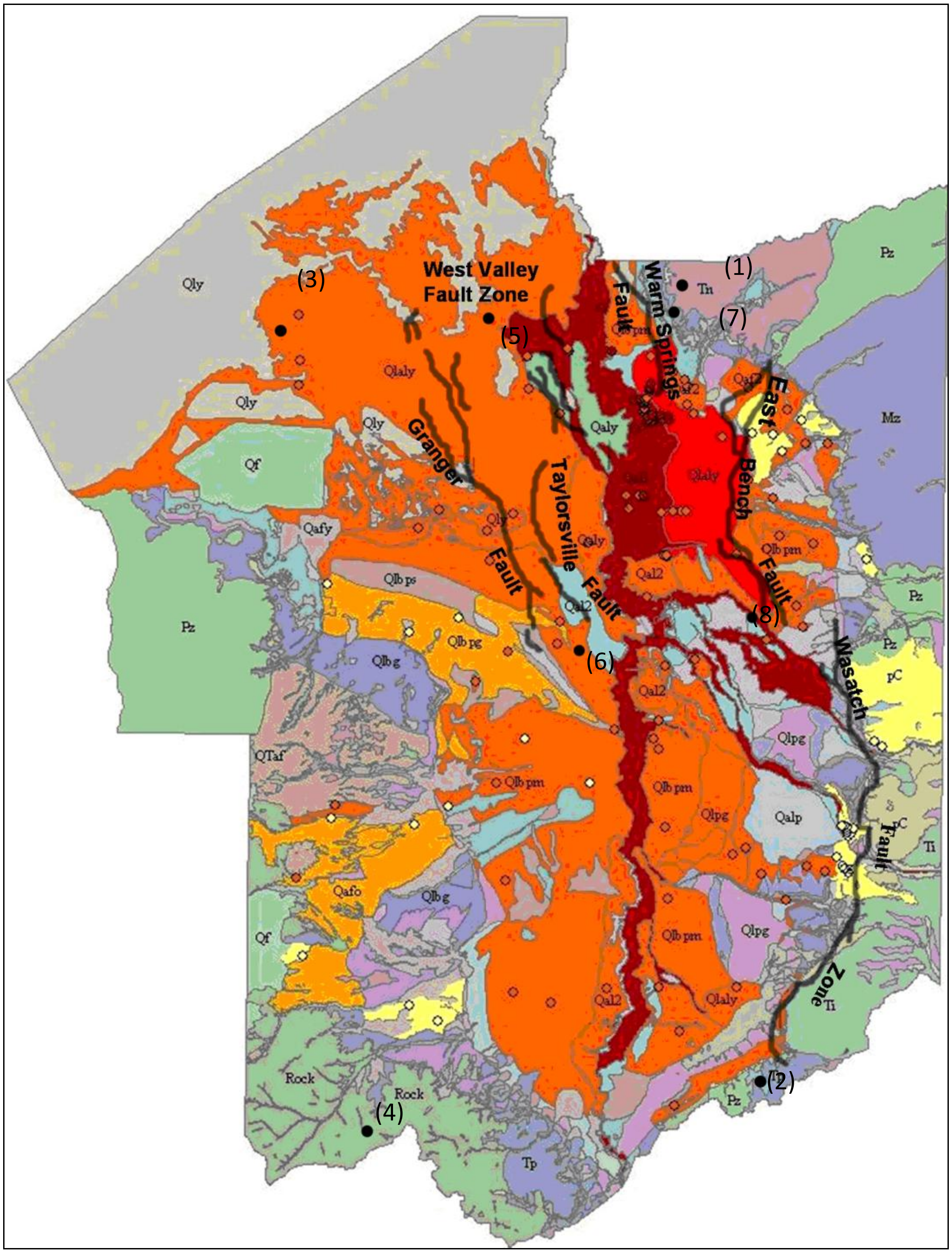

Figure 2 Surficial geology map of the Salt Lake Valley (modified from Personius and Scott, 1992; Biek et al., 2004; and Biek, 2005). Dots show Vs_{30} measurement locations

Table 2 Geologic units and descriptions for Figure 2

Name	Description	Age
Qaf1	Fan alluvium 1	Upper Holocene
Qaf2	Fan alluvium 2	Middle Holocene - Upper Pleistocene
Qafo	Older fan alluvium, undivided	Middle Pleistocene
Qafy	Younger fan alluvium, undivided	Holocene - Uppermost Pleistocene
Qal1	Stream alluvium 1	Upper Holocene
Qal2	Stream alluvium 2	Middle Holocene - Uppermost Pleistocene
Qaly	Younger stream alluvium, undivided	Holocene - Uppermost Pleistocene
Qalp	Stream alluvium related to Lake Bonneville regressive phase	Uppermost Pleistocene
Qes	Eolian sand	Holocene - Upper Pleistocene
Qf	Artificial fill	Historical
Qg	Glacial deposits	Middle - Upper Pleistocene
Qlaly	Lacustrine, marsh, and alluvial deposits, undivided	Holocene - Upper Pleistocene
Qlao	Lacustrine and alluvial deposits, undivided	Holocene - Upper Pleistocene
Qlbg	Lacustrine sand and gravel related to Lake Bonneville transgressive phase	Upper Pleistocene
Qlbm	Lacustrine clay and silt related to Lake Bonneville transgressive phase	Upper Pleistocene
Qlbpg	Lacustrine sand and gravel, undivided by Lake Bonneville phase	Upper Pleistocene
Qlbps	Lacustrine sand and silt, undivided by Lake Bonneville phase	Upper Pleistocene
Qlpg	Lacustrine sand and gravel related to Lake Bonneville regressive phase	Upper Pleistocene
Qlps	Lacustrine sand and silt related to Lake Bonneville regressive phase	Upper Pleistocene
Qly	Marsh and lacustrine deposits, undivided	Holocene - Uppermost Pleistocene
QTaf	Oldest alluvial-fan deposits	Middle Pleistocene
Rock	Bedrock	Various

2.0 Liquefaction Assessment Outputs

Liquefaction damage to the transportation network can be estimated by REDARS for lateral spread and ground settlement. However, REDARS does not contain routines to calculate if liquefaction will be triggered for the scenario earthquake. This must be done external to the REDARS program by the user and later provided as input to REDARS for assessing potential damage to each component of the network. Thus, we performed liquefaction-triggering analyses using computer routines that follow the liquefaction methodology outlined in NCEER (1997). The geotechnical borehole data used to calculate the liquefaction hazard were obtained from several different sources and screened using quality indicators developed by Bartlett and Olsen (2005). In total, 930 standard penetration test (SPT) boreholes were analyzed for the study area. The primary source of subsurface data was the Utah Department of Transportation, which provided a significant electronic subsurface database from the recently finished I-15 Reconstruction project and other previous projects (Bartlett and Olsen, 2005). These data were most heavily concentrated at bridge and retaining wall locations. Other subsurface data were obtained from Salt Lake County Planning, local area consultants and data used in the previous liquefaction potential map by Anderson et al. (1986). The subsurface database includes: SPT N values, groundwater levels, soil descriptions, and other classification properties such as fines content and Atterberg limits.

Some required soil information was missing in some of the boreholes (e.g., soil unit weight, fines content, etc.). For these boreholes, Microsoft Visual Basic for Applications (VBA) routines were used to fill in data gaps by averaging according to soil type and geologic unit (Bartlett and Olsen, 2005). However, in no case were SPT N values estimated; if this information was not available, the corresponding borehole information was not used because of the large uncertainty in estimating SPT N values. In addition, the depth to groundwater was estimated for some boreholes lacking this information. These estimates were made from nearby boreholes using an inverse distance squared method to interpolate groundwater elevations between boreholes. The inverse distance squared method was compared with results from kriging and spline interpolation methods and appeared to produce reasonable results (Bartlett and Olsen, 2005).

We performed liquefaction-triggering calculations at each borehole and interpolated the results to each network component location. To do this, the factor of safety against liquefaction was calculated at each borehole location for the scenario earthquakes and averaged at each component location using an inverse-distance weighting scheme. The developed routine used the factors of safety against triggering liquefaction for the three nearest boreholes in the weighted average. If the weighted average was less than 1.0, then liquefaction was assumed to occur at the component location and that component was further evaluated for horizontal and vertical ground displacement, as discussed in the following sections.

Once a component has been flagged by the user as being susceptible to liquefaction, REDARS v.2 determines the amount of liquefaction-induced lateral spread and vertical settlement for all components susceptible to liquefaction. The REDARS model also determines the amount of surface fault rupture displacement. The earthquake induced permanent ground displacement (PGD) resulting from liquefaction and surface fault rupture is used to determine the damage state and repair costs of highway links, as explained below.

2.1 Liquefaction – Induced Lateral Spread

REDARS uses a four-parameter model of Bardet et al. (2002) to estimate the amount of lateral spread (i.e., horizontal) displacement from liquefaction. For sloping ground conditions, Bardet et al. (2002) model is:

$$\log_{10}(D_H + 0.01) = -6.815 + 1.017M_w - 0.278\log_{10} R - 0.026R + 0.454\log_{10} S + 0.558\log_{10} T_{15} \quad (1)$$

For free-face conditions, the model is:

$$\log_{10}(D_H + 0.01) = -7.280 + 1.017M_w - 0.278\log_{10} R - 0.026R + 0.497\log_{10} W + 0.558\log_{10} T_{15} \quad (2)$$

Equation (1) is valid for sloping ground conditions; whereas, Equation (2) is used near river channels or other abrupt topographic features. D_H is the horizontal displacement (m), M_w is the moment magnitude, R is the distance to the fault rupture or nearest seismic source (km), S is the ground slope (%), W is the free face ratio (%), which is the height (H) of the free face divided by the distance (L) to the free face and T_{15} is the cumulative thickness of saturated, granular sediments with normalized standard penetration test (SPT) blow counts (i.e., N_{160}) less than 15

(Bardet et al. 2002). (The normalization consists of converting the N value to a hammer energy ratio of 60 percent and to an effective overburden stress of 1 tsf.) Also, prior to calculating T_{15}, the N_{160} values are converted to clean sand values (i.e., N_{160CS}) when applying equations (1) and (2) (Bardet et al., 2002; NCEER 1997).

REDARS uses the inputted M_w provided in Table 1 to estimate D_H at each component and link location. In addition, REDARS calculates the appropriate R using the fault geometry parameters given in Table 1. However, the topographical factors (W and S) are not directly calculated by REDARS and must be estimated by the user. We calculated these factors at each location using a digital elevation model (DEM) for Salt Lake Valley (Olsen et al., 2005). Lastly, the soil factor (T_{15}) was obtained from our borehole database and interpolated to the network component and link locations using the same weighted averaging method employed in the liquefaction triggering analysis.

2.2 Liquefaction – Induced Vertical Settlement

REDARS uses the volumetric strain curves of Tokimatsu-Seed (1987) to estimate the amount of liquefaction settlement at the network component locations. The inputs for these curves are: pga, SPT N_{160} values, thickness and depth and total and effective vertical stresses (σ_v and σ_v') for the liquefied zone(s). We used the borehole database of (Olsen et al. 2005) to populate the REDARS tables using an inverse distance weighted average of the three nearest boreholes. REDARS calculates the appropriate pga values for the network components using the information in Table 1 and the Abrahamson and Silva (1997) attenuation relation.

All liquefied layers are included in the vertical settlement calculations. The settlement for each layer was calculated using N_{160CS} values (i.e., N_{160} corrected to a clean sands value) (NCEER, 1997) and settlement was summed for all sub-layers.

$$Z = \sum_{i=1}^{L} (\Delta T)_i \tag{3}$$

The REDARS input table allows the user to specify only two layers for the vertical settlement calculation; however some sites in the Salt Lake Valley had more than two liquefiable layers in the borehole log. For these cases, we performed liquefaction settlement analysis external to the program (NCEER, 1997) and then back-calculated the N_{160CS} value that produced the same settlement for a single layer system. The back-calculated N_{160CS} value and the corresponding cumulative thickness of the liquefied layers were given to REDARS for its subsequent liquefaction settlement analyses.

3.0 Component Module Outputs

The component module of REDARS 2 consists of models that determine the earthquake induced damage states from the hazard modules and the subsequent repair requirements for bridges, approach fills and roadway links in the traffic system. The component module outputs estimates of the post-event component states and the associated repair costs. The component damage state for bridges is dependent on the ground motion model in the form of fragility curves. Fragility curves are presented as lognormal curves that relate the probability of being in, or exceeding a building damage state for a given spectral acceleration. The different damage states (DS) are: slight or DS = 2, moderate or DS = 3, extensive or DS = 4 and collapse or DS = 5 (see also Table 6).

The default REDARS v. 2 bridge fragility curves were taken from HAZUS 99 (FEMA 2002) and are expressed in terms of spectral accelerations leading to the onset (i.e., threshold) of each of the five damage states which are shown in the threshold spectral acceleration table for seismically designed bridges (built after 1990) and conventionally designed bridges in the REDARS v.2 manual (Werner et al. 2006b). The threshold spectral accelerations are given at a period of 1.0 sec. The threshold spectral accelerations are shown for standard bridges, which are bridges with no 3D effects from deck arching membrane action, bridges with no skew, and the NEHRP soil Type B soft rock conditions are used.

REDARS v.2 has differing default threshold accelerations for conventionally designed and seismically designed bridges. However, all default spectral accelerations need to be corrected by factors that account for skew and 3D effects of the actual bridge. This is done in the following manner. The default threshold spectral acceleration is determined by REDARS for non-seismically and seismically designed bridges. Following this, the Abrahamson and Silva (1997) attenuation relation is used to obtain the demand spectral accelerations at 1.0 and 0.3 seconds, respectively (i.e., Sa (1.0) and Sa (0.3)) at the bridge for each scenario earthquake. Values of Sa (1.0) and (0.3) have been adjusted for soil effects as discussed in the Hazards Module section of this paper.

Once the demand spectral accelerations have been determined, they are compared to the capacity spectral acceleration to define the damage state. In this step, demand spectral acceleration is compared with the capacity spectral acceleration starting with the highest damage state (i.e., damage state 5). If the demand spectral acceleration is less than the capacity spectral acceleration, then the capacity spectral acceleration for the next lower state is considered (i.e., damage state 4). The process is repeated until the demand spectral acceleration first exceeds the capacity spectral acceleration. The damage state corresponding to this first exceedance is assigned as the damage realized by this component.

The bridge attributes required to calculate the damage state were obtained from the NBI. The REDARS software uses the ITYPE parameter to determine the bridge type and the STATE parameter to distinguish between bridges constructed in California and those constructed other states. In order to convert from a standard bridge to the actual bridge, the skew angle is required and calculated as:

$$K_{skew} = \sqrt{\sin(90 - ANGLE)} \quad (4)$$

where: ANGLE is the skew angle and is defined as the angle between a line normal to the centerline of the roadway to the centerline of the supporting piers.

In addition, a 3D factor, K_{3D}, is used in the calculations and its value is a function of whether or not the bridge has been seismically designed, the number of spans (NSPAN) and the bridge length (L).

For bridges with damage states of 3, 4 and 5, the long period response governs and the median spectral acceleration at the onset of the i^{th} damage state at the m^{th} bridge is termed as $C'(1.0)_{i,m}$. It is calculated from:

$$C'(1.0)_{i,m} = K_{skew} * K_{3D} * S_a(1.0)_{i,m} \quad (5)$$

where: $Sa(1.0)_{i,m}$ is the 1-second spectral acceleration for a standard bridge obtained from the threshold spectral acceleration table.

For bridges that are governed by short period response at damage state 2, the capacity spectral acceleration $C'(0.3)_{2,m}$ is modified by a shape factor, K_{shape},

$$K_{shape} = \frac{2.5 * S_a(1.0)}{S_a(0.3)} \tag{6}$$

where: $S_a(1.0)$ and $S_a(0.3)$ are the 1 s and 0.3 s demand spectral accelerations, respectively.

The short period capacity spectral acceleration for standard bridges at damage state 2, $C'(1.0)_{2S,m}$ (2S refers to damage state 2 where short period response governs) is calculated as shown in Equation (7).

$$C'(1.0)_{2S,m} = Minimum(1, K_{shape}) * C(1.0)_{2,m} \tag{7}$$

where: $C(1.0)_{2,m}$ is the 1.0 s spectral acceleration obtained from the threshold spectral acceleration table for damage state 2 in the standard form (no correction for skew and 3D effects)

For bridges governed by long period response at damage state 2, the capacity spectral acceleration leading to the onset of damage state 2 is equal to the threshold spectral acceleration for the standard bridge:

$$C'(1.0)_{2,m} = C(1.0)_{2,m} \tag{8}$$

Equations 7 and 8 for damage state 2 bridges do not include factors for 3D and skew effects because these effects are insignificant at small structural displacements.

3.1 Bridge damage state from ground shaking

Our initial runs with the REDARS 2 component module and the default fragility curves displayed more than expected damage to many of the newly constructed bridges along the I-15 corridor. These bridges were seismically designed for a 2500-year return period event as part of the I-15 Reconstruction Project during 1998 to 2002. The performance goal established by UDOT for these bridges is that they should incur only minor damage resulting from a 2500-year event and such bridges should be in service soon after the earthquake. Because our preliminary runs with the REDARS default fragility curves calculated more than expected damage to newly constructed bridges, we chose to input user-specified fragility curves (Figure 3) for all UDOT bridges constructed after 1998. The user-specified curves are based on ATC-13 (1985).

To implement the ATC-13 curves, we classified the newly constructed bridges into two different classes. These are: conventional bridges (less than 500 ft spans) and major bridges (greater than 500 ft spans). Because no bridge in the network had spans greater than 500 ft, only conventional bridges were used. However, conventional bridges were further divided into two groups: multiple simple span bridges and continuous bridges. The multiple span bridges are bridges with more than one span and with a total length less than 500 ft. Continuous conventional bridges are bridges with span lengths less than 500 ft and their number of spans is equal to one.

From Figure 3, it is clear that multiple span bridges are more susceptible to damage than continuous bridges because of potential damage to the joints connecting the different spans and multiple bents. As expected, such bridges are more likely to experience more extensive damage due to these connections and unseating of the bridge components.

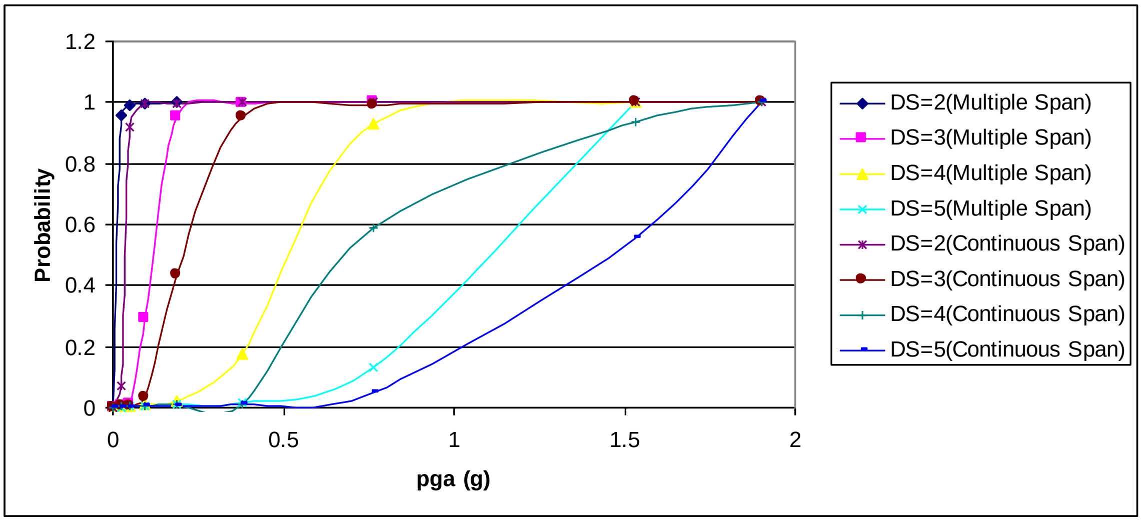

Figure 3 Fragility curves for multiple span and continuous bridges designed after 1998

The ATC-13 fragility curves shown in Figure 3 predicted somewhat less bridge damage in the collapsed and extensive categories (see Table 3) and were deemed more appropriate for the newly constructed UDOT bridges (i.e., bridges constructed after 1998). For example, Table 3 compares the results for the HAZAUS 99 fragility and ATC-13 fragility curves for strong motion damage only (i.e., liquefaction damage is not included). This table suggests that fewer bridges will be damaged in the collapsed and extensive categories when the ATC-13 curves are used. However, another significant difference is that the ATC-13 fragility curves suggest more damage in the moderate category when compared with the results from the HAZAUS 99 curves (Table 3). The increased number of bridges with moderate damage is a consequence due to the shape of the ATC-13 fragility curves for multiple span bridges. The ATC-13 fragility curves for these bridges have a relatively sharp curvature at pga values between 0.1 and 0.3 g (Figure 3). Because many of the pga values for this study fall within in this range, many multiple span bridges are categorized as having moderate damage using the ATC-13 fragility curves.

Lastly, we note that bridges with a damage state of moderate, extensive or collapse will not be in service following the event (Table 3). Such bridges should be considered unavailable for emergency response and recovery efforts. Bridges with slight damage should be available for such efforts but may require inspection before returning to full operation.

Table 3 Damage results for built in and constructed fragility curves

	M7.0 Salt Lake City Segment Earthquake Walkthrough file – HAZUS 99 fragility curves (with strong motion damage only)	M 7.0 Salt Lake City Segment Earthquake Walkthrough file –ATC-13 fragility curves (with strong motion damage only)
Bridge damage: None	923	676
Bridge damage: Slight	139	129
Bridge damage: Moderate	163	445
Bridge damage: Extensive	82	78
Bridge damage: Collapse	100	79
Total Bridges	1407	1407

3.2 Bridge damage states from permanent ground displacement

In addition to strong motion damage to bridges, the bridge damage states are determined from the amount PGD calculated by REDARS 2 resulting from liquefaction and fault rupture. This model is not completed in full since it only considers the damage to bridges from PGD as incipient unseating and collapse, which correspond to damage states 4 and 5, respectively. Initial damage to bearings, which would fall into damage state 2 or 3, is not considered as well as the effects of PGD on foundations and abutments. The process of obtaining the median PGD capacity is similar to obtaining the spectral acceleration capacity. The capacity PGD is obtained for the specific bridge using the PGD capacity table in the REDARS 2 manual (Werner et al. 2006b). The capacity PGD from the PGD capacity table is further modified to account for PGD induced unseating using Equation (9).

$$(PGD_{cap})'_{i,m} = (PGD_{cap})_{i,m} * f_i \quad (9)$$

The modification factor f_i depends on the length, width, skew angle and number of spans of the bridge.

After the bridge PGD capacity is obtained it is compared to the PGD demand from liquefaction or surface fault rupture. First it is determined if the bridge demand PGD is greater than the PGD capacity for damage state 5. If it is, the bridge is assigned a damage state 5. If it is not, the software checks if the demand PGD is greater than PGD capacity for damage state 4. If this is true damage state 4 is assigned and otherwise the bridge has no damage due to the permanent ground displacement hazard.

3.3 Surface Fault Rupture model

The surface fault rupture is a contributor to link damage. Surface fault rupture displacements are determined for all sites that are located in the zone of deformation of the fault rupture.

The input data to the surface rupture model is the fault attribute and rupture data specified in the walkthrough file. After the input data is inputted, each site in the traffic network is analyzed to determine if the site might experience fault displacement during the earthquake scenario. The fault rupture model assumes that the site is prone to surface fault rupture if any of the following conditions are met: a) the probability of some displacement at the site is greater than 0.4 % and there is a normal from the site to the ruptured fault zone; b) the component is within the fault zone of deformation (the default deformation zone of 500m on the hanging wall side of the normal fault was used); c) The component has a normal to the fault and is located within 100 m of the fault; d) the component has a normal to the fault and is located within 500 m of the hanging wall of the fault.

If a given site is determined to experience fault rupture, the surface fault displacements are calculated. The maximum surface fault displacement is calculated by using the Wells and Coppersmith 1994 equation. The maximum surface fault displacement is used to determine the median surface fault rupture PGD that is based on a cumulative probability of 0.5 (Werner et al. 2006b).

3.4 Approach fill damage methodology

Improperly compacted embankment at bridge abutments may be sensitive to differential settlement resulting from vibratory strong motion during the earthquake. REDARS software contains models for estimating damage states and repair costs of approach fills subjected to this type of earthquake-induced settlement. REDARS v.2 uses the Youd (2002) model for estimating the earthquake-induced settlement of bridge approach fills. The required inputs to the Youd (2002) model are bridge specific data. The bridge dependent data needed to determine the approach fill settlement are: a) bridge number and location; b) relative compaction of approach fill soils (standard proctor density); and c) maximum thickness of the approach fill. No relative compaction and fill height information was available, so we used REDARS default values of 95 percent relative compaction (i.e., RC=95%) and maximum fill thickness of 12 feet (i.e., T_{AF} = 12 ft). The REDARS default RC value of 95 percent is very close to the 96 percent RC value required by UDOT for embankments constructed near bridges (UDOT, 2008). Fill thickness at bridge approaches can vary widely, depending on the location and type of bridge. Typical values can be from 0 to about 24 feet, with 24 feet being representative of overpass structures. A mid-range value of 12 feet was selected for this study. (In addition, we note that damage to bridges and bridge approaches is not strongly affected by the selection of these parameters. The settlement caused by additional compaction of the embankment during the earthquake event is expected to be only a few inches, even for relatively high embankments. Thus, the consequences of this effect are small for most evaluation purposes.)

The earthquake dependent data required for calculating the approach fill settlement resulting from further compaction of the embankment during the dynamic event are: M_w and pga for each bridge site; these are calculated by REDARS in manner similar to that used for the the liquefaction settlement hazard assessment. The approach fill settlement S_{AF} is calculated from:

$$S_{AF} = \varepsilon_{AF} * T_{AF} \tag{10}$$

where ε_{AF} is the volumetric strain of the approach fill and TAF is the maximum fill thickness. Values of ε_{AF} are dependent on the earthquake magnitude M_w, pga and RC.

After the approach fill settlement is calculated, depending on the amount of the settlement, the damage state is determined and its associated repair costs. REDARS assigns three damage states based on the results of Equation (10). If the approach fill settlement is less than 1.0 in., no repairs are needed and bridge damage state 1 is assigned. If the approach fill settlement is between 1.0 and 6.0 in., damage state 2 (slight damage) is assigned and a temporary repair (i.e., a concrete asphalt ramp) is assigned. If the approach fill settles more than 6.0 in., the damage state 3 (moderate damage) is assigned. The REDARS manual suggest that for damage state 3, the approach fill should be stabilized by mud jacking (coring holes and pumping grout) and constructing an asphalt-concrete ramp. However, such remediation is not recommended for UDOT bridges because their approach fills have been seismically evaluated and constructed according to UDOT requirements. The expected settlement damage from additional compaction of the embankment is expected to be small.

3.5 Highway pavement (Link) model

A traffic system is comprised of four components: node, link, bridge and shape points. The node is a point in the transportation network, which represents the endpoints of links. A link is the connection between nodes. The collection of many links comprises a road network. The traffic network is also comprised of bridges, including the bridge identifier, the associated link identifier and other bridge attributes. Shape points are points in the traffic network in addition to the nodes, which define the shape of a link. The link damage states were also developed by Caltrans staff engineers and are used in the default link model to determine link damage. The link model does not differentiate between asphalt and concrete, which is another factor that needs to be considered for future updates. In addition, the model should be developed for application to other regions besides California.

REDARS v.2 determines the link damage state by calculating the permanent ground displacement PGD in the traffic system for all the links located on liquefiable soils and in the zone of the fault deformation. After the PGD for a link is found, the damage states are determined based on the displacement of the ground. The appropriate damage states and repair costs for each link in the traffic system, based on the PGD calculated by REDARS, are obtained from the Link damage and repair cost table from the REDARS 2 manual (Werner et al. 2006b). If the PGD is less than 1.0 in., damage state 1 is assigned to the link (no damage). If the PGD calculated is between 1.0 and 3.0 in., the damage state 2 (slight damage) is assigned and the link pavement has slight cracking or movement, but it does not cause any interruption of the traffic. For links with PGD between 3.0 and 6.0 in., the damage state 3 (moderate damage) is assigned and moderate cracking and movement to the pavement is observed. The damage state 4 (extensive damage) is assigned to links with PGD between 6 and 12 in. and failure to the pavement structure is observed and movement of the subsurface soils. Links with PGD of 12 in. and greater are assigned damage state 5 (irreparable damage) and show failure of the pavement structure and the subsurface soils.

For links located on non-liquefiable soils and links that are not located within the rupture zone of the fault, the REDARS v.2 will not calculate PGD hazards or estimate an induced damage state to the pavement.

4.0 Estimated Damage to Highway Network

The damage states and repair costs resulting from seismic events on the Salt Lake City segment of the Wasatch fault and the West Valley fault are shown in Table 4. REDARS estimates the Salt Lake City segment of the Wasatch fault rupture will produce $435 M (2004 value) and the West Valley fault will produce $71 M (2004 value) of damage to the Salt Lake Valley transportation network. These estimates include repair costs, but do not include user losses (i.e., losses due to decrease in the efficiency of the transportation network) and subsequent economic losses. User losses are discussed in the companion to this paper (Kim et al. 2008).

Of the 1407 bridges analyzed in our inventory, 602 or 47 percent of the bridges are expected to receive moderate or higher levels of damage for the M7.0 event. In comparison, the WFRC (2008) study suggests that approximately 71 percent of the bridges will receive moderate or higher damage. The reason(s) for the differences are not entirely apparent, but may be due in part to the different fragility curves used by this study for the post-1998 bridges and differences in the bridge inventories.

The REDARS model was run with and without permanent ground displacement (PGD) effects present in the model to see what additional damage was done to the network from liquefaction and other sources of PGD, as requested by the UDOT geotechnical group. The REDARS results suggest that losses resulting from PGD (i.e., lateral spread, liquefaction settlement and fault rupture) will be significant for the M7.0 event. For example, the expected damage increases from $55 M to $435 M (2004 value), when PGD effects from these phenomena are considered (Table 4). Much of the increased cost is due to an increase in the number of bridges being assigned extensive and collapse damage states from the PGD effects. For example, Figure 4 shows the expected damage states resulting from strong motion and PGD; whereas Figure 5 shows the expected damage states for strong motion only. Comparison of these figures reveals that PGD damage is expected to be more pronounced on I-15 (south of I-215), on I-215 (west side), on I-80 (from the downtown area westward) and on the east side (near the Wasatch fault) for the M7.0 earthquake. This is due to the softer, more granular surficial soil sediments deposited by recent rivers and streams that result in a relatively high liquefaction hazard for the highway corridors that are founded on these deposits. In addition, we note that the expected liquefaction damaged areas correspond to areas that have been mapped with a moderate to high liquefaction hazard by Anderson et al. (1986) and by Olsen et al. (2007).

The M6.0 event on the West Valley fault system is expected to produce much less damage and therefore have significantly lower repair costs. PGD effects from lateral spread, liquefaction settlement and surface fault rupture also contribute greatly to the damage of the traffic network in this scenario. The associated repair costs for ground motion only is about $25 M (2004 value), whereas the expected damage including PGD effects is $71 M (2004 value) in repair cost. Table 4 shows that there is a significant increase in the number of bridges and links predicted to be collapsed or extensively damaged from PGD effects and this approximately doubles the repair cost. For comparison, Figure 6 shows the M6.0 event damage states and the distribution of the damage in the Salt Lake City traffic network with PGD effects included; Figure 7 shows the same event with only strong ground motion damage. The location of the PGD damage is more pronounced on I-80 (in the downtown area) and on I-215 (west side) and is due to the moderate to high liquefaction hazards in these areas.

These damage states for the M7.0 event will be used in the subsequent traffic modeling presented in this report. The system state at different times, represented by the number and location of closed and damaged bridges and links, will be estimated from the predicted damage states and used to predict the traffic volume on different roads at different times after the earthquake. In addition, increases in trip or travel times and their associated user's costs will be estimated.

Table 4 Salt Lake City segment and West Valley faults damage states and repair cost

	SLC Segment with liquefaction effects	SLC Segment without liquefaction effects	West Valley fault with liquefaction effects	West Valley fault without liquefaction effects
Bridge damage: None (# Bridges)	622	676	985	1016
Bridge damage: Slight (# Bridges)	118	129	118	119
Bridge damage: Moderate (# Bridges)	353	445	229	262
Bridge damage: Extensive (# Bridges)	109	78	69	10
Bridge damage: Collapse (# Bridges)	205	79	6	0
Link damage: None (# links)	16984	18601	18000	18601
Link damage: Slight (# links)	2	0	248	0
Link damage: Moderate (# links)	200	0	197	0
Link damage: Extensive (# links)	247	0	139	0
Link damage: Collapse (# links)	1168	0	17	0
Bridge approach fill damage: None	108	2814	1392	2814
Bridge approach fill damage: Slight	2706	0	1422	0
Repair Cost (2004 value): ($M)	435	55	71	25

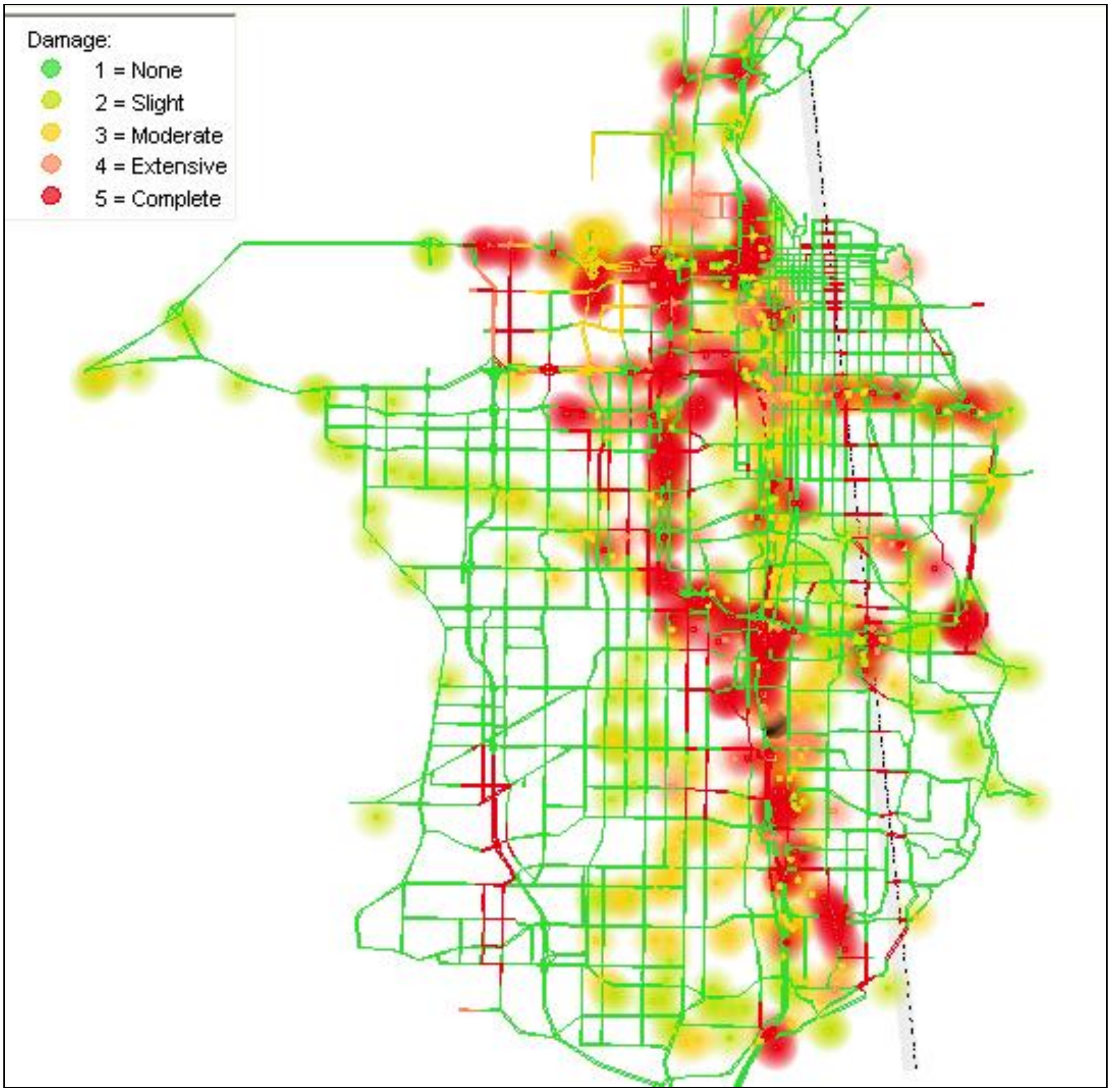

Figure 4 Map of damage states for the M7.0 event in the Salt Lake City Valley including PGD effects

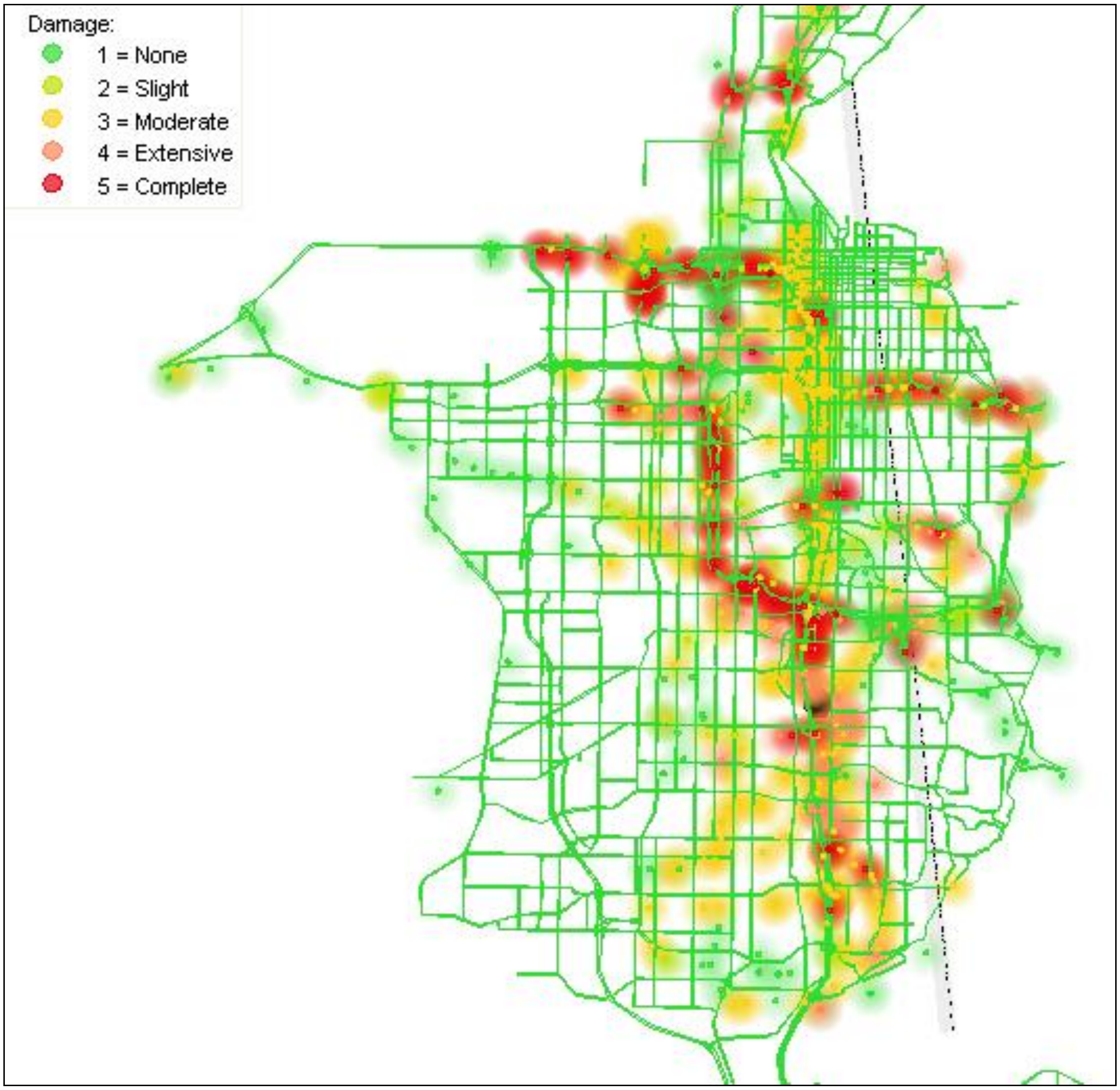

Figure 5 Map of damage states for the M7.0 event in the Salt Lake City Valley without PGD effects

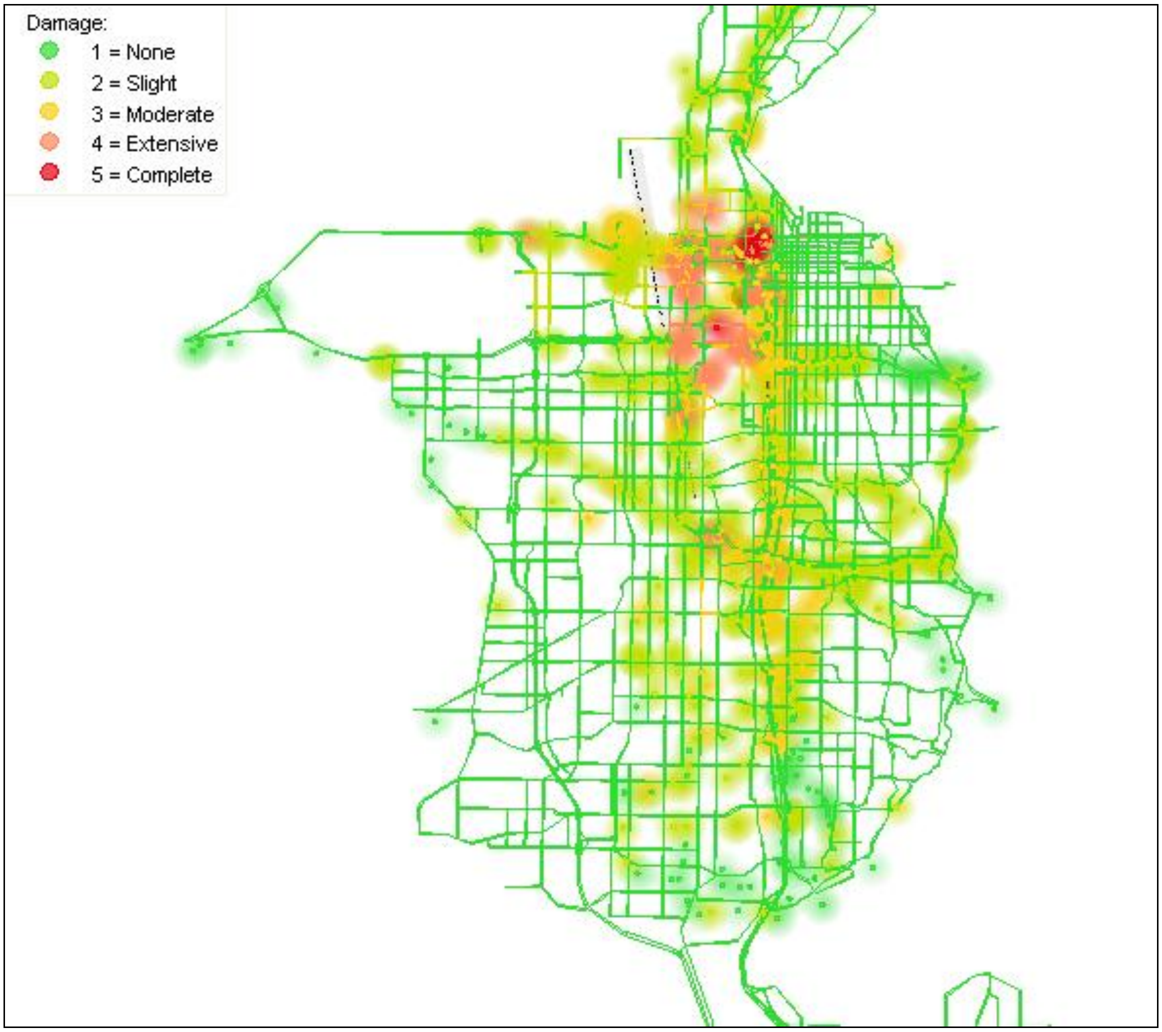

Figure 6 Map of damage states for the M6.0 event in the Salt Lake City Valley including PGD effects

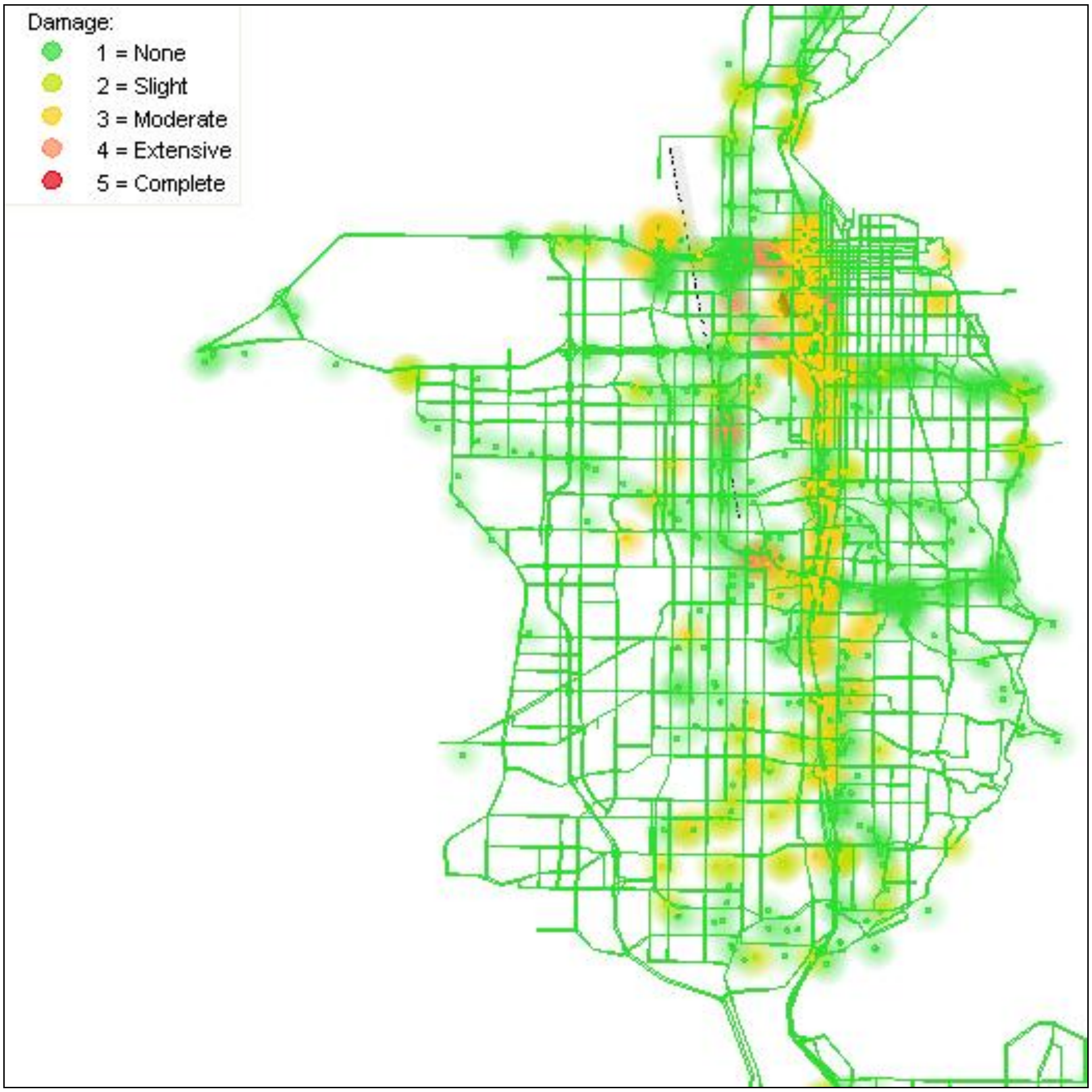

Figure 7 Map of damage states for the M6.0 event in the Salt Lake City Valley without PGD effects

5.0 Transportation Network Modeling

Earthquakes damage transportation infrastructure which impedes traffic flow. The impacts of bridge damage and decreased traffic efficiency include not only short-term costs of structural repair, but also long-term economic consequences (Dusicka et al. 2007). This research assumes that one long-term consequence is the loss of time as commuters and freight travel slows down to navigate disrupted networks. In addition to initial replacement or repair costs of damage to the transportation structures, large earthquakes increase time delays because of network components' loss of function (Cho et al. 2003). After a severe earthquake, different parts of a roadway system will receive various levels of damage, and the capacity of those severely affected portions will be reduced, which will cause further traffic congestion (Feng and Wen, 2005). Damage to the transportation network can disrupt traffic flows from months to years. The disrupted traffic flows can impact the economic recovery of the region as well as post-earthquake emergency response and reconstruction operations (Werner et al. 2006). The Utah Department of Transportation (UDOT) recognized the risks posed by these hazards and initiated this analysis.

Earthquake related economic losses due to the increased travel times may be evaluated by examining the difference between network performance before and after an earthquake. A user equilibrium network flow model is one of the most useful traffic assignment models in transportation analysis.

Post-earthquake travel times are compared to pre-earthquake travel times in order to understand the effects of earthquake damage on travel times (Werner et al, 1997). Werner et al. (2008) developed methodologies to estimate the delay based user costs using Risks from Earthquake Damage to Roadway Systems (REDARS) software. Post-earthquake damage information was supplied as REDARS output. The traffic disruption assessment is delivered through VISUM simulation software. VISUM is a refined and site-specific macro-simulation model of Salt Lake County.

This part of the report presents the estimated delay-based user costs due to the traffic disruptions caused by two earthquake scenarios: (1) the M7.0 Wasatch fault rupture scenario (2) the M6.0 Taylorsville fault rupture scenario. Road segments that come under fault zone are most likely to get damaged after an earthquake. These road segments are defined as vulnerable links. Links that can carry considerable detour traffic after an earthquake are defined as critical links. A list of links susceptible to damage, yet critical for each scenario, was prioritized for rehabilitation.

The objectives of the traffic modeling part of this report are:

- To compile a list of links that would be:
  - Vulnerable to both the M7.0 and M6.0 scenario events (The most vulnerable links)
  - Critical to both the M7.0 scenario and the M6.0 scenario (The most critical links)
  - Vulnerable in the M7.0 scenario and critical in the M6.0 scenario (Lifelines for the M6.0 scenario)
  - Vulnerable in the M6.0 scenario and critical in the M7.0 scenario (Lifelines for the M7.0 scenario)
- Recommend UDOT potential protection, improvement, and maintenance procedures for lifelines.
- Determine how the earthquake damage influence traffic in terms of AM peak, mid day, PM peak and off peak traffic.
- Assess the impact of degree of damage on the traffic in terms of user delay costs.

The following sections explain the data collection, software tools, and the methodology used in the study.

5.1 Methodology

5.1.1 Study Area

The study area is located in Salt Lake County (Figure 1). This part of the network, in which most of the damage is expected resulting from both the M7.0 scenario and the M6.0 scenario, is underlain by soft to medium stiff soils, some of which are potentially liquefiable. The transportation network for the study region encompasses several major roadways and bridge structures. Major highways in the area include Interstates 15, 80, 215 and several other state highways (Figure 1).

5.1.2 Flow Process of Methodology for Calculating Delay Costs

An economic analysis was developed to quantify the economic losses due to the decreased performance of the network from bridge damage. The methodology is shown as a schematic flowchart in Figure 8 below.

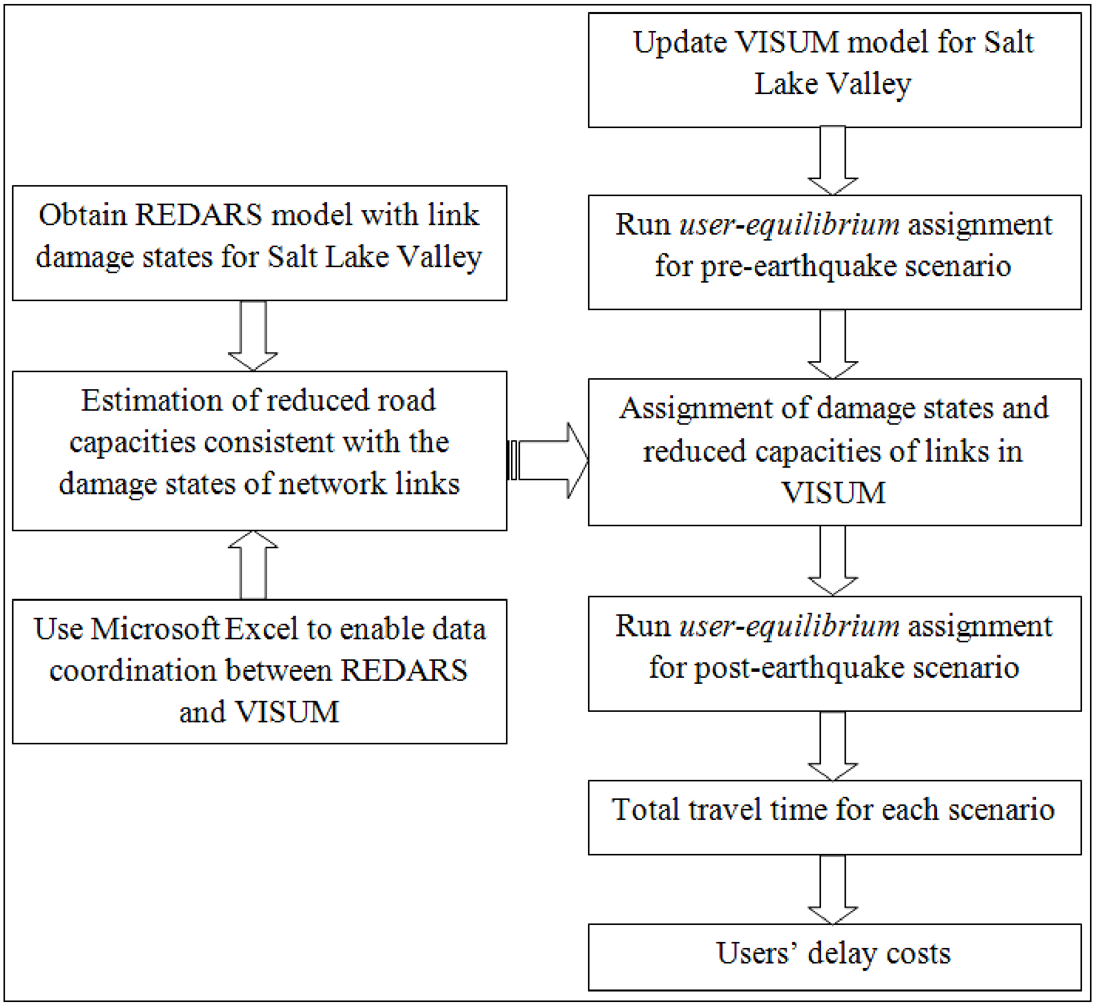

Figure 8 Flow chart for traffic modeling methodology

5.1.3 Delay Based User Costs

The economic losses due to earthquake are a combination of direct and indirect losses. Direct losses are due to rehabilitation of damaged network and indirect losses are due to impacts on traffic delays. The indirect costs associated with the functionality of the transportation network, can be much more significant than repairing the actual physical damage. Evaluating the economic loss of a highway transportation system in a metropolitan area is a significant and important task that can be used by decision makers to assign resources in accordance with the estimated economic risk (Luna et al. 2008). The first step in the transportation analysis was defining the Measure of Effectiveness (MOE). MOEs are used to compare and evaluate network performance. Since the major focus was the impact on road users, user cost was selected as the MOE. Impacts on road users can be estimated in terms of user costs due to travel time delay. User costs represent the monetary value of travel delays (Martin et al. 2007). US Department of Transportation (USDOT) suggests monetary value of time savings depending on the trip purpose and conditions under which the trip is made (USDOT, 1997).

5.2 Data Collection

5.2.1 OD Matrices

Local and state governments subdivide the roadway system into a set of sub-regions called Traffic Analysis Zones (TAZs) to monitor user trip demands on the roadway system. The O-D matrix defines the number of trips from each TAZ to all other TAZs in the region. Origin-Destination (O-D) data estimates the location of travel origins and destinations and the corresponding number of trips from and to all the different TAZs in the region (1). TAZ and O-D data enabled the current VISUM model to measure travel time between different sub-regions of the network as well as link volumes.

The Origin-Destination (OD) demand tables for the year 2008 were obtained from WFRC and used in the analysis. Diurnal periods in the analysis were defined in such a way that morning and afternoon peaks are distinguished from rest of the day. Additionally, hours after afternoon peak were split into evening and night periods as traffic demand significantly varies in those time periods (Martin et al., 2007). The diurnal periods for this study are presented in Table 5.

Table 5 Diurnal periods for the analysis

Notation	Description	Period
AM	Morning peak period (3 hours)	6am – 9am
MD	Midday period (6 hours)	9am – 3pm
PM	Afternoon peak period (3 hours)	3pm – 6pm
PEV	Evening period (4 hours)	6pm – 10pm
NEV	Night period (8 hours)	10pm – 6am

5.2.2 Truck Traffic

Truck percentages of Annual Average Daily Traffic (AADT) were obtained from UDOT's traffic statistics for the year 2008 (UDOT, 2008). Data was collected from the permanent traffic counters in the study area. Figure 9 shows the map of permanent traffic counters in Salt Lake County. The average value of truck percentage was derived as 9% of AADT.

5.2.3 Value of Travel (VOT)

Data for Values of Travel (VOTs) was gathered from Texas Department of Transportation. VOTs were estimated at $15.47 per hour of person travel and $102.12 per hour of truck time. These values are based on a calculation that weighs several value categories including average wages and fringe benefits, costs of employees, freight inventory values and average vehicle occupancies (TTI, 2009).

