Appendix D. Investigation and Analysis Report

D.1 Introduction

This Investigation and Analysis Report presents information that supports the formulation, evaluation, and conclusions of the American Fork River Supplemental Watershed Plan and Environmental Assessment for Flood Prevention Improvements in American Fork City and Lehi City (project). The required report is included as Appendix D to the Plan-EA.

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

This report presents and summarizes planning studies conducted which are based on standard methods, procedures, and software programs used and approved for use by the United States Department of Agriculture Natural Resources Conservation Service (NRCS). The information provided is a summary of the investigation and analysis for the key planning studies developed for the proposed project. The information in this report is summarized from technical memorandum (TM) that have been prepared for this project. The technical memos and any additional information can be requested from the following address:

USDA – NRCS
125 South State Street, Room 4010
Salt Lake City, UT 84138-1100

D.2 Existing Conditions (TM001)

The purpose of Technical Memorandum (TM001) is to identify and document the existing conditions, existing records, document work previous performed and present information gathered from site visits for all locations considered as part of this Supplemental Plan-EA. The project is located along sections of the American Fork River in American Fork City, sections of Dry Creek and Waste Ditch in Lehi City, and lower Dry Creek in Saratoga Springs City. A comprehensive summary of the existing conditions within the study areas are presented in *TM001 – Existing Conditions* (FCE & JDE, 2023a).

D.2.1 American Fork City

The American Fork River is an intermittent stream that flows from American Fork Canyon south through American Fork City until it discharges into Utah Lake. There are many areas of the river where the flow has been channelized with either a closed-top box culvert or an open-top rectangular concrete channel. American Fork City has had increasing concerns about the flood potential of four locations along the river. Results from a hydraulic model indicate that flooding occurs at the majority of road crossings during the 50-year storm event with the severity increasing with a 100-year storm event. The surrounding areas are at risk of flooding including homes, commercial buildings, an elementary school, and a church. Sections of the river channel need improvements in order to safely convey flood water and protect the surrounding community.

D.2.2 Lehi City

Developed areas in Lehi City and Saratoga Springs City have been flooded or are at risk for flooding along Dry Creek and Waste Ditch, which is also represented in the hydraulic model for the 50-year storm. In recent years, Lehi City, in partnership with private landowners and state agencies, has invested millions of dollars in improving Dry Creek's channel and Waste Ditch at various locations throughout the city. High flows have posed an increasing threat to residential structures and Lehi Elementary School in the sections of the channel that have not been improved due to lack of sufficient financial resources. In particular, the Dry Creek channel near Lehi Elementary School is restricted by the channel size and a culvert. In the past and again in 2023, high spring runoff have caused flooding of the elementary school and homes in the area as shown in the following photos.D.3 Design Criteria (TM002)

The project aims to address flooding concerns within the American Fork Canyon and Dry Creek-Jordan River Watersheds by rehabilitating compromised flood control structures within the area, which include culverts and natural and concrete-lined channels. This would increase the ability of these structures to safely convey flood water and reduce the risk of flooding and flood damage to the surrounding community. The design criteria including the list of the governing documents used to establish the design criteria are presented in *TM002 – Design Criteria* (FCE & JDE, 2022a). These criteria are in accordance with NRCS and other applicable requirements and standards.

D.4 Hydrology (TM003)

Hydrologic analyses were performed for the American Fork River and Dry Creek drainages using guidelines from NRCS National Engineering Handbook (NEH) Part 630, with consideration to the topography, land cover, soil types, and drainage features for the watersheds. The analysis modeled the 500-, 200-, 100-, 50-, 25-, and 10-year, 24-hour duration storm events. The resulting hydrographs will be used in the hydraulic analysis to model the prevailing and proposed conditions.

The analysis for the American Fork River watershed showed that the peak flow produced by NEH Part 630 seemed to be overestimated, hence calibration of the peak flows was done using a Bulletin-17B analysis with the USGS 101645000 stream gauge. From this analysis, the estimated design peak flow was 934 cfs, which represents a 100-year, 24-hour storm event per the American Fork City design criteria (American Fork City, 2008).

For the Dry Creek, the peak flows produced by the NEH 630 guidelines were comparable. The estimated design peak flows for Waste Ditch and Dry Creek were 640 cfs and 274 cfs, respectively. These peak flows represent the 50-yr, 24-hour storm events as per the Lehi City design criteria (Lehi City, 2016). Detailed information on the hydrologic analysis can be found in *TM003 - Hydrology* (FCE & JDE, 2022b).

D.5 Frequency Flood Routing (TM004)

The existing conditions and proposed improvements for the American Fork River, Dry Creek and Waste Ditch were modeled using a 2D U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center - River Analysis System (HEC-RAS) model (version 6.0). The model showed that the proposed improvements would result in a significant reduction in flooding and that there would be no induced flooding downstream of the proposed improvements. The methods, procedures and results from the frequency flood routing are described in *TM004 – Frequency Flood Routing* (FCE & JDE, 2023b).

D.6 Hydraulic Analysis (TM005)

A hydraulic analysis was completed to obtain a flood model for the project area and determine existing and proposed flood channel capacities. A 2D HEC-RAS model (version 6.0) was used for the hydraulic routing of the American Fork River, Dry Creek, and Waste Ditch. The storm events modeled were the 500-, 200-, 100-, 50-, 25-, and 10-year, 24-hour duration events. Hydrographs produced from the design peak flows in *TM003 – Hydrology* (FCE & JDE, 2022b) for each recurrence interval were used to model the conveyance systems. The model enabled a comparison between the No Action Alternative and the Action Alternative, which supported the economic analysis in Section D.7. *TM005 – Hydraulic Analysis* (FCE & JDE, 2023c) includes detailed information on the flood modeling, mapping of the inundation areas for the 100-year storm event, and cost estimates.

D.7 PR&G and Economics Analysis

The Plan-EA has been prepared in accordance with the PL-566 program's Federal Objective set forth in the Water Resources Development Act of 2007 (Act). The Federal Objective sets forth that water resource investments, including the Preferred Alternative, will reflect national priorities, encourage economic development, and protect the environment by maximizing sustainable economic development, avoiding the unwise use of flood-prone areas, and protecting and restore natural systems and mitigate any unavoidable impacts. The Act also directed the federal government to update and consolidate its past guidance to ensure investments meet the Federal Objective, resulting in the *Guidance for Conducting Analyses Under the Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies and Federal Water Resources Investments* (PR&G; USDA-NRCS, 2017) which is a comprehensive policy and guidance for projects. The economic analysis was performed to determine if the Action Alternative (FWFI) is economically feasible using the National Watershed Program Manual (NRCS 2015a) and the PR&G (USDA-NRCS, 2017). The National Economic Efficiency (NEE) follows the PR&G by considering a broad set of benefits to evaluate the economic, environment, and social impacts of the Preferred Alternative.

The purpose of this report was to describe the PR&G and Economic Analysis, how the NRCS's Nine-Step Conservation Planning Process and PR&G's Eight-Step Watershed Planning Process were followed, and results for the Plan-EA. The technical memo also outlines and evaluates PR&G's evaluation process including the six Guiding Principles and the four Ecosystem Services Framework evaluated. The PR&G 8-step process was adhered to and is documented in the *PR&G Alternative Formulation & Screening Matrix* in Appendix E and in the *PR&G Ecosystem Services Framework Worksheet,* also located in Appendix E. See the incremental economic analysis located in *the Economic Investigations & Analysis Report* (FCE and Gordon, 2024) in Appendix E. A summary is provided in Table D-1.

Criterion	No Action (FWOFI)	Flood Reduction Alternative	Property Buyouts Alternative
Alternative I.D.			
Locally Preferred	NA	X	NA
Nonstructural	NA	NA	X
Environmentally Preferred	NA	X	NA
National Economic Efficiency	NA	X	NA
Preferred Alternative	NA	X	NA
Guiding Principles			
The alternative marked with X and colored **green** is the plan that best meets the specified Guiding Principles of the PR&G			
Healthy/Resilient Ecosystems	NA	X	NA
Sustainable Economic Devel.	NA	X	NA
Floodplains	NA	X	NA
Public Safety	NA	X	NA
Environmental Justice	NA	X	NA
Watershed Approach	NA	X	NA
Ecosystem Services Effects			
The alternatives colored **green** indicates improvement in Service provision, red indicates impairment.			
Provisioning Services			
Instream Fish Species (Non-Monetized)	NO	YES	NO
Regulating Services			
Flood Control (Monetized – Damage Reduction Benefit)	NO	YES	YES
Water Quality (Non-Monetized)	NO	YES	NO
Wetlands/WOTUS (Non-Monetized)	NO	NO	NO
Cultural Services			
Aesthetic Value of Watershed (Non-Monetized)	NO	YES	NO
Public Safety (Non-Monetized)	NO	YES	NO

Criterion	No Action (FWOFI)	Flood Reduction Alternative	Property Buyouts Alternative
Ecosystem Viability (Non-Monetized)	NO	YES	NO
Supporting Services			
Not Evaluated in this Plan-EIS	NA	NA	NA
Economic Analysis			
Costs			
Total Project Investment	$0	$16,207,000	$394,346,259
Annual Project Investment	$0	$619,300	$14,606,948
Annual OM&R Costs	$37,500	$37,500	$0
Total Annual Project Costs	$37,500	$656,800	$14,606,948
Monetized Benefits for Ecosystem Services			
Provisioning	Not Monetized in Plan	Not Monetized in Plan	Not Monetized in Plan
Regulating	$0	$2,670,190	$2,670,190
Cultural	Not Monetized in Plan	Not Monetized in Plan	Not Monetized in Plan
Supporting	Not Monetized in Plan	Not Monetized in Plan	Not Monetized in Plan
Total Annual Monetized Benefits	$0	$2,670,190	$7,396,733
Total Annual Monetized Costs	$37,500	$656,800	$14,606,948
Benefit-Cost Ratio	0.0	4.07	0.51
Annual Monetized Net Benefit	$0	$2,013,390	-$7,210,215
Regional Economic Development/Economic Impact Assessment	Not Performed for this Plan-EA		
Regional Employment	NA	NA	NA
Regional Income	NA	NA	NA
Regional Impacts (Other)	NA	NA	NA

The economic analysis compared the average annual costs to the average annual benefits. A project is considered economically feasible if the benefits outweigh the costs. In the economic analysis, the No Action Alternative or Future Without Federal Investment (FWOFI) is considered as the baseline scenario. This alternative has no costs or benefits associated with it. The Action Alternatives involve actions with proposed measures. The changes implemented in an Action Alternative are measured as a cost or benefit relative to the baseline scenario.

Benefits and costs of each project element were quantified on an annual basis. The analysis used inundation models to estimate future flood damages within the study area. The inundation models were run with the following flood recurrence intervals: 50-percent- (2-year), 20-percent- (5-year), 10-percent- (10-year), 4-percent (25-year), 2-percent- (50-year), 1-percent- (100-year), 0.5-percent- (200-year), and 0.2-percent- (500-year) annual-probability flood events. Costs and benefits were evaluated for 50 years following project completion at a discount rate of 2.25%. A benefit-cost ratio was calculated for each project element, from which an aggregate benefit-cost ratio was obtained. The following is a summary of the analysis presented in *the Economic Investigations and Analysis Report (Appendix E).*

The total value of structures on impacted properties is shown below. This value does not include land values, only structure values.

Watershed Planning Area 500 yr Flooded Structures (W/O Project)

	Total Structures	**Residences & Apartments**	**Commercial Properties**	**Public Properties**
Number	1,336	1,209	125	2
Value	$241,673,943	$179,568,556	$61,917,707	$187,680

The table below shows that the current average annual floodwater damages without project (present condition) are $7,396,773. Floodwater damages with project (Alternative 1) were estimated at $4,726,583.

Summary of Annual Expected Damages

Plan Annual Expected Damages		
Category	**Present Condition**	**Alt 1**
Structure, Contents & Vehicles		
American Fork	$781,766	$246,810
Lehi Upstream	$5,419,884	$4,445,151
Lehi Downstream	$1,195,123	$34,622
Total:	$7,396,773	$4,726,583

1 Price base: 2024. Calculated using FY 20242 Water Resources Discount Rate (2.75%), annualized over 50 years, and 52-year period of analysis.

Project costs for flood control measures and channel work were estimated by Franson Civil Engineers, Jones & DeMille Engineering, and Horrocks Engineers. Installation and operation & maintenance costs for each activity are described in detail in the cost tabs in the economic analysis Excel worksheet.

All costs were allocated to the flood prevention purpose according to the procedure in the National Resource Economics Handbook, Part 611 Water Resources Handbook for Economics, Chapter 6 Costs and Cost Allocation (NRCS 2014b). Work Plan-EA tables were constructed based on the calculated cost allocated to flood prevention. Within this purpose, the costs were shared between NRCS and the local and state entities as specified in the NWPM; in this case, the cost share for flood prevention is 100 percent federal and 0 percent local. Within these guidelines, engineering is 100 percent federal, and operation, maintenance, and replacement are 100 percent local. See Work Plan Table 2 in the Plan-EA for the cost allocation/cost-sharing process results.

All costs were amortized at the Fiscal Year 2024 Federal Water Resource Discount of 2.75 percent for 52 years. Average Annual Costs are computed as the sum of the amortized construction and annual operation and maintenance costs. Engineers estimate that each structure would last 50 years, the project's life.

Project engineers estimated all project costs and converted them to Present Values by discounting each cost at the beginning of the period of analysis using the applicable project discount rate. Installation expenditures before the project was installed were brought forward to the end of the installation period by charging compound interest at the project discount rate from the date the costs were incurred. Finally, the project discount rate converted the present values to average annual equivalent terms. All estimated values and damages were assessed within a customized Excel template.

Watershed Project Annual Cost Summary

	Amortization of Installation Cost	Operation, Maintenance, and Replacement Cost2	Total
American Fork	$104,000	$8,600	$112,600
Lehi Upstream	$251,400	$14,200	$265,600
Lehi Downstream	$263,900	$14,700	$278,600
Total	$619,300	$37,500	$656,800

1/ Discount rate 2.75% with a 52 year period of analysis. Price base 2024

The table below shows that the current average annual benefits are $2,670,190, and the average annual costs are $656,800. The net annual benefits between with and without project that the project would provide to downstream properties are $2,013,390.

As reflected below, all three project areas had a B/C ratio greater than 1.0. Under Alternative 1, all three geographic areas produce a B/C ratio of 4.07.

Watershed Project Benefit-Cost Summary

Alternative 1	Average Annual Benefits 2/	Average Annual Costs 3/	Benefit Cost Ratio	Net Benefits
American Fork	$534,956	$112,600	4.75	$422,356
Lehi Upstream	$974,733	$265,600	3.67	$709,133
Lehi Downstream	$1,160,501	$278,600	4.17	$881,901
Grand Total	$2,670,190	$656,800	4.07	$2,013,390

1/ Discount rate 2.75% with a 52 year period of analysis. Price base 2024

D.8 30% Drawings

The Action Alternative was evaluated to a 30-percent design level. The design drawings show the geospatial locations and conceptual design details of the project elements, approximate disturbance areas, and also aided in preparing project cost estimates. These drawings can be found in *TM005 – Hydraulic Analysis* (FCE & JDE, 2023c).

D.9 Probable Cost

The cost of the project measures by location was estimated and included for the total probable project cost. These costs were determined using information from the 30-percent design quantities, past and present unit costs on similar projects, as well as engineering experience. Due to the volatility in materials and construction costs, a 25-percent contingency was used. The detailed quantities, unit cost, and total project element costs can be found in *TM005 – Hydraulic Analysis* (FCE & JDE, 2023c).

D.10 Statement of Limitations

The information presented in this document represents the professional judgment of Franson Civil Engineers and Jones & DeMille Engineering. It is based on the data available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practicing under similar conditions. No warranty, express or implied, is made.

D.11 References

American Fork City. (2008). *Storm Water Technical Manual*. May 2008.

FCE & JDE. 2023a. Technical Memo 001 – Existing Conditions

FCE & JDE. 2022a. Technical Memo 002 – Design Criteria

FCE & JDE. 2022b. Technical Memo 003 – Hydrology

FCE & JDE. 2023b. Technical Memo 004 – Frequency Flood Routing

FCE & JDE. 2023c. Technical Memo 005 – Hydraulic Analysis

FCE & Gordon, Hal. 2024a. Economic Investigations & Analysis Report

FCE. 2024b. PR&G Alternative Formulation & Screening Matrix

FCE. 2024c. PR&G Ecosystem Services Framework Worksheet.

Lehi City. (2016). Lehi City Design Standards and Public Improvement Specifications. 2016.

Attachment 1

Technical Memo 001 – Existing Conditions

TM001 – Existing Conditions

Table of Contents

1.0 Introduction

American Fork City as the project sponsor contracted with Franson Civil Engineering and Lehi City as a project co-sponsors contracted with Jones & DeMille Engineering, to complete a Natural Resources Conservation Service Supplemental Watershed Plan-Environmental Assessment (Plan-EA) of the American Fork River watershed in Utah County. The study includes evaluating how to reduce flooding in American Fork City and Lehi City, that are within the aforementioned watershed. The purpose of Technical Memorandum 1 (TM001) is to identify and document the existing conditions, existing records, document work previously performed and present information gathered form site visits for all sites considered as part of this Supplemental Plan-EA.

2.0 Existing Conditions – American Fork City

2.1 Background/Existing Conditions

The American Fork River (river) flows from American Fork Canyon southward through American Fork City (AFC) until it discharges into Utah Lake. There are many areas of the river where the flow has been channelized with either a closed-top box culvert or an open-top rectangular concrete channel. AFC has had increasing concerns about the structural integrity of five flood control structures along the river including several culverts and sections of concrete rectangular channel. In the event these structures fail during high flows, there is significant risk of flood damage to the surrounding area of about 128 acres which includes approximately 240 residential homes, 20 commercial buildings, one elementary school, and one church.

Using a consultant, AFC, in 2018, investigated the conditions of four of these structures and a Culvert Restoration Plan was developed. AFC determined that the four structures described in the report as well as one additional structure are deteriorating structurally, including deteriorating concrete, corroding rebar, and in some cases eroding streambed beneath the concrete floor, all of which pose a threat of eroding and cutting through the soil around the banks and beneath the structure. The structures are in need of rehabilitation in order to maintain public safety and provide necessary flood control protection.

Location 1 - Reinforced Concrete Pipe Culverts Beneath 400 North and 400 East (Not in Plan-EA)

At this location, the American Fork River crosses the 400 North and 400 East intersection diagonally from the northeast to the southwest through two parallel reinforced concrete pipe (RCP). Upstream of this culvert the river is an unimproved natural channel. There is a large headwall on the upstream side that directs the flow of the river into two parallel RCPs. These pipes cross the intersection and discharge into a concrete rectangular channel on the other side. In general, the upper part of the dual RCP is in very good condition. The issue with these pipes is that the concrete at the invert has been eroded and the reinforcement has been exposed. The reinforcement itself only has minor corrosion so far but will continue to corrode quickly if left exposed.

Photo 1. RCP with Exposed Rebar.

Photo 2. Close View of RCP with Exposed Rebar.

Also, there are several joints of the RCP that have widened or become disconnected due to settling, which is causing additional erosion on the floor of the RCP downstream of the joints. The split at the inlet into two RCP creates a place for debris to catch requiring extra time and effort by maintenance crews to avoid blockages during high spring flows.

Photo 3. RCP with Wide Gaps at Joints.

Location 2 – Culvert and Channel at 300 North (Location 1 in Plan-EA)

The road crossing of the American Fork River at 300 North is made up of two sections. The north part of the crossing is an older box culvert, and the south side is a rectangular concrete channel with steel I-beams for the roof support. Both sections of this box culvert are 12’ x 5’. The river is a natural channel upstream and downstream of this road crossing. There are several storm drain pipes that discharge into the culvert.

Photo 4. 300 North Upstream of Box Culvert.

The walls and roof of the structure are in good condition. The floor of the structure is in very poor condition. The floor in the upstream part of the structure has been completely eroded away and it now resembles a natural channel. The remains of the floor next to the walls are visible but have been undercut by erosion. The downstream floor is still in place but is in poor condition. The river has undercut the concrete floor and the top of the floor slab has been eroded enough to expose the rebar in some places.

Photo 5. Missing Floor and Undercutting of Walls.

The downstream apron is also completely eroded away and there is an eroded hole in the riverbed where the water falls out of the culvert. Concrete riprap has been added in this location to try to stop the erosion and back cutting of the structure.

Photo 6. Downstream Undercutting and Missing Apron.

Location 3 – Box Culvert Beneath 100 North and 200 East (Location 2 in Plan-EA)

This location features a box culvert with a center pier at 100 North that also crosses beneath a Union Pacific Railroad. The surrounding area includes several commercial buildings and residential homes. The box culvert appears to have been built in 1925. The center pier is deteriorating, and exposed rebar is corroding. The concrete floor and ceiling could not be investigated due to high flows, but it is anticipated that similar conditions as Location 5 and 6 are present.

Photo 7. Upstream Condition of Box Culvert.

Photo 8. Deteriorating Concrete and Exposed Rebar.

Photo 9. Downstream Condition of Box Culvert at 100 North and 200 East. Note the missing baffle blocks.

Location 4 – Box Culvert Beneath State Street (Not in Plan-EA)

The American Fork River crosses under State Street in a concrete box culvert near 200 East and Main Street and runs south under the strip mall parking lots, State Street to south of O'Reilly Auto Parts' parking lot, where it discharges. The box culvert under State Street and north of State Street appears to be in good condition but the concrete floor has eroded. In this section of the box culvert, the concrete floor of the structure has eroded, and is estimated to average about 3 inches thick. This erosion is much worse than the dual RCP pipes discussed previously, and some parts of the floor have eroded all the way through the concrete and rebar. In these areas, the underlying material has started to wash out, leaving voids under the concrete. If enough material is washed out of these holes in the concrete, the entire box culvert could settle, causing the parking lot above it to sink also.

Photo 10. Box Culvert Floor Erosion.

Location 5 – Rectangular Concrete Channel Between State Street and 200 South (Not in Plan-EA)

This location is the concrete rectangular channel south of the box culvert described in Location 4, where the river channel exits the box culvert south of State Street. The issue with this concrete channel is the concrete floor that is eroding away. A groove of concrete has eroded away in the channel exposing a long linear stretch of rebar, of which some rebar has completely eroded away. There are a few areas where the groove has eroded all the way through to the soil beneath the concrete floor and vegetation has started to grow through the cracks.

Photo 11. Open Channel Floor Rebar Exposed.

Photo 12. Open Channel Groove in Floor.

Location 6 – Box Culvert Beneath 200 South (Location 3 in Plan-EA)

This location features a road crossing of the American Fork River at 200 South and 100 East through a two-bay concrete box culvert. This road crossing is near Greenwood Elementary School and carries heavy bus traffic during the school year. Upstream of the culvert is a rectangular concrete channel and the downstream section of the culvert features energy dissipation blocks before the river returns to an unlined river channel.

Photo 13. 200 South Box Culverts.

The original structure has been repaired several times in the past. It appears that the original rebar was exposed and began to rust and corrode. A new layer of concrete with a thin reinforcement of welded wire mesh was placed in the ceiling to try to cover and preserve the corroding rebar. However, the welded wire mesh is now exposed and is corroding badly. Most of the original rebar is still covered by the additional layer of concrete, but the extent of its continued corrosion is unknown. There are some sections where the original rebar is still exposed, and it appears that approximately half of the steel has corroded away. If the rusting of the previously exposed rebar has continued, the structural integrity of the bridge could be jeopardized.

Another issue with this structure is the outlet of an 8-inch or 10-inch storm drainpipe. It appears the pipe was once grouted into place, but the grout has eroded away, which caused the pipe to become disconnected from the wall. Storm water appears to be running through the void between the pipe and the culvert's wall and is likely eroding away backfill material. If this continues, it is likely that a sinkhole will develop in the road just outside of the box culvert. All solutions considered will require extending the disconnected storm drain and properly grouting it in.

Photo 14. 200 South Culvert Ceiling Exposed Rebar.

Photo 15. Storm Drain inside of 200 South Culvert.

Location 7 – River Channel at 400 South (Location 4 in Plan-EA)

The road crossing at 400 South is a box culvert in good condition. The upstream channel has retaining walls in very poor condition that are only about 5 feet tall. These retaining walls are of unknown origin and are made of various concrete, wood, and metal materials. The retaining walls are restrictive to the flow in the river and vary between 12 to 15 feet apart. There are homes on one side of the riverbank right next to these retaining walls.

Photo 16. Retaining Walls.

The transition from the retaining walls into the box culvert under 400 South is also in poor condition. It appears that a thin layer of concrete was placed over the natural banks to help prevent erosion at the transition. This concrete is cracked and also causes a restriction to flow into the box culvert. Trees have grown in the channel behind this concrete liner which also restrict flow.

Photo 17. Transition into 400 South Box Culvert.

2.2 Available Data

The Culvert Restoration Plan is attached (Appendix A) as well as flood maps for each project location. The additional information is available for the project.

- Utility locations for American Fiber, Century Link and PacifiCorp.
- Soil conditions and calculations
- Structural calculations
- Channel slope calculations

2.3 Site Visits

The Culvert Restoration Plan has specific details for Locations 1 thru 7.

2.4 Proposed Action

AFC proposes to rehabilitate the following four locations as described below. All proposed design and construction procedures will meet the applicable NRCS standards and State Engineering criteria. The purpose is to maintain public safety around these structures and to protect surrounding areas from possible flood damage.

Location 1: Channel Improvements at 300 North

At this location, the upstream channel needs improvements to contain the flows and direct water to the existing box culvert under 300 North. The proposed improvements at this location include improving the embankments for approximately 350 feet upstream with 1.5-foot-high embankments, constructing new upstream and downstream wingwalls, and installing a new concrete apron will be placed on the downstream side at the outlet to protect against erosion. The embankments will be armored with gabions or riprap to protect against erosion. Trees and vegetation would be removed within the flow area. Other channel improvements may also be needed. These channel improvements would allow the 100-year flood to pass without any flooding upstream of the structure.

Location 2: Channel Improvements at 100 North and 200 East

At this location, channel improvements are needed to contain the flows and direct water to the existing box culvert beneath the intersection of 100 North and 200 East. The proposed improvements include reconstructing the embankments for approximately 350 feet upstream with 2.5-foot-high embankments and creating a new transition into the existing box culvert. The embankments will be armored with gabions or riprap to protect against erosion. Trees and vegetation would be removed within the flow area. Other channel improvements may also be needed. These channel improvements would allow the 100-year flood to pass without any flooding upstream of the structure.

Location 3: Channel Improvements at 200 South

There is an existing box culvert under 200 South which causes backup and flooding upstream of the structure. This section of river includes channel improvements to the concrete S-Channel floor to remove vegetation and repair eroded concrete. The improvements would also include removing energy dissipation baffle blocks that catch debris and cause backups in the channel that increase the flooding upstream of the structure. Riprap would be placed as erosion protection on the downstream banks instead of the baffle blocks. These improvements would allow the 100-year flood to pass without any flooding upstream of the structure and would prevent flooding the houses near the river. The existing culvert is anticipated to be replaced in the future under a separate action.

Location 4: Channel Improvements at 400 South

At this location, the upstream channel needs improvements to contain the flows and direct water to the existing box culvert under 400 South. The proposed improvement at this location includes widening the upstream channel and raising the riverbanks from 5 feet tall to 8 feet tall for approximately 300 feet using gabions. These improvements would allow the passage of the 100-year flood and would prevent flooding the houses near the river.

3.0 Existing Conditions – Lehi and Saratoga Springs Cities

3.1 Background/Existing Conditions

Developed areas in Lehi, Utah, have been flooded or are at risk for flooding along Dry Creek and the Waste Ditch (secondary canal which diverts excess water from Dry Creek and conveys it in a westerly direction to the Jordan River). In recent years, Lehi City, in partnership with private landowners and state agencies, has invested millions of dollars in improving the Dry Creek channel and the Waste Ditch in locations through the City. High flows have posed an increased threat to residential structures and Lehi Elementary School in the sections of the channel that have not been improved due to lack of sufficient financial resources.

3.2 Available Data

A preliminary flood map for the Dry Creek and Waste Ditch locations was created during the application process. It is attached to this document (Appendix B). Additional information is available for the project including:

- Utility locations for telecommunications/fiber optics, underground power, and gas lines.
- Soil conditions and calculations.
- Channel slope calculations.

3.3 Site Visits

Multiple site visits have been conducted through the early stages of this project. Site visits have occurred during and after flood events noting apparent infrastructure deficiencies and documenting these deficiencies with pictures. Additional site visits will be conducted to collect up-to-date field survey data for modeling purposes.

The following photos were taken during flood events for Dry Creek and the Waste Ditch.

Photo 4. Dry Creek Flooding in Lehi Elementary School Parking Lot.

Photo 5. Waste Ditch flooding in Lehi Elementary School Playground.

Photo 6. Dry Creek Flooding.

Photo 21. Waste Ditch Flooding.

Photo 22. Dry Creek Channel at Capacity. Photo Credit Matt Rascon.

3.4 Proposed Action

The proposed improvements would reconstruct several hundred feet of existing channel and box culverts to improve the channel capacity and hydraulics through the elementary school property, public transportation corridors, private property, and parks. It is also proposed that downstream portions of Dry Creek be improved to better convey high flow events to outfall at Utah Lake. Upgrades to the Dry Creek channel and the Waste Ditch would reduce the risk of flooding throughout the city. The proposed action consists of:

1) Lehi Elementary School Area and Willow Park Area:
    a. Replace the existing 48-inch aging culvert on the Waste Ditch through the school playground area with a 4-foot by 20-foot box culvert (approximately 350 linear feet).
    b. Widen and reconstruct the existing earthen Waste Ditch channel downstream of elementary school (near residential structures) with a new 15-foot-wide concrete channel with gabion basket walls (approximately 550 linear feet).
    c. Replace the existing 36-inch aging culvert on Dry Creek through the parking lot and playground of the elementary school with 5-foot by 12-foot box culvert (approximately 510 linear feet).
    d. Widen and reconstruct the existing earthen Dry Creek channel downstream of elementary school (near residential structures) with a new 12-foot-wide concrete channel with gabion basket walls (approximately 380 linear feet).
    e. Flooding occurs near the end of the Waste Ditch, approximately 1,400 ft upstream of its confluence with the Jordan River. This flooding occurs in an area called Willow Park. Most of the ground in this area is owned by Utah County and is under lease to Lehi City (long term lease). To prevent flooding from occurring in this area due to the upstream improvements, it is proposed that flood plain diversions be established to contain increased flows and prevent flooding of areas that were not flooded prior to the project. On the south side of the channel, a compacted earthen embankment is proposed, similar to a dike in nature, that will be grassed and become part of the park area. The road on the north side will be raised with imported gravel road base and reconstructed in order to

contain flood waters similar to how it has in the past. Parts of these improvements lie in the Jordan River Flood Plain area and will require a no-rise analysis be completed during the design portion of this project.

f. The culvert where waste ditch crosses 300 North is not properly sized to convey the design flows. It is proposed that the existing pipe culvert be replaced with a new 5-foot by 18-foot concrete box culvert. The channel upstream of Willow Park has largely been updated and reconstructed over the years as development has occurred. The 1000 feet of channel upstream of the 300 North crossing to Willow Park Road will be reconstructed and capacity increased to convey the design flows.

2) Lower Dry Creek Area

With the proposed improvements near Lehi Elementary School, the model also showed extensive flooding in downstream portions of Dry Creek and improvements have been proposed to reduce this flooding.

a. Rock lined channel improvements, including dredging and widening channel in areas to provide adequate channel capacity. These improvements are proposed to begin at 700 South and continue approximately 8,500 feet to approximately 300 feet upstream of the 1900 South box culvert. The channel dimensions will be 12 feet wide concrete floor, 2:1 riprap side slope, minimum average slope of 0.3%and 4.5 ft min channel depth. In several areas the channel is quite shallow and to provide proper channel depth, dredging of up to 2 feet will be required in some places.

b. Beginning 300 feet upstream of the 1900 South box culvert and extending to 300 feet downstream of the culver, a slightly different rock lined channel improvement, including dredging and channel widening is required to provide adequate channel capacity. The channel dimensions will be 14 feet wide concrete floor, 2:1 riprap side slope, minimum average slope of 0.23% and 5.5 ft min channel depth. In several areas the channel is quite shallow and to provide proper channel depth, dredging of up to 2 feet will be required in some places.

c. The box culvert at 1100 West is slightly smaller than the typical proposed box culvert in this project, however, it is not installed at the proper depth to properly convey flows through this channel reach. It is proposed to be replaced by a 5-foot by 12-foot box culvert to provide adequate hydraulic capacity.

d. Replace existing box culvert at 1700 West with 5-foot by 12-foot box culvert to provide adequate hydraulic capacity.

e. Replace existing box culvert at 1900 South with 5-foot by 14-foot box culvert to provide adequate hydraulic capacity. The channel in this area will need to be modified slightly from the general design plans.

f. Similar to the rock lined channel improvements mentioned above, from 300 feet downstream from the 1900 South to outfall in Utah Lake, the channel will be dredged to the same dimensions as the rock lined channel, however, the channel will not receive armoring in this area as it is outside of developable land and generally considered Utah Lake flood area. This channel reach is approximately 1,700 feet in length.

Appendix A. American Fork Culvert Restoration Plan

American Fork River

CULVERT RESTORATION PLAN

American Fork City

JUNE 2018

Prepared by

FRANSON CIVIL ENGINEERS

Table of Contents

1.0 GENERAL INFORMATION

1.1 Statement of Purpose

The American Fork River winds through the City of American Fork. There are many areas of the river where the flow has been channelized with either a closed-top box culvert or an open-top rectangular concrete channel. Some of the concrete has been eroded over the years and needs repair before failure of the channel occurs. American Fork City has contracted with Franson Civil Engineers to assess the existing facilities and propose options for repair or replacement. There are four sites that have been evaluated: the dual pipe culverts at 400 North and 400 East, the portion of the box culvert south of State Street under the O'Reilly Auto Parts parking lot, the open channel just south of this parking lot, and the box culvert under 200 South.

2.0 LOCATION 1 – 400 NORTH 400 EAST

The American Fork River crosses the intersection of 400 North and 400 East diagonally from the northeast to the southwest. Upstream of this culvert the river is an unimproved natural channel. There is a large headwall on the upstream side that directs the flow of the river into two parallel reinforced concrete pipes (RCP). These pipes cross the intersection and discharge into a concrete rectangular channel on the other side.

Photo: RCP with Exposed Rebar

2.1 Issues at This Site

In general, the upper part of the dual RCP is in very good condition. The issue with these pipes is that the concrete at the invert has been eroded and the reinforcement has been exposed. The reinforcement itself only has minor corrosion so far, but will continue to corrode quickly if left exposed.

Photo: Close View of RCP with Exposed Rebar

Also, some of the joints between the RCP sections are wide or are disconnected. This is causing additional erosion on the floor of the pipes downstream of the joints. The split of the flow at the dual pipes creates a place for debris to catch and requires extra time and effort by maintenance crews to avoid blockages during high spring flows.

Photo: RCP with Wide Gaps at Joints

2.2 Rehabilitation Options

As a temporary solution to the eroded pipe and exposed reinforcement, a high-strength non-shrink grout could be used to replace the eroded concrete and fill the joint gaps. The bottom of the pipes and exposed reinforcement would have to be sandblasted before application of the grout. This would extend the life of the existing pipes by 5 to 15 years and would not reduce the flow capacity of the crossing. The one downside to this option would be that it would not address the problem with debris catching at the upstream end between the pipes.

A long-term solution to all the issues at this site would be to excavate and remove the dual RCP and replace it with a box culvert. This would require the complete replacement of the upstream headwalls and would require a lengthy shutdown of the intersection during construction. It would also likely require the looping of culinary and secondary water lines under the box culvert.

2.3 Cost of Solutions

Rough cost estimates for these options were created. These cost estimates are for comparison purposes only. Until the rehabilitation options are fully designed, a detailed cost estimate is not possible. A rough estimate for the short-term solution to repair the existing pipes with grout is $57,000. A rough estimate for the long-term solution to remove the RCP and replace it with a box culvert is $598,000. A breakdown of these costs can be found in Appendix A.

3.0 LOCATION 2 – BOX CULVERT SOUTH OF STATE STREET

The box culvert that crosses under State Street starts near the Whistle Wok on 200 East and runs south under the strip mall parking lots, State Street, and then the O'Reilly Auto Parts parking lot. The box culvert discharges into a rectangular concrete open channel just south of this parking lot.

Photo: Exit of Box Culvert

3.1 Issues at This Site

The box culvert appears to be in very good shape within the UDOT Right-of-Way until it gets south of State Street. The box culvert under State Street and north of State Street appears to be relatively new and is in great condition. The area that needs to be rehabilitated is under the O'Reilly Auto Parts parking lot south of State Street. In this section of the box culvert, the concrete floor of the structure has eroded, and is estimated to average about 3 inches thick. This erosion is much worse than the dual RCP pipes discussed previously, and some parts of the floor have eroded all the way through the concrete and rebar. In these areas, the underlying material has started to wash out, leaving voids under the concrete. If enough material is washed out of these holes in the concrete, the entire box culvert could settle, causing the parking lot above it to sink also.

Photo: Box Culvert Floor Erosion

3.2 Rehabilitation Options

The priority at this site would be to stabilize the box culvert by filling in the voids under the concrete. The loose material would have to be removed by hand and then a flowable fill concrete or a pressure grout could be used to fill the voids up to the bottom of the existing concrete. This solution would stabilize the box culvert, but is a short-term solution since the entire floor of the box culvert is so thin that more voids will inevitably open up.

The walls and ceiling of this box culvert appear to be in good shape from a visual inspection of the interior of the culvert, so removal and replacement of the entire box culvert is not likely necessary. Instead, rebar and a concrete overlay could be installed inside of the existing box culvert to reinforce the floor of the structure. This option would be a long-term solution to the erosion of the concrete floor. The transition between the good UDOT floor upstream and the new floor would be critical to the design to avoid future problems with erosion of the concrete. There would be some reduction of the flow capacity of the box culvert since the elevation of the floor would have to be raised. If this reduction in capacity is not acceptable, then the existing concrete floor would have to be removed and completely replaced, which would extend the construction time and increase the cost of the rehabilitation.

Another option for repair of the floor, instead of pouring a new floor, would be to use a high-strength grout. The grout would not have to be the full thickness of a new floor but would just have to replace the eroded concrete. A wire mesh reinforcement would still be needed and the existing concrete floor would have to be cleaned perfectly to get a good bond between the concrete and the grout. This option would not be a permanent solution to the problem but would delay replacement of the floor for 5 to 15 years.

3.3 Cost of Solutions

A rough estimate to fill the voids with flowable fill concrete is $58,000. This will have to be done first in conjunction with either of the rehabilitation options. A rough estimate for the long-term solution to overlay the existing floor with rebar and concrete is $145,000. A rough estimate for the short-term solution to overlay the existing floor with grout is $129,000. A breakdown of these costs can be found in Appendix A.

4.0 LOCATION 3 – OPEN CHANNEL SOUTH OF STATE STREET

Where the river channel exits the box culvert under State Street, it opens into a rectangular concrete channel. This channel winds through the neighborhood to the south of State Street and ends at 200 South.

Photo: Open Channel Floor Rebar Exposed

4.1 Issues at This Site

The issue along this section of the river is the concrete floor. The walls are in good shape, but there is a groove eroded in the floor along the entire length of the channel. The rebar in the floor is exposed in this groove throughout this section, and where it is exposed, there are several places where the rebar has completely eroded away. There are a few areas where the groove has eroded all the way through to the soil under the concrete floor and vegetation has started to grow.


Photo: Open Channel Groove in Floor

4.2 Rehabilitation Options

Options for rehabilitation of this groove are similar to the options for the repair of the floor in the box culvert. An entirely new reinforced concrete floor can be poured over the top of the existing floor. Or high-strength grout with a wire mesh can be placed in the groove. Eventually, the entire floor will have to be replaced or overlaid so placing grout in the groove is a temporary solution.

4.3 Cost of Solutions

A rough estimate for the long-term solution to overlay the existing floor with rebar and concrete is $706,000. A rough estimate for the short-term solution to place grout in the groove is $155,000. A breakdown of these costs can be found in Appendix A.

5.0 LOCATION 4 – BOX CULVERT UNDER 200 SOUTH

The road crossing of the American Fork River at 200 South is a 2-bay box culvert. This road crossing is near Greenwood Elementary School and carries heavy bus traffic during the school year. It appears that the original concrete structure was cast-in-place. The channel upstream is an open rectangular channel. There is an energy dissipation structure on the outlet of the box culvert which discharges back into an unlined river channel.

Photo: 200 South Box Culverts

5.1 Issues at This Site

The original structure has been repaired several times in the past. Evidence suggests the roof of the box culvert had lamination of the concrete cover over the rebar and the rebar, being exposed, started to rust and corrode. A new layer of concrete with a thin reinforcement of welded wire mesh was placed in the ceiling of the box culvert to try to cover and preserve the rebar. This welded wire mesh is now exposed and is corroding badly. For the most part, the original rebar is still covered by this additional layer of concrete.

The extent of the damage to the original rebar is impossible to determine since it is covered up. Where the original rebar is exposed in the ceiling of the structure, approximately half of the steel has corroded away. If the rusting of the previously exposed rebar has continued, the structural integrity of the bridge could be jeopardized.

