Alpine Aqueduct Reach 1 Risk & Resiliency Project

Utah Seismic Safety Commission

Chris Elison

March 28, 2024

CENTRAL UTAH WATER
CONSERVANCY DISTRICT

Central Utah Water Conservancy District

Managing **$3.5 billion** in infrastructure

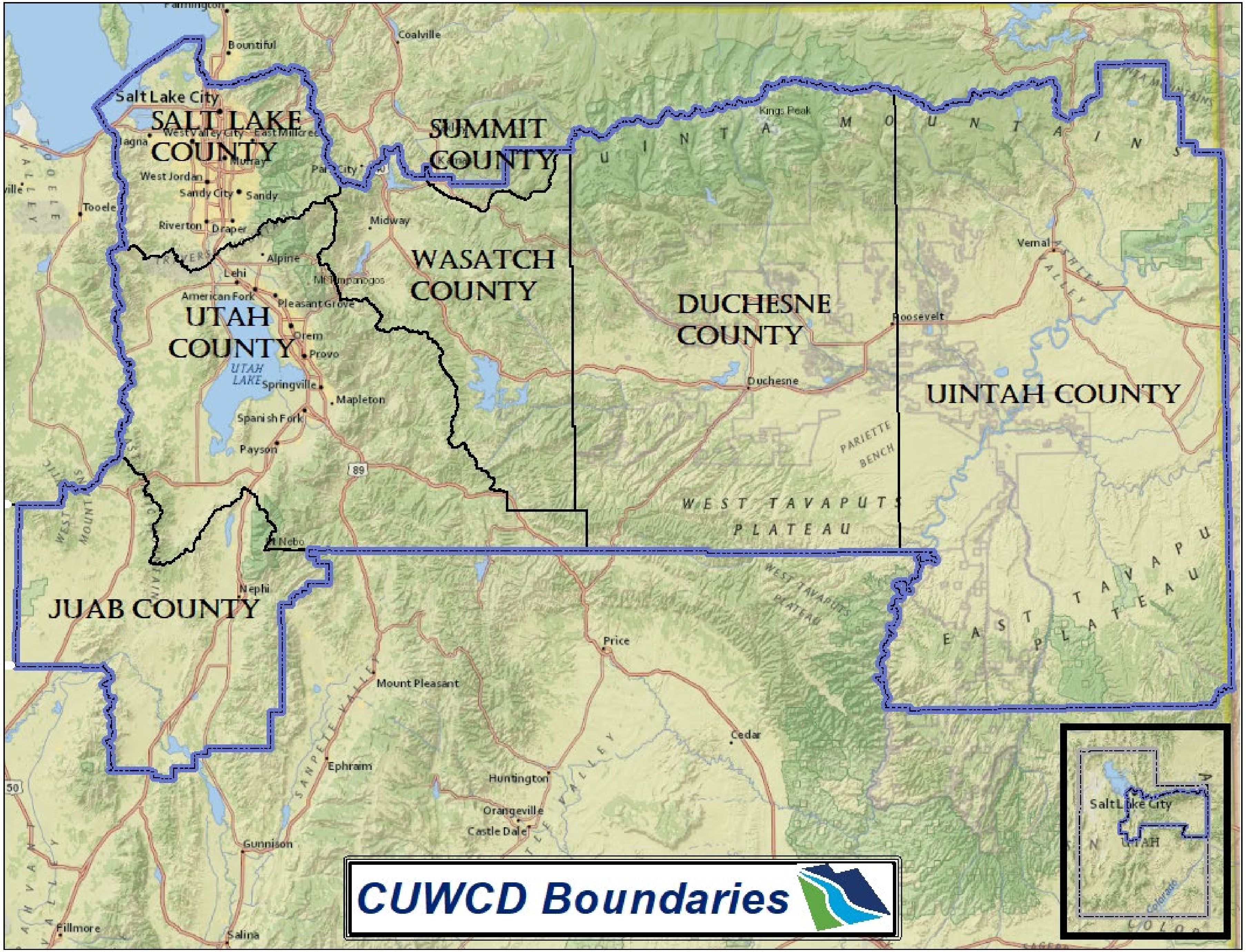
Treating more than **100 million** gallons per day

Serving **1.5 million** people every day

Maintaining **178 miles** of canals, tunnels and pipelines

Delivering more than **400,000 acre-feet** annually

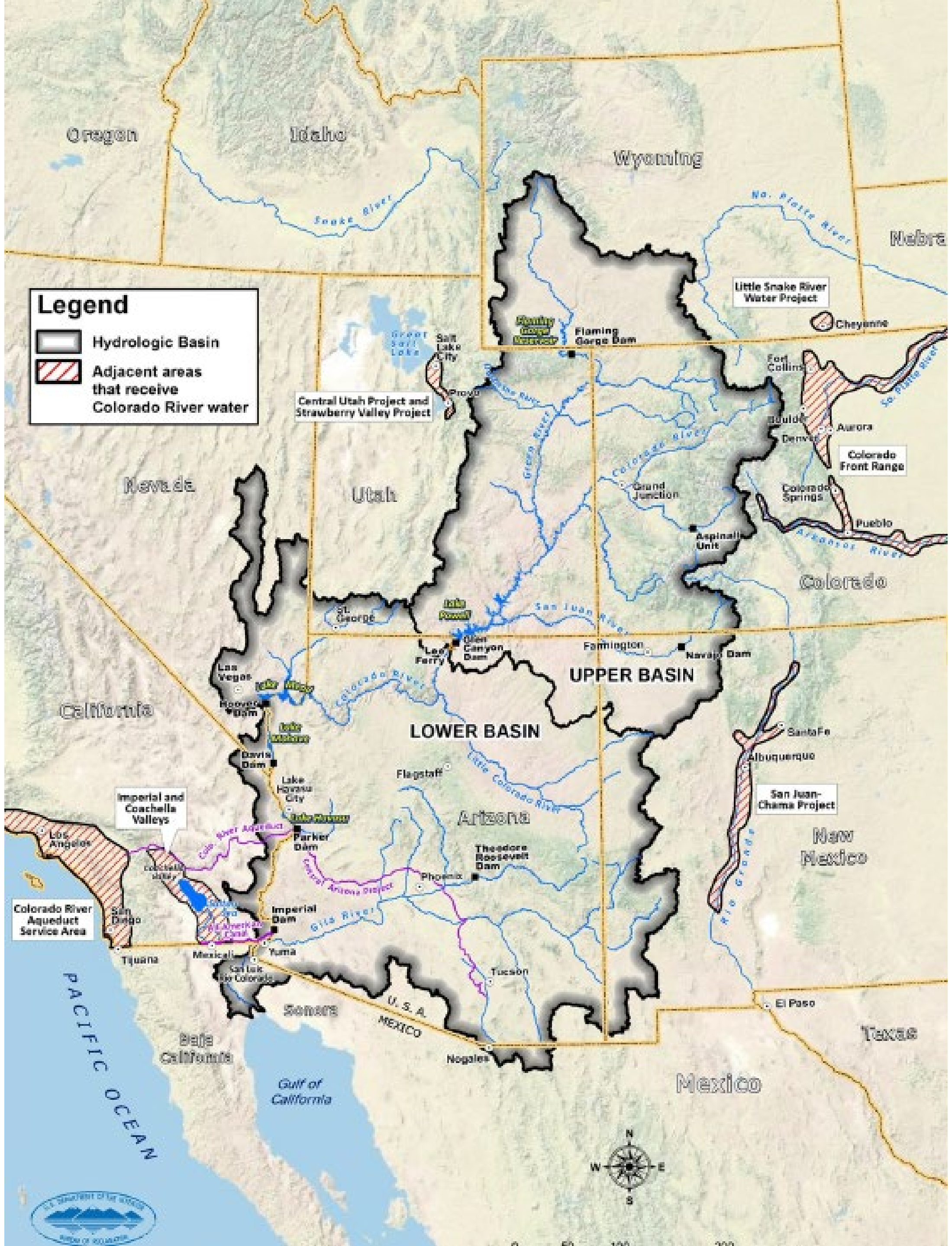
Storing **565 billion gallons** in reservoirs


CUWCD Boundaries
SALT LAKE COUNTY
SUMMIT COUNTY
WASATCH COUNTY
UTAH COUNTY
DUCHESNE COUNTY
UINTAH COUNTY
JUAB COUNTY
Salt Lake City
Bountiful
Coalville
West Jordan
Sandy City
Sandy
Riverton
Draper
Tooele
Midway
Alpine
Lehi
American Fork
Pleasant Grove
Orem
Provo
UTAH LAKE
Springville
Mapleton
Spanish Fork
Payson
Nephi
Vernal
Roosevelt
Duchesne
Kings Peak
U I N T A M O U N T A I N S
WEST TAVAPUTS PLATEAU
PARIETTE BENCH
EAST TAVAPUTS PLATEAU
Price
Mount Pleasant
Ephraim
Huntington
Orangeville
Castle Dale
Cedar
Gunnison
Fillmore
Salina
89
50

Colorado River Basin:

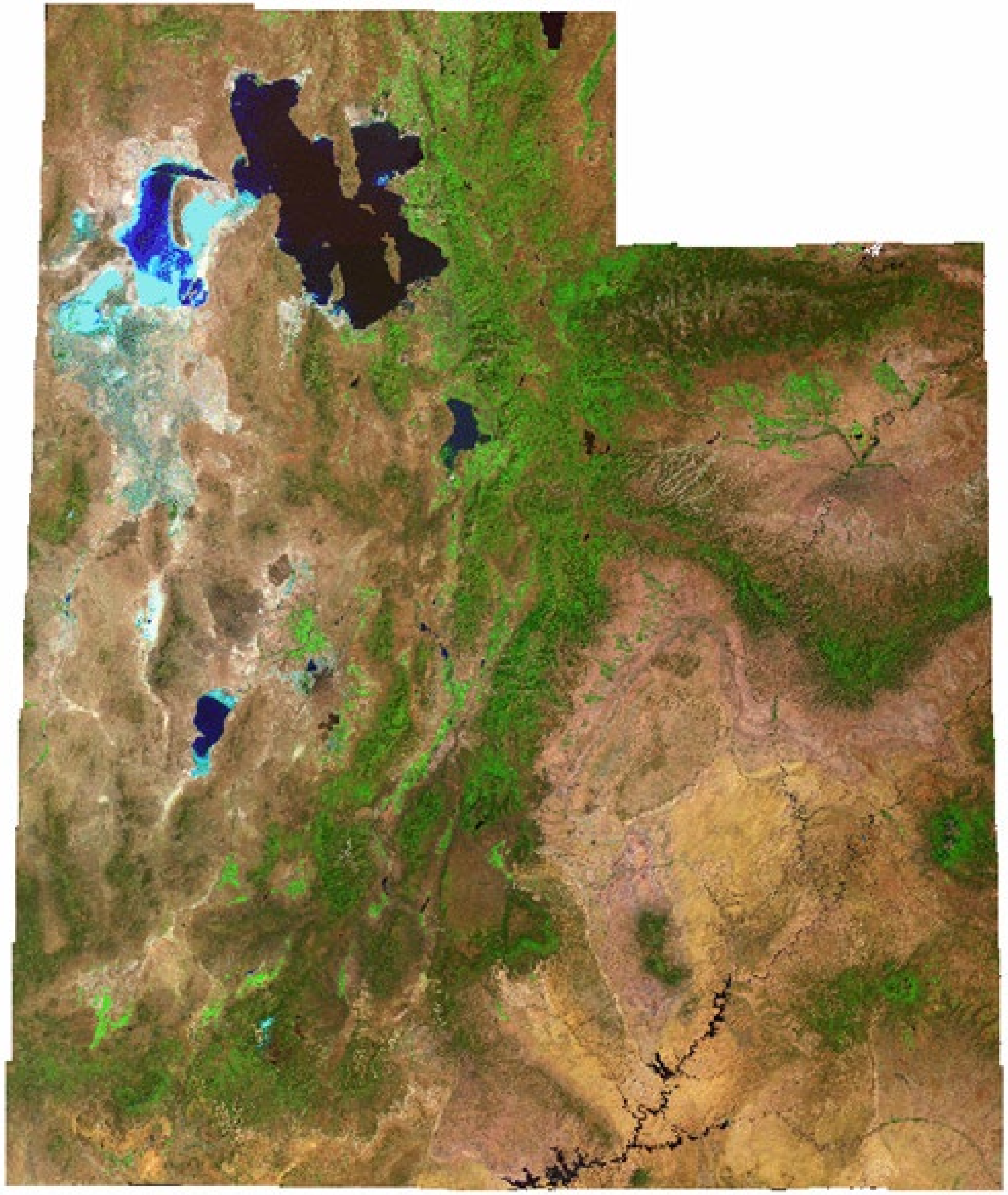
Why is this so important?

- Over 40 million people in the 7 Basin States and Mexico rely on the Colorado River and its tributaries
- ~4.5 million Acres of land irrigated in the basin and adjacent areas
- $1.4 trillion in economic benefit
- 29 federally recognized Tribes in the basin
- Unique habitat for a wide range of species, seven wildlife refuges, 11 units overseen by the national Park Service
- Myriad recreational opportunities – boating, fishing, rafting, tourism
- 11 hydroelectric powerplants on the river that produce approximately 5.7 million kilowatt-hours of hydropower

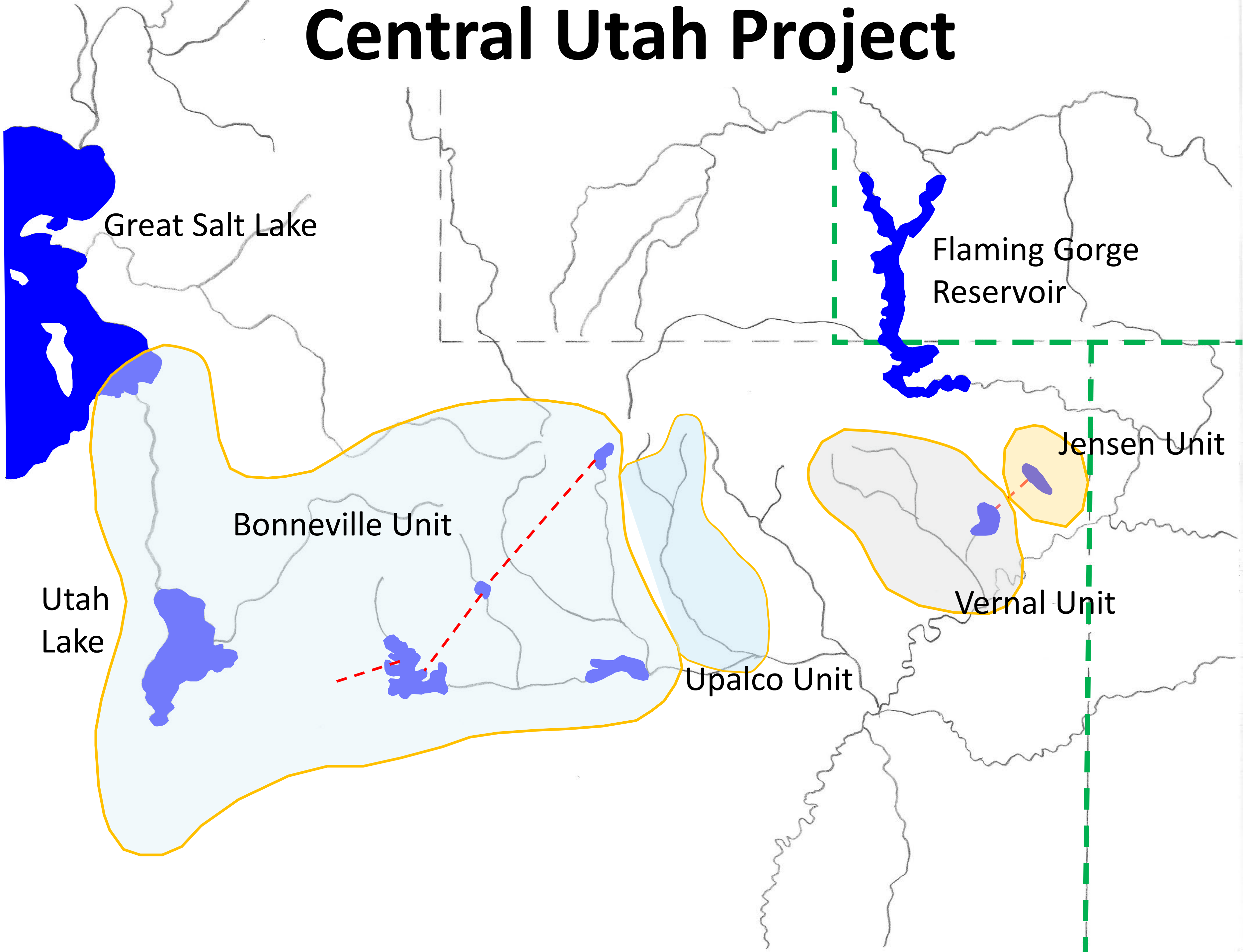


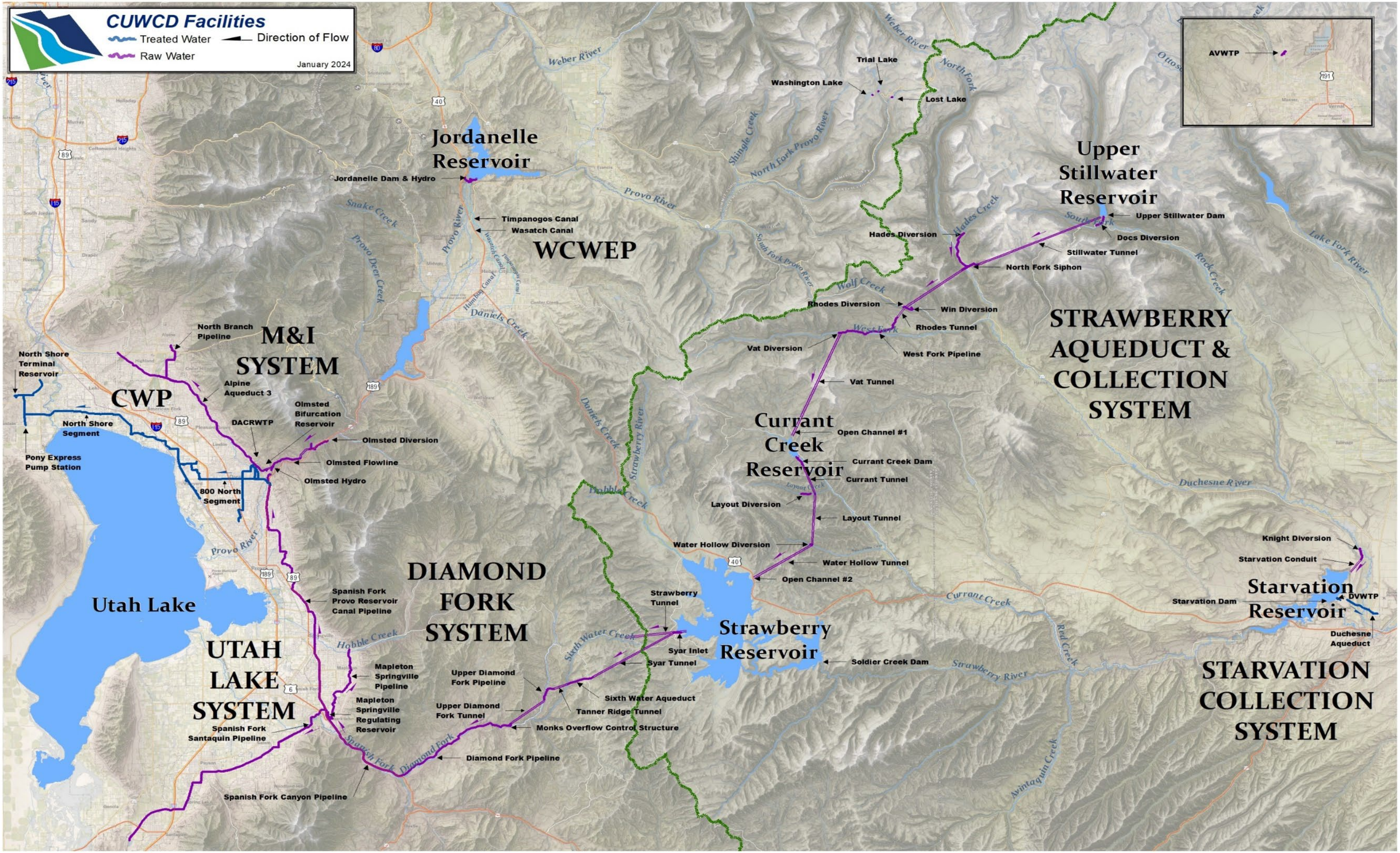
Why Does the Colorado River Matter to Utah?