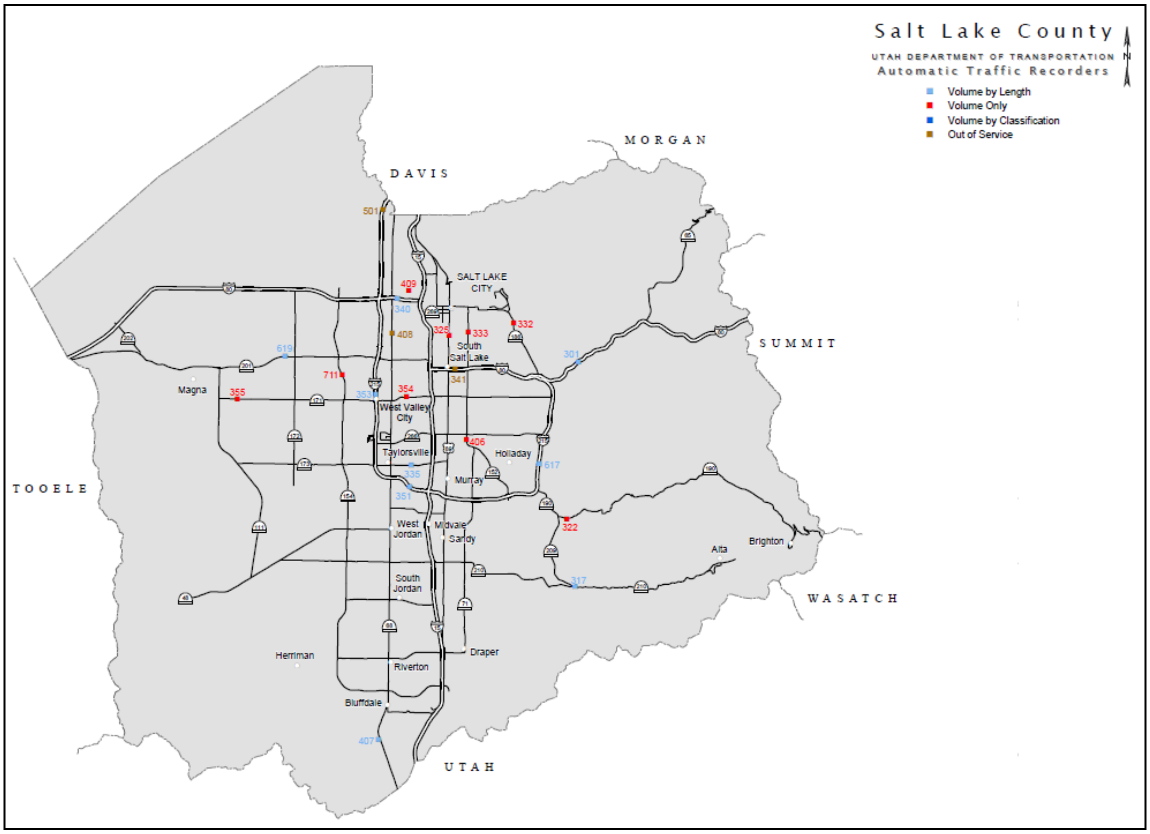

Figure 9 Permanent traffic counter location map in Salt Lake County, Utah

5.3 REDARS Analysis

REDARS was used to estimate the extent and location of earthquake damage to a roadway system, how this damage affects system-wide post-earthquake travel times and traffic flows, and the economic losses caused by travel time delays (REDARS, 2005). REDARS combines structural, geotechnical, transportation, and economic methodologies to perform deterministic and probabilistic analysis of the network model as part of a comprehensive seismic risk assessment.

Earthquakes result in damage to links. However, the severity of damage will not be the same for all the links. So, link damages should be classified in such a way that similar types of links will respond alike for a certain rehabilitation process. The different Permanent Ground Displacement Damage States (PGD DS) are: slight or PGD DS = 2, moderate or PGD DS = 3, extensive or PGD DS = 4 and collapse or PGD DS = 5. Table 6 shows the classification of damage states based on the type of damage in the structure.

Table 6 Classification of damage states for structures

Classification	Damage State (DS)	Damage Types
None	1	No damage
Slight	2	Minor cracks/spalling
Moderate	3	Cracking, spalling/cracking, shear keys, rocker bearing failure
Extensive	4	Column degradation without collapse (shear failure)
Complete	5	Unseating of deck, collapse of column

Figure 4 displays the M7.0 scenario post-earthquake network model in REDARS. Links at different PGD DS values are shown in different colors.

5.4 Transferring Data from REDARS to VISUM

REDEARS was not used for the traffic modeling, because more refined and site specific transportation planning model in VISUM is available for Salt Lake County. With a more refined VISUM model, the results of the traffic assignments reflect the dynamics of a post-earthquake traffic demand in a better way. Analysis of post-earthquake traffic flows in REDARS is based on a User-Equilibrium (UE) model of transportation-system user behavior, which assumes that all users follow routes that minimize their travel times. At user equilibrium conditions, no traveler has an incentive to change paths, because all paths used between any given origin-destination pair have equal cost/time (Shiraki et al., 2007). The assignment procedures in VISUM are based on search algorithms which determine routes between ODs. The search procedure is followed by a choice procedure, which distributes the travel demand of an OD pair onto links (VISUM, 2007). The default model in REDARS assumes that post-earthquake trip demands on the highway system are equal to pre-earthquake trip demands (Werner et al., 2006). (This assumption is not strictly true because driver behavior changes following the event, as discussed in Section 6.0.) Nonetheless, the REDARS assumption of pre and post-earthquake trip demand equality was made and adopted for VISUM analyses presented in the section.

The development and implementation of the interface between REDARS and VISUM was one of the key components of this study. The hazard and vulnerability assessments performed within REDARS were incorporated into VISUM using spreadsheet (Microsoft Excel) tools. Hazard and vulnerability assessments provided outputs in terms of link damage states. Capacity loss for a link depends upon the degree of damage to the link. The link damage represents the worst state of damage to the bridges in that link. For example, if at least one of the bridges in a link suffers major damage, and if that is the greatest state of damage, the whole link is considered having major damage (Shinozuka et al., 2006).

The damage data from post-earthquake REDARS model was incorporated into VISUM model. Figure 10 displays the freeway and state highway network in VISUM for Salt Lake County, Utah. The colors display links at different damage states.

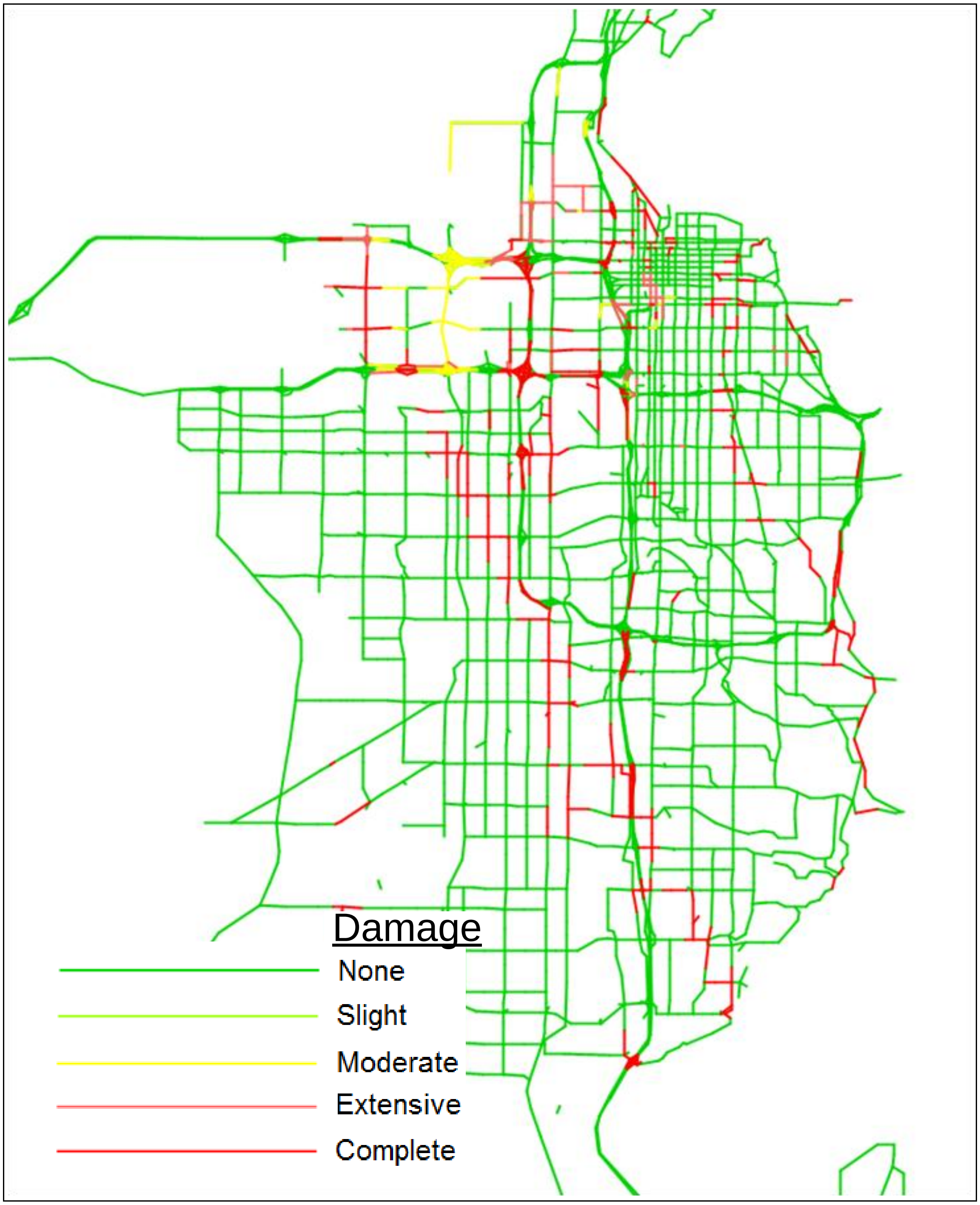

Figure 10 VISUM post-earthquake model with damaged links for M7.0 earthquake with PGD effects

5.5 Analysis in VISUM

The methods described in the following sections reflect all diurnal periods in both the M7.0 scenario and the M6.0 scenario.

5.5.1 Pre-Earthquake Analysis

The damage model in VISUM consists of links with PGD DS values ranging from 0 to 6. Each PGD DS value represents the level of damage on the link. However, these values do not affect the original capacities and free flow speeds that already existed in the VISUM model. These parameters were kept unchanged to conduct experiments for pre-earthquake conditions.

Traffic analysis was done for each diurnal period separately. The capacity available on a link was represented in terms of capacity per hour per lane (CPHPL). Both CPHPL and free flow speed on a link are constant and do not vary with time of day. In VISUM total capacity on a link is the product of CPHPL, number of lanes in that link, and the number of hours in the diurnal period. So, the total capacity for a link changes from one diurnal period to other. Total capacities were measured for all links and a model was prepared for initial traffic assignment.

The next step in the analysis was assigning traffic demand on the network. OD demand matrices were developed separately for each diurnal period. These demands were then assigned on the respective VISUM models, using equilibrium assignment (Shinozuka et al., 2006). This procedure resulted in average link travel times and link-volumes for all links in the network. The product of average link travel time and link-volume for a link resulted in total link travel time in vehicle-hours. Summation of all link travel times provided total network travel time for that diurnal period. It is not required to conduct pre-earthquake analysis separately for the M7.0 scenario and the M6.0 scenario, since the capacity and diurnal demands are constant in both cases. However, post-earthquake analysis must be done for each scenario separately, since each of them results in different magnitude of damage and have different levels of total network capacity. Therefore, the pre-earthquake travel times were the same for both the M7.0 scenario and the M6.0 scenario.

5.5.2 Post-Earthquake Analysis

Following an earthquake, the roadway links will encounter different levels of damage. The PGD DS value of a link represents the level of damage from permanent ground displacement. Link damage states and their default capacity and free flow speed change rates from REDARS are shown in Table 7. Percentage values also account for the changes resulting from the repair work, and the detour of traffic. (These values are preliminary default values in REDARS and future research is needed to validate these relations (Shinozuka et al., 2006).)

Table 7 Change in road capacity and free flow speed due to damages

State of Link Damage	PGD DS	Capacity Change Rate	Free Flow Speed Change Rate
None	1	100%	100%
Minor	2	100%	75%
Moderate	3	75%	50%
Major	4	50%	50%
Collapse	5	50%	50%

Table 8 shows the variation in timeframes for links at different damage states to reach fully-open status. (All of these values are based on a limited research and need to be further validated. For example, depending on the number of collapsed bridges in the Salt Valley is may require more the 140 to 220 days to reconstruct such bridges.)

Table 8 Default damage states and their timeframes to reach fully-open status

Damage State	PGD DS	Time to Reach Fully Open Status (Days, After Rehabilitation Started)
None	1	-
Slight	2	0
Moderate	3	4
Extensive	4	12
Collapse	5	140, 180 or 220 depending on the number of bridge spans

Any of the default values determining traffic states can be modified by the user, including the default assumption that a bridge is either fully opened or fully closed during repair. The user can override this assumption so that a “partially opened” bridge is considered where the number of lanes closed to traffic is a function of the damage state, total number of lanes and the number of bridge spans (Dusicka et al., 2007). This analysis assumed default values for capacity and free flow speed changes for all damage types except collapse. The collapse state should be redefined, for more accurate analysis. Although, the defaults values suggest that collapsed links will retain 50% capacity and speed (Table 7), it might not be the same in case of bridges. A bridge is very unlikely to carry any traffic when it has collapsed. The default traffic model in REDARS assumes that a bridge is either fully-closed or fully-open to traffic during repair. Therefore, all collapsed bridges are assumed to be closed, so that they have 0% capacity and 0% free flow speed during the entire rehabilitation period (Table 9). These values were used in our analyses.

Table 9 Modified road capacity and free flow speeds due to damages

State of Link Damage	**PGD DS**	**Capacity Change Rate**	**Free Flow Speed Change Rate**
None	1	100%	100%
Minor	2	100%	75%
Moderate	3	75%	50%
Major	4	50%	50%
Collapsed Bridges	5	0%	0%

From the REDARS user manual (REDARS, 2005), the relationship between travel-related costs and time suggests that for the first seven days the delay cost per day is constant. This may be due to the emergency activities that would take place during the initial days following an earthquake. During this time no rehabilitation would occur and the daily delay costs would be at peak level. The delay costs should be calculated immediately from the day the earthquake occurs, but not from the day when rehabilitation starts. Therefore, 7 more days were added to the total timeframes to measure delay costs. The changed timeframes are shown in Table 10.

Table 10 Damage states and modified timeframes to reach fully-open status

Damage State	PGD DS	Time to Reach Fully Open Status (Days, After Earthquake)
None	1	-
Slight	2	7
Moderate	3	11
Extensive	4	19
Collapse	5	187

These capacity and free flow speed changes were incorporated into the VISUM model and the traffic assignment was run again. Since the capacity was decreased for the same demand, traffic is congested and the total travel times were increased. Similar to the pre-earthquake conditions, the total daily network travel times were calculated for all diurnal periods. Tables 11-12 show pre-earthquake and post-earthquake travel times for all diurnal periods in both the M7.0 scenario and the M6.0 scenario.

Table 11 Average network travel times, M7.0 scenario event

	Average Network Travel Times (Vehicle Hours)				
	Pre-Earthquake	**Post-Earthquake**			
Diurnal Period	Total Rehabilitation Period	0-7 Days	7-11 Days	11-19 Days	19-187 Days
AM	155,100	205,778	205,774	199,471	193,895
MD	296,650	370,739	370,712	365,151	359,877
PM	273,637	469,891	469,914	462,658	446,992
PEV	140,998	163,404	163,382	161,558	160,035
NEV	49,675	54,179	54,174	53,689	53,296

Table 12 Average network travel times, M6.0 event

	Average Network Travel Times (Vehicle Hours)				
	Pre-Earthquake	**Post-Earthquake**			
Diurnal Period	**Total Rehabilitation Period**	0-7 Days	7-11 Days	11-19 Days	19-187 Days
AM	155,100	158,512	158,044	156,518	155,580
MD	296,650	305,868	304,722	301,372	299,054
PM	273,637	293,306	292,253	288,008	282,143
PEV	140,998	144,156	143,666	142,524	141,828
NEV	49,675	50,493	50,346	49,973	49,818

The difference between total travel times for pre-earthquake and post-earthquake conditions resulted in delay times in vehicle-hours. These delay times were multiplied with VOTs to derive travel costs. As link-volumes consist of both passenger cars and trucks, separate VOTs were used for measuring delay costs.

5.6 Evaluation of Vulnerability and Importance of the Links in Network

One of the objectives of this research was to recommend to UDOT potential protection, improvement, and maintenance procedures for critical lifelines for post-earthquake conditions. However, it is impractical to improve all vulnerable bridges for seismic hazards due to limited resources. Therefore, only road segments (links), which are vulnerable in one scenario but still can carry a considerable amount of detour traffic in the other scenario, were selected for rehabilitation. UDOT can concentrate only on these prioritized links and avoid all others to minimize the improvement costs.

Links, which are damaged under both earthquake scenarios, are defined as most vulnerable links.

Hence, all these links will have at least one damage state between slight and collapse in both scenarios. VISUM damage models were processed and filtered for the links with damage state between 2 and 5.

The most critical links are defined as the links with the highest increase in traffic (ratio of traffic volumes after and before the earthquake) under both earthquake scenarios. VISUM assigns the redundant traffic, which would go on damaged links had no earthquake occurred, onto the neighboring links. So, the traffic volumes on neighboring links were increased following each earthquake scenario. Critical links play an important role in maintaining regular traffic when all the freeway and major roads, which carry much of the daily traffic, are damaged due to earthquake.

Finally, a list of both critical and vulnerable links was prepared for each scenario. Due to the constraint of limited resources, it is vital to manage disaster mitigation resources with a strategic budget planning. These lists can be more informative for UDOT to optimize the rehabilitation resources and to reduce the vulnerability of the critical links.

All three categories of links which are most vulnerable, most critical and a combination of critical and vulnerable were produced using filtering process in VISUM.

5.7 Results of Vulnerability and Importance Evaluations

5.7.1 Average Daily User Costs

The cumulative average daily user costs were measured on the 7th, 11th, 19th and 187th day following each earthquake. This was to understand how the average costs varied due less damaged types opened during rehabilitation. Tables 13-14 show average user costs for the M7.0 scenario and the M6.0 scenario, respectively.

Table 13 Cumulative average user delay costs, M7.0 scenario event

	Cumulative Average User Delay Costs ($Million)			
Diurnal Period	**7 Days**	**11 Days**	**19 Days**	**187 Days**
AM	1.18	1.18	1.12	0.92
MD	1.72	1.72	1.67	1.49
PM	4.56	4.56	4.49	4.07
PEV	0.52	0.52	0.50	0.45
NEV	0.10	0.10	0.10	0.09
Total	**8.08**	**8.08**	**7.87**	**7.02**

Table 14 Cumulative average user delay costs, M6.0 scenario event

	Cumulative Average User Delay Costs ($Million)			
Diurnal Period	**7 Days**	**11 Days**	**19 Days**	**187 Days**
AM	0.08	0.08	0.06	0.02
MD	0.22	0.21	0.17	0.07
PM	0.46	0.45	0.41	0.22
PEV	0.08	0.07	0.06	0.03
NEV	0.02	0.02	0.01	0.01
Total	**0.86**	**0.83**	**0.71**	**0.35**

These results are also presented in Figures 11-12 to visualize the variation. Each data series represents cumulative average user costs for all diurnal periods. Regardless of time, the delay cost patterns found to be the similar with peak level at PM. As the rehabilitation progresses, the average delay cost tend to decrease relative to original costs.

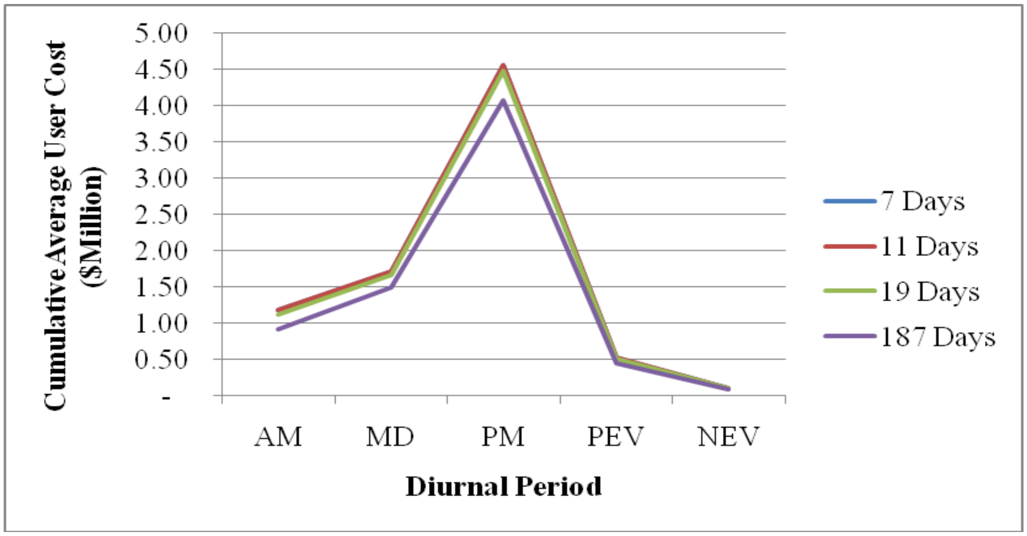

Figure 11 Post-earthquake cumulative average user delay costs, M7.0 scenario event

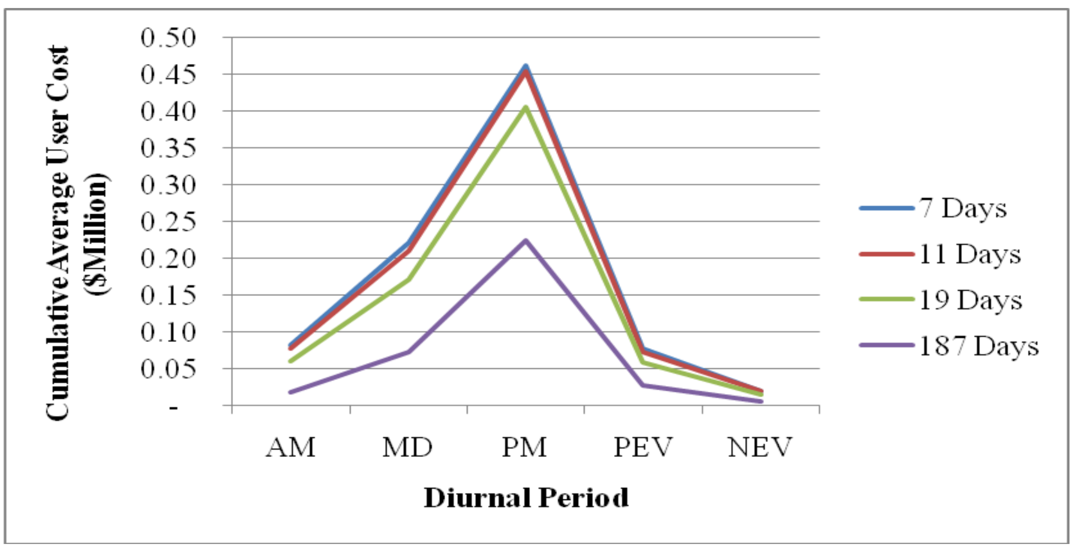

Figure 12 Post-earthquake cumulative average user delay costs, M6.0 scenario event

5.7.2 Total User Costs

Tables 15-16 show the cumulative total user costs at different points of time for which slightly, moderately, extensively and completely damaged links are fully-open to the traffic. The total cumulative user costs are presented in Figures 13 and 14 to visualize the variation. The graphs show a similar pattern from 7 to 19 days, but important differences are seen at 187 days. The user costs at 187 days for the M6.0 scenario have diminished when compared the 7, 11 and 19 day benchmarks. This is because significant portions of the traffic network have been repaired by this time. However for the M7.0 scenario the user costs at time 187 days is very similar to those at the 7, 11 and 19 day bench mark. This is because most of the links received DS=5 (i.e., complete damage), which requires 187 days for such links to regain full capacity. (Obviously, it is not reasonable to expect that full capacity will be restored to these links on day 188 and that the user delay costs will go to zero. Residual user delay costs may go on for considerable time after day 187, but this has not been estimated by the model.)

The calculated user delay costs show that the maximum impacts would be imposed on PM traffic. Also, the M6.0 scenario would incur $65 million, which is significantly lower than the Wasatch Scenario of $1,312 million at day 187. This is due to larger extent of damage in the Wasatch Scenario when compared with the M6.0 scenario.

Table 15 Cumulative total user delay costs ($Million), M7.0 scenario event

	Cumulative Total User Costs ($Million)			
Diurnal Period	**7 Days**	**11 Days**	**19 Days**	**187 Days**
AM	8.24	12.95	21.19	172.55
MD	12.04	18.92	31.65	278.33
PM	31.90	50.14	85.25	761.59
PEV	3.64	5.72	9.54	83.81
NEV	0.73	1.15	1.90	16.02
Total	**57**	**89**	**150**	**1,312**

Table 16 Cumulative total user delay costs ($million), M6.0 scenario event

	Cumulative Total User Costs ($Million)			
Diurnal Period	**7 Days**	**11 Days**	**19 Days**	**187 Days**
AM	0.57	0.85	1.14	3.41
MD	1.54	2.32	3.25	13.72
PM	3.24	4.99	7.71	41.90
PEV	0.54	0.81	1.13	5.07
NEV	0.14	0.21	0.27	1.02
Total	**6**	**9**	**13**	**65**

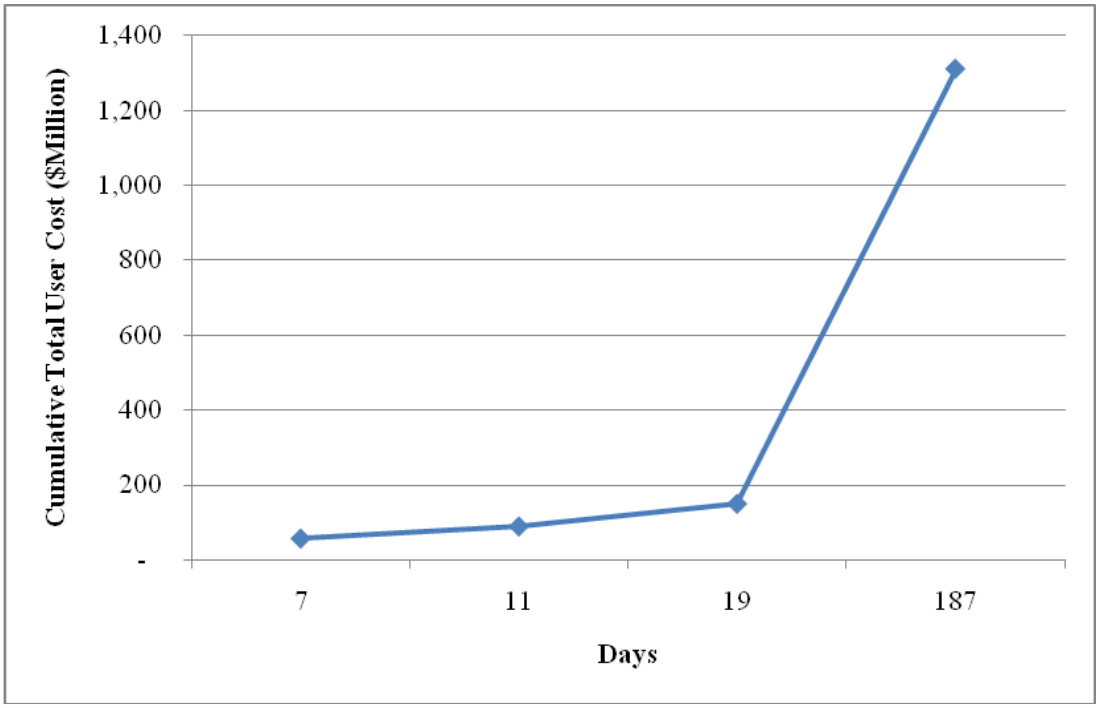

Figure 13 Post-earthquake cumulative total user delay costs, M7.0 scenario event

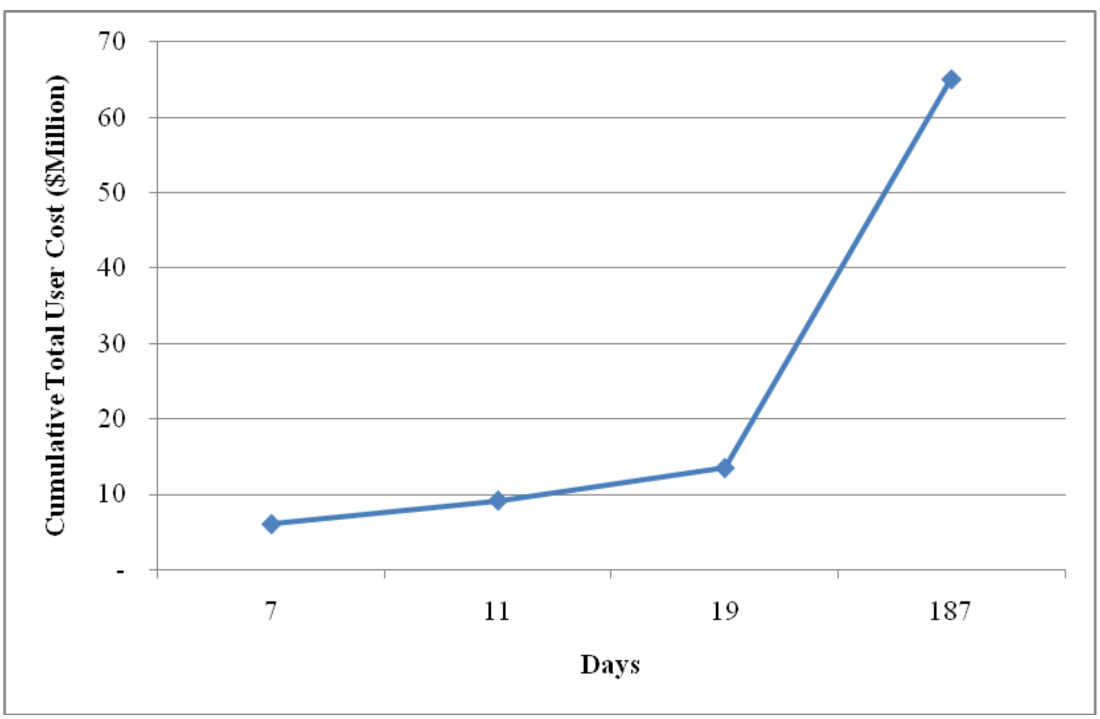

Figure 14 Post-earthquake cumulative total user delay costs, M6.0 scenario event

5.8 Vulnerable and Critical Road Segments

Figures 15-18 show maps of links classified into different types. Figure 15 shows the most vulnerable links and Figure 16 shows the most critical links. Figure 17 shows links that are critical in the Wasatch Scenario and vulnerable in the M6.0 scenario. Similarly, Figure 18 presents links that are critical the M6.0 scenario and vulnerable in the Wasatch Scenario.

Each map is also transformed into a table of links for detailed results, with the link numbers in ascending order. These tables are presented in Appendix 3. Tables A3-1 and A3-2 present the lists of most vulnerable and most critical links with link numbers in ascending order. The direction of each link is provided to distinguish links with only one direction (e.g. on/off ramps) from others. Generally, each road will have a single name throughout its length in the network. However, it might have both damaged and undamaged links in it as a result of earthquake. Therefore, to differentiate damaged links from all others, they are defined with names and from/to information.

In Table A3-1, among 237 most vulnerable links, around 25% have bridges in them. This provides a clear understanding of the severity of damage. However, some of these links might still be critical even after earthquake. For example, links which are slightly damaged would still have 100% capacity, although their speed is reduced for safety reasons. Most critical links in Table A3-2 are the ones on which traffic is increased (i.e. the ratio of traffic volumes after and before earthquake is more than 1) in both scenarios.

Finally, a list of vulnerable yet critical road sections is prepared for each scenario. Tables A3-3 and A3-4 present a combination of critical and vulnerable links (lifelines) for the Wasatch Scenario and the M6.0 scenario, respectively. All these links should have volumes increased due to detour traffic and should have a damage state between 2 and 5. For example, Table A3-3 shows a combination of links with traffic ratios more than 1 in the Wasatch Scenario and having damage states between 2 and 5 in the M6.0 scenario. A final list of links can be created from these two by eliminating all the repeated link numbers. This short list of links can be used by UDOT to minimize the traffic disruptions caused by any of the two earthquakes.

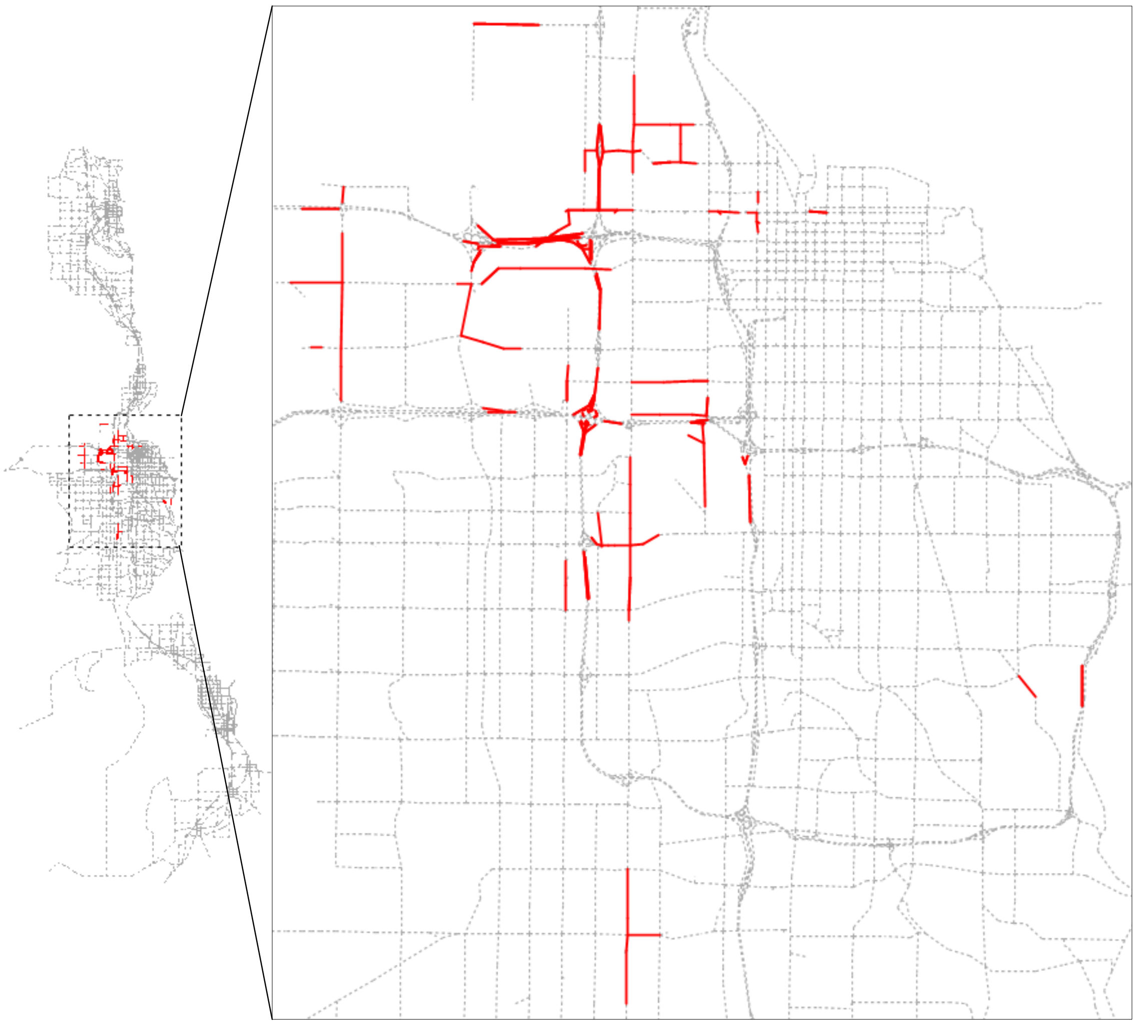

Figure 15 Most vulnerable links (VISUM) in Salt Lake County, Utah

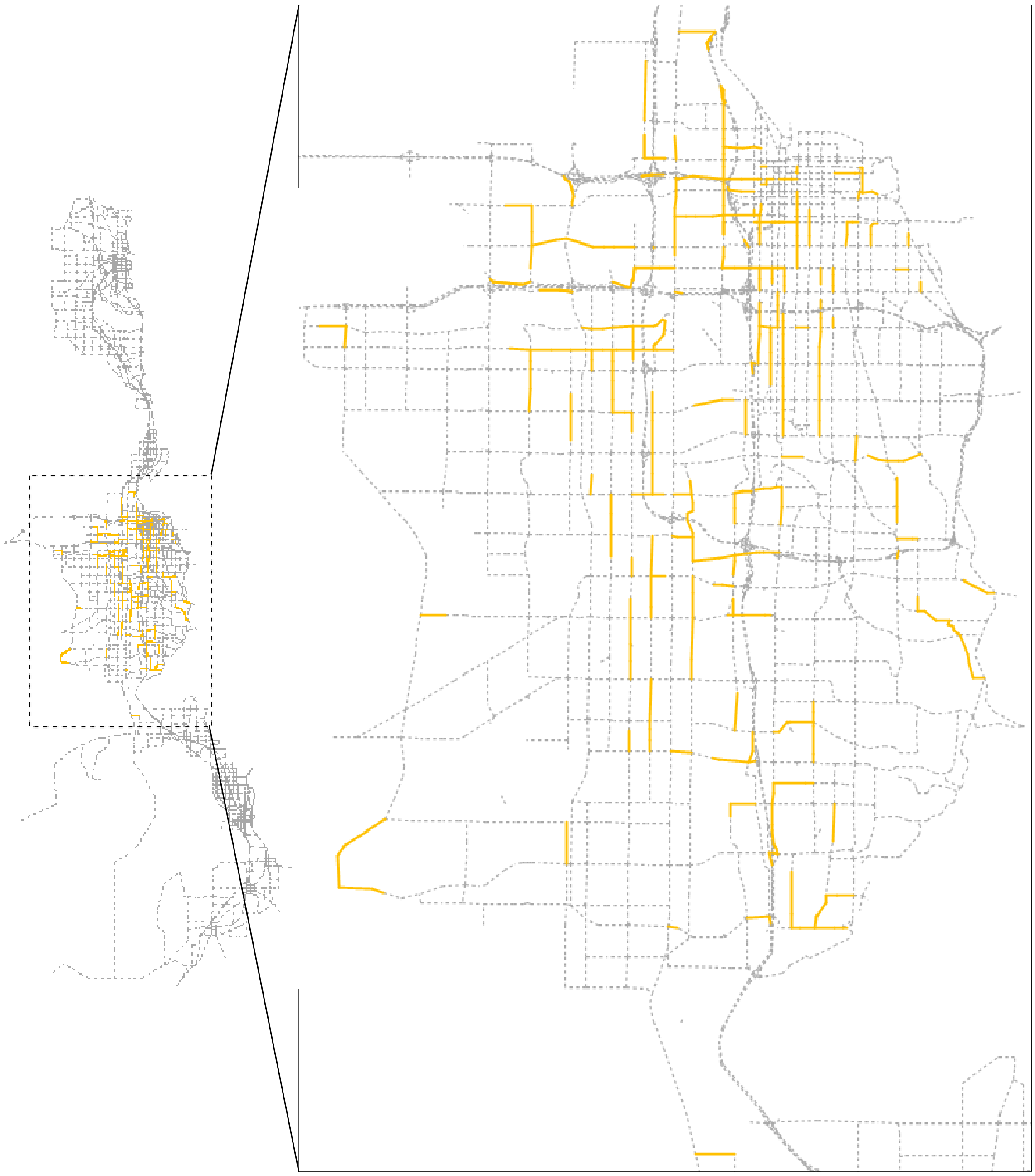

Figure 16 Most critical links (VISUM) in Salt Lake County, Utah

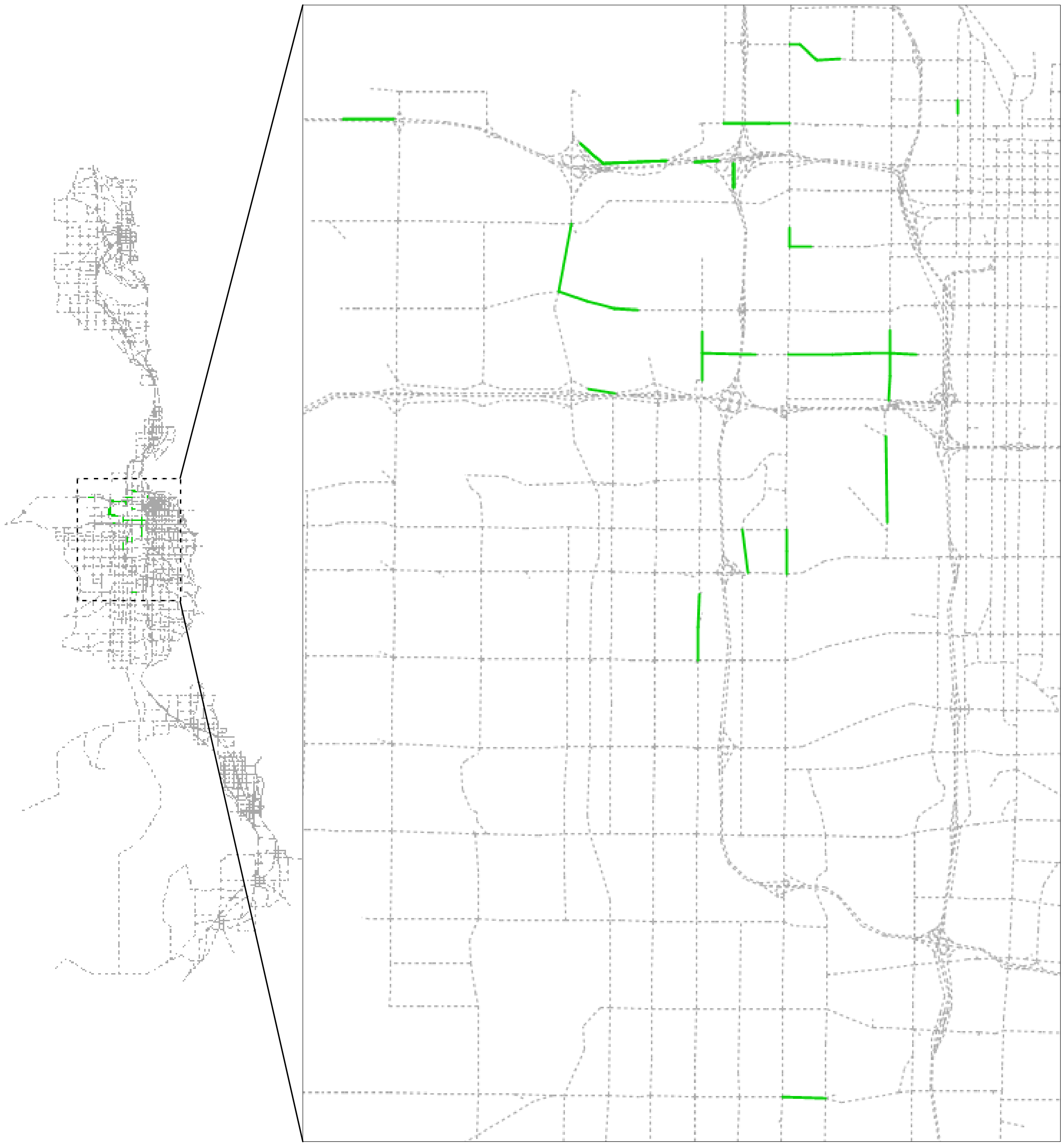

Figure 17 Combination of critical and vulnerable links (Lifelines for the M7.0 scenario event)

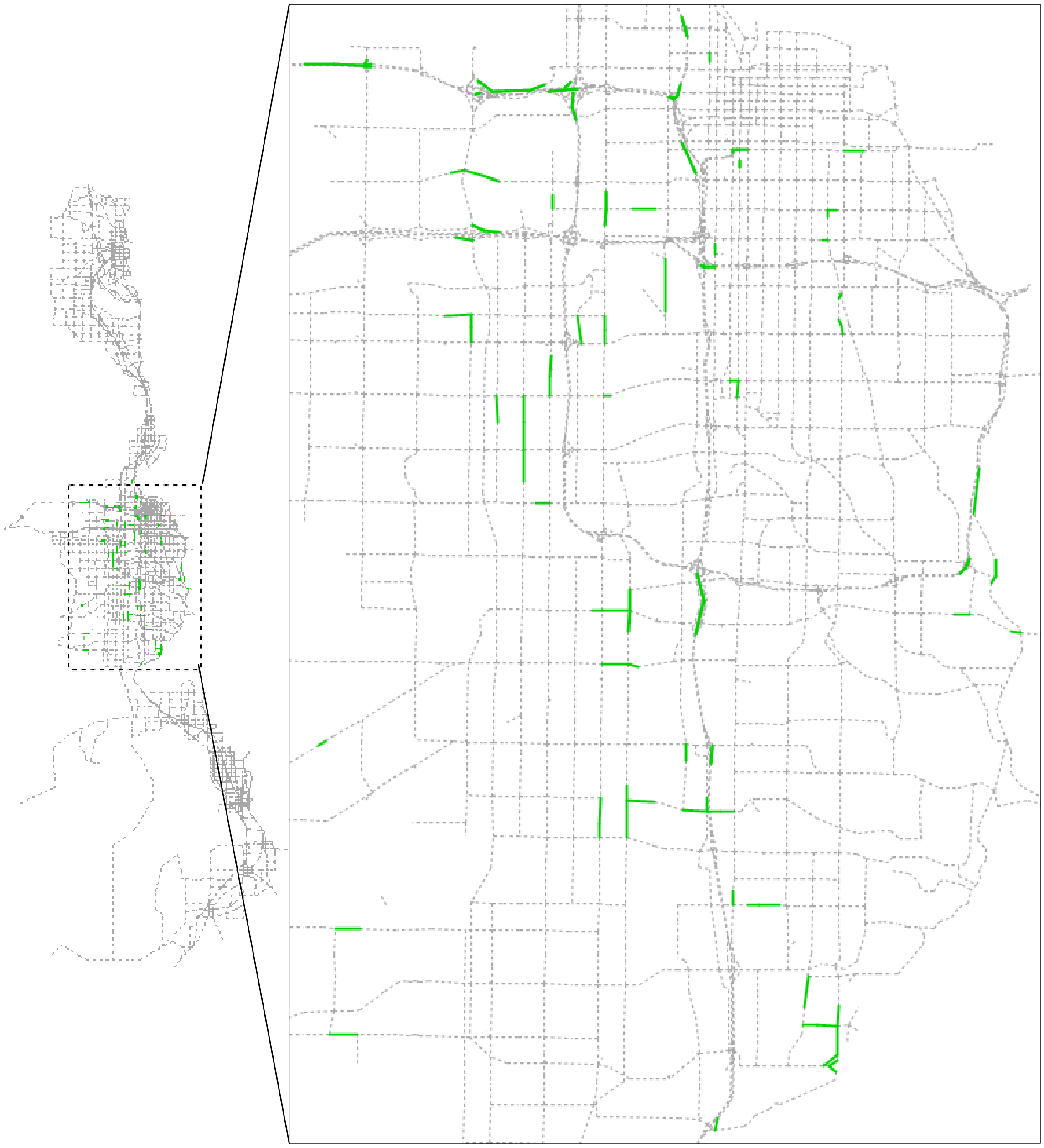

Figure 18 Combination of critical and vulnerable links (Lifelines for the M6.0 scenario event)

6.0 Dynamic Traveler Response Model

6.1 Introduction

Several studies have been devoted to examining seismic hazards and their impacts in metropolitan regions. Typically, physical damages to the transportation infrastructure first lead to significantly reduced traffic capacity and then further result in degradation of critical urban activities, such as post-earthquake emergency response. Unlike physical commodities, flow in utility lifeline systems and post-earthquake traffic flow patterns in roadway systems are extremely complex and difficult to estimate. This is because they not only are constrained by degraded capacity of links but also depend on various spatial and temporal factors, such as origin-destination demand, travel time, and trip length, as well as intricate traveler response behavior.

An urban seismic risk assessment method needs to address system performance for both infrastructure components and transportation network layers. Werner et al. (1997) proposed a scenario-based loss assessment method that focuses on seismic hazards to highway systems. Chang and Nojima (1997, 1998) and Nojima (1999) developed flow-dependent measures to estimate the post-earthquake performance of highway transportation network systems. Basoz and Kiremidjian (1996) estimated network-wide traffic delays for prioritizing retrofit strategies. In a study by Werner et al. (2000), the risk to the transportation system is computed based on the direct damage to major components (e.g., bridges) and the connectivity between a predefined set of origin-destination pairs.

Describing post-earthquake origin-destination (OD) demand patterns has been an essential but thorny issue for transportation-related systems and analyses. As indicated by Table 17 for the 1995 Northridge earthquake study, trip patterns and traveler responses during the reconstruction period demonstrates a diverse spectrum of behaviors (Schiff, 1995):

1. Continue to use freeway then divert to primary detour
2. Continue to use freeway, but divert to parallel freeway (located 8 mile south)
3. Continue to use freeway, but divert to other city or arterials

4. Shift to transit
5. Departure time change
6. Eliminate trip

Table 17 Changes in mode and route choice pattern (Schiff, 1995)

	Vehicle	People
Pre-Earthquake	*310,000*	*434,000*
During Reconstruction		
Primary detour	130,000	208,000 (48%)
Parallel freeway	5,000	7,000 (1.6%)
Arterial or other street	128,000	155,000 (35.4%)
Shift to transit	N/A	2,000 (0.5%)
Telecommuting	N/A	2,000 (0.5%)
Trip eliminated	N/A	60,000 (14%)
Reconstruction Total	*263,000*	*434,000*

Cho et al. (2003) developed both fixed and variable demand assignment methods. The variable demand model assumes that trip rates are influenced by the cost of the trip in terms of time or distance. In their model, travelers will decide if they need to cancel or continue to travel, and they further select the mode and route after a seismic event. In a recent study by Kiremidjian et al. (2008), the demand fluctuation was assumed to be the same as what has been observed from two recent earthquake cases in California (i.e., Loma Prieta, 1989 and Northridge, 1995).

Dynamic Traffic Assignment (DTA) modeling methodologies can accurately capture the buildup and dissipation of transportation system congestion by describing route, mode, and departure time choices of individual travelers. Using the Salt Lake City metropolitan network as a case study, this study adopts a multimodal DTA modeling framework developed by Mahmassani (2001) and Zhou et al. (2008) to evaluate the direct and indirect impact of earthquake damage on the transportation network.

This section is organized into two major parts. The first part (i.e., Section 6.2) seeks to determine link capacity breakdowns due to earthquake damage via a Seismic Risk Analysis (SRA) software package, namely REDARS 2 (Risks from Earthquake Damage to Roadway System). A wide range of hazards, including ground motion, liquefaction, and surface rupture fault, are systematically evaluated and used to estimate seismic damage in the study area. Two earthquake scenarios (M 7.0 and M 6.0 events) are used to generate realistic damage state estimates on the transportation network.

The second part of this section (i.e., Section 6.3) aims to evaluate network-wide traffic flow patterns by seamlessly integrating a simulation-based DTA modeling system with the seismic risk analysis model. By starting with a pre-earthquake travel pattern, the DTA model takes post-earthquake network capacity as an external input and iteratively simulates day-by-day changes in the post-earthquake traffic pattern until long-term traffic flow equilibrium is approached. Based on the Salt Lake City metropolitan area, a case study is used to illustrate the proposed methodology and modeling details.

6.2 Seismic Risk Analysis

6.2.1 System Input

The methodology for integrating Seismic Risk Analysis (REDARS 2) and Dynamic Traffic Assignment (DYNASMART-P) systems is shown in Figure 19. In the REDARS 2 seismic risk analysis, results are developed from a set of input parameters, such as soil, link, node, and bridge data. The evaluated seismic vulnerability of the transportation component results is mapped to the corresponding transportation network as capacity reduction parameters for the dynamic traffic assignment procedure, which provides modified travel demand and traffic time.

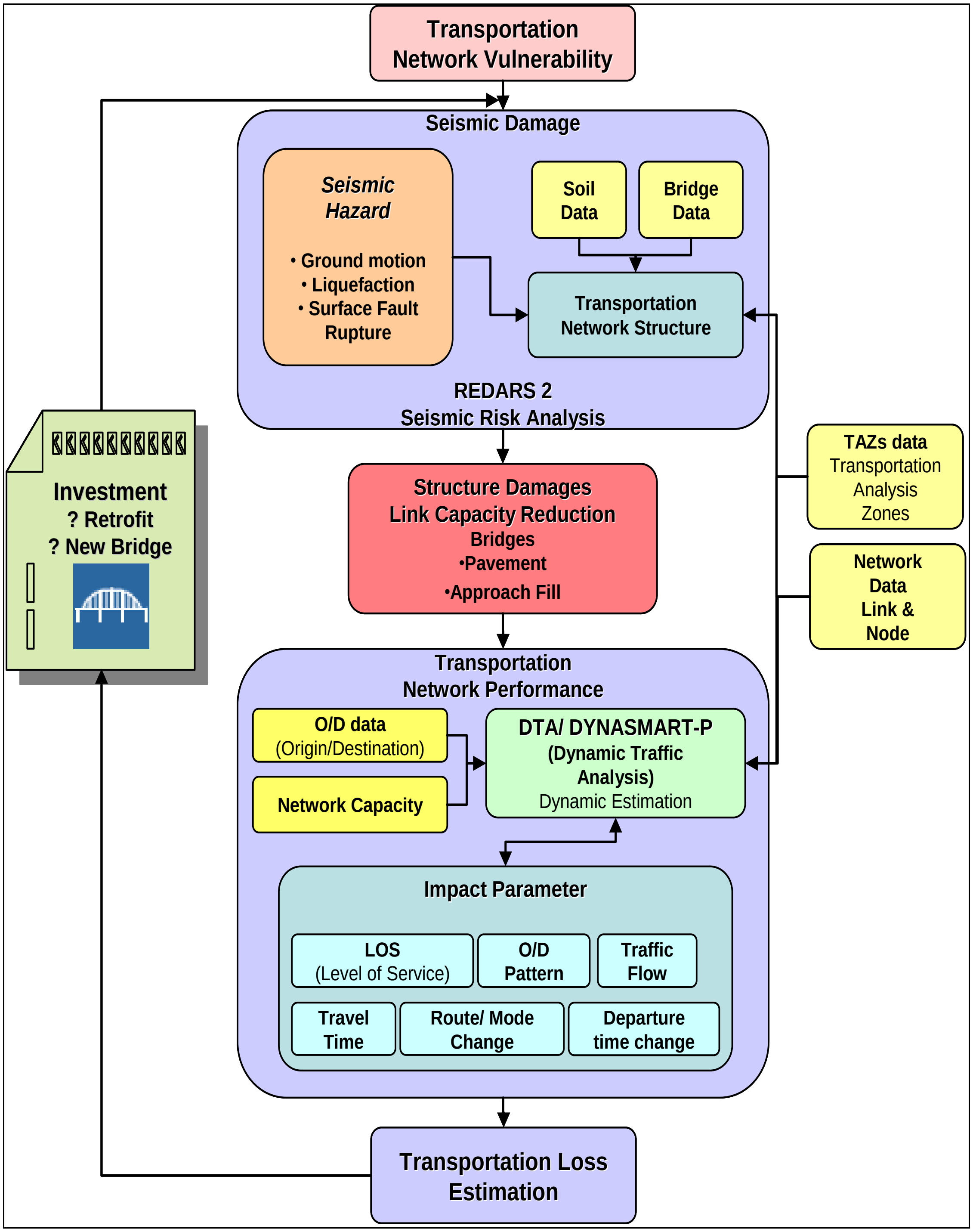

Figure 19 Flow chart for REDARS/ DYNASMART-P integration

The seismic risk analysis methodology in REDARS 2 can be carried out in both deterministic and probabilistic approaches. This software package has been developed and released by the Federal Highway Administration with a number of case studies in the states of California, Tennessee, and Oregon. In these studies, the seismic hazards and the resulting damage states are estimated for each component in the transportation network, and a *static* traffic assignment model (without departure time and traffic flow dynamic representation) is used to perform networkwide traffic delay estimation.

6.2.2 Seismic Hazard Scenarios

The local soil conditions and fault geometry are key inputs for estimating strong motion hazard. REDARS 2 includes two ground motion models, namely the Abrahamson-Silva (1997) ground motion model, applied to shallow crustal earthquakes in active tectonic regions, and the model by Silva et al. (2002 and 2003), applied to stable tectonic regions. These ground attenuation models typically characterize the effects of local soil conditions by a single term in the ground motion equation. In this study, the soil conditions along the roadway system consist of rock, soft rock, stiff soil, and soft soils, while the last two classes are the most common soil types; some soils are susceptible to liquefaction hazards.

The deterministic seismic hazard scenarios in this analysis used the Walkthrough file, which estimates strong ground motion, fault ruptures, and liquefaction effects. The primary source of seismic hazards is the Salt Lake City Segment of Wasatch fault, which is about 46 km long and parallels the base of the Wasatch Mountain range. According to a study by Wong et al. (2002), this range-bounding normal fault is capable of producing a magnitude 7.0 to 7.5 earthquake. Comparably, the West Valley fault zone is estimated to produce magnitude 6.0 events. Other potential sources of hazards include other mapped faults and smaller unmapped faults (expected magnitude less than 6.5) that are located close to population centers.