Photo: 200 South Culvert Ceiling Exposed Rebar

The other repair, which looks more recent, was to add concrete to the wall and center pier of the culvert. This concrete extends about half the way up the walls of the culvert. This concrete is in good shape and is protecting the structural integrity of the walls and center pier.

Photo: 200 South Culvert Recent Repair

Another issue at this site is the discharge of 8-inch or 10-inch storm drain pipes into the box culvert. The storm drain pipes may have been grouted into the box culvert at one time, but the grout has eroded away and the pipe has become disconnected from the box culvert wall. Stormwater from this pipe is most likely running into the void between the outside of the box culvert and the backfill material. If this continues, it is likely that a sinkhole will develop in the road just outside of the box culvert.

Photo: Storm Drain in Side of 200 South Culvert

5.2 Rehabilitation Options

The critical issue at this site is the structural integrity of the bridge. The first option to repair the bridge would be to extend the new concrete on the wall and pier up to the ceiling and place a new ceiling inside of the existing box structure. This new ceiling would have to be designed to carry the full traffic loading since it can be assumed that the old ceiling will eventually have no structural strength of its own. This option would slightly reduce the flow capacity of the culvert.

The second option would be to remove and completely replace the structure with a new box culvert. The new box culvert could be designed to eliminate the center pier. This would require closure of the road for an extended period of time during construction. The benefit of this option would be to remove the unknown variable of the existing concrete ceiling. With either of these options, the disconnected storm drain pipes would have to be extended and grouted in.

5.3 Cost of Solutions

A rough estimate to install a new concrete ceiling within the existing structure is $132,000. A rough estimate to replace the entire structure with a box culvert is $428,000. A breakdown of these costs can be found in Appendix A.

6.0 SUMMARY AND CONCLUSIONS

The two critical sites that are in danger of structural failure are the box culvert south of State Street and the box culvert at 200 South. We recommend that these two sites be addressed first. With the short-term solutions proposed, these sites can be stabilized until a permanent solution to the structural issues can be designed and implemented.

Once these two sites are stabilized, we would recommend addressing the RCP at 400 North and 400 East and the open channel south of State Street. These two sites are structurally stable for now, so their rehabilitation is not immediately critical. We do recommend periodic inspections of the facilities. Spring runoff and larger storm events can often damage an already weakened structure.

APPENDIX C

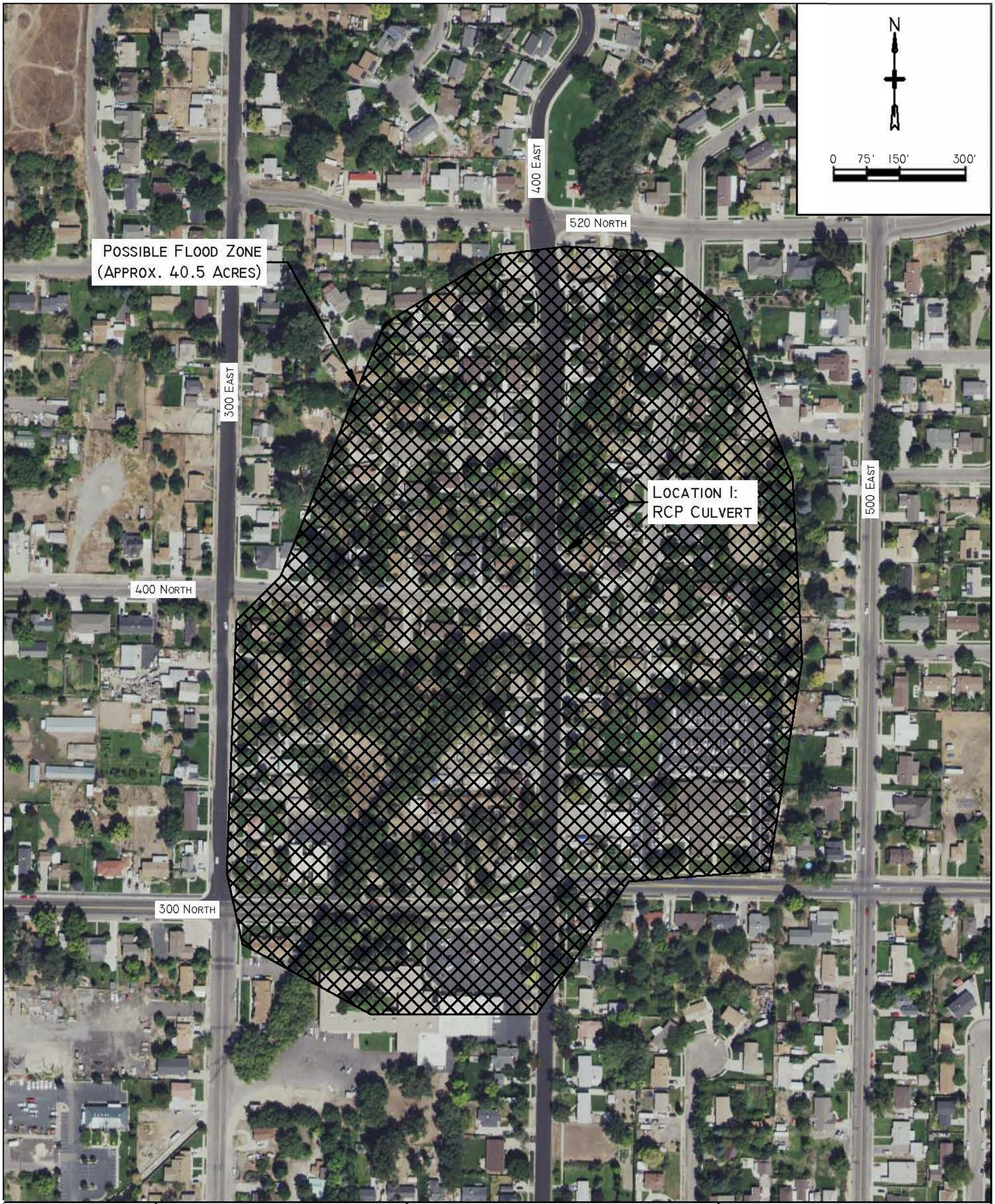
Photos – Location 5

Photo 1. Upstream condition of box culvert at 100 North and 200 East (Location 5).

Photo 2. Deteriorating concrete and exposed rebar.

Photo 3. Downstream condition of box culvert at 100 North and 200 East.
Note the missing baffle blocks.

FRANSON CIVIL ENGINEERS	DATE: JULY 17, 2019 SCALE: Figures.dwg P:\UT\Central\American Fork\AFC NRCS PL566 Application\3-Drawings LAYOUT: Overall	AMERICAN FORK CITY AMERICAN FORK RIVER CULVERT RESTORATION	OVERVIEW OF PROJECT LOCATIONS ALONG AMERICAN FORK RIVER



FRANSON CIVIL ENGINEERS

DATE: June 24, 2019

SCALE:

Figures.dwg
P:\UT\Central\American Fork\AFC NRCS PL566 Application\3-Drawings

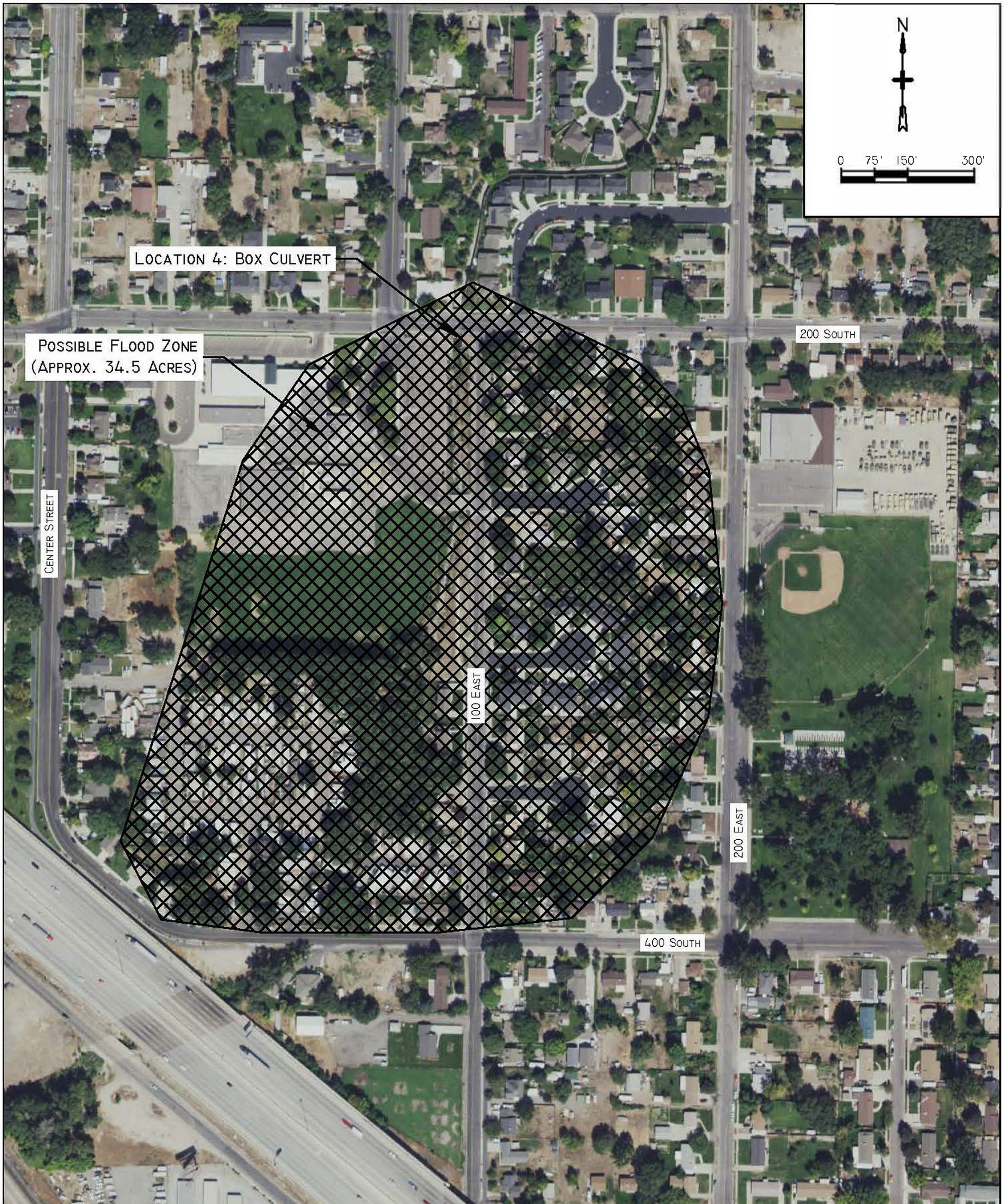
American Fork City

American Fork River
Culvert Restoration

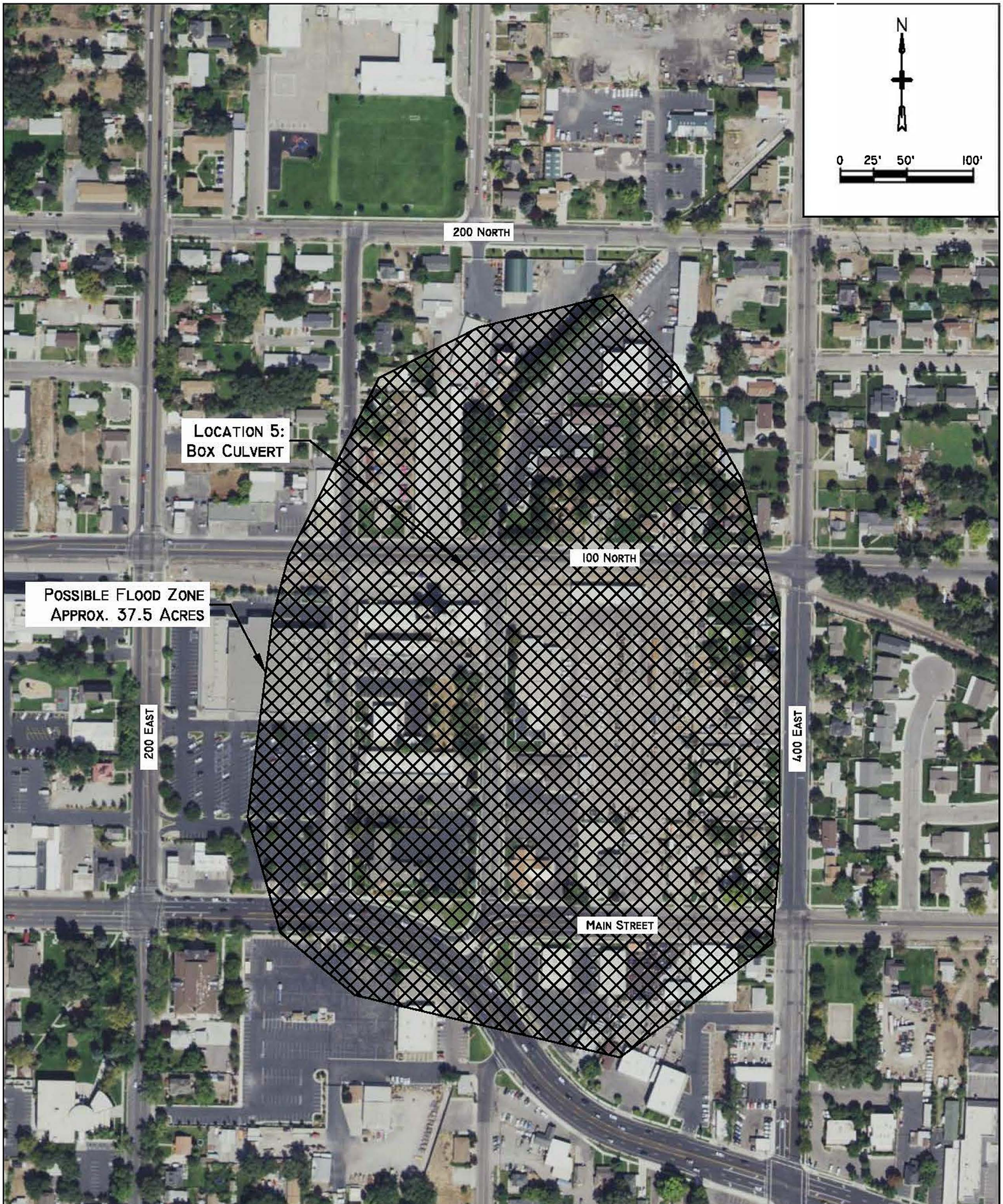
Location 1

RCP Culverts Beneath
400 North and 400 East

FRANSON CIVIL ENGINEERS	DATE: June 24, 2019 SCALE: Figures.dwg P:\UT\Central\American Fork\AFC NRCS PL566 Application\3-Drawings	American Fork City American Fork River Culvert Restoration	Location 2 & 3 Box Culvert and Rectangular Concrete



FRANSON CIVIL ENGINEERS	DATE: June 24, 2019 SCALE: Figures.dwg P:\UT\Central\American Fork\AFC NRCS PL566 Application\3-Drawings	American Fork City American Fork River Culvert Restoration	Location 4 Box Culvert Beneath 200 South and 100 East



FRANSON CIVIL ENGINEERS

DATE: JULY 17, 2019
SCALE:
Figures.dwg
P:\UT\Central\American Fork\AFC NRCS PL566 Application\3-Drawings
LAYOUT: Location 6

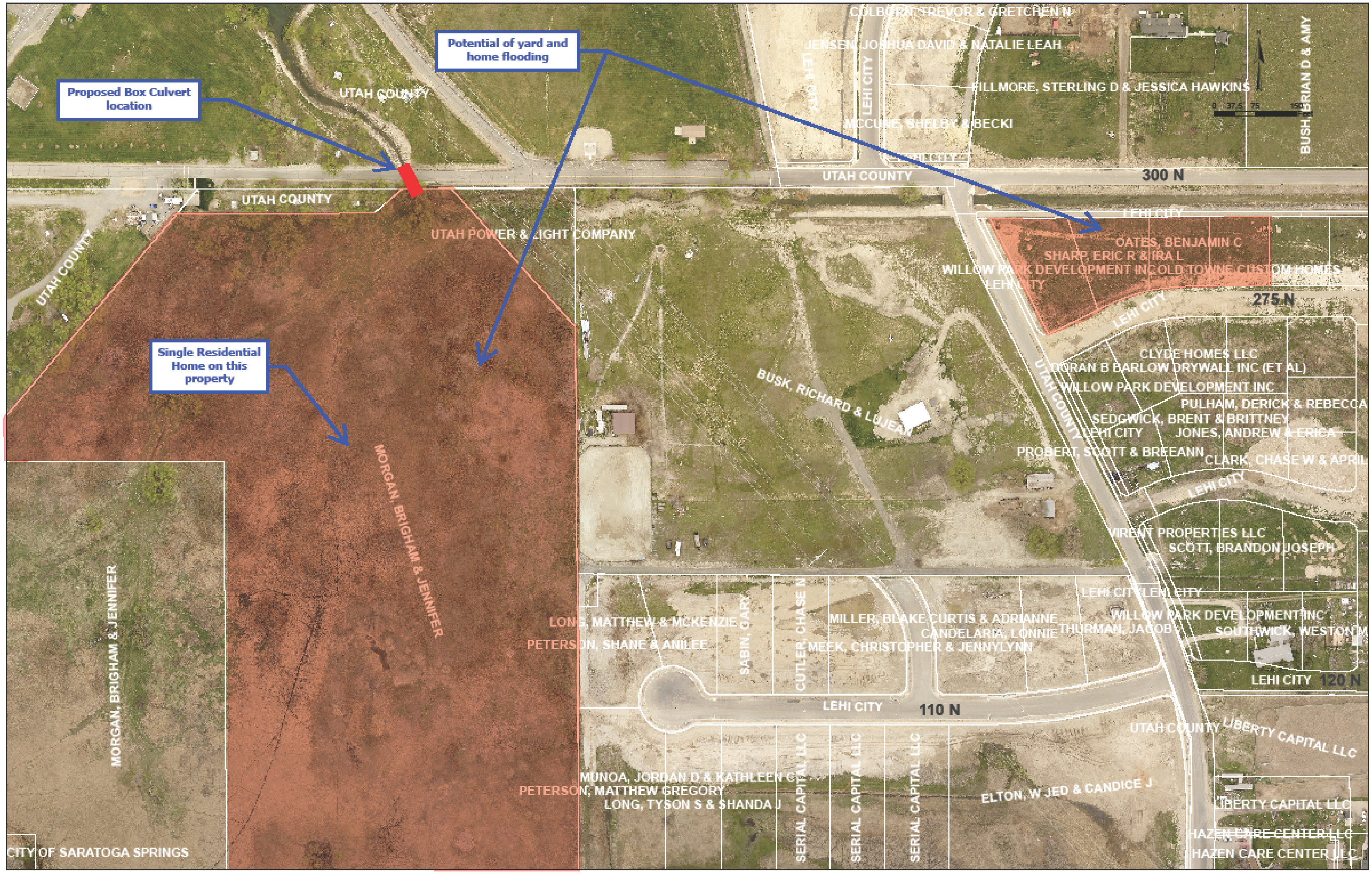
AMERICAN FORK CITY

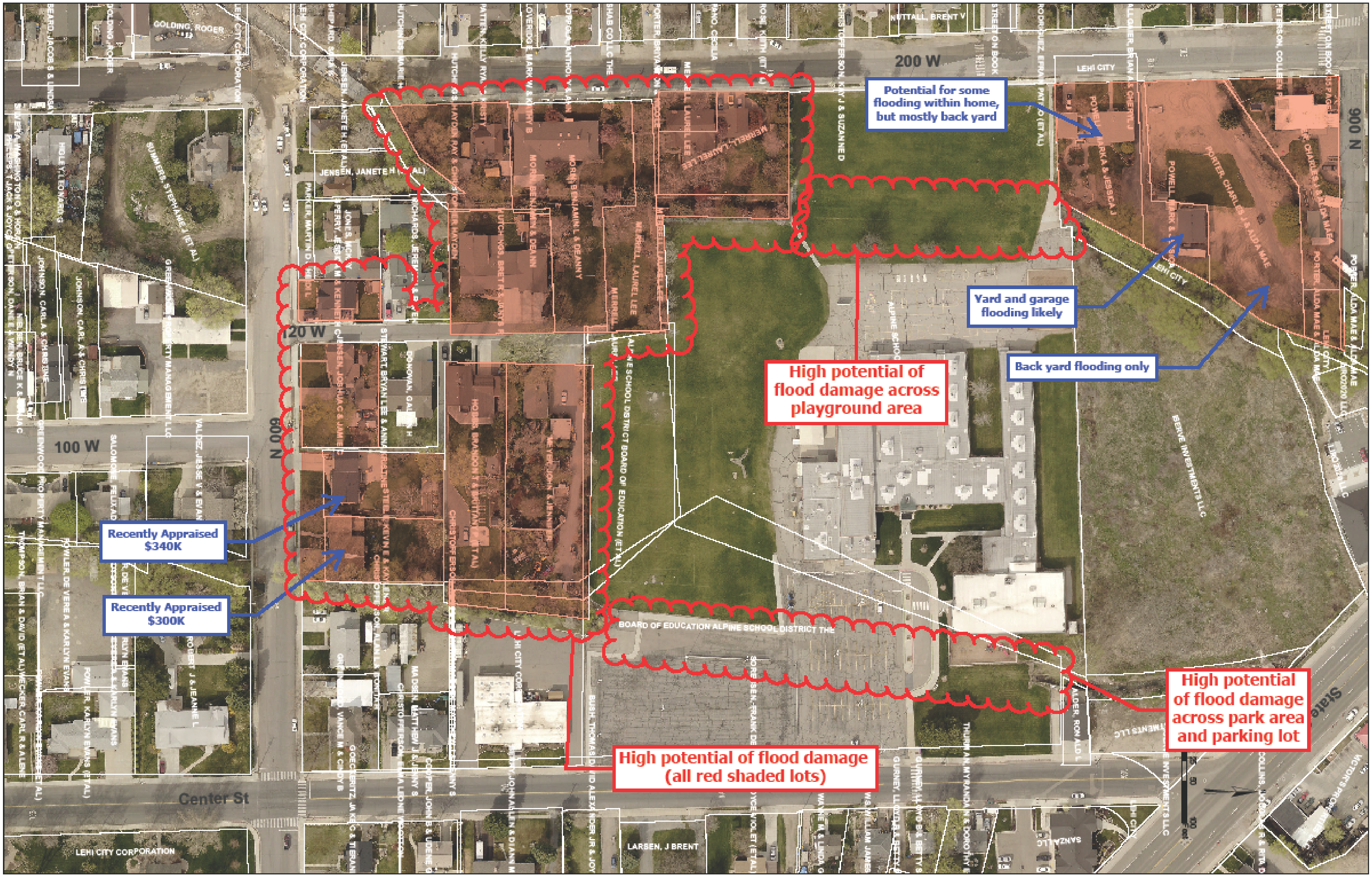
AMERICAN FORK RIVER CULVERT RESTORATION

LOCATION 5

BOX CULVERT BENEATH 100 NORTH AND 200 EAST

Appendix B. Lehi City Preliminary Flood Map


Proposed Box Culvert location
Potential of yard and home flooding
Single Residential Home on this property
UTAH COUNTY
UTAH POWER & LIGHT COMPANY
MORGAN, BRIGHAM & JENNIFER
300 N
275 N
110 N
120 N
LEHI CITY
CITY OF SARATOGA SPRINGS
OATES, BENJAMIN C
SHARP, ERIC R & IRA L
WILLOW PARK DEVELOPMENT INC
OLD TOWNE CUSTOM HOMES
BUSK, RICHARD & LUJEAN
CLYDE HOMES LLC
LIBERTY CAPITAL LLC
HAZEN CARE CENTER LLC
SERIAL CAPITAL LLC
ELTON, W JED & CANDICE J
FILLMORE, STERLING D & JESSICA HAWKINS
MCCUNE, SHELBY & BECKI


Potential for some flooding within home, but mostly back yard
Yard and garage flooding likely
Back yard flooding only
High potential of flood damage across playground area
Recently Appraised $340K
Recently Appraised $300K
High potential of flood damage across park area and parking lot
High potential of flood damage (all red shaded lots)
200 W
100 W
120 W
600 N
900 N
Center St

Attachment 2

Technical Memo 002 – Design Criteria

TM002 – Design Criteria

Table of Contents

Tables

1.0 Introduction

The U.S. Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS) and American Fork City as the project sponsor, and Lehi City and Pleasant Grove City as project co-sponsors have initiated a Supplemental Watershed Plan-Environmental Assessment (Plan-EA) of the American Fork River watershed in Utah County. The study includes evaluating how to reduce flooding in American Fork City, Lehi City, and Pleasant Grove City, that are within the aforementioned watershed. The purpose of Technical Memorandum 2 (TM002) is to identify the design criteria to meet NRCS and other applicable requirements.

This project is intended to address existing and future flooding issues in the American Fork River watershed. The proposed solutions to mitigate these issues involve the rehabilitation of several existing natural and flood channels and culverts in order to increase channel capacity and reduce flood risk for critical infrastructure.

The feasibility of rehabilitating these flood channels and culverts has been evaluated and a list of design criteria relating to these elements is presented in this technical memo. Note that this list includes NRCS and other applicable design standards and requirements such as from local municipalities, including the storm drainage ordinances, and Utah Department of Transportation (UDOT). Table 1 summarizes the applicable design standards upon which the 30% design for the project is based, and details the future final design standards.

Table 1: Design Criteria Utilized for Each Project Element

Design Criteria & Practice Standards	Channel Reconstruction	Box Culvert Reconstruction
NRCS Technical Release – 67 (TR-67)	X	X
American Concrete Institute – 318 (ACI -318)	X	X
American Concrete Institute – 350 (ACI -350)	X	X
NRCS National Engineering Handbook (NEH)	X	X
NRCS National Engineering Manual (NEM)	X	X
NRCS – UT 210 – Part 536 - Structural Engineering	X	X
NRCS Structure for Water Control (Code 587)		X
NRCS Open Channel (Code 582)	X	X
NRCS Lined Waterway or Outlet (Code 468)	X	X
NRCS Irrigation Pipeline (Code 430)	X	

Design Criteria & Practice Standards	Channel Reconstruction	Box Culvert Reconstruction
Storm Water Management Plans • **American Fork City** • **Lehi City** • **Pleasant Grove City**	X	X
UDOT Drainage Regulations • **State Street (Am. Fork)** • **PG BLVD outfall at 200 W.** • **I-15 (Lindon)**	X	X

2.0 Design Criteria

2.1 NRCS Technical Release 67 (TR-67)

TR-67 (NRCS 1980) provides minimum requirements for designing of reinforced concrete structures based on the strength design method. TR-67 will be applied to structural concrete sections, elements, and structures as directed by governing NRCS criteria, specifically the NEM and UT-210 – Part 536.

2.2 American Concrete Institute – 318 (ACI-318)

ACI – 318 pertains to design and construction requirements of structural concrete. This code will be used as referenced by NRCS design criteria and standards.

2.3 American Concrete Institute – 350 (ACI-350)

ACI – 318 pertains to design and construction requirements of environmental engineering concrete structures. This code will be used as referenced by NRCS design criteria and standards.

2.4 NRCS National Engineering Handbook (NEH)

The National Engineering Handbook (NEH; NRCS 2020a) provides design criteria for a number of different engineering applications. Only design criteria applicable to hydraulic structures and open channel modeling and design are included in this TM.

2.5 NRCS National Engineering Manual (NEM)

The National Engineering Manual (NEM; NRCS 2017) provides design policy for a number of different engineering applications. Only design policy applicable to hydraulic structures and open channel modeling and design are included in this TM.

2.6 NRCS - UT 210 – Part 536 Structural Engineering

UT 210 – Part 536 – Structural Engineering serves as a design criteria supplement for reinforced concrete structures. The table included in this reference, *Design Guidance for Reinforced Concrete*, contains applicable references/codes and design criteria that apply to different types of structures. It is anticipated that the proposed improvements for this project will fall into the *Service Hydraulic Structures* category.

2.7 CPS 430 - Irrigation Pipeline

NRCS Code 430 provides the minimum design criteria for water conveyance pipelines. The proposed project includes piping storm water in the PG BLVD Outfall from Pleasant Grove City and conveying it from a collection area to an existing open channel on 2000 West (Lindon) and thence to Utah Lake. An existing 48” culvert/pipeline will be replaced at Lehi Elementary School to safety convey water past the school playground and parking lot, discharging it back into the waste ditch downstream of the school.

2.8 CPS 468 - Lined Waterway or Outlet

NRCS Code 468 provides the minimum design criteria for lined waterways and outlets to provide safe conveyance of runoff from conservation structures, reduce erosion, stabilize existing and prevent future fully erosion, and to protect and improve water quality. The proposed design contains sections of lined channels in American Fork, Lehi, and Pleasant Grove Cities to safely convey flood waters through residential and commercial areas, as well as past schools, roads, and other critical infrastructure.

2.9 CPS 582 - Open Channel

NRCS Code 582 provides the minimum design criteria for improvement, construction, and restoration of open channels (NRCS 2015). The proposed project contains multiple flood channels. These flood channels require improvement and increased hydraulic capacity to convey flood flows. New portions of these flood channels will also be constructed to improve flood management and water conveyance.

2.10 CPS 587 - Structure for Water Control

NRCS Code 587 provides the minimum design criteria for water management systems that control the stage, discharge, distribution, delivery, or direction of water flow. The proposed design includes several culvert replacements (increased hydraulic capacity). These water control structures will be designed in accordance with NRCS Code 587 (NRCS 2005).

2.11 City Storm Water Management Plans

2.11.1 American Fork Standards and Storm Water Technical Manual

American Fork City Standards and Storm Water Technical Manual provides sizing standards for culverts and other storm water conveyance structures in American Fork City limits. This sizing criteria will be used to size box culverts on roads intersected by the American Fork River, including: 400 North and 400 East, State Street, 200 South, and 100 North.

2.11.2 Lehi City Storm Water Management Program

Lehi City Storm Water Management Program provides sizing standards for culverts and other storm water conveyance structures in Lehi City Limits. This sizing criteria will be used to size box culverts on roads intersected by Dry Creek and the waste ditch, including the entrance road to Willow Park and the Lehi Elementary playground area.

2.11.3 Pleasant Grove City Storm Water Management Plan

Pleasant Grove City Storm Water Management Plan provides sizing standards for culverts and other storm water conveyance structures in Pleasant Grove City limits. Sizing criteria within the plan in conjunction with their Storm Water Master Plan was used to size box culverts on roads intersected by the PG BLVD Outfall, including: 2000 West (Lindon), 140 South (2000 West Lindon), various driveways on 2000 South (300 North Lindon), 200 South (2000 West Lindon) and 2000 West (220 South Lindon).

2.12 <u>UDOT Drainage Manual of Instruction</u>

Utah Department of Transportation has provided this technical reference as a guide to design drainage structures and components in areas of UDOT jurisdiction. Design criteria pertaining to this project will be utilized on all UDOT drainage structure along with applicable NRCS and other design standards.

3.0 References

_____. 1980. Reinforced Concrete Strength Design, Technical Release (TR) 67. Natural Resources Conservation Service.

American Concrete Institute (ACI). 2014. ACI -318: Building Code Requirements for Structural Concrete

American Concrete Institute (ACI). 2006. ACI -350: Code Requirements for Environmental Engineering Concrete Structures and Commentary

Natural Resources Conservation Service (NRCS). 2020a. National Engineering Handbook (NEH).

Natural Resources Conservation Service (NRCS). 2017. National Engineering Manual (NEM).

Natural Resources Conservation Service (NRCS). 2019. UT 210 – Part 536 Structural Engineering

_____. 2014. Irrigation Pipeline – Code 430. Natural Resources Conservation Service.

_____. 2010. Lined Waterway or Outlet – Code 468. Natural Resources Conservation Service.

_____. 2015. Open Channel – Code 582. Natural Resources Conservation Service.

_____. 2014. Structure for Water Control – Code 587. Natural Resources Conservation Service.

American Fork City Standards and Storm Water Technical Manual

Lehi City Storm Water Management Program Manual – 2020

Pleasant Grove City Storm Water Management Plan – 2016

Utah Department of Transportation – 2018. Drainage Manual of Instruction

Attachment 3

Technical Memo 003 – Hydrology

TM003 – Hydrology

Table of Contents

Figures

Tables

1.0 Introduction

American Fork City and Lehi City are collectively working with Franson Civil Engineers and Jones & DeMille Engineering (JDE), respectively, to complete a Natural Resources Conservation Service (NRCS) Supplemental Watershed Plan-Environmental Assessment (Plan-EA) of the American Fork River and Dry Creek watersheds located in Utah County. The study includes evaluating how to reduce flooding in American Fork City and Lehi City that are within the aforementioned watershed.

The purpose of this technical memo is to describe the methods, procedures, and results of the hydrologic analysis performed for the Plan-EA.

1.1 Design Criteria Overview

The hydrologic analysis for this Plan-EA follows the guidelines outlined in the NRCS National Engineering Handbook (NEH) Part 630 – Hydrology. The recurrence-interval storms to be included in this hydrologic analysis are the 10-, 25-, 50-, 100-, 200-, and 500-year 24-hour duration storm events.

The hydrographs produced from this hydrologic analysis will be used for the hydraulic modeling of the existing and proposed conditions. The modeling of the hydrographs is described in *TM004 – Frequency Flood Routing.* The peak flows presented in this report will be used to design the proposed improvements such as culvert sizes and widening of existing open channels. The proposed improvements are described in *TM005 – Hydraulic Analysis*.

The design criteria for each proposed improvement shall meet the NRCS and respective city standards listed in *TM002 – Design Criteria*. For American Fork City, the proposed improvements shall be designed for the 100-year storm event (American Fork City, 2008). For Lehi City, the proposed improvements along Dry Creek and Waste Ditch shall at minimum be designed for the 50-year 24-hour storm event (Lehi City, 2016).

2.0 Previous Hydrologic Studies

2.1 American Fork River

URS Corporation prepared a hydrology report for the American Fork River in 2009 (URS, 2009) to update the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM) in Utah County. The study evaluated the peak flows for the river previously developed by the U.S. Army Corps of Engineers (USACE) and FEMA hydrologic studies. URS analyzed the peak flows for the river with a Bulletin 17-B analysis (USGS, 1981) and with the USGS Regression Equation (USGS, 2008). A summary of the developed peak flows from the report are included in Table 2-1.

Table 2-1. Summary of Peak Flows for American Fork River (URS, 2009)

Recurrence Interval	FEMA FIS (cfs)	USACE (cfs)	Bulletin 17-B (cfs)	USGS Regression (cfs)
10-yr	590	--	641	555
50-yr	1,750	--	843	741
100-yr	2,440	2,400	920	809
500-yr	3,660	4,300	1,082	985

URS concluded that the peak flows produced from the Bulletin 17-B and regression methods suggest that the FEMA and USACE studies overestimate the flows for the American Fork River. To support this, URS compared the American Fork River results with similar hydrologic studies for Alpine City and the Lower Provo River. Therefore, the peak flows from Bulletin 17-B analysis were used for the American Fork River. To be conservative, the upper limits of the 95% confidence interval for the 50-, 100-, and 500-year flood events were used. For more information, refer to URS's *Utah County Hydrology Report for a Detailed Study on the American Fork River* (URS, 2009).

The findings from the URS hydrologic study for the American Fork River produced reasonable reductions to the peak flows based on the extensive stream gage data available. Therefore, a similar approach was conducted to calibrate the hydrology for American Fork River, which is discussed in Section 5.1.

2.2 Dry Creek

Ames-Wadsworth Brothers Joint Venture (A-W) prepared a hydraulics report for Utah Department of Transportation's (UDOT) I-15 and Lehi Main to SR-92 Widening Structure (UDOT, 2018). The study evaluated the Dry Creek hydrology up to I-15 to design the proposed 12' x 7' box culvert improvement crossing beneath I-15. The report evaluated FEMA's FIRM along Dry Creek and determined the peak flows from FEMA's hydrologic study may be overestimated. After evaluating several other hydrologic methods (stream gage records, NSS regression equations, and previously conducted hydrologic models), A-W determined their final peak flows from the USGS Regression Equation method multiplied with a 1.39 factor (UDOT, 2018). The proposed peak flows were submitted to FEMA as a CLOMR application. A summary of peak outflows for the Dry Creek Debris Basin is shown in Table 2-2. The report also provides the developed rating curve for the proposed 12' x 7' box culvert crossing beneath I-15 (see Section 3.4.5).

Table 2-2. Summary of Peak Flows for Dry Creek Debris Basin (UDOT, 2018)

Recurrence Interval	FEMA FIS (cfs)	UDOT (cfs)
10-yr	480	490
50-yr	1,050	800
100-yr	2,000	930
500-yr	3,600	1,290

The peak flows determined in the A-W report were significantly lower than those developed by FEMA. The Dry Creek Debris Basin is also currently undergoing modifications that would affect the hydrology performed in the A-W report. Therefore, in an effort to be conservative, the hydrologic analysis for Dry Creek will be primarily based on NEH Part 630 methods and compared with the FEMA peak flows to check for reasonableness.

3.0 Watershed Characterization

All watersheds delineated for this project are located within Utah County, Utah. For the American Fork City portion of the analysis, the main drainage features within the watersheds consists of the American Fork River, Silver Lake Flat Dam, Tibble Fork Dam, the American Fork Irrigation Company diversion, and the American Fork Debris Basin. For Lehi City, the main drainage features within the watersheds consists of Fort Creek, Dry Creek, the Dry Creek Debris Basin, the box culvert at I-15, the Waste Ditch and Dry Creek Diversion, as well as a few irrigation diversions along Dry Creek.

Information on the proposed project locations within the watersheds is provided in *TM001 – Existing Conditions*.

3.1 Topographic Characteristics

The best available topographic data for the Wasatch Range mountains is a 2018 0.5-feet resolution LiDAR surface. For Utah Valley (American Fork, Lehi, Pleasant Grove, and surrounding cities), the best available surface is a 2013 0.5-feet resolution surface which covers the valley floor up to the foothills of the Wasatch Range mountains. Both surfaces were received from Utah's Automated Geographic Reference Center (AGRC) (Utah AGRC, 2021). The 2018 and 2013 LiDAR surfaces were used to determine watershed boundaries, elevations, slopes, longest flow paths, etc. The delineated watersheds and longest flow paths are shown in Exhibits 1 and 2 (see Appendix A). A summary of delineated watershed areas and longest flow paths is provided in Table 3-1.

A tour of the watershed was completed on June 10, 2021 to confirm watershed attributes such as the delineated watershed boundary, drainage features, land cover types, soil conditions, development, etc.

Table 3-1. Delineated Watersheds and Longest Flow Paths

Watershed	Area (sq. mi.)	Longest Flow Path (mi)
American Fork		
SL-01	4.3	4.6
TF-01	35.5	11.4
AF-01	24.8	14.1
AF-02	1.4	15.7
AF-03	0.2	1.9
AF-04	0.1	1.2
AF-05	0.8	4.8
Lehi		
FC-01	10.5	8.3
DC-01	20.5	10.9
DC-02	8.4	5.3
DC-03	0.5	2.2
DC-04	1.4	3.1

3.2 Land Cover

Land cover data from the 2016 National Land Cover Database (NLCD) (MRLC, 2018) and best available aerial imagery was utilized to characterize the watersheds according to land cover types found in NEH Part 630 Chapters 8 (NRCS, 2002) and 9 (NRCS, 2004a). The land cover classifications and their areas within with delineated watershed shown on Exhibit 1 (see Appendix A). The chosen hydrologic condition for each land cover was based on aerial imagery and observations made while touring the watershed.

3.3 Soil Types

Soil Survey Geographic Database (SSURGO) 2019 soil data was downloaded from the NRCS's Web Soil Survey (NRCS, 2019). The soil data includes the hydrologic soil group (typically classified as A, B, C, D) for the soils located within the delineated watersheds, which is shown in Exhibit 2 (see Appendix A). Note that the received SSURGO soil data had small areas with unclassified hydrologic soil groups. For these areas, the unclassified soil group was assigned based on surrounding soils groups.

3.4 Drainage Features

There are several major drainage features (dams, debris basins, irrigation diversions, and culverts) within the watersheds for this project. For the smaller irrigation diversions, it was conservatively assumed that the irrigation conveyance facilities (except for the American Fork Irrigation Company diversion) were running at full capacity; therefore, no water leaves the hydrologic routing at these irrigation diversions. For other major drainage facilities, data was gathered in order to account for them in the hydrologic modeling. A summary of this information is provided below. See Exhibit 1 and Exhibit 2 in Appendix A for the structure locations.

3.4.1 Silver Lake Flat Dam and Tibble Fork Dam

The record drawing sets for Silver Lake Flat Dam (dated May 15, 2015) and Tibble Fork Dam (dated May 2, 2016) were obtained from the NRCS to account for the dams' stage-storage and stage-discharge curves (see Appendix B). Where these are water storage reservoirs, it was assumed that the initial reservoir water elevation for each dam was at the auxiliary spillway crest elevation.

3.4.2 American Fork Irrigation Company Diversion

JDE met with Ernie John, American Fork Irrigation Company (AFIC) President, on June 10, 2021 at the diversion structure located at the mouth of American Fork Canyon to understand its operation. Based on discussion and coordination with Horrocks, who assists with the design and operation of the diversion, it was determined to assume that the diversion diverts 100% of the river up to 150 cfs to the various irrigation conveyances. Once the river exceeds 150 cfs at the diversion, the remaining flow is discharged into the American Fork River, which flows towards the American Fork Debris Basin located approximately 0.5 miles downstream.