- Colorado River represents approximately 1/3 of Utah's water supply
- Supplies water to over 1.5 million people including Salt Lake and Utah Counties
- 26 percent of Utah's agriculture is located in the Colorado River basin.
- Support two federally recognized Native American tribes
- 23 percent of the Upper Basin's apportionment -
- Future development



Central Utah Project

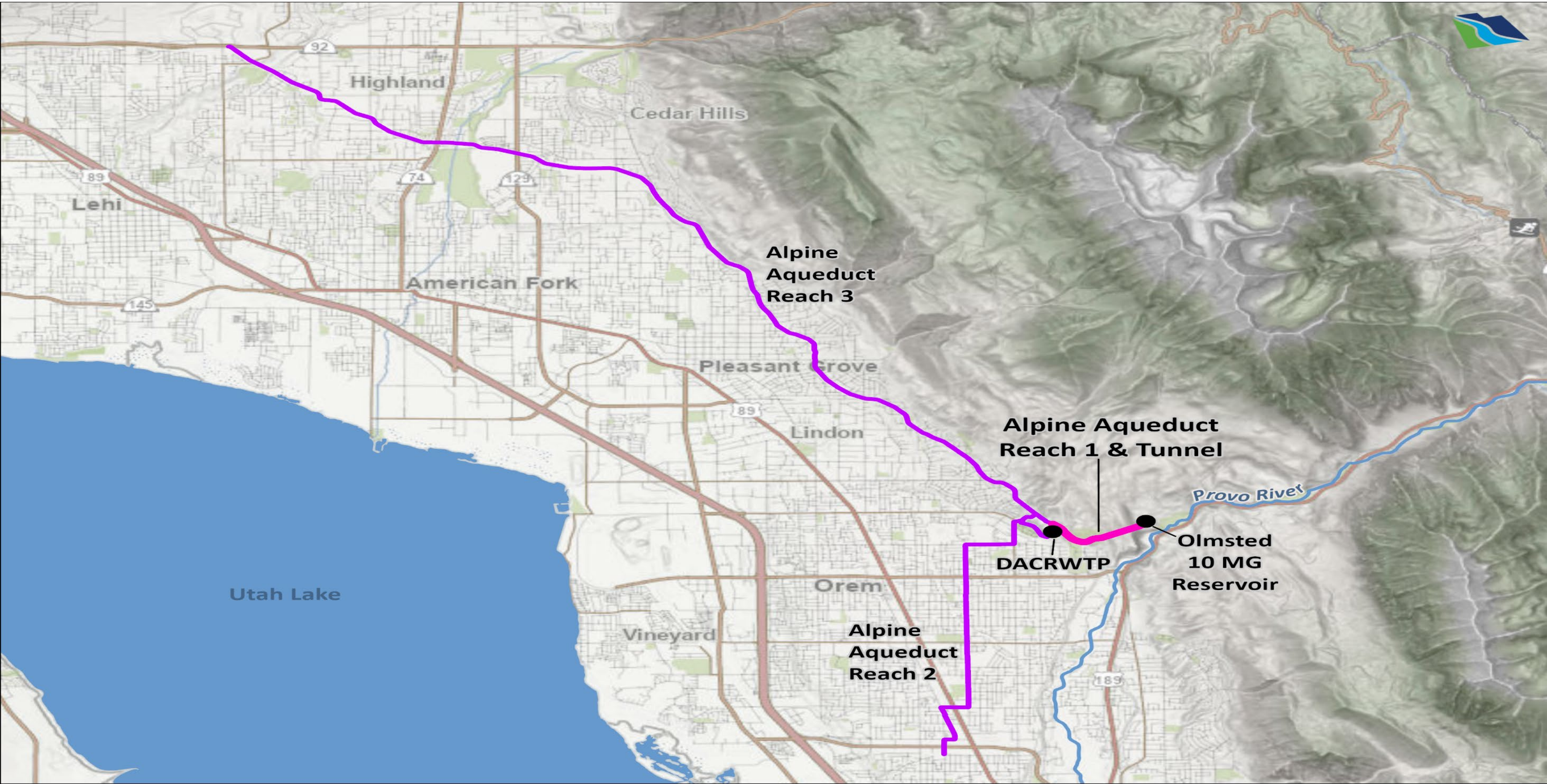



CUWCD Facilities
Treated Water
Direction of Flow
Raw Water
January 2024
Jordanelle Reservoir
Jordanelle Dam & Hydro
Timpanogos Canal
Wasatch Canal
WCWEP
Trial Lake
Washington Lake
Lost Lake
AVWTP
Upper Stillwater Reservoir
Upper Stillwater Dam
Docs Diversion
Stillwater Tunnel
Hades Diversion
North Fork Siphon
Rhodes Diversion
Win Diversion
Rhodes Tunnel
STRAWBERRY AQUEDUCT & COLLECTION SYSTEM
Vat Diversion
West Fork Pipeline
Vat Tunnel
Currant Creek Reservoir
Open Channel #1
Currant Creek Dam
Currant Tunnel
Layout Diversion
Layout Tunnel
Water Hollow Diversion
Water Hollow Tunnel
Open Channel #2
Knight Diversion
Starvation Conduit
Starvation Dam
Starvation Reservoir
DVWTP
Duchesne Aqueduct
STARVATION COLLECTION SYSTEM
North Branch Pipeline
M&I SYSTEM
North Shore Terminal Reservoir
CWP
Alpine Aqueduct 3
Olmsted Bifurcation Reservoir
DACRWTP
Olmsted Diversion
North Shore Segment
Olmsted Flowline
Pony Express Pump Station
Olmsted Hydro
800 North Segment
DIAMOND FORK SYSTEM
Spanish Fork Provo Reservoir Canal Pipeline
Utah Lake
UTAH LAKE SYSTEM
Mapleton Springville Pipeline
Mapleton Springville Regulating Reservoir
Spanish Fork Santaquin Pipeline
Upper Diamond Fork Pipeline
Upper Diamond Fork Tunnel
Sixth Water Aqueduct
Tanner Ridge Tunnel
Monks Overflow Control Structure
Diamond Fork Pipeline
Spanish Fork Canyon Pipeline
Strawberry Tunnel
Syar Inlet
Syar Tunnel
Strawberry Reservoir
Soldier Creek Dam
Weber River
Provo River
Snake Creek
Provo Deer Creek
Daniels Creek
Strawberry River
Hobble Creek
Sixth Water Creek
Spanish Fork
Diamond Fork
Currant Creek
Red Creek
Avintaquin Creek
Duchesne River
Rock Creek
Lake Fork River
West Fork
Wolf Creek
South Fork Provo River
North Fork Provo River
Shingle Creek
North Fork
Hades Creek
South Fork

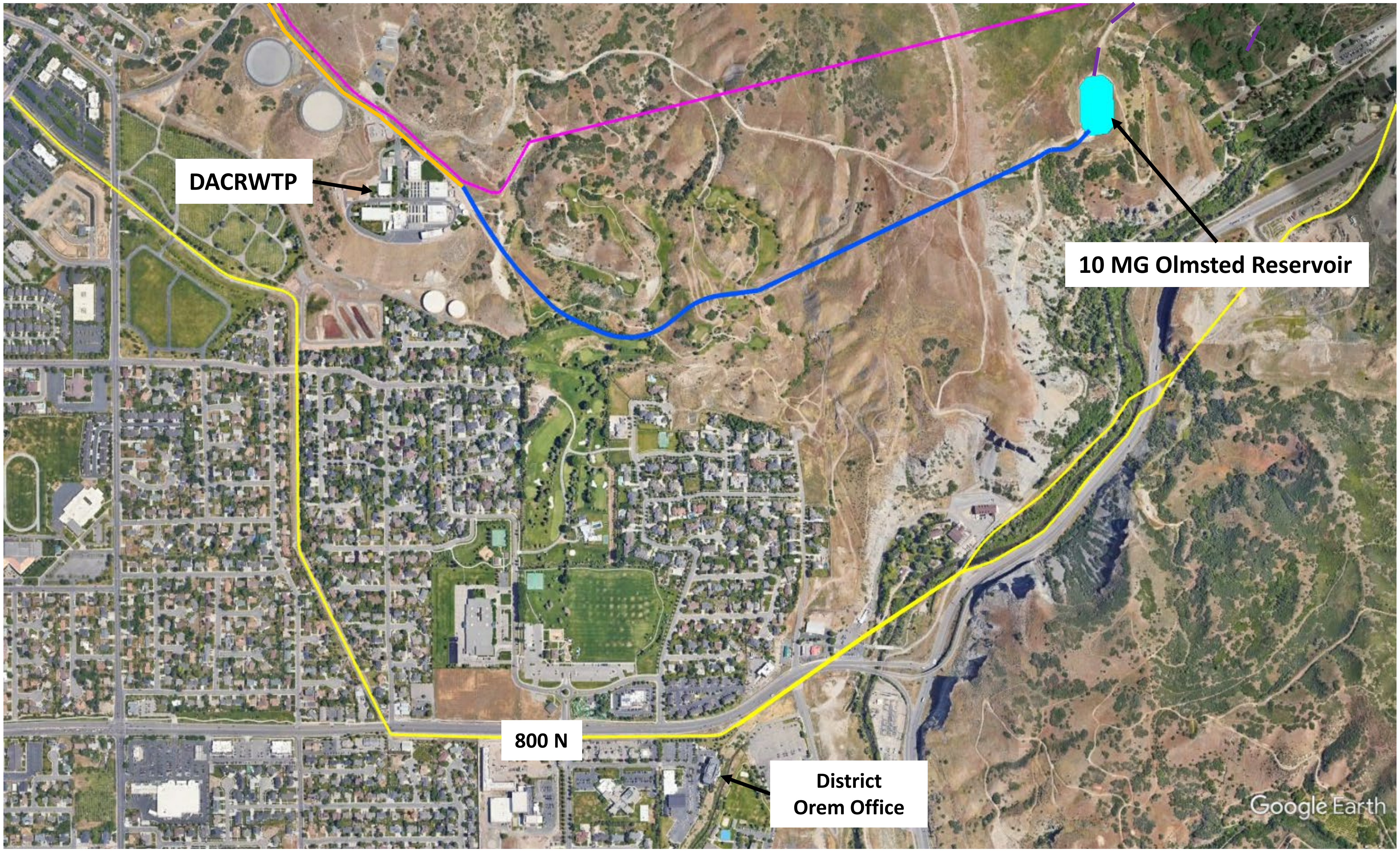
M&I System

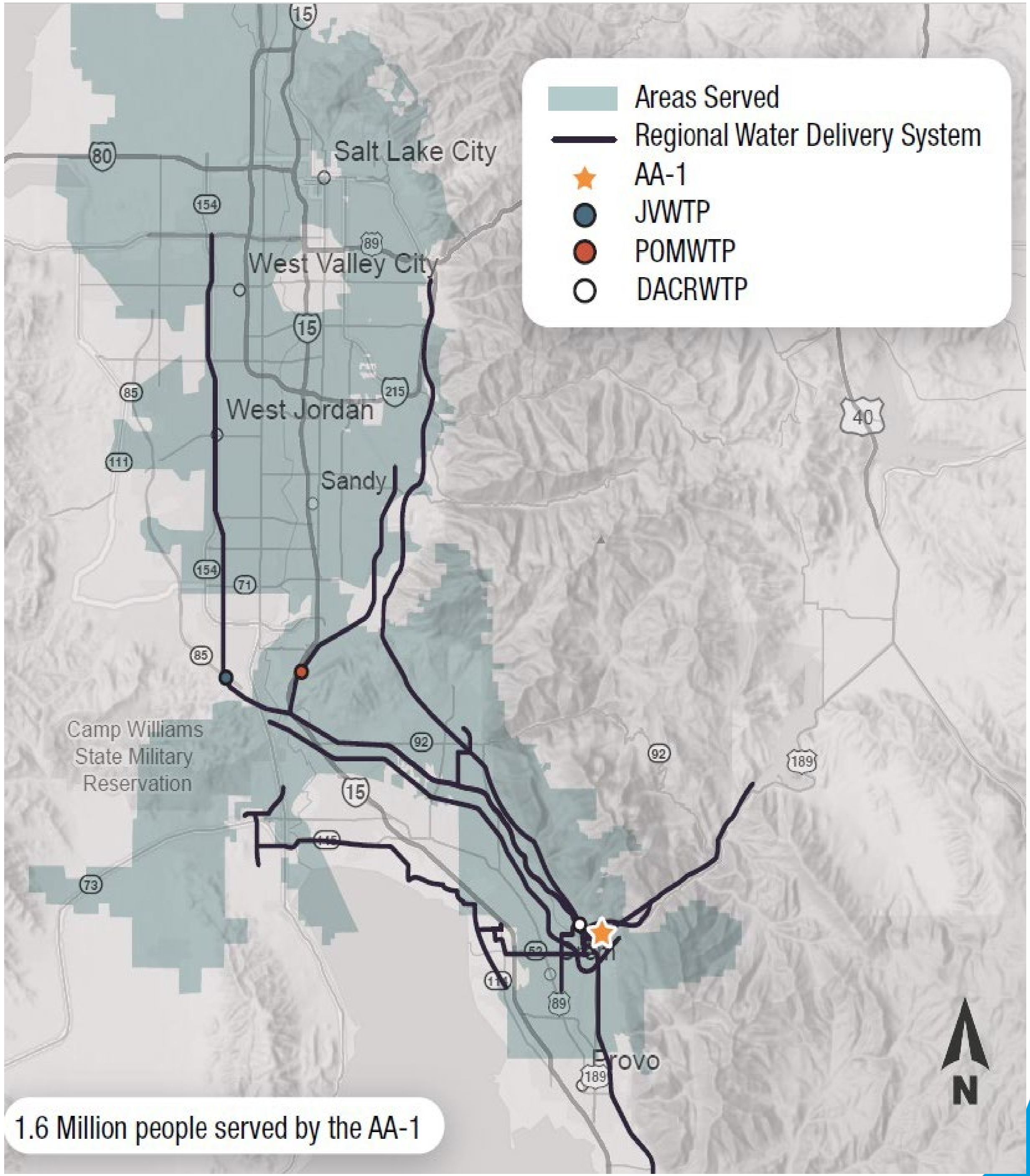
M&I System
North Branch Pipeline
Alpine Aqueduct Reach 3
Alpine Aqueduct Reach 1 & Tunnel
Olmsted Diversion
Olmsted Flowline
DACRWTP
Olmsted 10 MG Reservoir
Alpine Aqueduct Reach 2
Jordanelle Reservoir
Deer Creek Reservoir
Provo River
Utah Lake
Heber City

Alpine Aqueduct



Alpine Aqueduct Reach 1



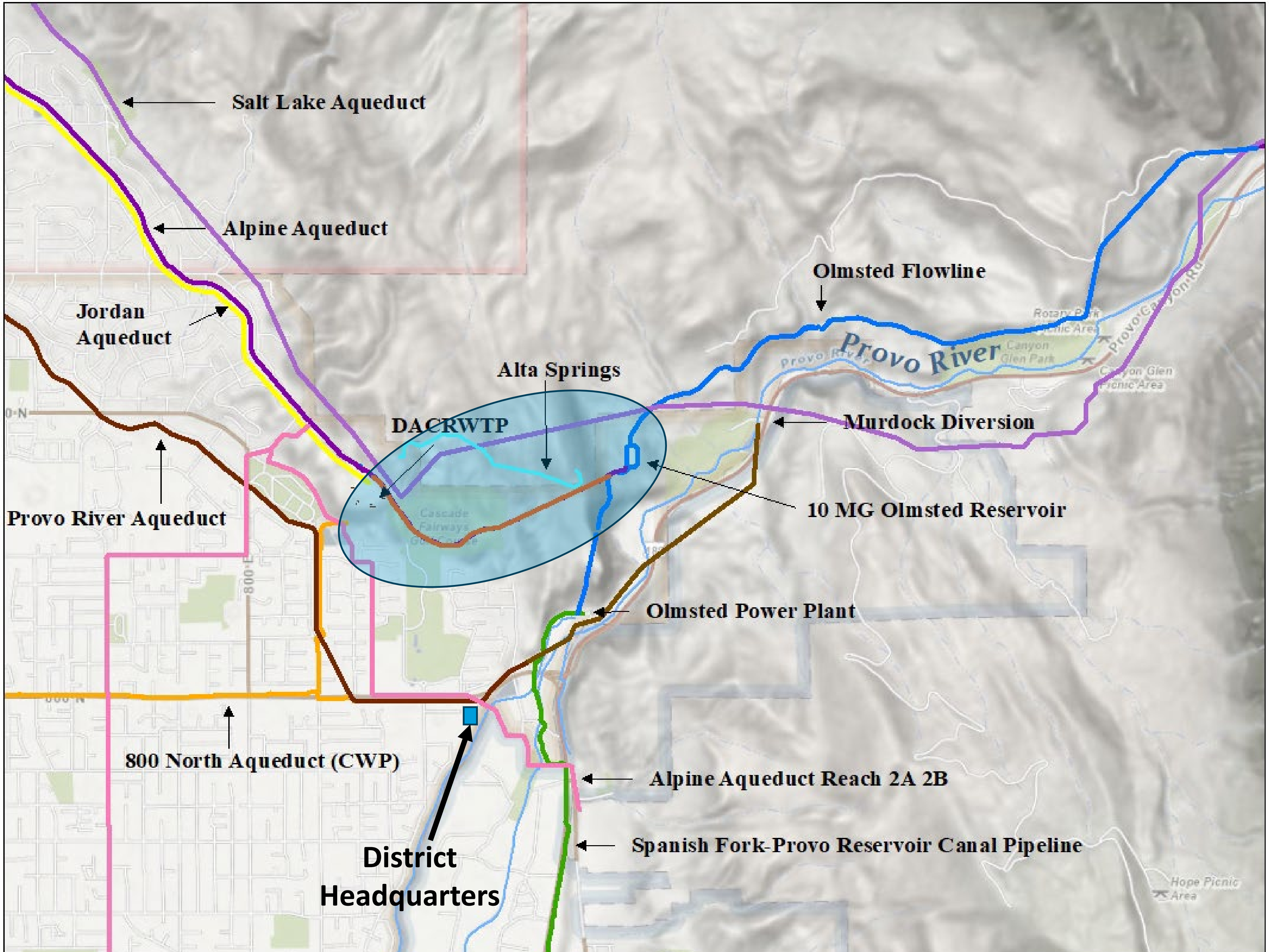


- 1.6 Million People
- Three Water Treatment Plants

- Constructed 1979/80
- 90-inch welded steel pipe
- 450 cubic feet per second

AA1 Functional Classification

Pipe Function Class	Seismic Importance	Description
I	Very low to None	Pipelines that represent very low hazard to human life in the event of failure. Not needed for post earthquake system performance, response, or recovery. Widespread damage resulting in long restoration times (weeks or longer) will not materially harm the economic well being of the community.
II	Ordinary, normal	Normal and ordinary pipeline use, common pipelines in most water systems. All pipes not identified as Function I, III, or IV.
III	Critical	Critical pipelines serving large numbers of customers and present significant economic impact to the community or a substantial hazard to human life and property in the event of failure.
IV	Essential	Essential pipelines required for post-earthquake response and recovery and intended to remain functional and operational during and following a design earthquake.

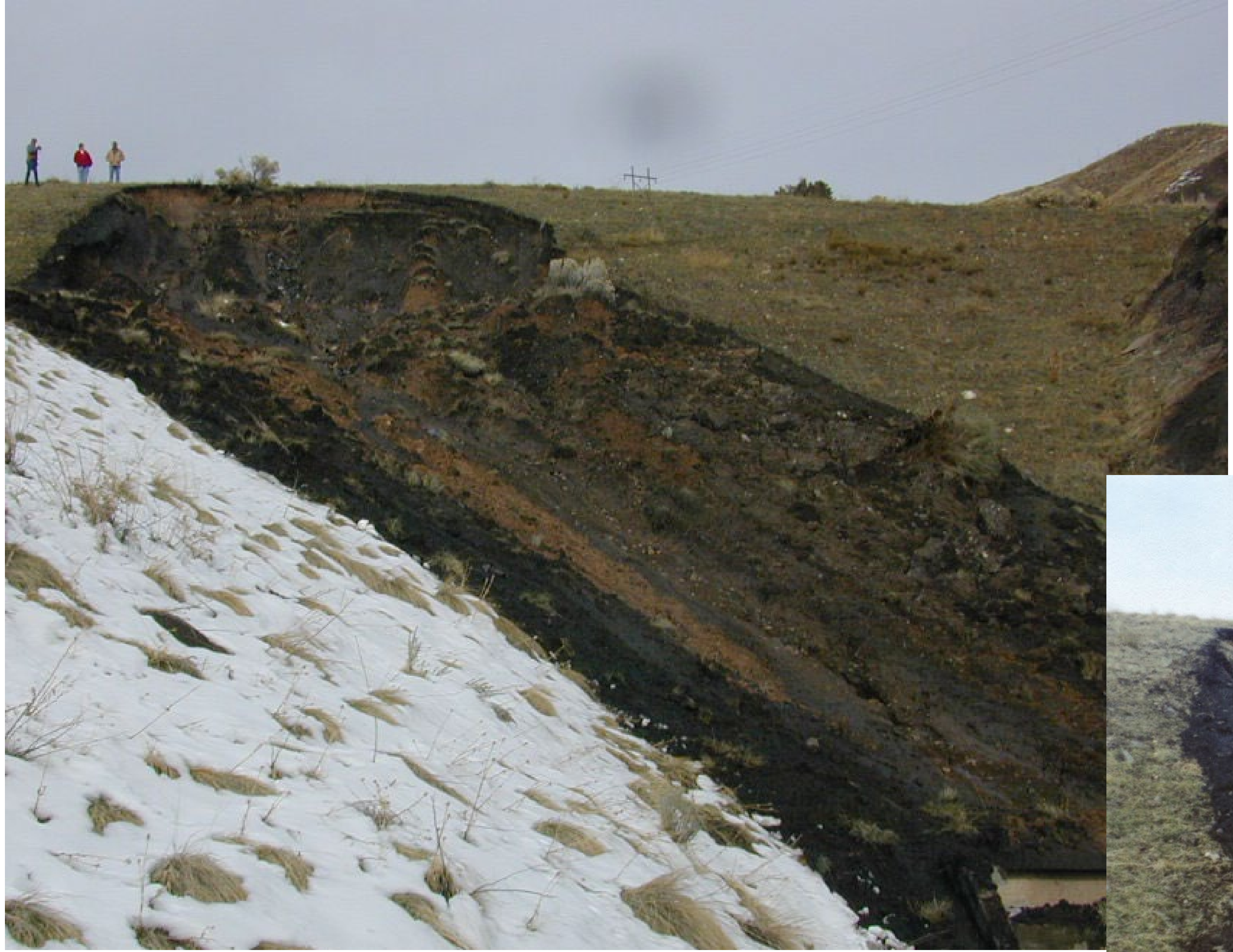


Salt Lake Aqueduct
Alpine Aqueduct
Jordan Aqueduct
Olmsted Flowline
Provo River
Alta Springs
DACRWTP
Murdock Diversion
Provo River Aqueduct
10 MG Olmsted Reservoir
Olmsted Power Plant
800 North Aqueduct (CWP)
Alpine Aqueduct Reach 2A 2B
Spanish Fork-Provo Reservoir Canal Pipeline
District Headquarters