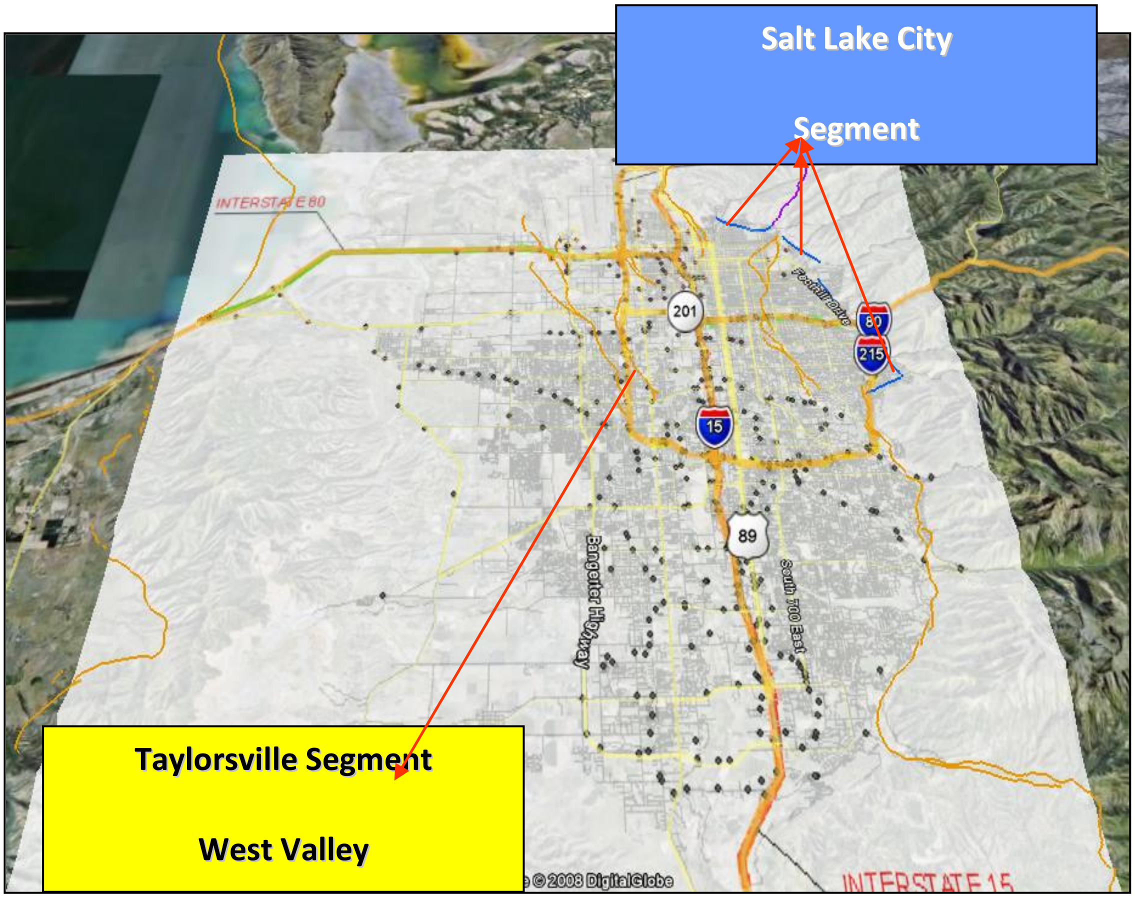

Figure 20 Salt Lake Valley, Utah seismic hazard scenarios map

In this study, we consider two potential seismic events that may impact or damage the transportation network (Figure 20 and Table 18). First, in the Wasatch fault zone, the Salt Lake City segment is located in the east bench of the valley. Second, the West Valley fault zone, the Taylorsville segment, is located on the west side of the valley, which is expected to give considerably less impact than the Wasatch fault in the Salt Lake City section. The scenarios that are used in this study represent realistic seismic events in the Salt Lake Valley.

Table 18 Seismic hazard scenarios

	Scenario 1	Scenario 2
Scenario name	Salt Lake City segment Wasatch fault zone	Taylorsville segment West Valley fault zone
Fault Rupture Plane Top and Base Endpoint (Latitude/ Longitude)	40.836/ -111.883 40.476/ -111.832 40.821/ -112.122 40.441/ -112.071	40.808/ -111.982 40.661/ -111.945 40.820/ -111.891 40.674/ -111.856
Magnitude	7.0	6.0
Depth	10.0 km	3.855 km

Figure 21 shows the study network in the Salt Lake City metropolitan area, which is one of the most rapidly growing urban areas in the United States. Its population was estimated by the Census Bureau to be 1,468,207 residents as of July 2006. There was an increase of 10.1% since the 2000 Census and 2.5% above the prior year (USCB, 2008). Utah has been widely recognized as having a relatively high seismic hazard. The 240-mile-long Wasatch fault is made up of several segments that are capable of producing up to magnitude 7.5 earthquakes. During the past 6000 years, the Salt Lake City segment has lain under the Salt Lake valley and has ruptured at least four times. The average recurrence interval for surface faulting earthquakes in this segment is 1350 +/-200 years, with the most recent earthquake occurring about 1300 (+/-250) years ago (Black et al., 1996).

The study network includes three major highways, namely I-15, I-80, and a bypass route, I-215, as well as major arterials. The traffic network contains 8524 nodes and 18,601 links, and its link capacity and origin-destination demand data are obtained from the Wasatch Front Regional Council (WFRC), which is the local planning organization for this area.

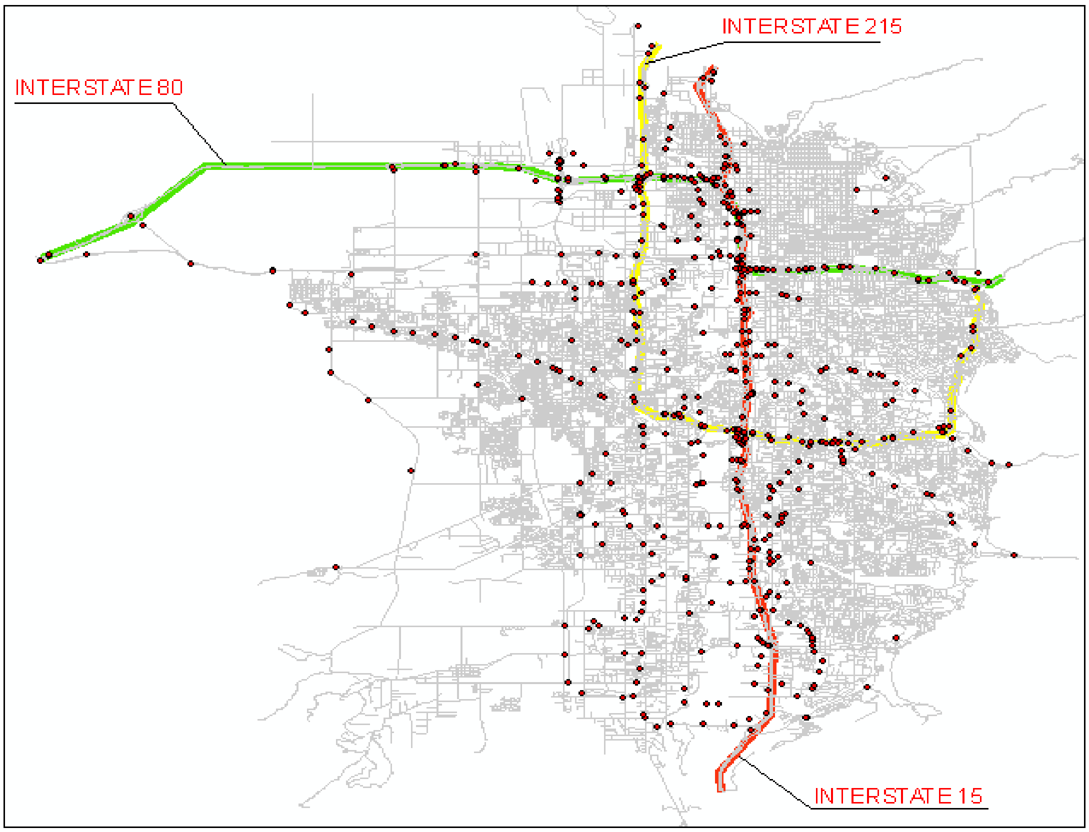

Figure 21 Study network for seismic risk analysis of the Salt Lake Valley, Utah

In 2007, 3813 bridges were recorded in the National Bridge Inventory (NBI) database in the state of Utah. The most up-to-date data from the NBI database and Utah Department of Transportation (UDOT) are used for the 1407 bridges covered in this study area, and a breakdown of bridge locations on different highways can be found in Table 19.

Table 19 Bridge locations in Salt Lake City metro area (NBI, 2008)

Locations	Bridges
Interstate 15 total	454
Interstate 15 only	214
Interstate 15 & 80	104
Interstate 80 only	160
Interstate 215	139
Salt Lake City Metro Total	844
Study Total	1407

6.2.3 Post-earthquake Network Capacity Analysis

As a result of the seismic hazard evaluations, the network damage states are shown in Figure 22. Due to the higher level of strong motion, permanent ground displacement (PGD) from liquefaction effects, and surface fault rupture, the Salt Lake City segment component damages are comparably higher than the Taylorsville segment event. By considering major networkwide traffic impacts, congestion that is induced by the seismic event of the Taylorsville segment may not be significant. On the other hand, the rupture of the Salt Lake City segment could impose dramatic damages on the transportation network due to critically damaged locations. The network damage contours from these two scenarios are shown on Table 20 and Figure 22. Based on the above considerations, further transportation network analysis will focus on network interruptions due to the activities and damage to the Salt Lake City segment.

Table 20 Damage status from seismic risk analysis from REDARS 2 simulation

	Scenario 1			Scenario 2		
Scenario Name	Salt Lake City Segment			Taylorsville Segment		
Damage	Bridge	Approach fill	Pavement	Bridge	Approach fill	Pavement
None	622	108	16984	985	1392	18186
Slight	118	2706	2	118	1422	0
Moderate	353	0	200	229	0	0
Extensive	109	0	247	69	0	0
Complete	205	0	1168	6	0	0

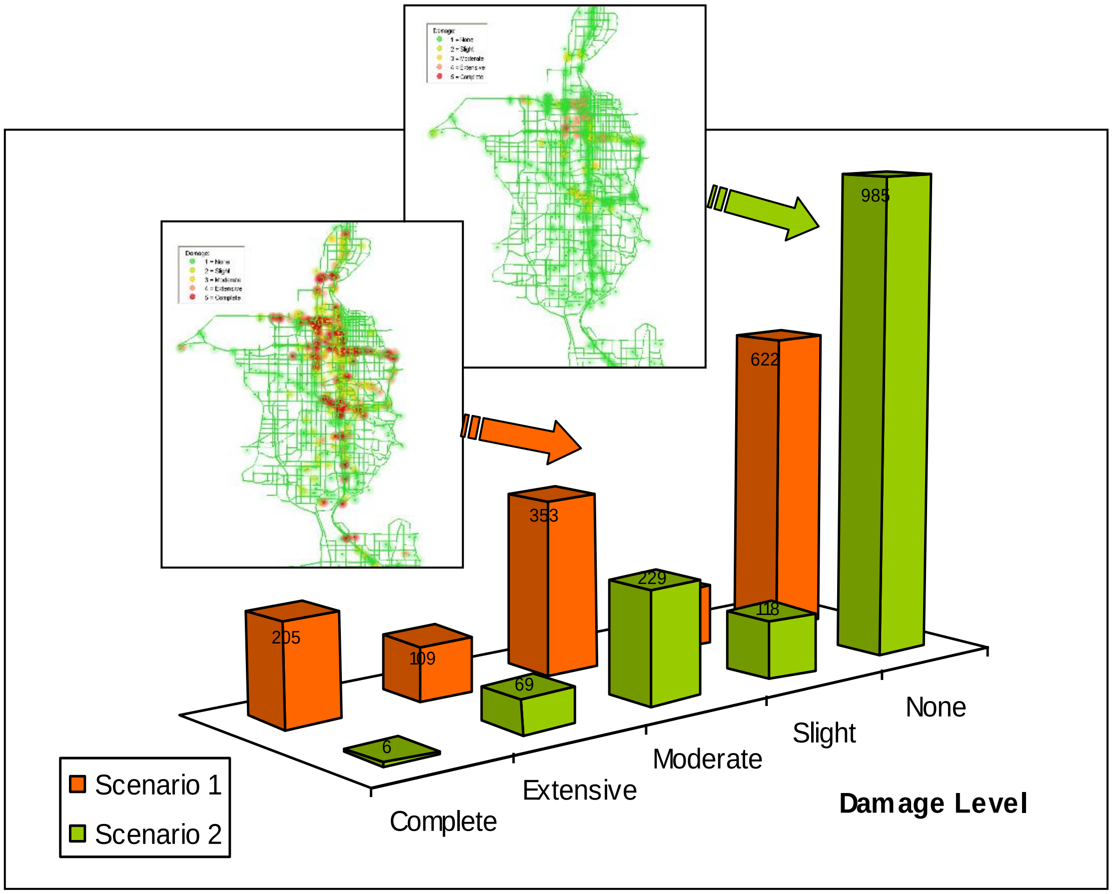

Figure 22 Bridge damage status contour from seismic risk analysis

The above earthquake damage evaluation gives the component damage status of the transportation network. Table 5 further describes the general repair consequences that are assumed in HAZUS99 (1999). In this study, damage states used as a default repair model from the REDARS2 simulation results. Further in the DYNASMART-P simulation, damaged link capacity is reduced based on Table 21.

6.3 Transportation Network Analysis

6.3.1 Model Overview and Notations

This section focuses on estimating the network flow transitions from the aftermath, approximately 2 weeks after the incidents, to the stabilized conditions. The multimodal DTA

(Dynamic Traffic Assignment) methodology by Mahmassani (2001) and Zhou et al. (2008) is extended to realistically describe post-earthquake traffic flow dynamics. The proposed procedure includes the following three steps:

(1) Convert a large number of transportation network damage states from SRA to DTA simulation,

(2) Load multiclass dynamic OD demand flows to an impacted network, modified to be suitable for modeling post-disaster situations,

(3) Evaluate the overall network performance in terms of traffic volumes, trip length, and travel time in a day-to-day meso-scopic simulation framework.

The following notation is used to represent variables in the problem formulation and solution algorithm:

<u>Notation</u>

i	origin zone index, $i \in I$
j	destination zone index, $j \in J$
p	superscript for trip purposes (e.g., home-based work, home-based shop),
m	travel mode index, $m \in M$
T	total number of time intervals in the analysis period for modeling departure time choice.
PAT	preferred arrival time interval index, PAT=1, 2,…, T
τ	departure time interval index, τ =1, 2,…, T

Consider a regional transportation network G(N, A) consisting of $|N|$ nodes, $|A|$ directed arcs, multiple origins $i \in I$, and destinations $j \in J$. The analysis period of interest, taken as the planning horizon, is discretized into small intervals 1,…,T. It is assumed that zone-to-zone static OD demand tables $d_{i,j,p}$ are available (e.g., from regional transportation planning agencies) over the study horizon, representing the number of individual travelers traveling from zone i to zone j with a trip purpose p. One simple way for obtaining dynamic OD demand tables is to convert static OD demand table $d_{i,j,p}$ to

$$d_{i,j,p,\tau} = d_{i,j,p} \times \beta_{p,\tau} \tag{1}$$

where $\beta_{p,\tau}$ is the temporal distribution for trip purpose p that translates static OD demand to dynamic OD demand.

Another commonly used method is to perform dynamic OD estimation using link counts. However, as the demand pattern is expected to have significant changes after a major earthquake, the post-earthquake link counts are unavailable before the event; thus, the temporal profile-based method in Equation (1) should be sufficient.

Table 21 Repair consequences and link capacity reduction for each bridge damage state (modified from HAZUS99 (1999))

Damage State	Link Capacity Reduction (%)	Repair Consequences
1 (None)	0	No damage
2 (Slight)	0	Minor cracking and spalling to the abutment, cracks in shear keys at abutments, minor spalling and cracks at hinges, minor spalling at the column (damage requires no more than cosmetic repair) or minor cracking to the deck.
3 (Moderate)	50	any column experiencing moderate (shear cracks) cracking and spalling (column structurally still sound), moderate movement of the abutment (<2”), extensive cracking and spalling of shear keys, any connection having cracked shear keys or bent bolts, keeper bar failure without unseating, rocker bearing failure or moderate settlement of the approach.
4 (Extensive)	100	Any column degrading without collapse – shear failure – (column structurally unsafe), significant residual movement at connections, or major settlement approach, vertical offset of the abutment, differential settlement at connections, shear key failure at abutments.
5 (Complete)	100	Any column collapsing and connection losing all bearing support, which may lead to imminent deck collapse, tilting of substructure due to foundation failure.

Applying damage states to quantitative measures of link capacity can be very subjective (Cho et al., 1999). The most reasonable approach for estimating damaged bridge functionality is to assume that the bridge is to be either fully open or closed after an earthquake. A safety-oriented local policy would close any damaged structures to traffic, regardless of its delay and cost impact on a traffic network. However, in this study, it is assumed that except for extensive damaged or collapsed bridges, all other damaged bridges need to be repaired within 6 months and would be restored to be functional at the first stage in the overall reconstruction period.

6.3.2 Modeling Changes in Spatial and Temporal Demand Patterns

As shown in Figure 23, the traffic assignment model with elastic demand can be solved by the standard fixed demand traffic assignment program through network representation. In other words, our current study considers two modes: drive alone and stay-at-home.

Moreover, an excess demand formulation is adopted to capture the split of OD flows between the physical network and the artificial link that represents the “stay-at-home” mode. A simple flow split function can be illustrated conceptually as the following, while a more elaborate formulation that integrates mode and departure time choice is given in the next session.

$$d_{i,j,\tau} = \sum_{m} d_{i,j,\tau}^{m} = d_{i,j,\tau}^{0} + d_{i,j,\tau}^{1} \quad (2)$$

$$d_{i,j,\tau}^{m} = d_{i,j,\tau} \frac{e^{\theta_{i,j} T_{i,j,\tau}^{m}}}{e^{\theta_{i,j} T_{i,j,\tau}^{0}} + e^{\theta_{i,j} T_{i,j,\tau}^{1}}} \quad (3)$$

where m = 0-1 indicator for bypassing or traversing flows

$d_{i,j,\tau}^{1}$ = demand flows that are accommodated in the physical network

$d_{i,j,\tau}^{0}$ = demand flows that are carried by the virtual link

$T_{i,j,\tau}^{1}$ and $T_{i,j,\tau}^{o}$ are average travel times for paths (i,j,τ) traversing and bypassing in the physical network respectively, and $\theta_{i,j}$ is a dispersion parameter to be estimated. If $T_{i,j,\tau}^{1}$ is dramatically increased for all of the available paths due to reduced capacity and is higher than a threshold value corresponding to $T_{i,j,\tau}^{o}$, then part of the travelers will switch to artificial links; i.e., cancel the trip and stay at home.

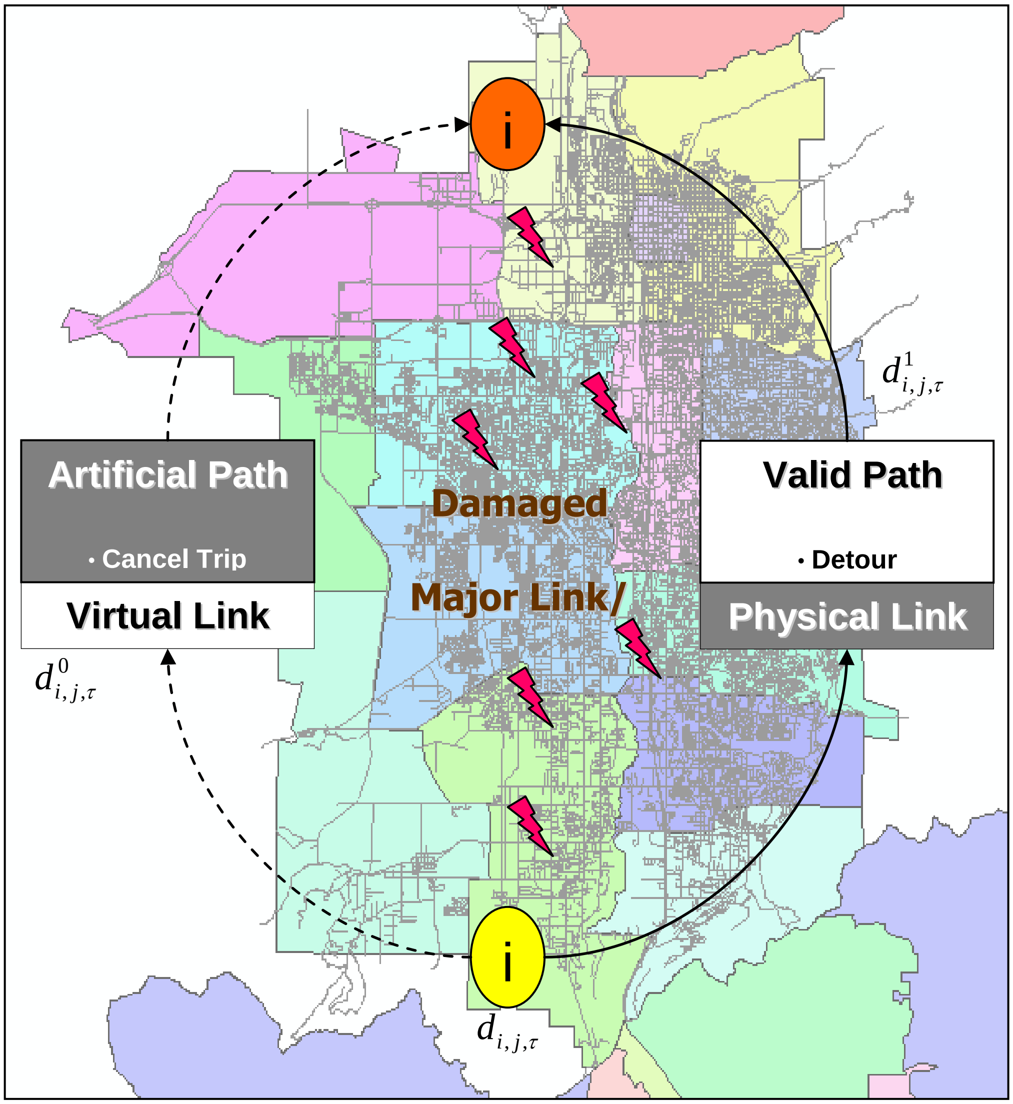

Figure 23 Virtual link for OD pair (i, j).

A damaged transportation network will change both spatial and temporal demand patterns during the reconstruction period. In the Hanshin-Awaji Earthquake case study, the research of Iida et al. (2000) found that an increase in the OD flow of short-distance trips is generated in large part by the need to rely on automobiles due to a lack of availability of other modes of transportation that normally are used for everyday activities. This indicates the desirability of trip activity to be regulated by physical network accessibility, which affects short-distance trips such as home-based shop trip (HBS) rather than home-based work (HBW) trips. Home-based work trips are usually have fixed destinations and more restricted arrival times, rather home-based shop trips, which have less restricted destination choices. The following discussion considers departure/arrival time adjustment, route change, and destination choice behavior for different trip purposes.

Home-based work trip (departure time and route changes)

This study assumes that the Preferred Arrival Time (PAT) is 8-9AM for the morning peak, and the alternative tree for each OD pair includes:

Spatial dimension:

Path (k=1, m=1)

Path (k=2, m=1)

….

Stay at home (m=0)

Temporal dimension:

Different departure time.

Given a fixed PAT, home-based work trips can change routes or departure times to avoid traffic. Let us further define $AAT_{i,j,PAT}^{\tau,m,k}$, $SD_{i,j,PAT}^{\tau,m,k}$, $SDE_{i,j,PAT}^{\tau,m,k}$, $SDL_{i,j,PAT}^{\tau,m,k}$, actual arrival time, schedule delay, early schedule delay, and late schedule delay, respectively, of an alternative (i, j, PAT, τ, m, k), where

$$SD_{i,j,PAT}^{\tau,m,k} = AAT_{i,j,PAT}^{\tau,m,k} - PAT \tag{4}$$

$$SDE_{i,j,PAT}^{\tau,m,k} = \max\{0, -SD_{i,j,PAT}^{\tau,m,k}\} \tag{5}$$

and $$SDL_{i,j,PAT}^{\tau,m,k} = \max\{0, SD_{i,j,PAT}^{\tau,m,k}\} \tag{6}$$

as illustrated in Figure 24.

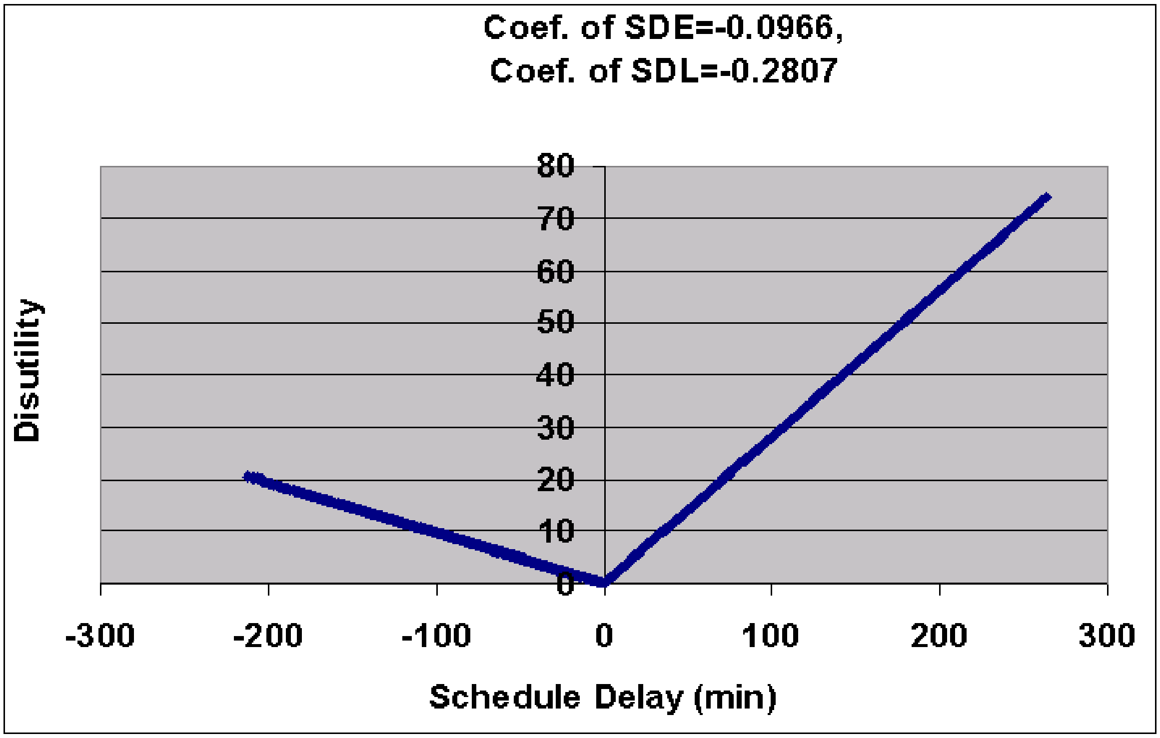

Figure 24 Illustration of disutility functions for schedule delay (Noland, Small, Koskenoja, and Chu 1998)

For each traveler with (*i*, *j*, *p*, *PAT*) where p= HBW, the systematic utility equation for an alternative (departure time τ , mode *m*, and path *k*) is:

$$V_{i,j,p,PAT}^{\tau,m,k} = \alpha_1 \times T_{i,j,p}^{\tau,m,k} + \alpha_2 \times SDE_{i,j,p,PAT}^{\tau,m,k} + \alpha_3 \times SDL_{i,j,p,PAT}^{\tau,m,k} . \quad (7)$$

The coefficients α_1 , α_2 , α_3 are utility coefficients for travel time, early schedule delay, and late schedule delay, respectively. Typically, α_3 is greater than α_2 , as a late schedule delay has higher penalties than early schedule delays.

By assuming that random error terms are independently identically distributed Gumbel variables, the choice probabilities for each alternative (τ, *m, k*) correspond to the usual unordered Multinomial Logit (MNL) choice function:

$$\Pr_{i,j,p,PAT}^{\tau,m,k} = \frac{Exp(V_{i,j,p,PAT}^{\tau,m,k})}{\sum_{\tau,m,k} Exp(V_{i,j,p,PAT}^{\tau,m,k})} \quad (8)$$

Other complicated and sophisticated forms, such as path-size logit ordered generalized extreme value models, can be used, because the approach considers details at the individual traveler level. The choice probabilities further link the OD demand to flows that are associated with each alternative:

$$r_{i,j,p,PAT}^{\tau,m,k} = d_{i,j,p,PAT} \times \Pr_{i,j,p,PAT}^{\tau,m,k} = d_{i,j,p,PAT} \times \frac{Exp(V_{i,j,p,PAT}^{\tau,m,k})}{\sum_{\tau,m,k} Exp(V_{i,j,p,PAT}^{\tau,m,k})}, \quad (9)$$

where $r_{i,j,PAT,p}^{\tau,m,k}$ number of travelers for alternative (i, j, PAT, τ, m, k) at iteration *n*

Home-based shop trip (destination and route changes)

For trip purpose p= HBS, the total production from each zone *i* is

$$d_{i,p,\tau} = \sum_j d_{i,j,p,\tau} \quad (10)$$

The alternative tree for each origin *i* includes

Destination *j* =1,

Path (j=1, k=1), m=1

Path (1,2), m=1

….

Destination *j* =2

Path (j=2,,k=1), m=1

Path (2,2), m=1

....

Stay at home, m =0

For each traveler with (i, τ), the systematic utility equation is

$$V_{i,p,\tau}^{j,m,k} = \alpha_1 \times TT_{i,p,\tau}^{j,m,k} \,, \tag{11}$$

where $V_{(i,j,PAT)}^{(\tau,m,k),n}$ is the systematic utility for alternative (i, j, PAT, τ, m, k) at iteration *n.*

The choice probabilities further link the OD demand to flows that are associated with each alternative using Eq. (12) for *p* = HBS.

$$, \; r_{i,p,\tau}^{j,m,k} = d_{i,p,\tau} \times \Pr_{i,p,\tau}^{j,m,k} = d_{i,p,\tau} \times \frac{Exp(V_{i,p,\tau}^{j,m,k})}{\sum_{j,m,k} Exp(V_{i,p,\tau}^{j,m,k})} \,. \tag{12}$$

6.3.3 Simulation-based Solution Framework

To solve the dynamic traveler assignment problem in transportation networks, we essentially want to determine the number of travelers for each alternative and the resulting temporal-spatial loading of vehicles. To this end, we extend the DTA solution methodology to support post-earthquake planning and operations decisions. The system features the following three components:

(1) Traffic simulation (or supply) component (with reduced link capacity),

(2) Traveler behavior component, departure time, destination, and route choice

(3) Path processing and traveler assignment component.

A traffic simulator, namely DYNASMART-P (Mahmassani, 2001), is used to capture the traffic flow propagation in the traffic network and evaluate network performance under reduced link capacity and a given mode, departure time, and route decisions that are made by the individual travelers. Given the user behavior parameters, the traveler behavior component aims to describe travelers' mode, departure time, and route selection decisions after an earthquake. The third component is intended to generate realistic alterative route choice sets and perform stochastic network loading for solving the traveler assignment problem under impacted network conditions.

This study presents an iterative procedure for solving the stochastic intermodal dynamic traveler assignment problem with joint mode and departure time choice. In this solution framework, a dynamic step size is used to simultaneously update flow and reference cost vectors (r, π) using the auxiliary solution. The iterative procedure that is adopted here can only be viewed as an approximate (heuristic) algorithm intended for modeling day-to-day traffic changes and learning processes, in which 10% or 25% of travelers (as modeled as different step sizes) every day consider making changes.

Without loss of generality, the following discussion only considers home-based work (HBW) trips, so trip purpose index p is ignored below. The main steps of the solution procedure are described as follows:

Step 1: Initialization

Let day n=0. Based on a set of initial link and node travel attributes, find an initial feasible shortest path set for each mode and each departure time in the damaged transportation network. Perform stochastic network loading using the path set. Generate the set of mode-departure time-path flow solution $\left[r\right]^{n=0}$.

Step 2: Compute time-dependent intermodal least-cost paths and update choice set

Day index n = n+1.

Given a time-dependent link travel time, find intermodal time-dependent K-least-cost paths in the multidimensional network for each mode at each departure time for each choice (i, j, PAT).

At iteration *n*, construct the feasible alternative set $\Omega^{n+1}_{(i,j,PAT)}$ for each (*i*, *j*, *PAT*), which contains all of the alternatives in $\Omega^{n}_{(i,j,PAT)}$ and the new alternatives that are found through the intermodal K-shortest path search process**.** Given path travel time and travel cost, calculate the schedule delay and travel time reliability that are associated with each path to provide a generalized cost vector $\left[V^{\tau,m,k}_{i,j,PAT}\right]^{n}$.

Step 3: Update path assignment solution

Use a predetermined size of move to find a new departure time-mode-path flow pattern. In the following example, a Method of Successive Average (MSA) is used.

$$r^{(\tau,m,k),n+1}_{(i,j,PAT)} = r^{(\tau,m,k),n}_{(i,j,PAT)} + \frac{1}{n}\left\{\underline{r}^{(\tau,m,k),n+1}_{(i,j,PAT)} - r^{(\tau,m,k),n}_{(i,j,PAT)}\right\} \qquad \forall i, j, PAT, \tau, m, k \tag{13}$$

where the auxiliary departure time-mode-path flow vector is

$$\underline{r}^{(\tau,m,k),n+1}_{(i,j,PAT)} = d_{i,j,PAT} \times \frac{Exp(V^{(\tau,m,k),n}_{(i,j,PAT)})}{\sum_{\tau,m,k} Exp(V^{(\tau,m,k),n}_{(i,j,PAT)})} \qquad \forall i, j, PAT, \tau, m, k \tag{14}$$

and an auxiliary reference cost vector

$$\underline{\pi}^{n+1}_{(i,j,PAT)} = \frac{d_{i,j,PAT}}{\sum_{\tau,m,k} Exp(V^{(\tau,m,k),n}_{(i,j,PAT)})} \qquad \forall i, j, PAT \tag{15}$$

For home-based shop trips,

and a new reference generalized cost,

$$\pi^{n+1}_{(i,j,PAT)} = \pi^{n}_{(i,j,PAT)} + \frac{1}{n}\left\{\underline{\pi}^{n+1}_{(i,j,PAT)} - \pi^{n}_{(i,j,PAT)}\right\} \qquad \forall i, j, PAT \tag{16}$$

Step 4: Stochastic network loading

Under the set of mode, departure time, and path assignment $\left[r_{i,\,j,\,PAT}^{\tau,m,k} \right]^{n+1}$, generate the vehicle/traveler attributes and simulate the assigned vehicles between each O-D pair for each departure interval τ and each mode *m*. Generate $V_{(i,j,PAT)}^{(\tau,m,k),n+1}$ with the latest simulation results.

Step 5: Convergence checking (if reaching steady state)

Calculate

$$Gap = \sum_{i,j,PAT} \left\{ \sum_{(i,j,PAT,\tau,m,k)\in\Omega_{i,j,PAT}^{n+1}} \frac{1}{2}(\ln r_{(i,j,PAT)}^{(\tau,m,k),n+1} - V_{(i,j,PAT)}^{(\tau,m,k),n+1} - \pi_{(i,j,PAT)}^{n+1})^2 \right\} \tag{17}$$

If *Gap* < δ, convergence is achieved, where δ is a prespecified parameter.

If convergence is attained, stop. Otherwise, go to Step 2.

In Step 3, as K routes are generated at each iteration and stored in the alternative set of $\Omega_{(i,j,PAT)}^{n}$. Thus, there are at most a total of *n**K alternatives for each choice (i, j, PAT) at iteration *n*. K=5 is used in the experiments of this study.

6.4 Application of Model to Salt Lake Valley

The Salt Lake City metro test network is modeled using 1500 traffic analysis zones (TAZs) for a 180-minute simulation horizon. Three different scenarios are tested, including a do-nothing scenario and two damaged network scenarios with network-wide capacity deductions, shown as Table 22.

Table 22 Pre-earthquake/ Post-earthquake network capacity

	Scenario 1 (Salt Lake City Segment)		Scenario 2 (Taylorsville Segment)	
Damage Type	Link Damage	Bridge Damage	Link Damage	Bridge Damage
Partial Capacity Deduction (Moderately Damaged)(%)	0.5376	12.5444	0.5295	8.1379
Full Capacity Deduction (Extensive/Collapse Damage)(%)	7.6071	22.3169	0.8386	5.3304
Total Capacity Deduction (%)	8.1447	34.86	1.3681	13.4683

Typically, overpass bridges may impact directly related underlying links. In this study, all of the links that are located under overpass bridges (that have extensive or complete damage) are assumed to be reopened shortly after structural debris is cleaned. The loaded Salt Lake City network includes highway corridors and major and minor arterial streets, as well as connectors, so the total capacity reduction values that are shown in Table 6 are statistically diluted. The mapping link damages from REDARS 2 to DYNASMART-P are shown in Figure 25.

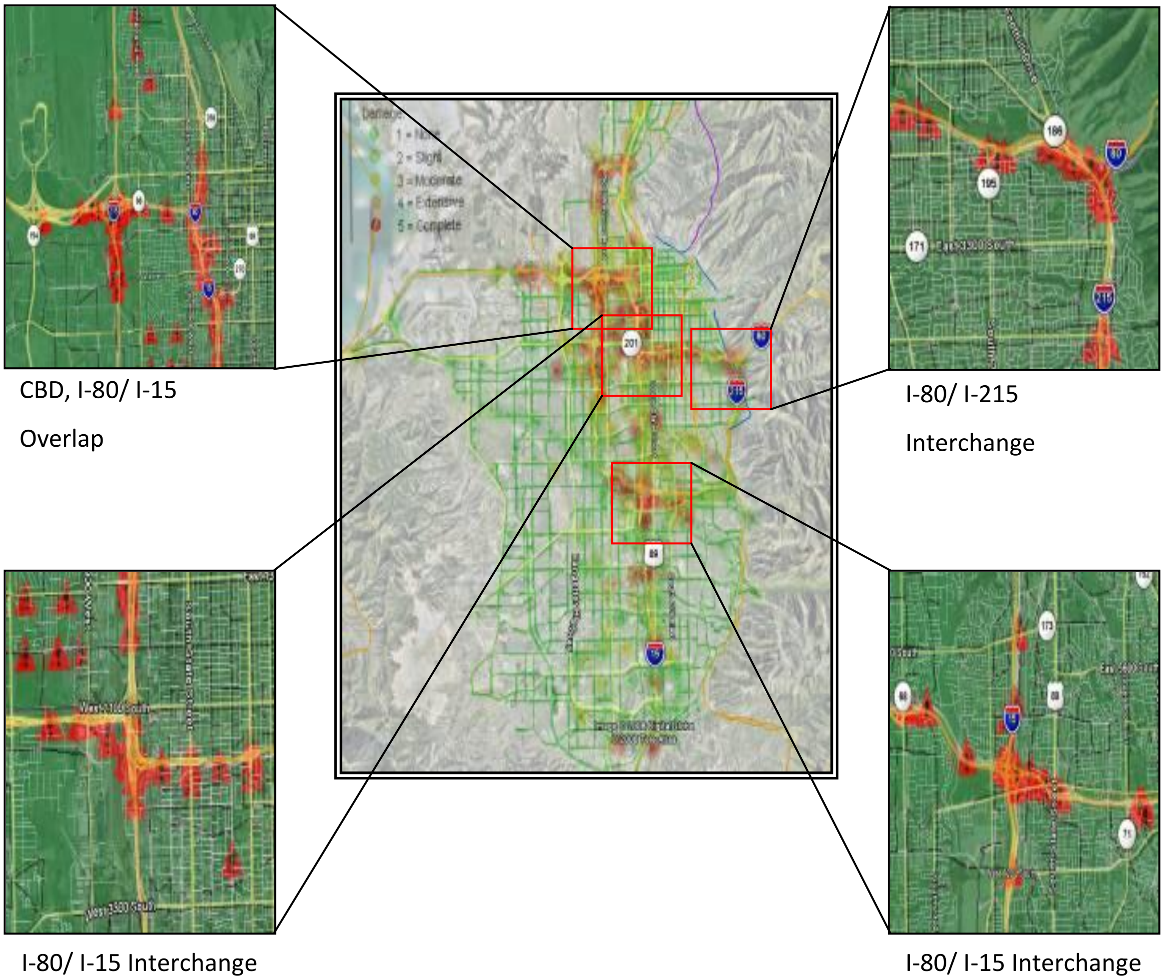

Figure 25 Mapping link damage to DYNARSMART-P (Scenario 1)

In the following discussion, we sequentially examine the network-wide, origin-destination-specific and path-specific travel times, extracted from vehicular simulation results from DYNASMART-P.

Table 23 first gives the network-wide average travel time in the do-nothing case as 21 minutes. Based on the simulation results, scenario 1 (Salt Lake City Segment) and scenario 2 (Taylorsville Segment) produce 123.3% and 31.9% increases, respectively, in terms of average travel time. In the first scenario, many parts of the interstate freeway system are accessible, so most vehicles use limited arterial streets or residual highway segments.

Table 23 Network-wide travel time changes

Network wide travel time	Pre- EQ	Scenario 1 Salt Lake City	Scenario 2 Taylorsville
Link capacity decreased by Pre-EQ		2.433%	0.6909%
Simulated Travel time (minutes)	21.0	46.9	27.7
Travel time increased by Pre-EQ		123.3%	31.9%

In addition, Table 24 provides useful OD-specific MOEs (measures of effectiveness), while OD pair 1480 to 195 is chosen for measuring the major traffic impact in the North-South bound using the I-15 corridor. By examining 26 vehicles that have traveled along this OD pair, in scenario 1, when the I-15 corridor is severely damaged, the impacted vehicles find alternative routes close to the I-15 corridor, further leading to a 29.89% increase in their average travel times. Comparably, the I-15 corridor has minor damage in scenario 2, and the average travel time is increased by 3.51% because additional trip length due to detours does not significantly impact the travel time along the whole trip.

Table 24 Travel time impact for OD pair 1480 to 195

Tested Trip OD 1480 to 195 (26 Vehicles)	Pre-EQ	Scenario 1 Salt Lake City	Scenario 2 Taylorsville
Travel Time (minutes)	55.0	71.44	57.0
Travel Time Increased (%)		29.89%	3.51%

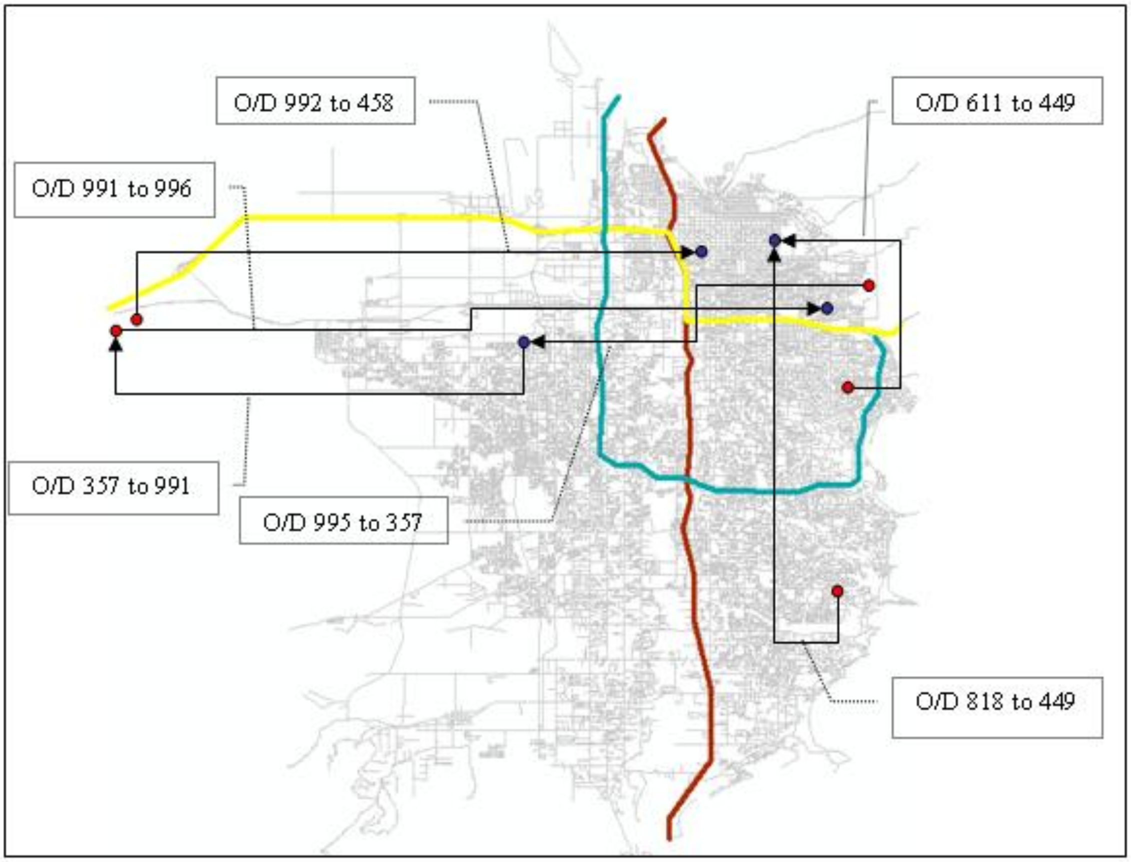

Figure 26 Tested sample OD pair

Based on the dynamic OD demand matrix in this network, 6 critical OD pairs are selected to be compared under both pre-earthquake and post-earthquake conditions (Figure 26). The OD pair 991 to 996 represents incoming traffic flow from the west side of Salt Lake City to the CBD area through the I-80 corridor. Those OD pairs that originally need to cross the I-15 or I-80 corridor in the pre-earthquake case either need to find detour routes or experience severe traffic congestion on available underpasses in the post-earthquake case. Overall, the average travel time is increased by 25% to 35%, and the additional delay for each OD pair depends on the related severity on its passing routes. Specifically, the heavy delays from OD pair 357 to 991 are mainly due to the lack of detour routes available in this impacted area. As only AM peak demand in considered, traffic flow OD pair 357 to 991 (in the counterflow direction) shows slightly reduced travel times. Figure 27 shows the difference in terms of average travel time between pre-earthquake and post-earthquake cases for each critical OD pair.

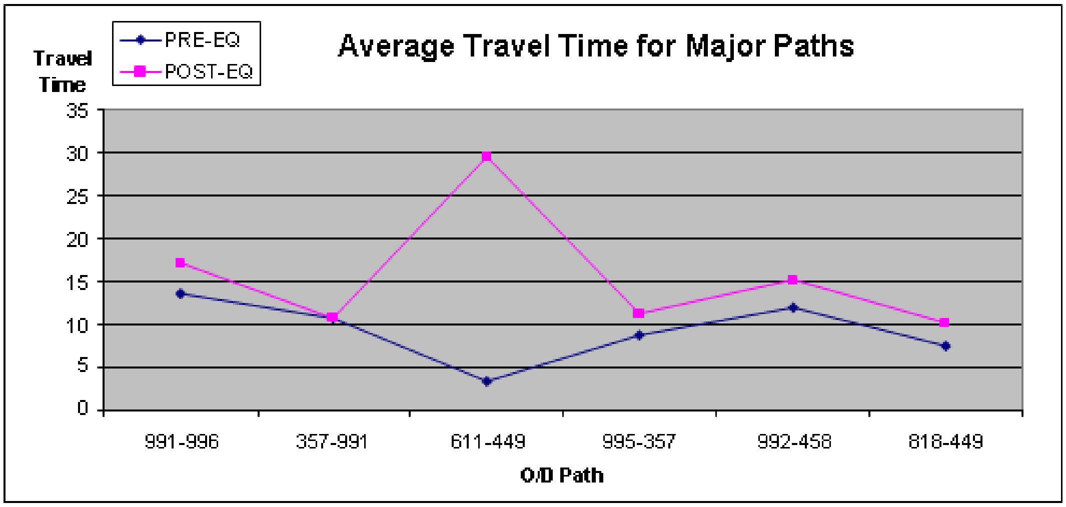

Figure 27 Average path travel time for major O/D pair

Table 25 further details vehicle-specific statistics as a result of route, mode, and departure time changes, while OD pair 995 to 357 is selected with 6 vehicles in the pre-earthquake case and 10 vehicles in the post-earthquake case. As illustrated in Figure 28, in the post-earthquake conditions, the departure times for 10 vehicles are almost evenly spread due to the congestion level on the projected paths.

Table 25 Adjusted departure time pattern for OD pair 995 to 357

Pre-Earthquake			Post-Earthquake		
# of vehicle traveled: 6			# of vehicle traveled: 10		
Average Travel Time: 8.71			Average Travel Time:11.29		
Vehicle ID	Departure Time	Travel Time	Vehicle ID	Departure Time	Travel Time
4866	5.8	8.77	4777	5.8	11.36
11223	13.5	8.77	19903	24.3	11.19
67227	82.6	8.56	33125	40.6	11.23
81201	99.7	8.58	58686	72	11.25
81527	100.1	8.78	70812	86.9	11.53
83822	102.9	8.82	71200	87.4	11.31
			84708	104.1	11.11
			84871	104.1	11.2
			90006	110.8	11.58
			138993	170.9	11.17

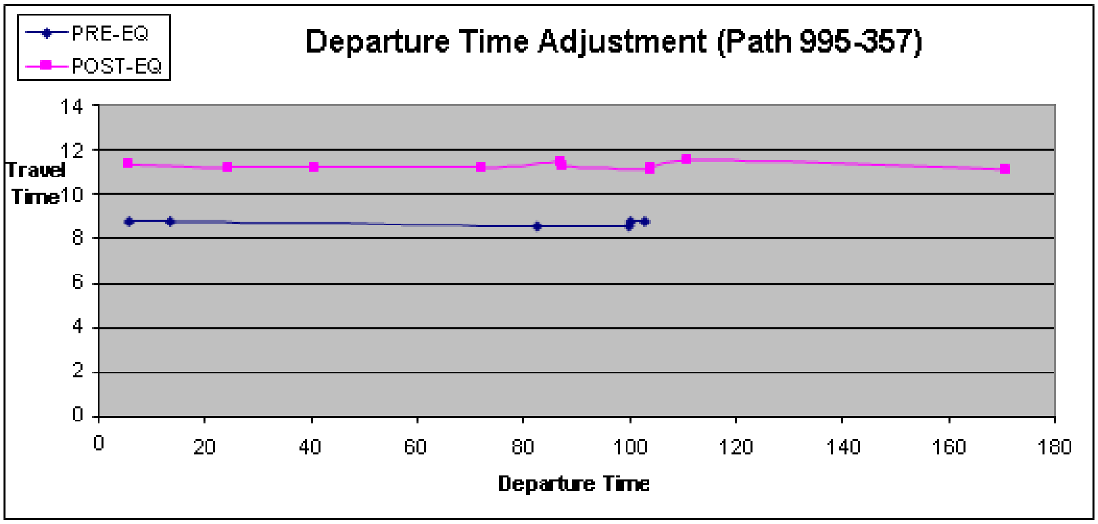

Figure 28 Departure time adjustment for path 995-357

6.4 Indirect Loss Estimation on Post-Earthquake Transportation Network

The risk assessment problem on capacity-reduced transportation networks could be more complex under this approach, since the indirect loss has two strongly correlated components: (1) the cost of the traffic delays and (2) the cost of the lost trips. Recently, Nilsson (2008) tested incremental seismic scenarios in the Charleston, SC urban area. The intensity of an Mw 7.0 earthquake used in this study leads to an estimated loss of $83 million and $1.1 billion for the direct and indirect damages, respectively. In Nilsson's study, the cost of indirect loss, such as expenditures associated with traffic diversion, was calculated approximately by using a multiplication factor of 13 based on the study by ATC (1991), in which indirect cost was estimated as 7 to 20 times the calculated direct costs.

As indicated by Moore et al. (2006), REDARS validation studies showed that the loss estimation model substantially overestimated travel volumes and delays in the Los Angeles network relative to the observations following the 1994 Northridge earthquake. In some cases, the overestimated travel volumes was about 2.5 times greater than what were observed on the day following the earthquake, and the modeled delays was around 12 times greater than what were observed (Cho et al. 2003a; Werner et al. 2004).

Moore et al. (2006) further conducted a study with an Mw 7.1 earthquake event along the Hayward fault in the San Francisco Bay Area. For this intense earthquake, the REDARS 2.0 model estimates 92 collapsed bridge, 466 damaged bridges as well as 36 links failures due to liquefaction. The total cost of transportation delays and the value of trips forgone (due to reductions in service) were estimated to be $656.81 Million. The REDARS recovery model suggests that all the collapsed and damaged bridges would be repaired or reconstructed within 231 days. It should be remarked that, this total loss does not include the cost of repairing transportation structures or the cost of freight flows forgone.

Estimated the indirect loss in the Salt Lake Valley study in this paper was based on the following assumptions: a value of time at $15 per person-hour, and average vehicle occupancy of 1.2 persons per passenger car unit, and a factor 4.0 for converting traffic demands from the four-hour peak to a daily pattern. The travel impacts of daily delay loss are estimated $1 to 3, million varied by reconstruction time frames. The total indirect loss subject to delayed travel time is estimated to be $1.8 to 2 billion for a reconstruction period of 18 months.

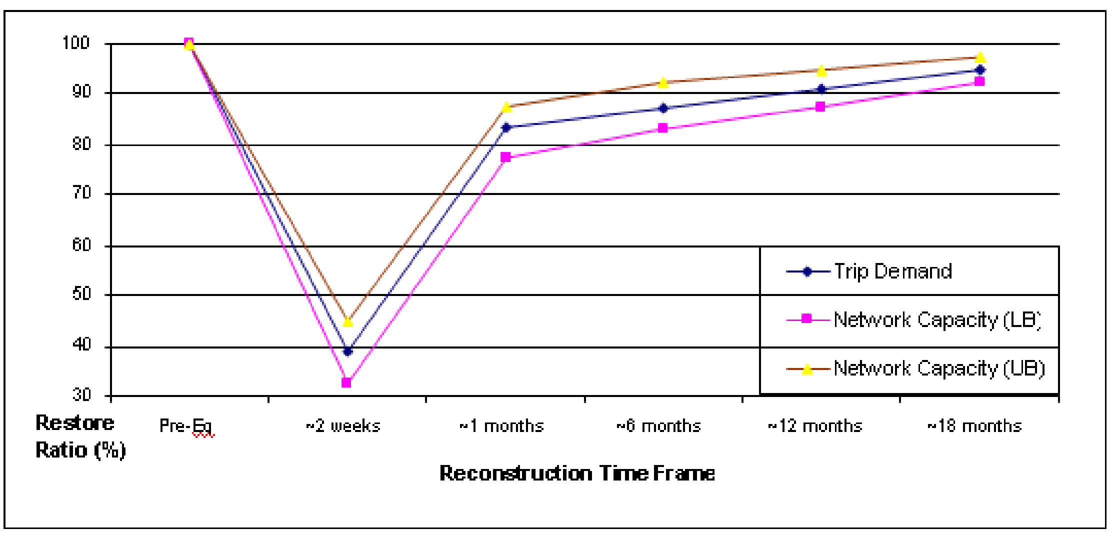

Figure 29 Trip demand/ network capacity restoration

Figure 29 shows the difference between upper bound network capacity recovery (UB) and lower bound network capacity recovery (LB). The daily total delay cost due to the reduction of transportation capacity was strongly related with network recovery capabilities provided by the transportation authority and returning volume of foregone travel demand in the network. The calculated cost was based on the number of trips on year of 2030 forecasted by Mountainland Association of Governments (MAG, 2002). Table 26 further summarized the delay cost following the earthquake and during the course of recovery.

Table 26 Estimated travel delay cost by level of traffic severity

Time	# of Trips	Daily Cost by Traffic Delay Severity (1,000$)				
	(4hr peak)	35%	25%	15%	10%	5%
Post Eq ~2 weeks	415,980	3,668	2,621	1,572		
~3 months	892,835	7,875	5,625	3,375	2,250	
~6 months	933,419		5,881	3,528	2,352	1,176
~12 months	974,002			3,682	2,455	1,227
~18 months	1,014,586					1,278

7.0 Conclusions

The expected damage to UDOT's traffic network is considerable for an earthquake occurring within the Salt Lake Valley. The estimated damage to the transportation system from a M7.0 rupture of the Salt Lake City segment of the Wasatch fault is approximately $435 M (2004 value). The expected damage resulting from a M6.0 rupture of the West Valley fault is approximately $71 M (2004 value). These estimates include damage resulting from strong motion, liquefaction and fault rupture.

The REDARS methodology suggests that the primary contributor to the expected damage is permanent ground displacement (PGD) resulting from liquefaction and fault rupture effects. All REDARS models suggest that the expected damage greatly increases when PGD effects are included. For example, we performed additional REDARS analysis without such effects and the estimated damage to the traffic system significantly decreased to $55 M (2004 value) for rupture on the M7.0 event and to about $25 M (2004 value) for the M6.0 event.

The PGD damage from liquefaction effects and fault rupture for the M7.0 earthquake is largely present on I-15 (south of I-215), on I-215 (west side), on I-80 (from the downtown area westward) and on the east side (near the Wasatch fault). The liquefaction PGD damage corresponds to areas having a mapped moderate to high liquefaction hazard (Anderson et al. 1986).

The PGD damage for the M6.0 earthquake scenario is prevalent on I-80 (downtown area) and I-215 (west side), which corresponds to the high liquefaction hazard mapped in this area.

Traffic modeling was also performed for each earthquake scenario to estimate the delay-based user costs following an earthquake and also help UDOT to make informed decisions on disaster mitigation plans. Costs were estimated for both the Wasatch Scenario and the M6.0 scenario. REDARS, VISUM and MS Excel were the tools used for this analysis.

1. A list of road segments (lifelines) with names, directions, and addresses was prepared for each scenario. These segments are vulnerable but still can carry considerable detour traffic if strengthened for seismic hazards. This information could help UDOT in prioritizing vulnerable links for improvements and using its limited resources effectively.

2. The calculated user costs indicated that the maximum impacts would be imposed on PM traffic.

3. The completely damaged links contributed more to the total delay costs. This is not only due to their severity of damage, but also due to larger rehabilitation periods required.

4. The M6.0 scenario would incur a delay cost of $65 million in the first six months were there to be an M6.0 earthquake on the Taylorsville fault system in West Valley City

5. The Wasatch Scenario would incur a user delay cost of $1.3 billion in the first six months were there to be an M7.0 earthquake on the Salt Lake City segment of the Wasatch fault.

6. The dynamic traveler model suggests that the user delay cost may range from $1.8 to 2.0 billion in an 18-month reconstruction period.

This report also presents a practical dynamic traveler microassignment model to simultaneously capture variable traffic demand and departure time choice dynamics. One particular focus is on how to represent different trip-making options and characteristics for different trip purposes. A case study using a large-scale transportation network is presented to illustrate the capability of the proposed system integration. The OD-, path-, and vehicle-specific information is systematically examined to provide a better understanding of traffic flow evolution after a major earthquake event in an urban region. The proposed methodology can uniquely meets the needs of metropolitan planning organization (MPO) and state department of transportation (DOT) agencies for sophisticated decision-making tools that involve large-scale dynamic traffic simulation.

The dynamic traveler microassignment model provide a platform for integrating a rich set of traveler choice models, applied at the individual traveler level within a realistic representation of the dynamics of traffic flow in networks with dramatic capacity changes due to earthquakes.

Furthermore, integrating REDARS 2 and DYNASMART-P to perform earthquake hazard evaluation and traffic impact studies through dynamic network simulation at a meso-scopic level can provide transportation planners with a realistic estimation of seismic risk-related road capacity damage and provide earthquake engineers with detailed evaluation of large-scale network-wide traffic impact.

8.0 Future Research and Improvements

The above damage estimates have considerable uncertainties that are attributable to limitations or simplifications of the REDARS methods and/or uncertainty or incomplete information in the modeling input data. One major source of uncertainty associated with the liquefaction susceptibility calculations was the necessity of interpolating subsurface borehole properties to the bridge locations. Although 930 SPT boreholes were used in this evaluation of the Salt Lake Valley, interpolation of the borehole information to the bridge locations was necessary, which introduces spatial uncertainty in the PGD estimates and the estimated damage. Another REDARS limitation related to fault rupture is that REDARS v.2 software does not allow for faults to be input as curvilinear features. Thus, the fault damage locations in this study are approximate.