3.4.3 American Fork River Debris Basin

The as-built drawings for the American Fork River Debris Basin were obtained from Horrocks. The drawings provided the stage-discharge curve of the auxiliary spillway (see Appendix B). The stage-storage curve for the debris basis, however, was not provided on the as-builts. Therefore, a stage-storage curve was developed in ArcGIS Pro software with the best available 2013 0.5-meter LiDAR surface obtained from Utah AGRC. The developed stage-storage data is provided in Table 3-2. Since the structure is a debris basin and the typical operation of the AFIC diversion structure, it was assumed that the debris basin is empty at the beginning of the storm and the three 48-inch outlet slide gates are fully-open.

Table 3-2. American Fork River Debris Basin Stage-Storage

Elevation (ft)	Storage Area (acres)	Storage Volume (ac-ft)
4951.3	0.0	0.0
4961.3	1.0	6.8
4971.3	10.9	66.1
4979.3	15.6	172.3
4981.3	16.8	204.8

3.4.4 Dry Creek Debris Basin

The Dry Creek Debris Basin is currently being rehabilitated for recreational use and flood control purposes; therefore, record drawings are not available for the structure. However, a portion of the drawing plans of the rehabilitated basin were obtained from the NRCS and RB&G Engineering to incorporate the anticipated stage-storage and stage-discharge curves of the structure (see Appendix B). It was confirmed with RB&G Engineering that the inflow design flood (IDF) could be routed with the reservoir water elevation at the spillway crest; therefore, it was assumed the reservoir water surface was at the spillway crest for the hydrologic model presented in this study.

In addition, a hydraulics and hydrology technical memorandum written for the proposed debris basin (dated August 13, 2014) was provided by the NRCS (Nelson, 2014). The technical memorandum states the contributing watershed area and Curve Number (CN) for the debris basin is 39.5 square miles and 68, respectively. Note that the hydrologic analysis presented in this report determined that the debris basin has a contributing area (watersheds DC-01, DC-02, and FC-01) and CN of 39.3 square miles and 66, respectively, which is within a reasonable tolerance.

3.4.5 I-15 12’ x 7’ Box Culvert

The A-W hydraulics report provides the rating curve (see Table 3-3) of the proposed 12’ x 7’ box culvert (which has since been installed) for the Dry Creek and I-15 crossing (UDOT, 2018). This data was utilized to route the hydrographs beyond I-15.

Table 3-3. I-15 12’ x 7’ Box Culvert Rating Curve (UDOT, 2018)

Water Surface Elevation (ft)[1]	Flow Through Culvert (cfs)
4591.07	400
4591.87	500
4592.62	600
4593.34	700
4594.06	800
4594.20	820
4594.79	900
4595.24	960
4595.93	1,050
4598.27	1,320
4611.19	**2,214**

[1]Elevation at the entrance of the culvert

3.4.6 Waste Ditch and Dry Creek Diversion

The Waste Ditch and Dry Creek diversion is located approximately 850 feet upstream of the Lehi Elementary School. The structure consists of two rectangular concrete channel sections each with a stop log gate (see Figure 3-1). The A-W report explains that Lehi City estimates the existing capacity of Dry Creek to be 150-200 cfs and the existing capacity of Waste Ditch to be 550 cfs (UDOT, 2018). After discussing the intended operation of the diversion with Lehi City, it was determined to assume that the diversion will be operated so that 60% of storm flows is conveyed to Waste Ditch and the remaining 40% is conveyed to Dry Creek.

Figure 3-1. Waste Ditch and Dry Creek Diversion

4.0 Hydrologic Analysis – NEH Part 630 Methods

4.1 Precipitation and Storm Distribution

Average precipitation depths in the study area were calculated using gridded precipitation data downloaded from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 Point Precipitation Frequency Data Server (see Table 4-1). The gridded data was processed in ArcGIS and an average precipitation depth was determined over the watershed. The recurrence intervals considered in this study were 10-, 25-, 50-, 100-, 200-, and 500-year storm events. A 24-hour storm duration was selected for all evaluated recurrence intervals.

Hyetographs were developed for each watershed by applying the precipitation depths to the temporal distributions published in NOAA's *Precipitation-Frequency Atlas of the United States – Volume I Version 5.0: Semiarid Southwest (Arizona, Southeast California, Nevada, New Mexico, Utah)* (NOAA, 2011). The NOAA 1st quartile distribution was used, which is the accepted NOAA distribution of the project area. The quartile distributions are defined by the duration quartile in which the greatest percentage of the total precipitation occurs.

4.2 Loss Method and Transform Methods

Rainfall losses were based on the Soil Conservation Service (SCS) CN method, per NEH Part 630 Chapters 9 (NRCS, 2004a) and 10 (NRCS, 2004b). The CNs were determined based off the Antecedent Runoff Condition Type II (ARC-II). Table 4-2 displays the published (NRCS, 2004a) CNs that were used for the developed watersheds. The CNs are based on the land cover, the hydrologic condition, and the hydrologic soil group.

The lag time (Lg) of the watershed was calculated using the SCS Velocity Method and the SCS Watershed Lag Method, as described in NEH Part 630 Chapter 15 (NRCS, 2010). The Velocity Method consists of flow path segments broken up into sheet flow, shallow concentrated flow, and open channel

Table 4-1. 24-Hour Duration NOAA Atlas 14 Precipitation Data (inches)

Watershed	Recurrence Interval					
	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
American Fork						
SL-01	3.57	4.17	4.65	5.14	5.64	6.33
TF-01	3.26	3.82	4.26	4.70	5.16	5.78
AF-01	3.18	3.73	4.15	4.59	5.04	5.67
AF-02	1.85	2.15	2.38	2.62	2.90	3.34
AF-03	1.68	1.94	2.15	2.35	2.62	3.07
AF-04	1.66	1.92	2.12	2.32	2.58	3.02
AF-05	1.68	1.95	2.15	2.36	2.62	3.07
Lehi						
FC-01	2.48	2.88	3.21	3.55	3.92	4.48
DC-01	2.81	3.28	3.65	4.04	4.46	5.06
DC-02	1.88	2.18	2.42	2.67	2.95	3.44
DC-03	1.73	2.01	2.22	2.45	2.75	3.21
DC-04	1.68	1.95	2.15	2.37	2.66	3.12

Table 4-2. SCS Curve Numbers (ARC-II)

Land Cover Type (NEH Part 630)	Hydrologic Condition	Hydrologic Soil Group			
		A[1]	B	C	D
Commercial-Business	Not Applicable	89	82	94	95
Residential – ¼ Acre	Not Applicable	61	75	83	87
Residential – ½ Acre	Not Applicable	54	70	80	85
Open Space	Good	39	61	84	80
Open Water	Not Applicable	100	100	100	100
Paved Roads-Curbs-Sewers	Not Applicable	98	98	98	98
Rock (50%)	Not Applicable	90	90	90	90
Row Crops – SR	Good	67	78	85	89
Pasture	Good	39	61	74	80
Oak-Aspen	Good		30	41	48
Oak-Aspen	Fair		48	57	63
Pinyon-Juniper	Good		41	61	71
Sage-Grass	Fair		51	63	70
Herbaceous	Fair		71	81	89

[1]CNs for group A in arid and semiarid rangelands have not been developed (NRCS, 2004a).

flow. Each segment requires the length and slope as well as the land cover type, flow type, and typical open channel geometry depending on the segment type. The Watershed Lag Method uses an empirical equation which requires the watersheds watercourse length, average basin slope, CN, and area. These parameters were delineated and estimated using topographic data, aerial imagery, and based on field visits. It was determined that the Velocity Method produced more reasonable and conservative results; therefore, the lag times from this method were used in the hydrologic analysis.

The CNs and lag times for each watershed are shown in Table 4-3.

The SCS Unit Hydrograph was selected as the transform method for all hydrology as recommended and discussed in NEH Part 30 Chapter 16 (NRCS, 2007). One variable of the SCS unit hydrograph is the Peak Rate Factor (PRF), which is generally adjusted depending on the steepness of a given watershed and to calibrate hydrology models. PRF's can range from 100 for relativity flat watershed to 600 for steep watersheds. Given the watershed slopes of this study, the standard PRF of 484 was considered a reasonably conservative estimate where it is on the higher range of PRF values. Although the projects are in the valley, the majority of watershed areas are within the Wasatch Range (see maps in Appendix A).

Table 4-3. SCS CNs and Velocity Method Lag Times

Watershed	CN (ARC-II)	Lag Time (min)
American Fork		
SL-01	56	37.6
TF-01	48	72.4
AF-01	50	97.2
AF-02	69	51.6
AF-03	60	15.4
AF-04	67	15.1
AF-05	63	44.7
Lehi		
FC-01	67	56.9
DC-01	61	86.4
DC-02	70	55.7
DC-03	72	24.6
DC-04	71	32.2

4.3 Hydrologic Modeling and Flood Routing

The U.S. Army Corps of Engineers (USACE) Hydrologic Modeling System (HEC-HMS version 4.8) was used for the hydrologic modeling of the watersheds. The previously discussed parameters were input into the model to estimate flows and volumes for each of the design storms. The kinematic wave routing method was used to route storms through channels to downstream junctions. Parameters for the routing (channel cross-section, Manning’s n, etc.) were estimated based on best available GIS data, aerial imagery, and observations during the June site visit.

4.3.1 Flood Routing for Dry Creek Beyond I-15 Box Culvert

After reviewing the A-W hydraulics report (UDOT, 2018) and the FEMA FIRM maps for Dry Creek (FEMA 2020a), it was understood that flooding occurs upstream of the I-15 12’ x 7’ box culvert. The upstream flooding navigates southwest and crosses beneath I-15 at 100 East and 600 East (see portion of FEMA FIRM Map in Figure 4-1). This flooding causes attenuation of hydrologic flows due to the limiting capacity of the box culvert and due to a portion of flows exiting the Dry Creek drainage. Therefore, the hydrologic modeling of Dry Creek was completed for upstream of I-15 using HEC-HMS. After which, the produced hydrographs from HEC-HMS were modeled in USACE’s River Analysis System (HEC-RAS version 6.0) to accurately model the attenuation of flows.

A 2D unsteady state HEC-RAS model was used to route the Dry Creek hydrographs through the I-15 box culvert using rating curve data from Table 3-3. The 2D modeling showed that flows crossing beneath 100 East and 600 East did not reenter the Dry Creek drainage; therefore, the peak flows being routed through the I-15 culvert were used to determine the peak design flows of Waste Ditch and Dry Creek. As previously discussed in Section 3.4.6, it was assumed that the diversion was operated so that Waste Ditch and Dry Creek take 60% and 40% of the peak flows, respectively.

Further information for the methods and procedures of the HEC-RAS modeling is provided in *TM004 – Frequency Flood Routing*.

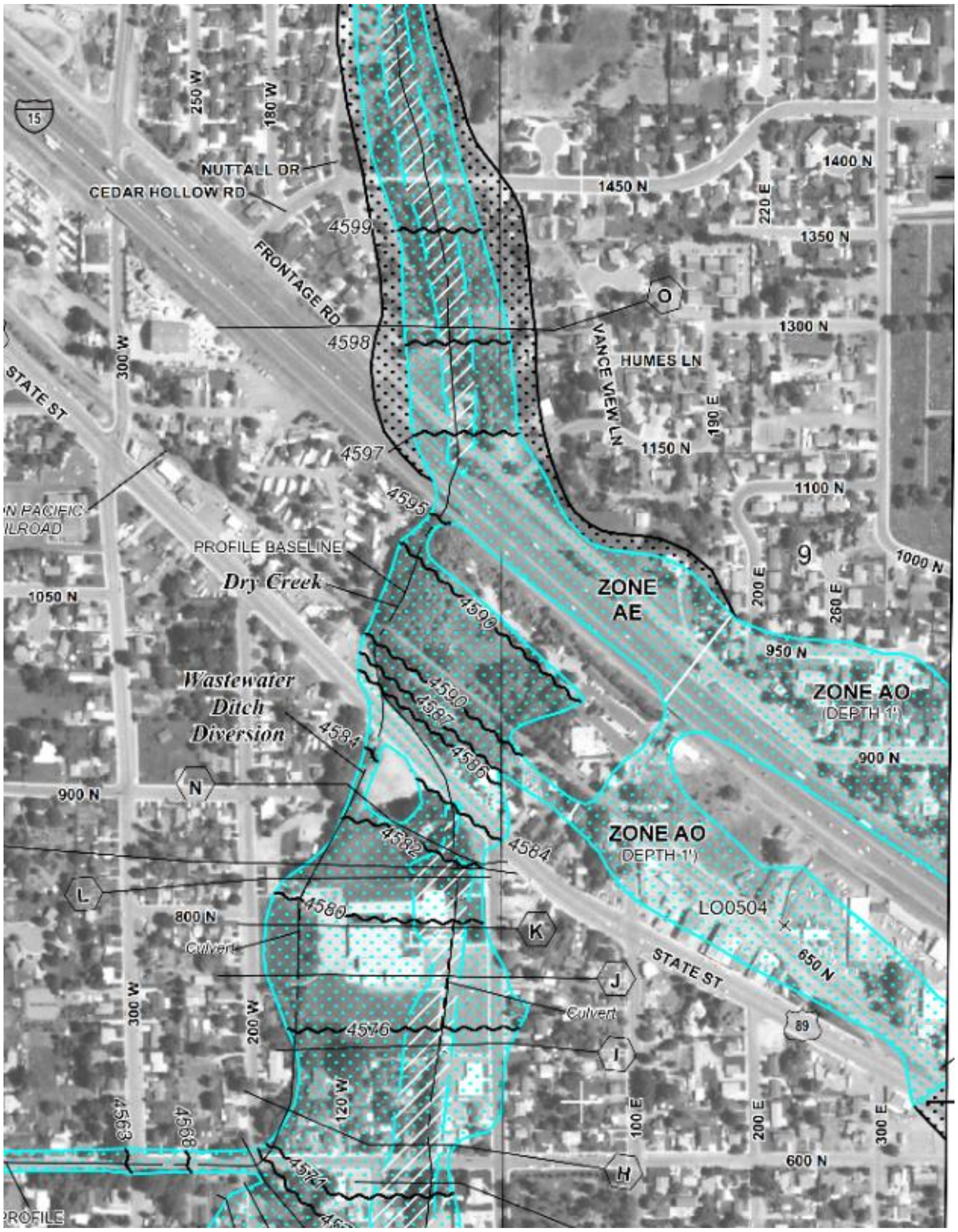


Figure 4-1. Portion of FEMA FIRM Map for Dry Creek near I-15 (FEMA, 2020a)

4.4 Results

The peak flows produced from the HEC-HMS model (and HEC-RAS model for the I-15 box culvert) at each watershed junction are provided in Table 4-4. Note that some watershed junctions SL-01, TF-01, AF-01, and DC-02 are located at dams or debris basins; therefore, the reported peak flow is the peak discharge of the dam or debris basin. Subbasins for Waste Ditch and Dry Creek downstream of I-15 were also delineated and considered for peak flows; however, the small size of the subbasins and the distance from the larger portion of the watershed showed that the resulting flows had negligible affects on the peak flood routing for locations of proposed improvements.

The hydrographs produced by the HEC-HMS hydrologic model will be used for the frequency flood hydraulic modeling, which is discussed in *TM004 – Frequency Flood Routing.*

Table 4-4. Peak Flows (cfs) for 24-Hour Recurrence Intervals Produced by NEH Part 630 Methods

Watershed Junction	Project Location[1]	Recurrence Interval 10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
American Fork							
SL-01	NA	134	134	134	146	185	238
TF-01	NA	333	493	633	818	1,080	1,506
AF-01	NA	353	619	899	1,251	1,708	2,443
AF-02	Locations 1 - 2	362	630	918	1,276	1,742	2,489
AF-03	Locations 3 - 4	362	631	919	1,277	1,744	2,493
AF-04	Locations 5 - 7	362	631	920	1,279	1,746	2,495
AF-05	NA	364	634	925	1,286	1,756	2,512
Lehi							
FC-01	NA	170	273	364	469	589	800
DC-01	NA	275	446	608	814	1,052	1,425
DC-02 (Dry Creek Debris Basin)	NA	383	683	974	1,328	1,758	2,473
DC-03	NA	387	690	982	1,339	1,771	2,493
DC-04 (Upstream of I-15 Box Culvert)	NA	396	705	1,001	1,367	1,807	2,543
Downstream of I-15 Box Culvert[2]	NA	395	704	922	1,053	1,150	1,257
Waste Ditch (60% of I-15 Box Culvert Flow)	All Waste Ditch Improvements	237	422	553	632	690	754
Dry Creek (40% of I-15 Box Culvert Flow)	All Dry Creek Improvements	158	282	369	421	460	503

[1]See *TM001 – Existing Conditions* for a description for each project location.
[2]Flows determined from HEC-RAS 2D model and capacity of I-15 Box Culvert (see Section 4.3.1)

5.0 Hydrologic Analysis – Calibrated Methods

5.1 American Fork River – Bulletin 17-B

The USGS 10164500 stream gauge on the American Fork River contains annual peak flow data since 1927, which is sufficient for a Bulletin 17-B analysis. The stream gauge data was imported into USACE's HEC-SSP version 2.2 software to determine the peak flows for the recurrence-interval storm events. The results are shown in Figure 5-1 and Table 5-1.

Since the USGS 10164500 stream gauge is located approximately four miles up the mouth of American Fork Canyon, the peak flows from the Bulletin 17-B analysis were transposed so the peak flows were representative of the entire American Fork Canyon watershed (SL-01, TF-01, and AF-01). The peak flows were transposed per methods outlined in USGS's *Methods for Estimating Magnitude and Frequency of Peak Flows for Natural Streams in Utah* (USGS, 2008). The summary of transposed peak flows at the mouth of American Fork Canyon are shown in Table 5-1.

Similar to the conclusion of the URS report, the peak flows produced from the Bulletin 17-B analysis were considered more reasonable than those produced by methods outlined in NEH Part 630. To be conservative, the upper 95% confidence limit peak flows were used for this project.

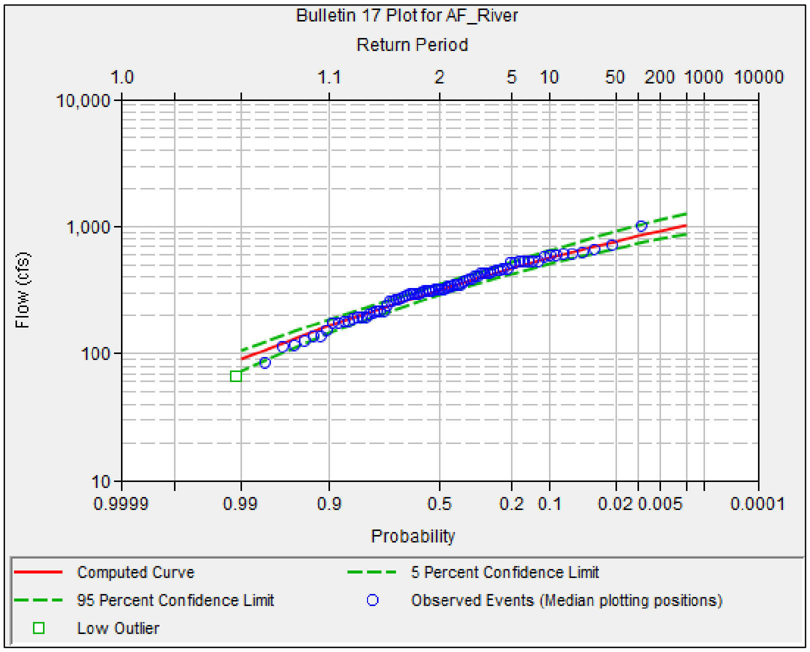


Figure 5-1. American Fork River (USGS 10164500) Bulletin 17-B Results

Table 5-1. Bulletin 17-B Peak Flows for American Fork River

Recurrence Interval	USGS 10164500 (Area = 51.1 sq. mi.)		Mouth of American Fork Canyon (Area = 64.6 sq. mi.)	
	Bulletin 17-B Peak Flow (cfs)	95% Confidence Limit (cfs)	Bulletin 17-B Peak Flow (Transposed) (cfs)	95% Confidence Limit (Transposed) (cfs)
10-yr	567	647	596	679
25-yr	685	798	720	839
50-yr	770	910	809	956
100-yr	851	1,019	894	1,071
200-yr	931	1,128	978	1,185
500-yr	1,033	1,269	1,085	1,333

5.1.1 American Fork River – Hydrographs

The Bulletin 17-B analysis provides an effective peak flow, but the method does not produce hydrograph that is representative of the watershed. In order to capture the hydrograph shape of the watershed (affected by watershed characteristics, existing dams, diversions, etc.), the HEC-HMS produced hydrographs for the NEH Part 630 Methods were used. The CNs for the watersheds were calibrated to match the Bulletin 17-B peak flow at the mouth of American Fork Canyon (AF-01). For example, for the 100-year storm event, the CNs were reduced by 7.3% which resulted in AF-01 peak flow of 1,069 cfs.

The hydrographs will be used to route the recurrence-intervals for the hydraulic modeling of the flood frequency analysis, which will be presented in *TM004 – Flood Frequency Routing*.

6.0 Conclusions

A hydrologic analysis per NEH Part 630 guidelines has been completed for the American Fork River and Dry Creek drainages.

For the American Fork Watershed, the peak flows produced by NEH Part 630 guidelines appeared to be overestimated, as was also found in previous hydrologic studies (URS, 2009). Therefore, the peak flows were calibrated using a Bulletin-17B analysis with the USGS 10164500 stream gauge. Based on this analysis, the design peak flow of the proposed improvements along the American Fork River is approximately 934 cfs which is representative of a 100-year 24-hour storm event per American Fork City design criteria (American Fork City, 2008).

For the Dry Creek drainage, the peak flows produced by NEH Part 630 guidelines were comparable, though less than, the peak flows developed in the FEMA FIS (FEMA, 2020b). Furthermore, it was found that the I-15 12’ x 7’ box culvert had limited capacity that caused further attenuation of flows and a portion of flood flows that leave the Dry Creek drainage. Based on this analysis, the design peak flows for Waste Ditch and Dry Creek are 640 cfs and 274 cfs, respectively. These design flows are for the 50-year 24-hour storm event, per Lehi City design criteria (Lehi City, 2016).

The summary of design peak flows of all considered improvements are summarized in Table 6-1.

Table 6-1. Design Peak Flows (cfs) for 24-Hour Recurrence Intervals

Project Location	**Watershed Junction**	**Recurrence Interval**					
		10-yr	**25-yr**	**50-yr**	**100-yr**	**200-yr**	**500-yr**
American Fork River Improvements	AF-04	526	678	818	934	1,048	1,199
Waste Ditch Improvements	DC-04 (Waste Ditch)	237	422	553	632	690	754
Dry Creek Improvements	DC-04 (Dry Creek)	158	282	369	421	460	503

7.0 References

American Fork City. (2008). *Storm Water Technical Manual*. May 2008.

Federal Emergency Management Agency (FEMA). (2020a). Flood Insurance Rate Map: Map No. 49049C0163F. Utah County, Utah and Incorporated Areas; Panel 163 of 1450. June 19, 2020.

FEMA. (2020b). Flood Insurance Study Number 49049CV001A. Utah County, Utah and Incorporated Areas; Volume 1 of 3. June 19, 2020.

Lehi City. (2016). *Lehi City Design Standards and Public Improvement Specifications*. 2016.

Multi-Resolution Land Characteristics Consortium. (2018). *2016 National Land Cover Dataset.* https://www.mrlc.gov/data

National Oceanic and Atmospheric Administration (NOAA). (2011). *Precipitation-Frequency Atlas of the United States – Volume I Version 5.0: Semiarid Southwest (Arizona, Southeast California, Nevada, New Mexico, Utah)*. NOAA Atlas 14. Revised 2011.

NOAA. (2017). Precipitation Frequency Data Server: NOAA Atlas 14 Point Precipitation Frequency Estimates. Hydrometeorological Design Studies Center. https://hdsc.nws.noaa.gov/hdsc/pfds/

Natural Resources Conservation Service (NRCS). (2002). *National Engineering Handbook, Part 630 Hydrology, Chapter 8: Land Use and Treatment Classes*. June 2002.

Nelson, Megan. (2014). *Technical Memorandum: Dry Creek Hydraulics & Hydrology Technical Memo*. McMillen, LLC. August 13, 2014.

NRCS. (2004a). *National Engineering Handbook, Part 630 Hydrology, Chapter 9: Hydrologic Soil-Cover Complexes*. July 2004.

NRCS. (2004b). *National Engineering Handbook, Part 630 Hydrology, Chapter 10: Estimation of Direct Runoff from Storm Rainfall*. July 2004.

NRCS. (2007). *National Engineering Handbook, Part 630 Hydrology, Chapter 16: Hydrographs*. March 2007.

NRCS. (2010). *National Engineering Handbook, Part 630 Hydrology, Chapter 15: Time of Concentration*. May 2010.

NRCS. (2019). Web Soil Survey. U.S. Department of Agriculture. July 31, 2019. https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

URS. (2009). *Utah County Hydrology Report for a Detailed Study on the American Fork River*. URS Corporation. Prepared for State of Utah Division of Homeland Security and FEMA Region VIII. September 1, 2009.

U.S. Army Corps of Engineers (USACE). (2021). Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS). Version 4.8. April 7, 2021

USACE. (2021). Hydrologic Engineering Center – River Analysis System (HEC-RAS). Version 6.0. May 2021.

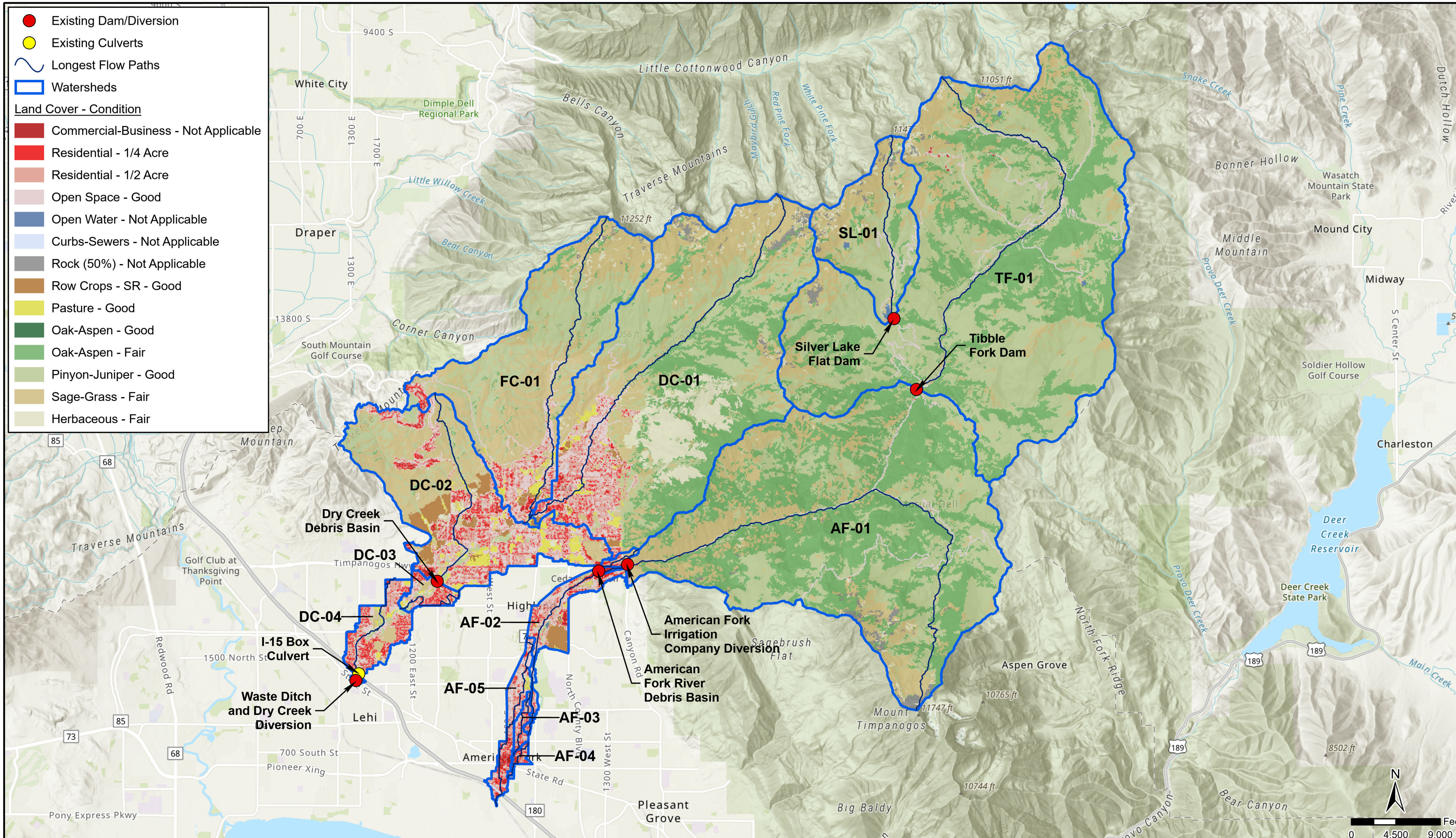
U.S. Geological Survey (USGS). (1981). *Guidelines for Determining Flood Flow Frequency – Bulletin #17B of the Hydrology Subcommittee*. U.S. Department of the Interior. Revised September 1981.

USGS. (2008). *Methods for Estimating Magnitude and Frequency of Peak Flows for Natural Streams in Utah*. Scientific Investigations Report 2007-5158, Version 4.0. U.S. Department of the Interior. March 10, 2008.

Utah AGRC. (2021). Utah Automated Geographic Reference Center. https://gis.utah.gov/

Utah Department of Transportation (UDOT). (2018). *I-15; Lehi Main to SR-92 Widening Structure No. E-2735 Hydraulics Report*. Prepared by Ames-Wadsworth Joint Venture Design Team. June 1, 2018.

Appendix A. Exhibits



American Fork - Pleasant Grove City - Lehi City

Utah County

American Fork Watershed Plan
Hydrology Watershed Overview - Land Cover

Scale: 1" = 9,000'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Ex_Hydrology_Overview_Land_Cover

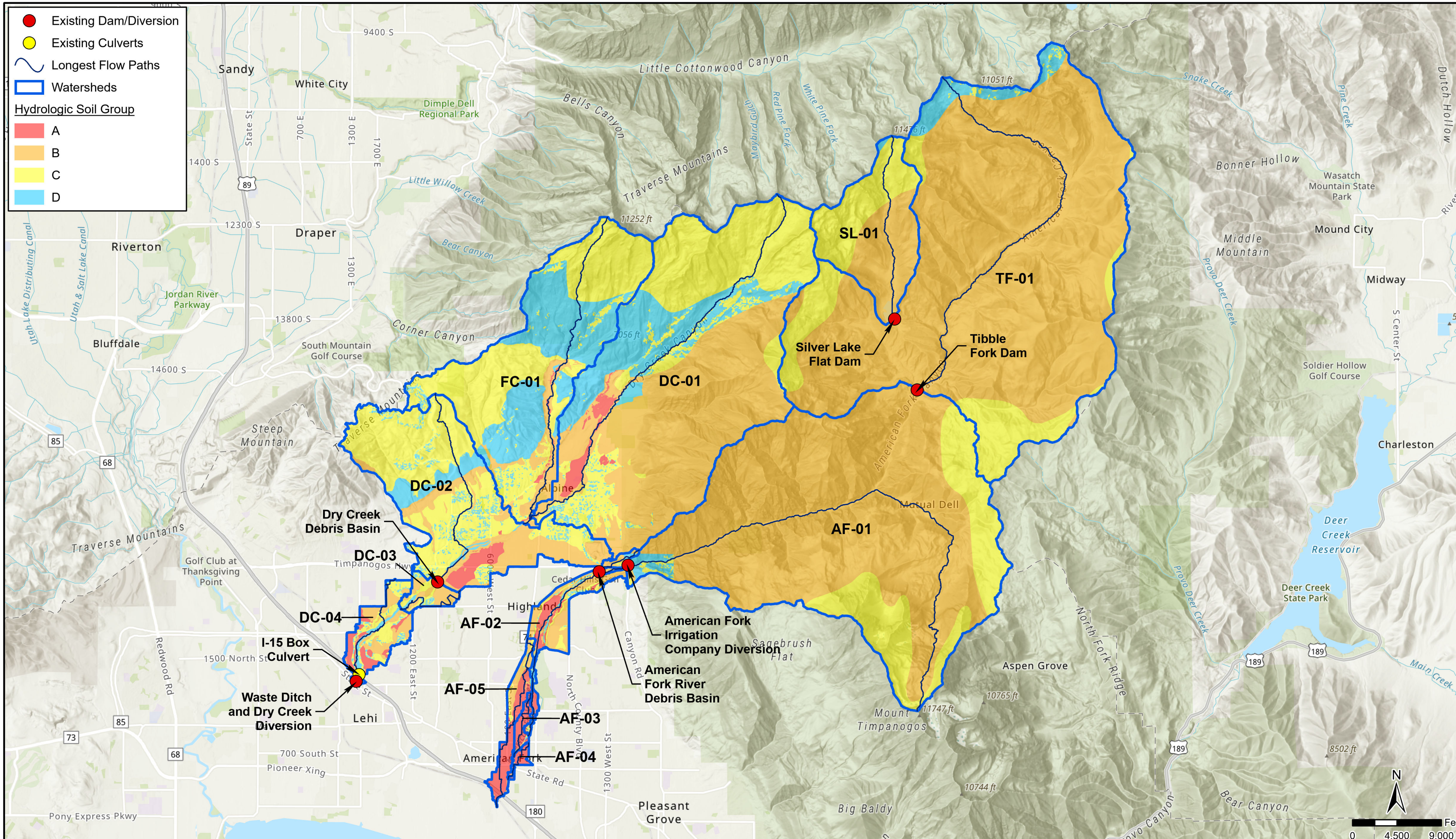
Project Number: 2004-028 | Drawn by: ALP 06-21 | Last Edit: 08/11/2021

1

FRANSON CIVIL ENGINEERS

HORROCKS ENGINEERS

Jones & DeMille Engineering



American Fork - Pleasant Grove City - Lehi City

Utah County

American Fork Watershed Plan
Hydrology Watershed Overview - Soils

Scale: 1" = 9,000'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Ex_Hydrology_Overview_Soils

Project Number: 2004-028 | Drawn by: ALP 06-21 | Last Edit: 08/11/2021

2

FRANSON CIVIL ENGINEERS
HORROCKS ENGINEERS
Jones & DeMille Engineering

Appendix B. Obtained Drawings for Dams and Debris Basins

B.1. Silver Lake Flat Dam – Portion of As-Built Drawing

PLANS FOR THE DAM SAFETY UPGRADE PROJECT OF

SILVER LAKE FLAT DAM

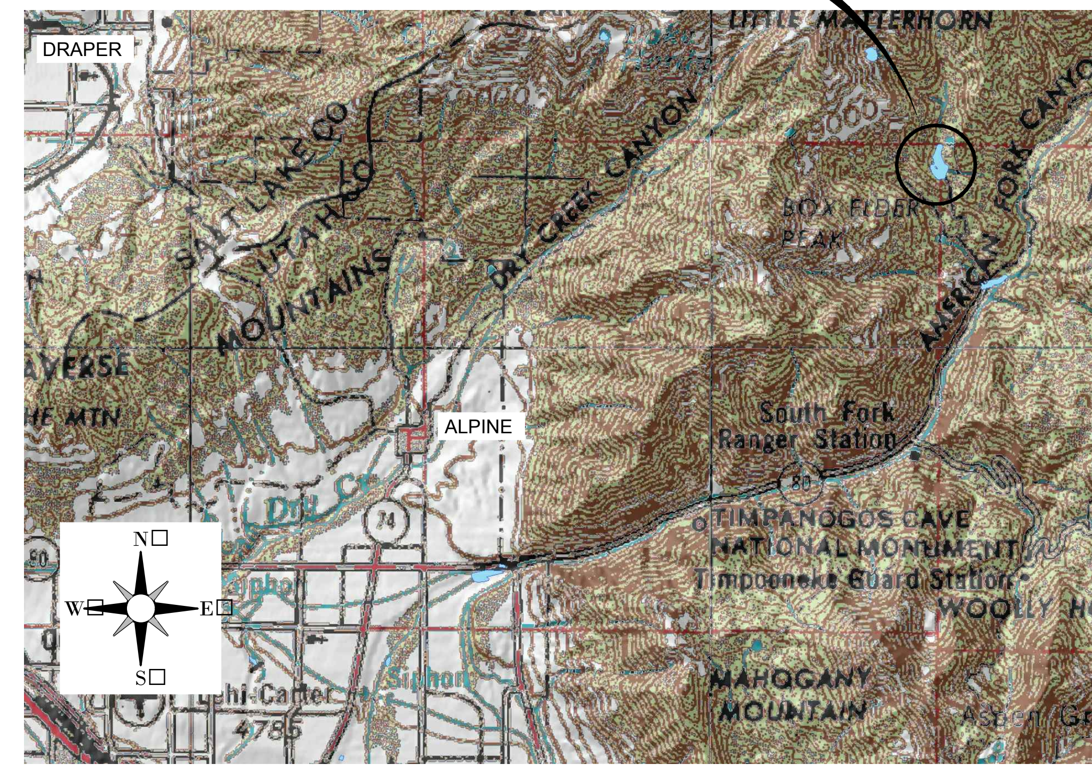
RECORD DRAWING SET

WARNING: THESE RECORD DRAWINGS HAVE BEEN PREPARED BASED ON INFORMATION PROVIDED BY OTHERS. THE CONSULTANT HAS NOT VERIFIED THE ACCURACY AND/OR COMPLETENESS OF THIS INFORMATION AND SHALL NOT BE FOR ANY ERRORS OR OMISSIONS THAT MAY BE INCORPORATED AS A RESULT OF ERRONEOUS INFORMATION PROVIDED BY OTHERS.

DESIGNED FOR NORTH UTAH COUNTY WATER CONSERVANCY DISTRICT
UTAH COUNTY, UTAH

INDEX OF DRAWINGS

SILVER LAKE FLAT

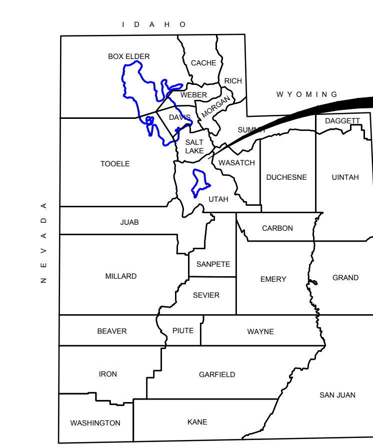


LOCATION MAP
SITE DATA T4S R3E SLBM SEC 6

HUNT WILLOUGHBY -- CHAIRMAN
NORTH UTAH COUNTY WATER CONSERVANCY DISTRICT

5/15/2015
DATE

REGISTERED PROFESSIONAL ENGINEER
5/15/2015
No. 4770018-2202
WILLIAM S CLARK
STATE OF UTAH



PROJECT LOCATION

STATE OF UTAH NATURAL RESOURCES Division of Water Resources	NO.	DATE	INITS.	REVISIONS
		1/24/18	CM	RECORD DRAWING SET

FILE PATH & NAME
O:_PROJECT FILES\E274_SilverLakeFlatDam\DesignConstruction\Plans\Record Dwgs\G1 G2 Title Sheet Surface Curves
Created: 2/1/2014 Plotted: 5/3/2018 Saved:10:19 AM

WARNING
0 ½
IF THIS BAR DOES NOT MEASURE 0.5" THEN DRAWING IS NOT TO SCALE

	DATE	APPROVED	DATE
SCALE: AS SHOWN		M CALL	5/15
DESIGNER: BJ CLARK	5/15	*CHIEF ENGINEER*	
DESIGNER:		BJ CLARK	5/15
DRAFTER: J HOLMAN	5/15	*PROJECT MANAGER*	
		BJ CLARK	5/15
DRAFTER: C McDONALD	5/15	*PROJECT ENGINEER*	

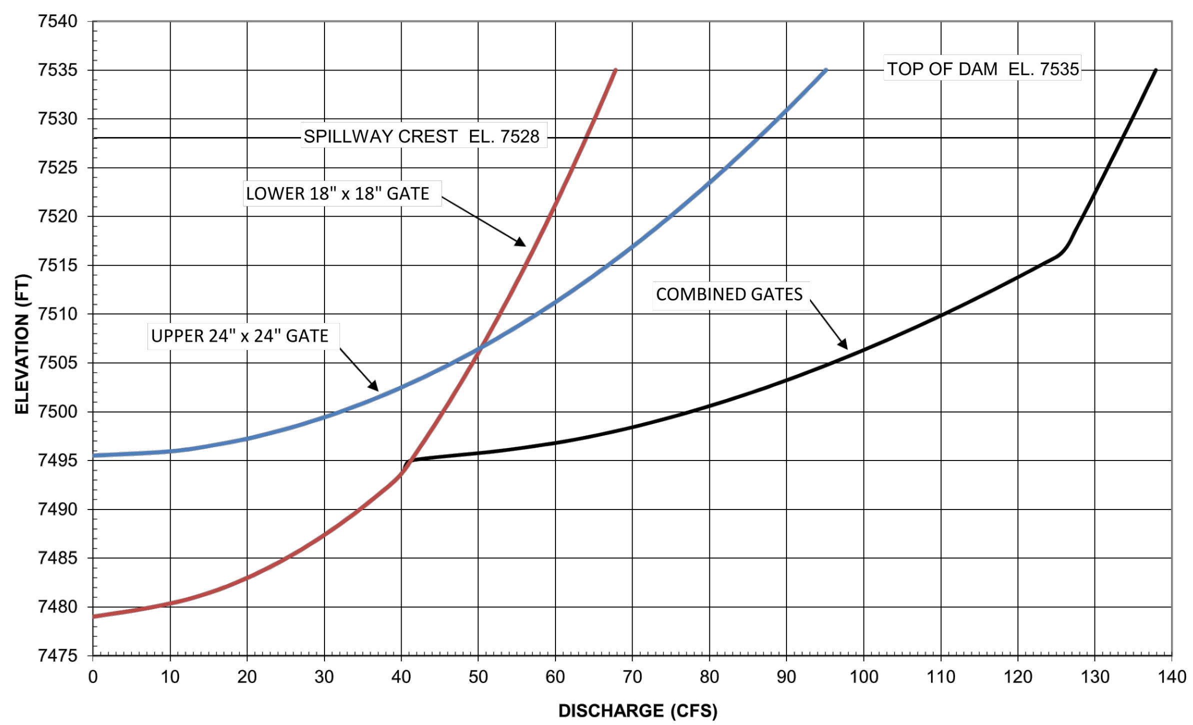
STATE OF UTAH
DIVISION OF WATER RESOURCES
SILVER LAKE FLAT DAM
DAM SAFETY UPGRADE

UTAH	RE274
COUNTY	APPL. NO.