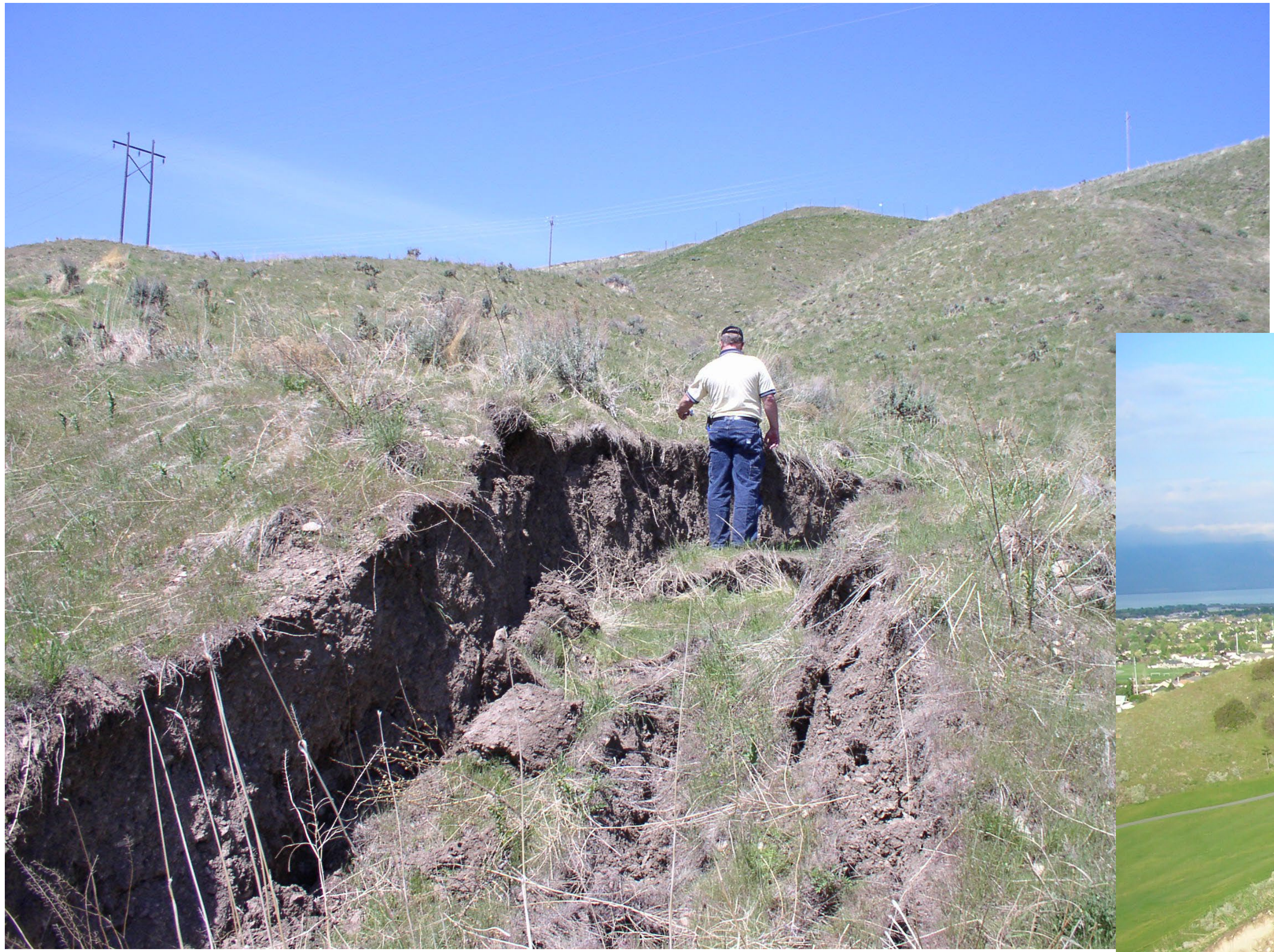
Aqueduct System	Capacity (cfs)	Non-Seismic		Seismic (475-year)		Seismic (2,475-year)		Reliability Ranking
		Failure	Outage	Failure	Outage	Failure	Outage	
AA-1	450	High	2 weeks	High	6 months	High	9 months	6
Olmsted	450	Low	0	Medium	4 weeks	High	6 months	4
Jordan	270	Low	0	Medium	4 weeks	High	6 months	5
SLA	170	Medium	2 weeks	High	6 to 9 months	High	12+ months	7
ULS	120	Low	0	Medium	2 weeks	Medium	4 weeks	3
PRA	600	Low	0	Medium	2 weeks	Medium	3 weeks	2
Provo River	1200	Low	0	Low	0	Low	0	1


2017 Slide
1988 Failure
1986 Failure
1985 and
1988 failure
2000 Failure

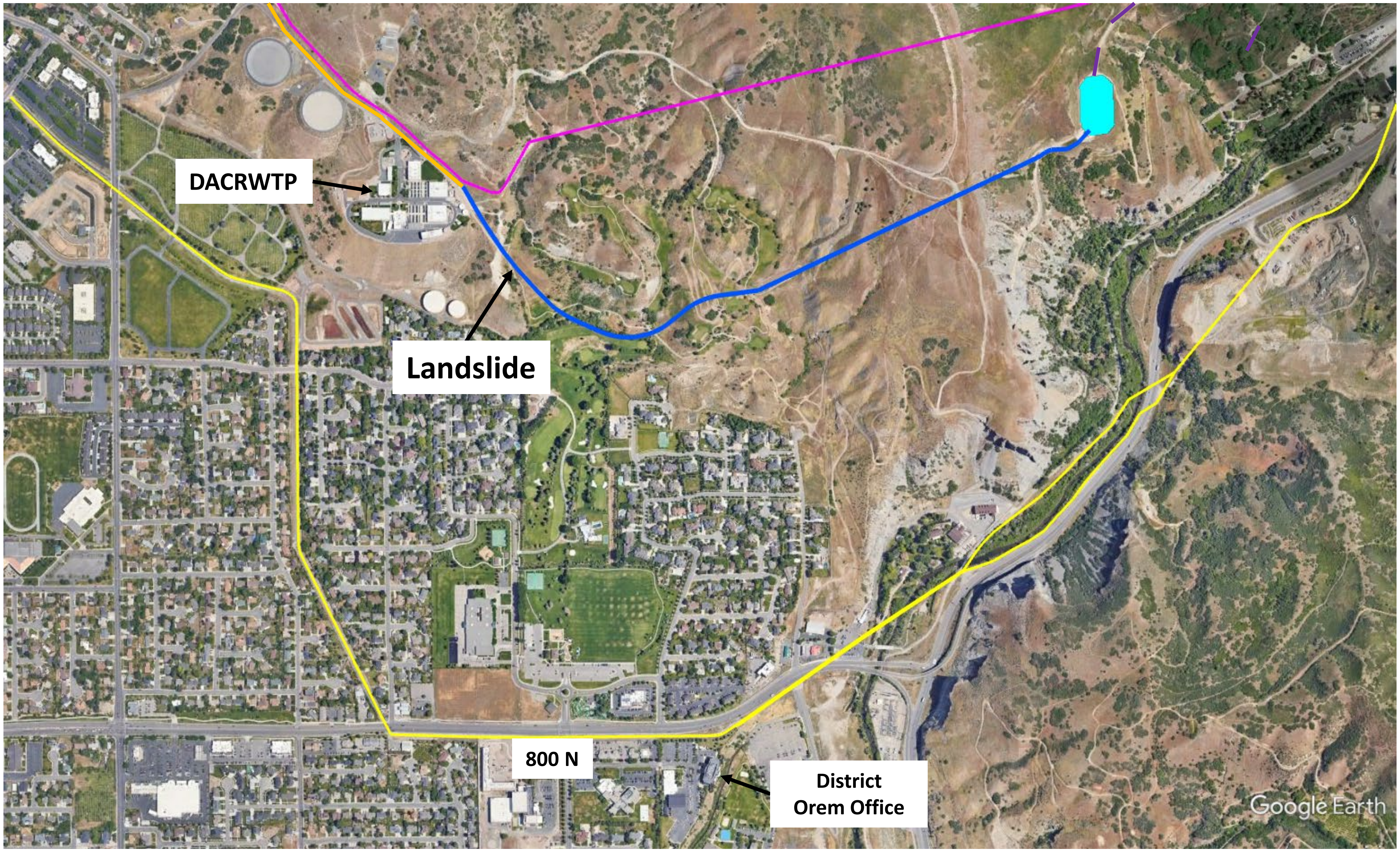


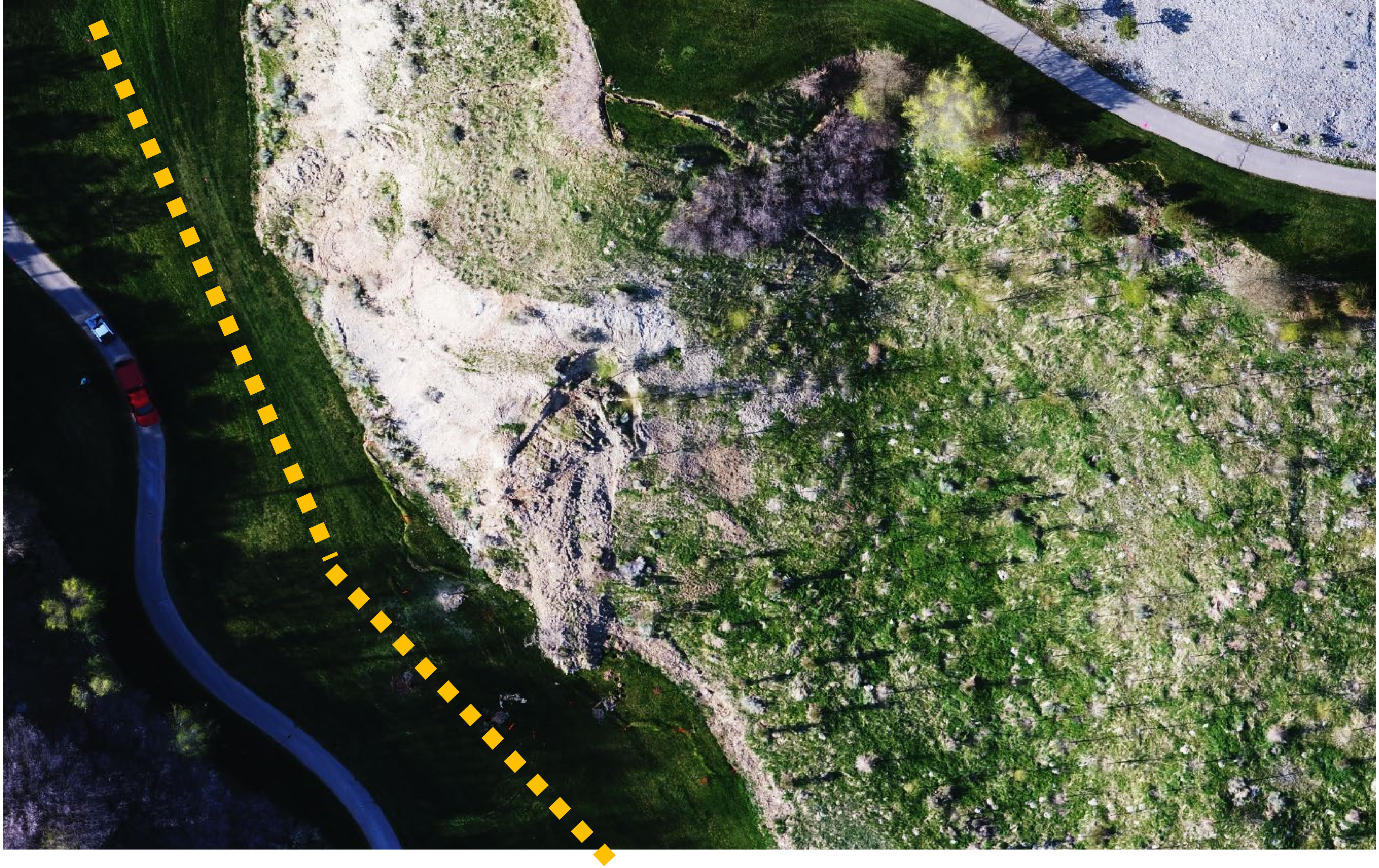


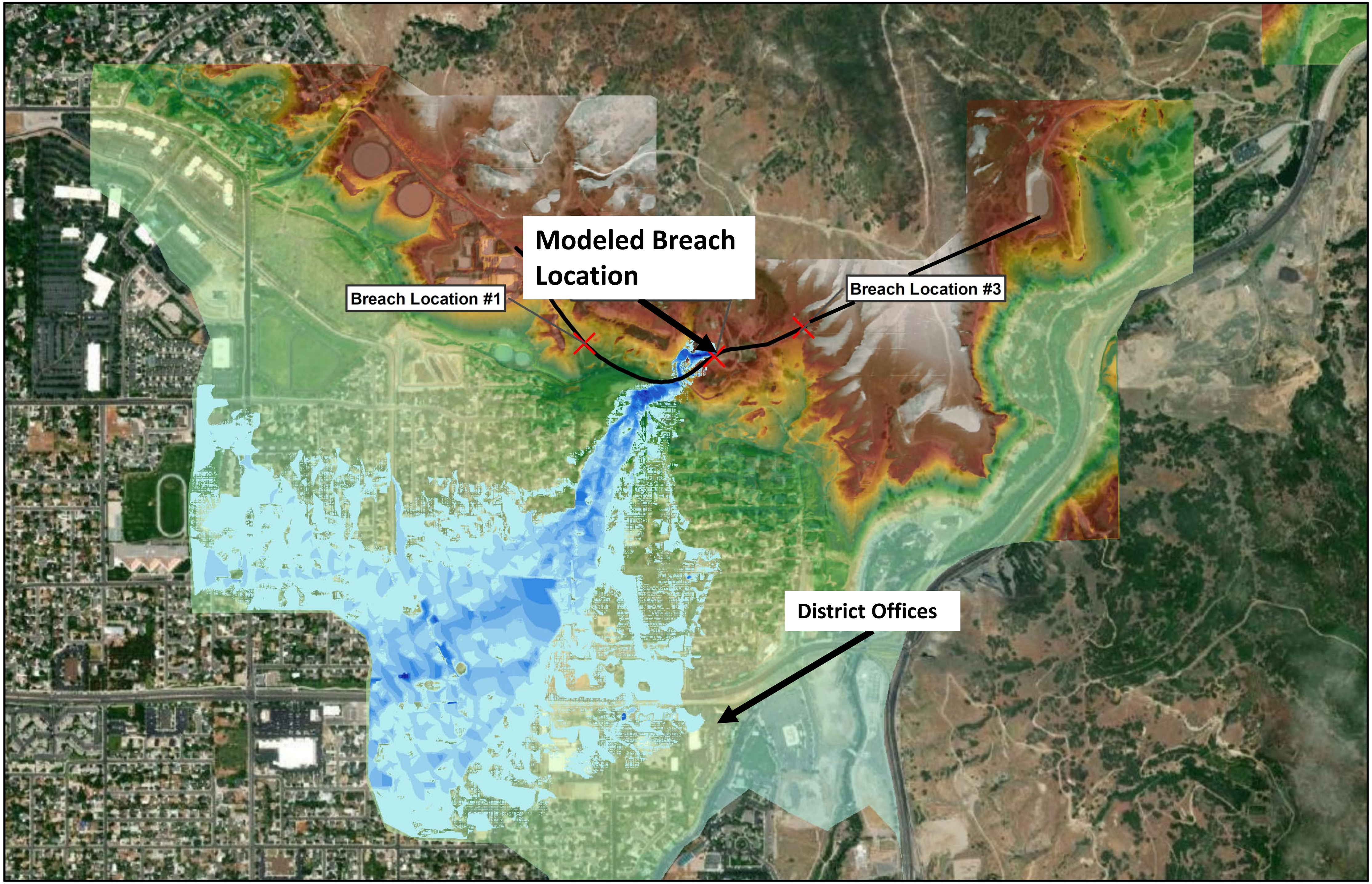

22 11'00




Spring 2017 Landslide




Modeled Breach Location
Breach Location #1
Breach Location #3
District Offices

Improve Resiliency

Identify/Map Geohazards

Solutions

Jacobs

Alpine Aqueduct Reach 1 Resiliency Assessment Project

Final Project Report

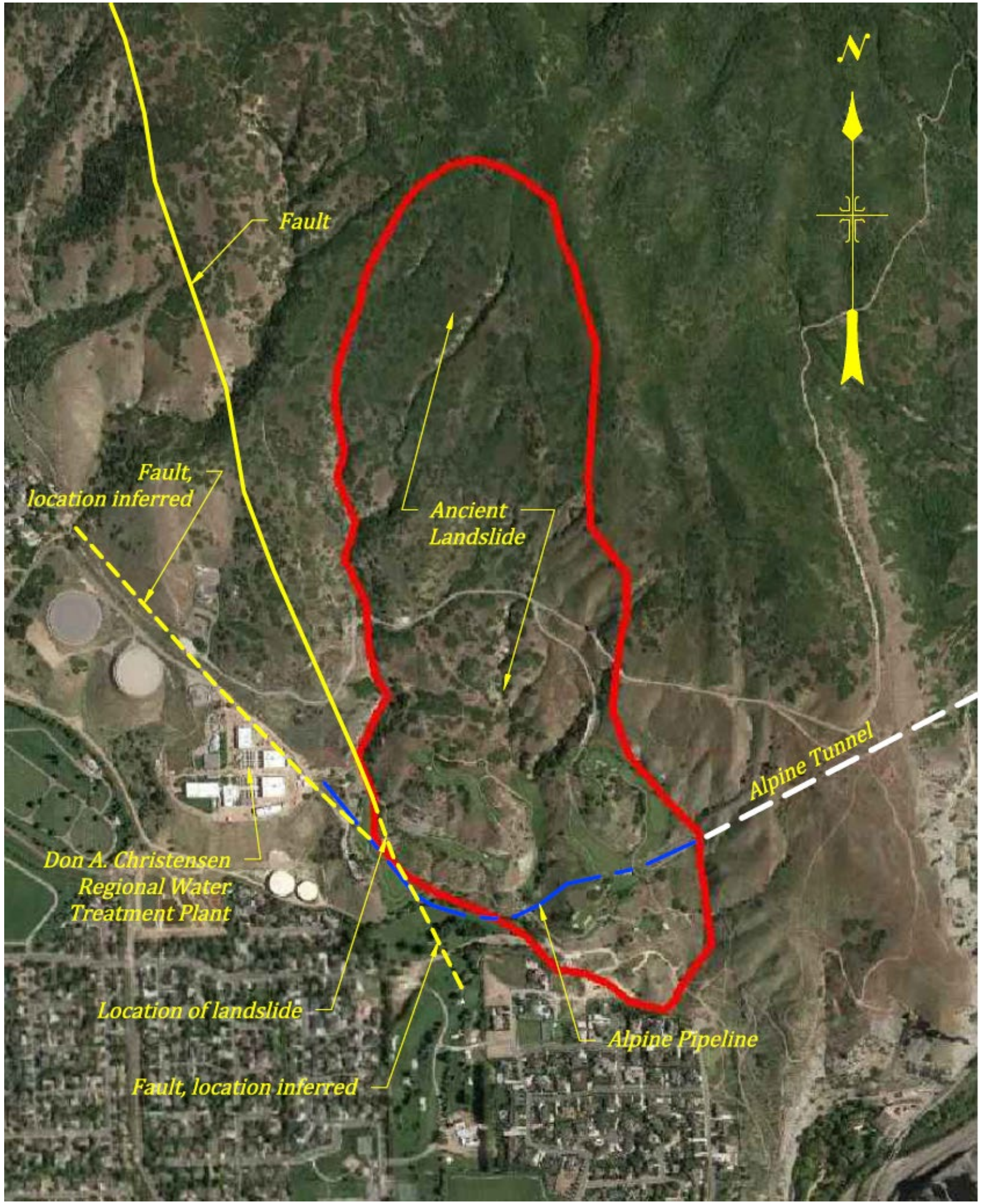
Prepared for:

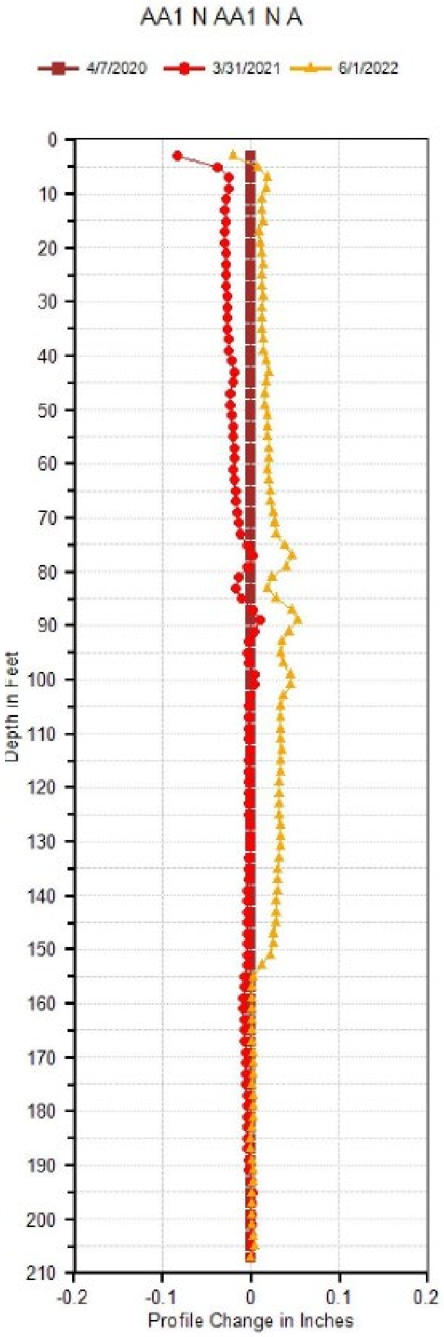
LICENSED PROFESSIONAL ENGINEER
No. 353911
ADAM A. MURDOCK
10-27-20
STATE OF UTAH