We also believe that the strong motion bridge damage estimates could be improved by using site-specific bridge fragility curves, which is allowed by the software. For this project, fragility curves based on ATC-13 (1985) were used for bridges built during or after 1998 because of their improved seismic design. For pre-1998 bridges, REDARS default curves were used. (A bridge-by-bridge assessment of the fragility curves was not performed because of the number of bridges, project funding and time constraints.) However, we found that bridge damage, when considered on regional basis, was not very sensitive to the two different sets of fragility curves that we employed for assessment of the bridges constructed after 1998.

Most of the traffic modeling part of this study used default values derived from limited research in this field. The hypothetical values to measure retained capacity and speed on damaged links, should be refined more accurately. A further classification of damage types and their capacities can affect final results. For estimation of more accurate delay based user costs and rehabilitation time periods, location based parameters should be taken into consideration. For example, emergency response system, immediate and log-term post-earthquake traffic volumes, weather conditions and type of work zone operations may significantly affect the delay costs and reconstruction activities. Considering hourly, daily, monthly and seasonal demand variations may considerably change final outputs.

Lastly, there are several process and software improvements to REDARS v.2 that would make it easier to implement and use. Currently, REDARS cannot read the current NHPN and the HPMS files and this format incompatibility caused us to bypass the REDARS v.2 import wizard and input the required data directly in the program input tables. This was a major programming effort and required considerable time. In addition, REDARS does not include any utilities for viewing, importing or modifying the location or the attributes of bridges or links; instead all attributes needed to be changed manually in the program input tables. Further, we believe that REDARS needs to incorporate liquefaction-induced PGD effects when the SHAKEMAP option is used. This feature would increase REDARS potential use for estimating losses that incorporate SHAKEMAP scenarios. Lastly, we believe it would be useful if the software could directly incorporate published results from liquefaction and ground deformation maps (Olsen et al., 2007) directly instead of calculating these values within the REDARS program. Also, all liquefaction-triggering calculations need to be done external to the program and these calculations could easily be incorporated within REDARS to simplify the liquefaction screening analyses.

References

Abrahamson, N. A. and Silva, W. J., (1997). “Empirical Response Spectral Attenuation Relations for Shallow Crustal Earthquakes,” Seismological Research Letters, Vol. 68, No. 1, pp. 94-127.

Anderson, L. R., Keaton, J. R., Spitzley, J. E., and Allen, A. C., (1986). Liquefaction potential map for Salt Lake County, Utah: Utah State University Department of Civil and Environmental Engineering and Dames and Moore, unpublished final technical report prepared for the U.S. Geological Survey, National Earthquake Hazards Reduction Program Award No. 14-08-0001-19910, 48 p.; published as Utah Geological Survey Contract Report 94-9, 1994.

Arnow, T., Van Horn, R., and LaPray, R. (1970). “The pre-Quaternary surface in the Jordan Valley, Utah,” *U.S. Geological Survey Professional Paper* 700, p. D257-D261 ASCE 7-05, “Minimum Design Loads for Buildings and Other Structures,” American Society of Civil Engineers, 2006, 424 p.

Applied Technology Council (ATC), 1991. Seismic Vulnerability and Impact of Disruption of Lifelines in the Conterminous United States, Report No. ATC-25.

ATC-13 (1985). Buscovich, P., Coronado, J., Kiremidjian, A.S., Pelham, S. H., Reaveley, L.D., Roth, R.J.. “Earthquake Damage Evaluation Data for California,” Applied Technology Council Paper, Federal Emergency Management Agency.

Ashland, F., and Rollins, K. (1999). "Unpublished geotechnical and shear wave velocity database for the Salt Lake Valley,” Utah Geological Survey.

Bardet, J-P. Tobita, T. Mace, N., and Hu, J. (2002). “Regional Modeling of Liquefaction-Induced Ground Deformation,” *Earthquake Spectra*, Vol. 18, No.1, February, pp 19-46.

Bartlett S. F., Olsen, M. J., and Solomon, B. J. (2005). “Lateral Spread Hazard Mapping of Northern Salt Lake County for a Magnitude 7.0 Scenario Earthquake,” United States Geological Survey, USGS Award No. 04HQGR0026, 218 p.

Biek, R. F., Solomon, B. J., Keith, J. D., and Smith T. W. (2004). Interim geologic maps of the Copperton, Magna, and Tickville Spring Quadrangles, Salt Lake and Utah Counties, Utah: Utah Geological Survey Open-File Report 434, scale 1:24,000.

Basoz, N. and Kiremidjian, A. 1996. Risk Assessment of Highway Transportation Systems. The John A. Blume Earthquake Engineering Center Report No. 118, Department of Civil and Environmental Engineering, Stanford University, Stanford, CA.

Biek, R. F. (2005). Geologic map of the Jordan Narrows Quadrangle, Salt Lake and Utah Counties, Utah: Utah Geological Survey Map 208, scale 1:24,000.

Bischoff, T.A., 2005, "Collection of shear wave velocity data for use in Utah Geological Survey Site-Conditions maps and database," Master's Project, Utah State University.

Black, B.D., Lund, W.R., Schwartz, D.P., Gill, H.E., and Mayes, B.H., 1996. 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, Utah Geological Survey Special Study, Vol. 92, pp 22.

FEMA (2002). HAZUS 99 Service Release 2 (SR2). "*Technical Manual* ", developed by the FEMA through agreements with National Institute for Building Sciences, Washington D.C.

Feng, C., and Wen, C. A. (2005). "Fuzzy Bi-Level and Multi-Objective Model to Control Traffic Flow into the Disaster Area Post Earthquake", Journal of the Eastern Asia Society for Transportation Studies, Vol. 6, pp. 4253 – 4268.

Chang, S. E., Nojima, N. 1997. Highway System Performance Measures and Economic Impact. *Proc. of the 7th U.S.-Japan Workshop on Earthquake Disaster Prevention for Lifeline Systems*, Seattle, WA.

Chang, S. E., Nojima, N. 1998. Measuring Lifeline System Performance: Highway Transportation Systems in Recent Earthquakes. *Proc. of the 6th National Conference on Earthquake Engineering*, Seattle, USA, Paper No.70, p 12.

Chang, S. E., Nojima, N. 1998. Measuring Lifeline System Performance: Highway Transportation Systems in Recent Earthquakes. *Proc. of the 6th National Conference on Earthquake Engineering*, Seattle, USA, Paper No.70, p 12.

Cho, S., Fan, Y., and Moore, J. 2003. Modeling Transportation Network Flows as a Simultaneous Function of Travel Demand, Network Damage, and Network Level of Service, the Proceedings of the ASCE Technical Council on Lifeline Earthquake Engineering (TCLEE) Sixth U.S. Conference and Workshop BIBLIOGRAPHY 81on Lifeline Earthquake Engineering, August 10-13, 2003, Long Beach, CA, pp 868-877.

Dusicka, P., Glickman, M., and Oppenheimer, H. (2007). "Seismic Vulnerability Assessment of Oregon Highway Bridges," Oregon Department of Transportation.

FEMA (2005). HAZUS-MH MR3 (HAZUS-MH Version 1.3).
King, S. A. and Kiremidjian, A. S. (1994). "Regional Seismic Hazard and Risk Analysis through Geographic Information Systems," The John A. Blume Earthquake Engineering Center, Stanford, CA.

HAZUS. 1999. Earthquake Loss Estimation Technical Manual, National Institute of Building Sciences, Washington D.C.

Iida, Y., Kurauchi, F. and Shimada, H. 2000. Traffic Management System Against Major Earthquakes. *IATSS Research*, Vol. 24 (2) pp 6-17.

Kiremidjian, A, Moore, J., Fan, Y., Yazlali, O., Basoz, N., Williams, M. 2008. Seismic Risk Assessment of Transportation Network Systems, Journal of Earthquake Engineering. *Journal of Earthquake Engineering,* Vol. 11 (3), pp 371 – 382

Luna, R., Hoffman, D., and Lawrence, W. (2008). "Estimation of Earthquake Loss due to Bridge Damage in the St. Louis Metropolitan Area. I: Direct Losses". Journal of American Society of Civil Engineers.

Lund, W. R., (2005). "Consensus Preferred Recurrence-Interval and Vertical Slip-Rate Estimates, Utah Geological Survey Bulletin 134, CD-ROM.

Mahmassani, H., 2001. Dynamic Network Traffic Assignment and Simulation Methodology for Advanced System Management Applications. *Networks and Spatial Economics*, Vol. 1, pp 267-292.

Martin, P.T., Jovanovic, D., and Stevanovic, A. (2007). " 4500 South (300 West To State Street) Closure: The Evaluation of Users' Impacts." University of Utah Traffic Lab, UTL-12-07-94.

Moore, J., Cho, S., Fan, Y., 2006. Quantifying Economic Losses from Travel Foregone Following a Large Metropolitan Earthquake, Pacific Earthquake Engineering Research Center Report No 2006/09, PEER, University of California, Berkeley, CA.

Mountainland Association of Governments (MAG), 2002. Inter-Regional Corridor Alternatives Analysis (IRCAA), Orem, Utah, Ch 2, pp15-18.

National Earthquake Hazards Reduction Program (NEHRP) (1997). "Recommended Provisions for the Development of Seismic Regulations for New Buildings," Building Seismic Safety Council, Washington D.C.

National Bridge Inventory, 2008. Federal Highway Administration http://www.fhwa.dot.gov/Bridge/nbi/ascii.cfm?year=2008

NCEER (1997). "Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils," edited by Youd, T. L., and Idriss, I. M., Technical Report NCEER-97-0022, National Center for Earthquake Engineering Research.

Nilsson, E., 2008. Seismic Risk Assessment of the Transportation Network of Charleston, SC, Master of Science Thesis, Department of Civil and Environmental Engineering, Georgia Institute of Technology.

Nojima, N. 1999. Performance-Based Prioritization for Upgrading Seismic Reliability of a Transportation Network, *Journal of Natural Disaster Science*, Vol.20, No.2, pp 57-66.

Noland, R., Small, K., Koskenoja, P., Chu., X. 1998. Simulating Travel Reliability. *Regional Science and Urban Economics*, Vol. 28(5), pp 535-564.

Olsen, M. J., Bartlett, S. F. and Solomon, B. J., (2007). "Lateral Spread Hazard Mapping of the Northern Salt Lake Valley, Utah, for M7.0 Scenario Earthquake," Earthquake Spectra, Vol. 23, Number 1, pp. 95-113.

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 Miscellaneous Investigations Map I-2106, scale 1:50,000.

Powers, M., Chiou, B., Abrahamson, N., Bozorgnia, Y., Shantz, T. and Roblee, C., (2008). "An Overview of the NGA Project," Earthquake Spectra, Vol. 24, No. 1, pp. 3-21.

REDARS 2 User Guide (2005). Multidisciplinary Center for Earthquake Engineering Research (MCEER).

Schiff, Anshel J. 1995. Northridge Earthquake: Lifeline Performance and Post Earthquake Response, *TCLEE Monograph*, No.8.

Shinozuka, M., Murachi, Y., Dong, X., Zhou, Y., and Orlikowski, M., Ghosh (2006). Effect of Seismic Retrofit of Bridges on Transportation Networks, California Department of Transportation (Caltrans).

Shiraki, N., Shinozuka, M., Hon, M., Moore, J., Chang, S., Kameda, H., and Tanaka, S. (2007). System Risk Curves: Probabilistic Performance Scenarios for Highway Networks Subject to Earthquake Damage.

Silva, W., Gregor, N., and Darragh, R. 2002. Development of Regional Hard-Rock Attenuation Relations for Central and Eastern North America, Pacific Engineering and Analysis, El Cerritto CA.

Silva, W., Gregor, N., and Darragh, R. 2003. Development of Regional Hard-Rock Attenuation Relations for Central and Eastern North America, Mid-Continent, and Gulf Coast Areas, Pacific Engineering and Analysis, El Cerritto CA.

Texas Transportation Institute (2009). Office of the Secretary of Transportation. Urban Mobility Report. http://tti.tamu.edu/documents/mobility_report_2009_wappx.pdf . Accessed on 07/30/2009.

Tokimatsu, K. and Seed, H B, (1987). "Evaluation of Settlements in Sands due to Earthquake Shaking," *Journal of the Geotechnical Engineering Division*, *ASCE*, Vol. 113, No. 8, August, pp 861-878.

UDOT (2008). Standard Specifications for Road and Bridge Construction."

UDOT (1977). "Utah Official Highway Map, 77/78" Utah Department of Transportation.

United States Census Bureau (USCB), Population Division. 2008. Annual Estimates of the Population of Metropolitan and Micropolitan Statistical Areas: April 1, 2000 to July 1, 2007 (CBSA-EST2007-01)" (CSV). 2007 *Population Estimates*.

U.S. Department of Transportation (1997). Office of the Secretary of Transportation. Department Guidance for the Valuation of Travel Time in Economic Analysis. Memorandum. Available Online: http://ostpxweb.dot.gov/policy/data/vot97guid.pdf. Accessed on 06/15/2009.

Utah Department of Transportation (2008). “Traffic Statistics. Annual Truck Traffic Data. http://www.udot.utah.gov/main/uconowner.gf?N=5829105802218755. Accessed on 05/15/2009.

Utah Department of Transportation (2009). Traffic Statistics. Hourly Traffic Volume Reports and ATR Maps. http://www.udot.utah.gov/main/f?P=100:pg:0::::v,t:,2315. Accessed on 05/15/2009.

USBLM (1985). “Utah Land Status, 13132817” United States Bureau of Land Management.

VISUM 10.0 User Manual (2007). PTV Planung Transport Verkehr AG, pp. 2−136.

WFRC (2008). “Natural Hazard Pre-Disaster Mitigation Plan,” Wasatch Regional Council, http://wfrc.org.

Wells, D. L. and Coppersmith, K. J., (1994). “New Empirical Relations among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement,” Bulletin of the Seismological Society of America, Vol. 84, No. 4, pp. 974-1002.

Werner, S., Craig, E. and Moore, J. 1997. Loss Estimation Due to Seismic Risks to Highway Systems, *Earthquake Spectra*, Vol.13, No.4, pp585-604.

Werner, S. D., Taylor, C. E., Moore, J. E. II, Walton, J. S. and Cho, S. (2000). “ A Risk-Based Methodology for Assessing the Seismic Performance of Highway Systems, Technical Report MCEER-00-0014, Multidisciplinary Center for Earthquake Engineering Research, University at Buffalo, NY.

Werner, S. D., Lavoie, JP, Eitzel, C, Cho, S. Huyck, C. Ghosh, S. Eguchi, R. T. Taylor, C. E. and Moore, J. E. (2003). “REDARS 1: Demonstration Software for Seismic Risk Analysis of Highway Systems, Multidisciplinary Center for Earthquake Engineering Research, Report MCEER-03-SP01.

Werner, S., Taylor, C., Cho, S., Lavoie, J., Huyck, C., Eitzel, C., Eguchi, R. and Moore, J., 2004. New Developments in Seismic Risk Analysis of Highway Systems, the Proceedings of the 13th Annual World Conference on Earthquake Engineering, Vancouver, August 1-6, 2004, Paper 2189.

Werner, S.D., Lavoie, J.P., Eitzel, C., Cho, S., Huyck, C., Ghosh, S., Eguchi, R.T., Taylor, C.E., and Moore, J. (2006), Technical Manual - REDARS 1: Demonstration Software for Seismic Risk Analysis of Highway Systems. Multidisciplinary Center for Earthquake Engineering Research (MCEER).

Werner, S. D. Cho, S. Taylor, C. E., Lavoie, JP and Huyck, C. K. (2006a). Seismic Analysis of a Roadway System in the Los Angeles, California Area, Proceedings of the Fifth National Conference (5NSC) on Bridges & Highways: Innovations in Earthquake Engineering for Highway Structures; San Mateo, California, September 18-20, 2006. MCEER Publications, Buffalo, NY, 2006.

Werner, S. D., Taylor, C. E. Cho, S., Lavoie, JP, Huyck, C., Eitzel, C., Chung, H., Eguchi, R. T. (2006b). "REDARS 2 Methodology and Software for Seismic Risk Analysis of Highway Systems, Multidisciplinary Center for Earthquake Engineering Research, Report MCEER-06-SP08.

Werner, S., Taylor, C., Cho, S., Lavoie, J., Huyck, C., and Eguchi, R. (2008). " REDARS 2 Methodology and Software for Seismic Risk Analysis of Highway Systems."Multidisciplinary Center for Earthquake Engineering Research (MCEER).

Wong, I., Silva, W., Wright, D., Olig, S., Ashland, F., Gregor, N., Christenson, G., Pechmann, J., Thomas, P., Dober, M., Gerth, R., (2002). "Ground-Shaking Map for a Magnitude 7.0 Earthquake on the Wasatch Fault, Salt Lake City, Utah, Metropolitan Area," Utah Geological Survey Public Information Series 76, Utah Geological Survey Miscellaneous Publication MP 02-05

Youd, T.L. (2002). "Pavements," Chapter 6 of *Seismic Retrofitting Manual for Highway Structures: Retaining Structures, Slopes, Tunnels, Culverts, and Pavements*, Buffalo NY: Multidisciplinary Center for Earthquake Engineering Research, January.

Youd, T. L, and Perkins, D. M. (1978). "Mapping liquefaction-induced ground failure potential," Journal of the Geotechnical Engineering Division, ASCE, pp. 443-446.

Zhou, X. and Mahmassani. H. S. 2007. A Structural State Space Model for Real-Time Origin-Destination Demand Estimation and Prediction in a Day-to-Day Updating Framework. *Transportation Research Part B*, Vol. 41, No.8, pp 823-840.

Zhou, X, Mahmassani, H.S. and Zhang, K. 2008. Dynamic Micro-assignment Modeling Approach for Integrated Multimodal Urban Corridor Management. *Transportation Research Part C*. Vol. 16, No. 2, pp 167-186.

Appendix 1 – Soil Classification Map for Salt Lake Valley

A1. Introduction

Local site conditions have an important influence on the characteristics of strong ground motion during major earthquakes. In short, wave propagation from a major earthquake on the Salt Lake City Segment of the Wasatch fault is expected to be strongly affected by the sharp impedance contrasts at the bedrock/sediment interface and the attenuation of seismic wave energy in the central part of the basin as a result of the relatively deep soil column and overlying soft lacustrine and alluvial deposits.

This appendix presents a site class map for the various soil/rock conditions in Salt Lake Valley, Utah using geological, geophysical data and the classification system developed by the National Earthquake Hazards Reduction Program (NEHRP, 1997). This map is required for REDAR analyses and is also useful for strong motion studies and developing design spectra according to the seismic provision in ASCE 7-05 and MCEER-ATC-49. To produce the site class map, SH-wave velocities at several sites in the Salt Lake Valley were compiled from conventional downhole, crosshole and surface geophysical techniques. NEHRP site class boundaries were created using the average shear wave velocity of the upper 30 m of the soil profile and surficial geological mapping. The mapping showed that the central portion of the valley, near the Jordan River, is predominantly Site Class E (<180 m/s); however some Site Class F soils may exist, due to the possibility of liquefaction. Sites away from active river and stream deposits, but still found in the central part of the valley floor are underlain by lacustrine silts and clays and typically classify as Site Class D (180–360 m/s.). At higher elevations, denser sand and gravel deposits of terrace, fan, delta and glacial origin generally have Vs30 velocities greater than 360 m/s and classify as Site Class C (360–760 m/s.).

Currently, Utah uses the International Building Code (IBC 2006) for its seismic provisions for buildings and MCEER-ATC-49 for interstate bridges. These codes are essentially the same in outlining the methods for determining the strong motion and design spectra at a given site. IBC (2006), in turn, references ASCE 7-05 for its seismic provisions. Thus, ASCE 7-05 is an integral part of the building codes of the United States and is a complete revision of ASCE 7-02. This new standard has revised and significantly reorganized provisions for seismic design of structures, as well as revisions in the provisions for determining live, flood, wind, snow, and atmospheric ice loads.

The seismic provisions for critical (i.e., interstate) highway bridge design adopted by the Utah Department of Transportation (UDOT) are found in MCEER-ATC49 as implemented in UDOT (2007). These criteria apply to the design of bridges using a performance-based approach. The three performance levels are Operational, Repairable and Life Safety. These performance levels are defined by the expected damage, service and functionality after design earthquakes and depend on the bridge category (Table A1-1).

Table A1-1 Design Events and Performance Levels (UDOT 2007).

Design Earthquakes and Seismic Performance Levels

Seismic Performance Levels					
Ground Motion Level	Event	Design Levels	Critical Bridges	Essential Bridges	Normal Bridges
Maximum Considered EQ (MCE)	2% PE in 50 yrs	Performance Objective	Operational	Repairable	Life Safety
		Service	Immediate	Limited	Significant Disruption
		Damage	Minimal	Moderate	Significant
Expected EQ (EE)	10% PE in 50 yrs	Service	Immediate	Immediate	Immediate
		Damage	Minimal	Minimal	Minimal

Generally, unless specified otherwise by UDOT, the seismic design loading for bridges is based on a 75-year life of the structure and the design considers to design basis ground motions: (1) Maximum Considered Earthquake (MCE) event with strong motion that has a 2 percent probability of exceedance in 50 years and (2) Design level Expected Earthquake (EE) event with strong motion that has a 10 percent probability of exceedance in 50 years (Table A1-1). Further, UDOT classifies its bridges as: (1) Critical bridges that must remain open to all traffic immediately after the MCE, (2) Essential bridges that can only be closed to traffic for a limited period of time for repairs after a design level event (MCE). These bridges should be open for emergency vehicles and for security/defense purposes immediately after the design earthquake and (3) Normal bridges are all other bridges not classified as Critical or Essential.

Both building and bridge code use the National Seismic Hazard Maps to determine the design basis events (USGS 2008a, b). The national maps show the distribution of earthquake strong motion for various levels of exceedance probability in the United States. These maps were created to provide the most accurate and detailed information possible to assist planners, engineers and risk assessors in planning, designing and evaluating infrastructure (e.g., buildings, bridges, highways, utilities, etc.) to withstand shaking from major earthquakes in the United States. For example, the central part of the Salt Lake Valley has pga values that range from about 0.48 to 0.65 g (USGS, 2008b).

A1.2 Soil Effects

For strong motion evaluations of existing facilities and for construction of new facilities located on soils profiles, it is important to consider soil effects. Soft and/or deep soil profiles will either amplify or de-amplify the strong motion depending on the nature and frequency content of the strong motion and the characteristics of the soil profile. Nonlinear behavior of soft and deep soil profiles at higher levels of strong ground motion is of particular interest to Utah, because much of its urban population and infrastructure is located within 10 km of the Wasatch Fault, where future peak ground acceleration (pga) is expected to be 0.3 g to 1.0 g, depending on the site conditions and proximity to the Wasatch fault (Wong et al. 2002). In addition, the Salt Lake Valley, which contains approximately 50 percent of the State's population, is a relatively deep intermountain basin filled with interbedded alluvium and lacustrine deposits that extend to considerable depths. For example, Arnow et al. (1970; see also Wong et al. 2002) estimate that the thickness of unconsolidated Quaternary sediments is about 100 to 360 m near downtown Salt Lake City (Figure A1-1); and such sediments extend to a depth of over 600 m, just north of the downtown area. In addition, late-Pleistocene and Holocene surficial sediments deposited by the Pleistocene-age Lake Bonneville and the present Great Salt Lake are soft, compressible and typically classify as soft to medium consistency clays. Undoubtedly, soft soil effects will play a significant role in modifying the strong motion in the Salt Lake Valley.

The National Seismic Hazard Maps are valid for soft rock conditions (i.e., NEHRP site Class B) where the shear wave velocity in the upper 30 meters (i.e., V_S30) of the profile is between 2500 to 5000 ft/s (Table A1-2). For other site conditions, the national maps must be adjusted for soil effects using either site-specific ground response analyses or generic techniques outlined in MCEER/ATC-49 and ASCE 7-05. Because soil conditions predominate throughout most of Salt Lake Valley, it is necessary to adjust spectral values obtained from the national maps for soil conditions using either ground response analyses or generic techniques in current building or bridge code.

Table A1-2. NEHRP Site Classes used in current building and bridge codes (after MCEER/ATC/49).

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A	> 1500 m/sec (> 5000 ft/sec)	–	–
B	760 to 1500 m/sec (2500 to 5000 ft/sec)	–	–
C	360 to 760 m/sec (1200 to 2500 ft/sec)	> 50	> 100 kPa (> 2000 psf)
D	180 to 360 m/sec (600 to 1200 ft/sec)	15 to 50	50 to 100 kPa (1000 to 2000 psf)
E	< 180 m/sec (<600 ft/sec)	<15 blows/0.30 m (15 blows/ft)	< 50 kPa (<1000 psf)

Table note: If the $\bar{s}_u$ method is used and the $\bar{N}_{ch}$ and $\bar{s}_u$ criteria differ, select the category with the softer soils (for example, use Site Class E instead of D).

MCEER/ATC-49 and ASCE 7-05 use generic site factors to adjust Site Class B spectral values for soil effects. These methods are very similar and a two-factor approach based on recommendations developed by the NCEER/SEAOC/BSSC Site Response Workshop (Rinne and Dobry, 1992; Borcherdt, 1994.). In this simplified approach, the short period acceleration (0.2 s) rock spectral value, S_s, is multiplied by a short-period site coefficient F_a. The longer period spectral values are represented by a curve that begins with the one-second period rock acceleration value, S_1, divided by the period (i.e., S_1/T) and multiplied by the long-period site coefficient, F_v. Recently, ASCE 7-05 has introduced a long period transition period, T_L, in the design spectra that marks the change from constant velocity to constant displacement. Crouse et al. (2006) describe the development of the constant displacement period for ASCE 7-05. For the Salt Lake City Valley, the constant displacement period is 8 seconds (Crouse et al. 2006).

Values of the site coefficients F_a and F_v vary according to soil conditions and level of strong motion. Hence a determination of the site class (Table A1-2) is required to implement MCEER/ATC-49 and ASCE 7-05 and to perform REDARS analyses. The basis for this determination can be obtained from site-specific geophysical or geotechnical testing or it may be estimated from published mapping and shear wave velocity data, such as presented in this appendix.

A1.3 Development of NEHRP Site Class Map

Currently, there is no NEHRP site class map available for the Salt Lake Valley for earthquake resistant design or other seismic evaluations such as REDARS. Thus, the map developed in this appendix will be useful to civil engineers and others, who must implement seismic design procedures or make other evaluations that required site classification. Geographical Information Systems (GIS) is the primary tool used for graphic representation of geospatial data, including: geotechnical, geographical and geologic information. It is the tool used to develop the maps described herein.

In order to create a suitable map for NEHERP site classification, a combination of existing GIS maps and additional geophysical data were used. The process and sources for these data are discussed in the following sections.

A1.3.1 Geologic Mapping

The geologic data for Salt Lake Valley was acquired from two main sources: a surficial geologic map of the Salt Lake City segment of the Wasatch fault zone (Personius and Scott, 1992) for the eastern side of the valley and several quadrangle maps (Biek et al., 2004 and Biek, 2005) that cover the remainder of the valley. These maps were combined to produce the geologic map of the entire valley (Figure A1-2) that was later used in conjunction with the hazard calculations to define the extent of each hazard zone. Table A1-3 summarizes the geologic map units shown on Figure A1-2.

Table A1-3. Geological units and descriptions for Figure A1-2.

Name	Description	Age
Qaf1	Fan alluvium 1	Upper Holocene
Qaf2	Fan alluvium 2	Middle Holocene - Upper Pleistocene
Qafo	Older fan alluvium, undivided	Middle Pleistocene
Qafy	Younger fan alluvium, undivided	Holocene - Uppermost Pleistocene
Qal1	Stream alluvium 1	Upper Holocene
Qal2	Stream alluvium 2	Middle Holocene - Uppermost Pleistocene
Qaly	Younger stream alluvium, undivided	Holocene - Uppermost Pleistocene
Qalp	Stream alluvium related to Lake Bonneville regressive phase	Uppermost Pleistocene
Qes	Eolian sand	Holocene - Upper Pleistocene
Qf	Artificial fill	Historical
Qg	Glacial deposits	Middle - Upper Pleistocene
Qlaly	Lacustrine, marsh, and alluvial deposits, undivided	Holocene - Upper Pleistocene
Qlao	Lacustrine and alluvial deposits, undivided	Holocene - Upper Pleistocene
Qlbg	Lacustrine sand and gravel related to Lake Bonneville transgressive phase	Upper Pleistocene
Qlbm	Lacustrine clay and silt related to Lake Bonneville transgressive phase	Upper Pleistocene
Qlbpg	Lacustrine sand and gravel, undivided by Lake Bonneville phase	Upper Pleistocene
Qlbps	Lacustrine sand and silt, undivided by Lake Bonneville phase	Upper Pleistocene
Qlpg	Lacustrine sand and gravel related to Lake Bonneville regressive phase	Upper Pleistocene
Qlps	Lacustrine sand and silt related to Lake Bonneville regressive phase	Upper Pleistocene
Qly	Marsh and lacustrine deposits, undivided	Holocene - Uppermost Pleistocene
QTaf	Oldest alluvial-fan deposits	Middle Pleistocene
Rock	Bedrock	Various

A1.3.2 Geophysical Measurements

The best method to determine Site Class is shear wave velocity measurements. NEHRP Site Class determination requires that the shear wave velocity measurements be averaged in the upper 30 meters of the profile, which produces a V_s30 value. The V_s30 values for the Salt Lake Valley were superimposed on the geologic map (Figure A1-2). These values were obtained from Ashland and Rollins (1999) and from Bischoff (2005) and entered into the GIS database by Bartlett et al. (2005). In addition to the geological units shown in Figure A1-2, maps of the Salt Lake Valley major roads was obtained from UDOT and the Salt Lake County boundaries were obtained from USDA and NRCS.

A1.3.3 Compilation of the GIS Database and Map Production

All the geospatial data was in the NAD 1983 projected coordinate system data from the three maps into one new map. The geologic data and the major roads had to be clipped to the county boundary polygon.

The shear wave velocity along with the coordinates were imported into the ArcGIS map and then saved as a shape file. The velocities were then displayed as different colors representing their appropriate site class determined using Table A1-2 above. The velocity point data was then clipped to the county boundary (Figure A1-3).

The USGS geologic units with shear wave velocity were given a NEHERP site classification. All the geologic polygons with the same site classification were saved as layer files (Figure A1-3). By extrapolating the known data and using the properties of the soil classified in the USGS map the remaining polygons were converted to NEHRP site classifications.

To complete the final NEHRP soil map, a new color scheme was chosen, legend, metadata, north arrow, and title were added (Figure A1-4).

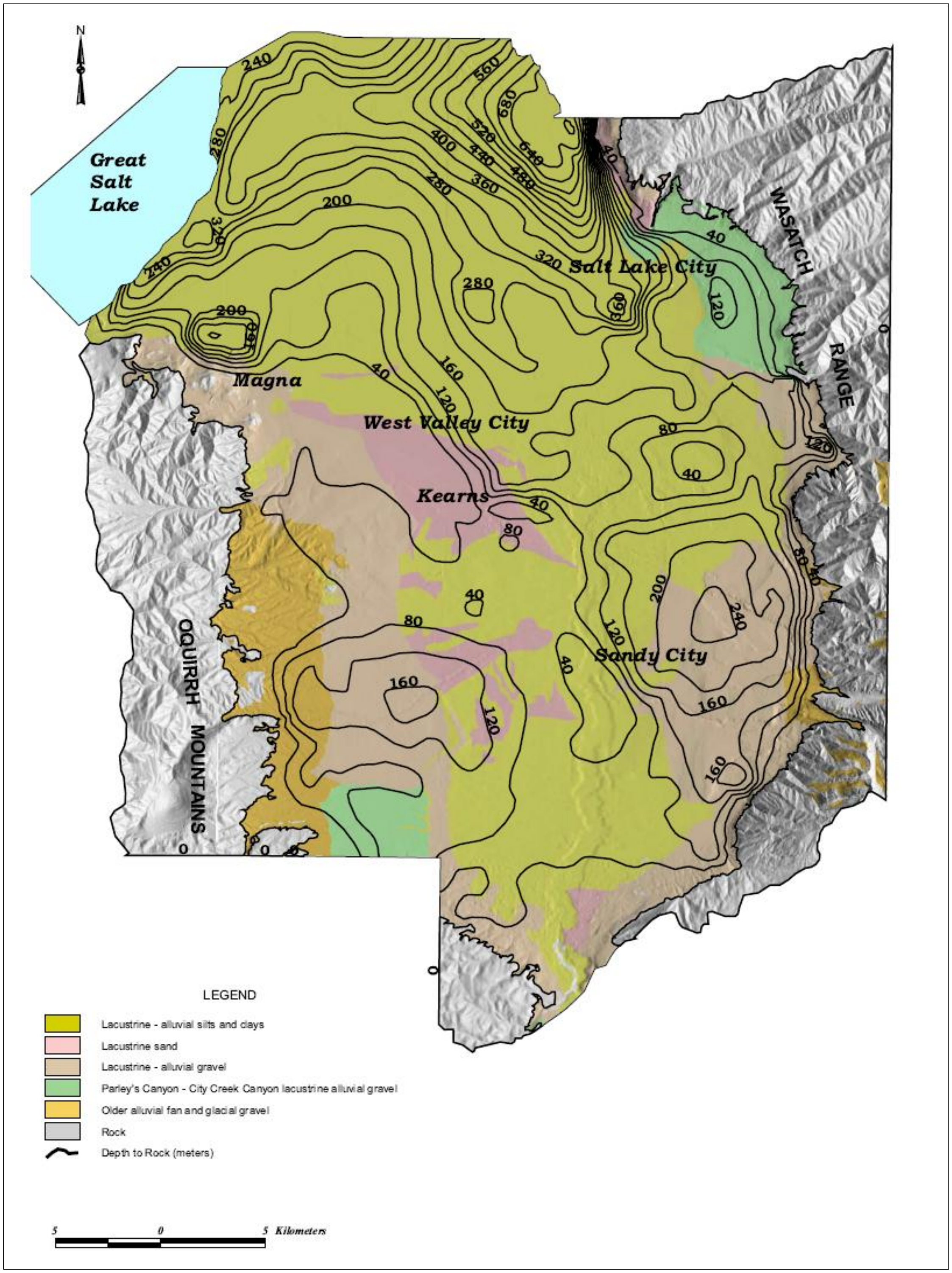

Figure A1-1: Surficial deposits and depth of Quaternary unconsolidated sediments in Salt Lake Valley (after Wong et al. 2002).

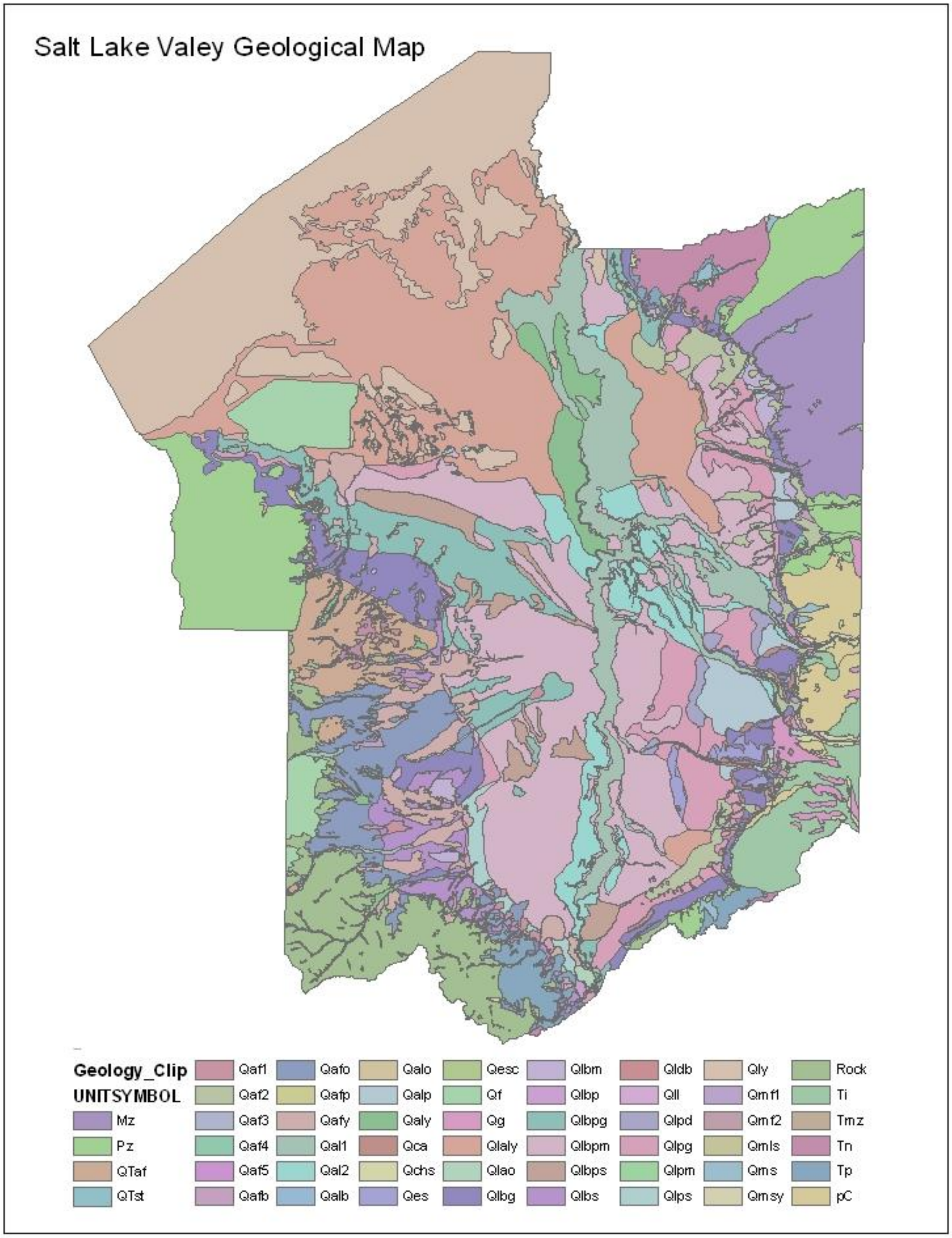

Figure A1-2: Surficial geology map of the Salt Lake Valley, Utah (modified from Personius and Scott, 1992; Biek et al., 2004; and Biek, 2005).

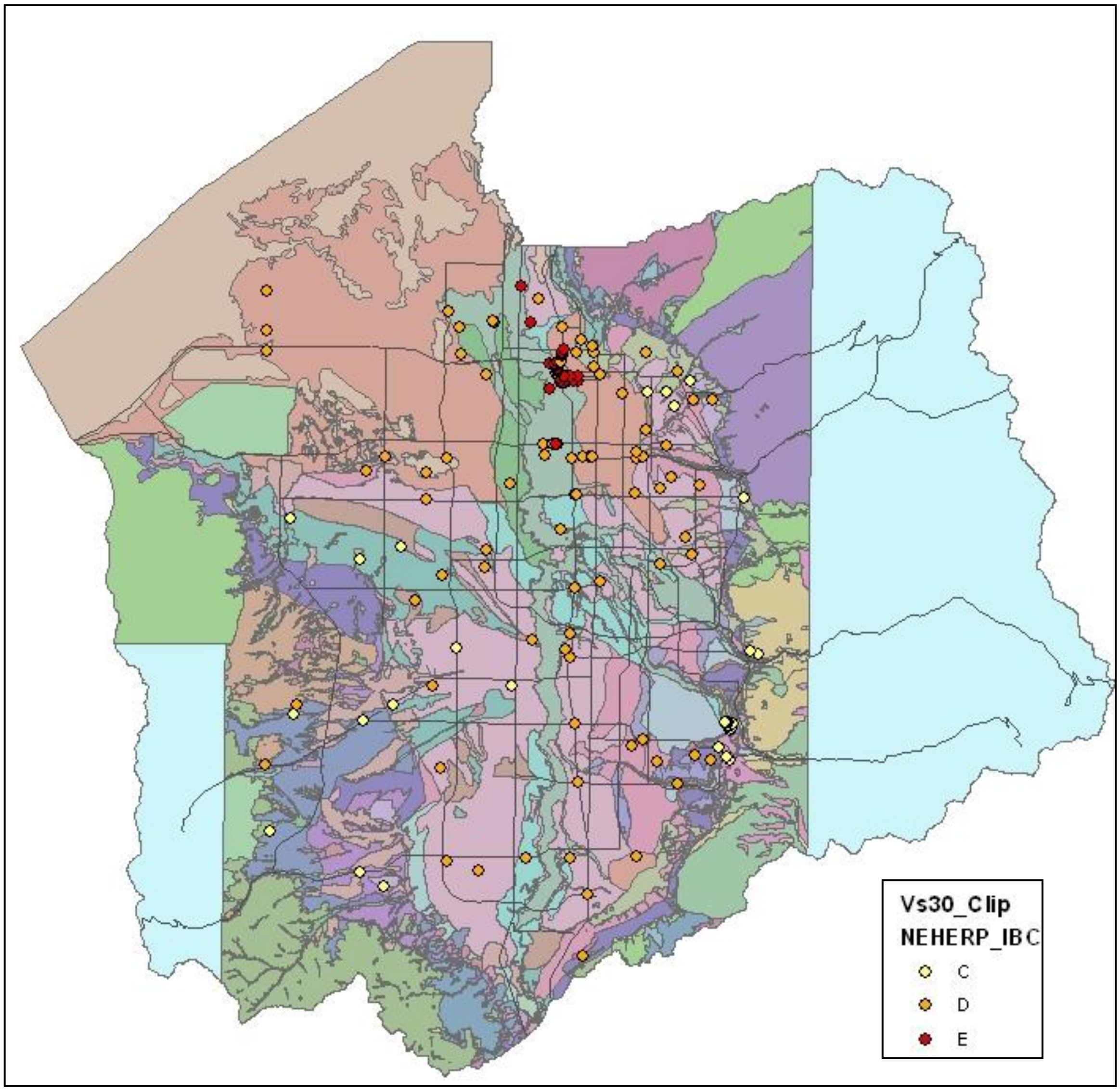

Figure A1-3: Location of Vs30 measurements in Salt Lake Valley, Utah from geophysical testing.

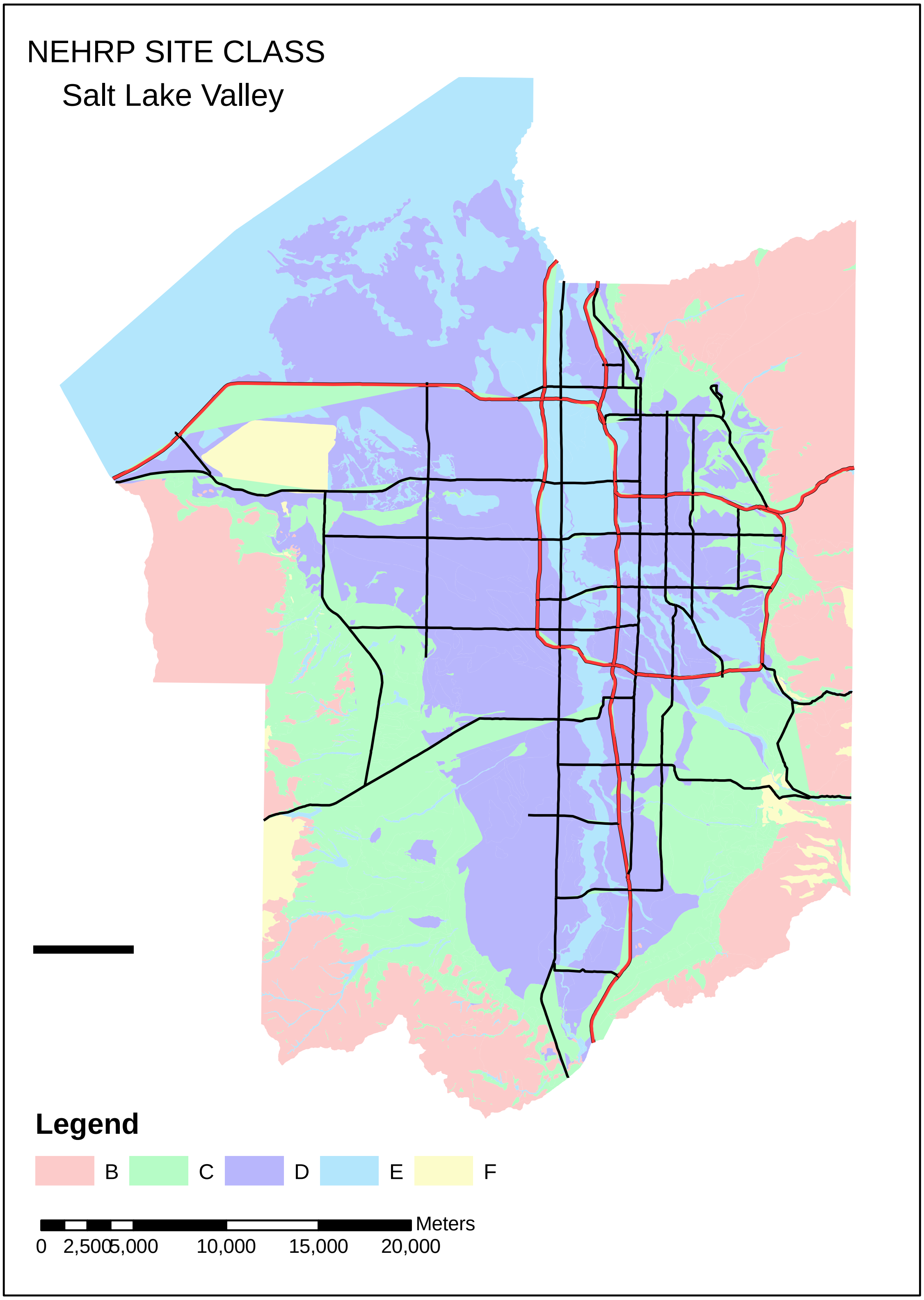

Figure A1-4: NEHRP site class map for Salt Lake Valley, Utah.

Appendix 1 - References

Arnow, T., Van Horn, R., and LaPray, R. (1970). "The pre-Quaternary surface in the Jordan Valley, Utah," *U.S. Geological Survey Professional Paper* 700, p. D257-D261
ASCE 7-05, "Minimum Design Loads for Buildings and Other Structures," American Society of Civil Engineers, 2006, 424 p.

Ashland, F., and Rollins, K. (1999). "Unpublished geotechnical and shear wave velocity database for the Salt Lake Valley," Utah Geological Survey.

Bartlett S. F., Olsen, M. J., and Solomon, B. J. (2005). "Lateral Spread Hazard Mapping of Northern Salt Lake County for a Magnitude 7.0 Scenario Earthquake," United States Geological Survey, USGS Award No. 04HQGR0026, 218 p.

Biek, R. F., Solomon, B. J., Keith, J. D., and Smith T. W. (2004). Interim geologic maps of the Copperton, Magna, and Tickville Spring Quadrangles, Salt Lake and Utah Counties, Utah: Utah Geological Survey Open-File Report 434, scale 1:24,000.

Biek, R. F. (2005). Geologic map of the Jordan Narrows Quadrangle, Salt Lake and Utah Counties, Utah: Utah Geological Survey Map 208, scale 1:24,000.

Bischoff, T.A., 2005, "Collection of shear wave velocity data for use in Utah Geological Survey Site-Conditions maps and database," Master's Project, Utah State University.

Borcherdt, R. D. (1994). Simplified site classes and empirical amplification factors for site-dependent code provisions, *Proceedings of the NCEER/SEAOC/BSSC Workshop on Site Response During Earthquakes and Seismic Code Provision*s, University of Southern California, Los Angeles, November 18-20.

Crouse, C.B., Leyendecker, E.V., Somerville, P.G., Power, M. and Silva, W. J. (2006). Development of seismic ground-motion criteria for the ASCE 7 standard, *Proceedings of the 8th National Earthquake Engineering Conference*, San Francisco California, April 18th – 22nd, 2006.
International Building Code (2006). International Code Council.

MCEER/ATC-49 (2003). "Recommended LRFD Guidelines for the Seismic Design of Highway Bridges," Part I: Specifications, University at Buffalo, State University of New York, 107 Red Jacket Quadrangle, Buffalo, New York.

National Earthquake Hazards Reduction Program (NEHRP) (1997). "Recommended Provisions for the Development of Seismic Regulations for New Buildings," Building Seismic Safety Council, Washington D.C.

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 Miscellaneous Investigations Map I-2106, scale 1:50,000.

Rinne, E., and R. Dobry (1992). Preliminary site recommendations, Memorandum to Roland Sharpe, Chairman TS 2, Building Seismic Safety Council, December 11.

UDOT (2007). "UDOT Structures Design Manual, Section 6: Seismic Design Criteria." Utah Department of Transportation.

USGS (2008a). "2008 United States National Seismic Hazard Maps Fact Sheet 2008-3018, April 2008.

USGS (2008b). "Documentation for the 2008 Update of the United States National Seismic Hazard Maps," USGS Open File Report 2008-1128.

Wong, I. G., Silva, W., Olig, S., Thomas, P., Wright, D., Ashland, F., Gregor, N., Pechmann, J., Dober, M., Christenson, G., and Gerth, R. (2002). Earthquake scenario and probabilistic ground shaking maps for the Salt Lake City, Utah, metropolitan area, *Utah Geological Survey Miscellaneous Publication 02-5*.

Appendix 2 – Liquefaction Evaluations for Transportation Network

REDARS performs an initial screening of the soils based on an assessment of local geology and soil conditions. In this step, the geologic units and depositional processes are evaluated in order to identify those sites along the highway system that can be classed as low-hazard sites. These sites are eliminated from further liquefaction analysis. This evaluation is based on comparisons of the geologic input data to geologic screening criteria that are shown in Table A2-1 and are based on analysis of geologic conditions at sites of past liquefaction (Youd and Perkins, 1978). Table A2-2 shows the hazard assigned to each geological unit based on Table A2-1. The hazard column of Table A2-2 shows the following: 3.00 = high hazard, 2.00 = moderate hazard, 1.00 = low hazard and 0.00 = very low hazard.

Unfortunately, REDARS does not perform liquefaction triggering evaluations and this must be done a priori using other means such as computer algorithms. We performed liquefaction-triggering calculations at each borehole and interpolated the results to each network component location. To do this, the factor of safety against liquefaction was calculated at each borehole location using NCEER (1997) for the scenario earthquake and averaged at each component location using an inverse-distance weighting scheme. The developed routine used the factors of safety against triggering liquefaction for the three nearest boreholes in the weighted average. If the weighted average was less than 1.0, then liquefaction was assumed to occur at the component location and that component was further evaluated for horizontal and vertical liquefaction ground displacement. The liquefaction ground displacement methods are contained within REDARS and were done within this environment.

An extensive ArcGIS® geotechnical database was used for the liquefaction analysis in the Salt Lake Valley (Bartlett et al., 2005; Olsen et al. 2007, Erickson, 2007). The borehole locations are shown in Figure A2-1. Efforts have been made to gather subsurface information for nearly all major geologic units and to document the quality of data of the borehole information. At the time of this study, the database contained subsurface information from 963 boreholes drilled in the valley since 1959 (Figure A2-1). Many of the boreholes are from recent Utah Department of Transportation (UDOT) projects where explorations generally extend to depths of 15 m or greater, especially near bridge structures. In other areas of the valley, the major contributors of subsurface data were Salt Lake County, city municipalities and geotechnical consultants. The electronic geotechnical database used for the liquefaction evaluations can be found at: http://www.civil.utah.edu/~bartlett/ULAG/

The information compiled in the ArcGIS® geotechnical database includes borehole logs, soil descriptions, groundwater levels, SPT blow counts, fines content, mean grain size and soil unit weights. Because the subsurface information originated from a variety of sources and data quality varied, a system was developed to assign data quality indicators to each individual datum (Bartlett et al., 2005). In this system, a "1" was assigned to data where the supporting information was well documented in the original geotechnical report. (In total there were 2,261 fines content and 315 mean grain size measurements in the database that had data quality rankings of "1.") A data quality indicator of "2" was given to data that could be reasonably estimated from nearby borehole logs for the same site, and a "3" denoted data that were averaged from other nearby boreholes based on their soil type and geologic unit. Missing soil unit weight, fines content and mean grain size data that could not be estimated from nearby boreholes were averaged from high quality data within the entire database. For these averages, a "4" was assigned to data that represent averaged properties for the same soil type and geologic unit; and a "5" was assigned to data that represent averaged properties for the same soil type irrespective of the geologic unit. (No SPT penetration resistance data were averaged for this study; if such data were missing, the borehole information was not used.)

A groundwater depth map is required for liquefaction, lateral spread and ground settlement calculations. A comprehensive groundwater map did not exist for the mapped area, nor was there sufficient historical data to accurately model groundwater depths and fluctuations throughout the valley. Thus, the recorded groundwater depths from the borehole logs were used to generate a groundwater map using an inverse distance square interpolation method (Bartlett et al., 2005).

Tables A2-2 and A2-3 show whether or not liquefaction is triggered at the bridge locations for the M6.0 and M7.0 events, respectively. The NBI_REF column is the National Bridge Inventory Reference Number of each structure. The LINK_ID is the link number used by REDARS, X is the latitude of the bridge location, Y is the longitude of the bridge location, UNIT is the respective geologic unit where the bridge is located (see Table 2, main report) and Liquefaction shows if liquefaction is triggered for the input event. The information in these tables was passed to REDARS so that it could calculate the lateral spread and settlement damage at each bridge. Similar analysis was done for each roadway link in the traffic network, but this has not been included in this report due to its length. In addition, the roadway link liquefaction evaluation is deemed less valuable for potential seismic upgrading of the network because it is UDOT's general policy not to remediate potential liquefaction damage to typical roadway. This is based on the fact that most roadways are easily repaired following the liquefaction event.

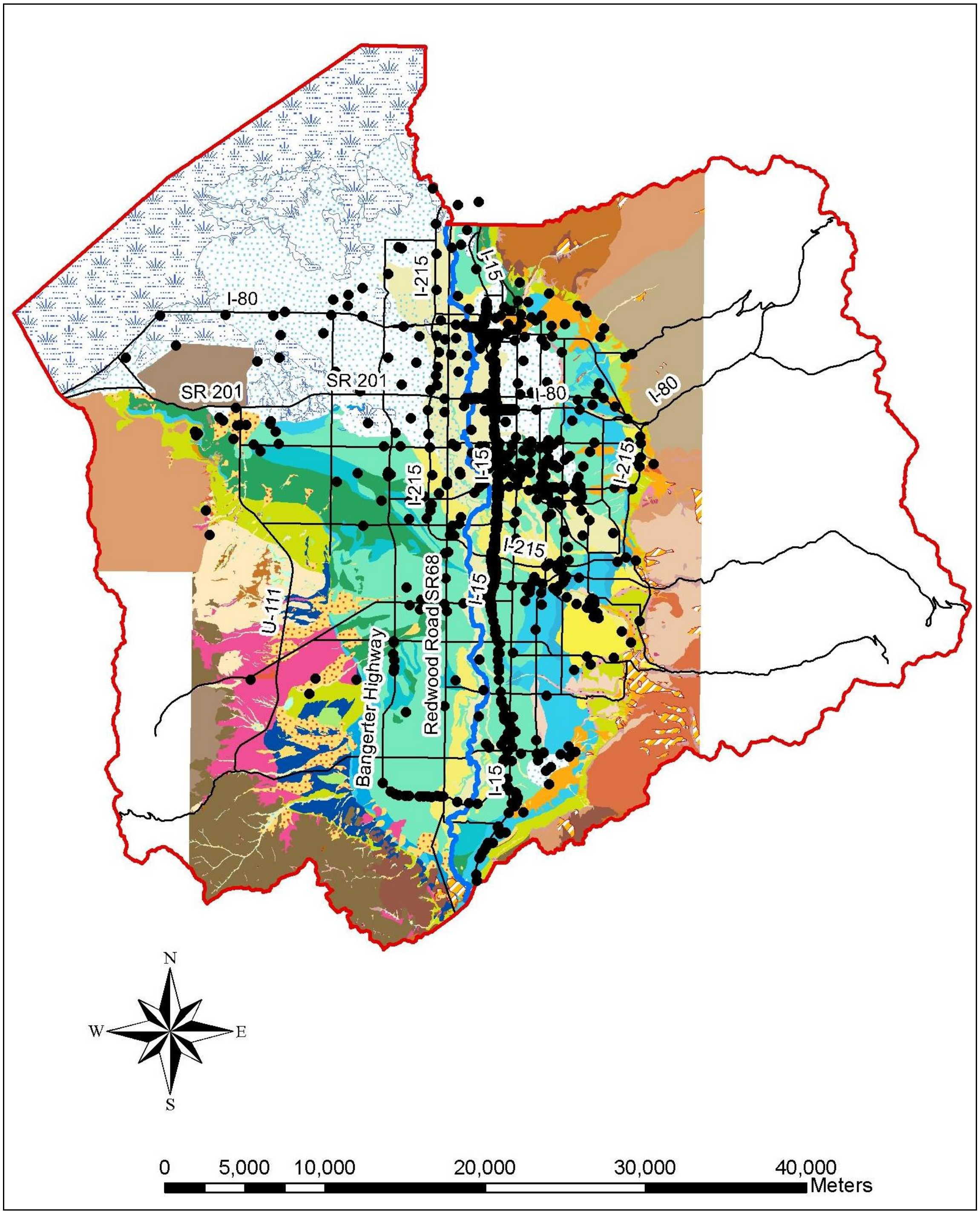

Figure A2-1: Locations of geotechnical boreholes contained in ArcGIS® geotechnical database, Salt Lake Valley, Utah.