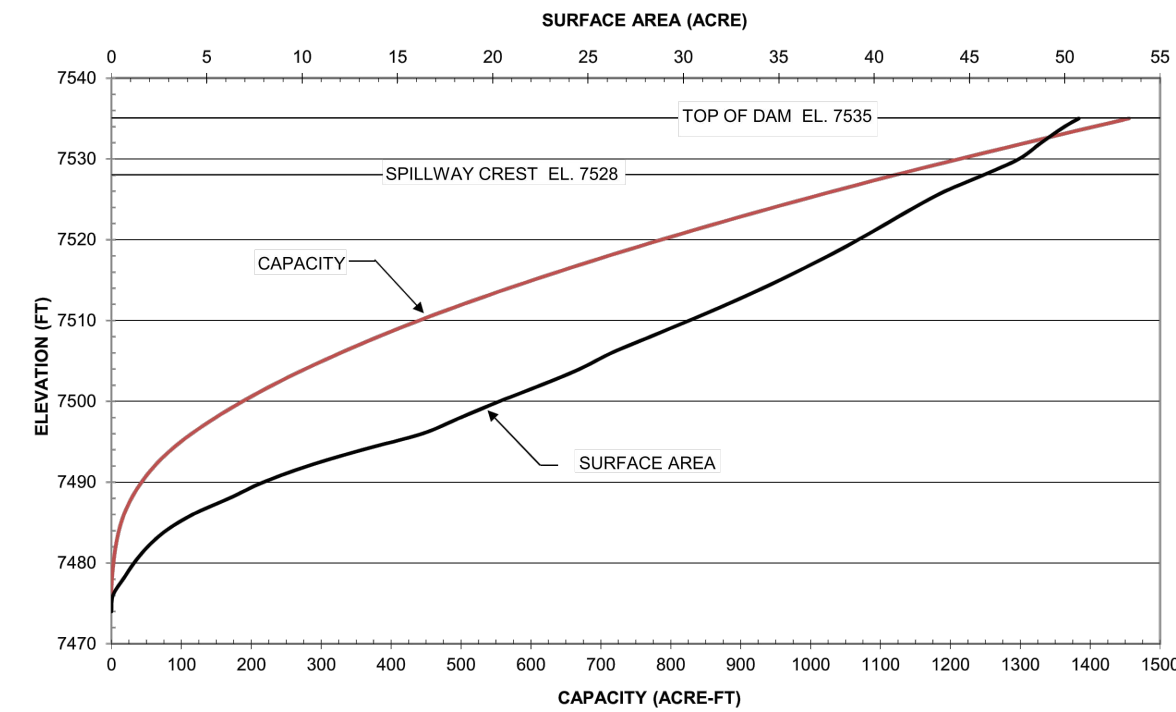
DRAWING LIST/ TITLE SHEET

G1

OUTLET DISCHARGE CURVE



SURFACE AREA - CAPACITY CURVE



SPILLWAY DISCHARGE

ELEVATION (FT)	DISCHARGE (CFS)
7528.0	0
7528.5	17
7529.0	47
7529.5	86
7530.0	132
7530.5	185
7531.0	243
7531.5	306
7532.0	374
7532.5	447
7533.0	523
7533.5	604
7534.0	688
7534.5	776
7535.0	867

V-NOTCH WEIR

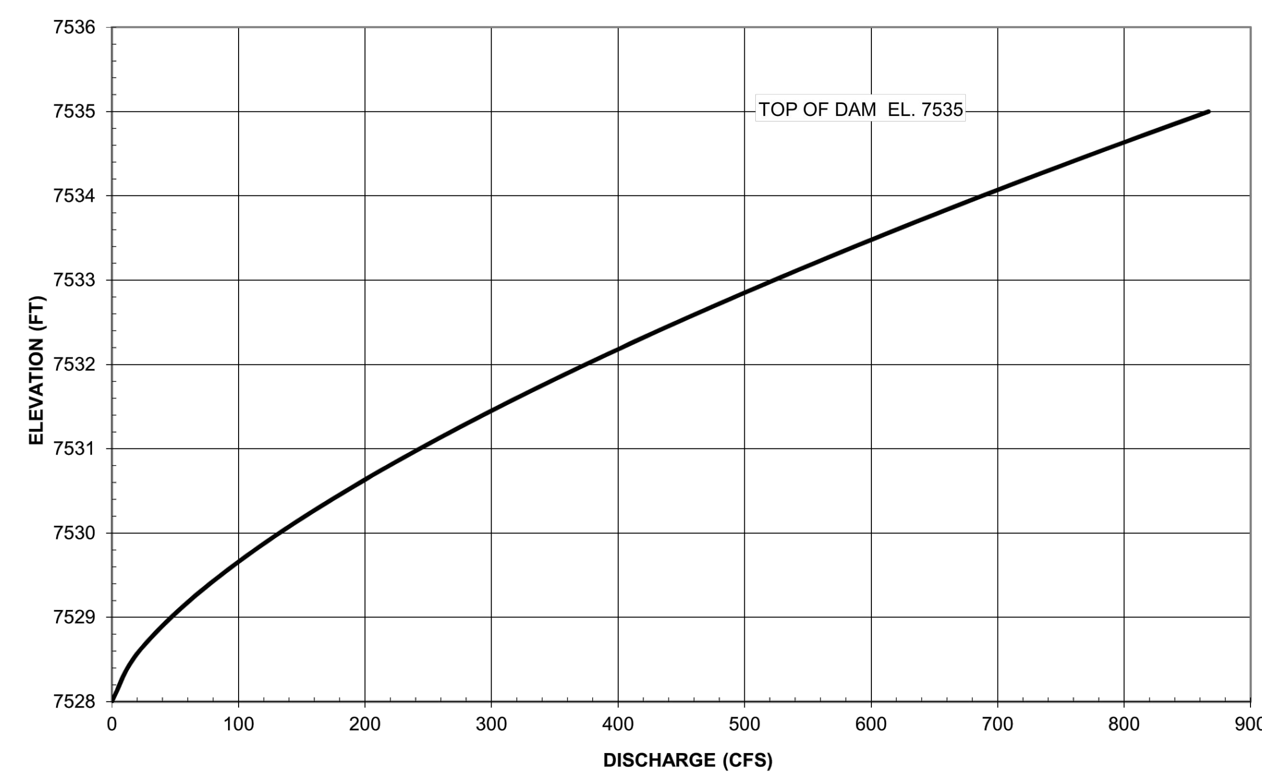
HEAD (FT)	FLOW (GPM)
0.0	0
0.1	4
0.2	21
0.3	56
0.4	115
0.5	200
0.6	315
0.7	461
0.8	643
0.9	861
1.0	1118

FLOW = $[2.49\ (\text{HEAD})^{2.48}]\ 448.8$

SURFACE AREA, CAPACITY, & COMBINED GATES OUTLET DISCHARGE

ELEVATION (FT)	AREA (AC)	CAPACITY (AC-FT)	DISCHARGE (CFS)	NOTES
7474	0	0	0	
7476	0.1	0.1	0	
7478	0.6	1	0	
7480	1	3	8	LOWER INTAKE
7482	2	6	17	
7484	3	11	23	
7486	4	18	27	
7488	6	29	31	
7490	8	43	35	
7492	10	61	38	
7494	13	85	40	
7496	16	115	53	UPPER INTAKE
7498	18	149	68	
7500	20	188	78	
7502	23	230	86	
7504	25	277	93	
7506	26	328	99	
7508	28	382	105	
7510	30	440	110	
7512	32	502	116	
7514	34	568	121	
7516	36	638	125	
7518	38	710	127	
7520	39	786	128	
7522	41	865	130	
7524	42	947	131	
7526	44	1032	132	
7528	46	1120	134	SPILLLWAY CREST
7530	48	1213	135	
7532	49	1308	136	
7534	50	1406	137	
7535	51	1455	138	DAM CREST

SPILLWAY DISCHARGE CURVE



STATE OF UTAH
NATURAL RESOURCES
Division of Water Resources

NO.	DATE	INITS.	REVISIONS
	1/24/18	CM	**RECORD DRAWING SET** (SEE TITLE SHEET FOR DISCLAIMER)

FILE PATH & NAME
O:_PROJECT FILES\E274_SilverLakeFlatDam\DesignConstruction\Plans\Record Dwgs\G1 G2 Title Sheet
Surface Curves
Created: 2/1/2014 Plotted: 5/3/2018 Saved:10:19 AM

WARNING
0 ½
IF THIS BAR DOES NOT MEASURE 0.5" THEN DRAWING IS NOT TO SCALE

SCALE: AS SHOWN	DATE
DESIGNER: BJ CLARK	5/15
DESIGNER:	
DRAFTER: J HOLMAN	5/15
DRAFTER: C McDONALD	5/15

APPROVED	DATE
M CALL	5/15
CHIEF ENGINEER	
BJ CLARK	5/15
PROJECT MANAGER	
BJ CLARK	5/15
PROJECT ENGINEER	

REGISTERED PROFESSIONAL ENGINEER No. 4770018-2202 WILLIAM G. CLARK STATE OF UTAH

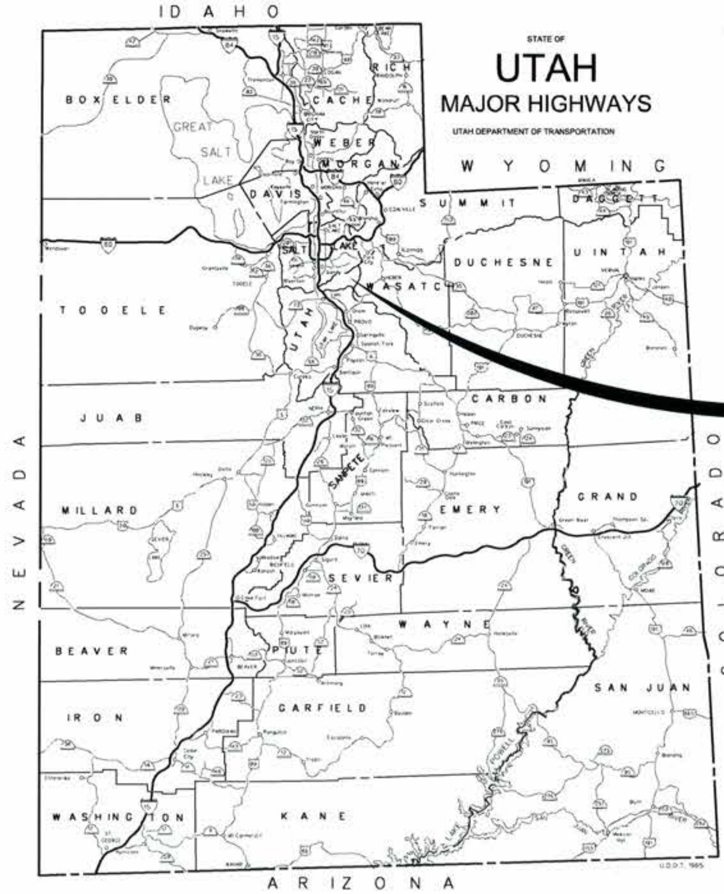
STATE OF UTAH
DIVISION OF WATER RESOURCES
SILVER LAKE FLAT DAM
DAM SAFETY UPGRADE

UTAH
COUNTY
RE274
APPL. NO.

HYDRAULIC DATA & CURVES

G2

B.2. Tibble Fork Dam – Portion of As-Built Drawing



TIBBLE FORK DAM
REHABILITATION

UTAH COUNTY, UTAH

NORTH UTAH COUNTY WATER CONSERVANCY DISTRICT

Utah County
HEART of UTAH

OWNER'S ACCEPTANCE

THE NORTH UTAH COUNTY WATER CONSERVANCY DISTRICT CERTIFIES THAT THEY ACCEPT THE PLANS AND SPECIFICATIONS FOR THE WORK FOR TIBBLE FORK DAM.

Hunt Willoughby — 3 June 16
CHAIRMAN — DATE

ENGINEER'S CERTIFICATE

RB&G ENGINEERING, INC. CERTIFIES THAT THE CORPORATION WAS EMPLOYED TO PREPARE THE DRAWINGS & SPECIFICATIONS FOR TIBBLE FORK DAM IN UTAH COUNTY, UTAH AND THAT THESE DRAWINGS CONSISTING OF 134 SHEETS AND THE ACCOMPANYING SPECIFICATIONS ARE THE INFORMATION TO BE SUBMITTED FOR APPROVAL.

Bradford E. Price — 05/02/2016
RB&G ENGINEERING — DATE

PROFESSIONAL ENGINEERS LICENSE NO. 162291

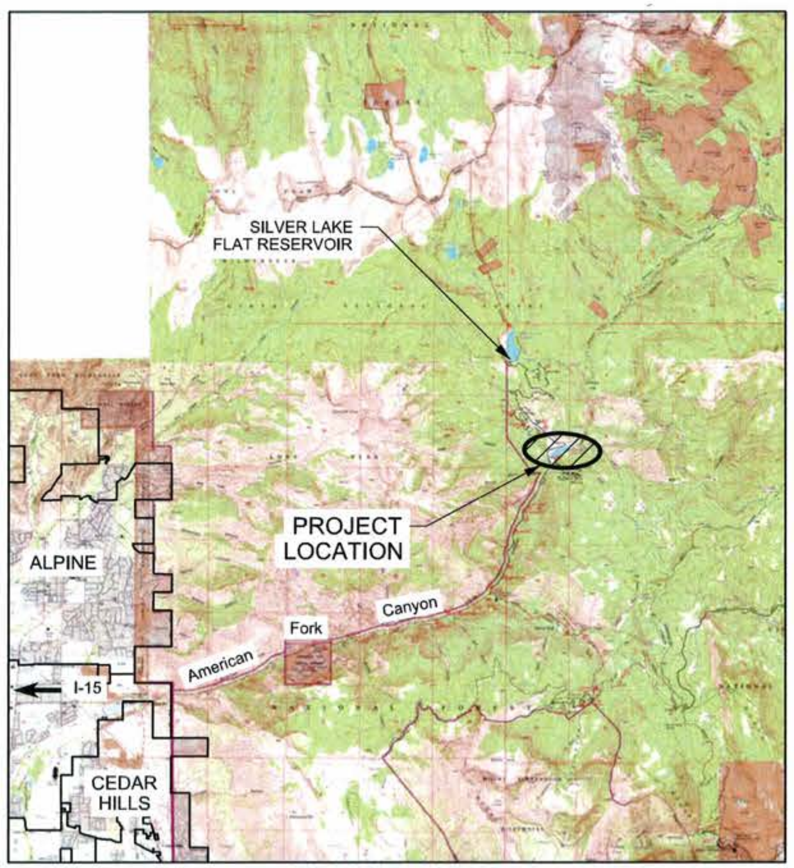
SITE AERIAL PHOTO

NORTH

LAT: N 40°28'52" LONG: W 111°38'47"

WATER RIGHTS	
55-103 (a40793)	55-6955
55-12601	55-7071
55-6951 (a40794)	55-7197 (a40797)
55-6952 (a40798)	55-7199 (a40796)
55-6953 (a40795)	55-7200

NRCS Natural Resources Conservation Service



VICINITY MAP

02-MAY-2016
DGN File: H:\DAMS\NUCWCD DAMS\TibbleFork.201504-004\CAD\Sheet_Files\G-1.dgn

RB&G ENGINEERING, INC.
1435 WEST 820 NORTH
PROVO, UTAH 84601-1343
801 374-5771 PROVO
801 521-5771 SALT LAKE CITY

HORROCKS ENGINEERS

BARRETT ENGINEERING, LLC

NO.	AUTHORIZED BY	REVISION	MADE BY	DATE
6				
5				
4				
3				
2				
1				

DESIGNED BY B. HORROCKS
DRAWN BY J. RUSBY
CHECKED BY B.E. PRICE
SCALE HORIZ.
VERT.
DATE MAY 2, 2016

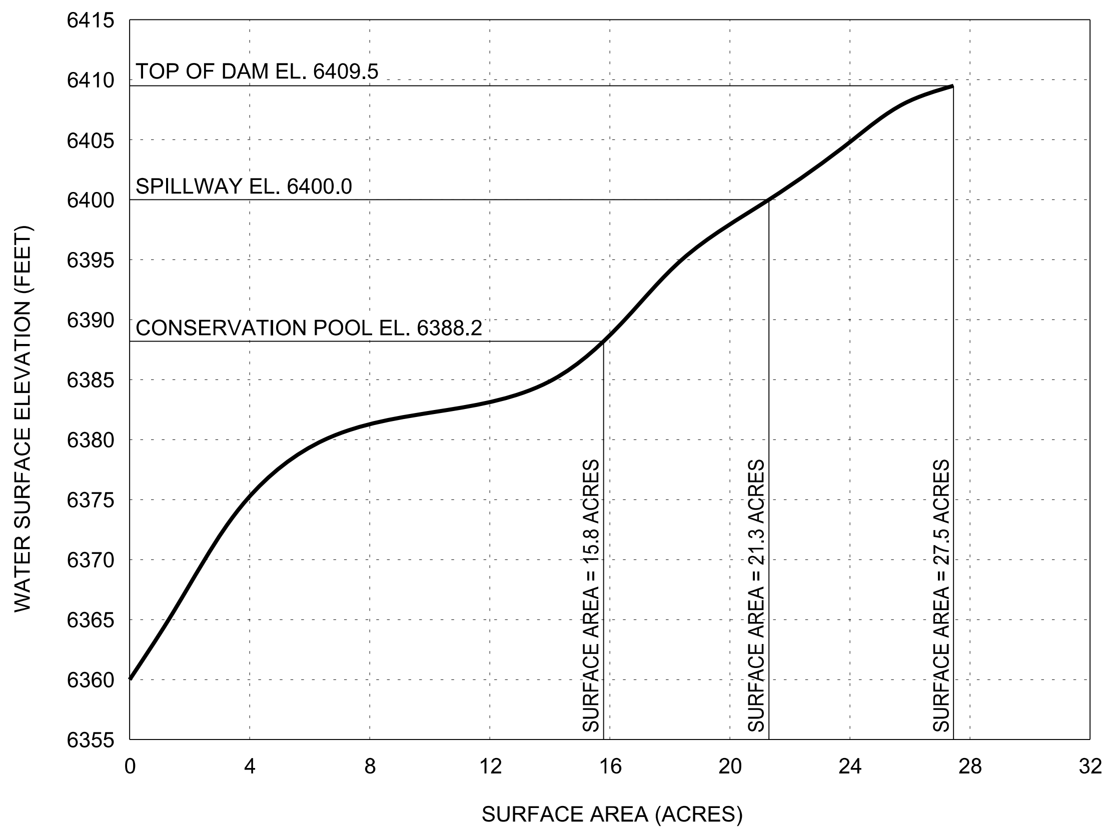
UTAH COUNTY, UTAH

TIBBLE FORK DAM REHABILITATION

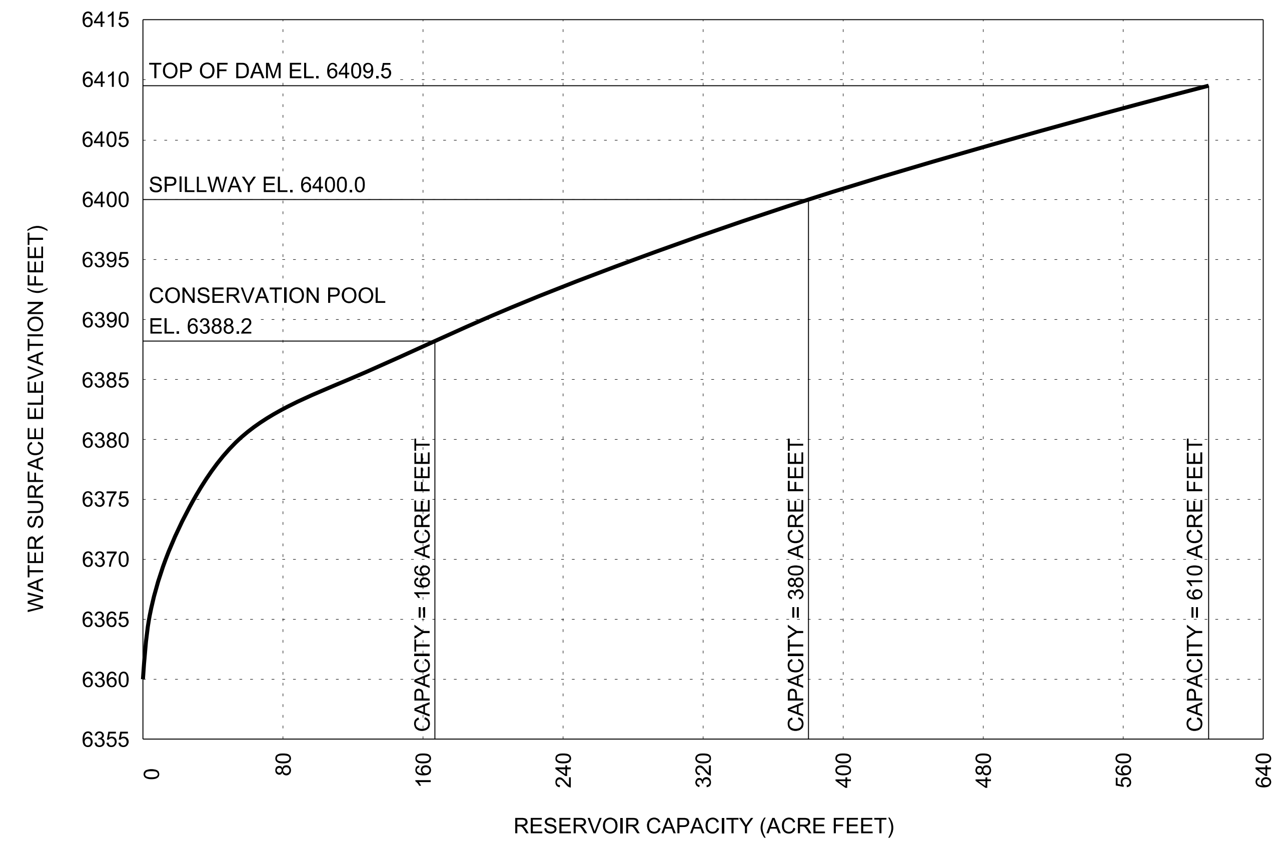
TITLE SHEET

201504-004
PROJECT NO.
SEE FILE
FILE DRAWER NO.
SHEET G-1

AS-BUILT

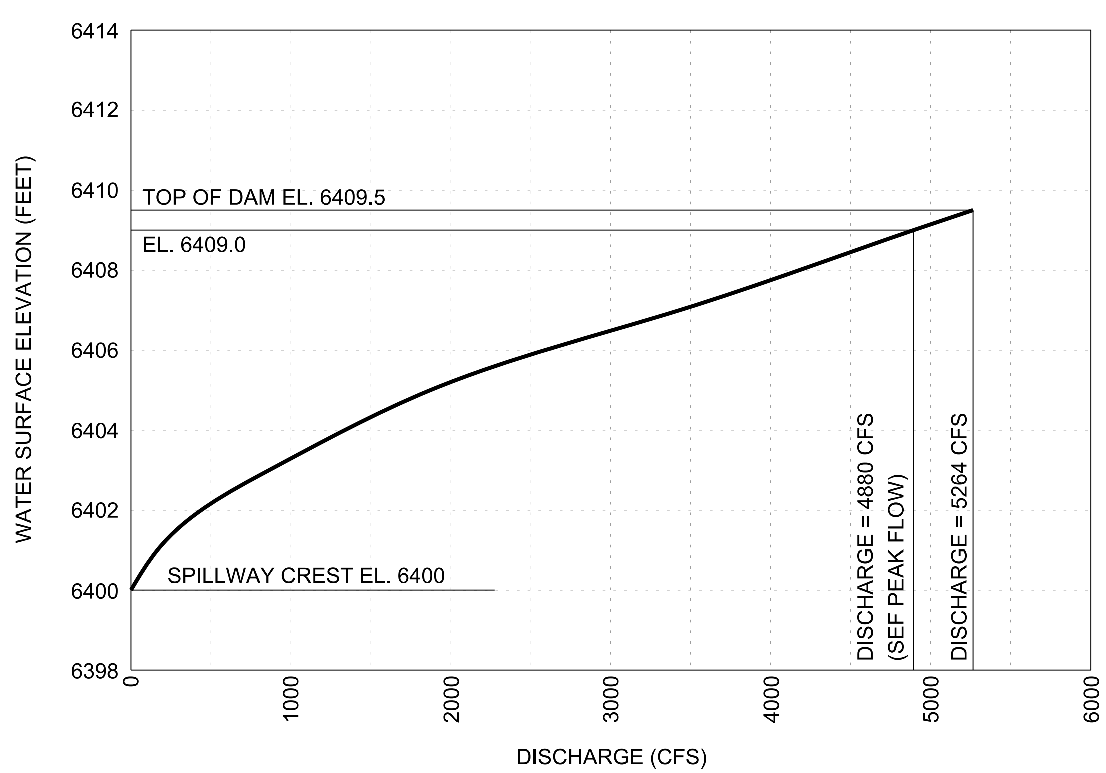


RESERVOIR AREA CURVE

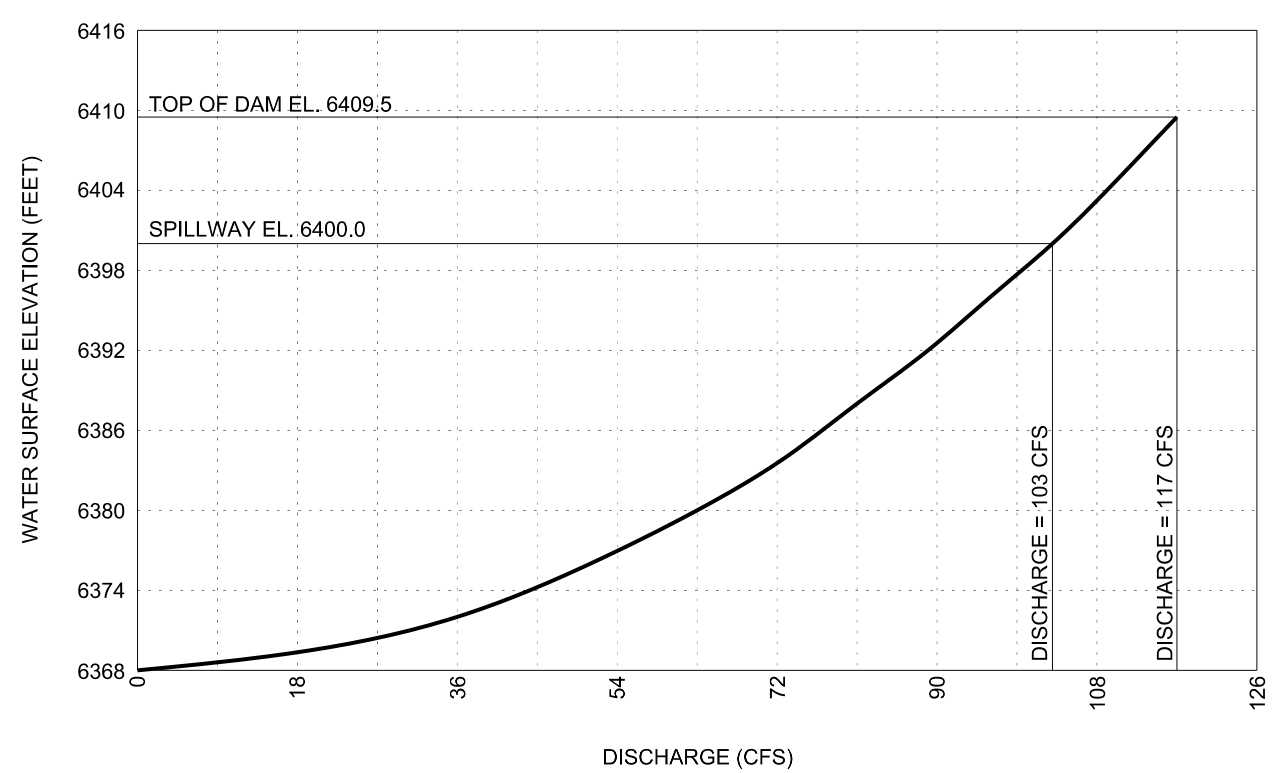


RESERVOIR CAPACITY CURVE

AREA/CAPACITY		
WATER SURFACE ELEVATION (FEET)	STORAGE AREA (ACRES)	STORAGE CAPACITY (ACRE-FEET)
6360	0	0
6365	1.3	3.5
6370	2.5	13
6375	3.9	29
6380	6.5	55
6385	14.1	118
6390	16.5	194
6395	18.4	281
6400	21.3	380
6405	24.1	494
6408	25.8	569
6409.5	27.5	610



SPILLWAY DISCHARGE RATING CURVE



OUTLET DISCHARGE RATING CURVE

OUTLET DISCHARGE RATING TABLE	
WATER SURFACE ELEVATION (FEET)	OUTLET DISCHARGE (CFS)
6368	0
6372	36
6376	51
6380	63
6384	73
6388	81
6392	89
6396	96
6400	103
6406	112
6409.5	117

SPILLWAY DISCHARGE TABLE	
WATER SURFACE ELEVATION (FEET)	SPILLWAY DISCHARGE (CFS)
6400	0
6401	165
6403	864
6405	1872
6407	3432
6409	4893
6409.5	5264

02-MAY-2016
DGN File: ...\DAMS\...CWCD DAMS\TibbleFork.201504-004\CAD\Sheet_Files\G-4.dgn

PROFESSIONAL ENGINEER No. 162291 BRADFORD E. PRICE ELECTRONIC SEAL STATE OF UTAH
05/02/2016

RB&G ENGINEERING, INC.
1435 WEST 820 NORTH
PROVO, UTAH 84601-1343
801 374-5771 PROVO
801 521-5771 SALT LAKE CITY

HORROCKS ENGINEERS

BARRETT ENGINEERING, LLC

NO.	AUTHORIZED BY	REVISION	MADE BY	DATE
6				
5				
4				
3				
2				
1				

DESIGNED BY J. RUSBY
DRAWN BY J.P. NIELSON
CHECKED BY B.E. PRICE
SCALE HORIZ.
VERT.
DATE MAY 2, 2016

UTAH COUNTY, UTAH
AS-BUILT

TIBBLE FORK DAM REHABILITATION

CAPACITY, AREA & RATING CURVES

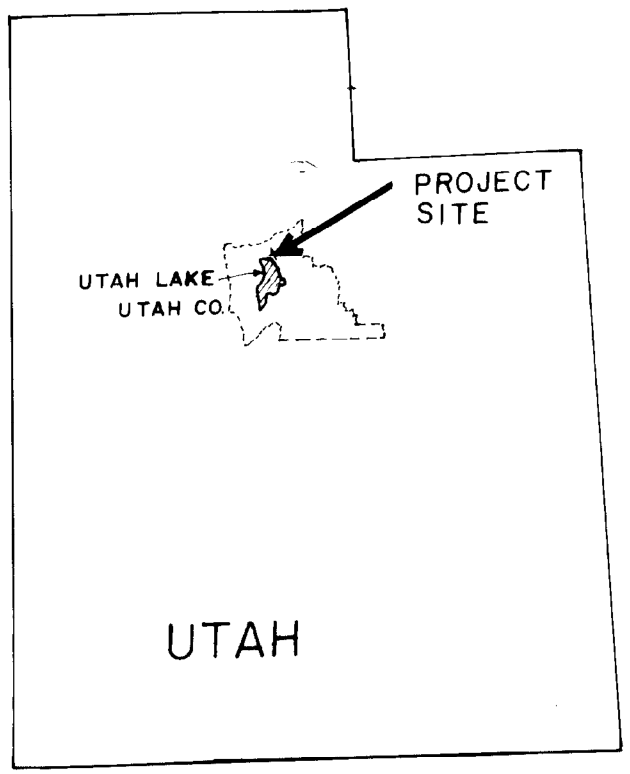
201504-004
PROJECT NO.
SEE FILE
FILE DRAWER NO.
SHEET G-4

B.3. American Fork River Debris Basin – Portion of As-Built Drawing

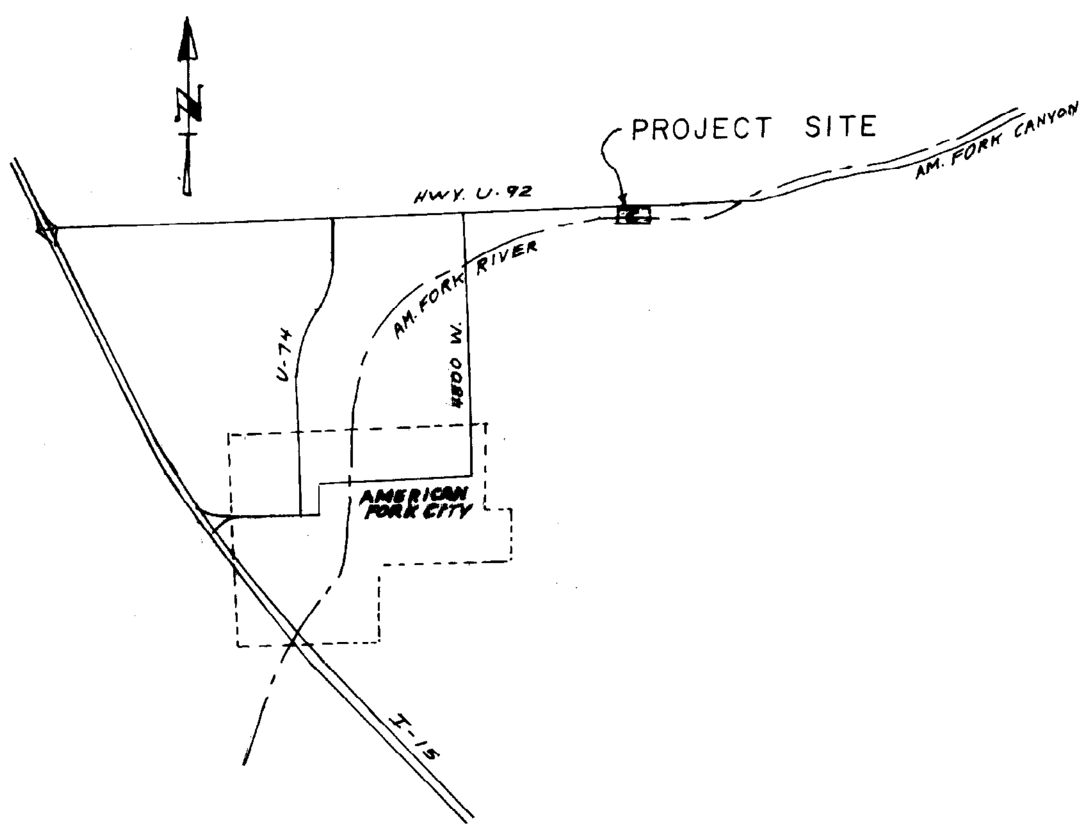
AMERICAN FORK RIVER

DEBRIS BASIN

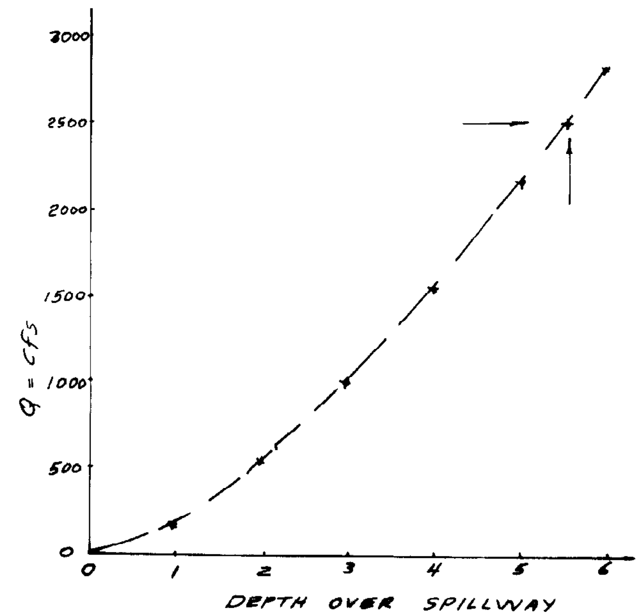
AS BUILT DRAWINGS



LOCATION MAP



SPILLWAY FLOW



$Q = CLH^{3/2}$ $L = 58'$

MAX DEPTH @ SPILLWAY = 5.6'

STATE ENGINEERS APPROVAL

IN ACCORDANCE WITH SECTION 73-5-5 UTAH CODE ANNOTATED 1953, AS AMENDED, APPROVAL IS HEREBY GIVEN FOR CONST. OF AMERICAN FORK RIVER DEBRIS BASIN

Dee C. Hansen
STATE ENGR.

APPROVED BY UTAH CO.

Clyde M. Naylor
CLYDE NAYLOR COUNTY ENGR.

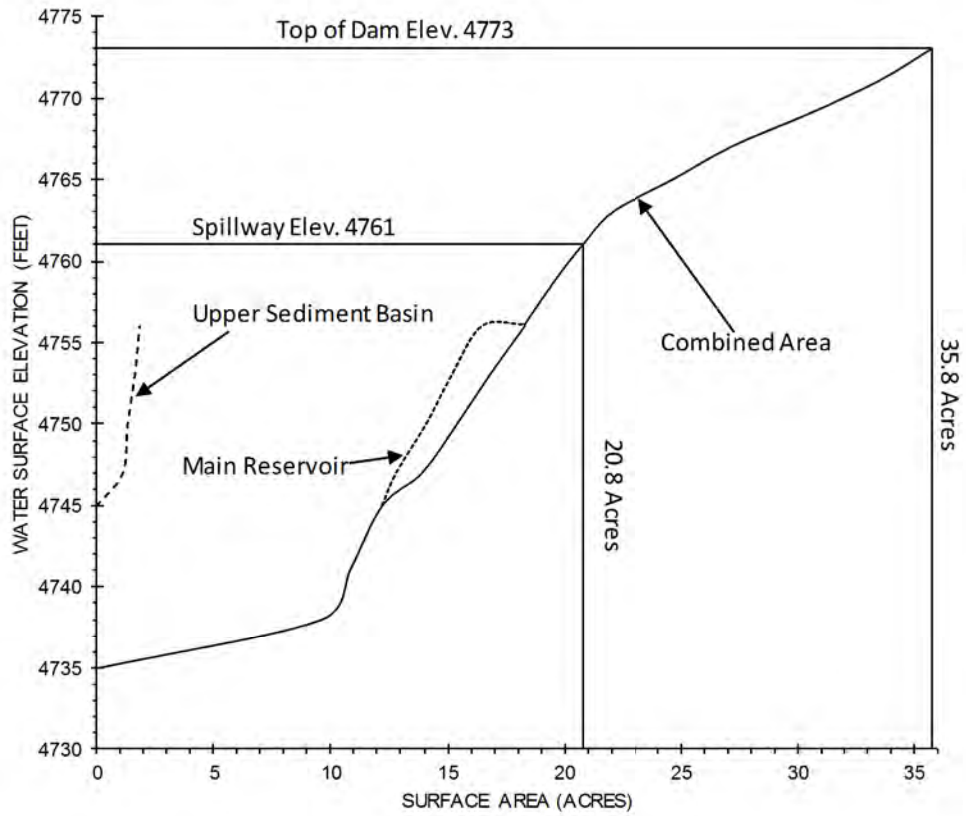
UTAH CO. American Fork DB.
UT00469

John A. Zirbes
JOHN ZIRBES P.E.