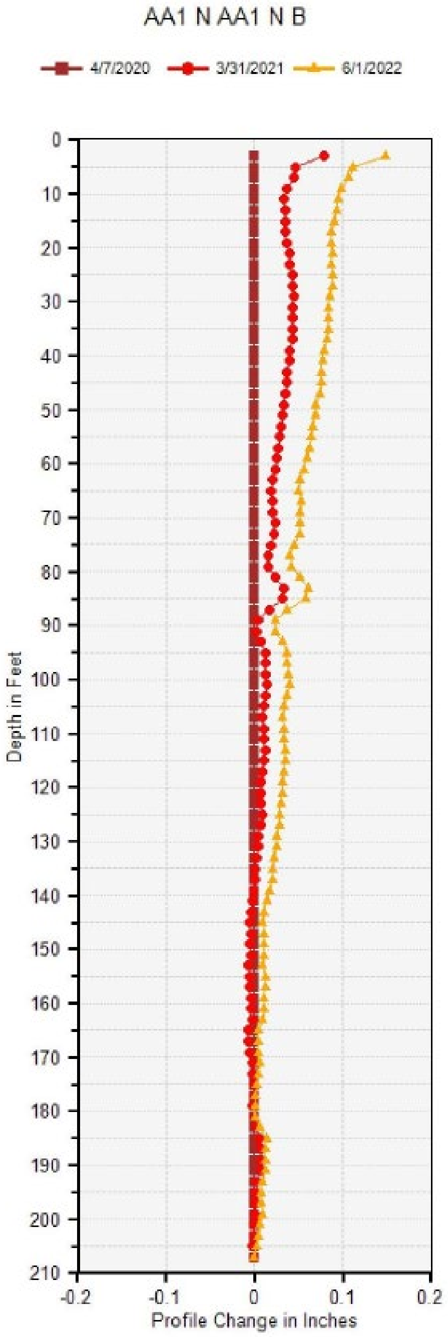
CENTRAL UTAH WATER CONSERVANCY DISTRICT

Document No. | 1

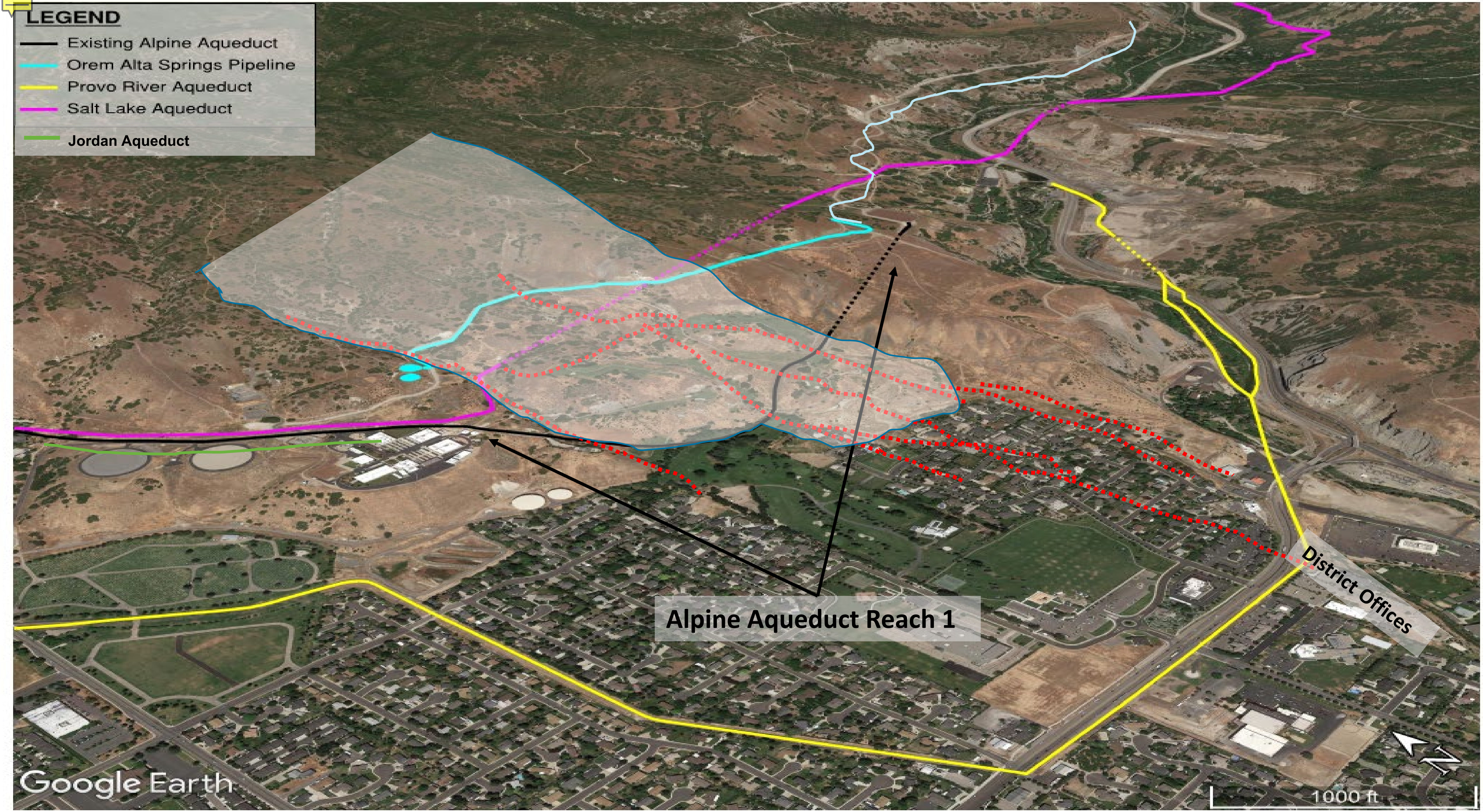
October 27, 2020

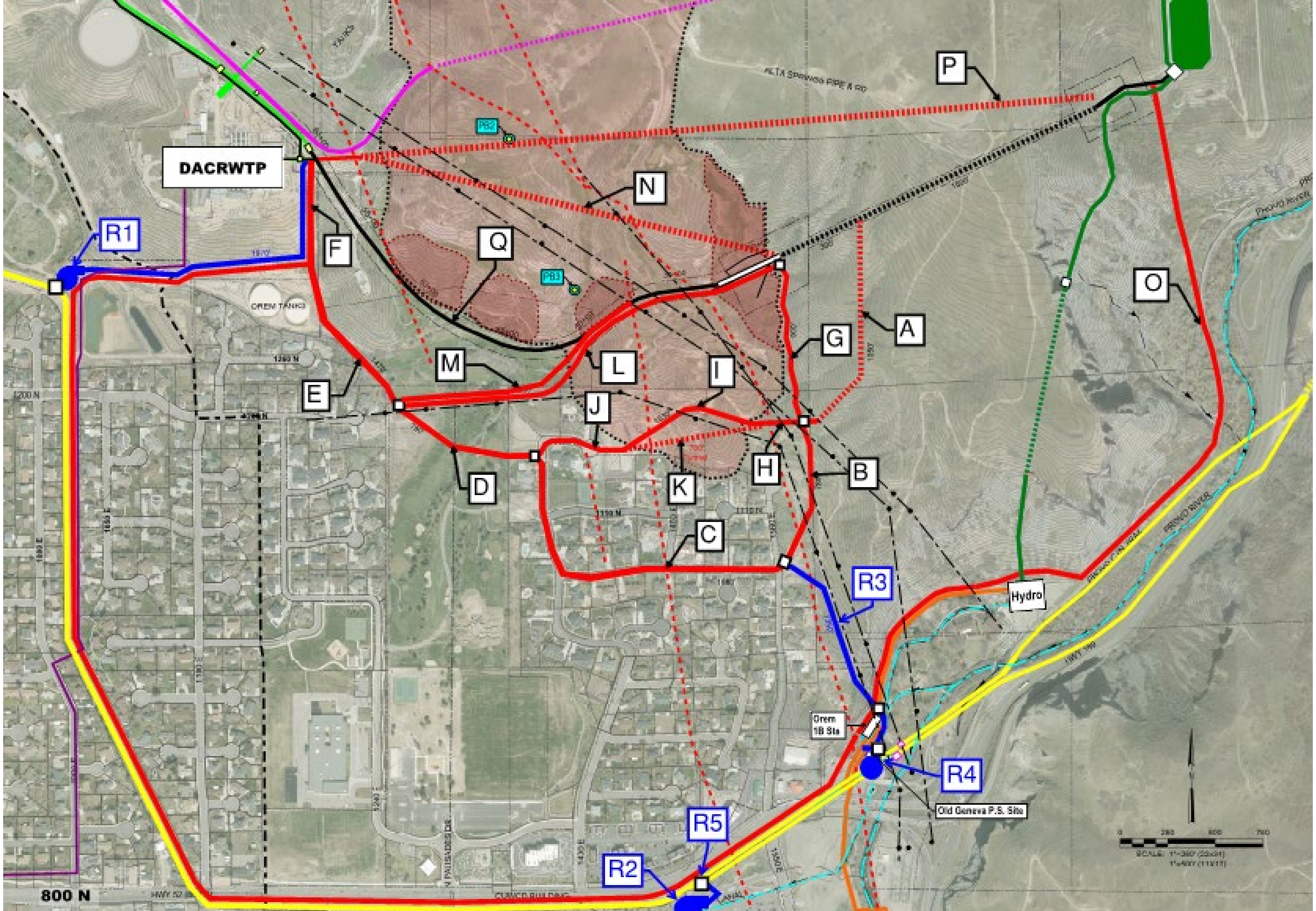

N
Fault
Fault, location inferred
Ancient Landslide
Alpine Tunnel
Don A. Christensen Regional Water Treatment Plant
Location of landslide
Alpine Pipeline
Fault, location inferred


AA1 N AA1 N A
4/7/2020
3/31/2021
6/1/2022
Depth in Feet
Profile Change in Inches


AA1 N AA1 N B
4/7/2020
3/31/2021
6/1/2022
Depth in Feet
Profile Change in Inches

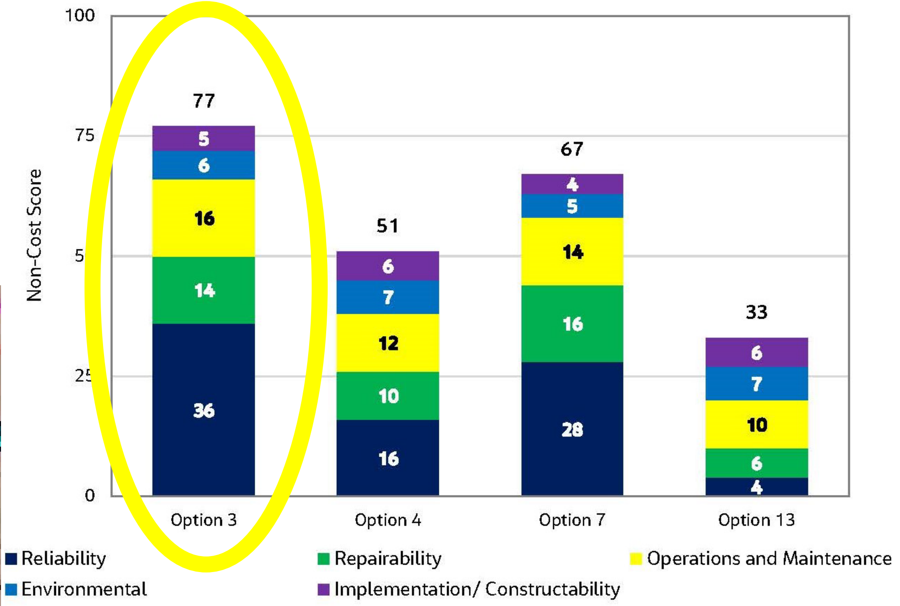
Smaller Landslides within a Large Landslide

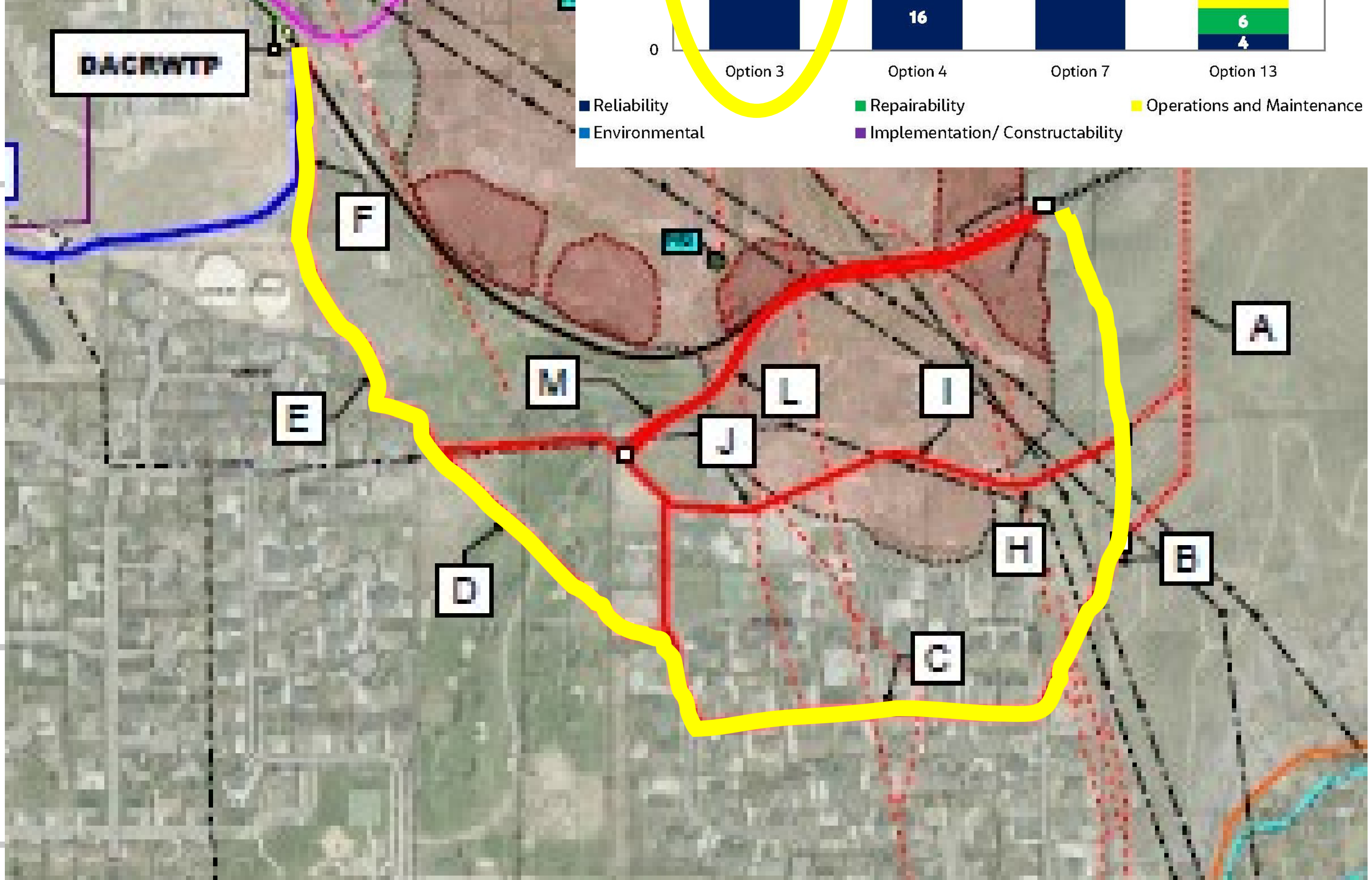

LEGEND
Existing Alpine Aqueduct
Orem Alta Springs Pipeline
Provo River Aqueduct
Salt Lake Aqueduct
Jordan Aqueduct
Alpine Aqueduct Reach 1
District Offices
Google Earth
1000 ft



DACRWTP
R1
R2
R3
R4
R5
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
Hydro
Orem 1B Sta
Old Geneva P.S. Site
800 N

Criteria	Items Considered	Weight
Reliability	Non-Seismic Events Seismic Events Consequences of Failure/Flooding Risk Potential for Interconnection	40%
Repairability	Accessibility Repair Materials and Methods Time to Repair	20%
Operations and Maintenance	Access Maintenance Security	20%
Environmental	Wetlands/Rivers/Groundwater Species/Land Disruption Community Impacts Visual/Safety	10%
Implementation/Constructability	Construction Risk Property/Right-of-Way Schedule	10%