Table A2-1 Estimated Susceptibility of Sedimentary Deposits to Liquefaction during Strong Seismic Shaking (Youd and Perkins, 1978)

Type of deposit (1)	General distribution of cohesionless sediments in deposits (2)	Likelihood that Cohesionless Sediments, When Saturated, Would Be Susceptible to Liquefaction (by age of Deposit)			
		<500 yr (3)	Holocene (4)	Pleistocene (5)	Pre-Pleistocene (6)
(a) Continental Deposits					
River channel	Locally variable	Very high	High	Low	Very low
Flood plain	Locally variable	High	Moderate	Low	Very low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very low
Marine terraces and plains	Widespread	----	Low	Very low	Very low
Delta and fan-delta	Widespread	High	Moderate	Low	Very low
Lacustrine and playa	Variable High	Moderate	Low	Very low	
Colluvium	Variable High	Moderate	Low	Very low	
Talus	Widespread	Low	Low	Very low	Very low
Dunes	Widespread	High	Moderate	Low	Very low
Loess	Variable High	High	High	Unknown	
Glacial till	Variable Low	Low	Very low	Very low	
Tuff	Rare	Low	Low	Very low	Very low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very low	Very low
Sebka	Locally variable	High	Moderate	Low	Very low
(b) Coastal Zone					
Delta	Widespread	Very high	High	Low	Very low
Esturine	Locally variable	High	Moderate	Low	Very low
Beach					
High wave energy	Widespread	Moderate	Low	Very low	Very low
Low wave energy	Widespread	High	Moderate	Low	Very low
Lagoonal	Locally variable	High	Moderate	Low	Very low
Fore shore	Locally variable	High	Moderate	Low	Very low
(c) Artificial					
Uncompacted fill	Variable	Very high	----	----	----
Compacted fill	Variable	Low	----	----	----

Table A2-2 Liquefaction Evaluations for Bridges for M6.0 Event

NBI_REF	LINK_ID	X	Y	UNIT	Hazard	Liquefaction
035001E	472	-111.967593000	40.711157000	Qlaly	3.00	does not liquefy
035002E	909	-111.972176000	40.711389000	Qlaly	3.00	does not liquefy
035003D	1344	-111.951245000	40.507912000	Qlbpm	0.00	does not liquefy
035005D	1276	-111.968995000	40.537102000	Qlbpm	0.00	does not liquefy
035006E	1127	-111.923426000	40.630463000	Qal1	3.00	does not liquefy
035007D	1124	-111.926523000	40.630000000	Qlbpm	2.00	does not liquefy
035008E	910	-111.958287000	40.711343000	Qlaly	3.00	does not liquefy
035009D	1052	-111.882356000	40.660324000	Qal1	3.00	does not liquefy
035010D	1054	-111.875694000	40.656204000	Qal1	3.00	does not liquefy
035011D	993	-111.891111000	40.679722000	Qal1	3.00	does not liquefy
035012D	1036	-111.908611000	40.666991000	Qal1	3.00	does not liquefy
035013E	1092	-111.876759000	40.649769000	Qal2	2.00	does not liquefy
035014F	1133	-111.872912000	40.628611000	Qal2	2.00	does not liquefy
035015E	10113	-111.832778000	40.530833000	Qaf1	0.00	does not liquefy
035016D	1244	-111.929167000	40.560602000	Qlbps	0.00	does not liquefy
035017F	1051	-111.906343000	40.666528000	Qal1	3.00	does not liquefy
035018D	1137	-111.851389000	40.626574000	Qlbpm	0.00	does not liquefy
035020D	1042	-111.864903000	40.667731000	Qal1	3.00	does not liquefy
035021D	1212	-111.957315000	40.594167000	Qlbpg	0.00	does not liquefy
035022D	1149	-111.965648000	40.624028000	Qlbpm	0.00	does not liquefy
035023E	823	-111.938565000	40.711435000	Qaly	3.00	does not liquefy
035024F	475	-112.062958000	40.687176000	Qlbps	0.00	does not liquefy
035025F	477	-112.044120000	40.685139000	Qlbps	0.00	does not liquefy
035026F	979	-112.034213000	40.683657000	Qlbps	0.00	does not liquefy
035027D	978	-112.053704000	40.686296000	Qlbps	0.00	does not liquefy
035028D	982	-112.026713000	40.682083000	Qlbps	0.00	does not liquefy
035029F	483	-112.020181000	40.680139000	Qlbps	0.00	does not liquefy
035030D	984	-112.005690000	40.674722000	Qlbps	0.00	does not liquefy
035031F	892	-112.110324000	40.700093000	Qafy	2.00	does not liquefy
035032D	935	-112.081667000	40.691389000	Qlbpg	0.00	does not liquefy
035033F	933	-112.102958000	40.696481000	Qlbpg	0.00	does not liquefy
035034D	1164	-111.881898000	40.615278000	Qlbpm	2.00	does not liquefy
035035F	1190	-111.889028000	40.605926000	Qlbpm	2.00	does not liquefy
035036F	1193	-111.877681000	40.606528000	Qlpg	1.00	does not liquefy
035037D	1192	-111.886157000	40.609491000	Qlbpm	2.00	does not liquefy
035038D	1221	-111.883745000	40.593935000	Qlpg	1.00	does not liquefy
035039E	10091	-111.884856000	40.593148000	Qlpg	1.00	does not liquefy
035040C	1254	-111.885046000	40.591759000	Qlpg	1.00	does not liquefy
035041D	10640	-111.949769000	40.514676000	Qlbpm	0.00	does not liquefy
035042E	1236	-111.967222000	40.578519000	Qlbps	0.00	does not liquefy
035043D	1132	-111.877634000	40.620741000	Qlpg	1.00	does not liquefy
035044F	1358	-111.897546000	40.506991000	Qlbpm	3.00	does not liquefy
035045E	1288	-111.886389000	40.551574000	Qlbpm	3.00	does not liquefy
035046E	1324	-111.876759000	40.537130000	Qlbpm	3.00	does not liquefy
035047F	485	-111.997269000	40.670926000	Qlbpm	0.00	does not liquefy

035048E	1215	-111.954398000	40.587685000	Qlbpm	0.00	does not liquefy
035049D	1321	-111.897500000	40.541574000	Qlbpm	3.00	does not liquefy
035050F	1220	-111.897593000	40.580648000	Qlbpm	3.00	does not liquefy
035051F	1250	-111.892824000	40.580648000	Qlbpm	1.00	does not liquefy
035052E	1219	-111.891435000	40.592037000	Qlbpm	2.00	does not liquefy
035053F	9821	-111.892315000	40.593056000	Qlbpm	2.00	does not liquefy
035054D	1186	-111.921486000	40.609477000	Qal1	3.00	does not liquefy
035055D	1135	-111.871523000	40.617750000	Qlpg	1.00	does not liquefy
035056F	1348	-111.895833000	40.516250000	Qlbpm	3.00	does not liquefy
035057F	1325	-111.888750000	40.544259000	Qlbpm	3.00	does not liquefy
035058F	537	-111.947454000	40.489537000	Qlbpm	0.00	does not liquefy
035059E	4272	-111.948611000	40.491157000	Qal2	2.00	does not liquefy
035060D	1141	-111.806667000	40.631898000	Qal1	3.00	does not liquefy
035061E	10459	-111.956667000	40.540417000	Qlbpm	0.00	does not liquefy
035062C	1047	-111.840278000	40.664722000	Qal1	3.00	does not liquefy
035063D	1143	-111.800278000	40.626204000	Qal1	3.00	does not liquefy
035064D	9363	-111.823935000	40.656296000	Qal1	3.00	does not liquefy
035065D	1104	-111.834347000	40.652037000	Qal1	3.00	does not liquefy
035066D	1062	-111.838704000	40.663935000	Qal1	3.00	does not liquefy
035067C	9252	-111.811528000	40.635556000	Qal1	3.00	does not liquefy
035068D	8695	-111.832917000	40.660278000	Qal1	3.00	does not liquefy
035069D	9370	-111.813148000	40.637917000	Qal1	3.00	does not liquefy
035070D	7043	-111.984301000	40.711713000	Qly	3.00	does not liquefy
035071D	1196	-111.833426000	40.608287000	Qal1	3.00	does not liquefy
035072D	1198	-111.818935000	40.604028000	Qal1	3.00	does not liquefy
035073D	1202	-111.816014000	40.603148000	Qal1	3.00	does not liquefy
035074V	1267	-111.796991000	40.577917000	Qal1	3.00	does not liquefy
035076E	9930	-111.873468000	40.534398000	Qlbpm	3.00	does not liquefy
035077D	1330	-111.872269000	40.532639000	Qlbpm	3.00	does not liquefy
035078E	1353	-111.871204000	40.528704000	Qlbpm	3.00	does not liquefy
035079D	9978	-111.870880000	40.526991000	Qlbpm	3.00	does not liquefy
035080E	10537	-111.870278000	40.523194000	Qlbpm	3.00	does not liquefy
035081D	1360	-111.871204000	40.504583000	Qlbpm	3.00	does not liquefy
035082D	1094	-111.874579000	40.644954000	Qal2	2.00	does not liquefy
035083D	1080	-111.948935000	40.638611000	Qlbpm	0.00	does not liquefy
035084C	1123	-111.948380000	40.638102000	Qlbpm	0.00	does not liquefy
035085F	1391	-111.948657000	40.634167000	Qlbps	0.00	does not liquefy
035086D	1025	-111.967593000	40.654167000	Qlbps	0.00	does not liquefy
035087D	1026	-111.977079000	40.660370000	Qlbpm	0.00	does not liquefy
035088D	487	-111.988056000	40.667593000	Qlbpg	0.00	does not liquefy
035089D	1023	-111.986667000	40.666759000	Qlbpg	0.00	does not liquefy
035090F	954	-111.921343000	40.686435000	Qal1	3.00	does not liquefy
035091F	768	-111.923704000	40.733472000	Qal1	3.00	does not liquefy
035092F	787	-111.933056000	40.733102000	Qal1	3.00	does not liquefy
035093C	734	-111.923190000	40.740602000	Qal1	3.00	does not liquefy
035094P	699	-111.926389000	40.745880000	Qaly	3.00	does not liquefy
035095D	700	-111.921292000	40.751481000	Qal1	3.00	does not liquefy
035096P	664	-111.923009000	40.754167000	Qal1	3.00	does not liquefy
035097F	662	-111.923514000	40.758426000	Qal1	3.00	does not liquefy

035098D	665	-111.923333000	40.758611000	Qal1	3.00	does not liquefy
035099D	618	-111.924676000	40.762778000	Qal1	3.00	does not liquefy
035100F	617	-111.926343000	40.764722000	Qal1	3.00	does not liquefy
035101C	659	-111.953102000	40.750231000	Qal1	3.00	does not liquefy
035102F	6025	-111.958333000	40.758380000	Qaly	3.00	does not liquefy
035103E	575	-111.987315000	40.772778000	Qly	4.00	liquefies
035104E	5300	-111.985880000	40.772639000	Qly	4.00	liquefies
035105V	1216	-111.957912000	40.595417000	Qlbpg	0.00	does not liquefy
035106F	553	-111.935736000	40.791065000	Qal1	3.00	does not liquefy
035107F	560	-111.936528000	40.784444000	Qal1	3.00	does not liquefy
035108D	577	-111.938236000	40.780185000	Qal1	3.00	does not liquefy
035109D	468	-111.999106000	40.711944000	Qly	3.00	does not liquefy
035110D	1045	-111.844625000	40.664861000	Qal1	3.00	does not liquefy
035111D	1370	-111.929444000	40.504722000	Qal2	2.00	does not liquefy
035112D	10430	-111.948611000	40.548380000	Qlbpm	0.00	does not liquefy
035113D	1101	-111.860880000	40.631620000	Qal1	3.00	does not liquefy
035114E	1359	-111.885181000	40.507083000	Qal1	3.00	does not liquefy
035115F	995	-111.899856000	40.681250000	Qal1	3.00	does not liquefy
035116D	1103	-111.853745000	40.634722000	Qal2	2.00	does not liquefy
035117D	918	-111.916991000	40.708426000	Qal1	3.00	does not liquefy
035118F	488	-111.955093000	40.679815000	Qal2	2.00	does not liquefy
035119F	824	-111.935370000	40.717037000	Qlbpm	2.00	does not liquefy
035120F	5015	-111.935139000	40.714213000	Qlbpm	2.00	does not liquefy
035121V	1278	-111.948148000	40.554815000	Qlbpm	0.00	does not liquefy
035122F	6185	-112.062958000	40.769259000	Qlaly	2.00	does not liquefy
035123F	870	-111.885458000	40.705694000	Qal1	3.00	does not liquefy
035124D	1373	-111.878148000	40.500741000	Qlbpm	3.00	does not liquefy
035125C	1084	-111.929537000	40.647639000	Qlbpm	2.00	does not liquefy
035126F	873	-111.882681000	40.704861000	Qal1	3.00	does not liquefy
035127F	957	-111.900139000	40.686806000	Qal2	2.00	does not liquefy
035128C	1085	-111.922958000	40.645324000	Qal1	3.00	does not liquefy
035129F	9642	-111.856759000	40.619537000	Qal1	3.00	does not liquefy
035130F	9909	-111.843468000	40.614444000	Qal1	3.00	does not liquefy
035131D	1060	-111.837403000	40.649398000	Qal1	3.00	does not liquefy
035133D	8488	-111.905556000	40.680000000	Qal1	3.00	does not liquefy
035134D	9575	-111.858009000	40.625694000	Qal1	3.00	does not liquefy
035135E	1056	-111.851245000	40.666759000	Qal1	3.00	does not liquefy
035138E	947	-111.958657000	40.682361000	Qal2	2.00	does not liquefy
035139V	1239	-111.948287000	40.577824000	Qlbpm	0.00	does not liquefy
035140E	869	-111.899722000	40.706343000	Qlaly	4.00	liquefies
035141D	474	-112.072361000	40.688889000	Qlbps	0.00	does not liquefy
035142E	813	-112.082269000	40.715972000	Qlaly	4.00	liquefies
035143D	571	-112.034167000	40.772037000	Qlaly	2.00	does not liquefy
035144D	985	-111.970926000	40.667639000	Qlbps	0.00	does not liquefy
035145F	736	-111.910370000	40.741806000	Qal1	3.00	does not liquefy
035146C	791	-111.908333000	40.725000000	Qal1	3.00	does not liquefy
035147F	1350	-111.894120000	40.521435000	Qlbpm	3.00	does not liquefy
035150D	5531	-111.975556000	40.771389000	Qaly	3.00	does not liquefy
035151E	9644	-111.857593000	40.622870000	Qal1	3.00	does not liquefy

035152C	733	-111.939769000	40.740880000	Qal1	3.00	does not liquefy
035153D	1317	-111.949023000	40.544167000	Qlbpm	0.00	does not liquefy
035154D	875	-111.876944000	40.703194000	Qlaly	4.00	liquefies
035155F	6855	-111.894769000	40.529259000	Qlbpm	3.00	does not liquefy
035156D	9029	-111.895926000	40.530880000	Qlbpm	3.00	does not liquefy
035157E	1286	-111.892176000	40.551481000	Qlbpm	3.00	does not liquefy
035158D	1252	-111.889213000	40.569769000	Qlpg	1.00	does not liquefy
035159V	1255	-111.886523000	40.572315000	Qlpg	1.00	does not liquefy
035160D	9900	-111.856944000	40.620833000	Qal1	3.00	does not liquefy
035161F	1201	-111.807361000	40.593056000	Qal1	3.00	does not liquefy
035162F	10067	-111.807222000	40.588935000	Qal1	3.00	does not liquefy
035163E	10052	-111.941806000	40.587731000	Qlbpm	0.00	does not liquefy
035164D	10540	-111.881759000	40.538657000	Qlbpm	3.00	does not liquefy
035165D	1361	-111.867917000	40.513194000	Qlaly	4.00	liquefies
035166D	906	-111.999167000	40.711944000	Qly	3.00	does not liquefy
035167D	4042	-111.991847000	40.711157000	Qly	3.00	does not liquefy
035168D	8862	-111.989625000	40.668333000	Qlbpg	0.00	does not liquefy
035169E	10463	-111.951569000	40.540046000	Qlbpm	0.00	does not liquefy
035170V	9381	-111.873750000	40.489815000	Qlpg	0.00	does not liquefy
035171V	10732	-111.874120000	40.489861000	Qlpg	0.00	does not liquefy
035172V	1379	-111.846157000	40.505231000	Qaf1	0.00	does not liquefy
035173D	9038	-111.893657000	40.527778000	Qlbpm	3.00	does not liquefy
035174D	10597	-111.870278000	40.506435000	Qlbpm	3.00	does not liquefy
035175D	8983	-111.931523000	40.643148000	Qlbpm	2.00	does not liquefy
035176E	10086	-111.885278000	40.589306000	Qlpg	1.00	does not liquefy
035177D	1316	-111.973148000	40.535324000	Qlbpm	0.00	does not liquefy
035178V	10460	-111.970833000	40.538889000	Qlbpm	0.00	does not liquefy
035179D	1188	-111.923935000	40.609028000	Qlbpm	2.00	does not liquefy
035181F	1245	-111.915833000	40.571944000	Qal1	3.00	does not liquefy
035182V	1249	-111.916569000	40.572083000	Qlbpm	2.00	does not liquefy
035183D	9331	-111.948333000	40.628380000	Qlbpm	0.00	does not liquefy
035184D	5999	-111.899491000	40.575926000	Qlpg	1.00	does not liquefy
035185D	3733	-111.895736000	40.575926000	Qlpg	1.00	does not liquefy
035188C	1049	-111.898056000	40.655278000	Qal1	2.00	does not liquefy
035189E	1354	-111.866667000	40.519028000	Qlaly	4.00	liquefies
035191C	5532	-111.985926000	40.773519000	Qly	4.00	liquefies
035192F	5542	-111.986389000	40.774444000	Qly	4.00	liquefies
035193C	5544	-111.991111000	40.777222000	Qly	4.00	liquefies
035194C	5533	-111.986847000	40.773472000	Qly	4.00	liquefies
035195C	5902	-111.980278000	40.777778000	Qlaly	4.00	liquefies
035197D	1284	-111.927500000	40.543056000	Qlbpm	2.00	does not liquefy
035198E	1320	-111.917403000	40.548657000	Qal1	3.00	does not liquefy
035199E	10336	-111.944347000	40.559815000	Qlbpm	0.00	does not liquefy
035200E	1241	-111.944583000	40.573194000	Qlbpm	0.00	does not liquefy
0C 369	580	-111.932778000	40.765509000	Qal1	3.00	does not liquefy
0C 377	5813	-111.935556000	40.765787000	Qal1	3.00	does not liquefy
0C 401	701	-111.899444000	40.747546000	Qal1	3.00	does not liquefy
0C 417	559	-111.913426000	40.786528000	Qal2	2.00	does not liquefy
0C 420	828	-111.888657000	40.718102000	Qlaly	4.00	liquefies

0C 422	841	-111.806157000	40.713704000	Mz	0.00	does not liquefy
0C 460	661	-111.948468000	40.751759000	Qal1	3.00	does not liquefy
0C 493	5290	-111.920833000	40.815509000	Qly	4.00	liquefies
0C 518	891	-111.797361000	40.686898000	Qalp	0.00	does not liquefy
0C 576	584	-111.906389000	40.771667000	Qlaly	4.00	liquefies
0C 584	1129	-111.898333000	40.634722000	Qlbpm	2.00	does not liquefy
0C 620	1096	-111.889537000	40.631574000	Qlbpm	2.00	does not liquefy
0C 621	1098	-111.891111000	40.633889000	Qlbpm	2.00	does not liquefy
0C 629	489	-111.951847000	40.682222000	Qal2	2.00	does not liquefy
0C 635	6190	-112.063148000	40.770694000	Qlaly	2.00	does not liquefy
0C 649	9450	-111.920278000	40.638426000	Qal1	3.00	does not liquefy
0C 659	914	-111.952500000	40.704259000	Qlaly	3.00	does not liquefy
0C 662	473	-111.953333000	40.712500000	Qaly	3.00	does not liquefy
0C 669	573	-112.025093000	40.770880000	Qlaly	4.00	liquefies
0C 688	6069	-111.950833000	40.758843000	Qal1	3.00	does not liquefy
0C 689	6075	-111.950556000	40.759769000	Qal1	3.00	does not liquefy
0C 692	616	-111.950458000	40.765139000	Qaly	3.00	does not liquefy
0C 693	5563	-111.948981000	40.771296000	Qaly	3.00	does not liquefy
0C 704	5967	-111.950926000	40.762361000	Qal1	3.00	does not liquefy
0C 709	471	-111.968565000	40.726759000	Qlaly	2.00	does not liquefy
0C 725	9306	-111.872037000	40.629815000	Qal2	2.00	does not liquefy
0C 726	9310	-111.864722000	40.629583000	Qal2	2.00	does not liquefy
0C 752	6605	-111.949167000	40.706759000	Qaly	3.00	does not liquefy
0C 757	1110	-111.808611000	40.638426000	Qlpd	0.00	does not liquefy
0C 759	9505	-111.811065000	40.638426000	Qal2	0.00	does not liquefy
0C 806	566	-111.901944000	40.782500000	Qlaly	4.00	liquefies
0C 812	955	-111.903333000	40.686667000	Qal2	2.00	does not liquefy
0C 813	851	-111.904444000	40.712222000	Qal1	3.00	does not liquefy
0C 814	1087	-111.901847000	40.660741000	Qal2	2.00	does not liquefy
0C 815	534	-111.976569000	40.502593000	Qlbpm	0.00	does not liquefy
0C 816	583	-111.911111000	40.781944000	Qlaly	4.00	liquefies
0C 817	10448	-111.929301000	40.497810000	Qal1	3.00	does not liquefy
0C 819	9146	-111.891435000	40.504167000	Qlbpm	3.00	does not liquefy
0D 410	10542	-111.871111000	40.530787000	Qlbpm	3.00	does not liquefy
0D 480	767	-111.938889000	40.740093000	Qal1	3.00	does not liquefy
0D 564	547	-111.939069000	40.808056000	Qal1	4.00	liquefies
0D 775	581	-111.926389000	40.771528000	Qal1	3.00	does not liquefy
0D 805	9171	-111.923333000	40.653056000	Qal1	3.00	does not liquefy
0D 807	1399	-111.778792000	40.572407000	Qchs	2.00	does not liquefy
0D 809	917	-111.924903000	40.699444000	Qal1	3.00	does not liquefy
0D 811	996	-111.888148000	40.679630000	Qal1	3.00	does not liquefy
0E 907	1398	-111.781435000	40.618657000	Qalp	2.00	does not liquefy
0E1032	1371	-111.900093000	40.489028000	Qlbpm	3.00	does not liquefy
0E1064	9818	-111.890694000	40.601806000	Qlbpm	2.00	does not liquefy
0E1065	3731	-111.890736000	40.583148000	Qlpg	1.00	does not liquefy
0E1066	1257	-111.890787000	40.574306000	Qlpg	1.00	does not liquefy
0E1067	1258	-111.890694000	40.571250000	Qlpg	1.00	does not liquefy
0E1068	1259	-111.890736000	40.567685000	Qlpd	0.00	does not liquefy
0E1070	5165	-111.890278000	40.554167000	Qlbpm	3.00	does not liquefy

0E1200	920	-111.904167000	40.706389000	Qal1	3.00	does not liquefy
0E1201	3797	-111.901898000	40.680898000	Qal1	3.00	does not liquefy
0E1218	998	-111.880926000	40.674259000	Qal1	3.00	does not liquefy
0E1227	1044	-111.867454000	40.666528000	Qal1	3.00	does not liquefy
0E1229	8951	-111.854213000	40.667361000	Qal1	3.00	does not liquefy
0E1272	5772	-112.203611000	40.725926000	Qlaly	4.00	liquefies
0E1283	988	-111.937315000	40.667505000	Qal2	2.00	does not liquefy
0E1286	8609	-111.911250000	40.674907000	Qal1	3.00	does not liquefy
0E1324	546	-111.946111000	40.828333000	Qly	2.00	does not liquefy
0E1445	1248	-111.900278000	40.565556000	Qlbpm	3.00	does not liquefy
0E1683	536	-111.942037000	40.485231000	Qal2	2.00	does not liquefy
0E1709	652	-111.850648000	40.758935000	Qlbpm	0.00	does not liquefy
0E1767	1377	-111.892083000	40.492269000	Qlbpm	3.00	does not liquefy
0E1833	7454	-111.953102000	40.711389000	Qaly	3.00	does not liquefy
0E1858	1100	-111.865181000	40.642037000	Qal2	2.00	does not liquefy
0E1908	821	-111.960926000	40.725370000	Qlaly	2.00	does not liquefy
0E1909	1035	-111.929491000	40.652870000	Qal2	2.00	does not liquefy
0E2113	1030	-111.966343000	40.653102000	Qlbps	0.00	does not liquefy
0E2150	1125	-111.938657000	40.634259000	Qlbps	2.00	does not liquefy
0E2225	1090	-111.888148000	40.660926000	Qal1	3.00	does not liquefy
0E2372	7119	-111.979856000	40.708611000	Qlaly	3.00	does not liquefy
0E2374	8867	-111.981343000	40.662778000	Qlbpg	0.00	does not liquefy
0E2379	1180	-111.963380000	40.609463000	Qlbpm	0.00	does not liquefy
0E2381	1185	-111.919069000	40.587639000	Qal1	3.00	does not liquefy
0E2405	512	-111.970046000	40.588426000	Qlbpg	0.00	does not liquefy
0E2421	983	-112.024583000	40.681389000	Qlbps	0.00	does not liquefy
0E2439	10587	-111.953333000	40.500556000	Qlbpm	0.00	does not liquefy
0E2475	4998	-111.906713000	40.486111000	Qlbpm	3.00	does not liquefy
0E2480	10339	-111.940000000	40.562222000	Qlbps	0.00	does not liquefy
0E2486	1243	-111.938704000	40.582037000	Qlbpm	0.00	does not liquefy
0E2507	10478	-111.921921000	40.523676000	Qal1	3.00	does not liquefy
0E2528	1343	-111.949537000	40.522315000	Qlbpm	0.00	does not liquefy
0F 6	4934	-111.929954000	40.764912000	Qal1	3.00	does not liquefy
0F 7	5825	-111.926435000	40.764583000	Qal1	3.00	does not liquefy
0F 33	5815	-111.938935000	40.764167000	Qal1	3.00	does not liquefy
0F 34	5817	-111.938935000	40.764722000	Qal1	3.00	does not liquefy
0F 35	5995	-111.939028000	40.765926000	Qal1	3.00	does not liquefy
0F 48	834	-111.853657000	40.719583000	Qlbm	2.00	does not liquefy
0F 49	836	-111.842125000	40.718565000	Qal1	0.00	does not liquefy
0F 52	890	-111.808843000	40.716667000	Qlbg	0.00	does not liquefy
0F 54	1396	-111.795556000	40.716435000	Mz	0.00	does not liquefy
0F 115	8932	-111.908333000	40.674769000	Qal1	3.00	does not liquefy
0F 131	1128	-111.910231000	40.635833000	Qlbpm	2.00	does not liquefy
0F 156	1012	-111.803009000	40.674630000	Qlbg	0.00	does not liquefy
0F 244	1218	-111.913102000	40.587731000	Qal1	3.00	does not liquefy
0F 344	5536	-112.025000000	40.768426000	Qlaly	4.00	liquefies
0F 410	6282	-111.948102000	40.746250000	Qal1	3.00	does not liquefy
0F 419	5931	-111.965880000	40.764444000	Qaly	3.00	does not liquefy
0F 431	5497	-111.949769000	40.813194000	Qal1	4.00	liquefies

0F 458	9415	-111.807958000	40.646204000	Qaf2	2.00	does not liquefy
0F 470	552	-111.949815000	40.805648000	Qal1	4.00	liquefies
0F 475	9533	-111.862454000	40.629861000	Qal2	2.00	does not liquefy
0F 477	4760	-111.949306000	40.733056000	Qaly	3.00	does not liquefy
0F 500	576	-111.948611000	40.784676000	Qaly	3.00	does not liquefy
0F 504	9577	-111.854583000	40.630185000	Qal2	2.00	does not liquefy
0F 505	1108	-111.825134000	40.634907000	Qlpg	0.00	does not liquefy
0F 506	1138	-111.833981000	40.632824000	Qlpg	0.00	does not liquefy
0F 522	762	-111.986157000	40.725694000	Qlaly	2.00	does not liquefy
0F 523	5020	-112.024722000	40.725602000	Qlaly	2.00	does not liquefy
0F 547	570	-112.182824000	40.745139000	Qly	2.00	does not liquefy
0F 562	9646	-111.789347000	40.619722000	Qal2	2.00	does not liquefy
0F 571	1154	-111.921245000	40.623750000	Qal1	3.00	does not liquefy
0F 576	1211	-111.977037000	40.593519000	Qlbpg	0.00	does not liquefy
0F 579	10085	-111.886759000	40.588426000	Qlpg	1.00	does not liquefy
0F 580	1290	-111.883148000	40.558796000	Qlbpm	3.00	does not liquefy
0F 595	718	-112.177546000	40.740833000	Qlaly	4.00	liquefies
0F 596	1314	-111.984120000	40.536759000	Qlbpm	0.00	does not liquefy
0F 607	4999	-111.919722000	40.497130000	Qal1	3.00	does not liquefy
0F 608	539	-111.936204000	40.486435000	Qal1	3.00	does not liquefy
0F 663	5998	-111.897870000	40.559074000	Qlbpm	3.00	does not liquefy
0F 683	5997	-111.908236000	40.558889000	Qal1	3.00	does not liquefy
0F 687	620	-111.911065000	40.761157000	Qal1	3.00	does not liquefy
0F 693	11070	-111.922037000	40.523380000	Qlbpm	2.00	does not liquefy
0F 727	1261	-111.871944000	40.568889000	Qca	0.00	does not liquefy
0V 737	5789	-112.155880000	40.721620000	Qlbpg	0.00	does not liquefy
1C 520	948	-111.952269000	40.696204000	Qlaly	3.00	does not liquefy
1C 528	1032	-111.952269000	40.667454000	Qlbpm	2.00	does not liquefy
1C 587	1081	-111.952361000	40.651157000	Qlbpm	2.00	does not liquefy
1C 617	6861	-111.951481000	40.725046000	Qaly	3.00	does not liquefy
1C 628	658	-111.987222000	40.764167000	Qlaly	4.00	liquefies
1C 663	950	-111.951481000	40.689306000	Qal2	2.00	does not liquefy
1C 664	7927	-111.950278000	40.696389000	Qlaly	3.00	does not liquefy
1C 668	729	-111.986713000	40.758287000	Qlaly	2.00	does not liquefy
1C 698	6163	-111.950000000	40.758380000	Qal1	3.00	does not liquefy
1C 699	6165	-111.950000000	40.760093000	Qal1	3.00	does not liquefy
1C 700	9400	-111.949769000	40.762824000	Qaly	3.00	does not liquefy
1C 701	6032	-111.948102000	40.764861000	Qaly	3.00	does not liquefy
1C 737	5630	-111.986759000	40.752917000	Qlaly	2.00	does not liquefy
1C 738	5777	-111.986713000	40.754583000	Qlaly	2.00	does not liquefy
1C 827	1157	-111.903611000	40.620093000	Qlbpm	2.00	does not liquefy
1C 829N	1159	-111.903009000	40.628843000	Qlbpm	2.00	does not liquefy
1C 832N	4534	-111.904722000	40.634722000	Qlbpm	2.00	does not liquefy
1C 833	4016	-111.902315000	40.631574000	Qal1	3.00	does not liquefy
1C 836N	1089	-111.902870000	40.642917000	Qal2	2.00	does not liquefy
1C 849	792	-111.903333000	40.721389000	Qal1	3.00	does not liquefy
1C 850	843	-111.900556000	40.717222000	Qlaly	4.00	liquefies
1C 860N	7069	-111.904259000	40.722269000	Qal1	3.00	does not liquefy
1C 861	7405	-111.903333000	40.721389000	Qal1	3.00	does not liquefy

1C 868N	715	-111.841944000	40.747500000	Qlbpm	0.00	does not liquefy
1C 870	666	-111.908333000	40.758333000	Qal1	3.00	does not liquefy
1C 875N	5822	-111.922912000	40.766667000	Qal1	3.00	does not liquefy
1C 880N	622	-111.905787000	40.768704000	Qlaly	4.00	liquefies
1C 931	974	-111.797222000	40.688889000	Qalp	0.00	does not liquefy
1D 672	5394	-111.916481000	40.818565000	Qlbpg	0.00	does not liquefy
1E1322	5501	-111.948009000	40.811389000	Qal1	4.00	liquefies
1F 56	6854	-111.894491000	40.544213000	Qlbpm	3.00	does not liquefy
1F 207	9192	-111.898889000	40.483611000	Qlpg	0.00	does not liquefy
1F 609N	10072	-111.900370000	40.587870000	Qlbpm	3.00	does not liquefy
1F 610N	1160	-111.903333000	40.620278000	Qlbpm	2.00	does not liquefy
1F 611N	4536	-111.903704000	40.630787000	Qal1	3.00	does not liquefy
1F 613N	8659	-111.904347000	40.632083000	Qal1	3.00	does not liquefy
1F 615N	8714	-111.904537000	40.635972000	Qlbpm	2.00	does not liquefy
1F 616N	3993	-111.899537000	40.654815000	Qal2	2.00	does not liquefy
1F 617N	1037	-111.901806000	40.674870000	Qal1	3.00	does not liquefy
1F 618N	3799	-111.902500000	40.693426000	Qal2	2.00	does not liquefy
1F 619N	959	-111.900736000	40.697778000	Qal2	2.00	does not liquefy
1F 622	852	-111.900556000	40.717222000	Qlaly	4.00	liquefies
1F 628	7598	-111.904167000	40.718333000	Qal1	3.00	does not liquefy
1F 629	7600	-111.903981000	40.717685000	Qal1	3.00	does not liquefy
1F 630N	7070	-111.904069000	40.725370000	Qal1	3.00	does not liquefy
1F 631	793	-111.903472000	40.725370000	Qal1	3.00	does not liquefy
1F 633N	771	-111.904537000	40.733472000	Qal1	3.00	does not liquefy
1F 634	7026	-111.904537000	40.733472000	Qal1	3.00	does not liquefy
1F 636N	738	-111.904444000	40.745741000	Qal1	3.00	does not liquefy
1F 637N	2289	-111.906481000	40.747639000	Qal1	3.00	does not liquefy
1F 646N	7314	-111.899537000	40.569769000	Qlbpm	3.00	does not liquefy
1F 647N	1189	-111.904815000	40.605648000	Qlbpm	2.00	does not liquefy
1F 648N	5104	-111.905602000	40.610602000	Qlbpm	2.00	does not liquefy
1F 649N	7162	-111.901667000	40.667778000	Qal1	3.00	does not liquefy
1F 655N	6425	-111.903935000	40.741481000	Qal1	3.00	does not liquefy
1F 656	7023	-111.903056000	40.740833000	Qal1	3.00	does not liquefy
1F 658N	682	-111.910417000	40.751944000	Qal1	3.00	does not liquefy
1F 660N	5824	-111.921292000	40.765000000	Qal1	3.00	does not liquefy
1F 661N	4422	-111.910370000	40.771574000	Qlaly	4.00	liquefies
1F 662N	5595	-111.910181000	40.776065000	Qlaly	4.00	liquefies
1F 664	8756	-111.901389000	40.632222000	Qal2	2.00	does not liquefy
1F 694	1352	-111.890833000	40.526667000	Qlbpm	3.00	does not liquefy
2C 400	2290	-111.903190000	40.747315000	Qal1	3.00	does not liquefy
2C 402	7014	-111.905278000	40.741944000	Qal1	3.00	does not liquefy
2C 421	885	-111.817958000	40.712870000	Qlbm	2.00	does not liquefy
2C 438	1394	-112.220556000	40.725139000	Qly	2.00	does not liquefy
2C 551	798	-111.871667000	40.718611000	Qlaly	4.00	liquefies
2C 554	8804	-111.907269000	40.636528000	Qlbpm	2.00	does not liquefy
2C 585	9166	-111.939259000	40.644583000	Qlbpm	2.00	does not liquefy
2C 624	5564	-111.966111000	40.765463000	Qaly	3.00	does not liquefy
2C 631	5719	-111.982917000	40.763796000	Qlaly	4.00	liquefies
2C 633	5827	-111.986620000	40.769815000	Qly	4.00	liquefies

2C 637	5835	-111.982731000	40.765370000	Qlaly	4.00	liquefies
2C 702	5965	-111.949722000	40.765278000	Qaly	3.00	does not liquefy
2C 710	6183	-112.039583000	40.771111000	Qlaly	2.00	does not liquefy
2C 732	6175	-112.005556000	40.769769000	Qlaly	4.00	liquefies
2C 761	9507	-111.811157000	40.634954000	Qal1	3.00	does not liquefy
2C 838	772	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 839	794	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 844	7034	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 845	7036	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 854	7605	-111.898889000	40.718333000	Qlaly	4.00	liquefies
2C 871	7038	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 876	6093	-111.915370000	40.761296000	Qal1	3.00	does not liquefy
2C 884	6056	-111.916944000	40.763611000	Qal1	3.00	does not liquefy
2C 887	5427	-111.917125000	40.814213000	Pz	0.00	does not liquefy
2C 919	7470	-112.117958000	40.717731000	Qlbpg	0.00	does not liquefy
2F 43	830	-111.882361000	40.718380000	Qlaly	4.00	liquefies
2F 44	853	-111.893704000	40.717870000	Qlaly	4.00	liquefies
2F 46	800	-111.865000000	40.719120000	Qlaly	4.00	liquefies
2F 47	802	-111.858380000	40.719537000	Qlbpm	0.00	does not liquefy
2F 50	839	-111.822731000	40.712963000	Qlbm	2.00	does not liquefy
2F 51	886	-111.822731000	40.712963000	Qlbm	2.00	does not liquefy
2F 71	846	-111.874347000	40.718148000	Qlaly	4.00	liquefies
2F 76	5472	-111.944301000	40.831759000	Qal1	4.00	liquefies
2F 133	9467	-111.922222000	40.638657000	Qal1	3.00	does not liquefy
2F 283	9440	-111.932546000	40.644491000	Qlbpm	2.00	does not liquefy
2F 620E	789	-111.925000000	40.724074000	Qal1	3.00	does not liquefy
2F 621E	825	-111.917269000	40.724537000	Qal1	3.00	does not liquefy
2F 624	7604	-111.899722000	40.718889000	Qlaly	4.00	liquefies
2F 625	7608	-111.899722000	40.718889000	Qlaly	4.00	liquefies
2F 626E	854	-111.891389000	40.718333000	Qlaly	4.00	liquefies
2F 627	7629	-111.891389000	40.718333000	Qlaly	4.00	liquefies
2F 640	668	-111.907778000	40.755833000	Qal1	3.00	does not liquefy
2F 643	6058	-111.919903000	40.764444000	Qal1	3.00	does not liquefy
2F 645	6084	-111.920000000	40.764074000	Qal1	3.00	does not liquefy
2F 651E	7619	-111.894722000	40.717778000	Qlaly	4.00	liquefies
3C 423	889	-111.805556000	40.712778000	Mz	0.00	does not liquefy
3C 520	7820	-111.952870000	40.697037000	Qlaly	3.00	does not liquefy
3C 528	8854	-111.952778000	40.667500000	Qlbpm	2.00	does not liquefy
3C 587	3266	-111.952958000	40.653380000	Qlbpm	2.00	does not liquefy
3C 617	6898	-111.951481000	40.725787000	Qaly	3.00	does not liquefy
3C 625	5840	-111.987269000	40.765185000	Qlaly	4.00	liquefies
3C 663	7932	-111.952083000	40.690000000	Qal2	2.00	does not liquefy
3C 668	5846	-111.987269000	40.758843000	Qlaly	2.00	does not liquefy
3C 694	9438	-111.951292000	40.758796000	Qal1	3.00	does not liquefy
3C 695	9532	-111.951991000	40.760000000	Qal1	3.00	does not liquefy
3C 696	5992	-111.947315000	40.766204000	Qaly	3.00	does not liquefy
3C 697	6055	-111.945000000	40.767130000	Qaly	3.00	does not liquefy
3C 703	9480	-111.951065000	40.766019000	Qaly	3.00	does not liquefy
3C 737	5848	-111.987222000	40.753426000	Qlaly	2.00	does not liquefy

3C 738	5850	-111.987222000	40.755139000	Qlaly	2.00	does not liquefy
3C 739	6077	-111.946759000	40.766343000	Qaly	3.00	does not liquefy
3C 828	1163	-111.903611000	40.621111000	Qlbpm	2.00	does not liquefy
3C 829S	8885	-111.903935000	40.629861000	Qlbpm	2.00	does not liquefy
3C 830	4015	-111.904120000	40.629444000	Qlbpm	2.00	does not liquefy
3C 832S	8984	-111.905417000	40.635324000	Qlbpm	2.00	does not liquefy
3C 834	9225	-111.905556000	40.635370000	Qlbpm	2.00	does not liquefy
3C 835	9445	-111.905412000	40.636667000	Qlbpm	2.00	does not liquefy
3C 836S	1086	-111.903333000	40.643472000	Qal2	2.00	does not liquefy
3C 842	7756	-111.902778000	40.715278000	Qlaly	4.00	liquefies
3C 859	7596	-111.904722000	40.718657000	Qal1	3.00	does not liquefy
3C 860S	7597	-111.904861000	40.722685000	Qal1	3.00	does not liquefy
3C 862	7624	-111.905370000	40.722593000	Qal1	3.00	does not liquefy
3C 868S	6423	-111.909537000	40.749167000	Qal1	3.00	does not liquefy
3C 875S	6095	-111.914769000	40.761481000	Qal1	3.00	does not liquefy
3C 878	657	-111.998056000	40.763333000	Qlaly	4.00	liquefies
3C 880S	4424	-111.911801000	40.769676000	Qlaly	4.00	liquefies
3C 886	6097	-111.915968000	40.764815000	Qal1	3.00	does not liquefy
3C 931	7449	-111.797778000	40.689444000	Qalp	0.00	does not liquefy
3F 53	8433	-111.796894000	40.707593000	Qlbm	0.00	does not liquefy
3F 56	9238	-111.895181000	40.544537000	Qlbpm	3.00	does not liquefy
3F 207	6449	-111.902593000	40.747407000	Qal1	3.00	does not liquefy
3F 609S	10074	-111.901944000	40.588704000	Qlbpm	3.00	does not liquefy
3F 610S	4014	-111.903611000	40.621111000	Qlbpm	2.00	does not liquefy
3F 611S	9446	-111.904444000	40.630972000	Qal1	3.00	does not liquefy
3F 612	9484	-111.904815000	40.630648000	Qal1	3.00	does not liquefy
3F 613S	9496	-111.905000000	40.632269000	Qal1	3.00	does not liquefy
3F 614	9486	-111.905833000	40.633056000	Qal2	2.00	does not liquefy
3F 615S	9495	-111.904537000	40.636667000	Qlbpm	2.00	does not liquefy
3F 616S	3995	-111.901111000	40.653333000	Qal2	2.00	does not liquefy
3F 617S	8931	-111.901898000	40.674861000	Qal1	3.00	does not liquefy
3F 618S	8010	-111.902634000	40.695787000	Qal2	2.00	does not liquefy
3F 619S	8012	-111.902315000	40.697778000	Qal2	2.00	does not liquefy
3F 630S	922	-111.897222000	40.706111000	Qlaly	4.00	liquefies
3F 632	7789	-111.902778000	40.715278000	Qlaly	4.00	liquefies
3F 633S	7071	-111.905134000	40.733889000	Qal1	3.00	does not liquefy
3F 635	7263	-111.905324000	40.733333000	Qal1	3.00	does not liquefy
3F 636S	6707	-111.904722000	40.744583000	Qal1	3.00	does not liquefy
3F 637S	6711	-111.907037000	40.747083000	Qal1	3.00	does not liquefy
3F 646S	10246	-111.899625000	40.569722000	Qlbpm	3.00	does not liquefy
3F 647S	9175	-111.905231000	40.606250000	Qlbpm	2.00	does not liquefy
3F 648S	9748	-111.906528000	40.611204000	Qlbpm	2.00	does not liquefy
3F 649S	8935	-111.901759000	40.667593000	Qal1	3.00	does not liquefy
3F 653	7627	-111.905509000	40.722731000	Qal1	3.00	does not liquefy
3F 654	7791	-111.905556000	40.723611000	Qal1	3.00	does not liquefy
3F 655S	7029	-111.904583000	40.741944000	Qal1	3.00	does not liquefy
3F 657	7033	-111.905134000	40.741898000	Qal1	3.00	does not liquefy
3F 658S	6119	-111.911389000	40.752315000	Qal1	3.00	does not liquefy
3F 660S	5842	-111.913981000	40.765417000	Qal1	3.00	does not liquefy

3F 661S	5829	-111.911204000	40.772130000	Qlaly	4.00	liquefies
3F 662S	5626	-111.910926000	40.776250000	Qlaly	4.00	liquefies
3F 665	8024	-111.906014000	40.718889000	Qal1	3.00	does not liquefy
3F 694	9114	-111.891389000	40.526667000	Qlbpm	3.00	does not liquefy
4C 400	6599	-111.902593000	40.747546000	Qal1	3.00	does not liquefy
4C 402	683	-111.896111000	40.747778000	Qal1	3.00	does not liquefy
4C 424	16778	-111.790134000	40.711944000	Mz	0.00	does not liquefy
4C 438	17029	-112.220139000	40.725694000	Qly	2.00	does not liquefy
4C 551	848	-111.870833000	40.718935000	Qlaly	4.00	liquefies
4C 585	9333	-111.938514000	40.645000000	Qlbpm	2.00	does not liquefy
4C 710	17321	-112.038889000	40.771343000	Qlaly	2.00	does not liquefy
4C 727	9535	-111.861435000	40.630000000	Qal1	3.00	does not liquefy
4C 736	1139	-111.833981000	40.631759000	Qlpg	0.00	does not liquefy
4C 760	9593	-111.811245000	40.635648000	Qal1	3.00	does not liquefy
4C 837	6635	-111.912958000	40.724907000	Qal1	3.00	does not liquefy
4C 841	6702	-111.909167000	40.750000000	Qal1	3.00	does not liquefy
4C 846	6708	-111.909167000	40.750000000	Qal1	3.00	does not liquefy
4C 847	8026	-111.902222000	40.718056000	Qlaly	4.00	liquefies
4C 848	6964	-111.909167000	40.750000000	Qal1	3.00	does not liquefy
4C 851	8030	-111.902222000	40.718056000	Qlaly	4.00	liquefies
4C 852	8039	-111.902222000	40.718056000	Qlaly	4.00	liquefies
4C 853	7633	-111.899444000	40.718056000	Qlaly	4.00	liquefies
4C 855	7632	-111.896801000	40.718380000	Qlaly	4.00	liquefies
4C 856	7639	-111.896759000	40.718750000	Qlaly	4.00	liquefies
4C 873	6099	-111.910000000	40.755556000	Qal1	3.00	does not liquefy
4C 874	624	-111.900278000	40.759167000	Qlaly	4.00	liquefies
4C 883	6101	-111.919167000	40.764444000	Qal1	3.00	does not liquefy
4C 885	6104	-111.916759000	40.764769000	Qal1	3.00	does not liquefy
4C 919	7487	-112.117824000	40.718056000	Qlaly	4.00	liquefies
4F 36	6531	-111.965972000	40.765046000	Qaly	3.00	does not liquefy
4F 43	856	-111.882361000	40.718380000	Qlaly	4.00	liquefies
4F 44	857	-111.877037000	40.717870000	Qlaly	4.00	liquefies
4F 46	849	-111.865412000	40.719630000	Qlaly	4.00	liquefies
4F 47	859	-111.856944000	40.720000000	Qlbpm	0.00	does not liquefy
4F 50	838	-111.833611000	40.716806000	Qal1	3.00	does not liquefy
4F 51	8384	-111.822222000	40.713287000	Qlbm	2.00	does not liquefy
4F 71	877	-111.873792000	40.718750000	Qlaly	4.00	liquefies
4F 133	9471	-111.921847000	40.638889000	Qal1	3.00	does not liquefy
4F 283	9453	-111.931991000	40.645000000	Qlbpm	2.00	does not liquefy
4F 415	9761	-111.966292000	40.765509000	Qaly	3.00	does not liquefy
4F 620W	3728	-111.925046000	40.724537000	Qal1	3.00	does not liquefy
4F 621W	6732	-111.917269000	40.724537000	Qal1	3.00	does not liquefy
4F 623	7840	-111.899444000	40.718056000	Qlaly	4.00	liquefies
4F 626W	7641	-111.891389000	40.718333000	Qlaly	4.00	liquefies
4F 641	641	-111.900278000	40.759167000	Qlaly	4.00	liquefies
4F 642	7064	-111.914167000	40.727269000	Qal1	3.00	does not liquefy
4F 651W	7651	-111.893889000	40.718472000	Qlaly	4.00	liquefies
4F 652	7654	-111.893889000	40.718750000	Qlaly	4.00	liquefies
035191C	5879	-111.985926000	40.773519000	Qly	4.00	liquefies

035192F	5885	-111.986389000	40.774444000	Qly	4.00	liquefies
035194C	5901	-111.986847000	40.773472000	Qly	4.00	liquefies
0C 141	5105	-111.890787000	40.608148000	Qlbpm	2.00	does not liquefy
0C 253	932	-112.092037000	40.677222000	Qafy	0.00	does not liquefy
0C 254	499	-112.054676000	40.615370000	QTaf	0.00	does not liquefy
0C 317	953	-111.905278000	40.702500000	Qal1	3.00	does not liquefy
0C 369	6074	-111.932778000	40.765509000	Qal1	3.00	does not liquefy
0C 384	1040	-111.896806000	40.674398000	Qal2	2.00	does not liquefy
0C 385	1039	-111.894213000	40.674398000	Qal2	2.00	does not liquefy
0C 401	740	-111.899444000	40.747546000	Qal1	3.00	does not liquefy
0C 417	564	-111.913426000	40.786528000	Qal2	2.00	does not liquefy
0C 420	7661	-111.888657000	40.718102000	Qlaly	4.00	liquefies
0C 422	8413	-111.806157000	40.713704000	Mz	0.00	does not liquefy
0C 436	1014	-112.074023000	40.652065000	Qlbg	0.00	does not liquefy
0C 441	9619	-111.905556000	40.620880000	Qlbpm	2.00	does not liquefy
0C 460	6679	-111.948468000	40.751759000	Qal1	3.00	does not liquefy
0C 493	5492	-111.920833000	40.815509000	Qly	4.00	liquefies
0C 497	9443	-111.907546000	40.620926000	Qlbpm	2.00	does not liquefy
0C 505	9474	-111.898611000	40.635000000	Qlbpm	2.00	does not liquefy
0C 508	9844	-111.902315000	40.634769000	Qlbpm	2.00	does not liquefy
0C 509	9516	-111.902037000	40.635556000	Qlbpm	2.00	does not liquefy
0C 518	7451	-111.797361000	40.686898000	Qalp	0.00	does not liquefy
0C 545	8739	-111.798657000	40.678472000	Qlbg	0.00	does not liquefy
0C 561	8946	-111.898426000	40.655093000	Qal2	2.00	does not liquefy
0C 576	5843	-111.906389000	40.771667000	Qlaly	4.00	liquefies
0C 579	9442	-111.934306000	40.643889000	Qlbpm	2.00	does not liquefy
0C 584	9473	-111.898333000	40.634722000	Qlbpm	2.00	does not liquefy
0C 620	9452	-111.889537000	40.631574000	Qlbpm	2.00	does not liquefy
0C 621	9490	-111.891111000	40.633889000	Qlbpm	2.00	does not liquefy
0C 629	1389	-111.951847000	40.682222000	Qal2	2.00	does not liquefy
0C 635	6192	-112.063148000	40.770694000	Qlaly	2.00	does not liquefy
0C 649	9482	-111.920278000	40.638426000	Qal1	3.00	does not liquefy
0C 659	7802	-111.952500000	40.704259000	Qlaly	3.00	does not liquefy
0C 662	7741	-111.953333000	40.712500000	Qaly	3.00	does not liquefy
0C 669	5538	-112.025093000	40.770880000	Qlaly	4.00	liquefies
0C 675	990	-111.939069000	40.675648000	Qal2	2.00	does not liquefy
0C 688	9552	-111.950833000	40.758843000	Qal1	3.00	does not liquefy
0C 692	9598	-111.950458000	40.765139000	Qaly	3.00	does not liquefy
0C 693	5966	-111.948981000	40.771296000	Qaly	3.00	does not liquefy
0C 704	9622	-111.950926000	40.762361000	Qal1	3.00	does not liquefy
0C 705	9309	-111.881898000	40.632870000	Qal2	2.00	does not liquefy
0C 709	6596	-111.968565000	40.726759000	Qlaly	2.00	does not liquefy
0C 725	9308	-111.872037000	40.629815000	Qal2	2.00	does not liquefy
0C 726	9536	-111.864722000	40.629583000	Qal2	2.00	does not liquefy
0C 752	7803	-111.949167000	40.706759000	Qaly	3.00	does not liquefy
0C 757	9638	-111.808611000	40.638426000	Qlpd	0.00	does not liquefy
0C 759	9631	-111.811065000	40.638426000	Qal2	0.00	does not liquefy
0C 762	3971	-112.091157000	40.666019000	Qlbg	0.00	does not liquefy
0C 766	1019	-112.024625000	40.659444000	Qlbpg	0.00	does not liquefy

0C 779	10641	-111.920968000	40.486963000	Qlbps	0.00	does not liquefy
0C 785	5200	-111.976944000	40.593426000	Qlbpg	0.00	does not liquefy
0C 800	1238	-111.977315000	40.573056000	Qlbpm	0.00	does not liquefy
0C 806	568	-111.901944000	40.782500000	Qlaly	4.00	liquefies
0C 807	10077	-111.902778000	40.587870000	Qlbpm	3.00	does not liquefy
0C 809	6826	-111.901236000	40.559116000	Qlbpm	3.00	does not liquefy
0C 812	992	-111.903333000	40.686667000	Qal2	2.00	does not liquefy
0C 813	8016	-111.904444000	40.712222000	Qal1	3.00	does not liquefy
0C 814	8836	-111.901847000	40.660741000	Qal2	2.00	does not liquefy
0C 815	6697	-111.976569000	40.502593000	Qlbpm	0.00	does not liquefy
0C 816	5592	-111.911111000	40.781944000	Qlaly	4.00	liquefies
0C 817	11286	-111.929301000	40.497810000	Qal1	3.00	does not liquefy
0C 818	9140	-111.913935000	40.497269000	Qal2	2.00	does not liquefy
0C 819	10582	-111.891435000	40.504167000	Qlbpm	3.00	does not liquefy
0C 822	10606	-111.957454000	40.500287000	Qlbpm	0.00	does not liquefy
0C 823	7121	-111.979856000	40.703657000	Qlaly	3.00	does not liquefy
0C 890	8448	-111.801801000	40.712176000	Mz	0.00	does not liquefy
0C 891	8452	-111.796204000	40.708519000	Mz	0.00	does not liquefy
0C 895	1071	-112.004255000	40.652778000	Qlbpg	0.00	does not liquefy
0C 896	4334	-111.982634000	40.507593000	Qlbpm	0.00	does not liquefy
0C 897	486	-111.981523000	40.682037000	Qlbpm	0.00	does not liquefy
0C 906	1341	-111.984444000	40.522037000	Qlbpm	0.00	does not liquefy
0C 911	1282	-111.928981000	40.562037000	Qlbps	0.00	does not liquefy
0C 920	9499	-111.898514000	40.635370000	Qlbpm	2.00	does not liquefy
0C 921	595	-111.837315000	40.765000000	Qlpm	0.00	does not liquefy
0C 927	1178	-111.971944000	40.614444000	Qlbpm	0.00	does not liquefy
0C 934	10450	-111.956991000	40.522361000	Qlbpm	0.00	does not liquefy
0C 939	7740	-111.938889000	40.712778000	Qaly	3.00	does not liquefy
0D 449	10146	-112.089213000	40.566259000	Qafo	0.00	does not liquefy
0F 6	6086	-111.929954000	40.764912000	Qal1	3.00	does not liquefy
0F 34	6087	-111.938935000	40.764722000	Qal1	3.00	does not liquefy
0F 35	6090	-111.939028000	40.765926000	Qal1	3.00	does not liquefy
0F 48	861	-111.853657000	40.719583000	Qlbm	2.00	does not liquefy
0F 49	864	-111.842125000	40.718565000	Qal1	0.00	does not liquefy
0F 52	8412	-111.808843000	40.716667000	Qlbg	0.00	does not liquefy
0F 54	11902	-111.795556000	40.716435000	Mz	0.00	does not liquefy
0F 131	9485	-111.910231000	40.635833000	Qlbpm	2.00	does not liquefy
0F 156	8757	-111.803009000	40.674630000	Qlbg	0.00	does not liquefy
0F 310	9193	-111.888472000	40.653704000	Qlbpm	2.00	does not liquefy
0F 410	6307	-111.948102000	40.746250000	Qal1	3.00	does not liquefy
0F 431	5769	-111.949769000	40.813194000	Qal1	4.00	liquefies
0F 458	9641	-111.807958000	40.646204000	Qaf2	2.00	does not liquefy
0F 470	5771	-111.949815000	40.805648000	Qal1	4.00	liquefies
0F 475	9683	-111.862454000	40.629861000	Qal2	2.00	does not liquefy
0F 477	6427	-111.949306000	40.733056000	Qaly	3.00	does not liquefy
0F 500	5557	-111.948611000	40.784676000	Qaly	3.00	does not liquefy
0F 504	9685	-111.854583000	40.630185000	Qal2	2.00	does not liquefy
0F 505	1140	-111.825134000	40.634907000	Qlpg	0.00	does not liquefy
0F 506	9627	-111.833981000	40.632824000	Qlpg	0.00	does not liquefy