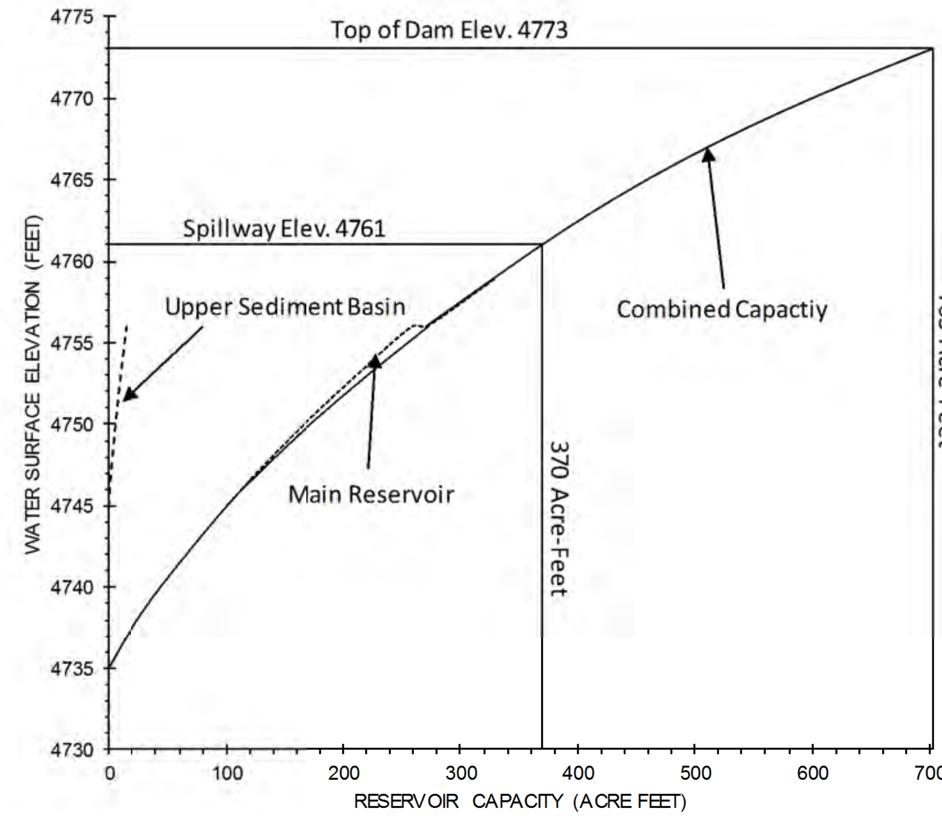
ZIRBES ENGINEERING ASSOCIATES
PROVO, UTAH
FOR
UTAH COUNTY
AMERICAN FORK DEBRIS BASIN

UT469

B.4. Dry Creek Dam and Reservoir – Proposed Capacity, Area, & Rating Curves

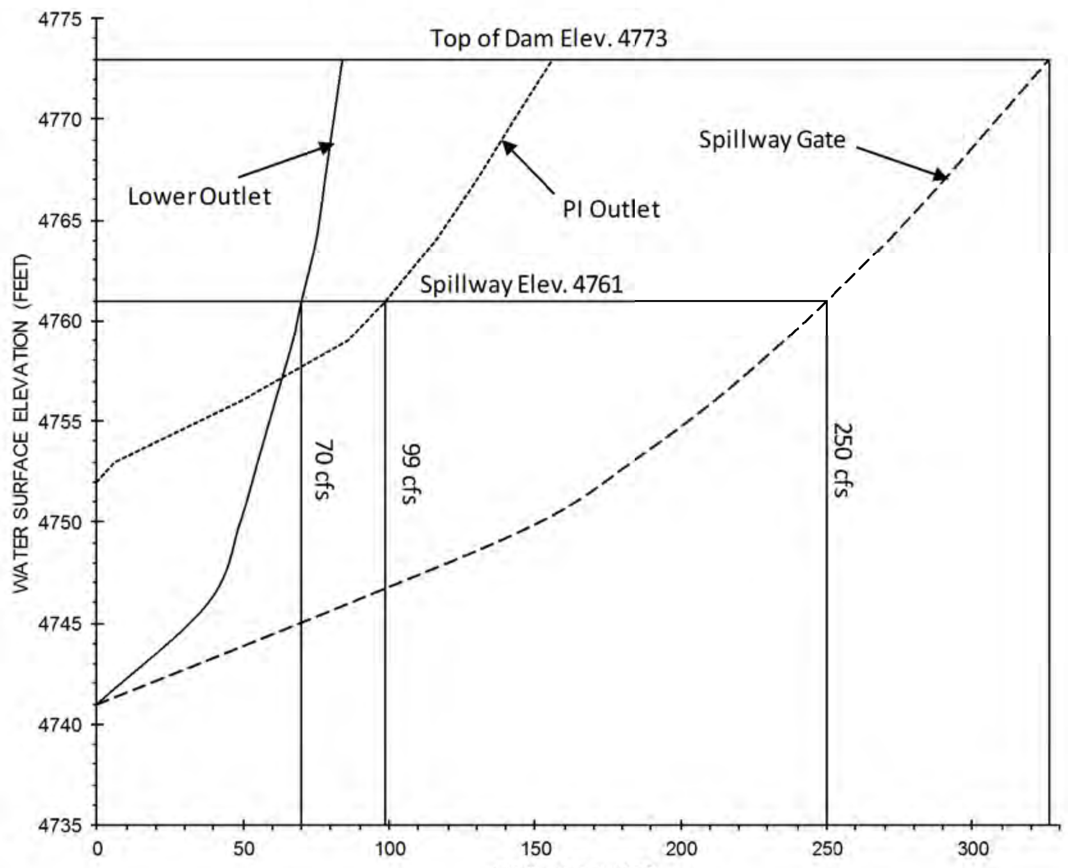


RESERVOIR AREA CURVES

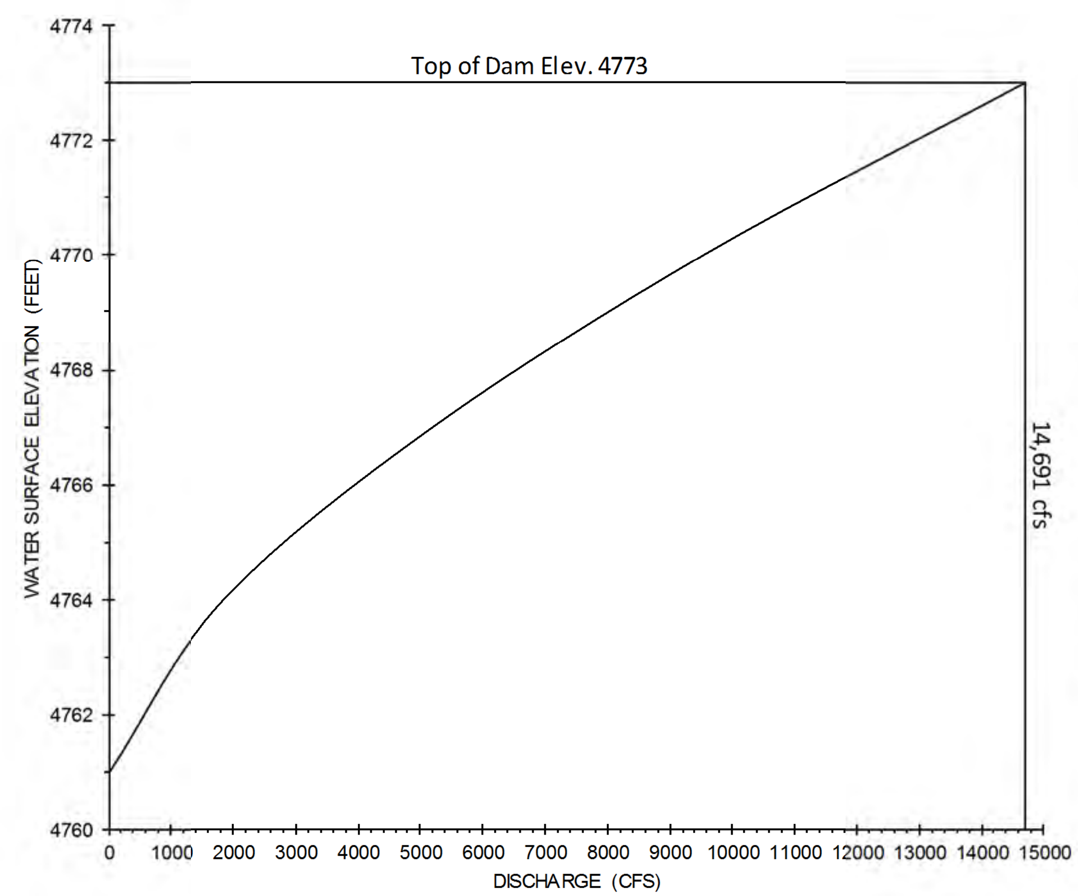


RESERVOIR CAPACITY CURVES

WATER SURFACE ELEVATION (FEET)	Upper Sediment Basin SURFACE AREA (ACRES)	Upper Sediment Basin STORAGE CAPACITY (ACRE-FEET)	Main Reservoir SURFACE AREA (ACRES)	Main Reservoir STORAGE CAPACITY (ACRE-FEET)	Combined SURFACE AREA (ACRES)	Combined STORAGE CAPACITY (ACRE-FEET)
4735			0	0	0	0
4738			9.6	24.3	9.6	24.3
4741			10.8	55.1	10.8	55.1
4745	0.0	0.0	12.2	101	12.2	101.0
4747	1.1	2.0	12.8	126	13.9	128
4750	1.3	5.7	14.1	166	15.4	172
4753	1.6	10.0	15.2	211	16.8	221
4756	1.8	15.0	16.5	258	18.3	273
4759			19.7	330	19.7	330
4761			20.8	370	20.8	370
4763			22.1	413	22.1	413
4765			24.7	460	24.7	460
4767			27.2	512	27.2	512
4769			30.5	570	30.5	570
4771			33.5	634	33.5	634
4773			35.8	703	35.8	703



OUTLET RATING CURVES



SPILLWAY RATING CURVE

WATER SURFACE ELEVATION (feet)	LOWER OUTLET (cfs)	SPILLWAY GATE (cfs)	PI OUTLET (cfs)	SPILLWAY DISCHARGE (cfs)
4741	0	0		
4746	38	86		
4750	49	151	0	
4753	55	183	6	
4756	61	211	49	
4759	67	235	86	
4761	70	250	99	0
4764	75	271	116	1836
4767	78	290	130	5194
4770	81	308	143	9542
4773	84	326	156	14691

NO.	REVISION	MADE BY	DATE	AUTHORIZED BY
1	OUTLET RATING CURVES	JBR	9-27-19	BDH

HORROCKS ENGINEERS

BARRETT ENGINEERING, LLC

RB&G ENGINEERING, INC.

DRY CREEK DAM AND RESERVOIR MODIFICATION, UTAH COUNTY, UTAH

CAPACITY, AREA & RATING CURVES

SEAL: BRANDON D. HORROCKS, STATE OF UTAH, 03/05/2019

DRAWING NO. **G103**

SHEET 4 OF 96

Attachment 4

Technical Memo 004 – Frequency Flood Routing

TM004 – Frequency Flood Routing

Table of Contents

Figures

Tables

1.0 Introduction

American Fork City and Lehi City are collectively working with Franson Civil Engineers (FCE) and Jones & DeMille Engineering (JDE), respectively, to complete a Natural Resources Conservation Service (NRCS) Supplemental Watershed Plan-Environmental Assessment (Plan-EA) for the American Fork River watershed in Utah County. The study includes evaluating how to reduce flooding in American Fork City and Lehi City that are within the aforementioned watershed.

The purpose of this technical memo is to describe the methods, procedures, and results of the flood frequency routing and hydraulic modeling performed for the Supplemental Plan-EA. The recurrence-interval storms to be included in the flood frequency routing are the 10-, 25-, 50-, 100-, 200-, and 500-year 24-hour duration storm events.

2.0 Hydrology

The hydrologic analysis for the American Fork River and Dry Creek watersheds was completed following guidelines outline in the NRCS National Engineering Handbook (NEH) Part 630 – Hydrology (NRCS, 2002). The recurrence interval storms included in the analysis are the 10-, 25-, 50-, 100-, 200-, and 500-year 24-hour duration storm events. *TM003 – Hydrology* documents the methods, procedures, calibration efforts, watershed mapping, and results of the hydrologic analysis; refer to this document for further information on the analysis (FCE & JDE, 2021b).

The summary of design peak flows for all considered improvements along the American Fork River, Waste Ditch, and Dry Creek are shown in Table 2-1. The produced hydrographs for each recurrence intervals storm were used in the hydraulic modeling of the conveyance systems. Note that the proposed alternatives for this Plan-EA do not include any detention basins or other major flood control infrastructure; therefore, the hydrology for existing conditions and the proposed alternatives remained the same.

Table 2-1. Design Peak Flows (cfs) for 24-Hour Recurrence Intervals

Project Location	Recurrence Interval					
	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
American Fork River Improvements	526	678	818	934	1,048	1,199
Waste Ditch Improvements	237	422	553	632	690	754
Dry Creek Improvements	158	282	369	421	460	503

3.0 Hydraulic Modeling

The U.S. Army Corps of Engineers (USACE) River Analysis System (HEC-RAS Version 6.0) was used to model the hydraulic routing (USACE, 2021). This section will outline the development and results of the HEC-RAS 2D hydraulic modeling.

3.1 HEC-RAS 2D Modeling – Methods and Procedures

3.1.1 Terrain Data

The best available elevation surface data for the area was obtained from Utah Geospatial Resource Center (UGRC, 2021). The terrain is a 0.5-meter resolution LiDAR surface that was collected in 2013. The datum for the LiDAR surface is NAVD 88, and it has been projected to the 1983 Utah Central State Plane coordinate system.

After processing and reviewing the quality of the LiDAR, it was found that the LiDAR doesn't sufficiently capture some cross-sections of the open channels. Furthermore, a detailed survey of the open channels was not available for the project. Therefore, modifications were made to the terrain, where appropriate, based on higher quality cross-sections of the LiDAR, site observations, and field measurements.

3.1.2 Surface Roughness (Manning's n)

Land cover data from the 2016 National Land Cover Database (NLCD) was utilized to model the surface roughness for the model (MRLC, 2018). Colorado Dam Safety Branch recommendations for Manning's n values by NLCD land use were used (CDSB, 2020). In addition, Manning's n values for the open channels of American Fork River, Dry Creek, and Waste Ditch were selected based on observed site conditions and aerial imagery. Open channels with natural streambanks ranged from 0.025 to 0.035 depending on the location of the channel; improved channels (formed concrete channels, concrete bottom channel with riprap stream banks, etc.) ranged from 0.013 to 0.028. Multiple areas near Lehi City have significantly developed into residential and commercial buildings since the 2016 NLCD was developed; therefore, land cover was adjusted to the 'Developed, Medium Intensity' category with aerial imagery for these developed areas. The Manning's n values chosen for the hydraulic model are shown in Table 3-1.

Table 3-1. Manning's n Values by Land Cover

NLCD Code	Land Use Description	Manning's n
11	Open Water	0.032
21	Developed, Open Space	0.046
22	Developed, Low Intensity	0.095
23	Developed, Medium Intensity	0.104
24	Developed, High Intensity	0.147
41	Deciduous Forest	0.115
42	Evergreen Forest	0.122
52	Shrub/Scrub	0.082
71	Herbaceous	0.037
81	Pasture/Hay	0.04
82	Cultivated Crops	0.047
90	Woody Wetlands	0.095
95	Emergent Herbaceous Wetlands	0.075
NA	Natural Open Channels	0.025 – 0.035
NA	Improved Open Channels	0.013 – 0.028

3.1.3 2D Mesh Parameters

A computational grid, or mesh, was created for the HEC-RAS 2D model. The cells of the mesh measured 100-feet by 100-feet. Where appropriate, refinement meshes were used to capture hydraulic simulation in the more critical areas (open channels of interest, road crossings, areas of proposed improvements, etc.) of the model. Break lines were also used to capture channel centerlines, streambanks, major roads, and other significant features. The extent of the American Fork River model starts upstream the intersection at 400 N and 400 E road crossing and extends downstream to Utah Lake. The extent of the Dry Creek and Waste Ditch model starts upstream of Interstate 15 (I-15) and extends downstream to Utah Lake and the Jordan River.

Time steps for the model were selected to maintain a Courant number of approximately 1.0. Several time steps were considered for a sensitivity analysis to ensure stable and accurate results. The diffusion wave equation set, as described in the HEC-RAS Reference Manual, was used for the 2D simulations.

3.1.4 Boundary Conditions

The hydrographs developed in *TM003 – Hydrology* for the 24-hour recurrence interval storms shown in Table 2-1 were used for the upstream boundary conditions (FCE & JDE, 2022b). For the model of American Fork City, the upstream boundary conditions were placed approximately 100-yards upstream of the 400 N and 400 E road crossing. For Lehi City's model, the upstream boundary conditions for Waste Ditch and Dry Creek were placed downstream of Highway 89 (State Street). See *TM003* – Hydrology for further detail (FCE & JDE, 2022b).

The downstream boundary conditions were modeled using a normal flow depth method using approximate slopes from the 2013 LiDAR terrain.

3.1.5 Road Crossing Data

There is a significant amount of road crossings along the American Fork River, Dry Creek, and Waste Ditch. For the American Fork River, the initial data for the bridges and culverts at the road crossings were obtained from a HEC-2 model developed by FEMA in 1979 (FEMA, 2021). Dimensions for bridges and culverts were updated with site observations and measurements. For Dry Creek and Waste Ditch, bridge and culverts dimensions and material type were received from Lehi City for the majority of road crossings. Invert elevation data was not available for the project; therefore, inverts and slopes selected for the HEC-RAS 2D inline structures were based on the 2013 LiDAR data. More pertinent road crossings were further verified with site observations. If necessary, terrain modifications were made to implement the site measurements.

3.1.6 Waste Ditch and Dry Creek Diversion

The Waste Ditch and Dry Creek diversion is located approximately 850 feet upstream of Lehi Elementary School. The structure consists of two rectangular concrete channel sections each with a stop log gate (see Figure 3-1). A hydrology and hydraulics report completed for Utah Department of Transportation (UDOT) explains that Lehi City estimates the existing capacity of Dry Creek to be 150-200 cfs and the existing capacity of Waste Ditch to be 550 cfs (UDOT, 2018). After discussing the intended operation of the diversion with Lehi City, it was determined to assume that the diversion will be operated so that 60% of storm flows is conveyed to Waste Ditch and the remaining 40% is conveyed to Dry Creek. This was accomplished distributing the hydrographs accordingly and inputting them into the model downstream of Highway 89, as described in Section 3.1.4.

Figure 3-1. Waste Ditch and Dry Creek Diversion

3.2 Modeling of Existing Conditions and Proposed Alternatives

Hydraulic modeling was performed for the existing conditions and the proposed alternative conditions. The incremental differences in flood depths will be used to determine the economic benefits produced from the project, which is further discussed in *TM006 – Economics* (Long Watershed Planning Economics, 2023).

A detailed description of the proposed improvements, hydraulic analyses, exhibits, and cost estimates of the proposed improvements for American Fork City and Lehi City is provided in *TM005 – Hydraulic Analysis* (FCE & JDE, 2023c). Per City standards, the improvements for American Fork River provide flood protection up to the 100-year storm event (American Fork City, 2008); Waste Ditch and Dry Creek improvements provide flood protection up to the 50-year storm event (Lehi City, 2016). A summary of improvements for the proposed conditions hydraulic model are listed below:

Note that there are three sets of hydraulic modeling and economics analysis: 1) American Fork River improvements, 2) Waste Ditch and upper portion of Dry Creek improvements, and 3) lower portion of Dry Creek improvements. All improvements proposed for Waste Ditch and the upper Dry Creek improvements are dependent on each other for successful flood protection. The hydraulic modeling for the lower Dry Creek assumes that all upstream infrastructure along the conveyance has been improved in future projects (no flooding occurs between Lehi Elementary School and 700 South).

3.3 Results and Inundation Maps

Depth rasters and inundation boundaries from the hydraulic modeling results were exported to create the inundation maps (see Appendix A) and to determine the number of inundated infrastructure that would be used for the economic analysis (see Appendix B).

The 10-year and 25-year storm event inundation maps for the proposed conditions were not created due to their similar mapping to the 50-year storm event.

To assist with the economic analysis, the depth rasters were intersected with building footprint and parcel GIS data (UGRC, 2021). The number of inundated structures were counted and categorized based on their flood depths and building category (residential, commercial, school, etc.). This data is then correlated with 2021 tax and market values obtained from Utah County. For more information and results on the economic analysis, refer to *TM006 – Economics* (Long Watershed Planning Economics, 2022).

3.3.1 American Fork City

For existing conditions, there is minimal flooding during the 10-year storm event (flooding is isolated to the 400 North and 400 East road crossing). During the 50-year storm event, flooding starts to occur at the majority of road crossings, and the severity of flooding increases for less frequent storm events. According to the hydraulic modeling results for existing conditions, the 100-year storm event inundates a total of 54 mobile homes, 102 residential homes, 57 commercial buildings, one school building, three churches, and nine other buildings.

The proposed improvements contain the majority of the 100-year storm event within the river. Note that the proposed improvements do not cause induced flooding downstream of I-15. The total of inundated structures for the 100-year storm event with proposed improvements is reduced to one residential building, 10 commercial buildings (located downstream of I-15), and one other building.

3.3.2 Lehi City – Waste Ditch and Upper Dry Creek

As Lehi City has already experienced, the hydraulic modeling shows significant flooding near Lehi Elementary School for the existing conditions. Note that a significant portion of flooding from Waste Ditch flows and enters the floodplain produced by Dry Creek. Existing flooding that crosses the Union Pacific and Utah Transit Authority railroad is shown to spread through the majority of the City. According to the modeling results, the existing conditions may inundate approximately 5 mobile homes, 762 residential homes, 48 commercial buildings, 7 school buildings, and 35 other structures during the 50-year flood event.

The proposed improvements for Waste Ditch and the upper portion of Dry Creek successfully provide protection for the 50-year storm event, and significant improvements for the 100-year storm event. For proposed conditions, 142 residential homes, 12 commercial buildings, 4 school buildings (which include Lehi Elementary School buildings), and 8 other structures are removed from the existing floodplain during the 50-year storm event.

It is noted that Dry Creek continues to have insufficient capacity downstream of the proposed improvements for high flood events. Although the proposed improvements do not result in induced flooding, it is recommended that Lehi City improves the remaining conveyance of Dry Creek during future projects to provide further flood protection.

3.3.3 Lehi City – Lower Dry Creek

Pioneer Crossing (major road) provides a separation of flooding extents on the lower portion of Dry Creek. This causes flooding of several homes upstream of Pioneer Crossing. Downstream of Pioneer Crossing, there is existing flooding on newly developed residential homes and several acres of agricultural land that could likely be developed in the future. Existing flooding for the 50-year storm event includes approximately 135 residential homes and/or plots and 4 other structures.

The proposed improvements would remove all mentioned residential homes and other structures from flooding during the 50-year storm event. The proposed improvements also provide significant flood protection during higher flood events; for example, the 100-year storm event reduces the number of inundated residential homes to 7 (existing conditions inundates 147 homes).

4.0 Summary

A HEC-RAS 2D model was created to model the existing conditions and proposed improvements for American Fork City (American Fork River) and Lehi City (Dry Creek and Waste Ditch). The proposed improvements resulted in a significant reduction of flooding and the modeling does not show induced flooding downstream of the proposed improvements.

Refer to *TM005 – Hydraulic Analysis* (FCE & JDE, 2023c) and *PR&G and Economics Analysis* (Long Watershed Planning Economics, 2023) for a detailed description of the proposed improvements and the economic analysis completed with the modeling results presented in this report.

5.0 References

American Fork City. (2008). *Storm Water Technical Manual*. May 2008.

Lehi City. (2016). *Lehi City Design Standards and Public Improvement Specifications*. 2016.

Long Watershed Planning Economics. (2022). Technical Memo 006 – Economics.

Colorado Dam Safety Branch. (2020). *Guidelines for Hydrologic Hazard Analysis*. January 21, 2020.

Federal Emergency Management Agency (FEMA). (2020a). Flood Insurance Rate Map: Map No. 49049C0163F. Utah County, Utah and Incorporated Areas; Panel 163 of 1450. June 19, 2020.

FEMA. (2020b). Flood Insurance Study Number 49049CV001A. Utah County, Utah and Incorporated Areas; Volume 1 of 3. June 19, 2020.

FEMA. (2021c). Flood Insurance Study Data Request: HEC-2 Models for American Fork, Utah County, Utah; Alpine, Utah County, Utah; Lehi, Utah County, Utah. FEMA Engineering Library. Data was received on July 20, 2021.

Franson Civil Engineers and Jones & DeMille Engineering (FCE & JDE). (2021a). Technical Memo 001 – Existing Conditions.

FCE & JDE. (2021b). Technical Memo 003 – Hydrology.

FCE & JDE. (2021c). Technical Memo 005 – Hydraulic Analysis.

Multi-Resolution Land Characteristics Consortium. (2018). 2016 National Land Cover Dataset. https://www.mrlc.gov/data

Natural Resources Conservation Service. (2002). National Engineering Handbook, Part 630 Hydrology, Chapter 8: Land Use and Treatment Classes. June 2002.

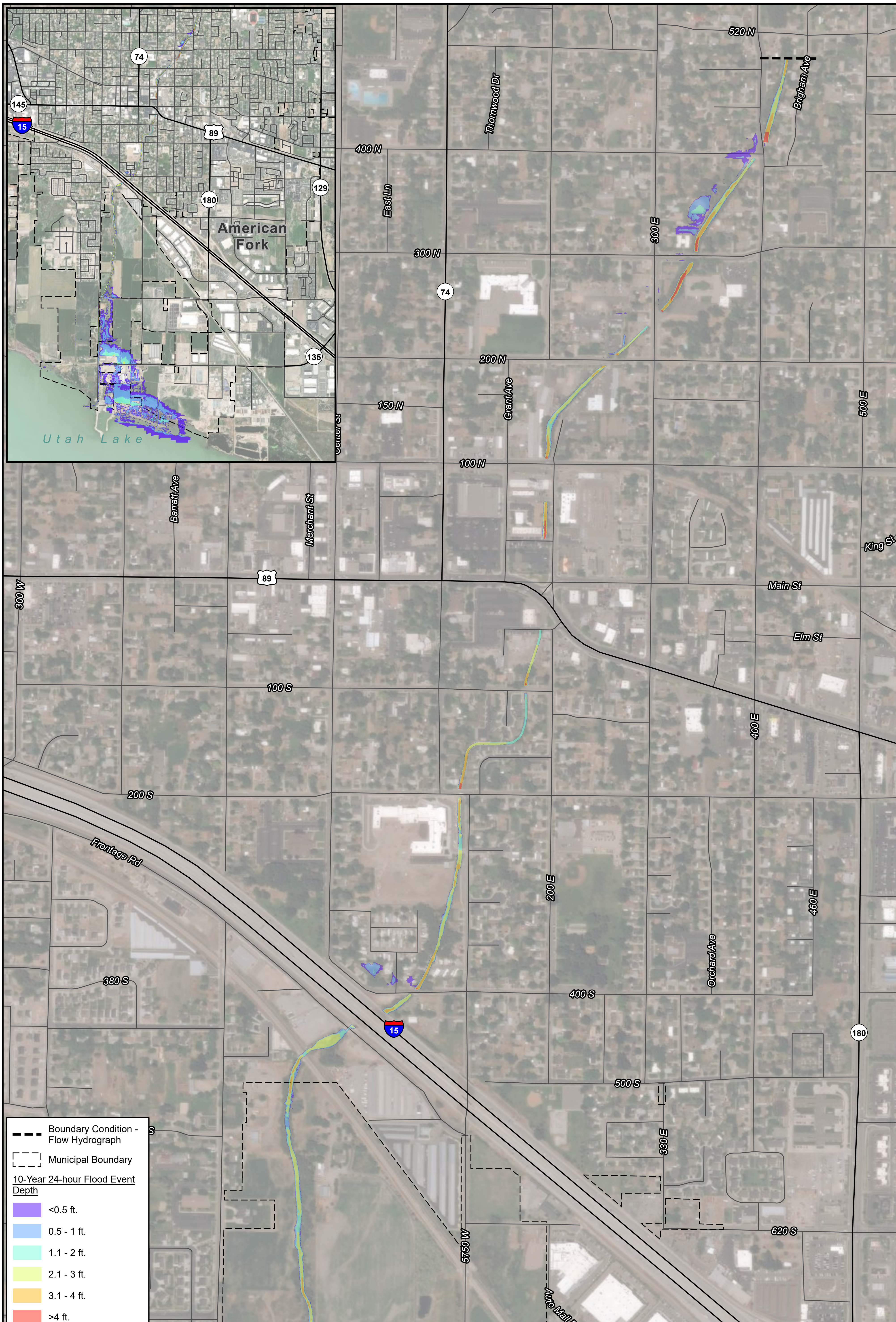
U.S. Army Corps of Engineers. (2021). Hydrologic Engineering Center – River Analysis System (HEC-RAS). Version 6.0. May 2021.

Utah Department of Transportation. (2018). *I-15; Lehi Main to SR-92 Widening Structure No. E-2735 Hydraulics Report.* Prepared by Ames-Wadsworth Joint Venture Design Team. June 1, 2018.

Utah Geospatial Resource Center. (2021). https://gis.utah.gov/

Appendix A. Exhibits

A.1. American Fork City Inundation Maps



N

Feet
0 300 600

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

American Fork City

Watershed Plan EA
Existing Conditions - 10-year 24-hour Flood Event

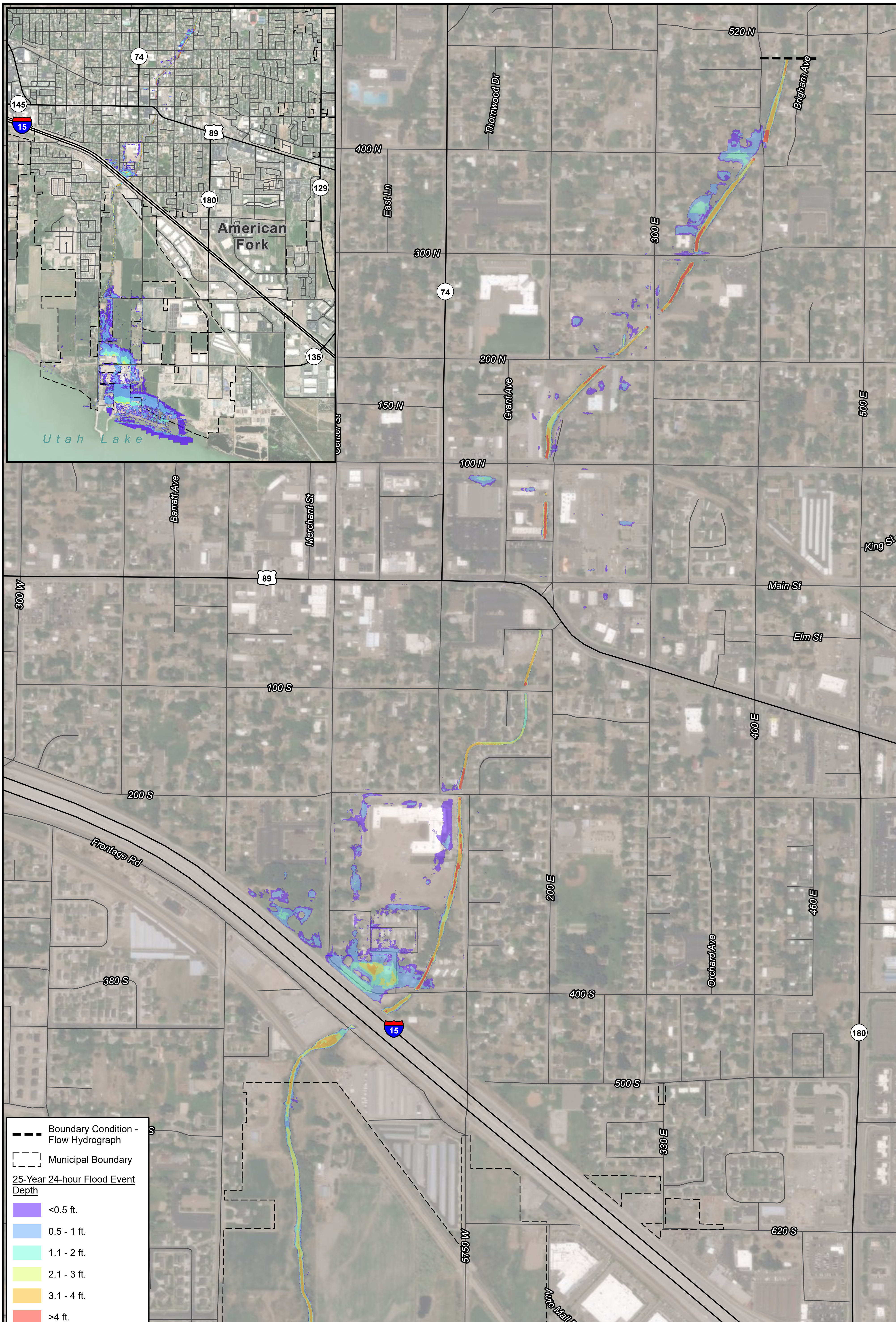
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Existing Conditions - 10-Year 24-hour Flood Event 11x17P

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 12/21/2021

Utah County

Scale: 1" = 600'

1



N

0 300 600 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

American Fork City

Utah County

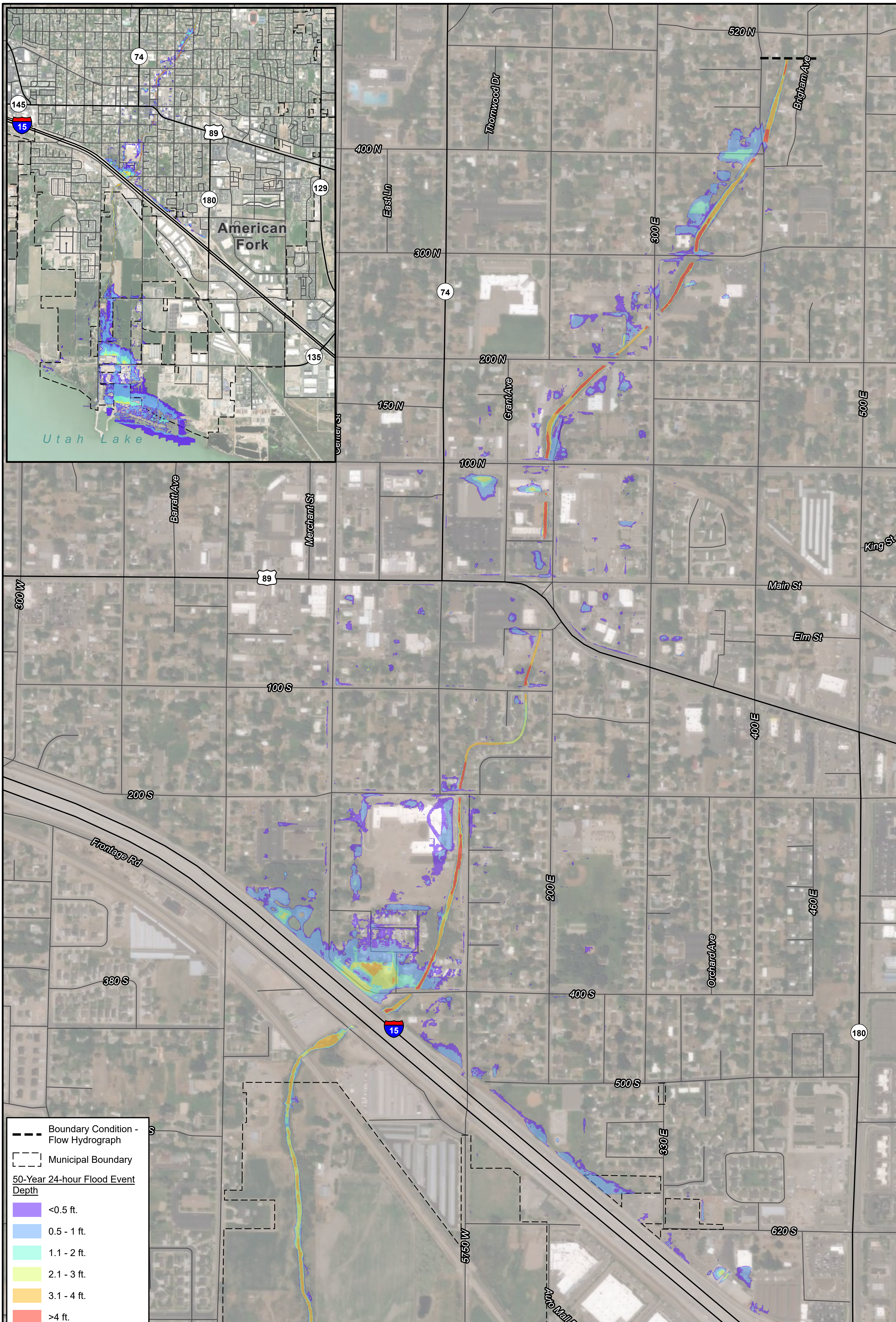
Watershed Plan EA
Existing Conditions - 25-year 24-hour Flood Event

Scale: 1" = 600'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Existing Conditions - 25-Year 24-hour Flood Event 11x17P

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 12/21/2021

2



N

Feet

0 300 600

FRANSON
CIVIL ENGINEERS

Jones & DeMille Engineering

American Fork City

Watershed Plan EA
Existing Conditions - 50-year 24-hour Flood Event

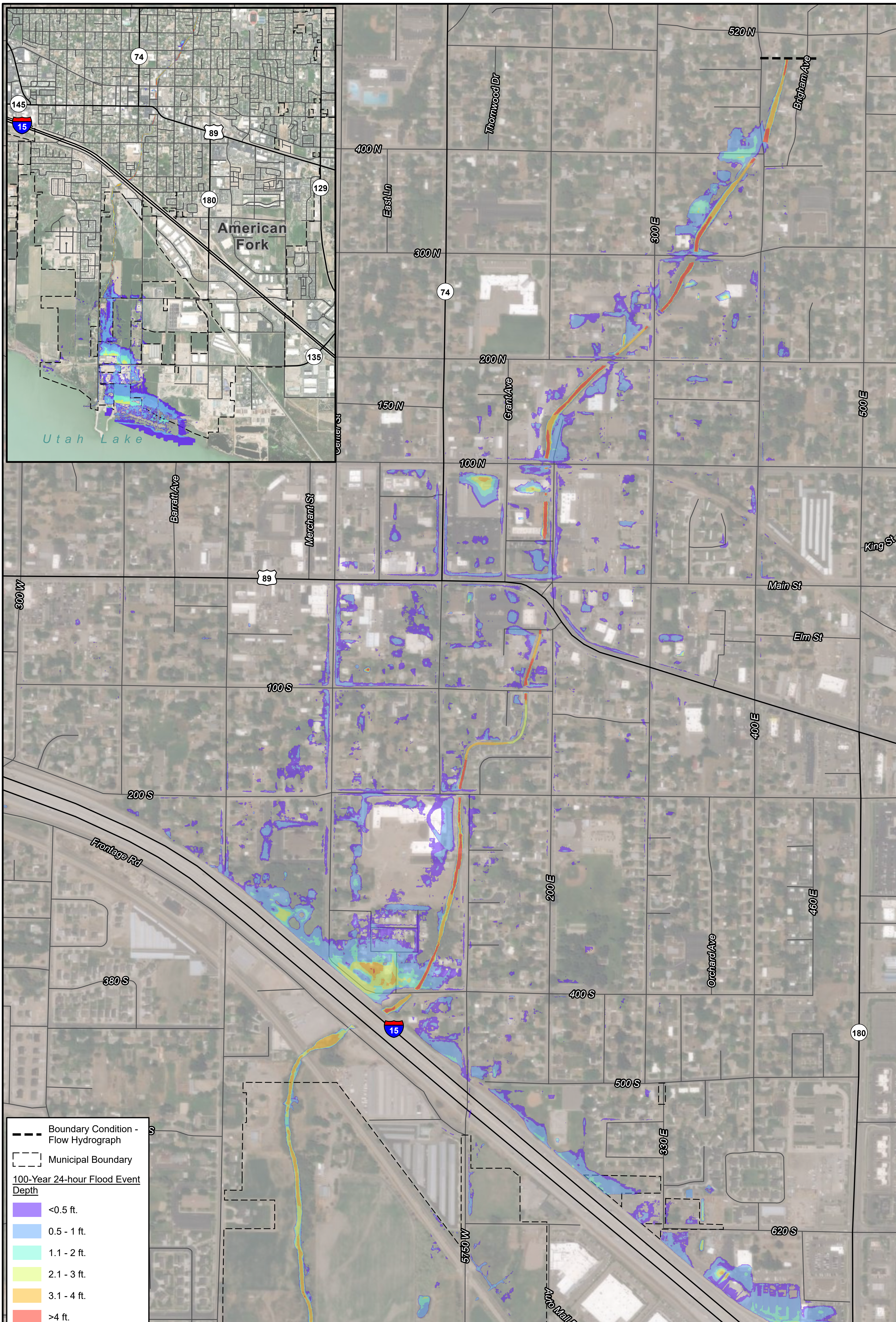
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Existing Conditions - 50-Year 24-hour Flood Event 11x17P

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 12/21/2021

Utah County

Scale: 1" = 600'