National Environmental Policy Act

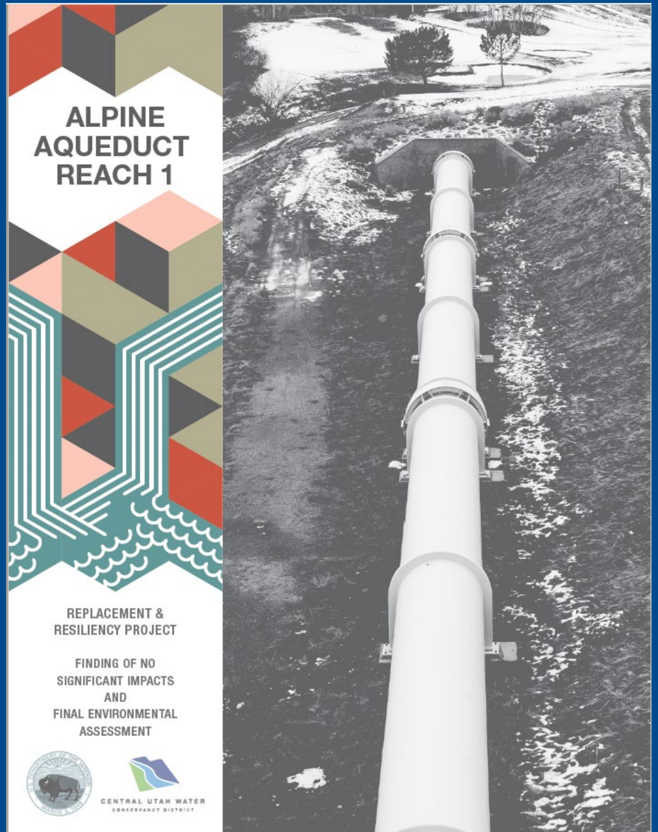
Required by federal agencies

Evaluate the environmental impacts

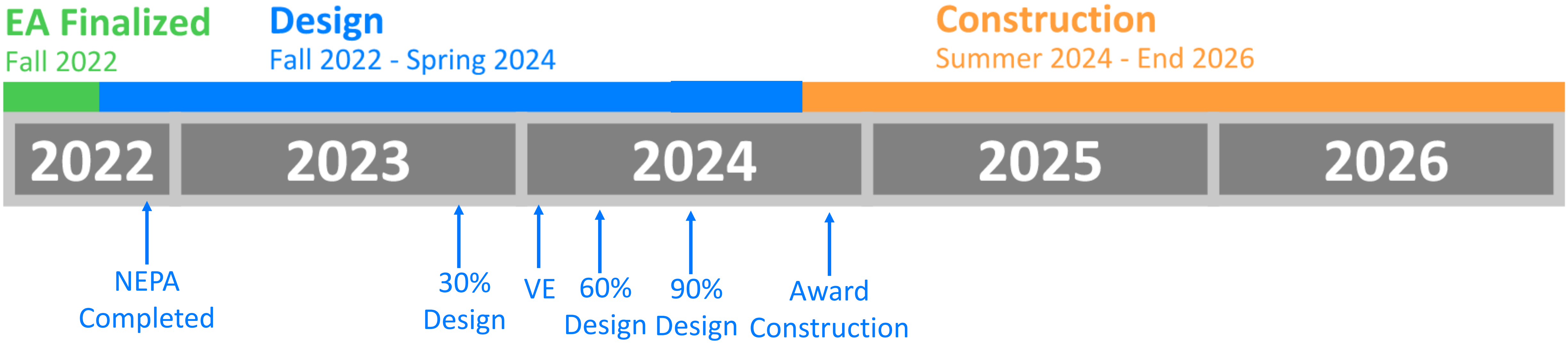
Interdisciplinary approach

Detailed document assessing the environmental impacts

Public review



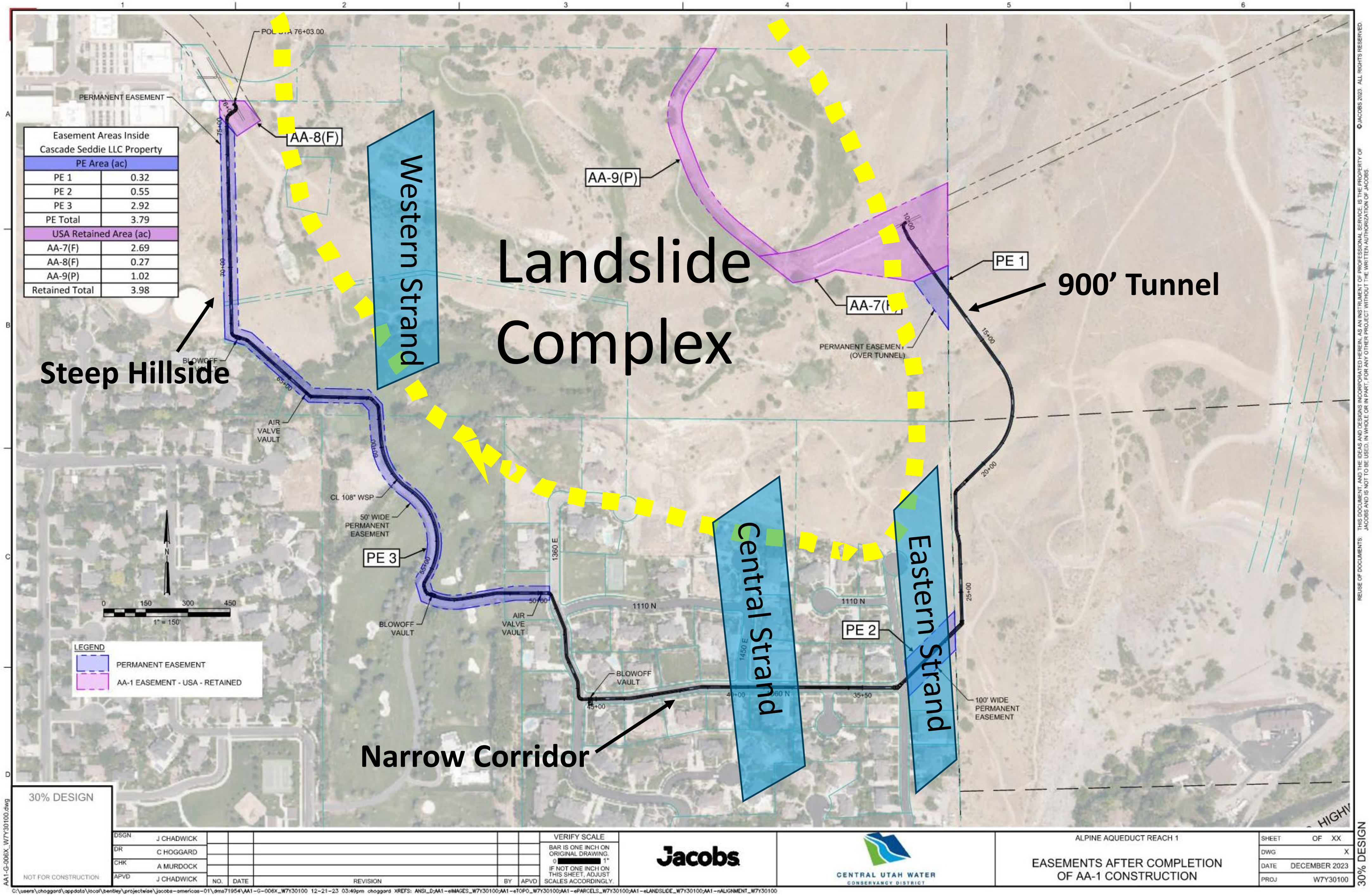
AA1 Schedule and Funding



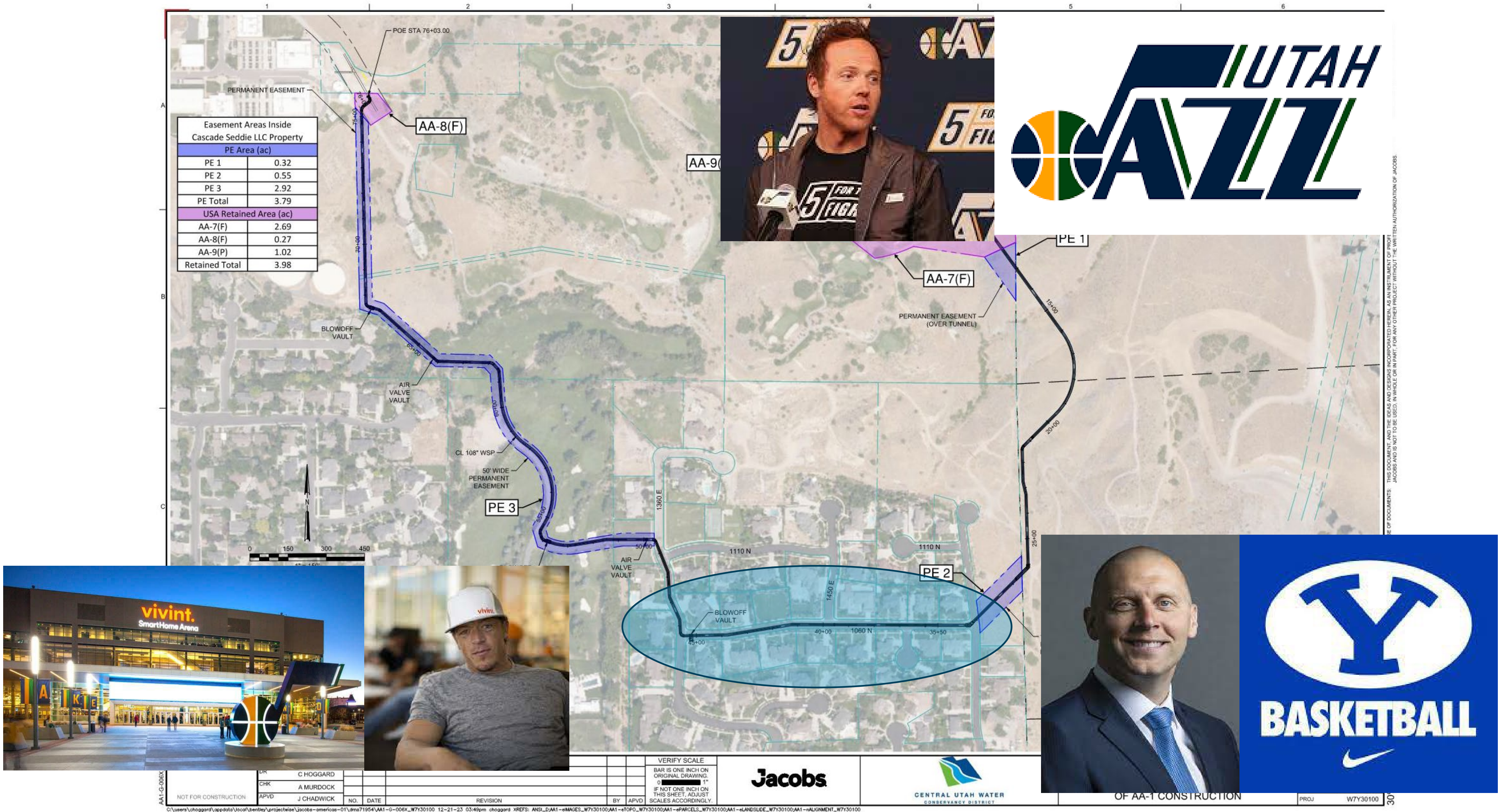
Aqueduct Resiliency Grant - $22 million

BRIC Grant - $46.6 million?

Final Completion Spring/Summer 2027



Easement Areas Inside Cascade Seddie LLC Property	
PE Area (ac)	
PE 1	0.32
PE 2	0.55
PE 3	2.92
PE Total	3.79
USA Retained Area (ac)	
AA-7(F)	2.69
AA-8(F)	0.27
AA-9(P)	1.02
Retained Total	3.98


POE STA 76+03.00
PERMANENT EASEMENT
AA-8(F)
Easement Areas Inside Cascade Seddie LLC Property
PE Area (ac)
PE 1 0.32
PE 2 0.55
PE 3 2.92
PE Total 3.79
USA Retained Area (ac)
AA-7(F) 2.69
AA-8(F) 0.27
AA-9(P) 1.02
Retained Total 3.98
AA-9(
UTAH JAZZ
PE 1
AA-7(F)
PERMANENT EASEMENT (OVER TUNNEL)
BLOWOFF VAULT
AIR VALVE VAULT
CL 108" WSP
50' WIDE PERMANENT EASEMENT
PE 3
1360 E
1110 N
PE 2
1450 E
BLOWOFF VAULT
1060 N
AIR VALVE VAULT
0 150 300 450
vivint. SmartHome Arena
vivint
BASKETBALL
VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.
Jacobs
CENTRAL UTAH WATER CONSERVANCY DISTRICT
C HOGGARD
A MURDOCK
J CHADWICK
NOT FOR CONSTRUCTION
NO. DATE REVISION BY APVD
OF AA-1 CONSTRUCTION
PROJ W7Y30100

Aging Aqueducts and "The Big One"

UTAH | THE WEST | ENVIRONMENT

Aging aqueducts and earthquakes: Why millions in Utah could lack water

Report says major delivery systems couldn't survive 'Big One'

By Amy Joi O'Donoghue | Jan 12, 2022, 10:04am MDT

SHARE

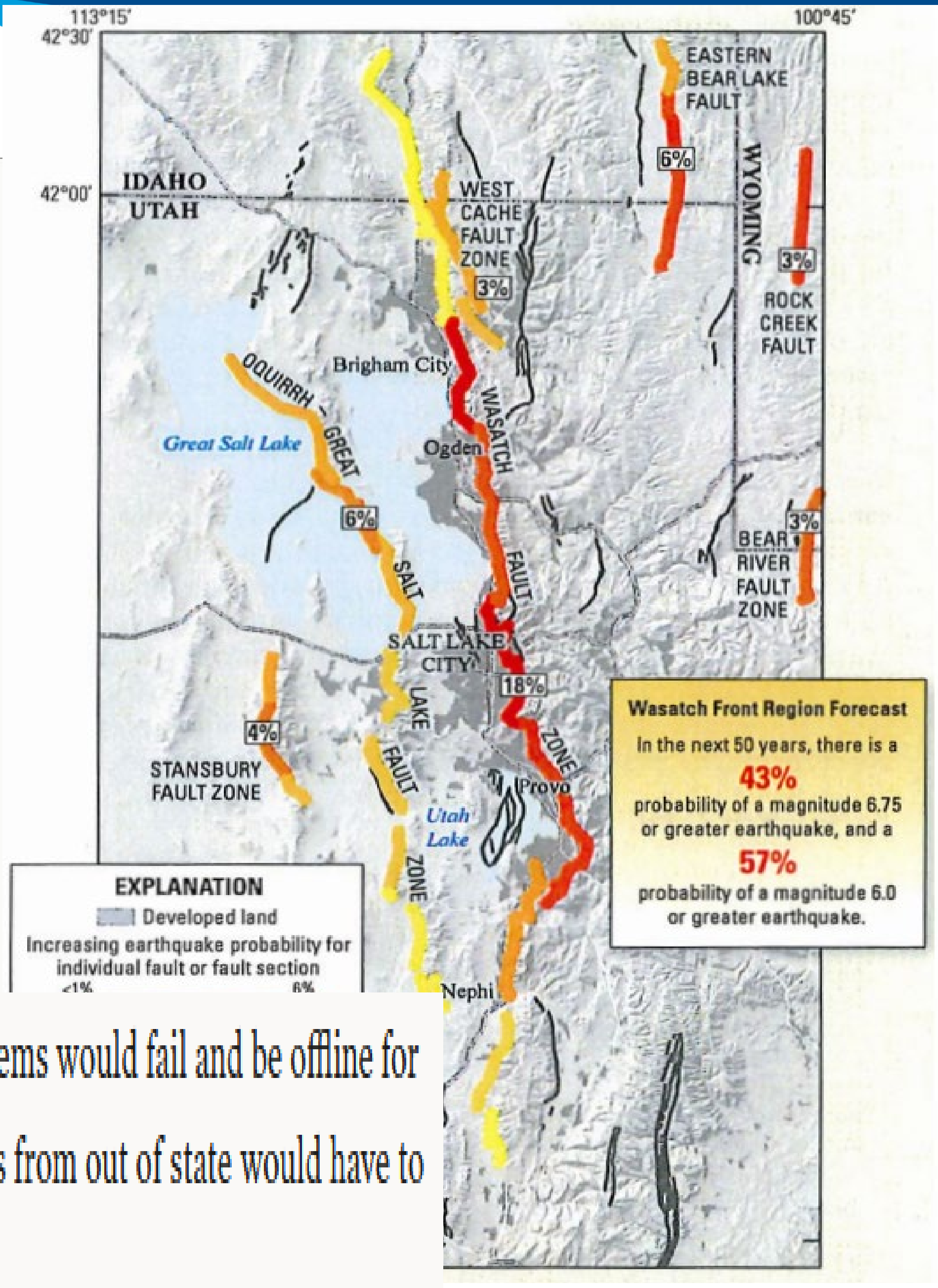
A section of the Alpine Aqueduct runs above ground where it crosses a fault in the hills above Orem on Thursday, Jan. 6, 2022. | Spenser Heaps, Deseret News | Purchase Photo

Deseret News

A section of the Alpine Aqueduct runs above ground where it crosses a fault in the hills above Orem on Thursday, Jan. 6, 2022. | Spenser Heaps, Deseret News | Purchase Photo

'Unacceptable risk'

In the event of the "Big One," these aging water delivery systems would fail and be offline for several months, maybe as long as six months, as custom parts from out of state would have to be shipped to Utah.



Utah Seismic Safety Commission

What we can do to save lives and the economy

The USSC recommends the following prioritized actions:

1. KEEP WATER FLOWING

Invest in seismic improvements for the four major water aqueducts that serve over two million residents. These aqueducts were built generations ago and pass through landslide and/or hazardous fault areas. Should any one of these pipelines rupture in an earthquake, many hundreds of thousands of Utahns would be left without water for six months or even longer. The potential effects on Utah's economy are incalculable. The total cost of improving these four pipelines is approximately $192 million. This is less than the cost of expanding three miles of U.S. 89 in Layton into a freeway or of building three freeway interchanges on Bangerter Highway.[2]

2. KEEP OUR KIDS SAFE

Significantly limit the danger to tens of thousands of Utah children who attend school in seismically unsound buildings. Build on prior legislative funding for school inventory work by providing financial assistance to local education agencies (LEAs) to conduct feasibility studies for retrofitting or replacing URM buildings. Allocate $3.5 million for this purpose to the applicable LEAs over the next three years.

3. KEEP OUR COMMUNITIES AND MARKETS INFORMED

Increase public awareness of the high risk from Utah's 140,000 unreinforced masonry (URM) buildings. These buildings, built before 1976, are scattered across the state and include single-family homes, multifamily structures, and offices. The vast majority of deaths and injuries will happen in these buildings, yet public awareness of the risk is low. Improved public awareness will increase market function and efficiency and apply market pressure to upgrade more of these buildings. A good public awareness campaign would cost $200,000 over two years.

4. KEEP OUR BUILDINGS STANDING

Ensure adequate building code enforcement. Rigorous structural plan reviews by independent and qualified experts, particularly for larger, complex buildings, can improve seismic safety of structural systems and possibly prevent very expensive—and potentially deadly—issues in an earthquake. Inspections can catch calamitous mistakes and ensure building owners are getting a code compliant building. Specifically, the USSC recommends that every building classified as International Building Code Risk Category III or IV (e.g., a hospital, school, or police station) or larger than 200,000 square feet be required to undergo a plan review conducted by a Utah-licensed Professional Structural Engineer.

5. KEEP UTAH READY TO RESPOND

Invest in a feasibility study for an Earthquake Early Warning System. Allocation of funds will support the development of a feasibility study by the USSC on the possible implementation of an Earthquake Early Warning system in Utah. The early warning system can save lives and the economy by providing tens of seconds of warning time to shut off various industrial, utility, and transportation systems before ground shaking begins. Utahns would have enough time to prepare for ground shaking and seek shelter. The feasibility study would be a one time cost of $150,000 with the funds administered through the Utah Geological Survey.

FEMA has called the Wasatch Fault "one of the most catastrophic natural threat scenarios in the U.S."[1] With a significant risk of a major earthquake in the coming decades and projected impacts that would severely damage the Utah economy, Utah could face a disaster similar in magnitude to some of the most devastating hurricanes and earthquakes in U.S. history.

Upgrade Water Infrastructure

Water infrastructure resilience is one of Utah's most critical needs in the face of an expected large earthquake.[6] **In the event of a major earthquake on the Wasatch fault, water and sewer service across the Wasatch Front is projected to be disrupted for more than a million people for many months**. Unlike freeway infrastructure, which is rebuilt far more often (at a much higher cost), much of Utah's major water instructure is over 50 years old. The Wasatch Front's most important aqueducts are located across and along major hazardous faults, landslide areas, high ground shaking areas, and liquefaction areas, putting them at high risk for significant damage.

Wasatch Front

Provo Segment of Wasatch Fault

- Five (5) surface rupturing events in the last 7,000 yrs.
- Slip-per-event average between 1.4-4.5 m
- Three paleoseismic sites with recorded coseismic offsets. These data were considered to estimate displacements at AA-1.

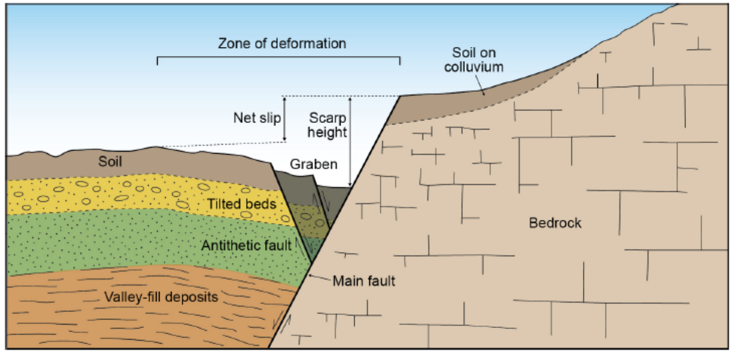
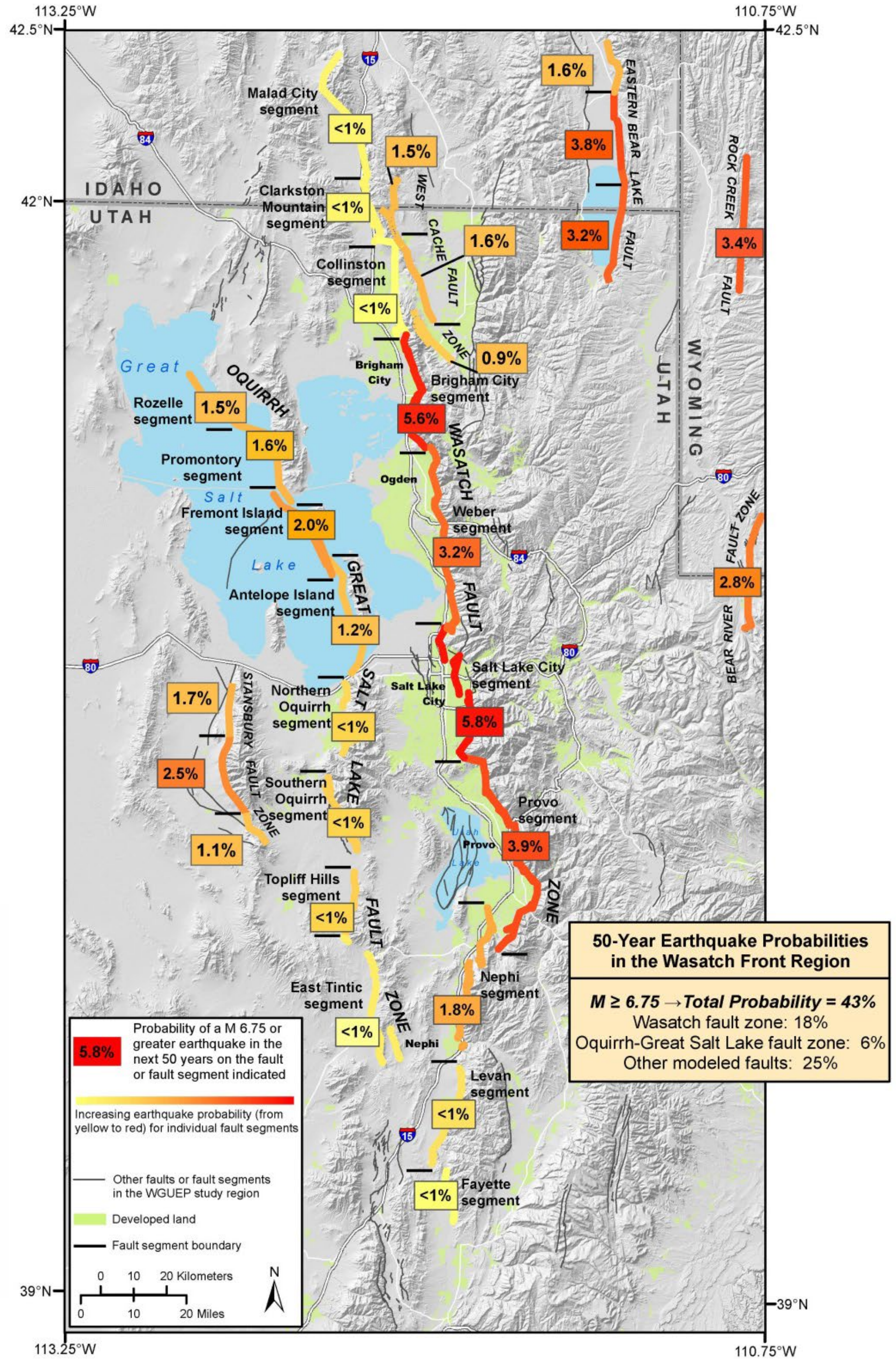
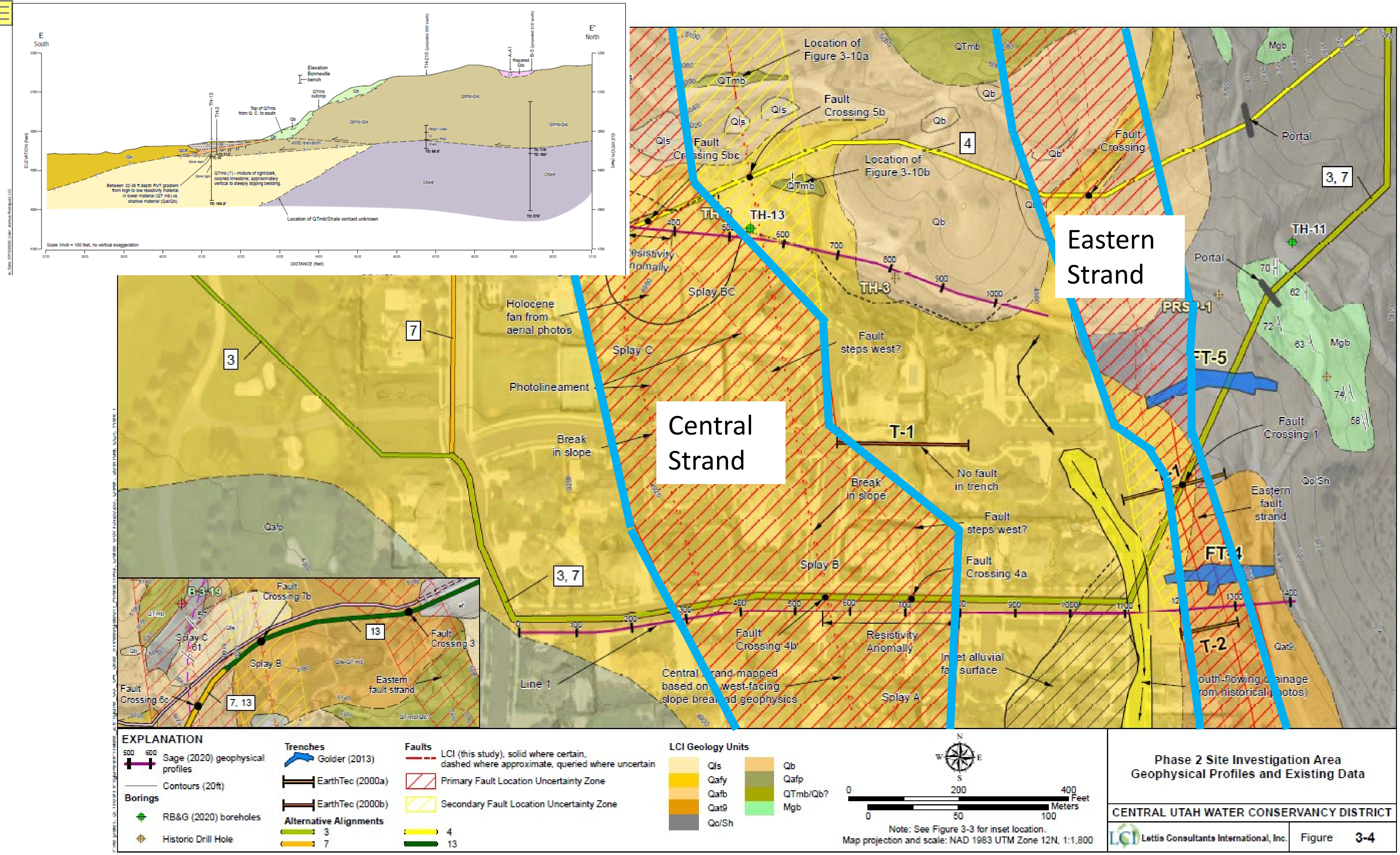


Figure 13. Schematic cross section through a normal fault zone.