0F 522	7011	-111.986157000	40.725694000	Qlaly	2.00	does not liquefy
0F 523	5069	-112.024722000	40.725602000	Qlaly	2.00	does not liquefy
0F 547	7444	-112.182824000	40.745139000	Qly	2.00	does not liquefy
0F 576	10843	-111.977037000	40.593519000	Qlbpg	0.00	does not liquefy
0F 596	4836	-111.984120000	40.536759000	Qlbpm	0.00	does not liquefy
0F 663	6828	-111.897870000	40.559074000	Qlbpm	3.00	does not liquefy
0F 696	4869	-111.905093000	40.526759000	Qlbpm	3.00	does not liquefy
0R 8	9313	-111.875417000	40.630694000	Qal1	2.00	does not liquefy
0R 32	9549	-111.866847000	40.630648000	Qal2	2.00	does not liquefy
0R 34	9888	-111.871944000	40.630324000	Qal2	2.00	does not liquefy
0R 35	9890	-111.866528000	40.630602000	Qal2	2.00	does not liquefy
0R 36	9893	-111.864722000	40.629583000	Qal2	2.00	does not liquefy
0R 54	9895	-111.854583000	40.630185000	Qal2	2.00	does not liquefy
0R 55	9896	-111.858611000	40.630324000	Qal2	2.00	does not liquefy
0R 56	9912	-111.859579000	40.629861000	Qal1	3.00	does not liquefy
0R 59	9405	-111.848704000	40.630833000	Qlbpm	0.00	does not liquefy
0R 61	9673	-111.837917000	40.631759000	Qlpg	0.00	does not liquefy
0R 255	9747	-111.921435000	40.609583000	Qal1	3.00	does not liquefy
0R 256	9791	-111.921435000	40.609583000	Qal1	3.00	does not liquefy
0R 257	9758	-111.976991000	40.609167000	Qlbpm	0.00	does not liquefy
0R 288	10845	-111.976991000	40.593009000	Qlbpg	0.00	does not liquefy
0V 984	9751	-111.907546000	40.620972000	Qlbpm	2.00	does not liquefy
1C 520	7929	-111.952269000	40.696204000	Qlaly	3.00	does not liquefy
1C 528	8891	-111.952269000	40.667454000	Qlbpm	2.00	does not liquefy
1C 587	3345	-111.952361000	40.651157000	Qlbpm	2.00	does not liquefy
1C 617	6989	-111.951481000	40.725046000	Qaly	3.00	does not liquefy
1C 628	6033	-111.987222000	40.764167000	Qlaly	4.00	liquefies
1C 663	7935	-111.951481000	40.689306000	Qal2	2.00	does not liquefy
1C 664	7936	-111.950278000	40.696389000	Qlaly	3.00	does not liquefy
1C 698	7482	-111.950000000	40.758380000	Qal1	3.00	does not liquefy
1C 700	9737	-111.949769000	40.762824000	Qaly	3.00	does not liquefy
1C 700	9817	-111.949769000	40.762824000	Qaly	3.00	does not liquefy
1C 701	6685	-111.948102000	40.764861000	Qaly	3.00	does not liquefy
1C 738	6035	-111.986713000	40.754583000	Qlaly	2.00	does not liquefy
1C 827	9753	-111.903611000	40.620093000	Qlbpm	2.00	does not liquefy
1C 832N	9838	-111.904722000	40.634722000	Qlbpm	2.00	does not liquefy
1C 833	9834	-111.902315000	40.631574000	Qal1	3.00	does not liquefy
1C 836N	9267	-111.902870000	40.642917000	Qal2	2.00	does not liquefy
1C 849	8044	-111.903333000	40.721389000	Qal1	3.00	does not liquefy
1C 850	8022	-111.900556000	40.717222000	Qlaly	4.00	liquefies
1C 860N	8047	-111.904259000	40.722269000	Qal1	3.00	does not liquefy
1C 861	8049	-111.903333000	40.721389000	Qal1	3.00	does not liquefy
1C 868N	717	-111.841944000	40.747500000	Qlbpm	0.00	does not liquefy
1C 875N	6106	-111.922912000	40.766667000	Qal1	3.00	does not liquefy
1C 880N	5863	-111.905787000	40.768704000	Qlaly	4.00	liquefies
1C 931	8434	-111.797222000	40.688889000	Qalp	0.00	does not liquefy
1D 672	5480	-111.916481000	40.818565000	Qlbpg	0.00	does not liquefy
1F 56	9240	-111.894491000	40.544213000	Qlbpm	3.00	does not liquefy
1F 207	9303	-111.898889000	40.483611000	Qlpg	0.00	does not liquefy

1F 609N	10079	-111.900370000	40.587870000	Qlbpm	3.00	does not liquefy
1F 610N	9814	-111.903333000	40.620278000	Qlbpm	2.00	does not liquefy
1F 613N	9837	-111.904347000	40.632083000	Qal1	3.00	does not liquefy
1F 615N	11046	-111.904537000	40.635972000	Qlbpm	2.00	does not liquefy
1F 616N	9011	-111.899537000	40.654815000	Qal2	2.00	does not liquefy
1F 617N	8939	-111.901806000	40.674870000	Qal1	3.00	does not liquefy
1F 619N	8015	-111.900736000	40.697778000	Qal2	2.00	does not liquefy
1F 628	8045	-111.904167000	40.718333000	Qal1	3.00	does not liquefy
1F 629	8428	-111.903981000	40.717685000	Qal1	3.00	does not liquefy
1F 630N	7293	-111.904069000	40.725370000	Qal1	3.00	does not liquefy
1F 631	7096	-111.903472000	40.725370000	Qal1	3.00	does not liquefy
1F 633N	7294	-111.904537000	40.733472000	Qal1	3.00	does not liquefy
1F 634	7297	-111.904537000	40.733472000	Qal1	3.00	does not liquefy
1F 636N	6712	-111.904444000	40.745741000	Qal1	3.00	does not liquefy
1F 637N	6714	-111.906481000	40.747639000	Qal1	3.00	does not liquefy
1F 646N	10364	-111.899537000	40.569769000	Qlbpm	3.00	does not liquefy
1F 647N	9806	-111.904815000	40.605648000	Qlbpm	2.00	does not liquefy
1F 648N	9803	-111.905602000	40.610602000	Qlbpm	2.00	does not liquefy
1F 649N	8942	-111.901667000	40.667778000	Qal1	3.00	does not liquefy
1F 655N	7040	-111.903935000	40.741481000	Qal1	3.00	does not liquefy
1F 656	7042	-111.903056000	40.740833000	Qal1	3.00	does not liquefy
1F 658N	6123	-111.910417000	40.751944000	Qal1	3.00	does not liquefy
1F 660N	6108	-111.921292000	40.765000000	Qal1	3.00	does not liquefy
1F 661N	5833	-111.910370000	40.771574000	Qlaly	4.00	liquefies
1F 662N	5628	-111.910181000	40.776065000	Qlaly	4.00	liquefies
1F 664	9843	-111.901389000	40.632222000	Qal2	2.00	does not liquefy
1F 694	9199	-111.890833000	40.526667000	Qlbpm	3.00	does not liquefy
2C 400	6601	-111.903190000	40.747315000	Qal1	3.00	does not liquefy
2C 402	7054	-111.905278000	40.741944000	Qal1	3.00	does not liquefy
2C 421	8393	-111.817958000	40.712870000	Qlbm	2.00	does not liquefy
2C 551	879	-111.871667000	40.718611000	Qlaly	4.00	liquefies
2C 554	11880	-111.907269000	40.636528000	Qlbpm	2.00	does not liquefy
2C 585	9456	-111.939259000	40.644583000	Qlbpm	2.00	does not liquefy
2C 624	10300	-111.966111000	40.765463000	Qaly	3.00	does not liquefy
2C 631	6066	-111.982917000	40.763796000	Qlaly	4.00	liquefies
2C 633	6134	-111.986620000	40.769815000	Qly	4.00	liquefies
2C 637	6068	-111.982731000	40.765370000	Qlaly	4.00	liquefies
2C 702	9925	-111.949722000	40.765278000	Qaly	3.00	does not liquefy
2C 732	6641	-112.005556000	40.769769000	Qlaly	4.00	liquefies
2C 761	9650	-111.811157000	40.634954000	Qal1	3.00	does not liquefy
2C 838	7075	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 844	7097	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 845	7107	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 871	7109	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 876	6121	-111.915370000	40.761296000	Qal1	3.00	does not liquefy
2C 884	6136	-111.916944000	40.763611000	Qal1	3.00	does not liquefy
2C 884	6138	-111.916944000	40.763611000	Qal1	3.00	does not liquefy
2C 887	5507	-111.917125000	40.814213000	Pz	0.00	does not liquefy
2C 919	7622	-112.117958000	40.717731000	Qlbpg	0.00	does not liquefy

2F 43	7669	-111.882361000	40.718380000	Qlaly	4.00	liquefies
2F 44	7845	-111.893704000	40.717870000	Qlaly	4.00	liquefies
2F 46	880	-111.865000000	40.719120000	Qlaly	4.00	liquefies
2F 47	863	-111.858380000	40.719537000	Qlbpm	0.00	does not liquefy
2F 50	8395	-111.822731000	40.712963000	Qlbm	2.00	does not liquefy
2F 51	8397	-111.822731000	40.712963000	Qlbm	2.00	does not liquefy
2F 71	7670	-111.874347000	40.718148000	Qlaly	4.00	liquefies
2F 283	9458	-111.932546000	40.644491000	Qlbpm	2.00	does not liquefy
2F 621E	7281	-111.917269000	40.724537000	Qal1	3.00	does not liquefy
2F 624	7847	-111.899722000	40.718889000	Qlaly	4.00	liquefies
2F 625	8043	-111.899722000	40.718889000	Qlaly	4.00	liquefies
2F 626E	7920	-111.891389000	40.718333000	Qlaly	4.00	liquefies
2F 627	7961	-111.891389000	40.718333000	Qlaly	4.00	liquefies
2F 640	6140	-111.907778000	40.755833000	Qal1	3.00	does not liquefy
2F 643	6703	-111.919903000	40.764444000	Qal1	3.00	does not liquefy
2F 645	8928	-111.920000000	40.764074000	Qal1	3.00	does not liquefy
2F 651E	7998	-111.894722000	40.717778000	Qlaly	4.00	liquefies
3C 423	8419	-111.805556000	40.712778000	Mz	0.00	does not liquefy
3C 520	7930	-111.952870000	40.697037000	Qlaly	3.00	does not liquefy
3C 528	8890	-111.952778000	40.667500000	Qlbpm	2.00	does not liquefy
3C 587	9148	-111.952958000	40.653380000	Qlbpm	2.00	does not liquefy
3C 617	6992	-111.951481000	40.725787000	Qaly	3.00	does not liquefy
3C 625	6538	-111.987269000	40.765185000	Qlaly	4.00	liquefies
3C 663	7940	-111.952083000	40.690000000	Qal2	2.00	does not liquefy
3C 694	10377	-111.951292000	40.758796000	Qal1	3.00	does not liquefy
3C 696	9605	-111.947315000	40.766204000	Qaly	3.00	does not liquefy
3C 697	12654	-111.945000000	40.767130000	Qaly	3.00	does not liquefy
3C 703	12657	-111.951065000	40.766019000	Qaly	3.00	does not liquefy
3C 738	7020	-111.987222000	40.755139000	Qlaly	2.00	does not liquefy
3C 739	12656	-111.946759000	40.766343000	Qaly	3.00	does not liquefy
3C 828	9830	-111.903611000	40.621111000	Qlbpm	2.00	does not liquefy
3C 832S	12086	-111.905417000	40.635324000	Qlbpm	2.00	does not liquefy
3C 834	12088	-111.905556000	40.635370000	Qlbpm	2.00	does not liquefy
3C 835	11049	-111.905412000	40.636667000	Qlbpm	2.00	does not liquefy
3C 836S	9520	-111.903333000	40.643472000	Qal2	2.00	does not liquefy
3C 842	8059	-111.902778000	40.715278000	Qlaly	4.00	liquefies
3C 859	8232	-111.904722000	40.718657000	Qal1	3.00	does not liquefy
3C 860S	8259	-111.904861000	40.722685000	Qal1	3.00	does not liquefy
3C 862	12084	-111.905370000	40.722593000	Qal1	3.00	does not liquefy
3C 868S	7003	-111.909537000	40.749167000	Qal1	3.00	does not liquefy
3C 875S	7100	-111.914769000	40.761481000	Qal1	3.00	does not liquefy
3C 878	5820	-111.998056000	40.763333000	Qlaly	4.00	liquefies
3C 880S	6085	-111.911801000	40.769676000	Qlaly	4.00	liquefies
3C 886	8927	-111.915968000	40.764815000	Qal1	3.00	does not liquefy
3C 931	8677	-111.797778000	40.689444000	Qalp	0.00	does not liquefy
3F 53	8454	-111.796894000	40.707593000	Qlbm	0.00	does not liquefy
3F 56	10497	-111.895181000	40.544537000	Qlbpm	3.00	does not liquefy
3F 207	6718	-111.902593000	40.747407000	Qal1	3.00	does not liquefy
3F 609S	10081	-111.901944000	40.588704000	Qlbpm	3.00	does not liquefy

3F 610S	9835	-111.903611000	40.621111000	Qlbpm	2.00	does not liquefy
3F 613S	9813	-111.905000000	40.632269000	Qal1	3.00	does not liquefy
3F 614	12157	-111.905833000	40.633056000	Qal2	2.00	does not liquefy
3F 615S	12859	-111.904537000	40.636667000	Qlbpm	2.00	does not liquefy
3F 616S	9015	-111.901111000	40.653333000	Qal2	2.00	does not liquefy
3F 617S	8941	-111.901898000	40.674861000	Qal1	3.00	does not liquefy
3F 619S	8019	-111.902315000	40.697778000	Qal2	2.00	does not liquefy
3F 630S	7921	-111.897222000	40.706111000	Qlaly	4.00	liquefies
3F 632	11775	-111.902778000	40.715278000	Qlaly	4.00	liquefies
3F 633S	7303	-111.905134000	40.733889000	Qal1	3.00	does not liquefy
3F 635	7379	-111.905324000	40.733333000	Qal1	3.00	does not liquefy
3F 636S	7031	-111.904722000	40.744583000	Qal1	3.00	does not liquefy
3F 637S	7013	-111.907037000	40.747083000	Qal1	3.00	does not liquefy
3F 646S	10370	-111.899625000	40.569722000	Qlbpm	3.00	does not liquefy
3F 647S	10038	-111.905231000	40.606250000	Qlbpm	2.00	does not liquefy
3F 648S	10048	-111.906528000	40.611204000	Qlbpm	2.00	does not liquefy
3F 649S	8947	-111.901759000	40.667593000	Qal1	3.00	does not liquefy
3F 653	16809	-111.905509000	40.722731000	Qal1	3.00	does not liquefy
3F 654	8219	-111.905556000	40.723611000	Qal1	3.00	does not liquefy
3F 655S	7347	-111.904583000	40.741944000	Qal1	3.00	does not liquefy
3F 657	7359	-111.905134000	40.741898000	Qal1	3.00	does not liquefy
3F 658S	6706	-111.911389000	40.752315000	Qal1	3.00	does not liquefy
3F 660S	8929	-111.913981000	40.765417000	Qal1	3.00	does not liquefy
3F 661S	6336	-111.911204000	40.772130000	Qlaly	4.00	liquefies
3F 662S	5832	-111.910926000	40.776250000	Qlaly	4.00	liquefies
3F 665	16890	-111.906014000	40.718889000	Qal1	3.00	does not liquefy
3F 694	10498	-111.891389000	40.526667000	Qlbpm	3.00	does not liquefy
4C 400	6739	-111.902593000	40.747546000	Qal1	3.00	does not liquefy
4C 402	704	-111.896111000	40.747778000	Qal1	3.00	does not liquefy
4C 424	17129	-111.790134000	40.711944000	Mz	0.00	does not liquefy
4C 551	7681	-111.870833000	40.718935000	Qlaly	4.00	liquefies
4C 585	9460	-111.938514000	40.645000000	Qlbpm	2.00	does not liquefy
4C 727	9916	-111.861435000	40.630000000	Qal1	3.00	does not liquefy
4C 736	9681	-111.833981000	40.631759000	Qlpg	0.00	does not liquefy
4C 736	9688	-111.833981000	40.631759000	Qlpg	0.00	does not liquefy
4C 760	9652	-111.811245000	40.635648000	Qal1	3.00	does not liquefy
4C 837	7578	-111.912958000	40.724907000	Qal1	3.00	does not liquefy
4C 841	7009	-111.909167000	40.750000000	Qal1	3.00	does not liquefy
4C 846	8214	-111.909167000	40.750000000	Qal1	3.00	does not liquefy
4C 847	16899	-111.902222000	40.718056000	Qlaly	4.00	liquefies
4C 848	8479	-111.909167000	40.750000000	Qal1	3.00	does not liquefy
4C 853	8060	-111.899444000	40.718056000	Qlaly	4.00	liquefies
4C 873	6721	-111.910000000	40.755556000	Qal1	3.00	does not liquefy
4C 883	9756	-111.919167000	40.764444000	Qal1	3.00	does not liquefy
4C 885	11024	-111.916759000	40.764769000	Qal1	3.00	does not liquefy
4F 43	8000	-111.882361000	40.718380000	Qlaly	4.00	liquefies
4F 44	7684	-111.877037000	40.717870000	Qlaly	4.00	liquefies
4F 46	7683	-111.865412000	40.719630000	Qlaly	4.00	liquefies
4F 47	7694	-111.856944000	40.720000000	Qlbpm	0.00	does not liquefy

4F 50	867	-111.833611000	40.716806000	Qal1	3.00	does not liquefy
4F 51	8399	-111.822222000	40.713287000	Qlbm	2.00	does not liquefy
4F 71	7688	-111.873792000	40.718750000	Qlaly	4.00	liquefies
4F 283	9464	-111.931991000	40.645000000	Qlbpm	2.00	does not liquefy
4F 621W	7580	-111.917269000	40.724537000	Qal1	3.00	does not liquefy
4F 623	8062	-111.899444000	40.718056000	Qlaly	4.00	liquefies
4F 626W	8002	-111.891389000	40.718333000	Qlaly	4.00	liquefies
4F 641	670	-111.900278000	40.759167000	Qlaly	4.00	liquefies
4F 642	7283	-111.914167000	40.727269000	Qal1	3.00	does not liquefy
4F 651W	8004	-111.893889000	40.718472000	Qlaly	4.00	liquefies

Table A2-3 Liquefaction Evaluations for Bridges for M7.0 Event

NBI_REF	LINK_ID	X	Y	UNIT	Hazard	Liquefaction
035001E	472	-111.967593000	40.711157000	Qlaly	3.00	liquefies
035002E	909	-111.972176000	40.711389000	Qlaly	3.00	liquefies
035003D	1344	-111.951245000	40.507912000	Qlbpm	0.00	does not liquefy
035005D	1276	-111.968995000	40.537102000	Qlbpm	0.00	does not liquefy
035006E	1127	-111.923426000	40.630463000	Qal1	3.00	liquefies
035007D	1124	-111.926523000	40.630000000	Qlbpm	2.00	liquefies
035008E	910	-111.958287000	40.711343000	Qlaly	3.00	liquefies
035009D	1052	-111.882356000	40.660324000	Qal1	3.00	liquefies
035010D	1054	-111.875694000	40.656204000	Qal1	3.00	liquefies
035011D	993	-111.891111000	40.679722000	Qal1	3.00	liquefies
035012D	1036	-111.908611000	40.666991000	Qal1	3.00	liquefies
035013E	1092	-111.876759000	40.649769000	Qal2	2.00	liquefies
035014F	1133	-111.872912000	40.628611000	Qal2	2.00	liquefies
035015E	10113	-111.832778000	40.530833000	Qaf1	0.00	does not liquefy
035016D	1244	-111.929167000	40.560602000	Qlbps	0.00	does not liquefy
035017F	1051	-111.906343000	40.666528000	Qal1	3.00	liquefies
035018D	1137	-111.851389000	40.626574000	Qlbpm	0.00	does not liquefy
035020D	1042	-111.864903000	40.667731000	Qal1	3.00	liquefies
035021D	1212	-111.957315000	40.594167000	Qlbpg	0.00	does not liquefy
035022D	1149	-111.965648000	40.624028000	Qlbpm	0.00	does not liquefy
035023E	823	-111.938565000	40.711435000	Qaly	3.00	liquefies
035024F	475	-112.062958000	40.687176000	Qlbps	0.00	does not liquefy
035025F	477	-112.044120000	40.685139000	Qlbps	0.00	does not liquefy
035026F	979	-112.034213000	40.683657000	Qlbps	0.00	does not liquefy
035027D	978	-112.053704000	40.686296000	Qlbps	0.00	does not liquefy
035028D	982	-112.026713000	40.682083000	Qlbps	0.00	does not liquefy
035029F	483	-112.020181000	40.680139000	Qlbps	0.00	does not liquefy
035030D	984	-112.005690000	40.674722000	Qlbps	0.00	does not liquefy
035031F	892	-112.110324000	40.700093000	Qafy	2.00	liquefies
035032D	935	-112.081667000	40.691389000	Qlbpg	0.00	does not liquefy
035033F	933	-112.102958000	40.696481000	Qlbpg	0.00	does not liquefy
035034D	1164	-111.881898000	40.615278000	Qlbpm	2.00	liquefies
035035F	1190	-111.889028000	40.605926000	Qlbpm	2.00	liquefies
035036F	1193	-111.877681000	40.606528000	Qlpg	1.00	does not liquefy
035037D	1192	-111.886157000	40.609491000	Qlbpm	2.00	liquefies
035038D	1221	-111.883745000	40.593935000	Qlpg	1.00	does not liquefy
035039E	10091	-111.884856000	40.593148000	Qlpg	1.00	does not liquefy
035040C	1254	-111.885046000	40.591759000	Qlpg	1.00	does not liquefy
035041D	10640	-111.949769000	40.514676000	Qlbpm	0.00	does not liquefy
035042E	1236	-111.967222000	40.578519000	Qlbps	0.00	does not liquefy
035043D	1132	-111.877634000	40.620741000	Qlpg	1.00	does not liquefy
035044F	1358	-111.897546000	40.506991000	Qlbpm	3.00	liquefies
035045E	1288	-111.886389000	40.551574000	Qlbpm	3.00	liquefies
035046E	1324	-111.876759000	40.537130000	Qlbpm	3.00	liquefies
035047F	485	-111.997269000	40.670926000	Qlbpm	0.00	does not liquefy

035048E	1215	-111.954398000	40.587685000	Qlbpm	0.00	does not liquefy
035049D	1321	-111.897500000	40.541574000	Qlbpm	3.00	liquefies
035050F	1220	-111.897593000	40.580648000	Qlbpm	3.00	liquefies
035051F	1250	-111.892824000	40.580648000	Qlbpm	1.00	does not liquefy
035052E	1219	-111.891435000	40.592037000	Qlbpm	2.00	liquefies
035053F	9821	-111.892315000	40.593056000	Qlbpm	2.00	liquefies
035054D	1186	-111.921486000	40.609477000	Qal1	3.00	liquefies
035055D	1135	-111.871523000	40.617750000	Qlpg	1.00	does not liquefy
035056F	1348	-111.895833000	40.516250000	Qlbpm	3.00	liquefies
035057F	1325	-111.888750000	40.544259000	Qlbpm	3.00	liquefies
035058F	537	-111.947454000	40.489537000	Qlbpm	0.00	does not liquefy
035059E	4272	-111.948611000	40.491157000	Qal2	2.00	liquefies
035060D	1141	-111.806667000	40.631898000	Qal1	3.00	liquefies
035061E	10459	-111.956667000	40.540417000	Qlbpm	0.00	does not liquefy
035062C	1047	-111.840278000	40.664722000	Qal1	3.00	liquefies
035063D	1143	-111.800278000	40.626204000	Qal1	3.00	liquefies
035064D	9363	-111.823935000	40.656296000	Qal1	3.00	liquefies
035065D	1104	-111.834347000	40.652037000	Qal1	3.00	liquefies
035066D	1062	-111.838704000	40.663935000	Qal1	3.00	liquefies
035067C	9252	-111.811528000	40.635556000	Qal1	3.00	liquefies
035068D	8695	-111.832917000	40.660278000	Qal1	3.00	liquefies
035069D	9370	-111.813148000	40.637917000	Qal1	3.00	liquefies
035070D	7043	-111.984301000	40.711713000	Qly	3.00	liquefies
035071D	1196	-111.833426000	40.608287000	Qal1	3.00	liquefies
035072D	1198	-111.818935000	40.604028000	Qal1	3.00	liquefies
035073D	1202	-111.816014000	40.603148000	Qal1	3.00	liquefies
035074V	1267	-111.796991000	40.577917000	Qal1	3.00	liquefies
035076E	9930	-111.873468000	40.534398000	Qlbpm	3.00	liquefies
035077D	1330	-111.872269000	40.532639000	Qlbpm	3.00	liquefies
035078E	1353	-111.871204000	40.528704000	Qlbpm	3.00	liquefies
035079D	9978	-111.870880000	40.526991000	Qlbpm	3.00	liquefies
035080E	10537	-111.870278000	40.523194000	Qlbpm	3.00	liquefies
035081D	1360	-111.871204000	40.504583000	Qlbpm	3.00	liquefies
035082D	1094	-111.874579000	40.644954000	Qal2	2.00	liquefies
035083D	1080	-111.948935000	40.638611000	Qlbpm	0.00	does not liquefy
035084C	1123	-111.948380000	40.638102000	Qlbpm	0.00	does not liquefy
035085F	1391	-111.948657000	40.634167000	Qlbps	0.00	does not liquefy
035086D	1025	-111.967593000	40.654167000	Qlbps	0.00	does not liquefy
035087D	1026	-111.977079000	40.660370000	Qlbpm	0.00	does not liquefy
035088D	487	-111.988056000	40.667593000	Qlbpg	0.00	does not liquefy
035089D	1023	-111.986667000	40.666759000	Qlbpg	0.00	does not liquefy
035090F	954	-111.921343000	40.686435000	Qal1	3.00	liquefies
035091F	768	-111.923704000	40.733472000	Qal1	3.00	liquefies
035092F	787	-111.933056000	40.733102000	Qal1	3.00	liquefies
035093C	734	-111.923190000	40.740602000	Qal1	3.00	liquefies
035094P	699	-111.926389000	40.745880000	Qaly	3.00	liquefies
035095D	700	-111.921292000	40.751481000	Qal1	3.00	liquefies
035096P	664	-111.923009000	40.754167000	Qal1	3.00	liquefies
035097F	662	-111.923514000	40.758426000	Qal1	3.00	liquefies

035098D	665	-111.923333000	40.758611000	Qal1	3.00	liquefies
035099D	618	-111.924676000	40.762778000	Qal1	3.00	liquefies
035100F	617	-111.926343000	40.764722000	Qal1	3.00	liquefies
035101C	659	-111.953102000	40.750231000	Qal1	3.00	liquefies
035102F	6025	-111.958333000	40.758380000	Qaly	3.00	liquefies
035103E	575	-111.987315000	40.772778000	Qly	4.00	liquefies
035104E	5300	-111.985880000	40.772639000	Qly	4.00	liquefies
035105V	1216	-111.957912000	40.595417000	Qlbpg	0.00	does not liquefy
035106F	553	-111.935736000	40.791065000	Qal1	3.00	liquefies
035107F	560	-111.936528000	40.784444000	Qal1	3.00	liquefies
035108D	577	-111.938236000	40.780185000	Qal1	3.00	liquefies
035109D	468	-111.999106000	40.711944000	Qly	3.00	liquefies
035110D	1045	-111.844625000	40.664861000	Qal1	3.00	liquefies
035111D	1370	-111.929444000	40.504722000	Qal2	2.00	liquefies
035112D	10430	-111.948611000	40.548380000	Qlbpm	0.00	does not liquefy
035113D	1101	-111.860880000	40.631620000	Qal1	3.00	liquefies
035114E	1359	-111.885181000	40.507083000	Qal1	3.00	liquefies
035115F	995	-111.899856000	40.681250000	Qal1	3.00	liquefies
035116D	1103	-111.853745000	40.634722000	Qal2	2.00	liquefies
035117D	918	-111.916991000	40.708426000	Qal1	3.00	liquefies
035118F	488	-111.955093000	40.679815000	Qal2	2.00	liquefies
035119F	824	-111.935370000	40.717037000	Qlbpm	2.00	liquefies
035120F	5015	-111.935139000	40.714213000	Qlbpm	2.00	liquefies
035121V	1278	-111.948148000	40.554815000	Qlbpm	0.00	does not liquefy
035122F	6185	-112.062958000	40.769259000	Qlaly	2.00	liquefies
035123F	870	-111.885458000	40.705694000	Qal1	3.00	liquefies
035124D	1373	-111.878148000	40.500741000	Qlbpm	3.00	liquefies
035125C	1084	-111.929537000	40.647639000	Qlbpm	2.00	liquefies
035126F	873	-111.882681000	40.704861000	Qal1	3.00	liquefies
035127F	957	-111.900139000	40.686806000	Qal2	2.00	liquefies
035128C	1085	-111.922958000	40.645324000	Qal1	3.00	liquefies
035129F	9642	-111.856759000	40.619537000	Qal1	3.00	liquefies
035130F	9909	-111.843468000	40.614444000	Qal1	3.00	liquefies
035131D	1060	-111.837403000	40.649398000	Qal1	3.00	liquefies
035133D	8488	-111.905556000	40.680000000	Qal1	3.00	liquefies
035134D	9575	-111.858009000	40.625694000	Qal1	3.00	liquefies
035135E	1056	-111.851245000	40.666759000	Qal1	3.00	liquefies
035138E	947	-111.958657000	40.682361000	Qal2	2.00	liquefies
035139V	1239	-111.948287000	40.577824000	Qlbpm	0.00	does not liquefy
035140E	869	-111.899722000	40.706343000	Qlaly	4.00	liquefies
035141D	474	-112.072361000	40.688889000	Qlbps	0.00	does not liquefy
035142E	813	-112.082269000	40.715972000	Qlaly	4.00	liquefies
035143D	571	-112.034167000	40.772037000	Qlaly	2.00	liquefies
035144D	985	-111.970926000	40.667639000	Qlbps	0.00	does not liquefy
035145F	736	-111.910370000	40.741806000	Qal1	3.00	liquefies
035146C	791	-111.908333000	40.725000000	Qal1	3.00	liquefies
035147F	1350	-111.894120000	40.521435000	Qlbpm	3.00	liquefies
035150D	5531	-111.975556000	40.771389000	Qaly	3.00	liquefies
035151E	9644	-111.857593000	40.622870000	Qal1	3.00	liquefies

035152C	733	-111.939769000	40.740880000	Qal1	3.00	liquefies
035153D	1317	-111.949023000	40.544167000	Qlbpm	0.00	does not liquefy
035154D	875	-111.876944000	40.703194000	Qlaly	4.00	liquefies
035155F	6855	-111.894769000	40.529259000	Qlbpm	3.00	liquefies
035156D	9029	-111.895926000	40.530880000	Qlbpm	3.00	liquefies
035157E	1286	-111.892176000	40.551481000	Qlbpm	3.00	liquefies
035158D	1252	-111.889213000	40.569769000	Qlpg	1.00	does not liquefy
035159V	1255	-111.886523000	40.572315000	Qlpg	1.00	does not liquefy
035160D	9900	-111.856944000	40.620833000	Qal1	3.00	liquefies
035161F	1201	-111.807361000	40.593056000	Qal1	3.00	liquefies
035162F	10067	-111.807222000	40.588935000	Qal1	3.00	liquefies
035163E	10052	-111.941806000	40.587731000	Qlbpm	0.00	does not liquefy
035164D	10540	-111.881759000	40.538657000	Qlbpm	3.00	liquefies
035165D	1361	-111.867917000	40.513194000	Qlaly	4.00	liquefies
035166D	906	-111.999167000	40.711944000	Qly	3.00	liquefies
035167D	4042	-111.991847000	40.711157000	Qly	3.00	liquefies
035168D	8862	-111.989625000	40.668333000	Qlbpg	0.00	does not liquefy
035169E	10463	-111.951569000	40.540046000	Qlbpm	0.00	does not liquefy
035170V	9381	-111.873750000	40.489815000	Qlpg	0.00	does not liquefy
035171V	10732	-111.874120000	40.489861000	Qlpg	0.00	does not liquefy
035172V	1379	-111.846157000	40.505231000	Qaf1	0.00	does not liquefy
035173D	9038	-111.893657000	40.527778000	Qlbpm	3.00	liquefies
035174D	10597	-111.870278000	40.506435000	Qlbpm	3.00	liquefies
035175D	8983	-111.931523000	40.643148000	Qlbpm	2.00	liquefies
035176E	10086	-111.885278000	40.589306000	Qlpg	1.00	does not liquefy
035177D	1316	-111.973148000	40.535324000	Qlbpm	0.00	does not liquefy
035178V	10460	-111.970833000	40.538889000	Qlbpm	0.00	does not liquefy
035179D	1188	-111.923935000	40.609028000	Qlbpm	2.00	liquefies
035181F	1245	-111.915833000	40.571944000	Qal1	3.00	liquefies
035182V	1249	-111.916569000	40.572083000	Qlbpm	2.00	liquefies
035183D	9331	-111.948333000	40.628380000	Qlbpm	0.00	does not liquefy
035184D	5999	-111.899491000	40.575926000	Qlpg	1.00	does not liquefy
035185D	3733	-111.895736000	40.575926000	Qlpg	1.00	does not liquefy
035188C	1049	-111.898056000	40.655278000	Qal1	2.00	liquefies
035189E	1354	-111.866667000	40.519028000	Qlaly	4.00	liquefies
035191C	5532	-111.985926000	40.773519000	Qly	4.00	liquefies
035192F	5542	-111.986389000	40.774444000	Qly	4.00	liquefies
035193C	5544	-111.991111000	40.777222000	Qly	4.00	liquefies
035194C	5533	-111.986847000	40.773472000	Qly	4.00	liquefies
035195C	5902	-111.980278000	40.777778000	Qlaly	4.00	liquefies
035197D	1284	-111.927500000	40.543056000	Qlbpm	2.00	liquefies
035198E	1320	-111.917403000	40.548657000	Qal1	3.00	liquefies
035199E	10336	-111.944347000	40.559815000	Qlbpm	0.00	does not liquefy
035200E	1241	-111.944583000	40.573194000	Qlbpm	0.00	does not liquefy
0C 369	580	-111.932778000	40.765509000	Qal1	3.00	liquefies
0C 377	5813	-111.935556000	40.765787000	Qal1	3.00	liquefies
0C 401	701	-111.899444000	40.747546000	Qal1	3.00	liquefies
0C 417	559	-111.913426000	40.786528000	Qal2	2.00	liquefies
0C 420	828	-111.888657000	40.718102000	Qlaly	4.00	liquefies

0C 422	841	-111.806157000	40.713704000	Mz	0.00	does not liquefy
0C 460	661	-111.948468000	40.751759000	Qal1	3.00	liquefies
0C 493	5290	-111.920833000	40.815509000	Qly	4.00	liquefies
0C 518	891	-111.797361000	40.686898000	Qalp	0.00	does not liquefy
0C 576	584	-111.906389000	40.771667000	Qlaly	4.00	liquefies
0C 584	1129	-111.898333000	40.634722000	Qlbpm	2.00	liquefies
0C 620	1096	-111.889537000	40.631574000	Qlbpm	2.00	liquefies
0C 621	1098	-111.891111000	40.633889000	Qlbpm	2.00	liquefies
0C 629	489	-111.951847000	40.682222000	Qal2	2.00	liquefies
0C 635	6190	-112.063148000	40.770694000	Qlaly	2.00	liquefies
0C 649	9450	-111.920278000	40.638426000	Qal1	3.00	liquefies
0C 659	914	-111.952500000	40.704259000	Qlaly	3.00	liquefies
0C 662	473	-111.953333000	40.712500000	Qaly	3.00	liquefies
0C 669	573	-112.025093000	40.770880000	Qlaly	4.00	liquefies
0C 688	6069	-111.950833000	40.758843000	Qal1	3.00	liquefies
0C 689	6075	-111.950556000	40.759769000	Qal1	3.00	liquefies
0C 692	616	-111.950458000	40.765139000	Qaly	3.00	liquefies
0C 693	5563	-111.948981000	40.771296000	Qaly	3.00	liquefies
0C 704	5967	-111.950926000	40.762361000	Qal1	3.00	liquefies
0C 709	471	-111.968565000	40.726759000	Qlaly	2.00	liquefies
0C 725	9306	-111.872037000	40.629815000	Qal2	2.00	liquefies
0C 726	9310	-111.864722000	40.629583000	Qal2	2.00	liquefies
0C 752	6605	-111.949167000	40.706759000	Qaly	3.00	liquefies
0C 757	1110	-111.808611000	40.638426000	Qlpd	0.00	does not liquefy
0C 759	9505	-111.811065000	40.638426000	Qal2	0.00	does not liquefy
0C 806	566	-111.901944000	40.782500000	Qlaly	4.00	liquefies
0C 812	955	-111.903333000	40.686667000	Qal2	2.00	liquefies
0C 813	851	-111.904444000	40.712222000	Qal1	3.00	liquefies
0C 814	1087	-111.901847000	40.660741000	Qal2	2.00	liquefies
0C 815	534	-111.976569000	40.502593000	Qlbpm	0.00	does not liquefy
0C 816	583	-111.911111000	40.781944000	Qlaly	4.00	liquefies
0C 817	10448	-111.929301000	40.497810000	Qal1	3.00	liquefies
0C 819	9146	-111.891435000	40.504167000	Qlbpm	3.00	liquefies
0D 410	10542	-111.871111000	40.530787000	Qlbpm	3.00	liquefies
0D 480	767	-111.938889000	40.740093000	Qal1	3.00	liquefies
0D 564	547	-111.939069000	40.808056000	Qal1	4.00	liquefies
0D 775	581	-111.926389000	40.771528000	Qal1	3.00	liquefies
0D 805	9171	-111.923333000	40.653056000	Qal1	3.00	liquefies
0D 807	1399	-111.778792000	40.572407000	Qchs	2.00	liquefies
0D 809	917	-111.924903000	40.699444000	Qal1	3.00	liquefies
0D 811	996	-111.888148000	40.679630000	Qal1	3.00	liquefies
0E 907	1398	-111.781435000	40.618657000	Qalp	2.00	liquefies
0E1032	1371	-111.900093000	40.489028000	Qlbpm	3.00	liquefies
0E1064	9818	-111.890694000	40.601806000	Qlbpm	2.00	liquefies
0E1065	3731	-111.890736000	40.583148000	Qlpg	1.00	does not liquefy
0E1066	1257	-111.890787000	40.574306000	Qlpg	1.00	does not liquefy
0E1067	1258	-111.890694000	40.571250000	Qlpg	1.00	does not liquefy
0E1068	1259	-111.890736000	40.567685000	Qlpd	0.00	does not liquefy
0E1070	5165	-111.890278000	40.554167000	Qlbpm	3.00	liquefies

0E1200	920	-111.904167000	40.706389000	Qal1	3.00	liquefies
0E1201	3797	-111.901898000	40.680898000	Qal1	3.00	liquefies
0E1218	998	-111.880926000	40.674259000	Qal1	3.00	liquefies
0E1227	1044	-111.867454000	40.666528000	Qal1	3.00	liquefies
0E1229	8951	-111.854213000	40.667361000	Qal1	3.00	liquefies
0E1272	5772	-112.203611000	40.725926000	Qlaly	4.00	liquefies
0E1283	988	-111.937315000	40.667505000	Qal2	2.00	liquefies
0E1286	8609	-111.911250000	40.674907000	Qal1	3.00	liquefies
0E1324	546	-111.946111000	40.828333000	Qly	2.00	liquefies
0E1445	1248	-111.900278000	40.565556000	Qlbpm	3.00	liquefies
0E1683	536	-111.942037000	40.485231000	Qal2	2.00	liquefies
0E1709	652	-111.850648000	40.758935000	Qlbpm	0.00	does not liquefy
0E1767	1377	-111.892083000	40.492269000	Qlbpm	3.00	liquefies
0E1833	7454	-111.953102000	40.711389000	Qaly	3.00	liquefies
0E1858	1100	-111.865181000	40.642037000	Qal2	2.00	liquefies
0E1908	821	-111.960926000	40.725370000	Qlaly	2.00	liquefies
0E1909	1035	-111.929491000	40.652870000	Qal2	2.00	liquefies
0E2113	1030	-111.966343000	40.653102000	Qlbps	0.00	does not liquefy
0E2150	1125	-111.938657000	40.634259000	Qlbps	2.00	liquefies
0E2225	1090	-111.888148000	40.660926000	Qal1	3.00	liquefies
0E2372	7119	-111.979856000	40.708611000	Qlaly	3.00	liquefies
0E2374	8867	-111.981343000	40.662778000	Qlbpg	0.00	does not liquefy
0E2379	1180	-111.963380000	40.609463000	Qlbpm	0.00	does not liquefy
0E2381	1185	-111.919069000	40.587639000	Qal1	3.00	liquefies
0E2405	512	-111.970046000	40.588426000	Qlbpg	0.00	does not liquefy
0E2421	983	-112.024583000	40.681389000	Qlbps	0.00	does not liquefy
0E2439	10587	-111.953333000	40.500556000	Qlbpm	0.00	does not liquefy
0E2475	4998	-111.906713000	40.486111000	Qlbpm	3.00	liquefies
0E2480	10339	-111.940000000	40.562222000	Qlbps	0.00	does not liquefy
0E2486	1243	-111.938704000	40.582037000	Qlbpm	0.00	does not liquefy
0E2507	10478	-111.921921000	40.523676000	Qal1	3.00	liquefies
0E2528	1343	-111.949537000	40.522315000	Qlbpm	0.00	does not liquefy
0F 6	4934	-111.929954000	40.764912000	Qal1	3.00	liquefies
0F 7	5825	-111.926435000	40.764583000	Qal1	3.00	liquefies
0F 33	5815	-111.938935000	40.764167000	Qal1	3.00	liquefies
0F 34	5817	-111.938935000	40.764722000	Qal1	3.00	liquefies
0F 35	5995	-111.939028000	40.765926000	Qal1	3.00	liquefies
0F 48	834	-111.853657000	40.719583000	Qlbm	2.00	liquefies
0F 49	836	-111.842125000	40.718565000	Qal1	0.00	does not liquefy
0F 52	890	-111.808843000	40.716667000	Qlbg	0.00	does not liquefy
0F 54	1396	-111.795556000	40.716435000	Mz	0.00	does not liquefy
0F 115	8932	-111.908333000	40.674769000	Qal1	3.00	liquefies
0F 131	1128	-111.910231000	40.635833000	Qlbpm	2.00	liquefies
0F 156	1012	-111.803009000	40.674630000	Qlbg	0.00	does not liquefy
0F 244	1218	-111.913102000	40.587731000	Qal1	3.00	liquefies
0F 344	5536	-112.025000000	40.768426000	Qlaly	4.00	liquefies
0F 410	6282	-111.948102000	40.746250000	Qal1	3.00	liquefies
0F 419	5931	-111.965880000	40.764444000	Qaly	3.00	liquefies
0F 431	5497	-111.949769000	40.813194000	Qal1	4.00	liquefies

0F 458	9415	-111.807958000	40.646204000	Qaf2	2.00	liquefies
0F 470	552	-111.949815000	40.805648000	Qal1	4.00	liquefies
0F 475	9533	-111.862454000	40.629861000	Qal2	2.00	liquefies
0F 477	4760	-111.949306000	40.733056000	Qaly	3.00	liquefies
0F 500	576	-111.948611000	40.784676000	Qaly	3.00	liquefies
0F 504	9577	-111.854583000	40.630185000	Qal2	2.00	liquefies
0F 505	1108	-111.825134000	40.634907000	Qlpg	0.00	does not liquefy
0F 506	1138	-111.833981000	40.632824000	Qlpg	0.00	does not liquefy
0F 522	762	-111.986157000	40.725694000	Qlaly	2.00	liquefies
0F 523	5020	-112.024722000	40.725602000	Qlaly	2.00	liquefies
0F 547	570	-112.182824000	40.745139000	Qly	2.00	liquefies
0F 562	9646	-111.789347000	40.619722000	Qal2	2.00	liquefies
0F 571	1154	-111.921245000	40.623750000	Qal1	3.00	liquefies
0F 576	1211	-111.977037000	40.593519000	Qlbpg	0.00	does not liquefy
0F 579	10085	-111.886759000	40.588426000	Qlpg	1.00	does not liquefy
0F 580	1290	-111.883148000	40.558796000	Qlbpm	3.00	liquefies
0F 595	718	-112.177546000	40.740833000	Qlaly	4.00	liquefies
0F 596	1314	-111.984120000	40.536759000	Qlbpm	0.00	does not liquefy
0F 607	4999	-111.919722000	40.497130000	Qal1	3.00	liquefies
0F 608	539	-111.936204000	40.486435000	Qal1	3.00	liquefies
0F 663	5998	-111.897870000	40.559074000	Qlbpm	3.00	liquefies
0F 683	5997	-111.908236000	40.558889000	Qal1	3.00	liquefies
0F 687	620	-111.911065000	40.761157000	Qal1	3.00	liquefies
0F 693	11070	-111.922037000	40.523380000	Qlbpm	2.00	liquefies
0F 727	1261	-111.871944000	40.568889000	Qca	0.00	does not liquefy
0V 737	5789	-112.155880000	40.721620000	Qlbpg	0.00	does not liquefy
1C 520	948	-111.952269000	40.696204000	Qlaly	3.00	liquefies
1C 528	1032	-111.952269000	40.667454000	Qlbpm	2.00	liquefies
1C 587	1081	-111.952361000	40.651157000	Qlbpm	2.00	liquefies
1C 617	6861	-111.951481000	40.725046000	Qaly	3.00	liquefies
1C 628	658	-111.987222000	40.764167000	Qlaly	4.00	liquefies
1C 663	950	-111.951481000	40.689306000	Qal2	2.00	liquefies
1C 664	7927	-111.950278000	40.696389000	Qlaly	3.00	liquefies
1C 668	729	-111.986713000	40.758287000	Qlaly	2.00	liquefies
1C 698	6163	-111.950000000	40.758380000	Qal1	3.00	liquefies
1C 699	6165	-111.950000000	40.760093000	Qal1	3.00	liquefies
1C 700	9400	-111.949769000	40.762824000	Qaly	3.00	liquefies
1C 701	6032	-111.948102000	40.764861000	Qaly	3.00	liquefies
1C 737	5630	-111.986759000	40.752917000	Qlaly	2.00	liquefies
1C 738	5777	-111.986713000	40.754583000	Qlaly	2.00	liquefies
1C 827	1157	-111.903611000	40.620093000	Qlbpm	2.00	liquefies
1C 829N	1159	-111.903009000	40.628843000	Qlbpm	2.00	liquefies
1C 832N	4534	-111.904722000	40.634722000	Qlbpm	2.00	liquefies
1C 833	4016	-111.902315000	40.631574000	Qal1	3.00	liquefies
1C 836N	1089	-111.902870000	40.642917000	Qal2	2.00	liquefies
1C 849	792	-111.903333000	40.721389000	Qal1	3.00	liquefies
1C 850	843	-111.900556000	40.717222000	Qlaly	4.00	liquefies
1C 860N	7069	-111.904259000	40.722269000	Qal1	3.00	liquefies
1C 861	7405	-111.903333000	40.721389000	Qal1	3.00	liquefies

1C 868N	715	-111.841944000	40.747500000	Qlbpm	0.00	does not liquefy
1C 870	666	-111.908333000	40.758333000	Qal1	3.00	liquefies
1C 875N	5822	-111.922912000	40.766667000	Qal1	3.00	liquefies
1C 880N	622	-111.905787000	40.768704000	Qlaly	4.00	liquefies
1C 931	974	-111.797222000	40.688889000	Qalp	0.00	does not liquefy
1D 672	5394	-111.916481000	40.818565000	Qlbpg	0.00	does not liquefy
1E1322	5501	-111.948009000	40.811389000	Qal1	4.00	liquefies
1F 56	6854	-111.894491000	40.544213000	Qlbpm	3.00	liquefies
1F 207	9192	-111.898889000	40.483611000	Qlpg	0.00	does not liquefy
1F 609N	10072	-111.900370000	40.587870000	Qlbpm	3.00	liquefies
1F 610N	1160	-111.903333000	40.620278000	Qlbpm	2.00	liquefies
1F 611N	4536	-111.903704000	40.630787000	Qal1	3.00	liquefies
1F 613N	8659	-111.904347000	40.632083000	Qal1	3.00	liquefies
1F 615N	8714	-111.904537000	40.635972000	Qlbpm	2.00	liquefies
1F 616N	3993	-111.899537000	40.654815000	Qal2	2.00	liquefies
1F 617N	1037	-111.901806000	40.674870000	Qal1	3.00	liquefies
1F 618N	3799	-111.902500000	40.693426000	Qal2	2.00	liquefies
1F 619N	959	-111.900736000	40.697778000	Qal2	2.00	liquefies
1F 622	852	-111.900556000	40.717222000	Qlaly	4.00	liquefies
1F 628	7598	-111.904167000	40.718333000	Qal1	3.00	liquefies
1F 629	7600	-111.903981000	40.717685000	Qal1	3.00	liquefies
1F 630N	7070	-111.904069000	40.725370000	Qal1	3.00	liquefies
1F 631	793	-111.903472000	40.725370000	Qal1	3.00	liquefies
1F 633N	771	-111.904537000	40.733472000	Qal1	3.00	liquefies
1F 634	7026	-111.904537000	40.733472000	Qal1	3.00	liquefies
1F 636N	738	-111.904444000	40.745741000	Qal1	3.00	liquefies
1F 637N	2289	-111.906481000	40.747639000	Qal1	3.00	liquefies
1F 646N	7314	-111.899537000	40.569769000	Qlbpm	3.00	liquefies
1F 647N	1189	-111.904815000	40.605648000	Qlbpm	2.00	liquefies
1F 648N	5104	-111.905602000	40.610602000	Qlbpm	2.00	liquefies
1F 649N	7162	-111.901667000	40.667778000	Qal1	3.00	liquefies
1F 655N	6425	-111.903935000	40.741481000	Qal1	3.00	liquefies
1F 656	7023	-111.903056000	40.740833000	Qal1	3.00	liquefies
1F 658N	682	-111.910417000	40.751944000	Qal1	3.00	liquefies
1F 660N	5824	-111.921292000	40.765000000	Qal1	3.00	liquefies
1F 661N	4422	-111.910370000	40.771574000	Qlaly	4.00	liquefies
1F 662N	5595	-111.910181000	40.776065000	Qlaly	4.00	liquefies
1F 664	8756	-111.901389000	40.632222000	Qal2	2.00	liquefies
1F 694	1352	-111.890833000	40.526667000	Qlbpm	3.00	liquefies
2C 400	2290	-111.903190000	40.747315000	Qal1	3.00	liquefies
2C 402	7014	-111.905278000	40.741944000	Qal1	3.00	liquefies
2C 421	885	-111.817958000	40.712870000	Qlbm	2.00	liquefies
2C 438	1394	-112.220556000	40.725139000	Qly	2.00	liquefies
2C 551	798	-111.871667000	40.718611000	Qlaly	4.00	liquefies
2C 554	8804	-111.907269000	40.636528000	Qlbpm	2.00	liquefies
2C 585	9166	-111.939259000	40.644583000	Qlbpm	2.00	liquefies
2C 624	5564	-111.966111000	40.765463000	Qaly	3.00	liquefies
2C 631	5719	-111.982917000	40.763796000	Qlaly	4.00	liquefies
2C 633	5827	-111.986620000	40.769815000	Qly	4.00	liquefies

2C 637	5835	-111.982731000	40.765370000	Qlaly	4.00	liquefies
2C 702	5965	-111.949722000	40.765278000	Qaly	3.00	liquefies
2C 710	6183	-112.039583000	40.771111000	Qlaly	2.00	liquefies
2C 732	6175	-112.005556000	40.769769000	Qlaly	4.00	liquefies
2C 761	9507	-111.811157000	40.634954000	Qal1	3.00	liquefies
2C 838	772	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 839	794	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 844	7034	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 845	7036	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 854	7605	-111.898889000	40.718333000	Qlaly	4.00	liquefies
2C 871	7038	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 876	6093	-111.915370000	40.761296000	Qal1	3.00	liquefies
2C 884	6056	-111.916944000	40.763611000	Qal1	3.00	liquefies
2C 887	5427	-111.917125000	40.814213000	Pz	0.00	does not liquefy
2C 919	7470	-112.117958000	40.717731000	Qlbpg	0.00	does not liquefy
2F 43	830	-111.882361000	40.718380000	Qlaly	4.00	liquefies
2F 44	853	-111.893704000	40.717870000	Qlaly	4.00	liquefies
2F 46	800	-111.865000000	40.719120000	Qlaly	4.00	liquefies
2F 47	802	-111.858380000	40.719537000	Qlbpm	0.00	does not liquefy
2F 50	839	-111.822731000	40.712963000	Qlbm	2.00	liquefies
2F 51	886	-111.822731000	40.712963000	Qlbm	2.00	liquefies
2F 71	846	-111.874347000	40.718148000	Qlaly	4.00	liquefies
2F 76	5472	-111.944301000	40.831759000	Qal1	4.00	liquefies
2F 133	9467	-111.922222000	40.638657000	Qal1	3.00	liquefies
2F 283	9440	-111.932546000	40.644491000	Qlbpm	2.00	liquefies
2F 620E	789	-111.925000000	40.724074000	Qal1	3.00	liquefies
2F 621E	825	-111.917269000	40.724537000	Qal1	3.00	liquefies
2F 624	7604	-111.899722000	40.718889000	Qlaly	4.00	liquefies
2F 625	7608	-111.899722000	40.718889000	Qlaly	4.00	liquefies
2F 626E	854	-111.891389000	40.718333000	Qlaly	4.00	liquefies
2F 627	7629	-111.891389000	40.718333000	Qlaly	4.00	liquefies
2F 640	668	-111.907778000	40.755833000	Qal1	3.00	liquefies
2F 643	6058	-111.919903000	40.764444000	Qal1	3.00	liquefies
2F 645	6084	-111.920000000	40.764074000	Qal1	3.00	liquefies
2F 651E	7619	-111.894722000	40.717778000	Qlaly	4.00	liquefies
3C 423	889	-111.805556000	40.712778000	Mz	0.00	does not liquefy
3C 520	7820	-111.952870000	40.697037000	Qlaly	3.00	liquefies
3C 528	8854	-111.952778000	40.667500000	Qlbpm	2.00	liquefies
3C 587	3266	-111.952958000	40.653380000	Qlbpm	2.00	liquefies
3C 617	6898	-111.951481000	40.725787000	Qaly	3.00	liquefies
3C 625	5840	-111.987269000	40.765185000	Qlaly	4.00	liquefies
3C 663	7932	-111.952083000	40.690000000	Qal2	2.00	liquefies
3C 668	5846	-111.987269000	40.758843000	Qlaly	2.00	liquefies
3C 694	9438	-111.951292000	40.758796000	Qal1	3.00	liquefies
3C 695	9532	-111.951991000	40.760000000	Qal1	3.00	liquefies
3C 696	5992	-111.947315000	40.766204000	Qaly	3.00	liquefies
3C 697	6055	-111.945000000	40.767130000	Qaly	3.00	liquefies
3C 703	9480	-111.951065000	40.766019000	Qaly	3.00	liquefies
3C 737	5848	-111.987222000	40.753426000	Qlaly	2.00	liquefies

3C 738	5850	-111.987222000	40.755139000	Qlaly	2.00	liquefies
3C 739	6077	-111.946759000	40.766343000	Qaly	3.00	liquefies
3C 828	1163	-111.903611000	40.621111000	Qlbpm	2.00	liquefies
3C 829S	8885	-111.903935000	40.629861000	Qlbpm	2.00	liquefies
3C 830	4015	-111.904120000	40.629444000	Qlbpm	2.00	liquefies
3C 832S	8984	-111.905417000	40.635324000	Qlbpm	2.00	liquefies
3C 834	9225	-111.905556000	40.635370000	Qlbpm	2.00	liquefies
3C 835	9445	-111.905412000	40.636667000	Qlbpm	2.00	liquefies
3C 836S	1086	-111.903333000	40.643472000	Qal2	2.00	liquefies
3C 842	7756	-111.902778000	40.715278000	Qlaly	4.00	liquefies
3C 859	7596	-111.904722000	40.718657000	Qal1	3.00	liquefies
3C 860S	7597	-111.904861000	40.722685000	Qal1	3.00	liquefies
3C 862	7624	-111.905370000	40.722593000	Qal1	3.00	liquefies
3C 868S	6423	-111.909537000	40.749167000	Qal1	3.00	liquefies
3C 875S	6095	-111.914769000	40.761481000	Qal1	3.00	liquefies
3C 878	657	-111.998056000	40.763333000	Qlaly	4.00	liquefies
3C 880S	4424	-111.911801000	40.769676000	Qlaly	4.00	liquefies
3C 886	6097	-111.915968000	40.764815000	Qal1	3.00	liquefies
3C 931	7449	-111.797778000	40.689444000	Qalp	0.00	does not liquefy
3F 53	8433	-111.796894000	40.707593000	Qlbm	0.00	does not liquefy
3F 56	9238	-111.895181000	40.544537000	Qlbpm	3.00	liquefies
3F 207	6449	-111.902593000	40.747407000	Qal1	3.00	liquefies
3F 609S	10074	-111.901944000	40.588704000	Qlbpm	3.00	liquefies
3F 610S	4014	-111.903611000	40.621111000	Qlbpm	2.00	liquefies
3F 611S	9446	-111.904444000	40.630972000	Qal1	3.00	liquefies
3F 612	9484	-111.904815000	40.630648000	Qal1	3.00	liquefies
3F 613S	9496	-111.905000000	40.632269000	Qal1	3.00	liquefies
3F 614	9486	-111.905833000	40.633056000	Qal2	2.00	liquefies
3F 615S	9495	-111.904537000	40.636667000	Qlbpm	2.00	liquefies
3F 616S	3995	-111.901111000	40.653333000	Qal2	2.00	liquefies
3F 617S	8931	-111.901898000	40.674861000	Qal1	3.00	liquefies
3F 618S	8010	-111.902634000	40.695787000	Qal2	2.00	liquefies
3F 619S	8012	-111.902315000	40.697778000	Qal2	2.00	liquefies
3F 630S	922	-111.897222000	40.706111000	Qlaly	4.00	liquefies
3F 632	7789	-111.902778000	40.715278000	Qlaly	4.00	liquefies
3F 633S	7071	-111.905134000	40.733889000	Qal1	3.00	liquefies
3F 635	7263	-111.905324000	40.733333000	Qal1	3.00	liquefies
3F 636S	6707	-111.904722000	40.744583000	Qal1	3.00	liquefies
3F 637S	6711	-111.907037000	40.747083000	Qal1	3.00	liquefies
3F 646S	10246	-111.899625000	40.569722000	Qlbpm	3.00	liquefies
3F 647S	9175	-111.905231000	40.606250000	Qlbpm	2.00	liquefies
3F 648S	9748	-111.906528000	40.611204000	Qlbpm	2.00	liquefies
3F 649S	8935	-111.901759000	40.667593000	Qal1	3.00	liquefies
3F 653	7627	-111.905509000	40.722731000	Qal1	3.00	liquefies
3F 654	7791	-111.905556000	40.723611000	Qal1	3.00	liquefies
3F 655S	7029	-111.904583000	40.741944000	Qal1	3.00	liquefies
3F 657	7033	-111.905134000	40.741898000	Qal1	3.00	liquefies
3F 658S	6119	-111.911389000	40.752315000	Qal1	3.00	liquefies
3F 660S	5842	-111.913981000	40.765417000	Qal1	3.00	liquefies