3



N

0 300 600 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

American Fork City

Utah County

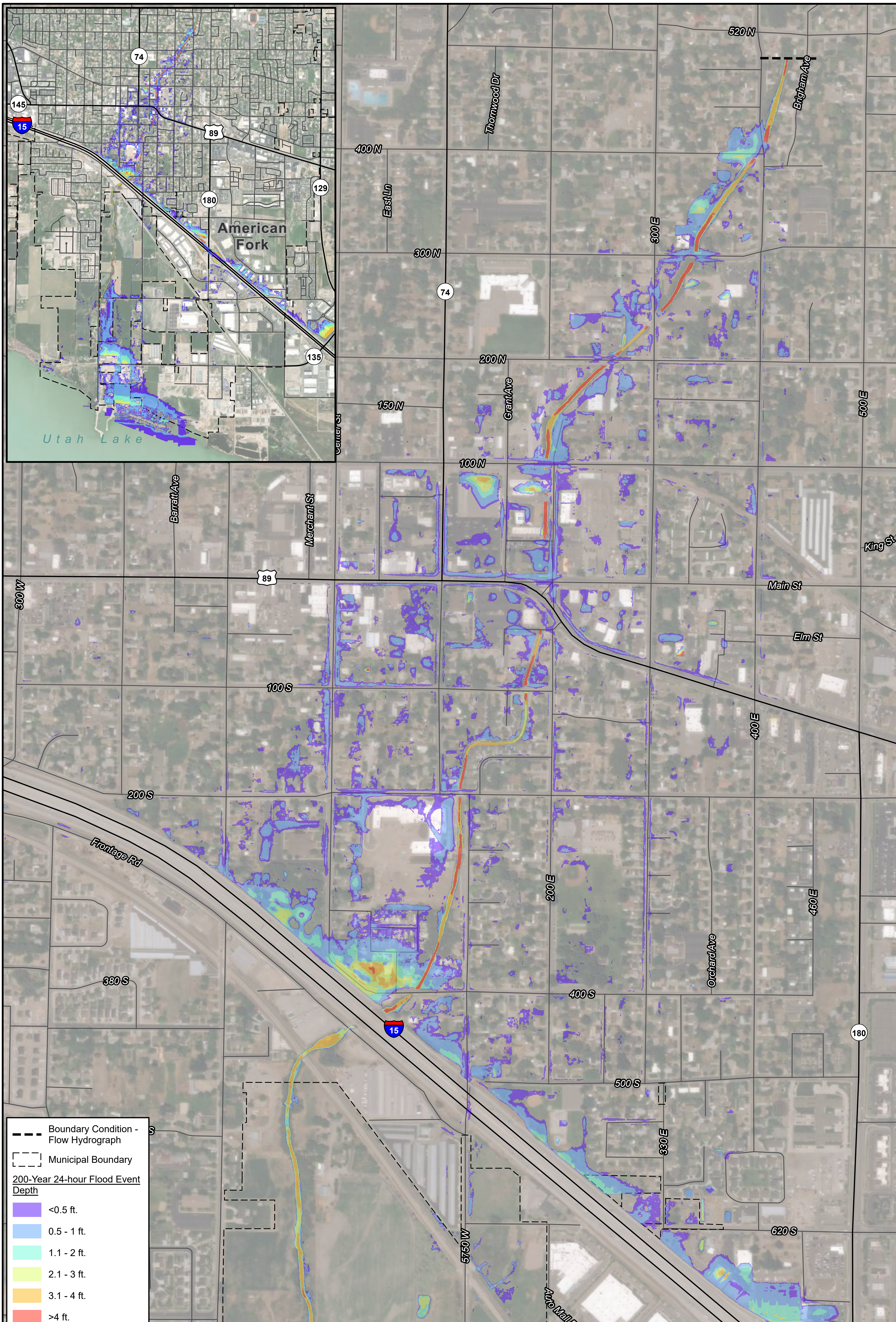
Watershed Plan EA
Existing Conditions - 100-year 24-hour Flood Event

Scale: 1" = 600'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Existing Conditions - 100-Year 24-hour Flood Event 11x17P

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 12/21/2021

4



N

Feet
0 300 600

FRANSON
CIVIL ENGINEERS

Jones & DeMille Engineering

American Fork City

Utah County

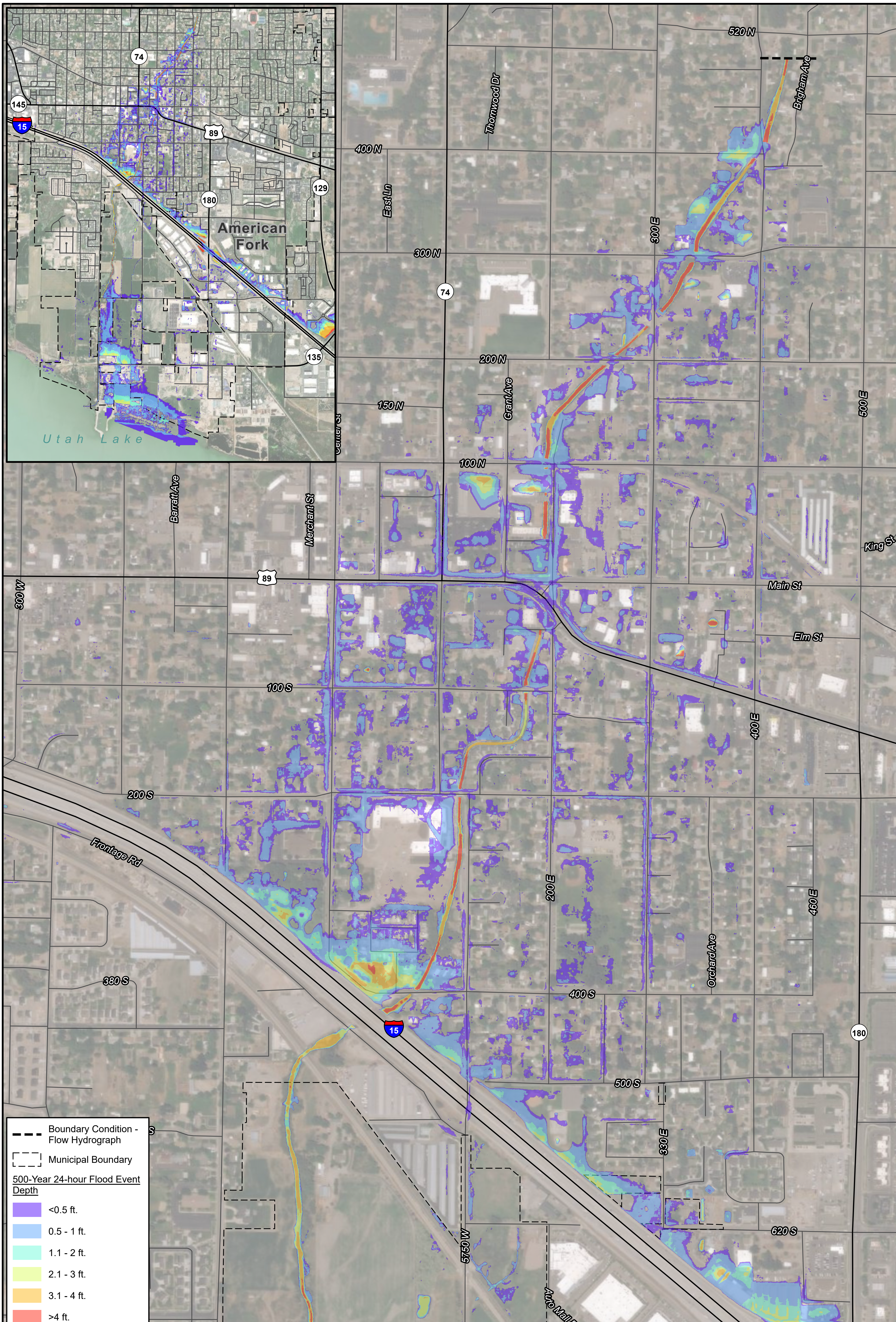
Watershed Plan EA
Existing Conditions - 200-year 24-hour Flood Event

Scale: 1" = 600'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Existing Conditions - 200-Year 24-hour Flood Event 11x17P

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 12/23/2021

5



N

0 300 600 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

American City Fork

Utah County

Watershed Plan EA

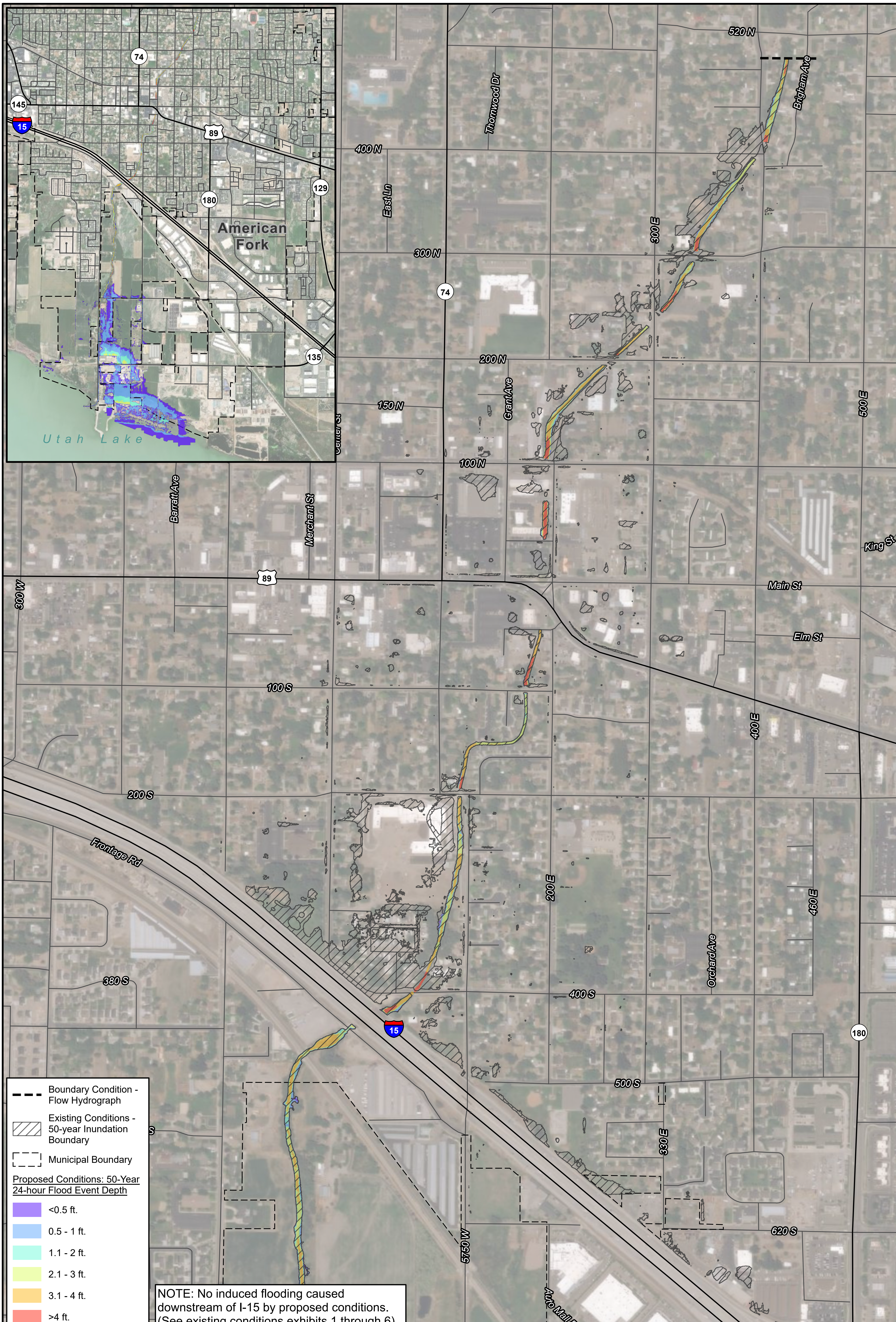
Existing Conditions - 500-year 24-hour Flood Event

Scale: 1" = 600'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Existing Conditions - 500-Year 24-hour Flood Event 11x17P

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 12/23/2021

6



FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

American Fork City

Watershed Plan EA
Proposed Conditions - 50-year 24-hour Flood Event

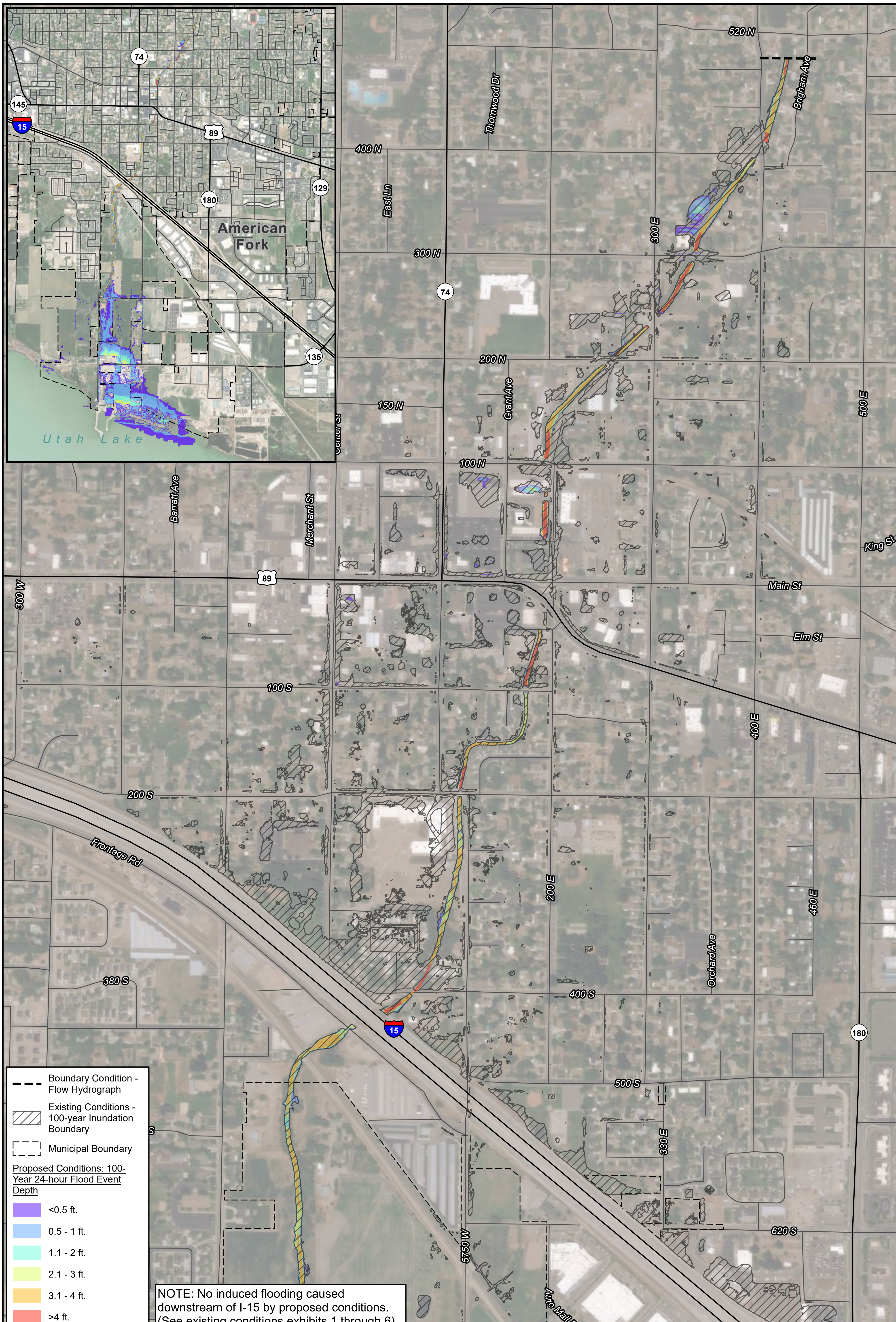
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Proposed Conditions - 50-Year 24-hour Flood Event 11x17P

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 12/23/2021

Utah County

Scale: 1" = 600'

7



FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

American Fork City

Utah County

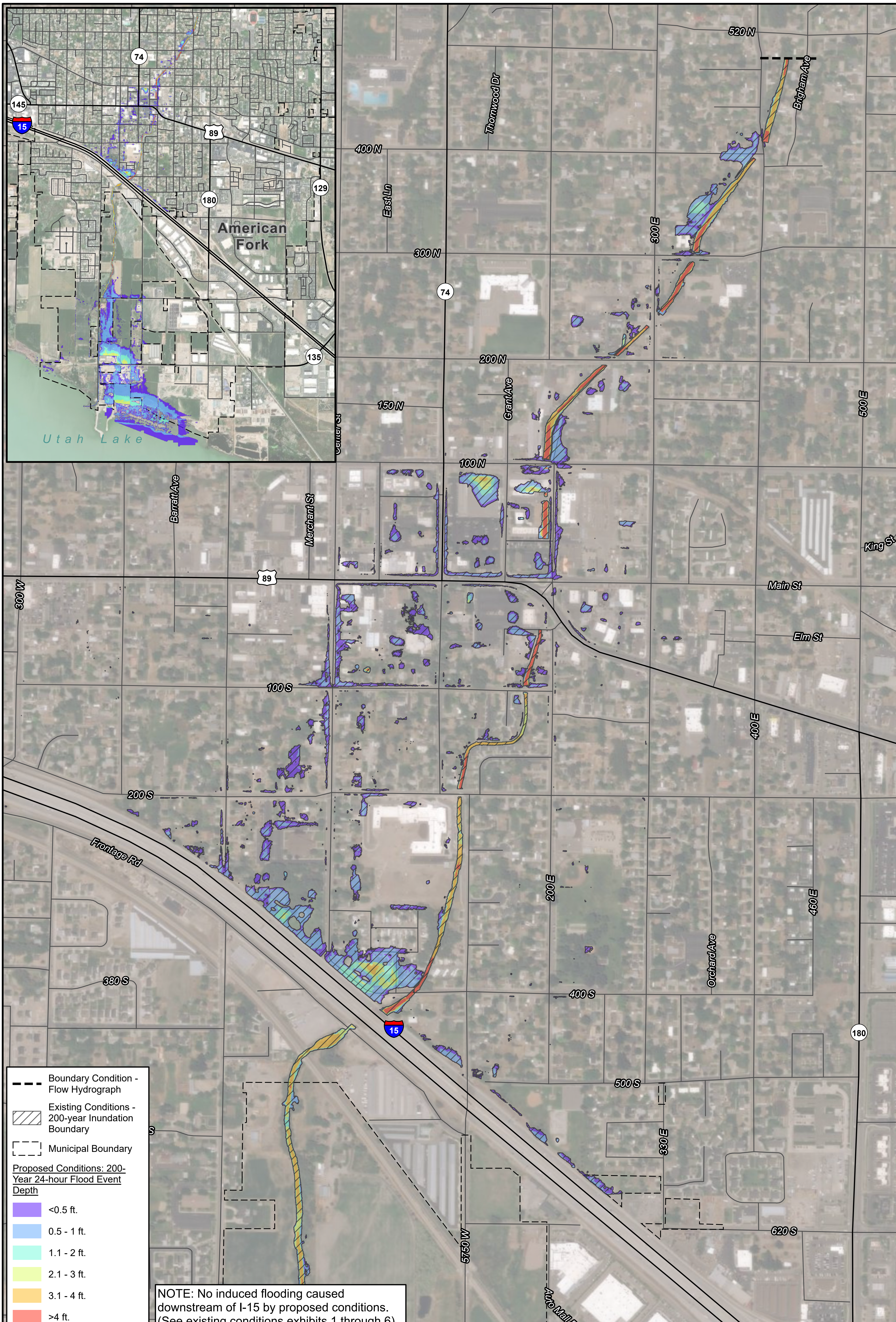
Watershed Plan EA
Proposed Conditions - 100-year 24-hour Flood Event

Scale: 1" = 600'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Proposed Conditions - 100-Year 24-hour Flood Event 11x17P

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 12/23/2021

8



N

Feet 0 300 600

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

American Fork City

Utah County

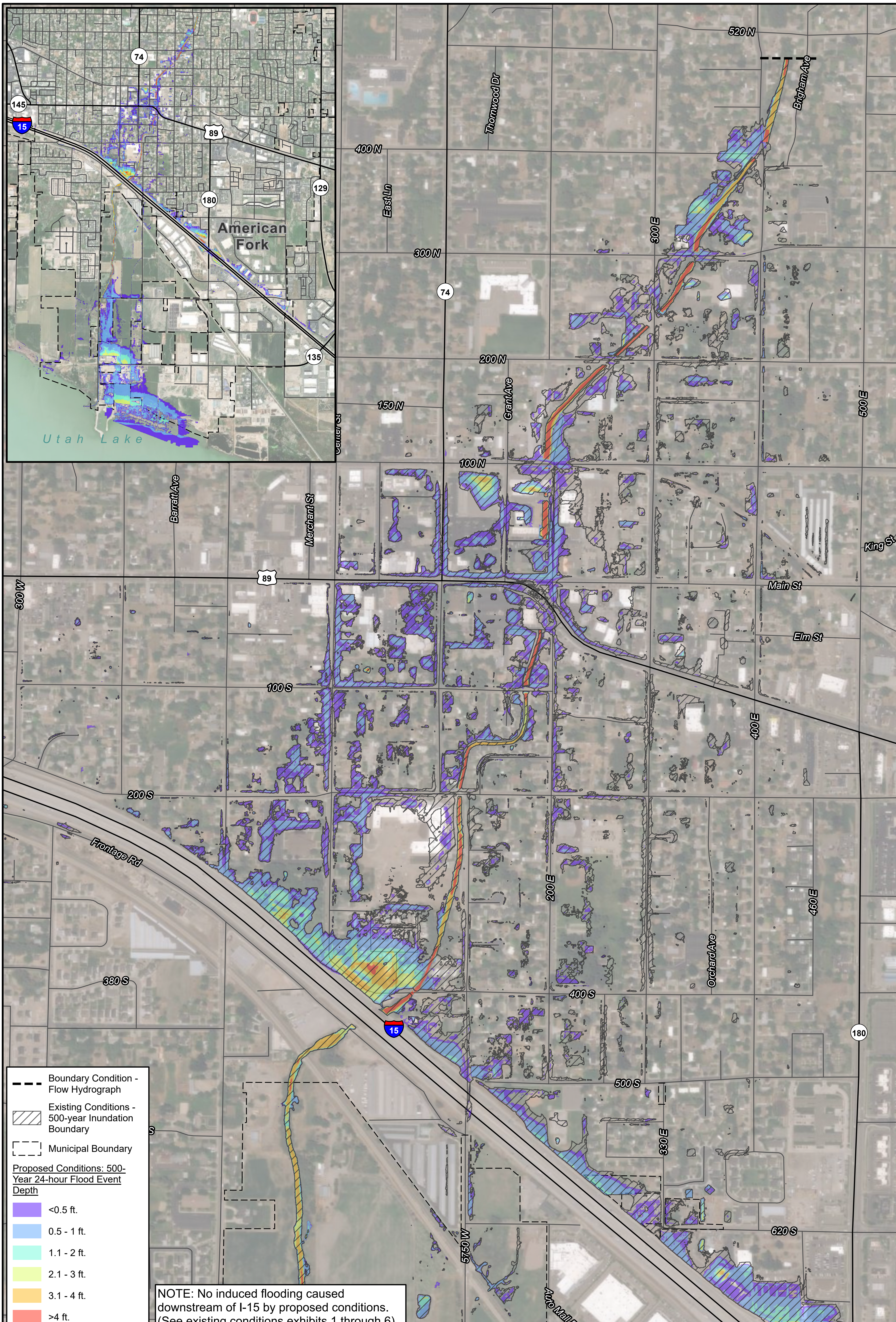
Watershed Plan EA
Proposed Conditions - 200-year 24-hour Flood Event

Scale: 1" = 600'

9

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Proposed Conditions - 200-Year 24-hour Flood Event 11x17P

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 12/23/2021



N
Feet
0 300 600

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

American Fork City

Watershed Plan EA
Proposed Conditions - 500-year 24-hour Flood Event

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Proposed Conditions - 500-Year 24-hour Flood Event 11x17P

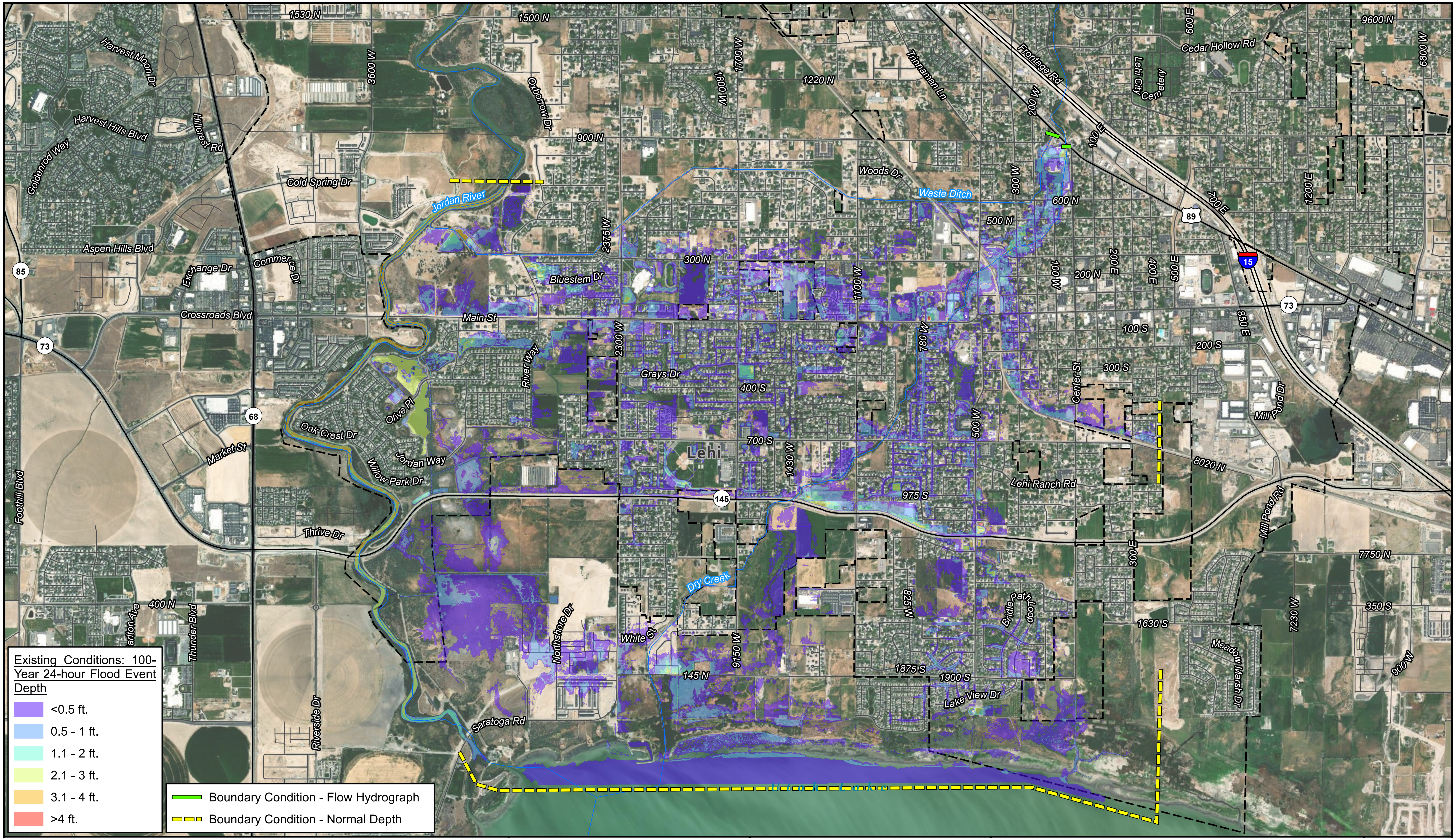
Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 12/23/2021

Utah County

Scale: 1" = 600'

10

A.2. Lehi City Inundation Maps – Waste Ditch and Upper Dry Creek



Municipal Boundary

N

0 1,000 2,000 Feet

Note: Index displays the inundation boundary for the 100-year 24-hour flood event. Each flood recurrence interval is mapped on Sheets A, B, and C only as those areas are directly related to the proposed improvements included in the Watershed Plan-EA. Maps are numbered beginning with the 10-year flood event at 1A through the 500-year event at 6A.

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Existing Conditions Flood Event Overview

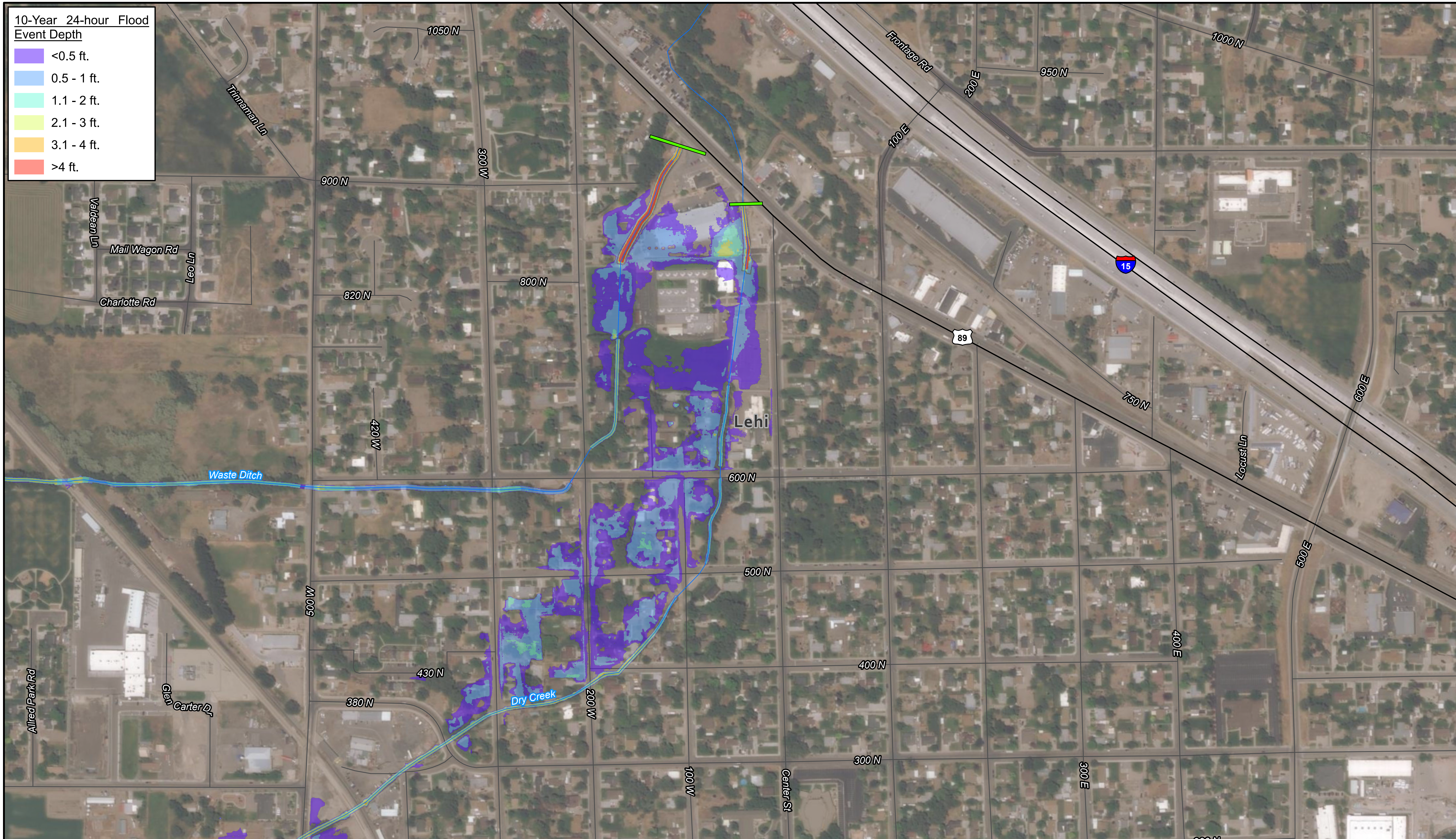
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions Flood Event Index 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

Utah County

Scale: 1" = 2,000'

Index



Boundary Condition - Flow Hydrograph
Municipal Boundary

N

Feet
0 200 400

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Existing Conditions - 10-year 24-hour Flood Event

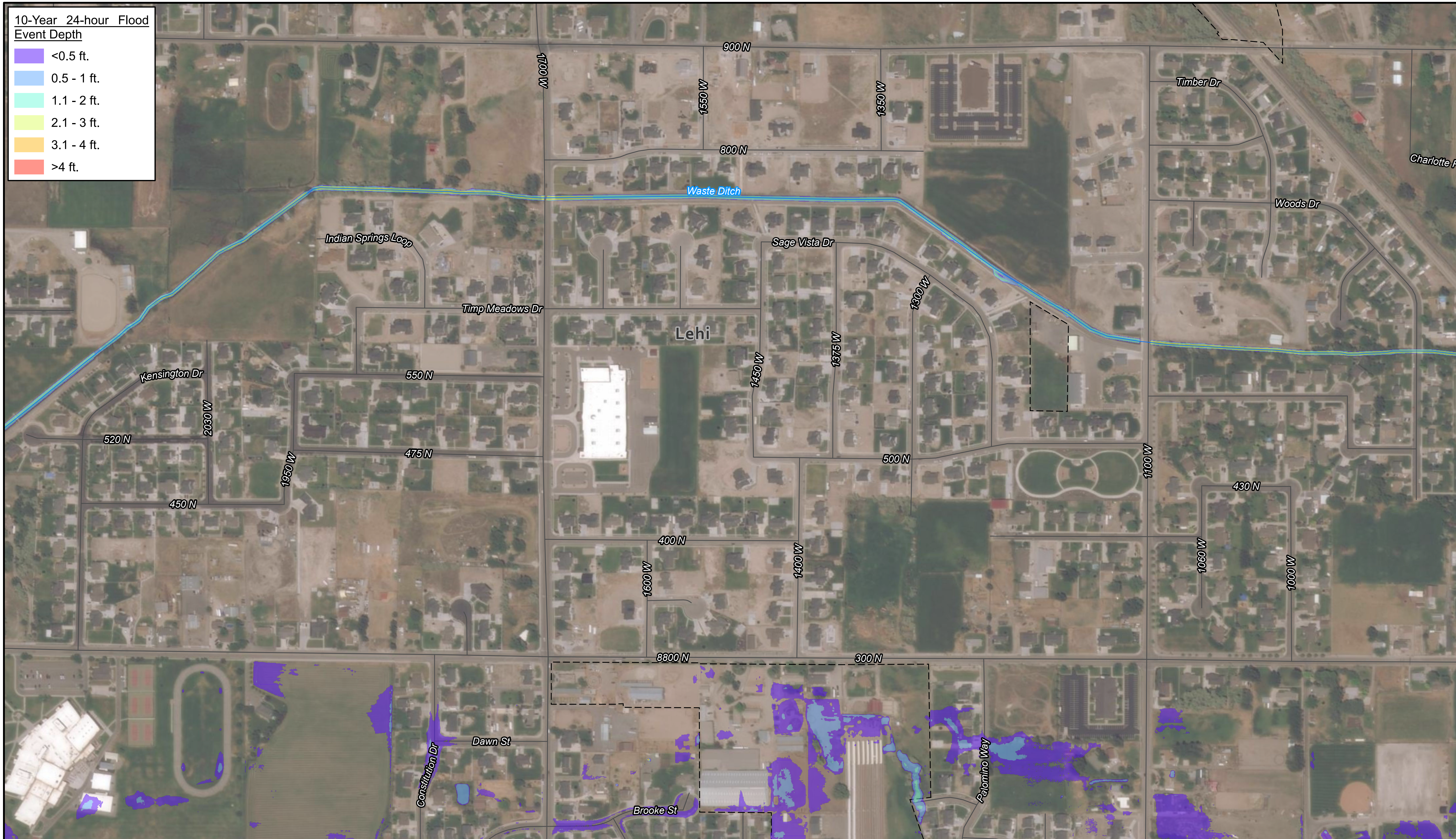
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 10-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

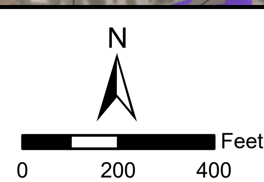
Utah County

Scale: 1" = 400'

1A



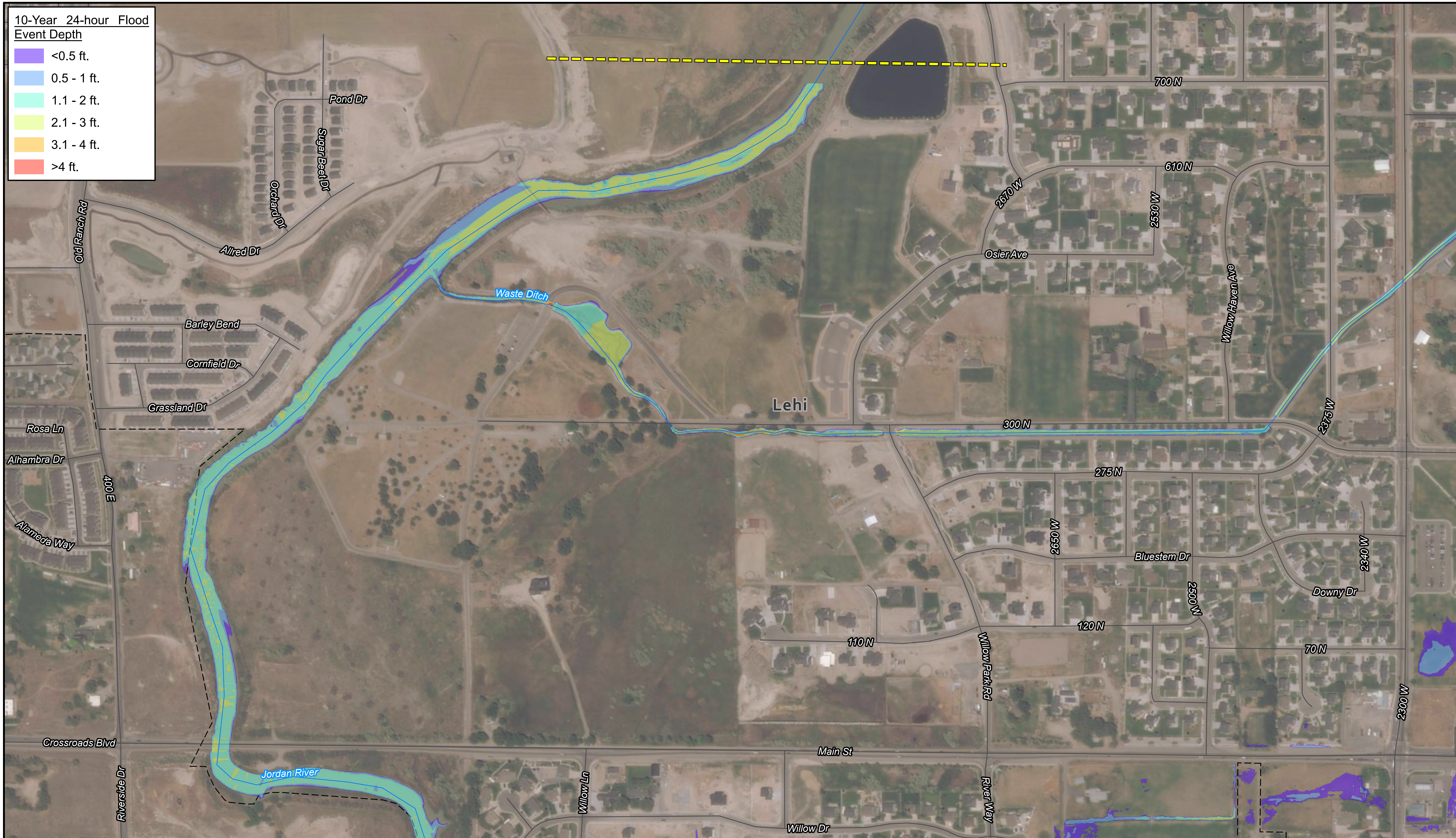
Municipal Boundary



FRANSON
CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City	Utah County
Watershed Plan EA *Existing Conditions - 10-year 24-hour Flood Event*	Scale: 1" = 400'
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 10-year 24-hour Flood Event 11x17L	1B
Project Number: 2004-028 Drawn by: JEM 12-21 Last Edit: 02/10/2022	