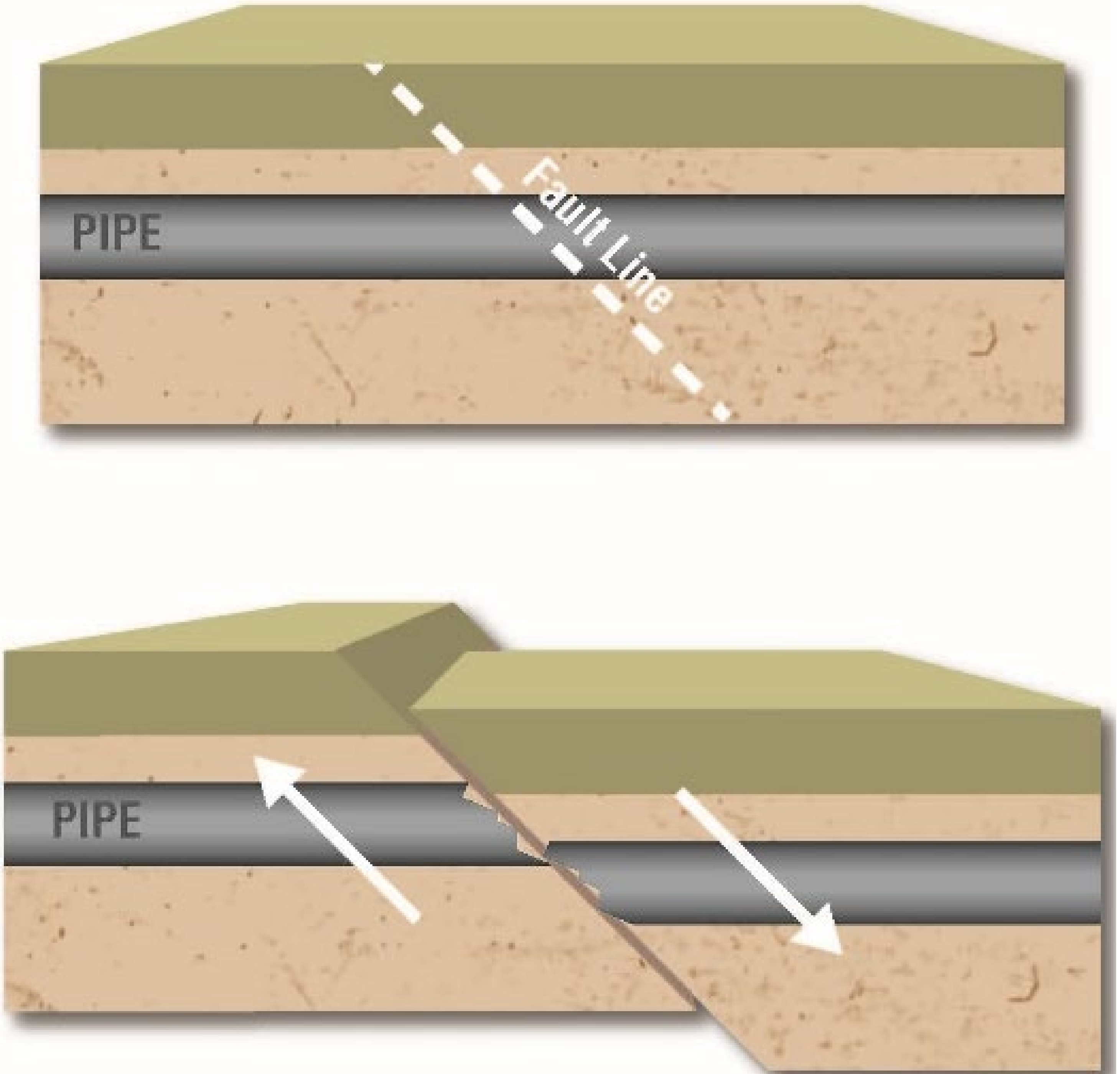


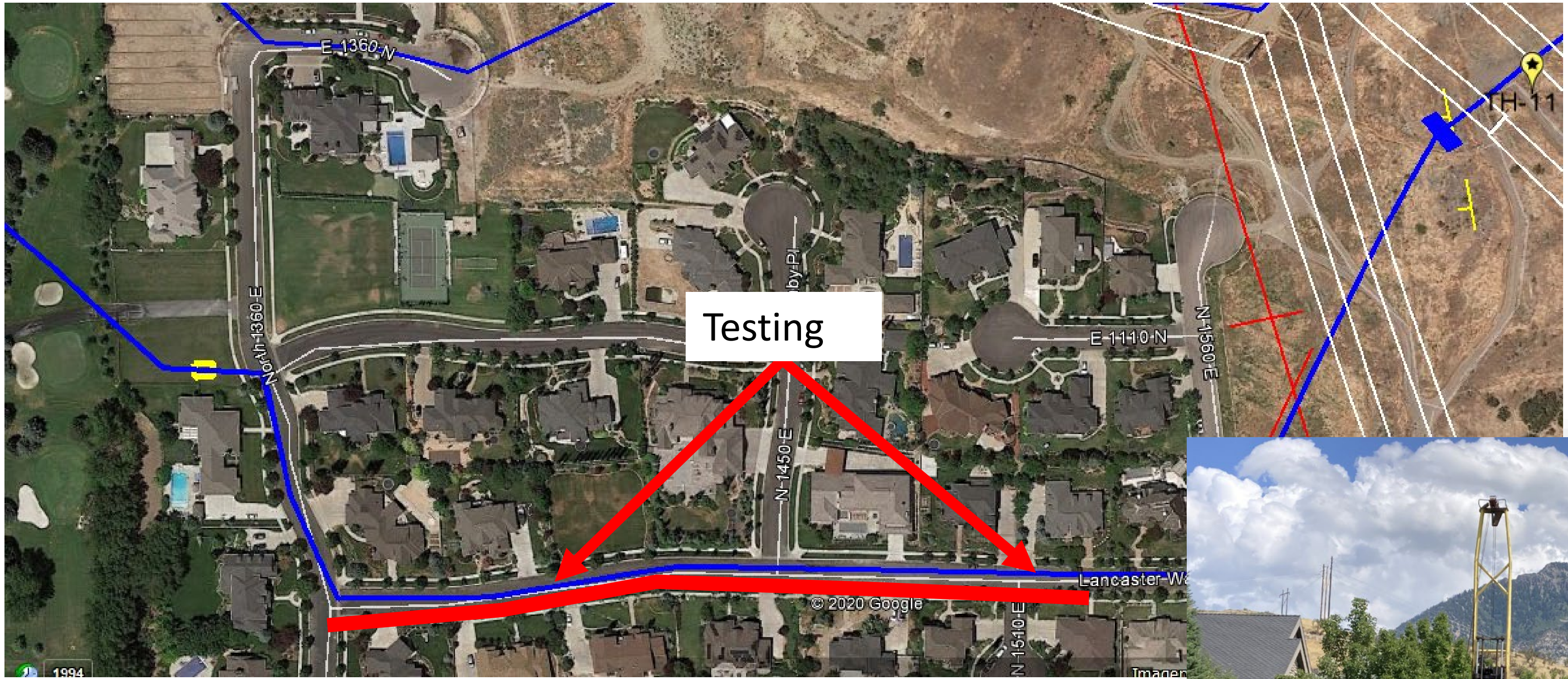


Eastern Strand
Central Strand
Location of Figure 3-10a
Fault Crossing 5b
Fault Crossing 5bc
Location of Figure 3-10b
Fault Crossing
Portal
3, 7
4
TH-13
TH-11
TH-3
PRSP-1
FT-5
FT-4
T-1
T-2
Splay BC
Splay C
Splay B
Splay A
Holocene fan from aerial photos
Photolineament
Break in slope
Fault steps west?
No fault in trench
Fault Crossing 4a
Fault Crossing 4b
Fault Crossing 1
Eastern fault strand
Resistivity Anomaly
Inset alluvial fan surface
South-flowing drainage from historical photos
Central strand mapped based on west-facing slope break and geophysics
Line 1
Fault Crossing 7b
Fault Crossing 3
Fault Crossing 6c
B-3-19
13
7, 13
3
7
EXPLANATION
Sage (2020) geophysical profiles
Contours (20ft)
Borings
RB&G (2020) boreholes
Historic Drill Hole
Trenches
Golder (2013)
EarthTec (2000a)
EarthTec (2000b)
Alternative Alignments
Faults
LCI (this study), solid where certain, dashed where approximate, queried where uncertain
Primary Fault Location Uncertainty Zone
Secondary Fault Location Uncertainty Zone
LCI Geology Units
Qls
Qafy
Qafb
Qat9
Qc/Sh
Qb
Qafp
QTmb/Qb?
Mgb
Feet
Meters
Note: See Figure 3-3 for inset location.
Map projection and scale: NAD 1983 UTM Zone 12N, 1:1,800
Phase 2 Site Investigation Area Geophysical Profiles and Existing Data
CENTRAL UTAH WATER CONSERVANCY DISTRICT
Lettis Consultants International, Inc.
Figure 3-4
E South
E' North
DISTANCE (feet)
Location of QTmb/Shale contact unknown

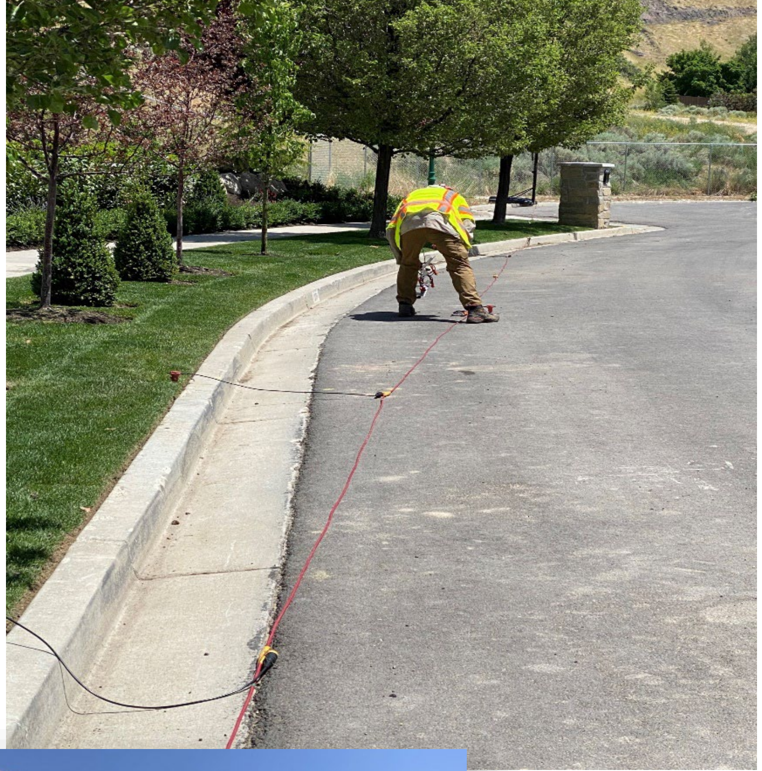
LCI—Summary of vertical, horizontal and total fault displacement estimates

Exceedance	Percentile	Assumed Fault Dip (°)	Method 2		
			Vertical Displacem	Horizontal Displacemen	Total Displaceme
0.5	50th	60	7.9	4.6	9.1
0.16	**84th**	**60**	**10.6**	**6.1**	**12.2**
0.1	90th	60	11.5	6.6	13.3

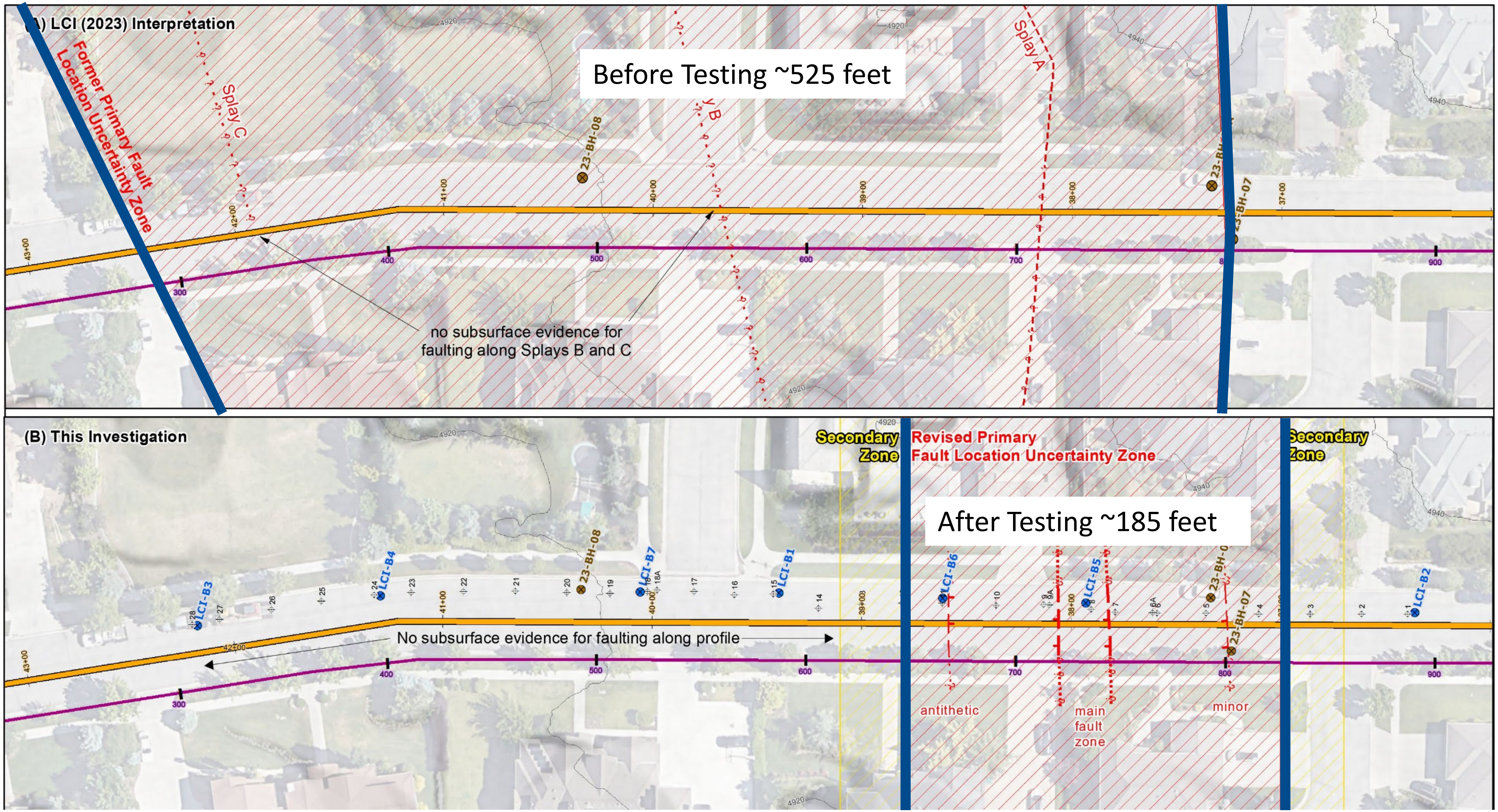

PIPE
Fault Line
PIPE



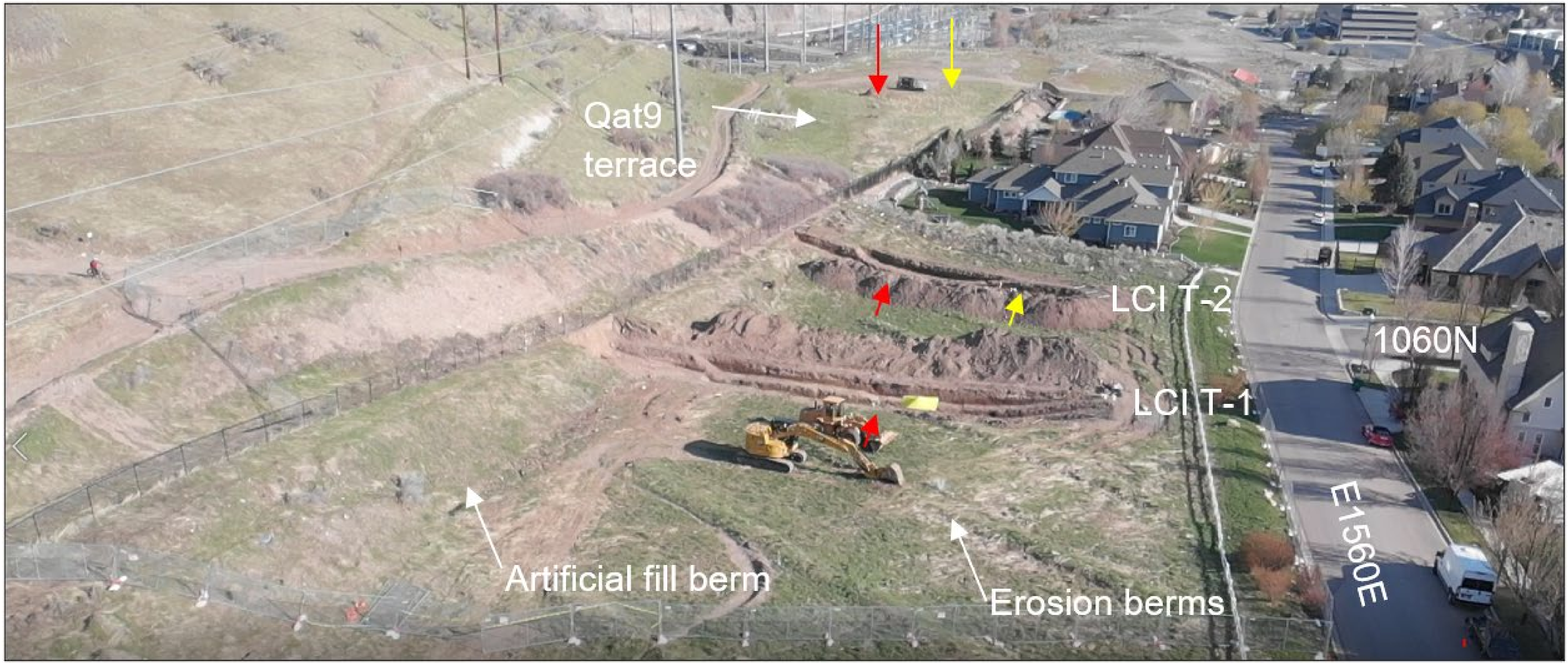
E 1360 N
North 1360 E
Testing
E 1110 N
N 1560 E
N 1450 E
N 1510 E
TH-11
© 2020 Google