3F 661S	5829	-111.911204000	40.772130000	Qlaly	4.00	liquefies
3F 662S	5626	-111.910926000	40.776250000	Qlaly	4.00	liquefies
3F 665	8024	-111.906014000	40.718889000	Qal1	3.00	liquefies
3F 694	9114	-111.891389000	40.526667000	Qlbpm	3.00	liquefies
4C 400	6599	-111.902593000	40.747546000	Qal1	3.00	liquefies
4C 402	683	-111.896111000	40.747778000	Qal1	3.00	liquefies
4C 424	16778	-111.790134000	40.711944000	Mz	0.00	does not liquefy
4C 438	17029	-112.220139000	40.725694000	Qly	2.00	liquefies
4C 551	848	-111.870833000	40.718935000	Qlaly	4.00	liquefies
4C 585	9333	-111.938514000	40.645000000	Qlbpm	2.00	liquefies
4C 710	17321	-112.038889000	40.771343000	Qlaly	2.00	liquefies
4C 727	9535	-111.861435000	40.630000000	Qal1	3.00	liquefies
4C 736	1139	-111.833981000	40.631759000	Qlpg	0.00	does not liquefy
4C 760	9593	-111.811245000	40.635648000	Qal1	3.00	liquefies
4C 837	6635	-111.912958000	40.724907000	Qal1	3.00	liquefies
4C 841	6702	-111.909167000	40.750000000	Qal1	3.00	liquefies
4C 846	6708	-111.909167000	40.750000000	Qal1	3.00	liquefies
4C 847	8026	-111.902222000	40.718056000	Qlaly	4.00	liquefies
4C 848	6964	-111.909167000	40.750000000	Qal1	3.00	liquefies
4C 851	8030	-111.902222000	40.718056000	Qlaly	4.00	liquefies
4C 852	8039	-111.902222000	40.718056000	Qlaly	4.00	liquefies
4C 853	7633	-111.899444000	40.718056000	Qlaly	4.00	liquefies
4C 855	7632	-111.896801000	40.718380000	Qlaly	4.00	liquefies
4C 856	7639	-111.896759000	40.718750000	Qlaly	4.00	liquefies
4C 873	6099	-111.910000000	40.755556000	Qal1	3.00	liquefies
4C 874	624	-111.900278000	40.759167000	Qlaly	4.00	liquefies
4C 883	6101	-111.919167000	40.764444000	Qal1	3.00	liquefies
4C 885	6104	-111.916759000	40.764769000	Qal1	3.00	liquefies
4C 919	7487	-112.117824000	40.718056000	Qlaly	4.00	liquefies
4F 36	6531	-111.965972000	40.765046000	Qaly	3.00	liquefies
4F 43	856	-111.882361000	40.718380000	Qlaly	4.00	liquefies
4F 44	857	-111.877037000	40.717870000	Qlaly	4.00	liquefies
4F 46	849	-111.865412000	40.719630000	Qlaly	4.00	liquefies
4F 47	859	-111.856944000	40.720000000	Qlbpm	0.00	does not liquefy
4F 50	838	-111.833611000	40.716806000	Qal1	3.00	liquefies
4F 51	8384	-111.822222000	40.713287000	Qlbm	2.00	liquefies
4F 71	877	-111.873792000	40.718750000	Qlaly	4.00	liquefies
4F 133	9471	-111.921847000	40.638889000	Qal1	3.00	liquefies
4F 283	9453	-111.931991000	40.645000000	Qlbpm	2.00	liquefies
4F 415	9761	-111.966292000	40.765509000	Qaly	3.00	liquefies
4F 620W	3728	-111.925046000	40.724537000	Qal1	3.00	liquefies
4F 621W	6732	-111.917269000	40.724537000	Qal1	3.00	liquefies
4F 623	7840	-111.899444000	40.718056000	Qlaly	4.00	liquefies
4F 626W	7641	-111.891389000	40.718333000	Qlaly	4.00	liquefies
4F 641	641	-111.900278000	40.759167000	Qlaly	4.00	liquefies
4F 642	7064	-111.914167000	40.727269000	Qal1	3.00	liquefies
4F 651W	7651	-111.893889000	40.718472000	Qlaly	4.00	liquefies
4F 652	7654	-111.893889000	40.718750000	Qlaly	4.00	liquefies
035191C	5879	-111.985926000	40.773519000	Qly	4.00	liquefies

035192F	5885	-111.986389000	40.774444000	Qly	4.00	liquefies
035194C	5901	-111.986847000	40.773472000	Qly	4.00	liquefies
0C 141	5105	-111.890787000	40.608148000	Qlbpm	2.00	liquefies
0C 253	932	-112.092037000	40.677222000	Qafy	0.00	does not liquefy
0C 254	499	-112.054676000	40.615370000	QTaf	0.00	does not liquefy
0C 317	953	-111.905278000	40.702500000	Qal1	3.00	liquefies
0C 369	6074	-111.932778000	40.765509000	Qal1	3.00	liquefies
0C 384	1040	-111.896806000	40.674398000	Qal2	2.00	liquefies
0C 385	1039	-111.894213000	40.674398000	Qal2	2.00	liquefies
0C 401	740	-111.899444000	40.747546000	Qal1	3.00	liquefies
0C 417	564	-111.913426000	40.786528000	Qal2	2.00	liquefies
0C 420	7661	-111.888657000	40.718102000	Qlaly	4.00	liquefies
0C 422	8413	-111.806157000	40.713704000	Mz	0.00	does not liquefy
0C 436	1014	-112.074023000	40.652065000	Qlbg	0.00	does not liquefy
0C 441	9619	-111.905556000	40.620880000	Qlbpm	2.00	liquefies
0C 460	6679	-111.948468000	40.751759000	Qal1	3.00	liquefies
0C 493	5492	-111.920833000	40.815509000	Qly	4.00	liquefies
0C 497	9443	-111.907546000	40.620926000	Qlbpm	2.00	liquefies
0C 505	9474	-111.898611000	40.635000000	Qlbpm	2.00	liquefies
0C 508	9844	-111.902315000	40.634769000	Qlbpm	2.00	liquefies
0C 509	9516	-111.902037000	40.635556000	Qlbpm	2.00	liquefies
0C 518	7451	-111.797361000	40.686898000	Qalp	0.00	does not liquefy
0C 545	8739	-111.798657000	40.678472000	Qlbg	0.00	does not liquefy
0C 561	8946	-111.898426000	40.655093000	Qal2	2.00	liquefies
0C 576	5843	-111.906389000	40.771667000	Qlaly	4.00	liquefies
0C 579	9442	-111.934306000	40.643889000	Qlbpm	2.00	liquefies
0C 584	9473	-111.898333000	40.634722000	Qlbpm	2.00	liquefies
0C 620	9452	-111.889537000	40.631574000	Qlbpm	2.00	liquefies
0C 621	9490	-111.891111000	40.633889000	Qlbpm	2.00	liquefies
0C 629	1389	-111.951847000	40.682222000	Qal2	2.00	liquefies
0C 635	6192	-112.063148000	40.770694000	Qlaly	2.00	liquefies
0C 649	9482	-111.920278000	40.638426000	Qal1	3.00	liquefies
0C 659	7802	-111.952500000	40.704259000	Qlaly	3.00	liquefies
0C 662	7741	-111.953333000	40.712500000	Qaly	3.00	liquefies
0C 669	5538	-112.025093000	40.770880000	Qlaly	4.00	liquefies
0C 675	990	-111.939069000	40.675648000	Qal2	2.00	liquefies
0C 688	9552	-111.950833000	40.758843000	Qal1	3.00	liquefies
0C 692	9598	-111.950458000	40.765139000	Qaly	3.00	liquefies
0C 693	5966	-111.948981000	40.771296000	Qaly	3.00	liquefies
0C 704	9622	-111.950926000	40.762361000	Qal1	3.00	liquefies
0C 705	9309	-111.881898000	40.632870000	Qal2	2.00	liquefies
0C 709	6596	-111.968565000	40.726759000	Qlaly	2.00	liquefies
0C 725	9308	-111.872037000	40.629815000	Qal2	2.00	liquefies
0C 726	9536	-111.864722000	40.629583000	Qal2	2.00	liquefies
0C 752	7803	-111.949167000	40.706759000	Qaly	3.00	liquefies
0C 757	9638	-111.808611000	40.638426000	Qlpd	0.00	does not liquefy
0C 759	9631	-111.811065000	40.638426000	Qal2	0.00	does not liquefy
0C 762	3971	-112.091157000	40.666019000	Qlbg	0.00	does not liquefy
0C 766	1019	-112.024625000	40.659444000	Qlbpg	0.00	does not liquefy

0C 779	10641	-111.920968000	40.486963000	Qlbps	0.00	does not liquefy
0C 785	5200	-111.976944000	40.593426000	Qlbpg	0.00	does not liquefy
0C 800	1238	-111.977315000	40.573056000	Qlbpm	0.00	does not liquefy
0C 806	568	-111.901944000	40.782500000	Qlaly	4.00	liquefies
0C 807	10077	-111.902778000	40.587870000	Qlbpm	3.00	liquefies
0C 809	6826	-111.901236000	40.559116000	Qlbpm	3.00	liquefies
0C 812	992	-111.903333000	40.686667000	Qal2	2.00	liquefies
0C 813	8016	-111.904444000	40.712222000	Qal1	3.00	liquefies
0C 814	8836	-111.901847000	40.660741000	Qal2	2.00	liquefies
0C 815	6697	-111.976569000	40.502593000	Qlbpm	0.00	does not liquefy
0C 816	5592	-111.911111000	40.781944000	Qlaly	4.00	liquefies
0C 817	11286	-111.929301000	40.497810000	Qal1	3.00	liquefies
0C 818	9140	-111.913935000	40.497269000	Qal2	2.00	liquefies
0C 819	10582	-111.891435000	40.504167000	Qlbpm	3.00	liquefies
0C 822	10606	-111.957454000	40.500287000	Qlbpm	0.00	does not liquefy
0C 823	7121	-111.979856000	40.703657000	Qlaly	3.00	liquefies
0C 890	8448	-111.801801000	40.712176000	Mz	0.00	does not liquefy
0C 891	8452	-111.796204000	40.708519000	Mz	0.00	does not liquefy
0C 895	1071	-112.004255000	40.652778000	Qlbpg	0.00	does not liquefy
0C 896	4334	-111.982634000	40.507593000	Qlbpm	0.00	does not liquefy
0C 897	486	-111.981523000	40.682037000	Qlbpm	0.00	does not liquefy
0C 906	1341	-111.984444000	40.522037000	Qlbpm	0.00	does not liquefy
0C 911	1282	-111.928981000	40.562037000	Qlbps	0.00	does not liquefy
0C 920	9499	-111.898514000	40.635370000	Qlbpm	2.00	liquefies
0C 921	595	-111.837315000	40.765000000	Qlpm	0.00	does not liquefy
0C 927	1178	-111.971944000	40.614444000	Qlbpm	0.00	does not liquefy
0C 934	10450	-111.956991000	40.522361000	Qlbpm	0.00	does not liquefy
0C 939	7740	-111.938889000	40.712778000	Qaly	3.00	liquefies
0D 449	10146	-112.089213000	40.566259000	Qafo	0.00	does not liquefy
0F 6	6086	-111.929954000	40.764912000	Qal1	3.00	liquefies
0F 34	6087	-111.938935000	40.764722000	Qal1	3.00	liquefies
0F 35	6090	-111.939028000	40.765926000	Qal1	3.00	liquefies
0F 48	861	-111.853657000	40.719583000	Qlbm	2.00	liquefies
0F 49	864	-111.842125000	40.718565000	Qal1	0.00	does not liquefy
0F 52	8412	-111.808843000	40.716667000	Qlbg	0.00	does not liquefy
0F 54	11902	-111.795556000	40.716435000	Mz	0.00	does not liquefy
0F 131	9485	-111.910231000	40.635833000	Qlbpm	2.00	liquefies
0F 156	8757	-111.803009000	40.674630000	Qlbg	0.00	does not liquefy
0F 310	9193	-111.888472000	40.653704000	Qlbpm	2.00	liquefies
0F 410	6307	-111.948102000	40.746250000	Qal1	3.00	liquefies
0F 431	5769	-111.949769000	40.813194000	Qal1	4.00	liquefies
0F 458	9641	-111.807958000	40.646204000	Qaf2	2.00	liquefies
0F 470	5771	-111.949815000	40.805648000	Qal1	4.00	liquefies
0F 475	9683	-111.862454000	40.629861000	Qal2	2.00	liquefies
0F 477	6427	-111.949306000	40.733056000	Qaly	3.00	liquefies
0F 500	5557	-111.948611000	40.784676000	Qaly	3.00	liquefies
0F 504	9685	-111.854583000	40.630185000	Qal2	2.00	liquefies
0F 505	1140	-111.825134000	40.634907000	Qlpg	0.00	does not liquefy
0F 506	9627	-111.833981000	40.632824000	Qlpg	0.00	does not liquefy

0F 522	7011	-111.986157000	40.725694000	Qlaly	2.00	liquefies
0F 523	5069	-112.024722000	40.725602000	Qlaly	2.00	liquefies
0F 547	7444	-112.182824000	40.745139000	Qly	2.00	liquefies
0F 576	10843	-111.977037000	40.593519000	Qlbpg	0.00	does not liquefy
0F 596	4836	-111.984120000	40.536759000	Qlbpm	0.00	does not liquefy
0F 663	6828	-111.897870000	40.559074000	Qlbpm	3.00	liquefies
0F 696	4869	-111.905093000	40.526759000	Qlbpm	3.00	liquefies
0R 8	9313	-111.875417000	40.630694000	Qal1	2.00	liquefies
0R 32	9549	-111.866847000	40.630648000	Qal2	2.00	liquefies
0R 34	9888	-111.871944000	40.630324000	Qal2	2.00	liquefies
0R 35	9890	-111.866528000	40.630602000	Qal2	2.00	liquefies
0R 36	9893	-111.864722000	40.629583000	Qal2	2.00	liquefies
0R 54	9895	-111.854583000	40.630185000	Qal2	2.00	liquefies
0R 55	9896	-111.858611000	40.630324000	Qal2	2.00	liquefies
0R 56	9912	-111.859579000	40.629861000	Qal1	3.00	liquefies
0R 59	9405	-111.848704000	40.630833000	Qlbpm	0.00	does not liquefy
0R 61	9673	-111.837917000	40.631759000	Qlpg	0.00	does not liquefy
0R 255	9747	-111.921435000	40.609583000	Qal1	3.00	liquefies
0R 256	9791	-111.921435000	40.609583000	Qal1	3.00	liquefies
0R 257	9758	-111.976991000	40.609167000	Qlbpm	0.00	does not liquefy
0R 288	10845	-111.976991000	40.593009000	Qlbpg	0.00	does not liquefy
0V 984	9751	-111.907546000	40.620972000	Qlbpm	2.00	liquefies
1C 520	7929	-111.952269000	40.696204000	Qlaly	3.00	liquefies
1C 528	8891	-111.952269000	40.667454000	Qlbpm	2.00	liquefies
1C 587	3345	-111.952361000	40.651157000	Qlbpm	2.00	liquefies
1C 617	6989	-111.951481000	40.725046000	Qaly	3.00	liquefies
1C 628	6033	-111.987222000	40.764167000	Qlaly	4.00	liquefies
1C 663	7935	-111.951481000	40.689306000	Qal2	2.00	liquefies
1C 664	7936	-111.950278000	40.696389000	Qlaly	3.00	liquefies
1C 698	7482	-111.950000000	40.758380000	Qal1	3.00	liquefies
1C 700	9737	-111.949769000	40.762824000	Qaly	3.00	liquefies
1C 700	9817	-111.949769000	40.762824000	Qaly	3.00	liquefies
1C 701	6685	-111.948102000	40.764861000	Qaly	3.00	liquefies
1C 738	6035	-111.986713000	40.754583000	Qlaly	2.00	liquefies
1C 827	9753	-111.903611000	40.620093000	Qlbpm	2.00	liquefies
1C 832N	9838	-111.904722000	40.634722000	Qlbpm	2.00	liquefies
1C 833	9834	-111.902315000	40.631574000	Qal1	3.00	liquefies
1C 836N	9267	-111.902870000	40.642917000	Qal2	2.00	liquefies
1C 849	8044	-111.903333000	40.721389000	Qal1	3.00	liquefies
1C 850	8022	-111.900556000	40.717222000	Qlaly	4.00	liquefies
1C 860N	8047	-111.904259000	40.722269000	Qal1	3.00	liquefies
1C 861	8049	-111.903333000	40.721389000	Qal1	3.00	liquefies
1C 868N	717	-111.841944000	40.747500000	Qlbpm	0.00	does not liquefy
1C 875N	6106	-111.922912000	40.766667000	Qal1	3.00	liquefies
1C 880N	5863	-111.905787000	40.768704000	Qlaly	4.00	liquefies
1C 931	8434	-111.797222000	40.688889000	Qalp	0.00	does not liquefy
1D 672	5480	-111.916481000	40.818565000	Qlbpg	0.00	does not liquefy
1F 56	9240	-111.894491000	40.544213000	Qlbpm	3.00	liquefies
1F 207	9303	-111.898889000	40.483611000	Qlpg	0.00	does not liquefy

1F 609N	10079	-111.900370000	40.587870000	Qlbpm	3.00	liquefies
1F 610N	9814	-111.903333000	40.620278000	Qlbpm	2.00	liquefies
1F 613N	9837	-111.904347000	40.632083000	Qal1	3.00	liquefies
1F 615N	11046	-111.904537000	40.635972000	Qlbpm	2.00	liquefies
1F 616N	9011	-111.899537000	40.654815000	Qal2	2.00	liquefies
1F 617N	8939	-111.901806000	40.674870000	Qal1	3.00	liquefies
1F 619N	8015	-111.900736000	40.697778000	Qal2	2.00	liquefies
1F 628	8045	-111.904167000	40.718333000	Qal1	3.00	liquefies
1F 629	8428	-111.903981000	40.717685000	Qal1	3.00	liquefies
1F 630N	7293	-111.904069000	40.725370000	Qal1	3.00	liquefies
1F 631	7096	-111.903472000	40.725370000	Qal1	3.00	liquefies
1F 633N	7294	-111.904537000	40.733472000	Qal1	3.00	liquefies
1F 634	7297	-111.904537000	40.733472000	Qal1	3.00	liquefies
1F 636N	6712	-111.904444000	40.745741000	Qal1	3.00	liquefies
1F 637N	6714	-111.906481000	40.747639000	Qal1	3.00	liquefies
1F 646N	10364	-111.899537000	40.569769000	Qlbpm	3.00	liquefies
1F 647N	9806	-111.904815000	40.605648000	Qlbpm	2.00	liquefies
1F 648N	9803	-111.905602000	40.610602000	Qlbpm	2.00	liquefies
1F 649N	8942	-111.901667000	40.667778000	Qal1	3.00	liquefies
1F 655N	7040	-111.903935000	40.741481000	Qal1	3.00	liquefies
1F 656	7042	-111.903056000	40.740833000	Qal1	3.00	liquefies
1F 658N	6123	-111.910417000	40.751944000	Qal1	3.00	liquefies
1F 660N	6108	-111.921292000	40.765000000	Qal1	3.00	liquefies
1F 661N	5833	-111.910370000	40.771574000	Qlaly	4.00	liquefies
1F 662N	5628	-111.910181000	40.776065000	Qlaly	4.00	liquefies
1F 664	9843	-111.901389000	40.632222000	Qal2	2.00	liquefies
1F 694	9199	-111.890833000	40.526667000	Qlbpm	3.00	liquefies
2C 400	6601	-111.903190000	40.747315000	Qal1	3.00	liquefies
2C 402	7054	-111.905278000	40.741944000	Qal1	3.00	liquefies
2C 421	8393	-111.817958000	40.712870000	Qlbm	2.00	liquefies
2C 551	879	-111.871667000	40.718611000	Qlaly	4.00	liquefies
2C 554	11880	-111.907269000	40.636528000	Qlbpm	2.00	liquefies
2C 585	9456	-111.939259000	40.644583000	Qlbpm	2.00	liquefies
2C 624	10300	-111.966111000	40.765463000	Qaly	3.00	liquefies
2C 631	6066	-111.982917000	40.763796000	Qlaly	4.00	liquefies
2C 633	6134	-111.986620000	40.769815000	Qly	4.00	liquefies
2C 637	6068	-111.982731000	40.765370000	Qlaly	4.00	liquefies
2C 702	9925	-111.949722000	40.765278000	Qaly	3.00	liquefies
2C 732	6641	-112.005556000	40.769769000	Qlaly	4.00	liquefies
2C 761	9650	-111.811157000	40.634954000	Qal1	3.00	liquefies
2C 838	7075	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 844	7097	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 845	7107	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 871	7109	-111.898889000	40.735000000	Qlaly	4.00	liquefies
2C 876	6121	-111.915370000	40.761296000	Qal1	3.00	liquefies
2C 884	6136	-111.916944000	40.763611000	Qal1	3.00	liquefies
2C 884	6138	-111.916944000	40.763611000	Qal1	3.00	liquefies
2C 887	5507	-111.917125000	40.814213000	Pz	0.00	does not liquefy
2C 919	7622	-112.117958000	40.717731000	Qlbpg	0.00	does not liquefy

2F 43	7669	-111.882361000	40.718380000	Qlaly	4.00	liquefies
2F 44	7845	-111.893704000	40.717870000	Qlaly	4.00	liquefies
2F 46	880	-111.865000000	40.719120000	Qlaly	4.00	liquefies
2F 47	863	-111.858380000	40.719537000	Qlbpm	0.00	does not liquefy
2F 50	8395	-111.822731000	40.712963000	Qlbm	2.00	liquefies
2F 51	8397	-111.822731000	40.712963000	Qlbm	2.00	liquefies
2F 71	7670	-111.874347000	40.718148000	Qlaly	4.00	liquefies
2F 283	9458	-111.932546000	40.644491000	Qlbpm	2.00	liquefies
2F 621E	7281	-111.917269000	40.724537000	Qal1	3.00	liquefies
2F 624	7847	-111.899722000	40.718889000	Qlaly	4.00	liquefies
2F 625	8043	-111.899722000	40.718889000	Qlaly	4.00	liquefies
2F 626E	7920	-111.891389000	40.718333000	Qlaly	4.00	liquefies
2F 627	7961	-111.891389000	40.718333000	Qlaly	4.00	liquefies
2F 640	6140	-111.907778000	40.755833000	Qal1	3.00	liquefies
2F 643	6703	-111.919903000	40.764444000	Qal1	3.00	liquefies
2F 645	8928	-111.920000000	40.764074000	Qal1	3.00	liquefies
2F 651E	7998	-111.894722000	40.717778000	Qlaly	4.00	liquefies
3C 423	8419	-111.805556000	40.712778000	Mz	0.00	does not liquefy
3C 520	7930	-111.952870000	40.697037000	Qlaly	3.00	liquefies
3C 528	8890	-111.952778000	40.667500000	Qlbpm	2.00	liquefies
3C 587	9148	-111.952958000	40.653380000	Qlbpm	2.00	liquefies
3C 617	6992	-111.951481000	40.725787000	Qaly	3.00	liquefies
3C 625	6538	-111.987269000	40.765185000	Qlaly	4.00	liquefies
3C 663	7940	-111.952083000	40.690000000	Qal2	2.00	liquefies
3C 694	10377	-111.951292000	40.758796000	Qal1	3.00	liquefies
3C 696	9605	-111.947315000	40.766204000	Qaly	3.00	liquefies
3C 697	12654	-111.945000000	40.767130000	Qaly	3.00	liquefies
3C 703	12657	-111.951065000	40.766019000	Qaly	3.00	liquefies
3C 738	7020	-111.987222000	40.755139000	Qlaly	2.00	liquefies
3C 739	12656	-111.946759000	40.766343000	Qaly	3.00	liquefies
3C 828	9830	-111.903611000	40.621111000	Qlbpm	2.00	liquefies
3C 832S	12086	-111.905417000	40.635324000	Qlbpm	2.00	liquefies
3C 834	12088	-111.905556000	40.635370000	Qlbpm	2.00	liquefies
3C 835	11049	-111.905412000	40.636667000	Qlbpm	2.00	liquefies
3C 836S	9520	-111.903333000	40.643472000	Qal2	2.00	liquefies
3C 842	8059	-111.902778000	40.715278000	Qlaly	4.00	liquefies
3C 859	8232	-111.904722000	40.718657000	Qal1	3.00	liquefies
3C 860S	8259	-111.904861000	40.722685000	Qal1	3.00	liquefies
3C 862	12084	-111.905370000	40.722593000	Qal1	3.00	liquefies
3C 868S	7003	-111.909537000	40.749167000	Qal1	3.00	liquefies
3C 875S	7100	-111.914769000	40.761481000	Qal1	3.00	liquefies
3C 878	5820	-111.998056000	40.763333000	Qlaly	4.00	liquefies
3C 880S	6085	-111.911801000	40.769676000	Qlaly	4.00	liquefies
3C 886	8927	-111.915968000	40.764815000	Qal1	3.00	liquefies
3C 931	8677	-111.797778000	40.689444000	Qalp	0.00	does not liquefy
3F 53	8454	-111.796894000	40.707593000	Qlbm	0.00	does not liquefy
3F 56	10497	-111.895181000	40.544537000	Qlbpm	3.00	liquefies
3F 207	6718	-111.902593000	40.747407000	Qal1	3.00	liquefies
3F 609S	10081	-111.901944000	40.588704000	Qlbpm	3.00	liquefies

3F 610S	9835	-111.903611000	40.621111000	Qlbpm	2.00	liquefies
3F 613S	9813	-111.905000000	40.632269000	Qal1	3.00	liquefies
3F 614	12157	-111.905833000	40.633056000	Qal2	2.00	liquefies
3F 615S	12859	-111.904537000	40.636667000	Qlbpm	2.00	liquefies
3F 616S	9015	-111.901111000	40.653333000	Qal2	2.00	liquefies
3F 617S	8941	-111.901898000	40.674861000	Qal1	3.00	liquefies
3F 619S	8019	-111.902315000	40.697778000	Qal2	2.00	liquefies
3F 630S	7921	-111.897222000	40.706111000	Qlaly	4.00	liquefies
3F 632	11775	-111.902778000	40.715278000	Qlaly	4.00	liquefies
3F 633S	7303	-111.905134000	40.733889000	Qal1	3.00	liquefies
3F 635	7379	-111.905324000	40.733333000	Qal1	3.00	liquefies
3F 636S	7031	-111.904722000	40.744583000	Qal1	3.00	liquefies
3F 637S	7013	-111.907037000	40.747083000	Qal1	3.00	liquefies
3F 646S	10370	-111.899625000	40.569722000	Qlbpm	3.00	liquefies
3F 647S	10038	-111.905231000	40.606250000	Qlbpm	2.00	liquefies
3F 648S	10048	-111.906528000	40.611204000	Qlbpm	2.00	liquefies
3F 649S	8947	-111.901759000	40.667593000	Qal1	3.00	liquefies
3F 653	16809	-111.905509000	40.722731000	Qal1	3.00	liquefies
3F 654	8219	-111.905556000	40.723611000	Qal1	3.00	liquefies
3F 655S	7347	-111.904583000	40.741944000	Qal1	3.00	liquefies
3F 657	7359	-111.905134000	40.741898000	Qal1	3.00	liquefies
3F 658S	6706	-111.911389000	40.752315000	Qal1	3.00	liquefies
3F 660S	8929	-111.913981000	40.765417000	Qal1	3.00	liquefies
3F 661S	6336	-111.911204000	40.772130000	Qlaly	4.00	liquefies
3F 662S	5832	-111.910926000	40.776250000	Qlaly	4.00	liquefies
3F 665	16890	-111.906014000	40.718889000	Qal1	3.00	liquefies
3F 694	10498	-111.891389000	40.526667000	Qlbpm	3.00	liquefies
4C 400	6739	-111.902593000	40.747546000	Qal1	3.00	liquefies
4C 402	704	-111.896111000	40.747778000	Qal1	3.00	liquefies
4C 424	17129	-111.790134000	40.711944000	Mz	0.00	does not liquefy
4C 551	7681	-111.870833000	40.718935000	Qlaly	4.00	liquefies
4C 585	9460	-111.938514000	40.645000000	Qlbpm	2.00	liquefies
4C 727	9916	-111.861435000	40.630000000	Qal1	3.00	liquefies
4C 736	9681	-111.833981000	40.631759000	Qlpg	0.00	does not liquefy
4C 736	9688	-111.833981000	40.631759000	Qlpg	0.00	does not liquefy
4C 760	9652	-111.811245000	40.635648000	Qal1	3.00	liquefies
4C 837	7578	-111.912958000	40.724907000	Qal1	3.00	liquefies
4C 841	7009	-111.909167000	40.750000000	Qal1	3.00	liquefies
4C 846	8214	-111.909167000	40.750000000	Qal1	3.00	liquefies
4C 847	16899	-111.902222000	40.718056000	Qlaly	4.00	liquefies
4C 848	8479	-111.909167000	40.750000000	Qal1	3.00	liquefies
4C 853	8060	-111.899444000	40.718056000	Qlaly	4.00	liquefies
4C 873	6721	-111.910000000	40.755556000	Qal1	3.00	liquefies
4C 883	9756	-111.919167000	40.764444000	Qal1	3.00	liquefies
4C 885	11024	-111.916759000	40.764769000	Qal1	3.00	liquefies
4F 43	8000	-111.882361000	40.718380000	Qlaly	4.00	liquefies
4F 44	7684	-111.877037000	40.717870000	Qlaly	4.00	liquefies
4F 46	7683	-111.865412000	40.719630000	Qlaly	4.00	liquefies
4F 47	7694	-111.856944000	40.720000000	Qlbpm	0.00	does not liquefy

4F 50	867	-111.833611000	40.716806000	Qal1	3.00	liquefies
4F 51	8399	-111.822222000	40.713287000	Qlbm	2.00	liquefies
4F 71	7688	-111.873792000	40.718750000	Qlaly	4.00	liquefies
4F 283	9464	-111.931991000	40.645000000	Qlbpm	2.00	liquefies
4F 621W	7580	-111.917269000	40.724537000	Qal1	3.00	liquefies
4F 623	8062	-111.899444000	40.718056000	Qlaly	4.00	liquefies
4F 626W	8002	-111.891389000	40.718333000	Qlaly	4.00	liquefies
4F 641	670	-111.900278000	40.759167000	Qlaly	4.00	liquefies
4F 642	7283	-111.914167000	40.727269000	Qal1	3.00	liquefies
4F 651W	8004	-111.893889000	40.718472000	Qlaly	4.00	liquefies
4F 652	8075	-111.893889000	40.718750000	Qlaly	4.00	liquefies
4F 652	8075	-111.893889000	40.718750000	Qlaly	4.00	Liquefies

Appendix 2 - References

Bartlett S. F., Olsen, M. J., and Solomon, B. J., 2005, *Lateral spread hazard mapping of northern Salt Lake County for a magnitude 7.0 scenario earthquake*, Technical Report submitted to the United States Geological Survey, USGS Award No. 04HQGR0026, 218 p.

Erickson, G., 2007, *Probabilistic liquefaction potential mapping of the Salt Lake Valley, Utah*, M.S. Thesis, Department of Civil and Environmental Engineering, University of Utah.

NCEER (1997). "Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils," edited by Youd, T. L., and Idriss, I. M., Technical Report NCEER-97-0022, National Center for Earthquake Engineering Research.

Olsen, M. J., Bartlett, S. F. and Solomon, B. J., 2007, *Lateral spread hazard mapping of the northern Salt Lake Valley, Utah, for M7.0 scenario earthquake*, Earthquake Spectra, Vol. 23, Number 1, pp. 95-113.

Appendix 3 – Vulnerable and Critical Links

Table A3-1: Most vulnerable links (VISUM) in Salt Lake County

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
20593909	2059	3909	Yes	5	4	2100 South	EB	Redwood Rd	900 W
20593909	3909	2059	Yes	5	4	2100 South	WB	Redwood Rd	900 W
20595749	2059	5749	No	5	4	2100 South	WB	Redwood Rd	900 W
20595749	5749	2059	No	5	4	2100 South	EB	Redwood Rd	900 W
23015364	2301	5364	Yes	4	3	400 West	SB	North Temp	200 S
23015364	5364	2301	Yes	4	3	400 West	NB	North Temp	200 S
23015470	2301	5470	Yes	5	4	400 West	NB	North Temp	200 S
23015470	5470	2301	No	5	4	400 West	SB	North Temp	200 S
25254329	2525	4329	Yes	5	4	Redwood R	NB	Parkway B	Cent
25254329	4329	2525	Yes	5	4	Redwood R	SB	Parkway B	Cent

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
25254396	2525	4396	Yes	5	3	Redwood R	SB	Cent	3100 S
25254396	4396	2525	No	5	3	Redwood R	NB	Cent	3100 S
26223832	2622	3832	No	4	2	California	EB	7200 W	5600 W
26223832	3832	2622	No	4	2	California	WB	7200 W	5600 W
34325013	3432	5013	Yes	3	2	Blank	EB	4000 W	SR-186
34335013	3433	5013	Yes	3	2	CD Road	EB	Terminal Dr	SR-186
35215013	3521	5013	Yes	3	2	CD Road	EB	I-80 E	SR-186
35215294	3521	5294	Yes	3	2	Blank	NB	I-80 E	4000 W
35223711	3522	3711	Yes	5	2	5600 West	SB	I-80	700 S
35223711	3711	3522	No	5	2	5600 West	NB	I-80	700 S
35295850	3529	5850	No	4	2	Blank	SB	Amelia Ea	I-80

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
35295850	5850	3529	No	4	2	Blank	NB	Amelia Ea	I-80
35303531	3530	3531	Yes	4	2	700 North	WB	2200 W	I-215
35303531	3531	3530	No	4	2	700 North	EB	2200 W	I-215
35313625	3531	3625	No	4	2	2200 West	SB	700 N	North Temp
35313625	3625	3531	No	4	2	2200 West	NB	700 N	North Temp
35323680	3532	3680	Yes	5	3	CD Road	EB	CD Road	2200 W
35333534	3533	3534	No	4	2	700 North	EB	I-215	Redwood Rd
35333534	3534	3533	No	4	2	700 North	WB	I-215	Redwood Rd
35343535	3534	3535	No	4	3	700 North	EB	I-215	Redwood Rd
35343535	3535	3534	No	4	3	700 North	WB	I-215	Redwood Rd
35353613	3535	3613	No	4	3	Redwood R	NB	1000 N	700 N

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
35353613	3613	3535	No	4	3	Redwood R	SB	1000 N	700 N
35353628	3535	3628	No	4	3	Redwood R	SB	700 N	North Temp
35353628	3628	3535	No	4	3	Redwood R	NB	700 N	North Temp
35354199	3535	4199	No	4	3	700 North	EB	Redwood Rd	1200 W
35363587	3536	3587	No	4	3	Redwood R	NB	1000 N	700 N
35363587	3587	3536	No	4	3	Redwood R	SB	1000 N	700 N
35363613	3536	3613	No	4	3	Redwood R	SB	1000 N	700 N
35363613	3613	3536	No	4	3	Redwood R	NB	1000 N	700 N
35363616	3536	3616	No	4	2	1000 North	EB	Redwood Rd	1200 W
35363616	3616	3536	No	4	2	1000 North	WB	Redwood Rd	1200 W
35373538	3537	3538	No	4	2	1200 West	NB	1000 N	600 N

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
35373538	3538	3537	No	4	2	1200 West	SB	1000 N	600 N
35373541	3537	3541	No	4	2	600 North	EB	1200 W	900 W
35373541	3541	3537	No	4	2	600 North	WB	1200 W	900 W
35373617	3537	3617	No	3	2	600 North	WB	Redwood Rd	1200 W
35373617	3617	3537	No	3	2	600 North	EB	Redwood Rd	1200 W
35383539	3538	3539	No	4	2	1200 West	NB	1000 N	600 N
35383539	3539	3538	No	4	2	1200 West	SB	1000 N	600 N
35393545	3539	3545	No	4	2	1000 North	EB	1200 W	900 W
35393545	3545	3539	No	4	2	1000 North	WB	1200 W	900 W
35393616	3539	3616	No	4	2	1000 North	WB	Redwood Rd	1200 W
35393616	3616	3539	No	4	2	1000 North	EB	Redwood Rd	1200 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
35874630	3587	4630	No	4	2	Redwood R	EB	Redwood Rd	1200 W
35874630	4630	3587	No	4	2	Redwood R	SB	1700 N	1000 N
36083610	3608	3610	No	3	2	2100 North	EB	4000 W	2200 W
36174191	3617	4191	No	4	2	700 North	WB	Redwood Rd	1200 W
36313710	3631	3710	Yes	5	4	North Tem	EB	900 W	I-15
36313710	3710	3631	Yes	5	4	North Tem	WB	900 W	I-15
36385470	3638	5470	Yes	5	5	North Tem	EB	I-15	400 W
36385470	5470	3638	No	5	5	North Tem	WB	I-15	400 W
36393640	3639	3640	Yes	3	2	Blank	NB	4000 W	SR-186
36403413	3640	3413	Yes	3	2	CD Road	NB	4000 W	I-80
36403801	3640	3801	Yes	3	2	Blank	NB	4000 W	SR-186

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
36663671	3666	3671	No	5	4	2nd Ave	EB	State St	B St
36803688	3688	3680	Yes	4	2	North Tem	WB	2200 W	Redwood Rd
36883717	3688	3717	Yes	4	3	North Tem	EB	I-215	Redwood Rd
36883717	3717	3688	Yes	4	3	North Tem	WB	I-215	Redwood Rd
37034204	3703	4204	Yes	3	2	700 South	WB	4800 W	4000 W
37034558	3703	4558	Yes	3	2	4000 West	SB	700 S	California
37034558	4558	3703	No	3	2	4000 West	NB	700 S	California
37105445	3710	5445	Yes	5	4	North Tem	EB	900 W	400 W
37105445	5445	3710	Yes	5	4	North Tem	WB	900 W	400 W
37113850	3711	3850	No	5	2	700 South	WB	7200 W	5600 W
37113850	3850	3711	No	5	2	700 South	EB	7200 W	5600 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
37115542	3711	5542	No	5	2	5600 West	SB	700 S	California
37115542	5542	3711	No	5	2	5600 West	NB	700 S	California
37133874	3713	3874	Yes	3	2	500 South	EB	4000 W	I-215
37133874	3874	3713	No	3	2	500 South	WB	4000 W	I-215
37134052	3713	4052	Yes	3	2	500 South	WB	4000 W	I-215
37143748	3714	3748	Yes	5	3	500 South	EB	4000 W	Redwood Rd
37143748	3748	3714	Yes	5	3	500 South	WB	4000 W	Redwood Rd
37143874	3714	3874	Yes	5	3	500 South	WB	4000 W	I-215
37143874	3874	3714	Yes	5	3	500 South	EB	4000 W	I-215
38724589	3872	4589	No	3	2	California	WB	4000 W	Pioneer Rd
38724589	4589	3872	No	3	2	California	EB	4000 W	Pioneer Rd

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
39094264	3909	4264	Yes	5	4	2100 South	EB	Redwood Rd	900 w
39094264	4264	3909	Yes	5	4	2100 South	WB	Redwood Rd	900 w
39444407	4407	3944	No	5	4	900 West	SB	SR-201	2300 S
39444535	3944	4535	Yes	5	4	900 West	SB	SR-201	2300 S
39444535	4535	3944	No	5	4	900 West	NB	SR-201	2300 S
40255852	4025	5852	No	5	2	Frontage	NB	California	2100 S
40255852	5852	4025	No	5	2	Frontage	SB	California	2100 S
40404141	4040	4141	No	5	4	Pioneer R	NB	1700 S	2100 S
40514239	4051	4239	No	3	2	2100 South	EB	4000 W	Gladiola
40514239	4239	4051	No	3	2	2100 South	WB	4000 W	Gladiola
40604143	4060	4143	No	5	4	1700 South	WB	Redwood Rd	900 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
40604143	4143	4060	No	5	4	1700 South	EB	Redwood Rd	900 W
40605088	4060	5088	No	5	4	1700 South	EB	Redwood Rd	900 W
40605088	5088	4060	No	5	4	1700 South	WB	Redwood Rd	900 W
40674264	4264	4067	Yes	5	4	900 West	NB	1700 S	2100 S
41415184	4141	5184	No	5	4	Pioneer R	NB	California	1700 S
41415184	5184	4141	No	5	4	Pioneer R	SB	California	1700 S
41455088	5088	4145	No	5	4	1700 South	EB	Redwood Rd	900 W
42444233	4244	4233	No	3	2	SR-201	WB	4000 W	Gladiola
42465236	4246	5236	No	5	4	SR-201 WB	SB	SR-201	I-215 S
42494251	4249	4251	No	5	3	SR-201	EB	I-215	Redwood Rd
43904391	4390	4391	Yes	5	3	3500 South	EB	I-215	2200 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
43904391	4391	4390	Yes	5	3	3500 South	WB	I-215	2200 W
43905461	4390	5461	Yes	5	3	I-215 NB	NB	3500 S	I-215 N
43914399	4391	4399	No	5	3	2200 West	NB	3100 S	3500 S
43914399	4399	4391	No	5	3	2200 West	SB	3100 S	3500 S
43914675	4391	4675	Yes	5	3	3500 South	EB	2200 W	Redwood Rd
43914675	4675	4391	No	5	3	3500 South	WB	2200 W	Redwood Rd
43915832	4391	5832	No	5	3	2200 West	SB	3500 S	4100 S
43915832	5832	4391	No	5	3	2200 West	NB	3500 S	4100 S
43924393	4392	4393	No	5	3	3500 South	EB	2200 W	Redwood Rd
43924393	4393	4392	No	5	3	3500 South	WB	2200 W	Redwood Rd
43924675	4392	4675	No	5	3	3500 South	WB	2200 W	Redwood Rd

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
43924675	4675	4392	No	5	3	3500 South	EB	2200 W	Redwood Rd
43934394	4393	4394	No	5	3	Redwood R	NB	3100 S	3500 S
43934394	4394	4393	No	5	3	Redwood R	SB	3100 S	3500 S
43934553	4393	4553	No	5	3	3300 South	EB	Redwood Rd	900 W
43934553	4553	4393	No	5	3	3300 South	WB	Redwood Rd	900 W
43934602	4393	4602	No	5	2	Redwood R	SB	3500 S	4100 S
43934602	4602	4393	No	5	2	Redwood R	NB	3500 S	4100 S
43944396	4394	4396	No	5	3	Redwood R	NB	3100 S	3500 S
43944396	4396	4394	No	5	3	Redwood R	SB	3100 S	3500 S
44014553	4401	4553	No	5	3	3300 South	WB	Redwood Rd	900 W
44014553	4553	4401	No	5	3	3300 South	EB	Redwood Rd	900 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
45355409	4535	5409	No	5	3	900 West	SB	SR-201	3300 S
45355409	5409	4535	No	5	3	900 West	NB	SR-201	3300 S
45574558	4557	4558	No	3	2	California	WB	4000 W	Pioneer Rd
45574558	4558	4557	No	3	2	California	EB	4000 W	Pioneer Rd
45574589	4557	4589	No	3	2	California	EB	4000 W	Pioneer Rd
45574589	4589	4557	No	3	2	California	WB	4000 W	Pioneer Rd
45954596	4595	4596	Yes	5	3	2700 West	NB	3500 S	4100 S
45954596	4596	4595	No	5	3	2700 West	SB	3500 S	4100 S
45964671	4596	4671	No	5	3	2700 West	NB	3500 S	4100 S
45964671	4671	4596	No	5	3	2700 West	SB	3500 S	4100 S
46014602	4601	4602	No	5	2	Redwood R	NB	3500 S	4100 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
46014699	4699	4601	No	5	2	Redwood R	NB	4100 S	Taylorsville
48735776	4873	5776	No	5	2	Holladay	SB	Murray Ho	6200 S
48735776	5776	4873	No	5	2	Holladay	NB	Murray Ho	6200 S
48824960	4882	4960	Yes	5	3	I-215 SB	EB	I-215 S	I-80 E
48844897	4884	4897	Yes	5	3	I-215 SB	EB	I-215 S	I-80 E
49604884	4960	4884	Yes	5	3	I-215 SB	EB	I-215 S	I-80 E
50135200	5013	5200	Yes	3	2	CD Road	EB	I-80 E	2200 W
50175018	5017	5018	No	5	3	Redwood R	NB	7000 S	7800 S
50175018	5018	5017	No	5	3	Redwood R	SB	7000 S	7800 S
50175022	5017	5022	No	5	3	7800 South	EB	Redwood Rd	1300 W
50175022	5022	5017	No	5	3	7800 South	WB	Redwood Rd	1300 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
50175736	5017	5736	No	5	3	Redwood R	SB	7800 S	9000 S
50175736	5736	5017	No	5	3	Redwood R	NB	7800 S	9000 S
50185436	5018	5436	Yes	5	3	Redwood R	NB	7000 S	7800 S
50185436	5436	5018	No	5	3	Redwood R	SB	7000 S	7800 S
51135736	5113	5736	No	5	3	Redwood R	NB	7800 S	9000 S
51135736	5736	5113	No	5	3	Redwood R	SB	7800 S	9000 S
51953669	5195	3669	Yes	4	2	CD Road	NB	4000 W	2200 W
52765825	5276	5825	No	5	4	I-215 NB	WB	I-215 N	SR-201 W
53255823	5325	5823	No	5	4	I-215 SB	EB	I-215 S	SR-201 E
53584241	5358	4241	No	5	4	CD Road	WB	I-215 S	SR-201 W
53665367	5366	5367	No	5	4	400 West	NB	300 N	North Temp

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
53665367	5367	5366	No	5	4	400 West	SB	300 N	North Temp
55425852	5542	5852	No	5	2	5600 West	SB	California	2100 S
55425852	5852	5542	No	5	2	5600 West	NB	California	2100 S
57905261	5790	5261	No	5	4	SR-201 WB	SB	SR-201 W	I-215 S
58215276	5821	5276	No	5	4	I-215 NB	WB	I-215 N	SR-201 W
58235293	5823	5293	No	5	4	I-215 SB	EB	I-215 S	SR-201 E
58254248	5825	4248	No	5	4	I-215 NB	WB	I-215 N	SR-201 W
100304407	10030	4407	No	5	4	SR-201 EB	EB	Off Ramp	900 W
101943660	10194	3660	No	3	2	CD Road	NB	SR-186	4000 W
101955039	10195	5039	Yes	4	3	CD Road	SB	I-80 E	I-215 S
101974950	10197	4950	Yes	5	3	CD Road	NB	I-80 W	I-215 N

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
101985149	10198	5149	No	5	3	CD Road	WB	I-215 S	I-80 W
102483530	10248	3530	No	3	2	I-215 SB	SB	Off Ramp	700 N
102513533	10251	3533	No	4	2	I-215 NB	NB	Off Ramp	700 N
102615325	10261	5325	No	5	4	I-215 SB	WB	I-215 S	SR-201 W
102625358	10262	5358	No	5	4	CD Road	EB	I-215 S	SR-201 E
102655270	10265	5270	No	5	4	I-215 NB	WB	I-215 N	SR-201 W
102692429	10269	2429	No	5	4	CD Road	EB	I-215 N	SR-201 E
230112501	12501	2301	No	4	3	Cent	NB	North Temp	200 S
241410268	2414	10268	Yes	5	4	CD Road	SB	SR-201 W	I-215 S
353010250	3530	10250	Yes	4	2	I-215 SB	SB	On Ramp	700 N
353210590	3532	10590	Yes	5	3	CD Road	WB	North Temple	I-80 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
353210590	10590	3532	No	5	3	CD Road	EB	North Temple	I-80 W
353212545	3532	12545	Yes	5	3	Cent		North Temple	I-80 W
353310249	3533	10249	No	3	2	I-215 NB	NB	On Ramp	700 N
366910590	3669	10590	Yes	4	3	CD Road	EB	I-80 E	2200 W
366910590	10590	3669	No	4	3	CD Road	WB	2200 W	I-80 W
368812553	12553	3688	No	4	3	Cent		I-215	Redwood Rd
371012546	3710	12546	Yes	5	4	Cent		900 W	I-15
425810030	4258	10030	No	5	3	SR-201	WB	Redwood Rd	900 W
426310079	4263	10079	Yes	5	4	SR-201 WB	WB	On Ramp	900 W
453512602	12602	4535	No	5	3	Cent		SR-201	3300 S
503910197	5039	10197	Yes	5	3	CD Road	SB	I-80 W	I-215 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
514910331	5149	10331	Yes	4	3	CD Road	WB	I-215 S	I-80 W
527910260	5279	10260	No	5	4	SR-201 EB	NB	SR-201 E	I-215 N
582410264	5824	10264	No	5	4	SR-201 WB	SB	SR-201 W	I-215 S
1003010040	10030	10040	No	5	4	SR-201	EB	Redwood Rd	900 W
1008810118	10088	10118	Yes	5	5	I-15	SB	I-80	3300 S
1011010088	10110	10088	No	5	3	I-15	SB	I-80	3300 S
1019310678	10193	10678	No	3	2	I-80	EB	4000 W	I-215
1019510203	10195	10203	No	4	3	I-80	EB	4000 W	I-215
1019610194	10196	10194	No	3	2	CD Road	WB	2200 W	I-80 W
1019710199	10197	10199	No	5	3	CD Road	SB	I-80 E	I-215 S
1019810196	10198	10196	No	4	3	CD Road	WB	I-215 S	I-80 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
1025010589	10250	10589	No	4	2	I-215	SB	700 N	North Temp
1025410587	10254	10587	No	5	3	I-215	SB	I-80	500 S
1025610592	10256	10592	No	5	3	I-215	SB	500 S	California
1026110268	10261	10268	No	5	4	I-215	SB	SR-201	Parkway B
1026210264	10262	10264	No	5	4	I-215	SB	1700 S	SR-201
1026310308	10263	10308	No	5	4	I-215	NB	SR-201	California
1026510263	10265	10263	No	5	4	I-215	NB	SR-201	1700 S
1026810593	10268	10593	No	5	4	I-215	SB	SR-201	Parkway B
1026910260	10269	10260	No	5	4	I-215	NB	Parkway B	SR-201
1027210597	10272	10597	No	5	3	I-215	SB	3500 S	4100 S
1030610591	10306	10591	No	4	3	I-215	NB	500 S	California

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
1033110679	10331	10679	No	4	2	I-80	WB	I-215	4000 W
1033310192	10333	10192	No	3	2	I-80	WB	I-215	4000 W
1033310194	10333	10194	No	3	2	CD Road	WB	I-80 W	4000 W
1039310703	10393	10703	No	4	2	I-80	EB	7200 W	5600 W
1054310110	10543	10110	No	5	3	I-15	SB	SR-201 E	I-15 S
1054510110	10545	10110	No	5	3	CD Road	SB	I-80 W	I-15 S
1058310251	10583	10251	No	4	2	I-215	NB	700 N	North Temp
1058810586	10588	10586	No	5	3	I-215	NB	500 S	I-80
1059110259	10591	10259	No	5	3	I-215	NB	500 S	California
1059210305	10592	10305	No	5	4	I-215	SB	500 S	California
1059410269	10594	10269	No	5	4	I-215	NB	SR-201	Parkway B

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Damage State	The M6.0 scenario Damage State	Road Name	Direction	From	To
1059510274	10595	10274	No	5	3	I-215	NB	3500 S	4100 S
1063710635	10637	10635	No	5	2	I-215	SB	4500 S	6200 S
1067810195	10678	10195	No	4	2	I-80	EB	4000 W	I-215
1067910333	10679	10333	No	3	2	I-80	WB	4000 W	I-215
1068010215	10680	10215	No	3	2	I-80	EB	On 4000 W	On 4000 W
1069510079	10695	10079	No	5	4	SR-201	WB	900 W	Redwood Rd
1070410392	10704	10392	No	4	2	I-80	WB	7200 W	5600 W

Table A3-2: Most critical links (VISUM) in Salt Lake County

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
19304592	4592	1930	No	4	4	3200 West	NB	3500 S	4100 S
19304593	1930	4593	No	5	5	3200 West	NB	3500 S	4100 S
19304593	4593	1930	No	4	4	3200 West	SB	3500 S	4100 S
20605224	5224	2060	No	11	11	9800 South	WB	State St	700 E
20605260	2060	5260	Yes	11	11	9800 South	WB	State St	700 E
21534923	2153	4923	Yes	2	2	5300 South	WB	I-15	State St
21535457	5457	2153	No	2	2	5300 South	WB	I-15	State St
23414916	2341	4916	Yes	6	6	Wincheste	WB	I-15	State St
23414916	4916	2341	Yes	6	6	Wincheste	EB	I-15	State St
23414917	2341	4917	Yes	7	7	Wincheste	EB	I-15	State St

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
23414917	4917	2341	Yes	8	8	Wincheste	WB	I-15	State St
25235653	2523	5653	No	3	3	Blank	WB	SR-111	13400 S
25235653	5653	2523	No	4	4	Blank	EB	SR-111	13400 S
25615034	2561	5034	Yes	5	5	Center St	WB	I-15	State St
25615035	5035	2561	No	4	4	Center St	EB	I-15	State St
34853511	3485	3511	Yes	3	3	I-15 SB o	SB	Off Ramp	2300 N
35053507	3505	3507	Yes	6	6	2300 North	EB	I-15	Redwood Rd
35053507	3507	3505	No	3	3	2300 North	WB	I-15	Redwood Rd
35073511	3507	3511	Yes	4	4	I-15 SB 2	SB	On Ramp	2300 N
35073511	3511	3507	No	3	3	I-15 SB 2	NB	On Ramp	2300 N

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
35113477	3511	3477	Yes	4	4	I-15 SB o	SB	On Ramp	2300 N
35313663	3663	3531	No	85	85	2200 West	SB	1700 N	700 N
35423544	3542	3544	No	5	5	900 West	NB	1000 N	600 N
35423544	3544	3542	No	44	44	900 West	SB	1000 N	600 N
35423634	3542	3634	Yes	6	6	900 West	SB	600 N	300 N
35423634	3634	3542	Yes	12	12	900 West	NB	600 N	300 N
35443771	3544	3771	No	5	5	I-15 NB o	NB	On Ramp	1000 N
35573639	3639	3557	Yes	3	3	4000 West	SB	I-80	700 S
35573703	3557	3703	Yes	3	3	4000 West	SB	I-80	700 S
35993592	3599	3592	No	5	5	I-15 NB o	NB	On Ramp	1000 N

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
36253680	3680	3625	Yes	3	3	2200 West	NB	700 N	North Temp
36283717	3717	3628	No	3	3	Redwood R	NB	700 N	North Temp
36313719	3631	3719	Yes	4	4	900 West	NB	300 N	North Temp
36313719	3719	3631	Yes	3	3	900 West	SB	300 N	North Temp
36313727	3727	3631	Yes	4	4	900 West	NB	North Temp	I-80
36323639	3632	3639	Yes	3	3	4000 West	SB	I-80	700 S
36333634	3633	3634	Yes	6	6	900 West	NB	600 N	300 N
36333634	3634	3633	Yes	4	4	900 West	SB	600 N	300 N
36333719	3633	3719	Yes	4	4	900 West	SB	300 N	North Temp
36333719	3719	3633	Yes	4	4	900 West	NB	300 N	North Temp

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
36335760	3633	5760	Yes	8	8	300 North	EB	900 W	400 W
36335760	5760	3633	No	17	17	300 North	WB	900 W	400 W
36475367	3647	5367	Yes	13	13	300 North	WB	400 W	300 W
36475367	5367	3647	No	9	9	300 North	EB	400 W	300 W
36743806	3674	3806	No	4	4	I-15 SB o	SB	Off Ramp	1000 N
36803688	3688	3680	Yes	3	3	North Tem	WB	2200 W	Redwood Rd
36895216	3689	5216	Yes	4	4	500 West	SB	9800 S	South Jor
36895216	5216	3689	Yes	5	5	500 West	NB	9800 S	South Jor
36895729	3689	5729	Yes	9	9	500 West	NB	9800 S	South Jor
36895729	5729	3689	No	7	7	500 West	SB	9800 S	South Jor

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
37023726	3702	3726	Yes	7	7	200 South	EB	Redwood Rd	900 W
37023726	3726	3702	Yes	10	10	200 South	WB	Redwood Rd	900 W
37024953	3702	4953		8	8	200 South	WB	Redwood Rd	900 W
37024953	4953	3702		3	3	200 South	EB	Redwood Rd	900 W
37094953	4953	3709	Yes	4	4	Redwood R	NB	I-80	200 S
37123893	3893	3712	No	3	3	700 South	WB	5600 W	4800 W
37163926	3716	3926	Yes	2	2	Redwood R	SB	400 S	Indiana Ave
37163926	3926	3716	Yes	5	5	Redwood R	NB	400 S	Indiana Ave
37164953	3716	4953	Yes	7	7	Redwood R	NB	400 S	I-80
37243725	3724	3725	Yes	5	5	900 West	NB	400 S	I-80

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
37243933	3933	3724	Yes	2	2	900 West	NB	400 S	Indiana Ave
37253726	3725	3726	Yes	4	4	900 West	NB	200 S	400 S
37263727	3726	3727	Yes	4	4	900 West	NB	North Temp	200 S
37263727	3727	3726	Yes	5	5	900 West	SB	North Temp	200 S
37263739	3726	3739		8	8	200 South	WB	900 W	400 W
37263739	3739	3726		9	9	200 South	EB	900 W	400 W
37314723	4723	3731	Yes	4	4	400 South	EB	I-15	400 W
37353837	3735	3837	No	6	6	4800 West	SB	700 S	California
37353837	3837	3735	No	8	8	4800 West	NB	700 S	California
37353893	3735	3893	No	38	38	4800 West	NB	700 S	California

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
37353893	3893	3735	No	15	15	4800 West	SB	700 S	California
37373632	3737	3632	Yes	3	3	I-80 EB o	SB	I-80 E	4000 W
37395469	3739	5469		5	5	200 South	WB	I-15	400 W
37395469	5469	3739		6	6	200 South	EB	I-15	400 W
37435533	3743	5533	No	5	5	300 South	EB	300 W	200 W
37435533	5533	3743	No	3	3	300 South	WB	300 W	200 W
37453746	3745	3746	No	7	7	200 South	EB	400 W	300 W
37453746	3746	3745	No	9	9	200 South	WB	400 W	300 W
37455469	3745	5469	No	9	9	200 South	WB	400 W	300 W
37455469	5469	3745	No	7	7	200 South	EB	400 W	300 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
37495530	3749	5530	No	3	3	South Tem	EB	300 W	200 W
37675532	3767	5532	No	3	3	200 South	WB	200 W	West Temp
37713599	3771	3599	No	5	5	I-15 NB o	NB	On Ramp	1000 N
37833797	3783	3797	No	2	2	200 South	EB	Main St	State St
37973813	3797	3813	No	3	3	200 South	EB	State St	200 E
38063544	3806	3544	No	4	4	I-15 SB o	SB	Off Ramp	1000 N
38133824	3813	3824	No	2	2	200 South	EB	200 E	300 E
38213980	3980	3821	No	3	3	300 East	NB	400 S	500 S
38263827	3826	3827	No	3	3	100 South	EB	200 E	300 E
38273829	3827	3829	No	12	12	300 East	NB	South Temp	100 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
38303935	3830	3935	Yes	2	2	Indiana A	EB	Redwood Rd	900 W
38303989	3830	3989	No	4	4	Indiana A	WB	Redwood Rd	900 W
38303989	3989	3830	No	3	3	Indiana A	EB	Redwood Rd	900 W
38373932	3837	3932	No	7	7	4800 West	SB	California	2100 S
38374548	4548	3837	No	5	5	California	WB	4800 W	California
38393935	3839	3935	Yes	4	4	800 South	WB	900 W	400 W
38393935	3935	3839	Yes	4	4	800 South	EB	900 W	400 W
38393936	3839	3936	Yes	3	3	800 South	EB	400 W	300 W
38395288	5288	3839	No	7	7	400 West	SB	600 S	800 S
38403987	3840	3987	Yes	3	3	I-215 SB	SB	Off Ramp	California