Boundary Condition - Normal Depth

Municipal Boundary

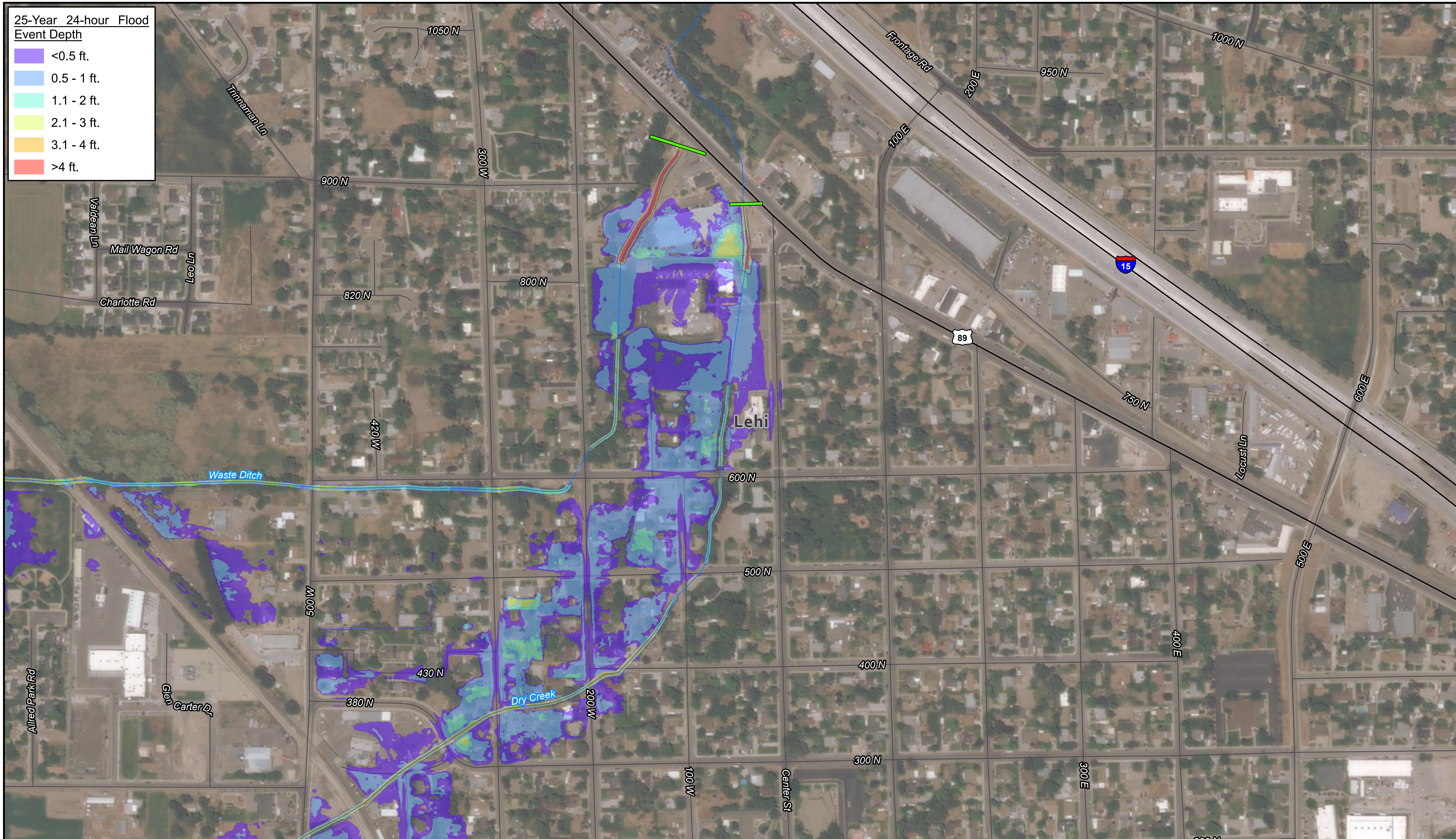
N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City	**Utah County**
Watershed Plan EA ***Existing Conditions - 10-year 24-hour Flood Event***	Scale: 1" = 400'
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 10-year 24-hour Flood Event 11x17L	**1C**
Project Number: 2004-028 · Drawn by: JEM 12-21 · Last Edit: 02/10/2022	



Boundary Condition - Flow Hydrograph

Municipal Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Utah County

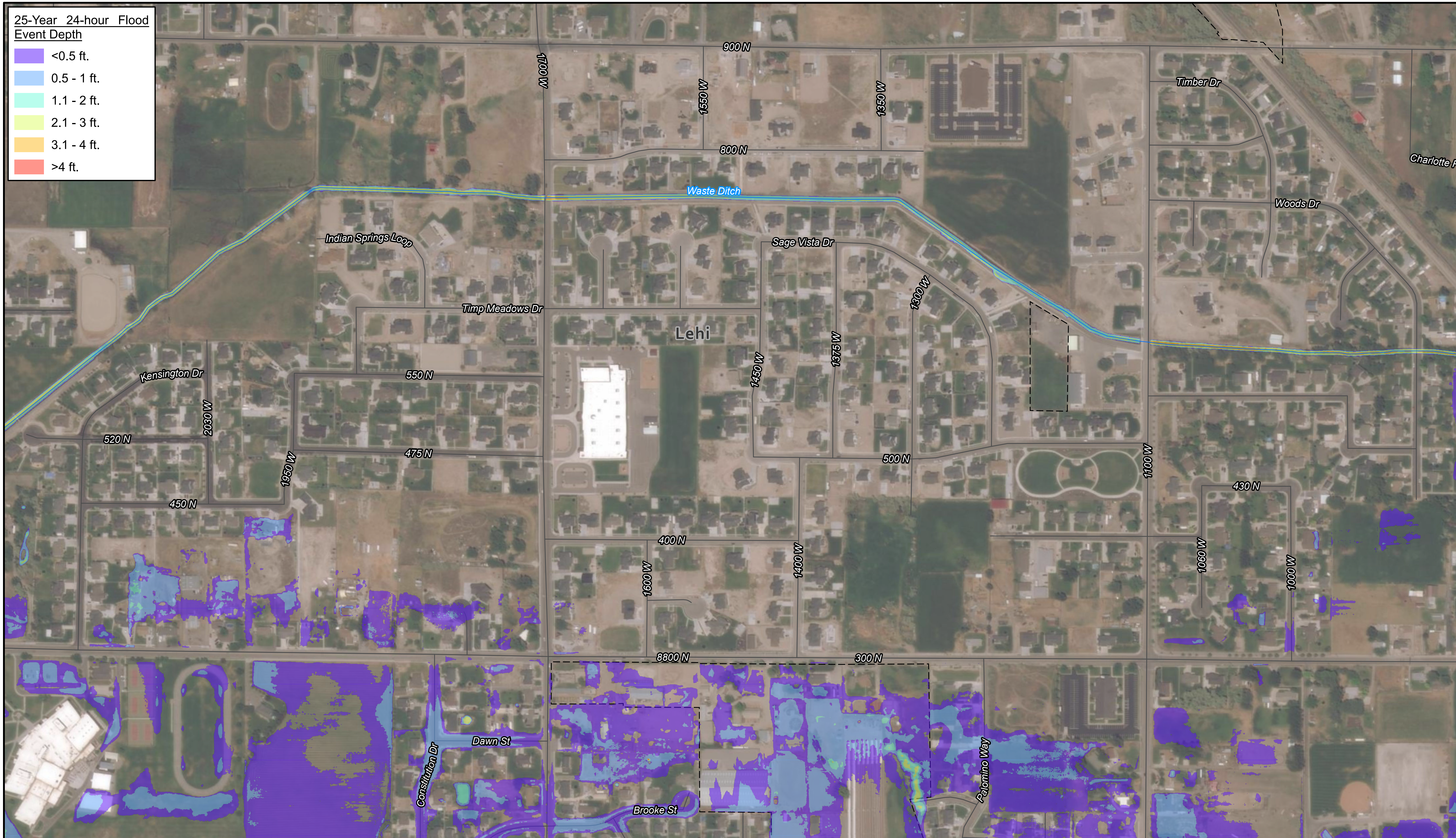
Watershed Plan EA
Existing Conditions - 25-year 24-hour Flood Event

Scale: 1" = 400'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 25-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

2A



Municipal Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Utah County

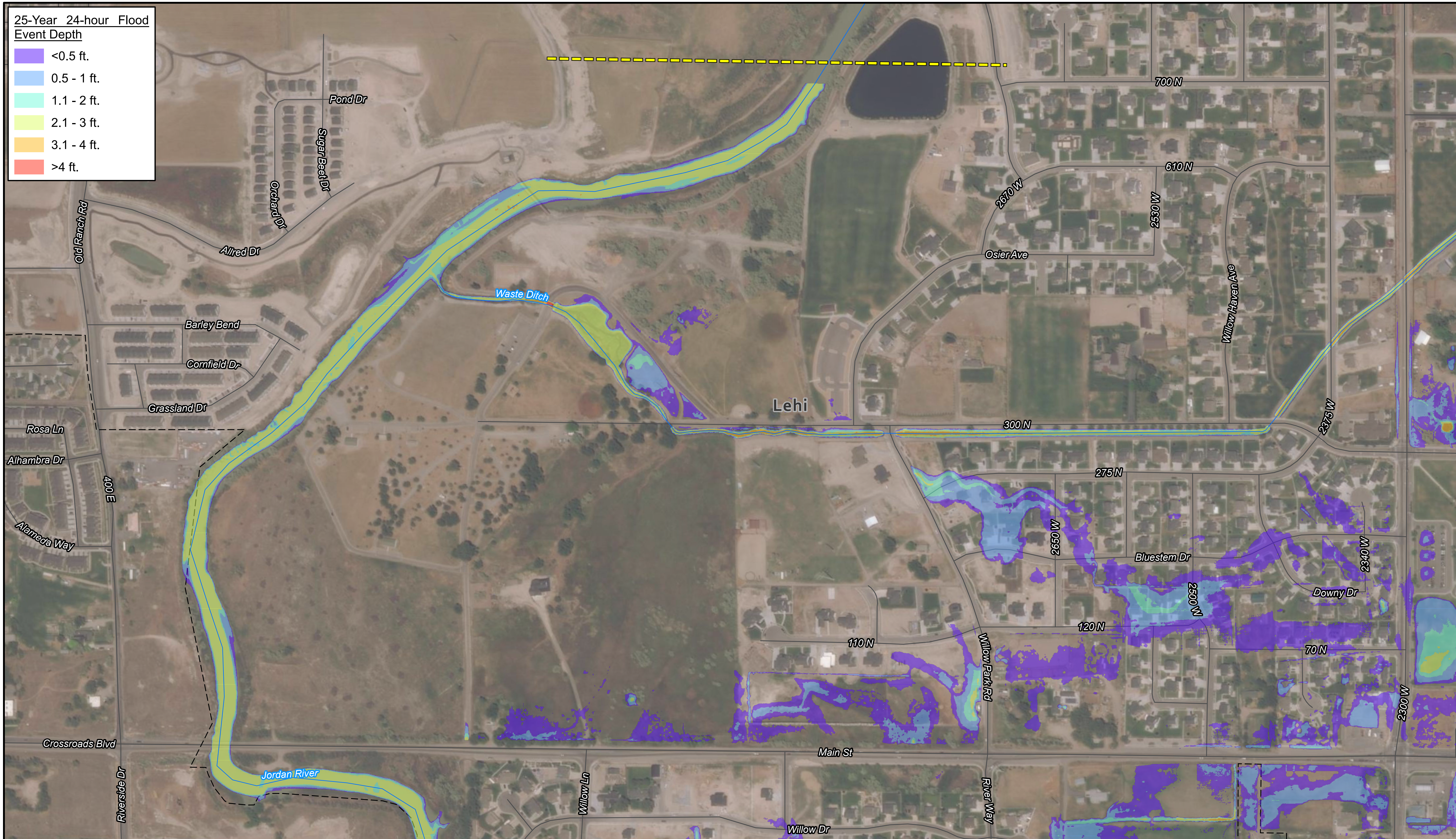
Watershed Plan EA
Existing Conditions - 25-year 24-hour Flood Event

Scale: 1" = 400'

2B

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 25-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022



Boundary Condition - Normal Depth

Municipal Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Existing Conditions - 25-year 24-hour Flood Event

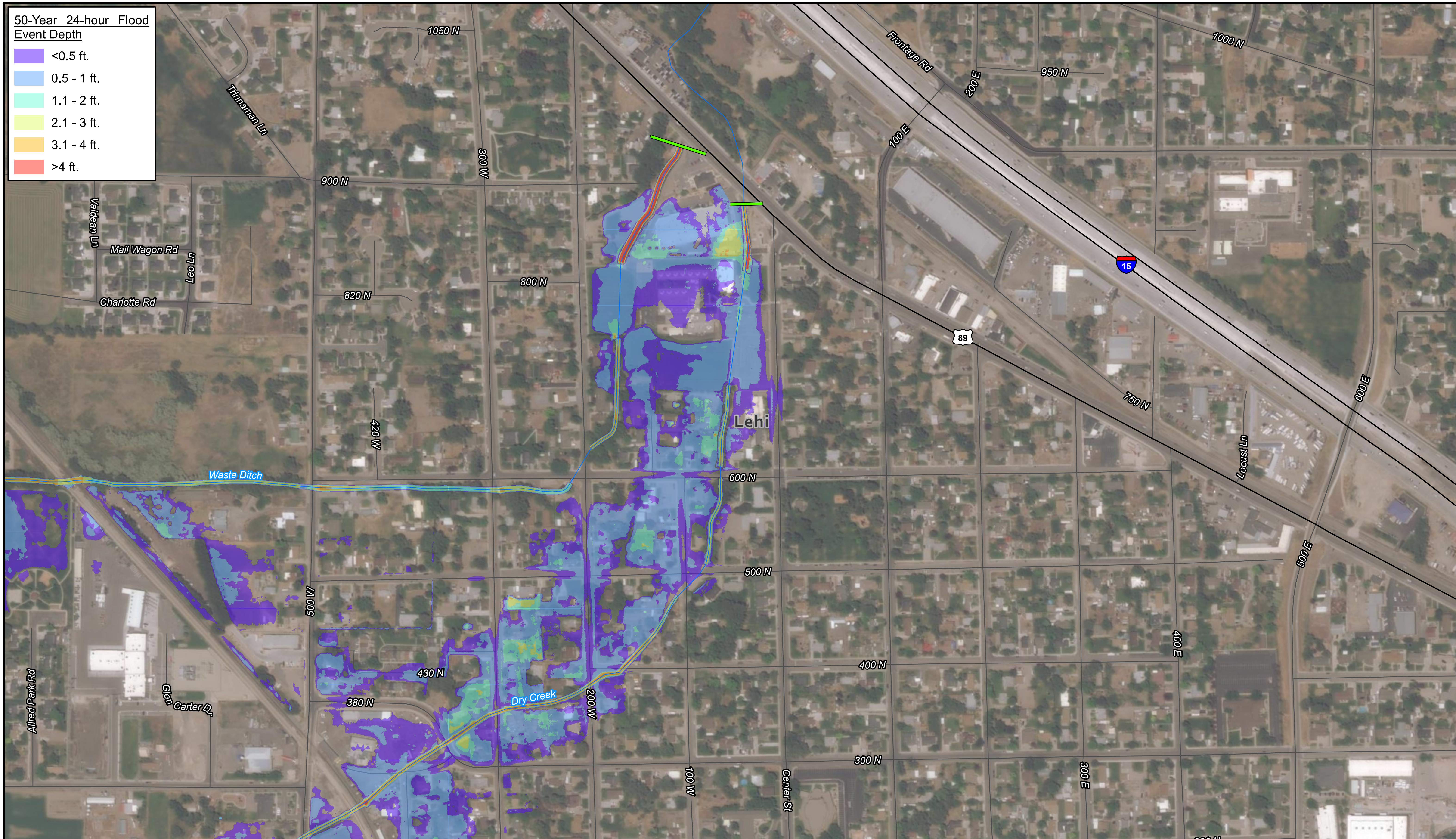
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 25-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

2C



Boundary Condition - Flow Hydrograph

Municipal Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Existing Conditions - 50-year 24-hour Flood Event

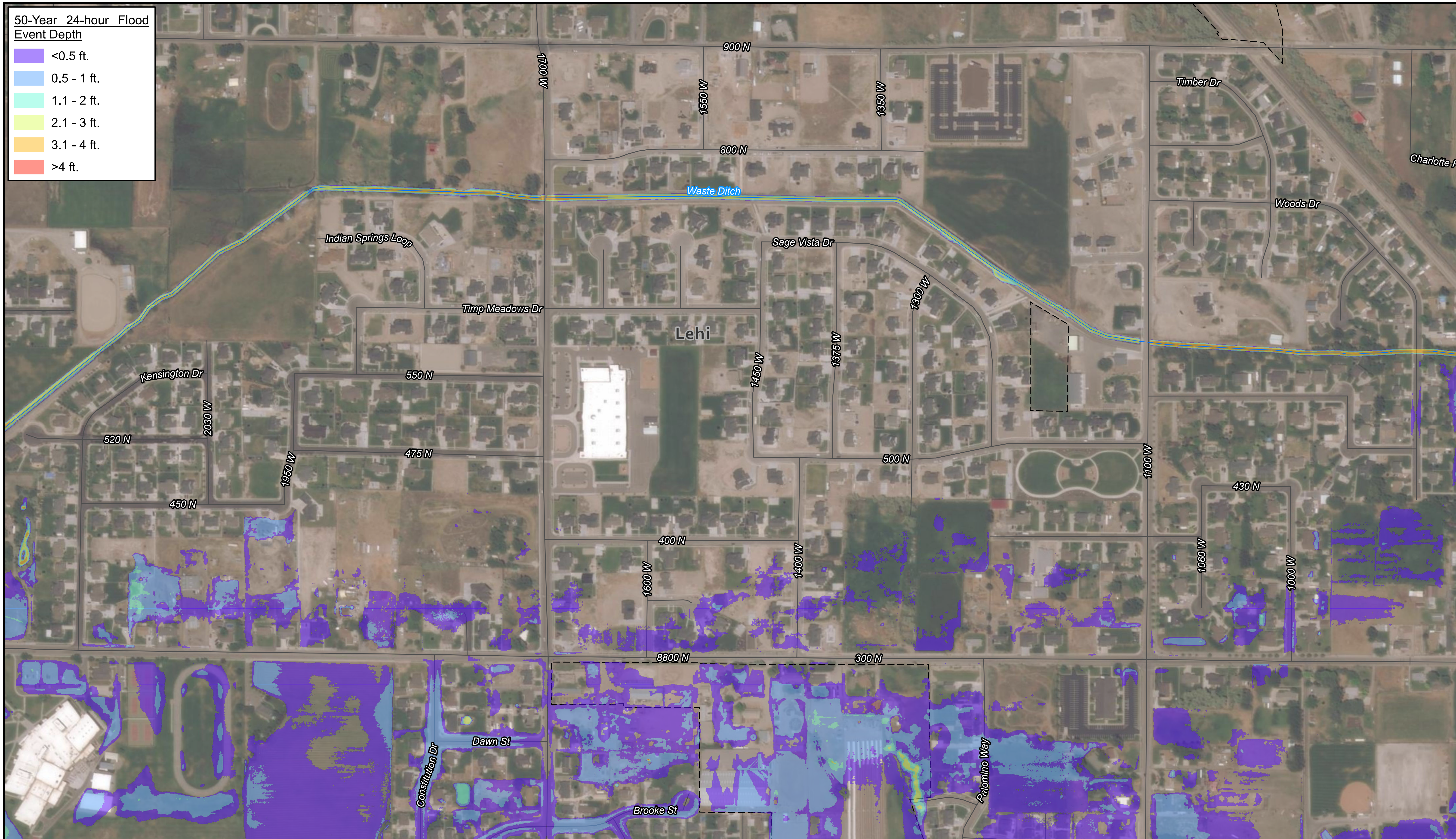
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 50-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

3A



Municipal Boundary

N

Feet
0 200 400

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Utah County

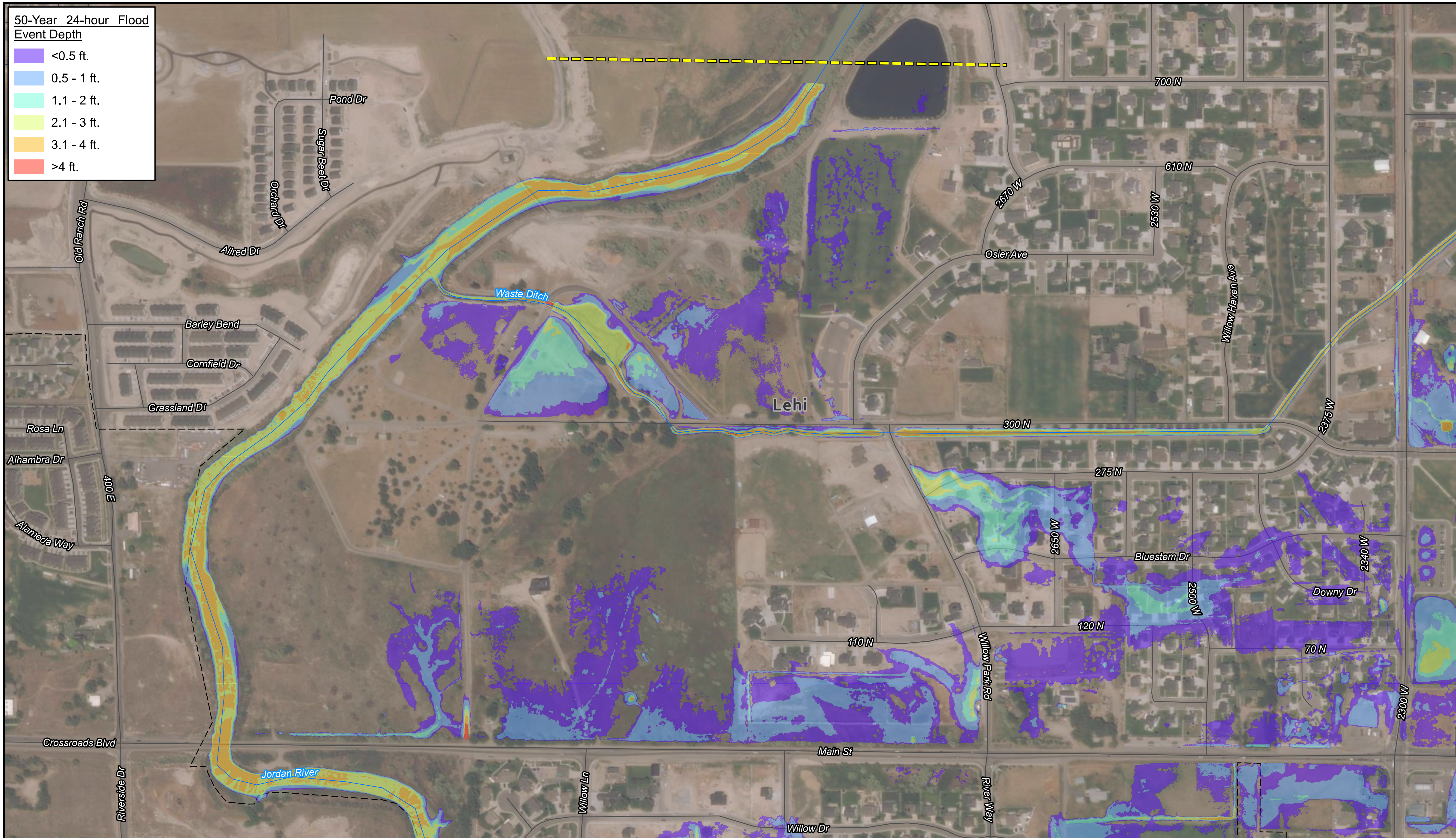
Watershed Plan EA
Existing Conditions - 50-year 24-hour Flood Event

Scale: 1" = 400'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 50-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

3B



Boundary Condition - Normal Depth

Municipal Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Existing Conditions - 50-year 24-hour Flood Event

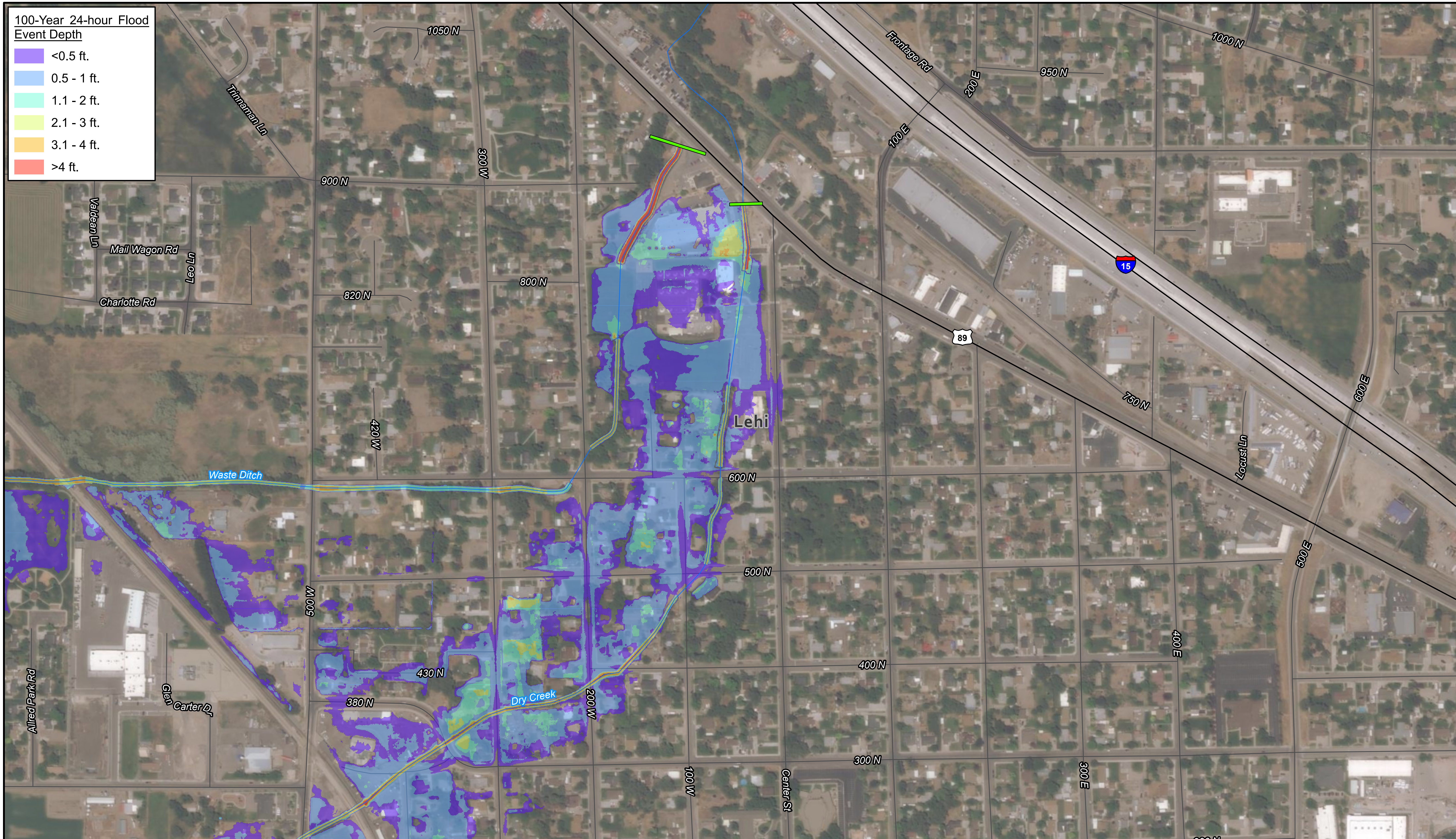
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 50-year 24-hour Flood Event 11x17L

Project Number: 2004-028	Drawn by: JEM 12-21	Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

3C



Boundary Condition - Flow Hydrograph

Municipal Boundary

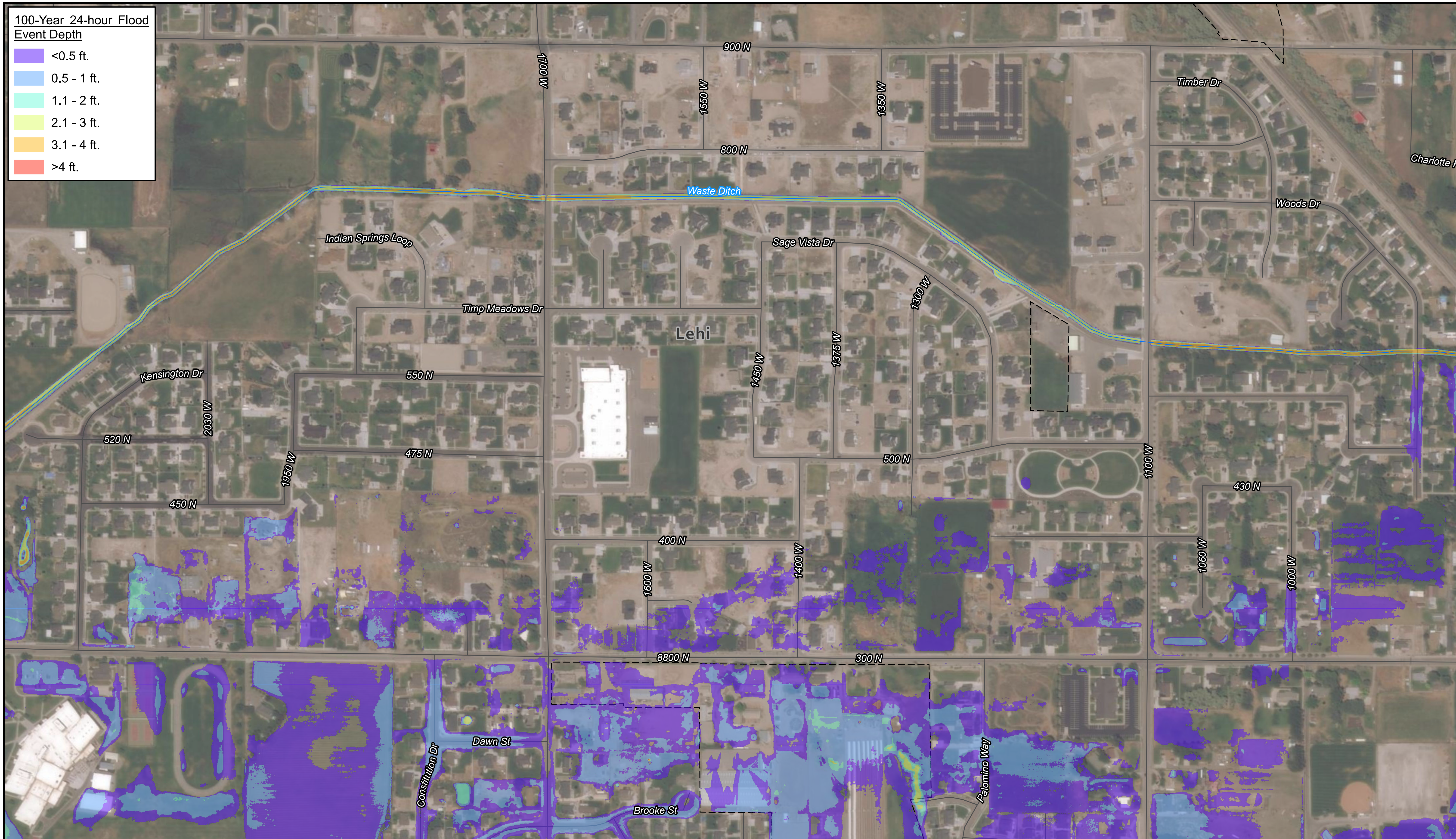
N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City		**Utah County**
Watershed Plan EA ***Existing Conditions - 100-year 24-hour Flood Event***		Scale: 1" = 400'
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 100-year 24-hour Flood Event 11x17L		**4A**
Project Number: 2004-028	Drawn by: JEM 12-21	Last Edit: 02/10/2022



Municipal Boundary

N

Feet
0 200 400

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Utah County

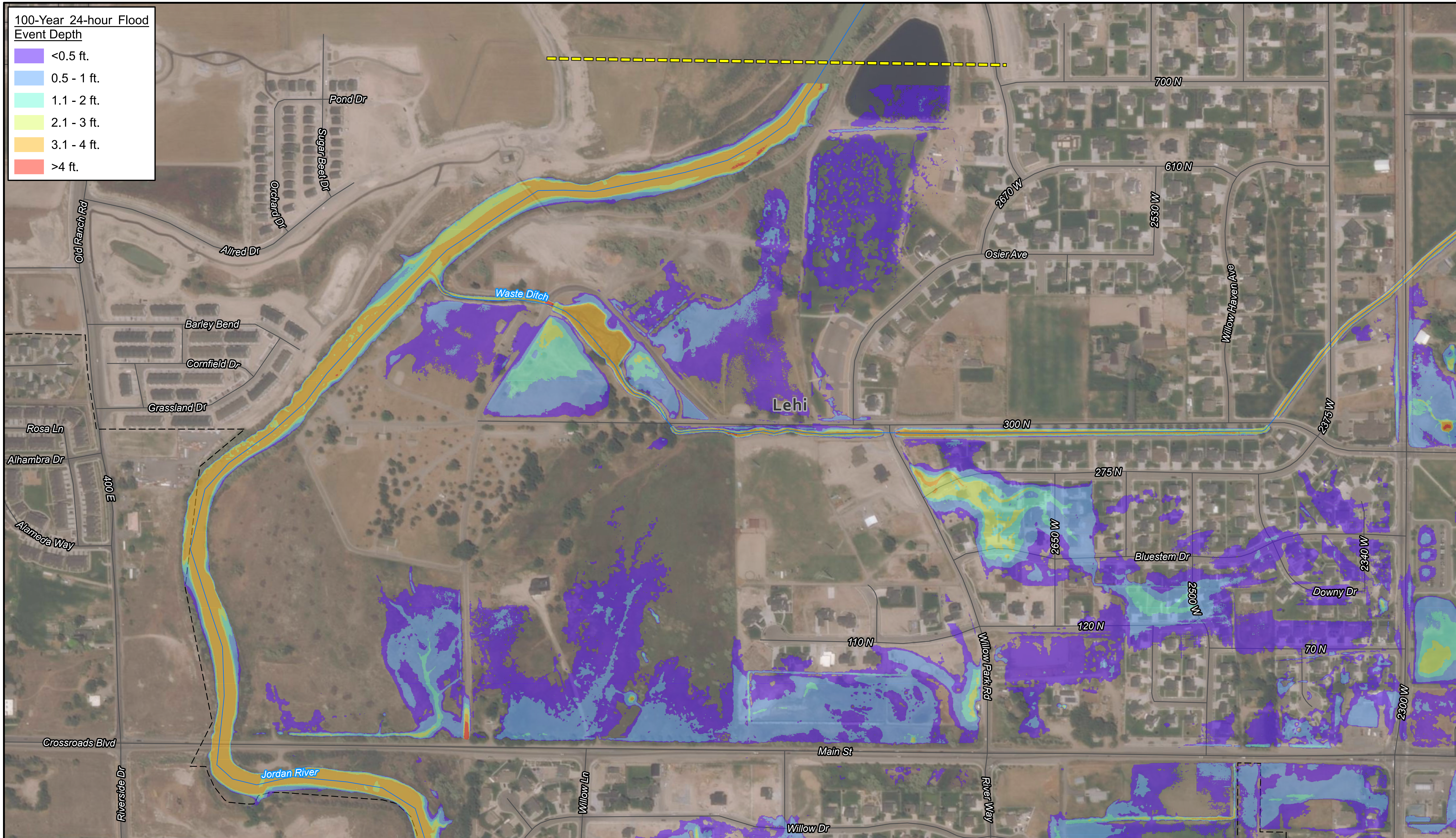
Watershed Plan EA
Existing Conditions - 100-year 24-hour Flood Event

Scale: 1" = 400'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 100-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

4B



Boundary Condition - Normal Depth

Municipal Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Utah County

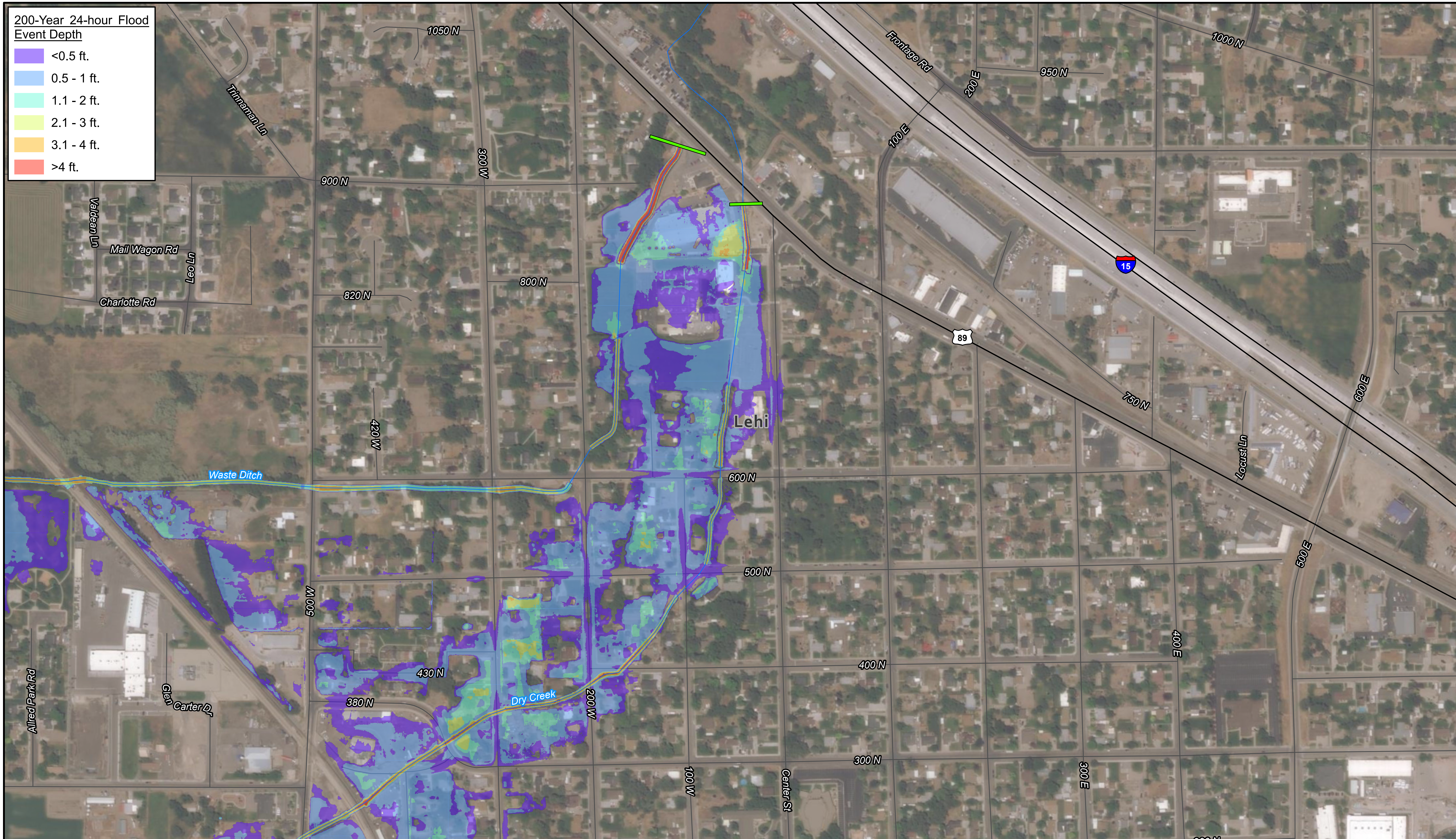
Watershed Plan EA
Existing Conditions - 100-year 24-hour Flood Event

Scale: 1" = 400'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 100-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

4C



Boundary Condition - Flow Hydrograph
Municipal Boundary

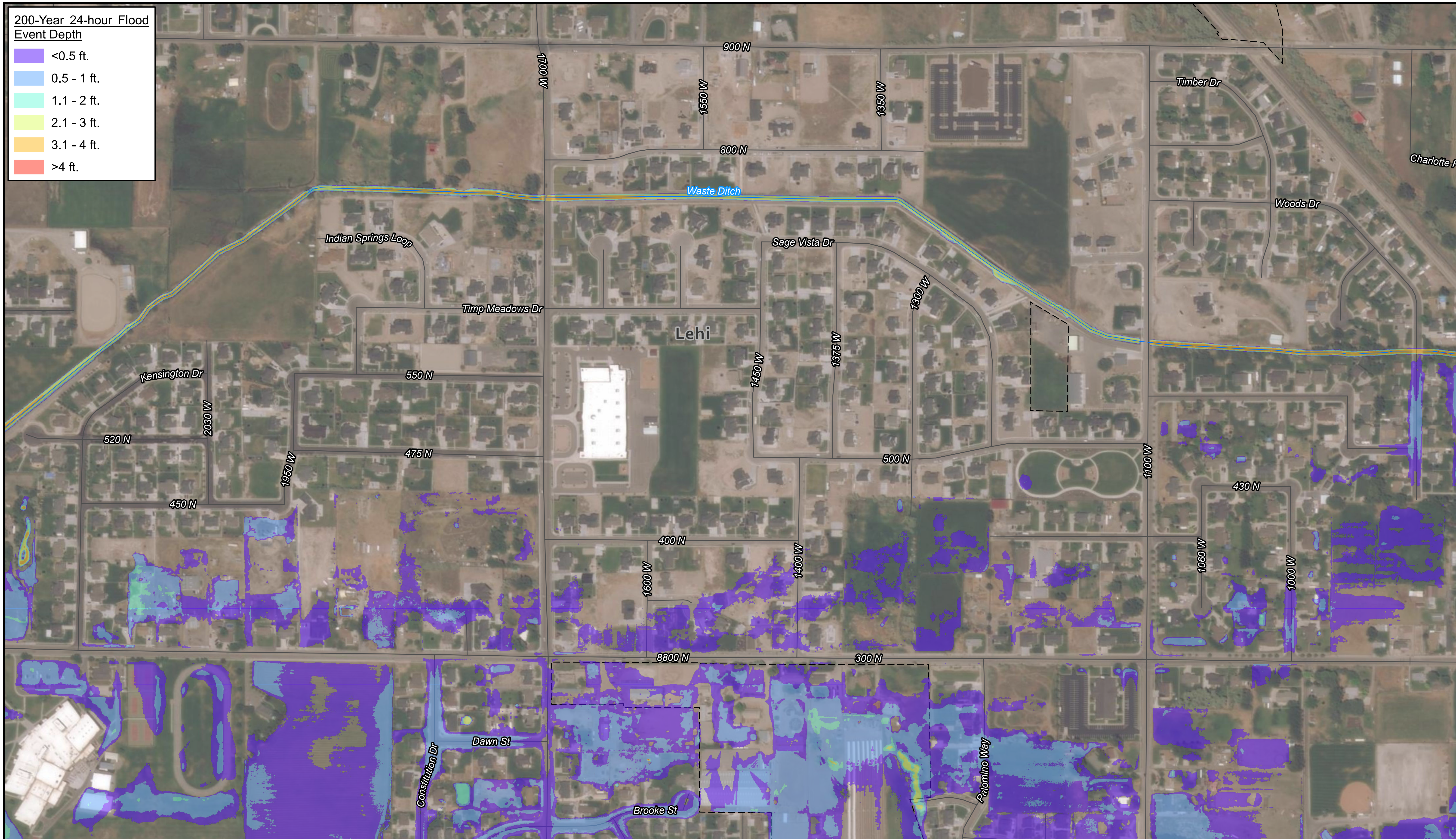
N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City			Utah County
Watershed Plan EA Existing Conditions - 200-year 24-hour Flood Event			Scale: 1" = 400'
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 200-year 24-hour Flood Event 11x17L			5A
Project Number: 2004-028	Drawn by: JEM 12-21	Last Edit: 02/10/2022	