Central Strand Success




Trenches
Olmsted Hydroelectric
Google Earth

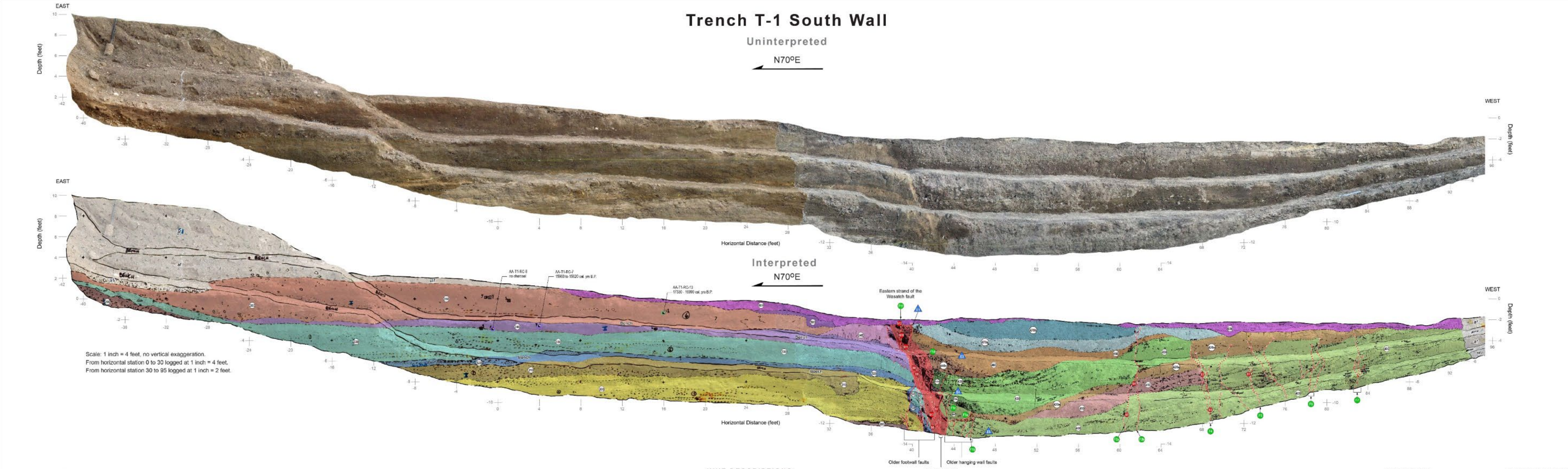

Qat9
terrace
LCI T-2
1060N
LCI T-1
E1560E
Artificial fill berm
Erosion berms


Artificial fill
Holocene alluvial / debris flow deposits
Primary fault
Bonneville deposits



USGS
UGS

Trench T-1 South Wall



UNIT DESCRIPTIONS

Late Holocene to historical deposits

Unit 600
Combination of slope wash colluvium and alluvium; may contain minor amounts of artificial fill that are difficult to differentiate. **[Historical to Late Holocene]**

Late Holocene to fluvial channel deposits

Unit 500
Clayey silty gravel (GC-GM), dominantly dark brown (7.5 YR 3/2) and dark grayish brown (2.5Y 4/2), with local areas of dark bluish gray (10B 4/1) and strong brown (7.5YR 5/8), damp, estimated 20% gravel, 20% sand, 60% fines, clasts are fine to coarse, poorly sorted, angular, up to 6 cm, majority highly weathered limestone; sand is fine to coarse, poorly sorted, subrounded to subangular, majority lithics and quartz; fines are mixed silt and clay, soft to medium stiff, low to medium dry strength, slow dilatancy, low toughness; unit appears to be composed of a disarticulated highly weathered rock and colluvial material, upper 10-20 cm of unit is highly oxidized, bottom 10 cm of unit apparently preserves the lower portion of a buried A-horizon that may suggest two periods of debris flow deposition; lower boundary is sharp across 2 cm and wavy. **[Late Holocene debris flow deposit]**

Unit 470b
Sandy silt to silty sand with gravel (SM), brown (10YR 4/3) with local white (10YR 8/1) precipitate; estimated 20% gravel, 40% sand, 40% fines, clasts are small to large pebbles, subangular to rounded, poorly sorted, mostly slightly weathered limestone; sand is very fine to fine and coarse to very coarse, poorly sorted to moderately-well sorted, coarse angular lithics, fine rounded quartz; fines are mainly silt with trace clay; medium stiff, medium dry strength, non-plastic, rapid dilatancy; unit is defined by presence of carbonate soil (Bk-horizon, Stage I to II) that infills root casts and coats ped faces and a weak subangular blocky structure (with small weak granular structure in pockets thought to be krotovinas), in upper 10 cm of unit is a weak organic soil (A horizon) defined by slight melanization; common filamental rootlets, common small pores; unit is best observed on south wall and was vague on north wall, defined by a basal stone line and unit diffusely fines upward to become massive, internally there is weak, subhorizontal crossbedding; the lower boundary is boundary is sharp over 2 cm where basal stone line is present, clear over 4 cm where stone line is not present, boundary is channelized. **[Late Holocene fluvial channel or alluvial fan deposit]**

Unit 470a
Sandy silt with gravel (ML), brown (7.5YR 4/3), estimated 30% gravel, 35% sand, 35% fines, clasts are mostly medium to large pebbles, slightly weathered limestone similar to those in Unit 470b but slightly more tabular; sand is very fine to very coarse with more medium sand than Unit 470b, fines are mainly silt with trace clay; medium stiff, medium dry strength, non-plastic, rapid dilatancy; while not developed uniformly throughout the unit, the carbonate soil from Unit 470b is developed in the portions of this unit closest to the fault; in contrast to Unit 470b there are very few filamental roots; basal contact defined by discontinuous stone line but not channelized like unit 470b. **[Late Holocene alluvial deposit]**

Unit 460
Silty sand to sandy silt with gravel (SM-ML), brown (7.5YR 4/3) to dark yellowish brown (10YR 3/4), estimated 10% pebbles, 25-50% sand, rest fines, clasts are small to large pebbles, rounded, poorly sorted, mostly slightly weathered limestone; sand is fine to very coarse, poorly sorted, coarse angular lithics, fine rounded quartz; fines are mainly silt with trace clay, medium stiff, medium dry strength, non-plastic, rapid dilatancy; unit is defined by the absence of concentrated clasts (in contrast to units above and below), basal contact is diffuse, wavy. **[Late Holocene alluvial deposit]**

Early to Late Holocene alluvial fan, debris flow, and colluvial deposits

Unit 440c
Silty clayey sand with very small pebbles to small cobbles; dark gray brown (10YR 4/2) to brown (10YR 4/3); 30-40% clasts, 20-50% sand, rest silt with trace clay; clasts are common very small to medium pebbles and rare large pebbles small cobbles, subrounded to subangular, rare round, tabular and spherical; sand is concentrated in pockets of very coarse subangular sand, and fine to coarse subangular sand distributed throughout; fines are silt with trace clay, nonplastic, very slightly cohesive (maybe only moisture), very low dry strength, high dilatancy; unit defined by multiple stone lines inclined to the west > 25° at fault contact to east to ~10° to the west (1-2 m), especially true on south wall; on north wall unit fines abruptly (capped?) by fine grained silty sand; filamental CaCO3 and partial coatings on clast bottoms, clasts also have discrete clay coatings under (suggesting possible Btk horizon, Stage I to II), single grain to small subangular blocky structure; common to abundant roots/rootlets, many small pores; basal contact clear to diffuse, defined by basal stone line of imbricated clasts, tabular which is inclined and thins to the west. **[Holocene Colluvial Wedge]?**

Unit 430
Sandy silty clay (CL) to gravelly clayey silt (ML), dark brown (7.5YR 3/2) with very dark grayish brown (10YR 3/2) mottling grading to brown (7.5YR 4/3) in upper portions of unit; broadly 5% gravels, 20% sand, 75% fines, but where unit is channelized gravels can be up to 75%; gravel is fine to coarse, poorly sorted to locally well sorted, subangular to subrounded, mostly limestone and shale; sand is fine with scattered coarse grains, well sorted, subrounded to subangular, mostly quartz and lithics; fines are mostly clay with silt, soft, medium plasticity, medium dry strength, slow dilatancy, low toughness; unit is massive at base but contains several nested continuous to discontinuous stone lines that suggest progressive channel deposition, that is especially prominent on the south wall, here unit contains at least three east-dipping channel beds, each 15 cm thick that grade upward from up to 75% gravel (tabular, subrounded to rounded large pebbles with rare very small cobbles up to 6 cm) to 10-20% gravel in upper portions, 60% sand (mostly fine to medium); the very dark grayish brown (10YR 3/2) mottling is constrained to bottom 20 cm of unit and may indicate groundwater interaction; strong HCl reaction throughout unit but little visible evidence of carbonate precipitation (Bkt-horizon, Stage I); lower boundary is gradational over 10 cm and irregular. **[Late Holocene alluvial deposit]?**

Unit 430c
Small pebbles to small cobbles in clayey silty sand matrix that vaguely fines up; brown (7.5YR 4/3); 20-40% clasts, 20-30% sand, rest silt with 10% clay; clasts are small pebbles to small cobbles, subangular to subrounded, mostly tabular limestone with some rare shale chips, loosely imbricated, defined by stone line of large pebbles and small cobbles; sand is very fine to medium, subangular to subrounded; fines are silt with trace to estimated 10% clay, dry to slightly moist, slightly friable, low dry strength, slow-fast dilatancy, non-plastic, slightly cohesive; few small roots, common small to medium pores; weak carbonate precipitation on argillic horizon (Bkt- horizon, Stage I), small to medium weak subangular blocky structure, possibly better developed argillic soil (Bt-horizon) in upper ~20 cm but obscured by bench; unit is only recognized on south wall, vaguely fines upward (lose bigger clasts) with coarsest material near fault contact to the east, basal contact may also truncate small faults outboard of main fault; basal contact very sharp, planar, inclined to west ~10°, laterally gradational to the west, defined by tabular stone line that thins and fines to the west. **[Holocene Colluvial Wedge]**

Unit 420a
Clayey silt with gravel (ML), dark grayish brown (10YR 4/2), estimated 10-20% gravel, 20-30% sand, rest fines; clasts are small to large pebbles, platy to tabular, mostly shale, clast content is up to 80% of unit along basal contact where unit appears incised into Unit 420 (only on north wall); sand is very fine to coarse, commonly concentrated within gravel near base of unit, subangular to subrounded, mostly quartz and lithics; fines are silt and clay in equal parts, low plasticity, medium dry strength, cohesive; disseminated CaCO3 throughout unit, weak but discrete filaments (Bkj-horizon, Stage I to II), weak subangular blocky soil structure, desiccation cracks along ped facies as unit dried; very fine small roots, common very small pores; basal contact abrupt where clast content is high and unit is clearly channelized, diffuse where unit is silty. **[Late Holocene alluvial / fluvial channel deposit]**

Unit 420
Clayey silt with gravel (ML), dark grayish brown (10YR 4/2), estimated 10% pebbles, 20% sand, 70% fines; pebbles are subangular, tabular, subhorizontally imbricated, concentrated along basal contact forming a discrete 5 cm thick stone line; sand is very fine to coarse, subangular to subrounded, predominantly quartz and lithics, concentrated within basal gravel; soil as in Unit 420a, but with slightly more clay; fines are silt and clay, low plasticity, medium dry strength, cohesive; no roots, few small pores, basal contact channelized, clear. **[Late Holocene alluvial deposit]**

Unit 400
Clayey silt with gravel (ML), brown (10YR 4/3), estimated 10% pebbles, 10% sand, 80% fines, pebbles are fine to medium, subangular, mostly limestone, subhorizontally imbricated within 2-5 cm thick east-dipping beds/channels, very rare to rare large pebbles and small cobbles are randomly distributed throughout unit; sand is fine to medium, subangular to subrounded, silt with clay makes up 80-90% of unit, medium stiff low plasticity, low dry strength; unit is vaguely channelized, especially to west where local lenticular pockets of gravel are inclined approximately 10-20° east, these gravel beds are also offset along antithetic faults in the western portion of the trench and unit is in fault contact to east at main fault; a disseminated carbonate soil is developed into an argillic soil (Bkt-horizon, Stage I), medium moderate subangular blocky structure; very small pores, no rootlets; basal contact not observed (below trench base). **[Early Holocene alluvial fan deposit]**

Bonneville-aged deltaic and dune deposits

Unit 350
Clayey silt with sand and gravel, (ML), dark brown (7.5YR 3/2 to 10YR 3/3), 10% clasts, 20% sand, 70% fines, clasts small to large pebbles and very rare small cobbles, poorly sorted, subrounded to subangular, mostly hard limestone; sand is coarse to fine, poorly sorted, subangular to subrounded, mostly quartz and lithic fragments; fines are mostly silt with clay, soft, low plasticity, low dry strength, slow dilatancy, low toughness; unit is stratified: bottom ~20 cm of unit is gravelly silt, middle ~50 cm is clayey silt with sand, upper ~30 cm is silty clayey sand with gravel; strong HCl reaction throughout unit indicated carbonate soil (Bk-horizon, Stage I), lower unit boundary is clear over 5 cm, wavy. **[Latest Pleistocene Bonneville-aged deltaic deposit]**

Unit 345
Sand with silt and clay (SP), yellow (2.5Y 7/6) to pale yellow (2.5Y 7/3) with brown 10YR 4/3) clayey infilled fractures; no clasts, 90% sand, rest fines; sand is medium to fine, very well sorted, subrounded, mostly quartz with very rare lithic fragments, in basal 10 cm, some discontinuous stringers are composed of coarse sand to granules; rest silt with trace clay, except along infilled fractures that increase in frequency close to the fault (to west), broadly unit is loose to medium dense, low plasticity, very low dry strength, rapid dilatancy, low toughness, locally and within infilled fractures, material is moist, highly cohesive, slightly to moderately plastic, soft; unit is massive to vaguely bedded; some vague evidence of soft sediment deformation is present in proximity to main fault zone and small offsets are interpreted along the discontinuous granular beds; abundant CaCO3 filaments and pore coatings especially on south wall in proximity to fault (Bkj-horizon, Stage I); lower unit boundary is sharp, wavy to irregular. **[Latest Pleistocene Bonneville-aged dune deposit]**

Unit 340
Clayey silt with sand (ML), dark grayish brown (2.5Y 4/2), estimated 20% sand, 80% fines; sand is mostly fine with occasional coarse grains present as discontinuous 5 cm thick beds rare throughout unit, well sorted, subrounded to subangular, mostly quartz and lithic, fines are primarily silt with clay, soft, low plasticity, low, dry strength, rapid dilatancy, low toughness, abundant CaCO3 filaments and pore coatings, strong reaction to HCl throughout unit (Bk-horizon, Stage II); locally, unit is stratified between sta. 32 to 40: upper 20-50 cm of unit is light olive brown (2.5Y 5/6) overlying discontinuous blobs of very dark brown (10YR 2/2) organic-rich sandy silt, between sta. -8 and 16 unit this organic layer contains a high concentration of charcoal fragments; lower boundary is sharp over 1 cm, wavy. **[Latest Pleistocene Bonneville-aged deltaic deposit]**

Unit 330
Silty clay with sand and gravel (CL), olive brown (2.5Y 4/3) to very dark grayish brown (2.5Y 3/2), estimated 10% clasts, 30% sand, 60% fines; clasts are well sorted fine gravel, subangular, mostly weak shale, sand is fine to coarse, poorly sorted, subangular, mostly quartz and lithics; fines are mixed silt and clay, soft to medium stuff, medium plasticity, medium dry strength, slow dilatancy, low to medium toughness; unit is diffusely and discontinuously bedded: silty clay with sand interfingering with sandy silty clay with gravel, beds range in thickness from 2 to 20 cm, beds with gravel have weak subhorizontal imbrication of clasts; upper 15 cm of unit is relatively fine-grained (silt and clay) and contains a 1-2 cm thick dark brown (7.5YR 3/2) organic soil (AB-horizon) overlying a 2-3 cm bed of find sand with a prominent carbonate soil evidenced by subvertical CaCO3 stringers, carbonate soil is more weakly developed at depth with strong HCl reaction throughout unit (Bk-horizon, Stage II); lower unit boundary is sharp across 1 cm, wavy. **[Latest Pleistocene Bonneville-aged deltaic deposit]**

Bonneville-aged deltaic and dune deposits

Unit 320
Silty clayey sand (SC-SM), light olive brown (2.5Y 5/4) to olive brown (2.5Y 4/4), trace clasts, 80% sand, 20% fines, few clasts distributed throughout, small to pebbles, subrounded, mostly hard limestone; sand is fine to medium, well sorted, subrounded, mostly quartz; fines are mixed clay and silt, loose to medium dense, low plasticity, very low dry strength, rapid dilatancy, low toughness; unit is massive except between Sta -12 to 8 where unit is thinly bedded to laminated and cross bedded; a strongly developed carbonate soil is developed throughout with common CaCO3 stringers and strong HCl reaction throughout (Bk-horizon, Stage II); lower boundary is sharp over 1 cm, wavy. **[Latest Pleistocene Bonneville-aged deltaic deposit]**

Unit 310
Sandy clay with silt and gravel (CL), brown (10YR 4/3) to light olive brown (2.5Y 5/4), damp, estimated 20% gravel, 30% sand, 50% fines, clasts are small to large pebbles, poorly sorted, angular to subrounded, mostly limestone and shale; sand is fine to coarse, poorly sorted, angular to subrounded, mostly lithics; fines are mixed clay and silt, soft to medium stiff, medium plasticity, low dry strength, slow dilatancy, low toughness; unit is stratified, interfingered beds of clayey sand with gravel, silty clay, and silty-clayey sand, bed thickness 5-20 cm, clast-rich beds have weak subhorizontal imbrication, beds of silty clayey sand are laminated and cross bedded; between sta. 32 and 36 on the south wall unit appears channelized and here contains up to 75% granules and small pebbles; strong HCl reaction throughout unit but little discrete carbonate precipitate visible (Bk-horizon, Stage I); lower unit boundary is clear across 5 cm, wavy. **[Latest Pleistocene Bonneville-aged deltaic deposit]**

Unit 300
Silty clay with sand and gravel (CL), brown (10YR 4/3) to light olive brown (2.5Y 5/3); estimated 10% gravel, 30% sand, 60% fines; clasts are fine to coarse gravel, moderately well sorted, organized in discontinuous and lenticular beds that are subhorizontal and increase to 20° west near fault, subangular to subrounded, mostly limestone and shale; sand is fine to coarse, moderately sorted, subangular to subrounded, mostly lithics and rare quartz; fines are mix of silt and clay, low plasticity, low dry strength, slow dilatancy, low toughness, soft to medium stiff; unit is composed of interfingered beds of silty clay, clayey sand with gravel, bottom 20 cm of unit is cross bedded silty fine sand with abundant soft sediment deformation features (flame structures, loading casts, etc.), beds are 2-10 cm thick, clast-rich beds have subhorizontal imbrication; strong HCl reaction throughout unit but little discrete carbonate precipitate visible (Bk-horizon, Stage I); lower unit boundary is clear across 2 cm, wavy to irregular, draped on gravels below. **[Latest Pleistocene Bonneville-aged deltaic deposit]**

Bonneville-aged fluvial and alluvial deposits

Unit 200
Sandy gravel (GW), light olive brown (2.5Y 5/4), pale brown (2.5Y 7/3), gray (5Y 6/1) estimated 10% cobbles, 60% gravel, 30% sand, trace fines; clasts are cobbles and fine to coarse gravels, subrounded to rounded, poorly sorted, mostly limestone; sand is fine to coarse, poorly sorted, subrounded to rounded, mostly quartz; unit is massive with weak subhorizontal imbrication, clasts have < 1 mm thick CaCO3 coatings, strong HCl reaction throughout unit, boundary is not exposed within trench. **[Late Pleistocene fluvial deposits]**

EXPLANATION

Trench Boundary

Contact
Dashed where approximate;
Queried where uncertain
Dotted where concealed

Fault
Dashed where approximate;
Queried where uncertain
Dotted where concealed

T1-RC-2 Radiocarbon ages (cal yrs BP-95% confidence)

Location of structural measurement

Fault discussed in text

Interpreted surface rupturing events

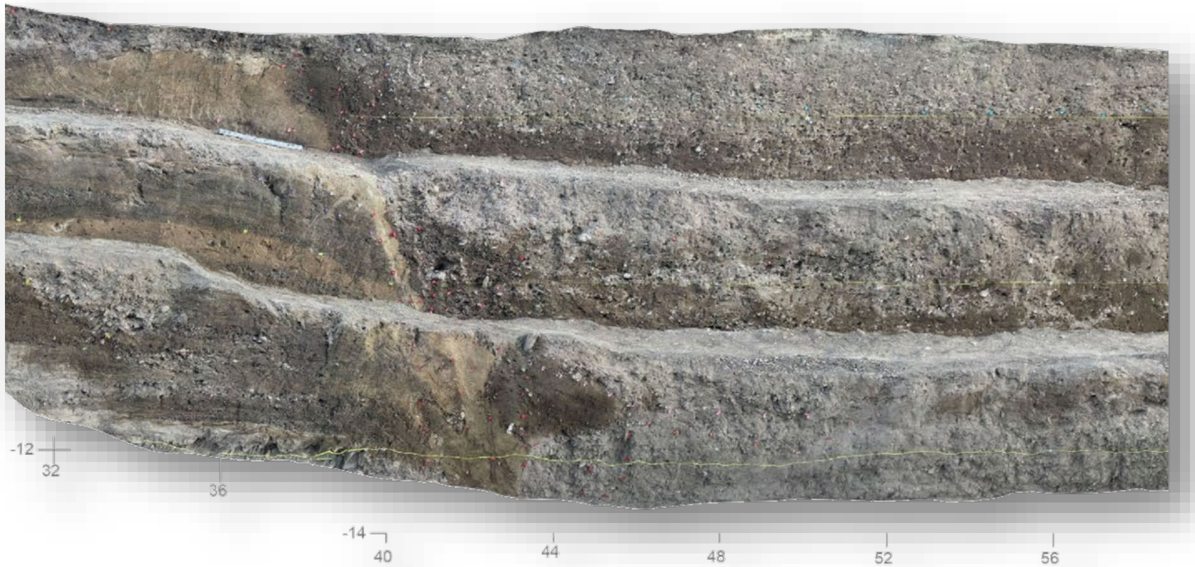
Structural Measurement:

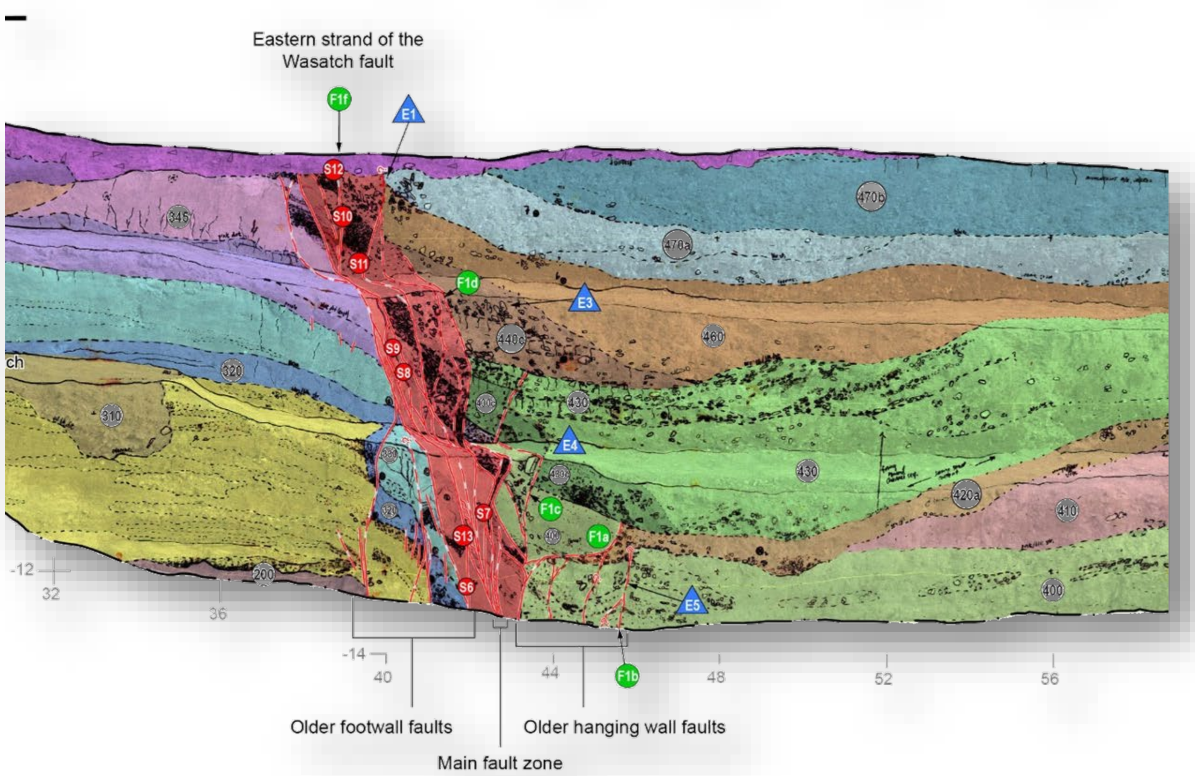
S1	N22°W, 76°NE
S2	N20°W, 80°SW
S3	N20°W, 72°NE
S4	N21°W, 73°NE
S5	N18°W, 70°NE
S6	N5°W, 81°SW
S7	N15°W, 72°W
S8	N15°W, 73°SW
S9	N14°W, 64°SW
S10	N15°W, 72°SW
S11	N10°W, 68°SW
S12	N6°W, 68°SW
S13	N5°W, 69°SW

Trench T-1 South Wall

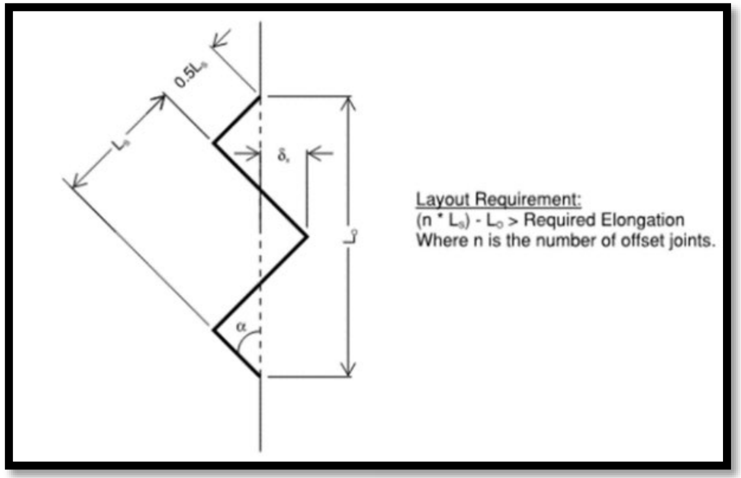
CENTRAL UTAH WATER CONSERVANCY DISTRICT

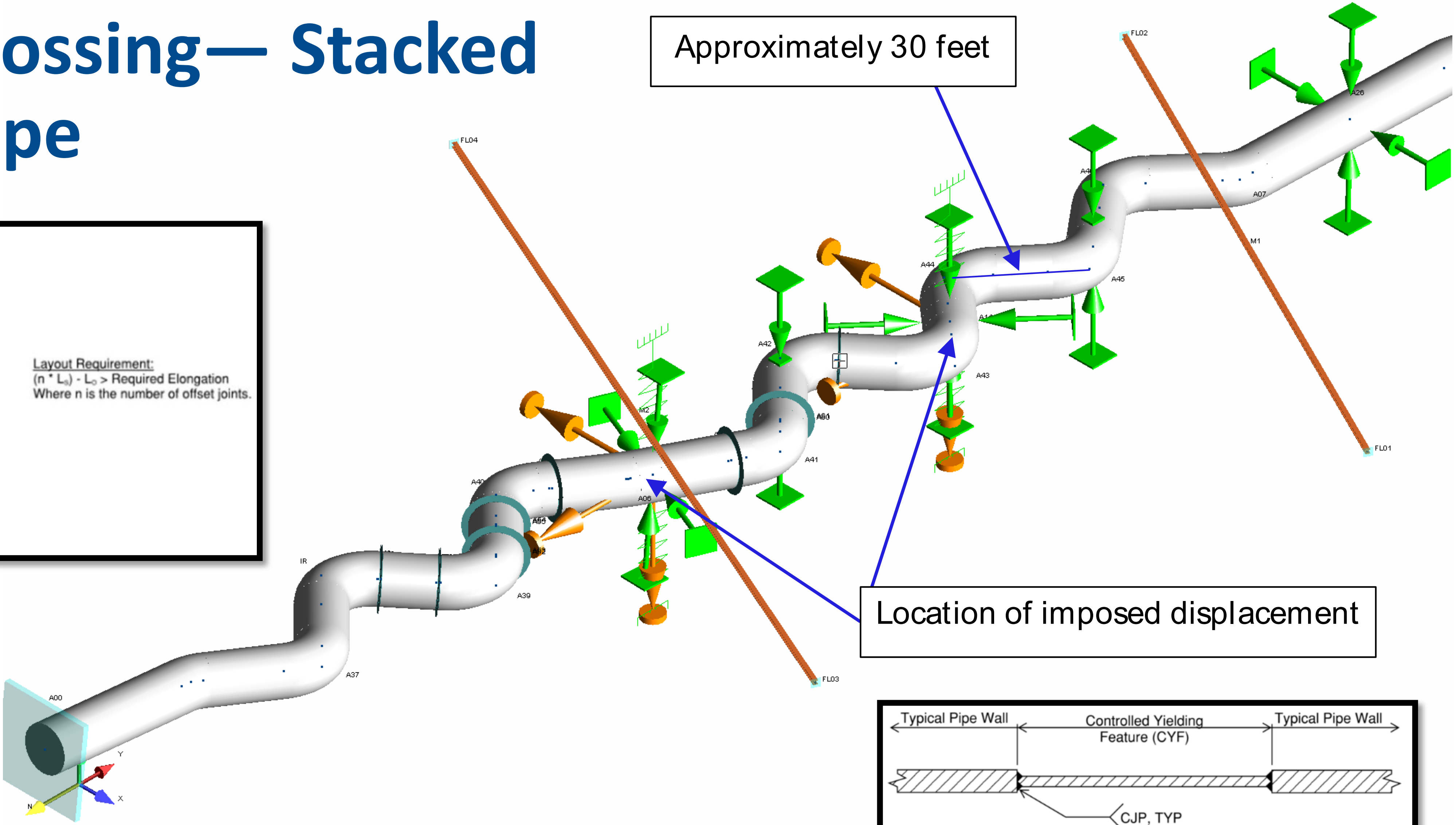
Lettis Consultants International, Inc. | Plate 1


-12
32
36
-14
40
44
48
52
56


Eastern strand of the Wasatch fault
F1f
E1
S12
S10
S11
F1d
E3
470b
470a
460
440c
345
320
310
ch
S9
S8
430
E4
420a
410
400
S7
S13
F1c
F1a
S6
E5
200
-12
32
36
-14
40
44
48
52
56
F1b
Older footwall faults
Older hanging wall faults
Main fault zone

Fault crossing— Stacked Steel Pipe





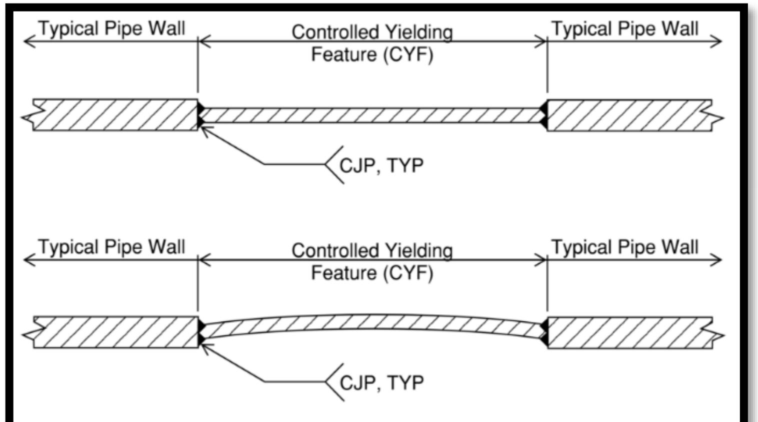
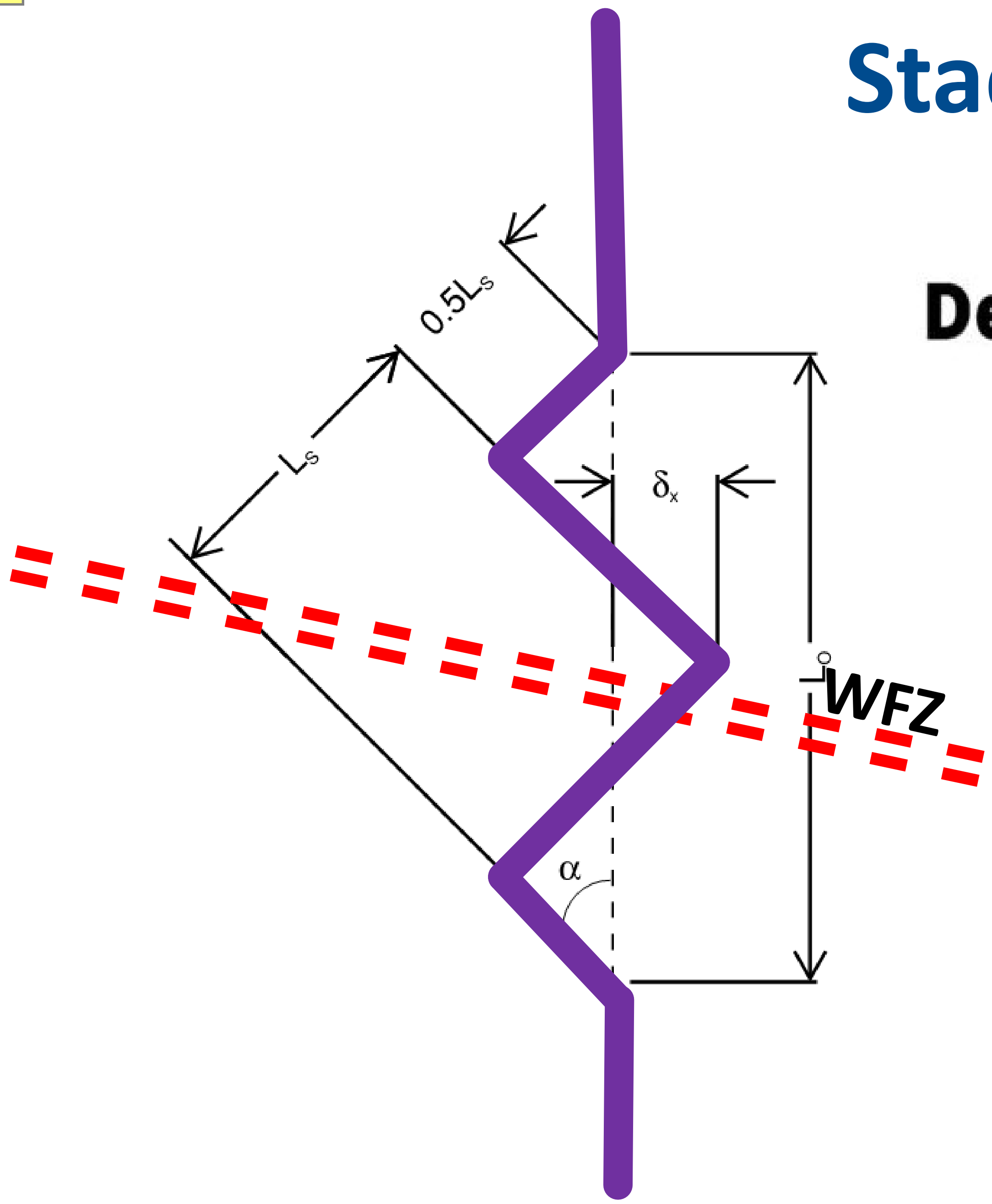
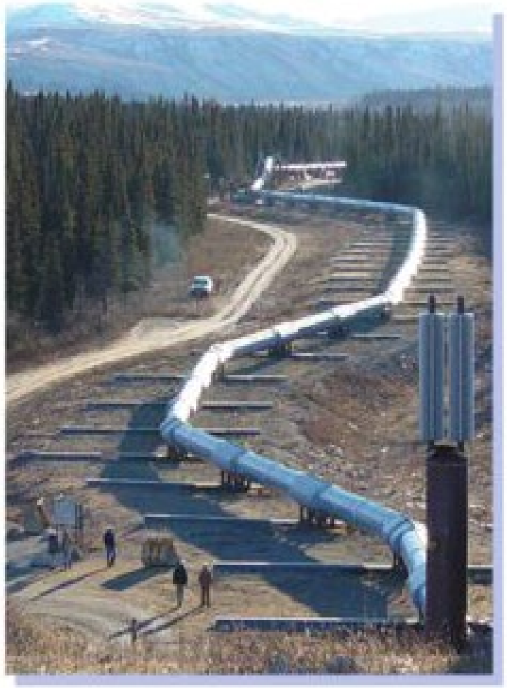


Figure 4-3. Conceptual Controlled Yielding Features

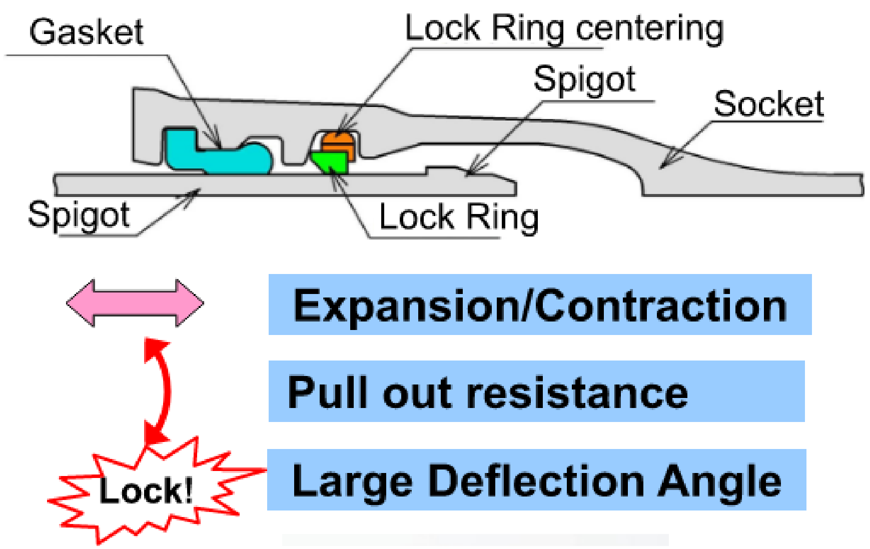
Stacked Pipe

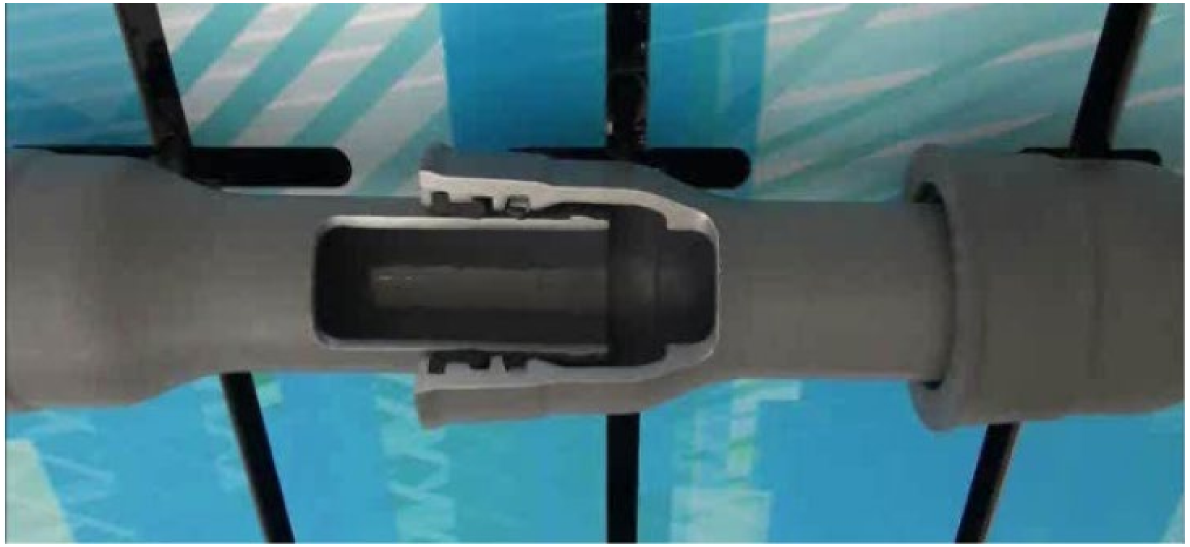


Denali Fault Crossing (Before & After)

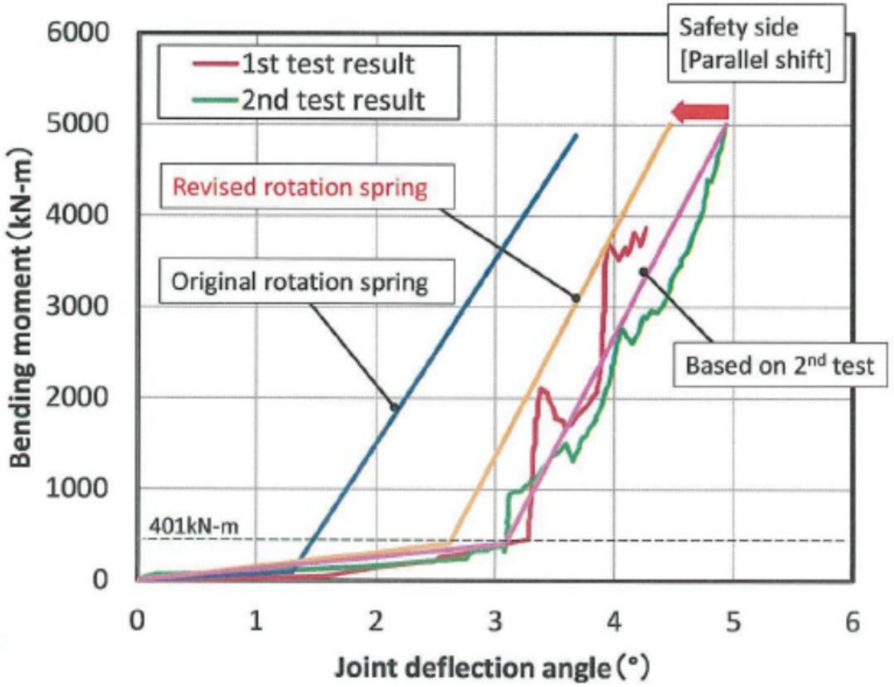


Fault crossing—Kubota HRDII





Test Results [Rotation Spring]



Earthquake Resistant Moveable Pipe Joints


132
ERDIP



GR50
GR50
07/15/


Kubota
GR50
GR50
GR50
07/15/2022

Chris Elison, PE

ENGINEERING MANAGER I
CENTRAL UTAH WATER CONSERVANCY DISTRICT
(801) 226-7166 office | (801) 960-5373 cell |
chrise@cuwcd.gov
1426 E. 740 N. Suite 400 | Orem, UT 84097