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
38493936	3849	3936	Yes	4	4	300 West	SB	600 S	800 S
38493936	3936	3849	Yes	4	4	300 West	NB	600 S	800 S
38493937	3849	3937	Yes	4	4	300 West	NB	600 S	800 S
38493937	3937	3849	Yes	4	4	300 West	SB	600 S	800 S
38683887	3868	3887	No	825	825	100 South	EB	900 E	1300 E
38683887	3887	3868	No	242	242	100 South	WB	900 E	1300 E
38723875	3875	3872	No	2	2	California	WB	4000 W	Pioneer Rd
38724589	3872	4589	No	2	2	California	WB	4000 W	Pioneer Rd
38753970	3970	3875	No	2	2	California	EB	4000 W	Pioneer Rd
38823883	3883	3882	No	7	7	1300 East	SB	400 S	500 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
38833891	3883	3891	No	753	753	South Cam	EB	1300 E	Univer St
38833891	3891	3883	No	533	533	South Cam	WB	1300 E	Univer St
38873888	3888	3887	No	8	8	100 South	WB	900 E	1300 E
38893894	3889	3894	No	4	4	South Tem	EB	1300 E	Univer St
38893894	3894	3889	No	3	3	South Tem	WB	1300 E	Univer St
38915330	3891	5330	No	9	9	Universit	NB	North Cam	South Cam
38915330	5330	3891	No	101	101	Universit	SB	North Cam	South Cam
38915765	3891	5765	No	86	86	South Cam	EB	Univer St	Guardsman
38915765	5765	3891	No	32	32	South Cam	WB	Univer St	Guardsman
38945330	3894	5330	No	234	234	Universit	SB	South Temp	100 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
39133982	3982	3913	No	3	3	500 East	NB	600 S	800 S
39223923	3923	3922	No	3	3	2100 South	WB	Frontage	4800 W
39224309	3922	4309	No	3	3	2100 South	WB	Frontage	4800 W
39243925	3924	3925	Yes	5	5	Redwood R	NB	400 S	Indiana Ave
39243925	3925	3924	No	2	2	Redwood R	SB	400 S	Indiana Ave
39243927	3924	3927	No	2	2	Indiana A	EB	Redwood Rd	900 W
39244038	3924	4038	Yes	2	2	Redwood R	SB	Indiana A	California
39244038	4038	3924	No	4	4	Redwood R	NB	Indiana A	California
39253926	3925	3926	Yes	5	5	Redwood R	NB	400 S	Indiana Ave
39253926	3926	3925	No	2	2	Redwood R	SB	400 S	Indiana Ave

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
39273989	3927	3989	No	3	3	Indiana A	EB	Redwood Rd	900 W
39273989	3989	3927	No	4	4	Indiana A	WB	Redwood Rd	900 W
39333935	3935	3933	Yes	2	2	900 West	NB	400 S	Indiana Ave
39354046	4046	3935	Yes	2	2	900 West	NB	800 S	900 S
39364055	3936	4055	Yes	5	5	300 West	SB	800 S	900 S
39364055	4055	3936	Yes	4	4	300 West	NB	800 S	900 S
39743975	3974	3975	No	9	9	300 East	NB	600 S	800 S
39743975	3975	3974	No	8	8	300 East	SB	600 S	800 S
39744095	3974	4095	No	8	8	300 East	SB	800 S	900 S
39744095	4095	3974	No	10	10	300 East	Nb	800 S	900 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
39753977	3975	3977	No	4	4	300 East	NB	600 S	800 S
39753977	3977	3975	No	4	4	300 East	SB	600 S	800 S
39773978	3977	3978	No	3	3	300 East	NB	500 S	600 S
39773978	3978	3977	No	3	3	300 East	SB	500 S	600 S
39783980	3978	3980	No	4	4	300 East	NB	500 S	600 S
39783980	3980	3978	No	4	4	300 East	SB	500 S	600 S
39824100	4100	3982	No	3	3	500 East	NB	800 S	900 S
39934006	4006	3993	Yes	17	17	2100 South	EB	Gladiola	2700 W
39934040	3993	4040	Yes	17	17	2100 South	EB	Gladiola	2700 W
40034006	4003	4006	No	17	17	2100 South	EB	Gladiola	2700 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
40034222	4222	4003	No	17	17	2100 South	EB	Gladiola	2700 W
40194113	4019	4113	No	9	9	1100 East	SB	900 S	1300 S
40194113	4113	4019	No	10	10	1100 East	NB	900 S	1300 S
40194115	4019	4115	No	12	12	1100 East	NB	900 S	1300 S
40194115	4115	4019	No	9	9	1100 East	SB	900 S	1300 S
40254309	4309	4025	No	3	3	2100 South	WB	4800 W	Frontage
40385060	5060	4038	No	2	2	Redwood R	NB	California	1700 S
40404141	4141	4040	No	6	6	Pioneer R	SB	1700 S	SR-201
40444146	4044	4146	No	3	3	900 West	SB	California	1700 S
40444146	4146	4044	No	6	6	900 West	NB	California	1700 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
40465750	5750	4046	No	2	2	900 West	NB	900 S	1300 S
40534054	4053	4054	Yes	4	4	300 West	NB	900 S	1300 S
40534054	4054	4053	Yes	3	3	300 West	SB	900 S	1300 S
40544055	4054	4055	Yes	4	4	300 West	NB	900 S	1300 S
40544055	4055	4054	Yes	4	4	300 West	SB	900 S	1300 S
40554066	4055	4066		20	20	900 South	EB	300 W	West Temp
40554066	4066	4055		60	60	900 South	WB	300 W	West Temp
40555003	4055	5003	Yes	30	30	900 South	WB	400 W	300 W
40664076	4066	4076	No	76	76	900 South	EB	West Temp	Main St
40704145	4070	4145	Yes	11	11	1700 South	WB	900 W	I-15

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
40704145	4145	4070	Yes	4	4	1700 South	EB	900 W	I-15
40704149	4070	4149	Yes	4	4	1700 South	EB	900 W	I-15
40704149	4149	4070	Yes	11	11	1700 South	WB	900 W	I-15
40734229	4229	4073	No	2	2	Frontage	WB	4800 W	4000 W
40735185	4073	5185	No	2	2	Frontage	WB	4800 W	4000 W
40764077	4076	4077	No	76	76	900 South	EB	West Temp	Main St
40774085	4077	4085	No	50	50	900 South	EB	Main St	State St
40784286	4078	4286	Yes	4	4	West Temp	NB	1700 S	2100 S
40854095	4085	4095	No	77	77	900 South	EB	State St	300 E
40854095	4095	4085	No	17	17	900 South	WB	State St	300 E

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
40874158	4158	4087	No	2	2	State St	SB	1700 S	2100 S
40874293	4087	4293	No	2	2	State St	SB	1700 S	2100 S
40884111	4088	4111	Yes	4	4	Parkway B	EB	4000 W	3600 W
40884111	4111	4088	Yes	4	4	Parkway B	WB	4000 W	3600 W
40924093	4092	4093	No	4	4	300 East	NB	900 S	1300 S
40924162	4162	4092	No	8	8	300 East	NB	1300 S	1700 S
40934095	4093	4095	No	4	4	300 East	NB	900 S	1300 S
40974098	4097	4098	No	4	4	500 East	NB	900 S	1300 S
40984100	4098	4100	No	3	3	500 East	NB	900 S	1300 S
41115053	4111	5053	No	6	6	Parkway B	EB	3600 W	3200 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
41115053	5053	4111	No	5	5	Parkway B	WB	3600 W	3200 W
41154119	4115	4119	No	15	15	900 South	EB	1100 E	1300 E
41154119	4119	4115	No	19	19	900 South	WB	1100 E	1300 E
41164141	4116	4141	No	9	9	1700 South	WB	Pioneer Rd	Redwood Rd
41164143	4143	4116	No	34	34	1700 South	WB	Pioneer Rd	Redwood Rd
41194120	4119	4120	No	14	14	900 South	EB	1100 E	1300 E
41224367	4122	4367	No	3	3	1500 East	NB	900 S	1300 S
41224367	4367	4122	No	4	4	1500 East	SB	900 S	1300 S
41234125	4123	4125	No	3	3	1500 East	NB	900 S	1300 S
41234125	4125	4123	No	4	4	1500 East	SB	900 S	1300 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
41234367	4123	4367	No	4	4	1500 East	SB	900 S	1300 S
41234367	4367	4123	No	3	3	1500 East	NB	900 S	1300 S
41254131	4125	4131	No	5	5	900 South	EB	1300 E	Guardsman
41344135	4134	4135	No	2	2	2100 East	NB	Sunnyside	1300 S
41354136	4135	4136	No	2	2	2100 East	NB	Sunnyside	1300 S
41454146	4145	4146	Yes	8	8	900 West	NB	California	1700 S
41454146	4146	4145	No	3	3	900 West	SB	California	1700 S
41494152	4149	4152	Yes	2	2	1700 South	EB	300 W	West Temp
41494152	4152	4149	Yes	4	4	1700 South	WB	300 W	West Temp
41494283	4149	4283	Yes	3	3	300 West	SB	1700 S	2100 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
41524155	4152	4155	No	2	2	1700 South	EB	West Temp	Main St
41524155	4155	4152	No	4	4	1700 South	WB	West Temp	Main St
41524286	4286	4152	No	4	4	West Temp	NB	1700 S	2100 S
41554158	4158	4155	No	3	3	1700 South	WB	Main St	State St
41684303	4168	4303	No	2	2	700 East	SB	1700 S	2100 S
41724308	4172	4308	No	4	4	900 East	SB	1700 S	2100 S
41854187	4187	4185	No	3	3	1700 South	WB	1900 E	2100 E
41904206	4190	4206	No	7	7	Parkway B	EB	3200 W	2700 W
41904206	4206	4190	No	8	8	Parkway B	WB	3200 W	2700 W
41905053	4190	5053	No	5	5	Parkway B	WB	3600 W	3200 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
41905053	5053	4190	No	6	6	Parkway B	EB	3600 W	3200 W
42064503	4206	4503	Yes	3	3	2700 West	SB	Parkway B	3100 S
42064503	4503	4206	No	3	3	2700 West	NB	Parkway B	3100 S
42065379	4206	5379	Yes	4	4	Parkway B	EB	2700 W	2200 W
42065379	5379	4206	No	5	5	Parkway B	WB	2700 W	2200 W
42204221	4221	4220	No	2	2	Parkway B	WB	9200 W	8400 W
42214349	4221	4349	No	2	2	8400 West	EB	9200 W	8400 W
42214349	4349	4221	No	2	2	8400 West	NB	Parkway B	3100 S
42594256	4259	4256	No	3	3	SR-201 WB	WB	Off Ramp	Redwood Rd
42814283	4283	4281	Yes	3	3	300 West	SB	1700 S	2100 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
42884362	4288	4362	Yes	4	4	Main St	SB	2100 S	I-80
42924293	4293	4292	Yes	2	2	State St	SB	1700 S	2100 S
43054306	4306	4305	No	4	4	900 East	SB	1700 S	2100 S
43064308	4308	4306	No	4	4	900 East	SB	1700 S	2100 S
43164382	4316	4382	No	3	3	3100 South	WB	3200 W	2700 W
43164382	4382	4316	No	2	2	3100 South	EB	3200 W	2700 W
43164385	4316	4385	No	4	4	3100 South	EB	3200 W	2700 W
43164385	4385	4316	No	3	3	3100 South	WB	3200 W	2700 W
43194462	4319	4462	Yes	2	2	700 East	SB	I-80	2700 S
43194464	4464	4319	No	2	2	700 East	SB	I-80	2700 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
43224369	4322	4369	No	4	4	3100 South	WB	4800 W	4000 W
43224369	4369	4322	No	4	4	3100 South	EB	4800 W	4000 W
43224376	4322	4376	No	3	3	3100 South	EB	4800 W	4000 W
43224376	4376	4322	No	3	3	3100 South	WB	4800 W	4000 W
43304416	4330	4416	Yes	4	4	300 West	SB	2700 S	3300 S
43304417	4417	4330	Yes	4	4	300 West	SB	2700 S	3300 S
43354346	4335	4346	Yes	2	2	2200 West	SB	Parkway B	3100 S
43355442	5442	4335	No	2	2	2200 West	SB	Parkway B	3100 S
43364338	4338	4336	No	2	2	2300 East	SB	1700 S	2100 S
43414417	4341	4417	Yes	3	3	300 West	SB	2100 S	2700 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
43464351	4346	4351	Yes	2	2	2200 West	SB	Parkway B	3100 S
43514399	4351	4399	Yes	2	2	2200 West	SB	Parkway B	3100 S
43584369	4369	4358	No	3	3	3100 South	WB	5600 W	4800 W
43604429	4360	4429	Yes	6	6	Main St	SB	2100 S	I-80
43604430	4430	4360	Yes	7	7	Main St	SB	2100 S	I-80
43624430	4362	4430	Yes	5	5	Main St	SB	2100 S	I-80
43695050	4369	5050	No	3	3	4800 West	NB	3100 S	3500 S
43695050	5050	4369	No	3	3	4800 West	SB	3100 S	3500 S
43734586	4373	4586	No	2	2	4800 West	SB	3500 S	4100 S
43735050	4373	5050	No	3	3	4800 West	NB	3100 S	3500 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
43735050	5050	4373	No	3	3	4800 West	SB	3100 S	3500 S
43754590	4375	4590	No	2	2	4000 West	SB	3500 S	4100 S
43765399	4376	5399	No	4	4	3100 South	EB	4000 W	Bangerter
43765399	5399	4376	No	3	3	3100 South	WB	4000 W	Bangerter
43775399	4377	5399	No	4	4	3100 South	WB	4000 W	3600 W
43775399	5399	4377	No	4	4	3100 South	EB	4000 W	3600 W
43775923	4377	5923	No	3	3	3100 South	EB	3600 W	3200 W
43775923	5923	4377	No	3	3	3100 South	WB	3600 W	3200 W
43775925	4377	5925	No	141	141	3600 West	SB	3100 S	3500 S
43775925	5925	4377	No	19	19	3600 West	NB	3100 S	3500 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
43805925	4380	5925	No	19	19	3600 West	NB	3100 S	3500 S
43805925	5925	4380	No	141	141	3600 West	SB	3100 S	3500 S
43814593	4381	4593	No	4	4	3200 West	SB	3500 S	4100 S
43814593	4593	4381	No	8	8	3200 West	NB	3500 S	4100 S
43815922	5922	4381	No	3	3	3200 West	SB	3100 S	3500 S
43825922	4382	5922	No	6	6	3200 West	SB	3100 S	3500 S
43825923	4382	5923	No	3	3	3100 South	WB	3600 W	3200 W
43825923	5923	4382	No	3	3	3100 South	EB	3600 W	3200 W
43844432	4384	4432	Yes	7	7	State St	SB	2700 S	3300 S
43844434	4434	4384	Yes	6	6	State St	SB	2700 S	3300 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
43854399	4385	4399	Yes	3	3	3100 South	EB	2700 W	2200 W
43854399	4399	4385	No	4	4	3100 South	WB	2700 W	2200 W
43854503	4385	4503	No	3	3	2700 West	NB	Parkway B	3100 S
43855921	4385	5921	Yes	4	4	2700 West	SB	3100 S	3500 S
43855921	5921	4385	No	4	4	2700 West	NB	3100 S	3500 S
43954396	4395	4396	No	5	5	3100 South	EB	2200 W	Redwood Rd
43954399	4399	4395	No	4	4	3100 South	EB	2200 W	Redwood Rd
43974434	4397	4434	Yes	5	5	State St	SB	I-80	2700 S
43974436	4436	4397	No	5	5	State St	SB	I-80	2700 S
44134414	4414	4413	Yes	2	2	3300 South	WB	500 W	300 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
44154416	4416	4415	No	4	4	300 West	SB	2700 S	3300 S
44174423	4423	4417	Yes	3	3	2700 South	WB	300 W	West Temp
44234429	4429	4423	Yes	2	2	2700 South	WB	West Temp	Main St
44235708	4423	5708	Yes	9	9	West Temp	SB	2700 S	3300 S
44314432	4432	4431	No	7	7	State St	SB	2700 S	3300 S
44314617	4431	4617	No	3	3	State St	SB	3300 S	3900 S
44454453	4453	4445	No	2	2	2700 South	WB	300 E	500 E
44564479	4479	4456	No	3	3	700 East	SB	2700 S	3300 S
44564624	4456	4624	No	2	2	700 East	SB	3300 S	3900 S
44624480	4462	4480	No	3	3	700 East	SB	2700 S	3300 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
44654488	4465	4488	No	2	2	700 East	NB	2100 S	I-80
44754476	4475	4476	No	3	3	900 East	NB	I-80	2700 S
44794480	4480	4479	No	3	3	700 East	SB	2700 S	3300 S
45484558	4558	4548	No	5	5	California	WB	4800 W	California
45574558	4557	4558	No	3	3	California	WB	4000 W	Pioneer Rd
45574558	4558	4557	No	8	8	California	EB	4000 W	Pioneer Rd
45574589	4557	4589	No	8	8	California	EB	4000 W	Pioneer Rd
45574589	4589	4557	No	3	3	California	WB	4000 W	Pioneer Rd
45645765	4564	5765	No	32	32	South Cam	WB	Univer St	Guardsman
45645765	5765	4564	No	86	86	South Cam	EB	Univer St	Guardsman

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
45854586	4585	4586	No	3	3	4800 West	NB	3500 S	4100 S
45854586	4586	4585	No	3	3	4800 West	SB	3500 S	4100 S
45905687	4590	5687	No	4	4	4000 West	SB	4100 S	4700 S
45905687	5687	4590	No	5	5	4000 West	NB	4100 S	4700 S
45924594	4594	4592	No	3	3	4100 South	WB	3200 W	2700 W
45944595	4594	4595	No	3	3	4100 South	EB	3200 W	2700 W
45944595	4595	4594	No	3	3	4100 South	WB	3200 W	2700 W
45955346	5346	4595	No	4	4	2700 West	NB	4100 S	4700 S
45984673	4598	4673	No	3	3	2200 West	NB	3500 S	4100 S
45984673	4673	4598	No	3	3	2200 West	SB	3500 S	4100 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
45984698	4598	4698	No	7	7	2200 West	SB	4100 S	Taylorsville
45984698	4698	4598	No	3	3	2200 West	NB	4100 S	Taylorsville
46035405	4603	5405	No	2	2	Meadow Br	EB	Redwood Rd	500 W
46084725	4608	4725	Yes	2	2	500 West	SB	Meadow Br	Taylorsville
46164676	4676	4616	No	3	3	State St	SB	3300 S	3900 S
46164734	4616	4734	No	3	3	State St	SB	3900 S	Hill Ave
46174676	4617	4676	No	3	3	State St	SB	3300 S	3900 S
46234624	4624	4623	No	2	2	700 East	SB	3300 S	3900 S
46234739	4623	4739	No	2	2	700 East	SB	3900 S	4500 S
46965230	4696	5230	Yes	8	8	9800 South	WB	State St	700 E

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
46965260	5260	4696	No	8	8	9800 South	WB	State St	700 E
46984715	4698	4715	Yes	13	13	2200 West	SB	4100 S	Taylorsville
46984715	4715	4698	No	4	4	2200 West	NB	4100 S	Taylorsville
47154798	4715	4798	No	3	3	2200 West	SB	Taylorsville	5400 S
47235468	5468	4723	No	3	3	400 South	WB	900 W	400 W
47334734	4734	4733	No	3	3	State St	SB	3900 S	4500 S
47384739	4739	4738	No	2	2	700 East	SB	3900 S	4500 S
47454806	4745	4806	No	2	2	700 West	NB	5400 S	5900 S
47454806	4806	4745	No	2	2	700 West	SB	5400 S	5900 S
47454915	4745	4915	No	2	2	700 West	SB	5400 S	5900 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
47454915	4915	4745	No	3	3	700 West	NB	5400 S	5900 S
47524806	4806	4752	Yes	3	3	5400 South	EB	700 W	I-15
47525784	4752	5784	Yes	2	2	5400 South	EB	700 W	I-15
47534855	4753	4855	No	2	2	1300 East	SB	4500 S	Murray Ho
47575271	4757	5271	Yes	7	7	State St	NB	11400 S	12300 S
47575271	5271	4757	Yes	13	13	State St	SB	11400 S	12300 S
47575720	4757	5720	Yes	13	13	State St	SB	11400 S	12300 S
47575720	5720	4757	No	7	7	State St	NB	11400 S	12300 S
47605269	4760	5269	Yes	13	13	State St	SB	11400 S	12300 S
47605269	5269	4760	No	7	7	State St	NB	11400 S	12300 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
47605720	4760	5720	Yes	7	7	State St	NB	11400 S	12300 S
47605720	5720	4760	No	13	13	State St	SB	11400 S	12300 S
47935297	4793	5297		3	3	Bangerter	EB	700 W	I-15
47945928	4794	5928	No	6	6	3200 West	SB	5400 S	6200 S
47945928	5928	4794	No	5	5	3200 West	NB	5400 S	6200 S
47964797	4796	4797		3	3	5400 South	EB	2700 W	2200 W
47964797	4797	4796		3	3	5400 South	WB	2700 W	2200 W
47974798	4797	4798	No	4	4	2200 West	NB	Taylorsville	5400 S
47974798	4798	4797	No	4	4	2200 West	SB	Taylorsville	5400 S
47975363	4797	5363	No	3	3	5400 South	EB	2200 W	Redwood Rd

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
47994800	4799	4800	No	8	8	3600 West	NB	4700 S	5400 S
47994800	4800	4799	No	12	12	3600 West	SB	4700 S	5400 S
48014805	4801	4805	No	2	2	5400 South	EB	Redwood Rd	Canal St
48034805	4803	4805	Yes	5	5	Canal St	NB	5400 S	6200 S
48034941	4941	4803	No	5	5	Canal St	NB	5400 S	6200 S
48054957	4805	4957	No	2	2	Canal St	NB	Murray Ta	5400 S
48224925	4822	4925	No	2	2	State St	SB	5300 S	5600 S
48264836	4836	4826	No	2	2	Murray Ho	WB	State St	900 E
48285405	5405	4828	No	2	2	Meadow Br	EB	Redwood Rd	500 W
48304864	4830	4864	No	2	2	Murray Ho	WB	Highland	Holladay

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
48304872	4872	4830	No	2	2	Murray Ho	WB	Highland	Holladay
48635775	4863	5775	No	2	2	Murray Ho	EB	1300 E	Highland
48635775	5775	4863	No	2	2	Murray Ho	WB	1300 E	Highland
48645775	4864	5775	No	2	2	Murray Ho	WB	1300 E	Highland
48645775	5775	4864	No	2	2	Murray Ho	EB	1300 E	Highland
48724873	4872	4873	No	2	2	Murray Ho	EB	Highland	Holladay
48724873	4873	4872	No	2	2	Murray Ho	WB	Highland	Holladay
48855383	4885	5383	No	4	4	7800 South	EB	SR-111	4800 W
48855383	5383	4885	No	2	2	7800 South	WB	SR-111	4800 W
48935437	4893	5437	No	3	3	3200 West	SB	6200 S	7000 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
48935928	4893	5928	No	42	42	3200 West	NB	5400 S	6200 S
48935928	5928	4893	No	36	36	3200 West	SB	5400 S	6200 S
48984996	4898	4996	Yes	7	7	6200 South	EB	Redwood Rd	1300 W
48994900	4899	4900	Yes	4	4	700 West	NB	Wincheste	7000 S
48994900	4900	4899	Yes	7	7	700 West	SB	Wincheste	7000 S
49004912	4900	4912	Yes	5	5	700 West	NB	Wincheste	7000 S
49004912	4912	4900	Yes	8	8	700 West	SB	Wincheste	7000 S
49064907	4907	4906	Yes	7	7	1300 West	SB	6200 S	Wincheste
49064911	4906	4911	Yes	3	3	Wincheste	EB	1300 W	700 W
49074984	4907	4984	Yes	4	4	Canal St	NB	5400 S	6200 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
49074996	4996	4907	No	7	7	6200 South	EB	Redwood Rd	1300 W
49114912	4911	4912	Yes	3	3	Wincheste	EB	1300 W	700 W
49125455	4912	5455	Yes	6	6	Wincheste	EB	700 W	State St
49125455	5455	4912	Yes	6	6	Wincheste	WB	700 W	State St
49165455	4916	5455	Yes	6	6	Wincheste	WB	700 W	State St
49165455	5455	4916	Yes	6	6	Wincheste	EB	700 W	State St
49244925	4925	4924	No	2	2	State St	NB	5600 S	5900 S
49414949	4949	4941	No	5	5	Canal St	NB	5400 S	6200 S
49495741	5741	4949	No	5	5	Canal St	NB	5400 S	6200 S
49525022	4952	5022	No	4	4	1300 West	SB	7000 S	7800 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
49525022	5022	4952	No	8	8	1300 West	NB	7000 S	7800 S
49525440	4952	5440	No	5	5	1300 West	NB	7000 S	7800 S
49544956	4956	4954	No	2	2	Highland	SB	5600 S	6200 S
49565777	5777	4956	No	2	2	Highland	SB	Murray Ho	5600 S
49624963	4963	4962	Yes	2	2	6200 South	WB	Highland	2300 E
49624988	4962	4988	Yes	2	2	6200 South	WB	Highland	2300 E
49624988	4988	4962	Yes	2	2	6200 South	EB	Highland	2300 E
49845741	4984	5741	No	4	4	Canal St	NB	5400 S	6200 S
50035466	5003	5466	Yes	30	30	900 South	WB	400 W	300 W
50095027	5027	5009	Yes	5	5	Center St	WB	1300 W	700 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
50105027	5010	5027	Yes	6	6	700 West	SB	7000 S	Center St
50145015	5014	5015	No	3	3	2700 West	NB	7000 S	7800 S
50145023	5023	5014	No	2	2	2700 West	NB	7800 S	9000 S
50165434	5434	5016	No	2	2	2700 West	NB	6200 S	7000 S
50225103	5022	5103	No	2	2	1300 West	SB	7800 S	9000 S
50235105	5105	5023	No	2	2	2700 West	NB	7800 S	9000 S
50275034	5034	5027	Yes	5	5	Center St	WB	700 W	State St
50305861	5861	5030	No	3	3	7000 South	EB	1300 W	700 W
50675069	5067	5069	No	3	3	2300 East	NB	Fort Unio	Bengal Bl
50675069	5069	5067	No	4	4	2300 East	SB	Fort Unio	Bengal Bl

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
50675446	5067	5446	No	2	2	Bengal Bl	EB	Highland	Danish Rd
50915377	5091	5377	No	6	6	Danish Rd	SB	Creek Rd	Wasatch B
50915377	5377	5091	No	8	8	Danish Rd	NB	Creek Rd	Wasatch B
50915427	5091	5427	No	2	2	Danish Rd	NB	Creek Rd	Bengal Bl
50915427	5427	5091	No	2	2	Danish Rd	SB	Creek Rd	Bengal Bl
50925360	5092	5360	No	3	3	Bengal Bl	WB	2300 E	Wasatch B
50925360	5360	5092	No	3	3	Bengal Bl	EB	2300 E	Wasatch B
50925388	5092	5388	No	2	2	Danish Rd	SB	Creek Rd	Bengal Bl
50925388	5388	5092	No	2	2	Danish Rd	NB	Creek Rd	Bengal Bl
50945600	5094	5600	No	6	6	Fort Unio	WB	3000 E	Wasatch B

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
50955600	5600	5095	No	6	6	Fort Unio	WB	3000 E	Wasatch B
51035114	5103	5114	No	2	2	1300 West	SB	7800 S	9000 S
51055107	5107	5105	No	2	2	2700 West	NB	7800 S	9000 S
51115579	5111	5579	No	8	8	2200 West	SB	9000 S	9800 S
51115579	5579	5111	No	8	8	2200 West	NB	9000 S	9800 S
51155377	5115	5377	No	8	8	Danish Rd	NB	Creek Rd	Wasatch B
51155377	5377	5115	No	6	6	Danish Rd	SB	Creek Rd	Wasatch B
51155598	5115	5598	Yes	3	3	Danish Rd	SB	Creek Rd	Wasatch B
51325235	5132	5235	No	3	3	700 East	SB	9400 S	9800 S
51525159	5152	5159	No	3	3	Blank	NB	SR-111	13400 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
51525159	5159	5152	No	4	4	Blank	SB	SR-111	13400 S
51525653	5152	5653	No	4	4	Blank	WB	SR-111	13400 S
51525653	5653	5152	No	3	3	Blank	EB	SR-111	13400 S
51595649	5159	5649	No	3	3	SR-111	NB	SR-111	13400 S
51595649	5649	5159	No	4	4	SR-111	SB	SR-111	13400 S
51665598	5598	5166	No	3	3	Danish Rd	SB	Creek Rd	Wasatch B
51745587	5587	5174	No	2	2	South Jor	WB	1300 W	500 W
51745868	5174	5868	No	2	2	South Jor	WB	1300 W	500 W
51755730	5175	5730	No	4	4	700 West	NB	9000 S	9800 S
52045205	5204	5205	No	2	2	2700 West	SB	9800 S	10400 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
52045205	5205	5204	No	2	2	2700 West	NB	9800 S	10400 S
52075734	5207	5734	No	5	5	2200 West	NB	9800 S	10400 S
52075734	5734	5207	No	3	3	2200 West	SB	9800 S	10400 S
52085214	5208	5214	No	2	2	South Jor	EB	Redwood Rd	1300 W
52165356	5216	5356	Yes	2	2	South Jor	EB	500 W	I-15
52165868	5868	5216	No	2	2	South Jor	WB	1300 W	500 W
52225228	5222	5228	No	2	2	700 East	NB	9800 S	10600 S
52225228	5228	5222	No	2	2	700 East	SB	9800 S	10600 S
52245235	5235	5224	No	3	3	700 East	SB	9400 S	9800 S
52245617	5224	5617	No	2	2	700 East	NB	9800 S	10600 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
52245617	5617	5224	No	2	2	700 East	SB	9800 S	10600 S
52285617	5228	5617	No	2	2	700 East	NB	9800 S	10600 S
52285617	5617	5228	No	2	2	700 East	SB	9800 S	10600 S
52635268	5268	5263	No	2	2	12300 Sou	WB	500 W	Minuteman
52685269	5269	5268	No	2	2	12300 Sou	WB	500 W	Minuteman
52715273	5271	5273	Yes	7	7	State St	NB	11400 S	12300 S
52715273	5273	5271	No	13	13	State St	SB	11400 S	12300 S
52735656	5656	5273	No	4	4	State St	SB	11000 S	11400 S
52995665	5299	5665	Yes	10	10	Fort St	NB	13200 S	13800 S
52995665	5665	5299	No	7	7	Fort St	SB	13200 S	13800 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
52995670	5299	5670	Yes	5	5	13800 Sou	WB	300 E	Fort St
52995670	5670	5299	No	6	6	13800 Sou	EB	300 E	Fort St
52995684	5299	5684	Yes	3	3	13800 Sou	EB	Fort St	1300 E
52995684	5684	5299	No	4	4	13800 Sou	WB	Fort St	1300 E
53185751	5318	5751	No	2	2	Bangerter	EB	Redwood Rd	1300 W
53235664	5323	5664	No	4	4	300 East	NB	12300 S	13800 S
53235664	5664	5323	No	4	4	300 East	SB	12300 S	13800 S
53235670	5323	5670	No	3	3	13800 Sou	EB	300 E	Fort St
53235670	5670	5323	No	3	3	13800 Sou	WB	300 E	Fort St
53265664	5326	5664	No	3	3	300 East	SB	12300 S	13800 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
53265664	5664	5326	No	3	3	300 East	NB	12300 S	13800 S
53605446	5360	5446	No	3	3	Bengal Bl	WB	2300 E	Wasatch B
53605446	5446	5360	No	3	3	Bengal Bl	EB	2300 E	Wasatch B
53675760	5367	5760	No	12	12	300 North	WB	I-15	400 W
53675760	5760	5367	No	9	9	300 North	EB	I-15	400 W
53715372	5371	5372	No	6	6	13200 Sou	NB	13200 S	13800 S
53715372	5372	5371	No	5	5	13200 Sou	SB	13200 S	13800 S
53715665	5371	5665	No	5	5	Fort St	SB	13200 S	13800 S
53715665	5665	5371	No	6	6	Fort St	NB	13200 S	13800 S
53725674	5674	5372	No	4	4	13200 Sou	WB	Fort St	1300 E

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
53755379	5375	5379	No	5	5	Parkway B	WB	I-215	2200 W
53755379	5379	5375	No	4	4	Parkway B	EB	I-215	2200 W
53755442	5375	5442	No	3	3	Parkway B	EB	I-215	2200 W
53885393	5388	5393	No	2	2	Danish Rd	SB	Creek Rd	Bengal Bl
53885393	5393	5388	No	2	2	Danish Rd	NB	Creek Rd	Bengal Bl
53935427	5427	5393	No	2	2	Danish Rd	NB	Creek Rd	Bengal Bl
54035607	5403	5607	No	4	4	700 West	NB	11400 S	12300 S
54035607	5607	5403	No	14	14	700 West	SB	11400 S	12300 S
54035732	5403	5732	No	14	14	11400 Sou	EB	700 W	500 W
54035732	5732	5403	No	4	4	11400 Sou	WB	700 W	500 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
54165674	5416	5674	No	5	5	13200 Sou	WB	Fort St	1300 E
54415861	5441	5861	No	3	3	7000 South	EB	1300 W	700 W
54755649	5475	5649	No	4	4	SR-111	SB	SR-111	13400 S
54755649	5649	5475	No	3	3	SR-111	NB	SR-111	13400 S
55325533	5532	5533	No	6	6	200 West	SB	200 S	300 S
55765737	5576	5737	No	3	3	2200 West	NB	7000 S	7800 S
55775738	5738	5577	No	2	2	7000 South	EB	2200 W	Redwood Rd
55795580	5579	5580	No	3	3	2200 West	SB	9800 S	10400 S
55795580	5580	5579	No	3	3	2200 West	NB	9800 S	10400 S
55805734	5580	5734	No	3	3	2200 West	SB	9800 S	10400 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
55805734	5734	5580	No	4	4	2200 West	NB	9800 S	10400 S
56185656	5618	5656	No	4	4	State St	SB	11000 S	11400 S
56185721	5618	5721	No	27	27	11000 Sou	EB	State St	700 E
56185721	5721	5618	No	19	19	11000 Sou	WB	State St	700 E
56205721	5620	5721	No	9	9	11000 Sou	WB	State St	700 E
56205721	5721	5620	No	12	12	11000 Sou	EB	State St	700 E
56255627	5625	5627	No	2	2	1000 East	NB	11400 S	12300 S
56835768	5683	5768	No	6	6	13800 Sou	WB	Fort St	1300 E
56835768	5768	5683	No	5	5	13800 Sou	EB	Fort St	1300 E
56845768	5684	5768	No	3	3	13800 Sou	EB	Fort St	1300 E

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
56845768	5768	5684	No	4	4	13800 Sou	WB	Fort St	1300 E
57025762	5762	5702	No	3	3	West Temp	SB	3300 S	3900 S
57085718	5708	5718	No	15	15	West Temp	SB	2700 S	3300 S
57085718	5718	5708	No	3	3	West Temp	NB	2700 S	3300 S
57185762	5718	5762	No	148	148	West Temp	SB	2700 S	3300 S
57375738	5737	5738	No	3	3	2200 West	NB	7000 S	7800 S
57385740	5738	5740	No	15	15	2200 West	NB	6200 S	7000 S
57805781	5780	5781	No	2	2	Highland	SB	I-215	I-215
58105812	5810	5812		3	3	4000 West	SB	11800 S	12600 S
58575855	5857	5855	No	12	12	CD Road	SB	I-15 S	1300 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
90719126	9126	9071	No	14	14	Blank	WB	Redwood Rd	500 W
100433485	10043	3485	No	3	3	I-15 SB o	SB	Off Ramp	2300 N
100473674	10047	3674	No	4	4	I-15 SB o	SB	Off Ramp	1000 N
347710045	3477	10045	Yes	4	4	I-15 SB o	SB	On Ramp	2300 N
359210046	3592	10046	No	5	5	I-15 NB o	NB	On Ramp	1000 N
373110002	3731	10002	Yes	2	2	I-15 NB o	NB	On Ramp	400 S
393710074	3937	10074	Yes	4	4	300 West	NB	600 S	800 S
393710074	10074	3937	No	4	4	300 West	SB	600 S	800 S
441310120	4413	10120	Yes	4	4	I-15 SB o	SB	On Ramp	3300 S
526310155	5263	10155	No	2	2	I-15 SB o	SB	On Ramp	12300 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario Volume Ratio (after/before)	Road Name	Direction	From	To
529710159	5297	10159		3	3	I-15 SB o	SB	On Ramp	Bangerter
1018512878	10185	12878		3	3	I-80 EB o	SB	I-80 E	4000 W
1020110207	10201	10207	No	2	2	I-80	EB	I-215	Redwood Rd
1020310201	10203	10201	No	2	2	I-80	EB	4000 W	Redwood Rd
1287610537	12878	3737		3	3	I-80 EB o	SB	I-80 E	4000 W
1288512949	12930	5457		2	2	5300 South	WB	300 W	S Intermountain
1288512950	4822	12930		2	2	5300 South	WB	S Intermountain	State St

Table A3-3: Links critical in the Wasatch Scenario and vulnerable in the M6.0 scenario

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario PGD DS	Road Name	Direction	From	To
35354199	3535	4199	No	2	3	700 North	EB	Redwood Rd	1200 W
36174191	4191	3617	No	2	2	700 North	EB	Redwood Rd	1200 W
36803688	3688	3680	Yes	3	2	North Tem	WB	2200 W	Redwood Rd
36883717	3717	3688	Yes	2	3	North Tem	WB	2200 W	Redwood Rd
37034558	3703	4558	Yes	2	2	4000 West	SB	700 S	California
38724589	3872	4589	No	2	2	California	WB	4000 W	Pioneer Rd
38724589	4589	3872	No	4	2	California	EB	4000 W	Pioneer Rd
39243925	3924	3925	Yes	5	3	Redwood R	NB	400 S	Indiana A
39243925	3925	3924	No	2	3	Redwood R	SB	400 S	Indiana A
39243927	3924	3927	No	2	3	Indiana A	EB	Redwood Rd	900 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario PGD DS	Road Name	Direction	From	To
39243927	3927	3924	No	3	3	Indiana A	WB	Redwood Rd	900 W
40404141	4040	4141	No	3	4	Pioneer R	NB	1700 S	SR-201
40404141	4141	4040	No	6	4	Pioneer R	SB	1700 S	SR-201
40514239	4051	4239	No	2	2	2100 South	EB	4000 W	Gladiola
40514239	4239	4051	No	8	2	2100 South	WB	4000 W	Gladiola
40604143	4143	4060	No	2	4	1700 South	WB	Redwood Rd	900 W
40605088	4060	5088	No	2	4	1700 South	EB	Redwood Rd	900 W
40674145	4145	4067	Yes	14	4	900 West	NB	1700 S	2100 S
40674264	4067	4264	Yes	2	4	900 West	SB	1700 S	2100 S
40704145	4070	4145	Yes	11	3	1700 South	WB	900 W	I-15
40704145	4145	4070	Yes	4	3	1700 South	EB	900 W	I-15

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario PGD DS	Road Name	Direction	From	To
41164141	4116	4141	No	9	4	1700 South	WB	Redwood Rd	Pioneer Rd
41164141	4141	4116	No	2	4	1700 South	EB	Redwood Rd	Pioneer Rd
41415184	4141	5184	No	3	4	Pioneer R	NB	1700 S	California
41415184	5184	4141	No	2	4	Pioneer R	SB	1700 S	California
41454146	4145	4146	Yes	8	3	900 West	NB	1300 S	1700 S
41454146	4146	4145	No	3	3	900 West	SB	1300 S	1700 S
41455088	4145	5088	Yes	2	4	1700 South	WB	Redwood Rd	900 W
41914199	4199	4191	No	2	3	700 North	WB	Redwood Rd	1200 W
43914399	4391	4399	No	3	3	2200 West	NB	3100 S	3500 S
43934394	4394	4393	No	2	3	Redwood R	NB	3100 S	3500 S
43944396	4396	4394	No	2	3	Redwood R	NB	3100 S	3500 S

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario PGD DS	Road Name	Direction	From	To
45355409	4535	5409	No	2	3	900 West	SB	SR-201	3300 S
45574558	4557	4558	No	3	2	California	WB	4000 W	Pioneer Rd
45574558	4558	4557	No	8	2	California	EB	4000 W	Pioneer Rd
45574589	4557	4589	No	8	2	California	EB	4000 W	Pioneer Rd
45574589	4589	4557	No	3	2	California	WB	4000 W	Pioneer Rd
45954596	4596	4595	No	2	3	2700 West	NB	3500 S	4100 S
45964671	4671	4596	No	2	3	2700 West	NB	3500 S	4100 S
50175022	5022	5017	No	2	3	7800 South	EB	Redwood Rd	1300 W
53665367	5366	5367	No	4	4	400 West	NB	300 N	North Temp
53665367	5367	5366	No	21	4	400 West	SB	300 N	North Temp
101943660	10194	3660	No	2	2	CD Road	WB	2200 W	4000 W

Link Number	From Node	To Node	Is Bridge Present	The Wasatch Scenario Volume Ratio (after/before)	The M6.0 scenario PGD DS	Road Name	Direction	From	To
1019510203	10195	10203	No	2	3	I-80	WB	4000 W	I-215
1019610194	10196	10194	No	2	2	CD Road	WB	2200 W	4000 W
1058810586	10588	10586	No	2	3	I-215	NB	I-80	500 S
1070410392	10704	10392	No	2	2	I-80	WB	7200 W	5600 W

Table A3-4: Links critical in the M6.0 scenario and vulnerable in the Wasatch Scenario

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
19414380	4380	1941	No	2	5	3600 West	SB	3500 S	4100 S
21694433	4433	2169	No	2	5	Parkway B	WB	4800 W	4000 W
35113477	3511	3477	Yes	4	3	I-15 SB o	SB	2300 N	On ramp
35354199	3535	4199	No	2	4	700 North	EB	Redwood Rd	1200 W
35573639	3639	3557	Yes	3	3	4000 West	SB	700 S	I-80
35573703	3557	3703	Yes	3	3	4000 West	SB	700 S	I-80
35623736	3562	3736	No	3	5	300 West	SB	600 N	Victory Rd
36155165	3615	5165	Yes	2	3	On Ramp	WB	400 W	I-80 W
36323639	3632	3639	Yes	3	3	4000 West	SB	I-80	700 S
36323639	3639	3632	Yes	2	3	4000 West	NB	I-80	700 S

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
36323650	3632	3650	Yes	2	3	4000 West	NB	I-80	700 S
36503652	3650	3652	Yes	2	3	4000 West	SB	I-80	700 S
36523615	3652	3615	Yes	2	3	On Ramp	WB	400 W	I-80 W
36803688	3688	3680	Yes	3	4	North Tem	WB	2200 W	Redwood Rd
36883717	3717	3688	Yes	2	4	North Tem	WB	2200 W	Redwood Rd
37034558	3703	4558	Yes	2	3	4000 West	SB	700 S	California
37123893	3893	3712	No	3	3	700 South	WB	5600 S	4800 S
37373632	3737	3632	Yes	3	3	I-80 EB o	On Ramp	I-80 E	400 W
37385380	3738	5380	Yes	2	3	On Ramp	WB	400 W	I-80 W
37653766	3765	3766	No	7	5	300 South	EB	200 W	West Temp

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
37653766	3766	3765	No	2	5	300 South	WB	200 W	West Temp
37675532	3767	5532	No	3	5	200 South	WB	200 W	West Temp
37675532	5532	3767	No	4	5	200 South	EB	200 W	West Temp
37733903	3773	3903	No	4	5	South Tem	WB	200 W	West Temp
37733903	3903	3773	No	6	5	South Tem	EB	200 W	West Temp
38365542	3836	5542	No	3	5	California	WB	5600 S	4800 S
38724589	3872	4589	No	2	3	California	WB	4000 W	Pioneer Rd
38724589	4589	3872	No	4	3	California	EB	4000 W	Pioneer Rd
39013921	3901	3921	No	2	5	Frontage	EB	Frontage	4800 W
39013952	3952	3901	No	2	4	Frontage	EB	Frontage	4800 W

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
39215185	3921	5185	No	2	5	Frontage	EB	4800 W	4000 W
39223923	3922	3923	No	3	5	2100 South	EB	Frontage	4800 W
39223923	3923	3922	No	3	5	2100 South	WB	Frontage	4800 W
39224309	4309	3922	No	3	3	2100 South	WB	Frontage	4800 W
39534077	3953	4077	No	2	4	Main St	SB	800 S	900 S
39624085	3962	4085	No	2	4	State St	SB	800 S	900 S
39705184	5184	3970	No	2	5	Pioneer R	NB	California	1700 S
39934006	3993	4006	Yes	324	4	2100 South	WB	3200 S	2700 S
39934006	4006	3993	Yes	17	4	2100 South	EB	3200 S	2700 S
39934040	3993	4040	Yes	17	4	2100 South	EB	3200 S	2700 S

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
39934040	4040	3993	Yes	324	4	2100 South	WB	3200 S	2700 S
40034006	4003	4006	No	17	5	2100 South	EB	3200 S	2700 S
40034006	4006	4003	No	324	5	2100 South	WB	3200 S	2700 S
40104179	4179	4010	No	12	5	3rd Ave	EB	State St	B St
40124014	4012	4014	No	2	5	Sunnyside	EB	1300 E	Guardsman
40124014	4014	4012	No	2	5	Sunnyside	WB	1300 E	Guardsman
40404041	4040	4041	Yes	4	4	2700 West	SB	1700 S	Parkway B
40404041	4041	4040	Yes	2	4	2700 West	NB	1700 S	Parkway B
40464048	4046	4048	Yes	6	3	900 South	EB	900 W	I-15
40485466	5466	4048	No	5	4	900 South	WB	900 W	400 W

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
40514231	4051	4231	Yes	8	4	2100 South	WB	4000 W	3600 W
40514231	4231	4051	No	2	3	2100 South	EB	4000 W	3600 W
40514239	4051	4239	No	2	3	2100 South	EB	4000 W	Gladiola
40514239	4239	4051	No	8	3	2100 South	WB	4000 W	Gladiola
40605088	4060	5088	No	2	5	1700 South	EB	Redwood Rd	900 W
40654068	4065	4068	No	2	4	West Temp	NB	900 S	CD Road
40664068	4068	4066	No	2	5	West Temp	NB	900 S	CD Road
40664076	4066	4076	No	76	5	900 South	EB	West Temp	Main St
40664076	4076	4066	No	6	4	900 South	WB	West Temp	Main St
40734229	4229	4073	No	2	3	Frontage	WB	4800 W	4000 W

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
40744075	4075	4074	No	2	4	Main St	SB	900 S	1300 S
40764077	4076	4077	No	76	4	900 South	EB	West Temp	Main St
40774085	4085	4077	No	8	3	900 South	WB	Main St	State St
41204125	4120	4125	No	2	5	900 South	EB	1300 E	1500 E
41415184	4141	5184	No	3	5	Pioneer R	NB	California	1700 S
41415184	5184	4141	No	2	5	Pioneer R	SB	California	1700 S
41424143	4142	4143	No	2	4	Redwood R	NB	1700 S	2100 S
41435060	4143	5060	No	2	4	Redwood R	NB	California	1700 S
41644175	4164	4175	No	2	5	1100 East	NB	1700 S	2100 S
41754177	4175	4177	No	2	5	1700 South	EB	1100 E	1300 E

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
43004493	4493	4300	No	2	5	1300 East	NB	2700 S	3300 S
43124650	4650	4312	No	2	5	2100 South	EB	900 E	1100 E
43144496	4314	4496	No	2	5	1300 East	NB	2700 S	3300 S
43224376	4322	4376	No	3	5	3100 South	EB	4800 W	4000 W
43224376	4376	4322	No	3	5	3100 South	WB	4800 W	4000 W
43414419	4341	4419	Yes	2	4	300 West	NB	I-80	2100 S
43414419	4419	4341	Yes	2	4	300 West	SB	I-80	2100 S
43914399	4391	4399	No	3	5	2200 West	NB	3100 S	3500 S
43934394	4394	4393	No	2	5	Redwood R	SB	3100 S	3500 S
43944396	4396	4394	No	2	5	Redwood R	SB	3100 S	3500 S

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
44924493	4492	4493	No	2	5	1300 East	NB	2700 S	3300 S
45355409	4535	5409	No	2	5	900 West	SB	SR-201	3300 S
45484558	4548	4558	No	2	3	California	EB	4800 W	4000 W
45484558	4558	4548	No	5	3	California	WB	4800 W	4000 W
45574558	4557	4558	No	3	3	California	WB	4000 W	Pioneer Rd
45574558	4558	4557	No	8	3	California	EB	4000 W	Pioneer Rd
45574589	4557	4589	No	8	3	California	EB	4000 W	Pioneer Rd
45574589	4589	4557	No	3	3	California	WB	4000 W	Pioneer Rd
45924707	4592	4707	No	2	5	3200 West	SB	4100 S	4700 S
45924707	4707	4592	No	2	5	3200 West	NB	4100 S	4700 S

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
45954596	4596	4595	No	2	5	2700 West	SB	3500 S	4100 S
45964671	4671	4596	No	2	5	2700 West	SB	3500 S	4100 S
45994600	4599	4600	No	2	5	3600 West	NB	4100 S	4700 S
46015217	4601	5217	No	2	5	Meadow Br	EB	Redwood Rd	500 W
46134614	4613	4614	No	2	5	3900 South	EB	West Temp	Main St
46144732	4614	4732	No	2	5	Main St	SB	3900 S	W Central Av
47064707	4706	4707	No	2	5	3200 West	NB	4100 S	4700 S
47064789	4706	4789	No	5	5	3200 West	SB	4700 S	5400 S
47064789	4789	4706	No	4	5	3200 West	NB	4700 S	5400 S
47965927	4796	5927	No	3	5	5400 South	WB	3200 W	2700 W

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
47965927	5927	4796	No	3	5	5400 South	EB	3200 W	2700 W
48165332	5332	4816	No	2	5	Minuteman	NB	Highland	Minuteman
49065440	4906	5440	No	2	5	1300 West	SB	Wincheste	7000 S
49525440	4952	5440	No	5	5	1300 West	NB	7000 S	7800 S
49525440	5440	4952	No	3	5	1300 West	SB	7000 S	7800 S
49745320	4974	5320	No	6	5	Wasatch B	NB	6200 S	5600 S
49745320	5320	4974	No	6	5	Wasatch B	SB	6200 S	5600 S
49955320	4995	5320	No	6	5	Wasatch B	SB	6200 S	5600 S
49955320	5320	4995	No	6	5	Wasatch B	NB	6200 S	5600 S
49995019	4999	5019	No	2	5	New Bingh	EB	SR-111	5600 W

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
49995019	5019	4999	No	2	5	New Bingh	WB	SR-111	5600 W
50175022	5022	5017	No	2	5	7800 South	WB	Redwood Rd	1300 W
50225524	5524	5022	No	3	5	7800 South	WB	1300 W	700 W
50435307	5043	5307	No	6	5	Wasatch B	SB	4500 S	6200 S
50435307	5307	5043	No	4	5	Wasatch B	NB	4500 S	6200 S
50705328	5328	5070	No	2	5	Fort St	NB	Pioneer Rd	13200 S
50955600	5095	5600	No	3	5	Fort Unio	WB	3000 E	Wasatch B
50955600	5600	5095	No	6	5	Fort Unio	EB	3000 E	Wasatch B
50975462	5097	5462	No	2	5	Fort Unio	WB	2300 E	3000 E
50975462	5462	5097	No	2	5	Fort Unio	EB	2300 E	3000 E

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
51175730	5730	5117	No	2	5	700 West	NB	9000 S	9800 S
51653738	5165	3738	No	2	3	On Ramp	WB	400 W	I-80 W
51755729	5729	5175	No	4	5	9800 South	WB	700 W	500 W
52085209	5209	5208	No	2	5	Redwood R	SB	9800 S	10400 S
52095211	5211	5209	No	2	5	Redwood R	SB	9800 S	10400 S
52145232	5214	5232	No	2	5	1300 West	NB	9800 S	South Jor
52145232	5232	5214	No	2	5	1300 West	SB	9800 S	South Jor
52155232	5232	5215	No	2	5	9800 South	EB	1300 W	700 W
52195232	5219	5232	No	2	5	1300 West	SB	9000 S	9800 S
52305929	5230	5929	No	3	5	9800 South	WB	I-15	State St

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
52305929	5929	5230	No	2	5	9800 South	EB	I-15	State St
52735656	5273	5656	No	2	5	State St	NB	11000 S	11400 S
52735656	5656	5273	No	4	5	State St	SB	11000 S	11400 S
53515683	5351	5683	No	2	5	Highland	WB	13800 S	1300 E
53515769	5769	5351	No	2	5	1300 East	WB	13800 S	Highland Dr
53665367	5366	5367	No	4	5	400 West	NB	300 N	North Temp
53665367	5367	5366	No	21	5	400 West	SB	300 N	North Temp
53725674	5372	5674	No	2	5	13200 Sou	EB	Fort St	1300 E
53725674	5674	5372	No	4	5	13200 Sou	WB	Fort St	1300 E
54015416	5401	5416	No	2	5	1300 East	SB	Pioneer Rd	13200 S

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
54165674	5416	5674	No	5	5	13200 Sou	WB	Fort St	1300 E
54165674	5674	5416	No	3	5	13200 Sou	EB	Fort St	1300 E
54165769	5416	5769	No	2	5	1300 East	SB	13200 S	13800 S
54225658	5422	5658	No	2	5	11400 Sou	EB	State St	700 E
54225658	5658	5422	No	2	5	11400 Sou	WB	State St	700 E
54365440	5436	5440	No	2	5	7000 South	EB	Redwood Rd	1300 W
54365577	5577	5436	No	2	5	7000 South	EB	2200 W	Redwood Rd
54485658	5448	5658	No	2	5	11400 Sou	WB	State St	700 E
54485658	5658	5448	No	3	5	11400 Sou	EB	State St	700 E
54965685	5685	5496	No	2	5	11800 Sou	EB	6000 W	4000 W

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
55285676	5528	5676	No	2	5	13400 Sou	EB	6000 W	5600 W
56825683	5683	5682	No	2	5	Vestry Rd	SB	Highland	Vestry Rd
57285729	5729	5728	No	2	5	500 West	NB	9000 S	9800 S
57295929	5729	5929	No	2	5	9800 South	EB	500 W	State St
57295929	5929	5729	No	3	5	9800 South	WB	500 W	State St
57685769	5768	5769	No	2	5	13800 Sou	EB	Fort St	1300 E
57685769	5769	5768	No	4	5	13800 Sou	WB	Fort St	1300 E
58565857	5856	5857	No	3	4	CD Road	SB	800 S	1300 S
100443497	10044	3497	No	4	3	I-15 NB o	NB	Off Ramp	2300 N
101465120	10146	5120	No	2	5	I-15 NB o	NB	Off Ramp	9000 S

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
101943660	10194	3660	No	2	3	CD Road	WB	2200 W	4000 W
347710045	3477	10045	Yes	4	3	I-15 SB o	SB	On Ramp	2300 N
366910196	3669	10196	Yes	2	4	CD Road	WB	2200 W	4000 W
437610596	4376	10596	No	28	5	4000 West	SB	3100 S	3500 S
437610596	10596	4376	No	21	5	4000 West	NB	3100 S	3500 S
437810596	4378	10596	No	21	5	4000 West	NB	3100 S	3500 S
437810596	10596	4378	No	28	5	4000 West	SB	3100 S	3500 S
538010190	5380	10190	No	2	3	CD Road	WB	4000 W	I-80 W
585010704	5850	10704	No	5	4	5600 West	On Ramp	5600 W	I-80 W
1005410048	10054	10048	No	2	5	I-15	NB	600 N	600 N

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
1011710111	10117	10111	No	2	3	CD Road	EB	I-15 S	I-80 E
1013610557	10136	10557	No	2	5	I-15	SB	I-215	7000 S
1013810141	10138	10141	No	2	5	I-15	SB	7200 S	7200 S
1019510203	10195	10203	No	2	4	I-80	EB	4000 W	I-215
1019610194	10196	10194	No	2	3	CD Road	WB	2200 W	4000 W
1020310201	10203	10201	No	2	5	I-80	EB	4000 W	I-215
1021310059	10213	10059	No	2	5	CD Road	On Ramp	I-80 E	I-15 S
1021310526	10213	10526	No	3	5	CD Road	On Ramp	I-80 E	I-15 N
1025910588	10259	10588	No	2	5	I-215	NB	500 S	I-80
1030910626	10309	10626	No	2	5	I-215	NB	2300 E	5600 S

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
1039210390	10392	10390	No	2	5	I-80	WB	7200 W	5600 W
1052510056	10525	10056	No	3	5	CD Road	On Ramp	I-80 E	I-15 N
1052610525	10526	10525	No	3	5	CD Road	On Ramp	I-80 E	I-15 N
1054710117	10547	10117	No	2	5	CD Road	EB	I-15 S	I-80 E
1055310136	10553	10136	No	2	5	I-15	SB	I-215	7200 S
1055710138	10557	10138	No	2	5	I-15	SB	I-215	7200 S
1058810586	10588	10586	No	2	5	I-215	NB	I-80	500 S
1062610628	10626	10628	No	2	5	I-215	NB	2300 E	5600 S
1062810311	10628	10311	No	2	5	I-215	NB	2300 E	5600 S
1069910198	10699	10198	No	2	5	CD Road	WB	I-215 S	I-80 W

Link Number	From Node	To Node	Is Bridge Present	The M6.0 scenario Volume Ratio (after/before)	The Wasatch Scenario PGD DS	Road Name	Direction	From	To
1070310706	10703	10706	No	2	4	I-80	EB	5600 W	5600 W
1070410392	10704	10392	No	2	4	I-80	WB	7200 W	5600 W
1070510704	10705	10704	No	2	4	I-80	WB	5600 W	5600 W