Municipal Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Utah County

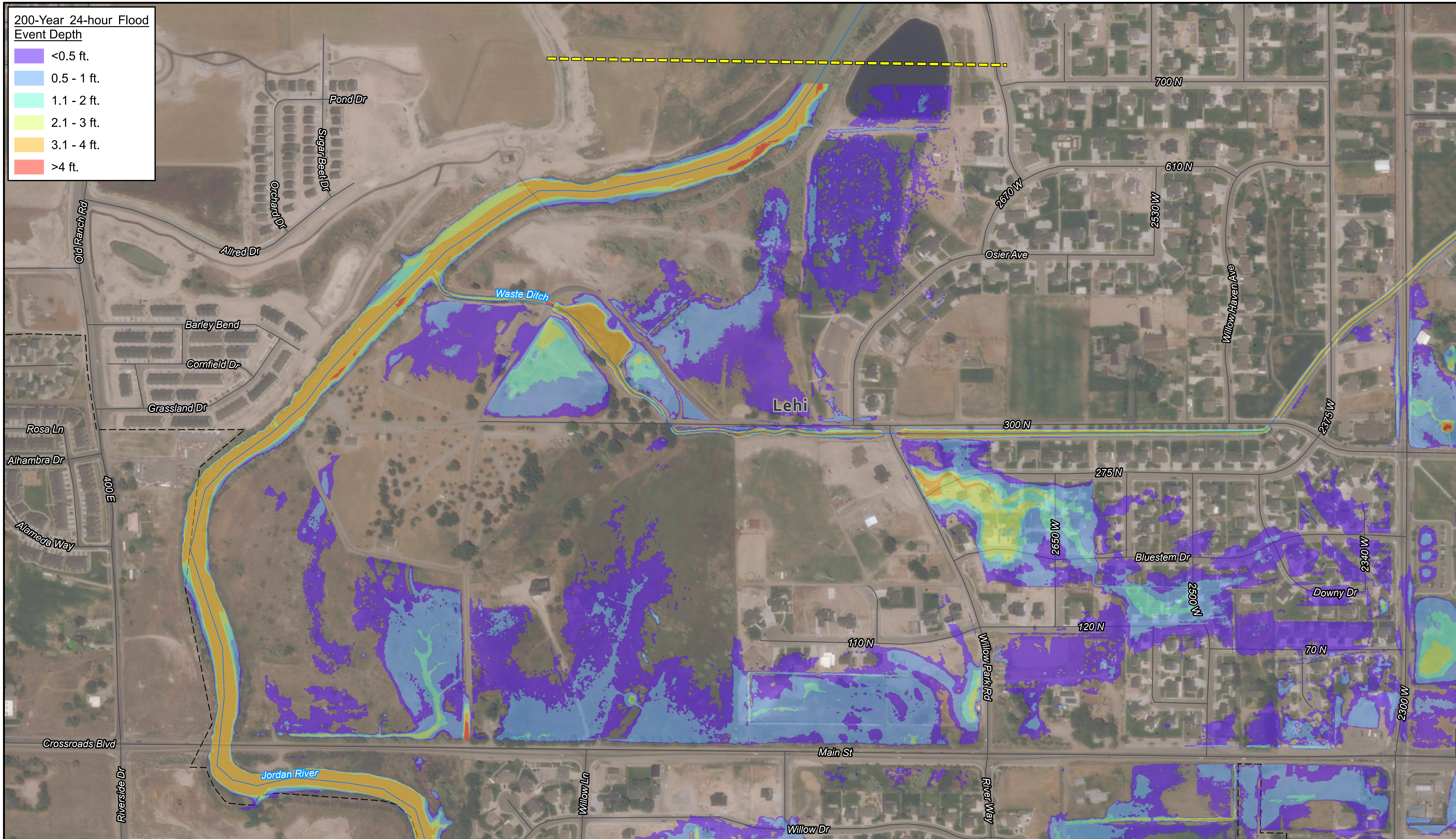
Watershed Plan EA
Existing Conditions - 200-year 24-hour Flood Event

Scale: 1" = 400'

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 200-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

5B



Boundary Condition - Normal Depth

Municipal Boundary

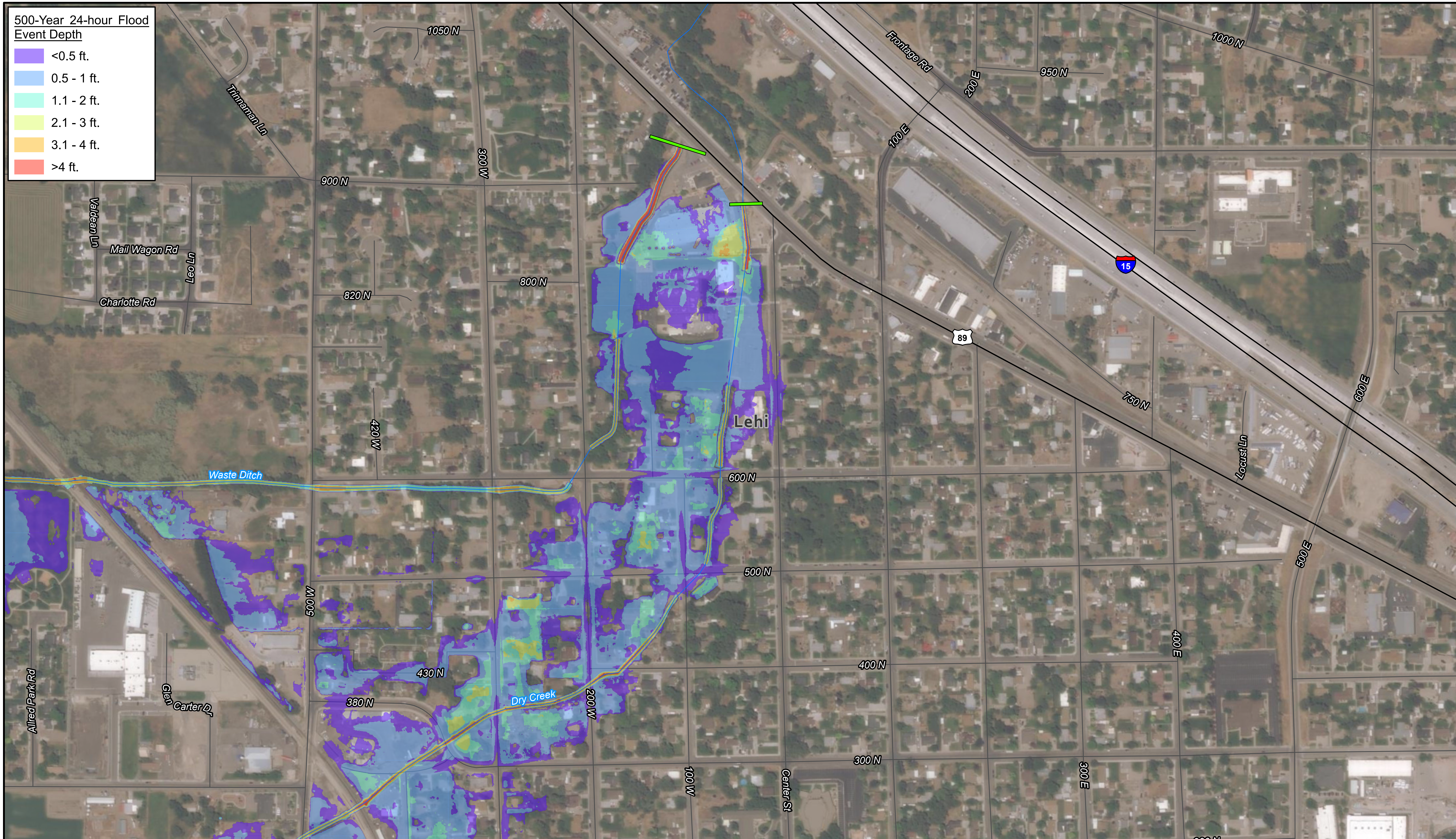
N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City		**Utah County**
Watershed Plan EA ***Existing Conditions - 200-year 24-hour Flood Event***		Scale: 1" = 400'
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 200-year 24-hour Flood Event 11x17L		**5C**
Project Number: 2004-028	Drawn by: JEM 12-21	Last Edit: 02/10/2022



Boundary Condition - Flow Hydrograph

Municipal Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Existing Conditions - 500-year 24-hour Flood Event

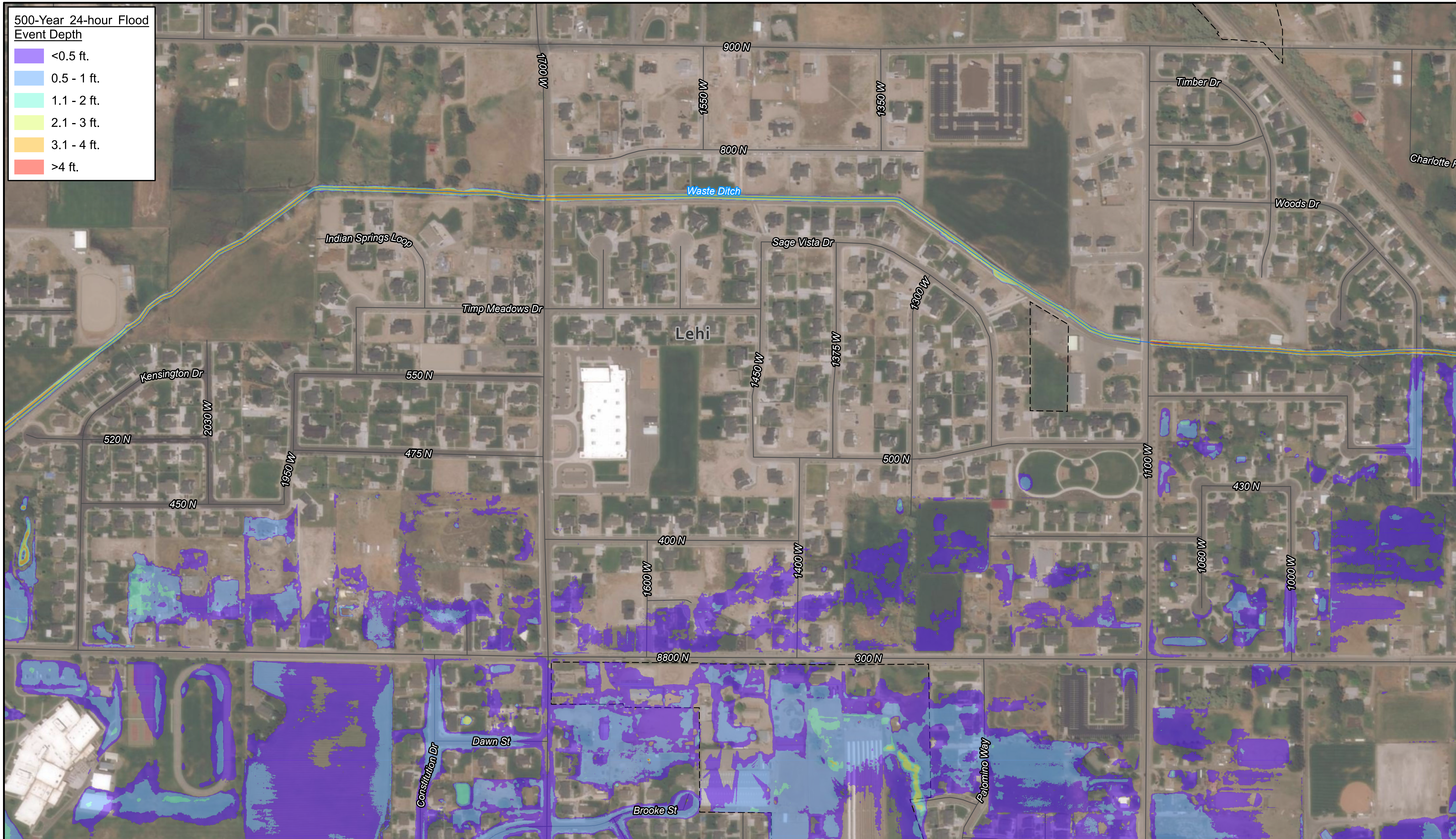
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 500-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

6A



Municipal Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Existing Conditions - 500-year 24-hour Flood Event

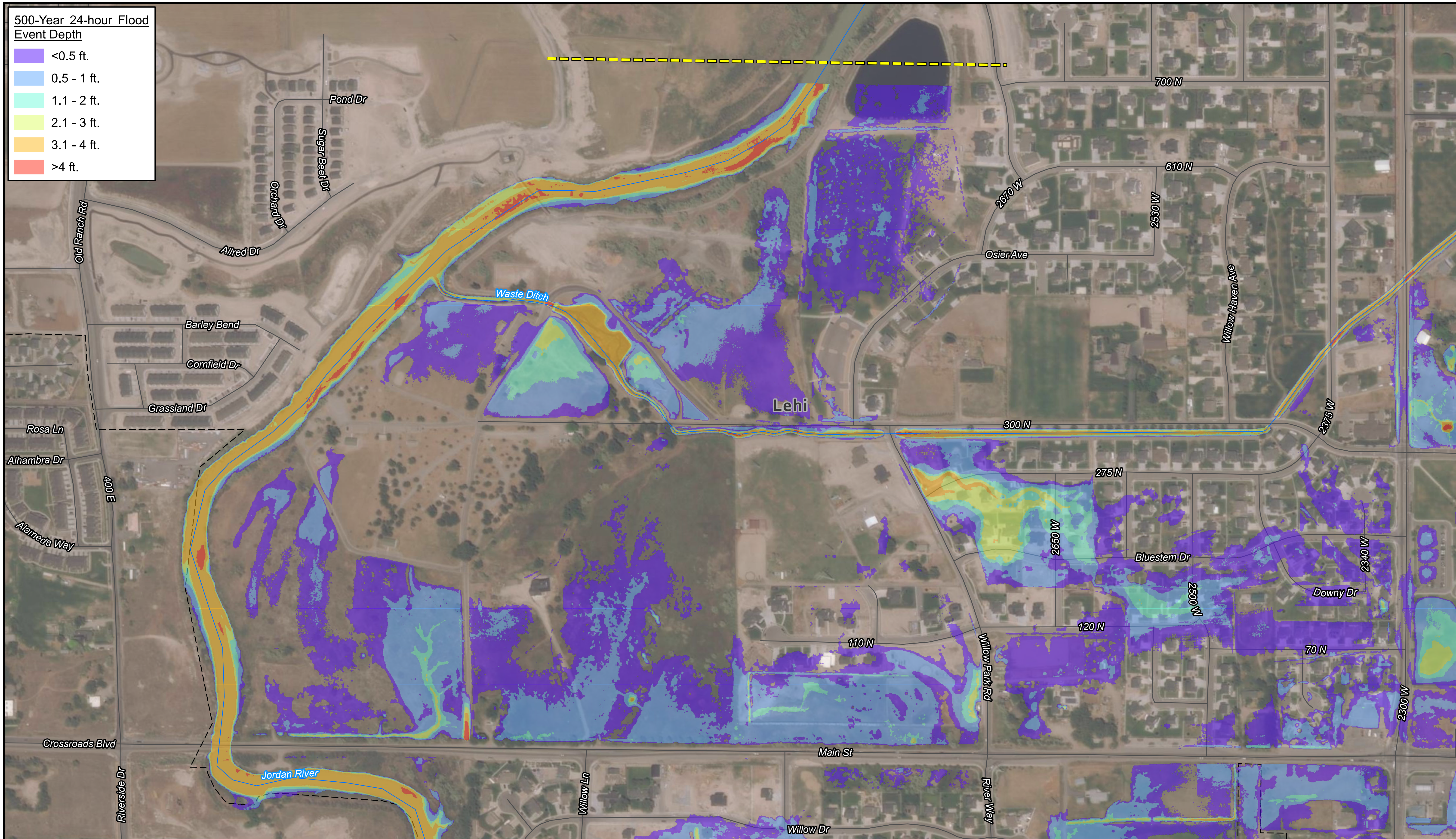
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 500-year 24-hour Flood Event 11x17L

Project Number: 2004-028	Drawn by: JEM 12-21	Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

6B



Boundary Condition - Normal Depth

Municipal Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Existing Conditions - 500-year 24-hour Flood Event

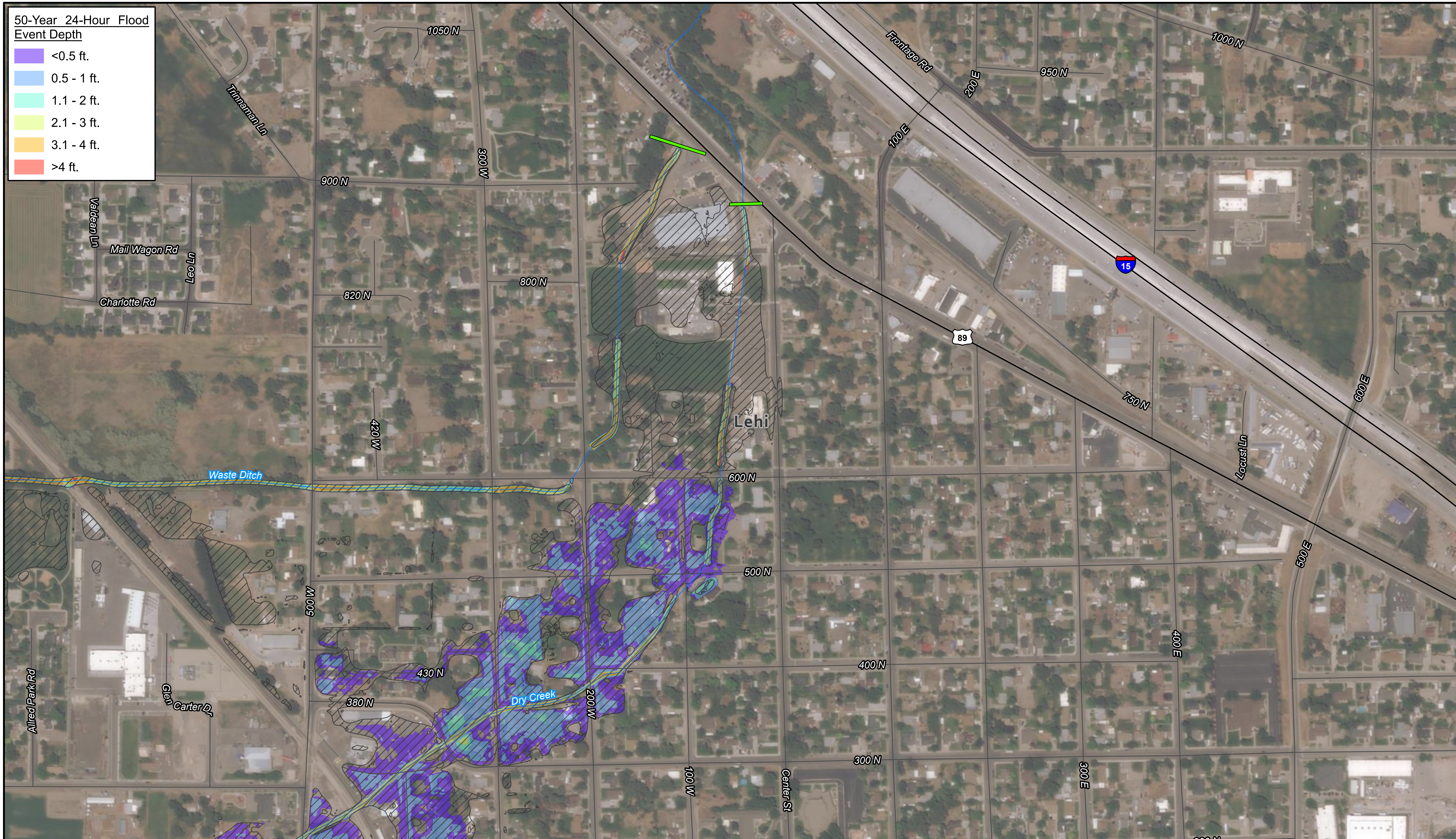
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Existing Conditions - 500-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JEM 12-21 | Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

6C



Boundary Condition - Flow Hydrograph

Municipal Boundary

Existing Conditions - 50-year Inundation Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Proposed Conditions - 50-year 24-hour Flood Event

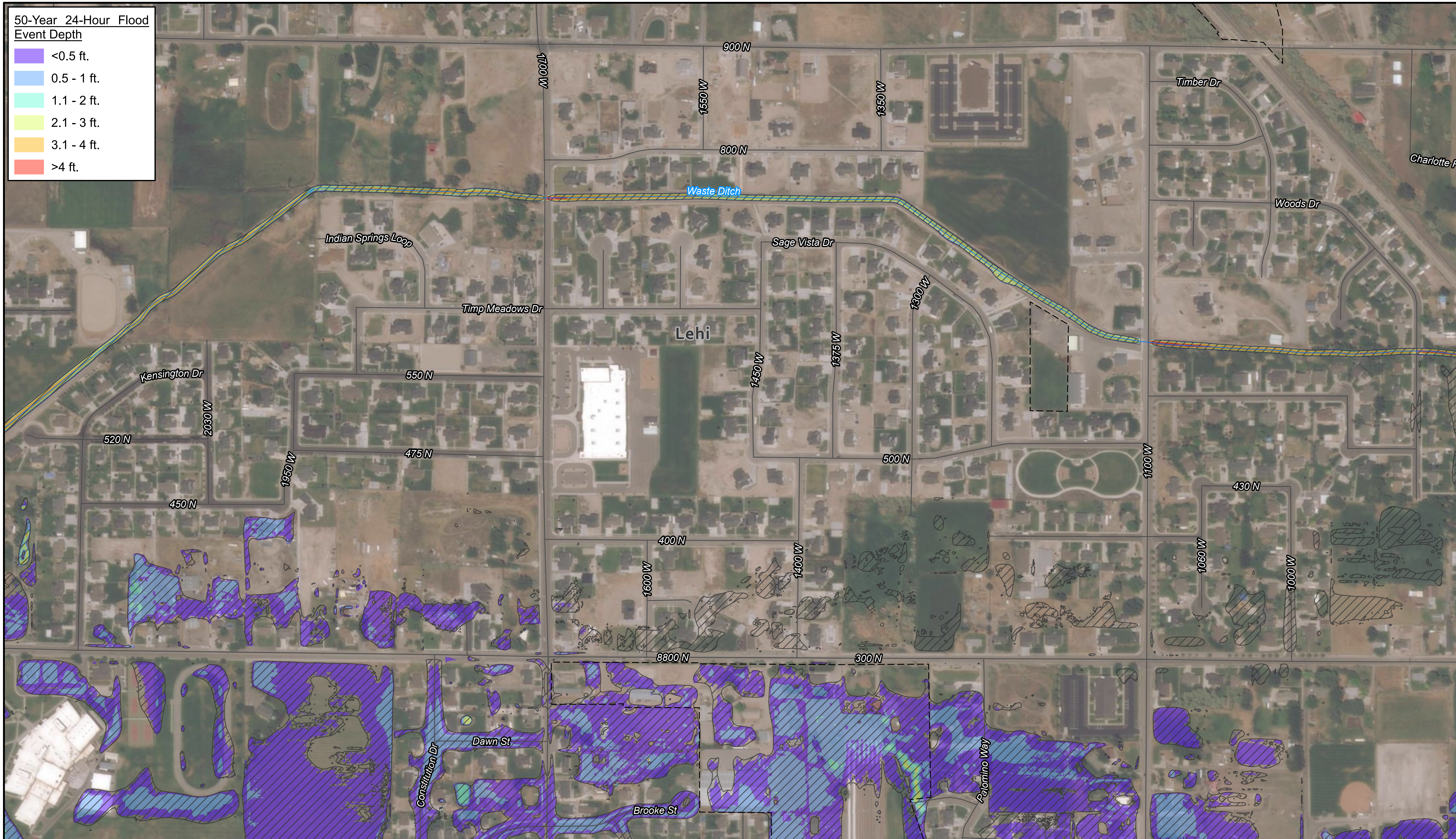
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 50-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JWW 02-22 | Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

7A



Municipal Boundary

Existing Conditions - 50-year Inundation Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Proposed Conditions - 50-year 24-hour Flood Event

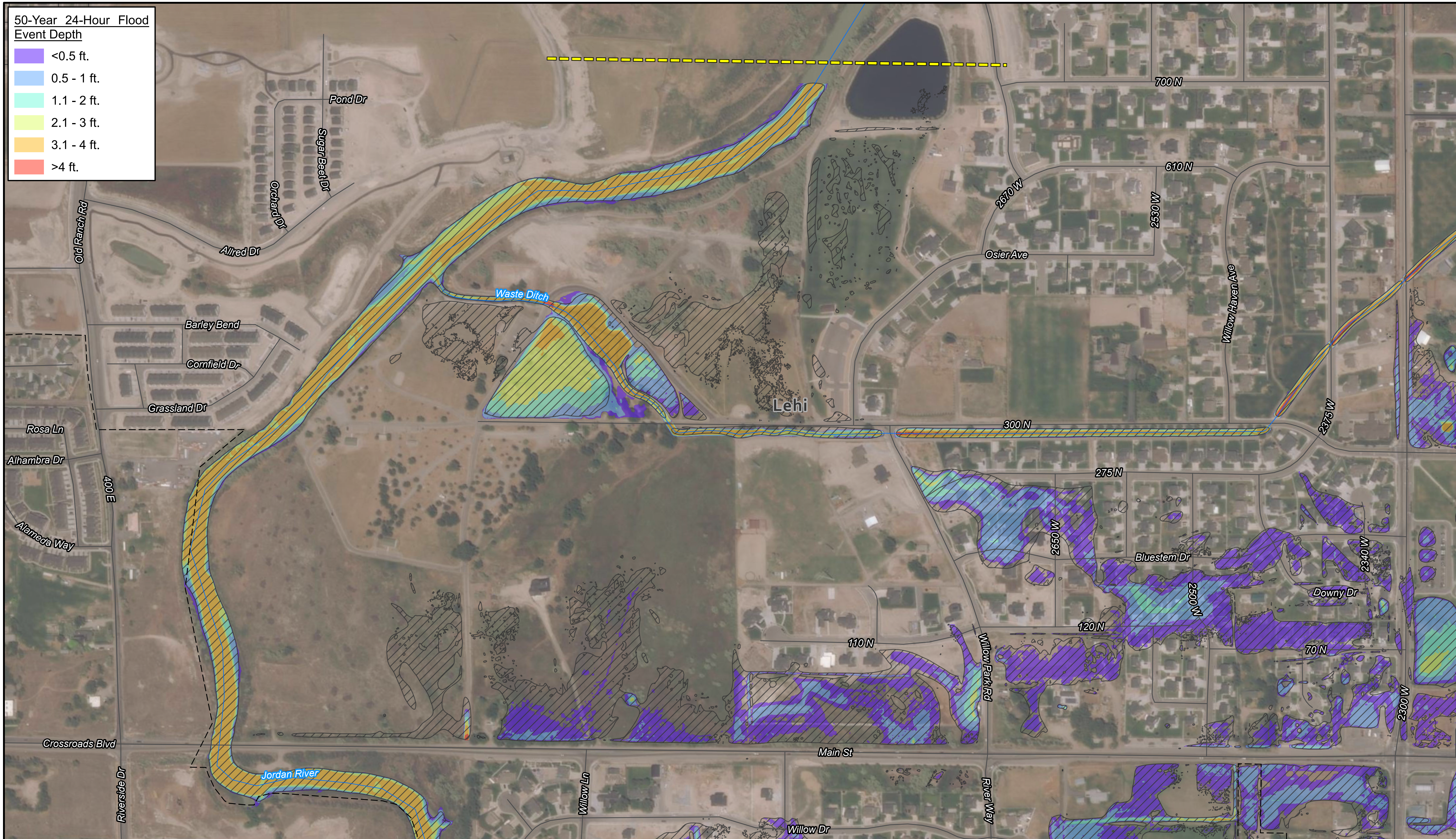
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 50-year 24-hour Flood Event 11x17L

Project Number: 2004-028	Drawn by: JWW 02-22	Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

7B



Boundary Condition - Normal Depth

Municipal Boundary

Existing Conditions - 50-year Inundation Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Proposed Conditions - 50-year 24-hour Flood Event

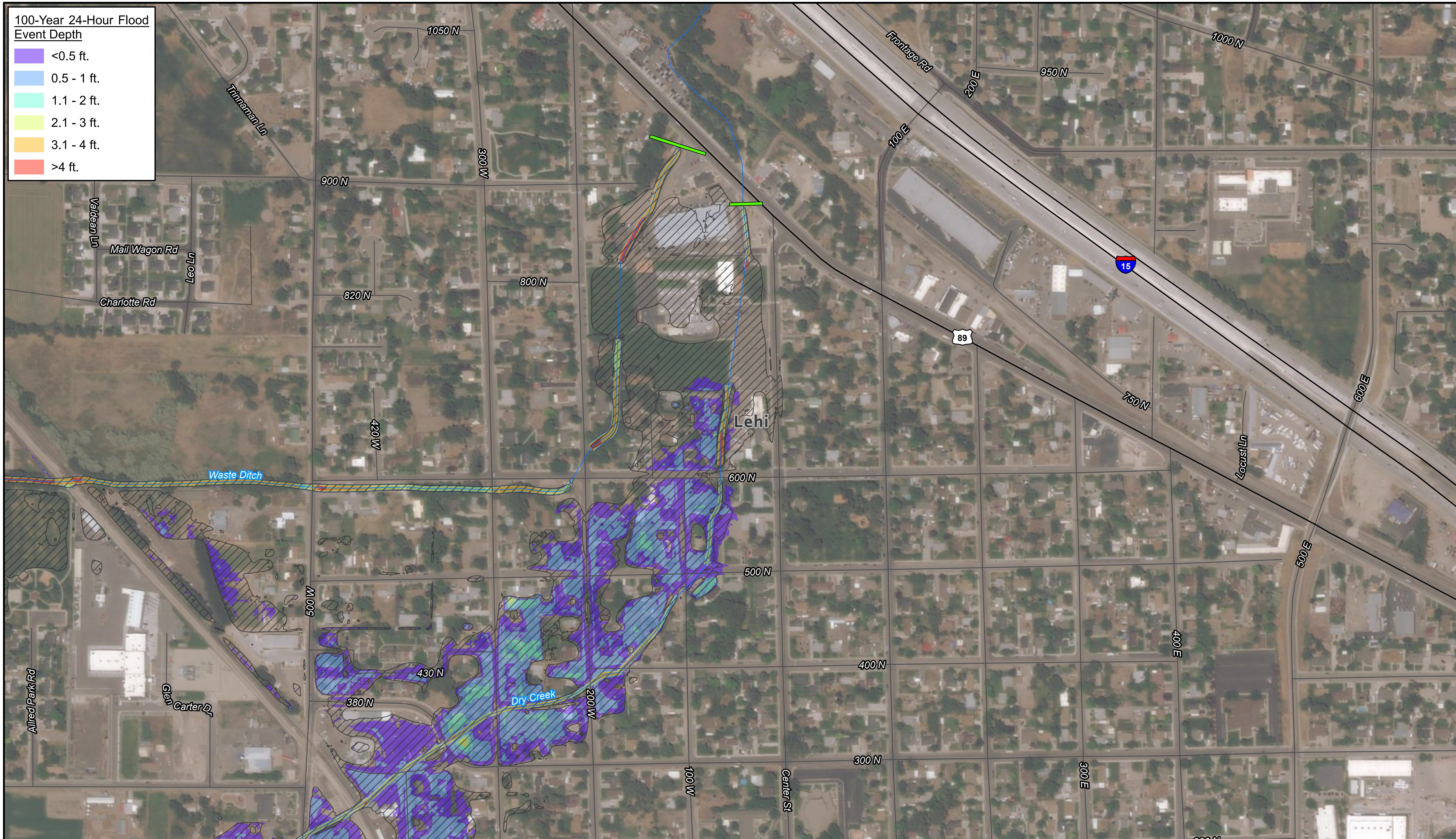
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 50-year 24-hour Flood Event 11x17L

Project Number: 2004-028	Drawn by: JWW 02-22	Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

7C



Boundary Condition - Flow Hydrograph

Municipal Boundary

Existing Conditions - 100-year Inundation Boundary

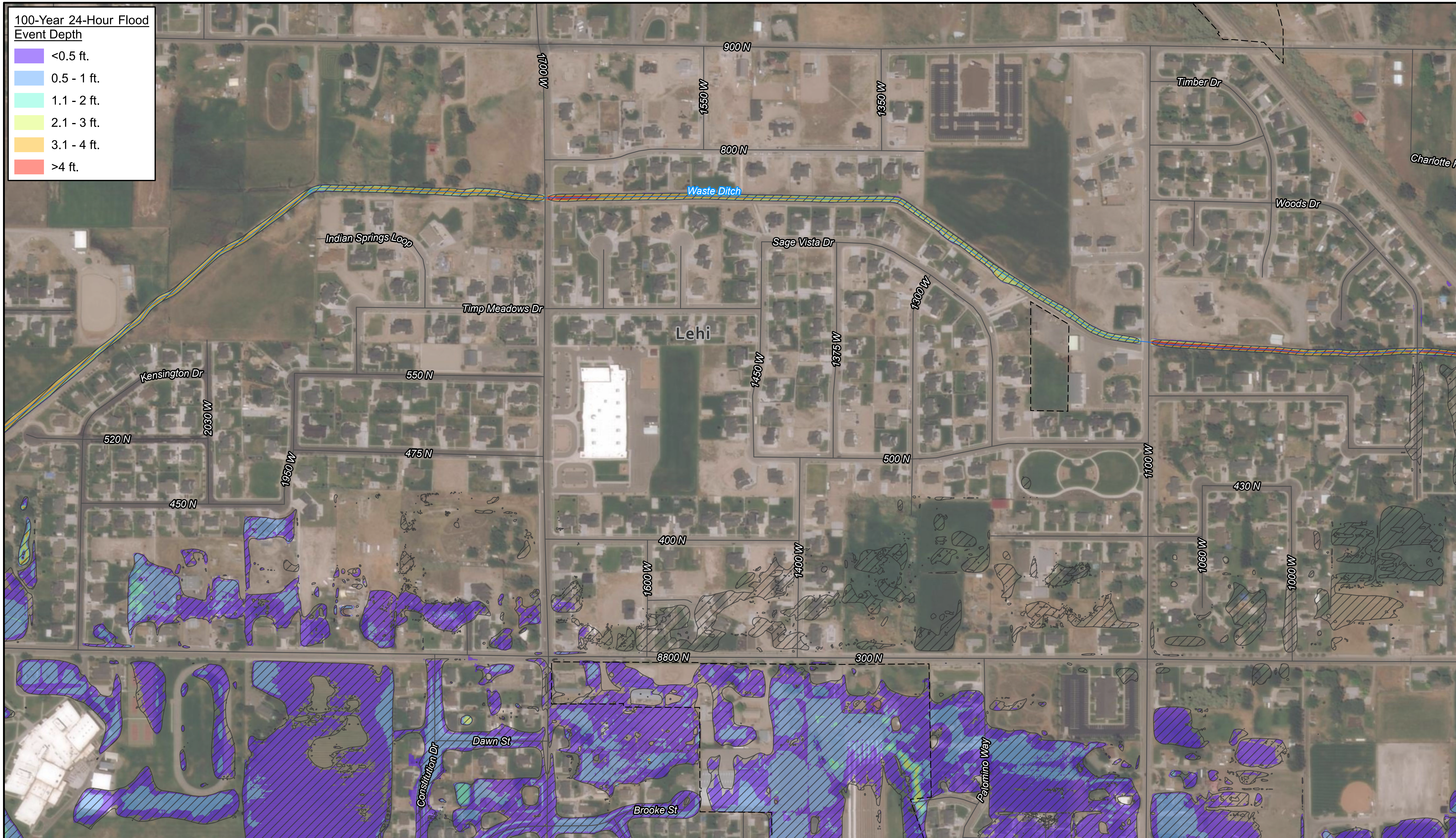
N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City	Utah County
Watershed Plan EA *Proposed Conditions - 100-year 24-hour Flood Event*	Scale: 1" = 400'
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 100-year 24-hour Flood Event 11x17L	8A
Project Number: 2004-028 / Drawn by: JWW 02-22 / Last Edit: 02/22/2022	



Municipal Boundary

Existing Conditions - 100-year Inundation Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Proposed Conditions - 100-year 24-hour Flood Event

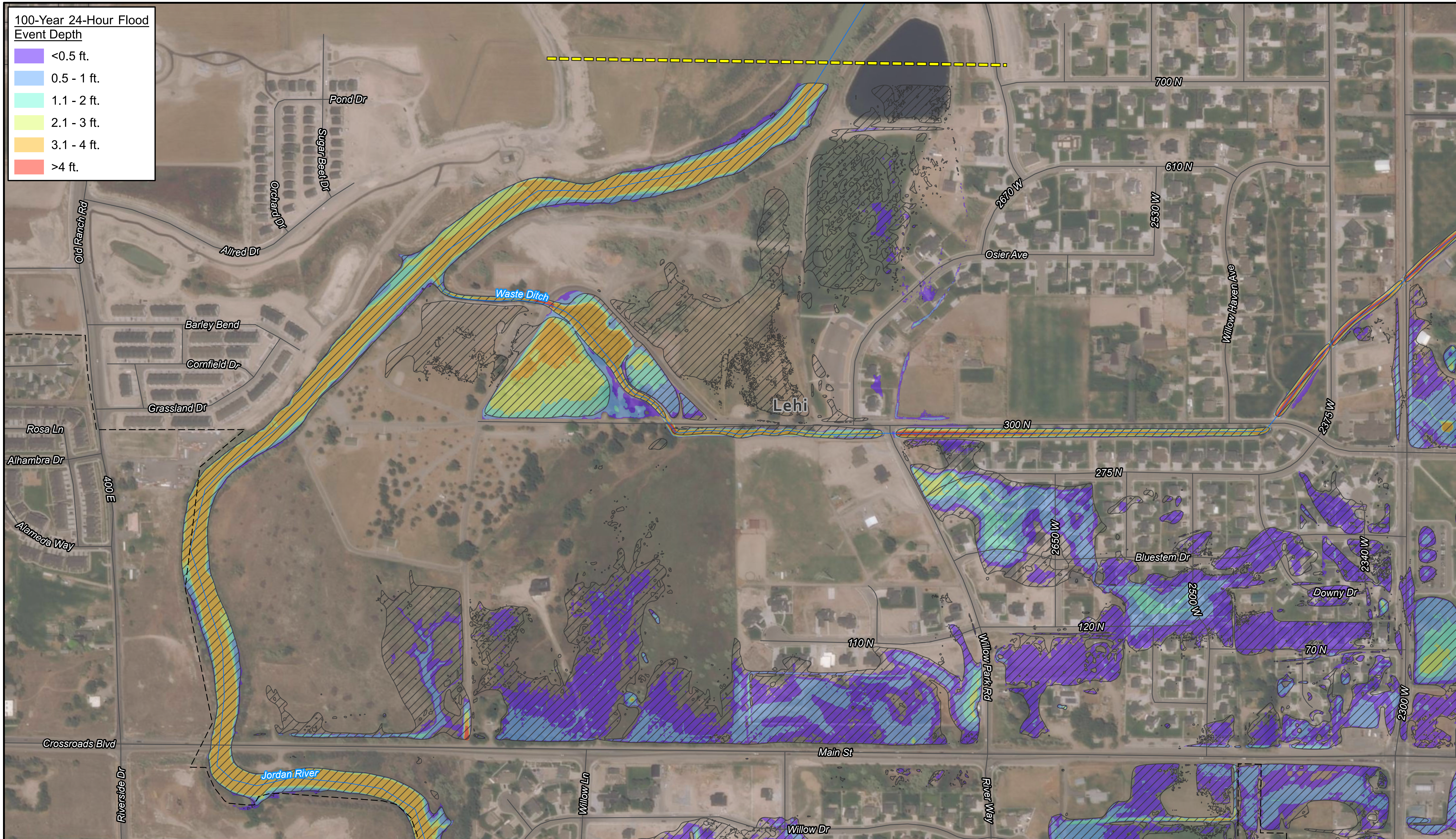
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 100-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JWW 02-22 | Last Edit: 02/22/2022

Utah County

Scale: 1" = 400'

8B



Boundary Condition - Normal Depth

Municipal Boundary

Existing Conditions - 100-year Inundation Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Proposed Conditions - 100-year 24-hour Flood Event

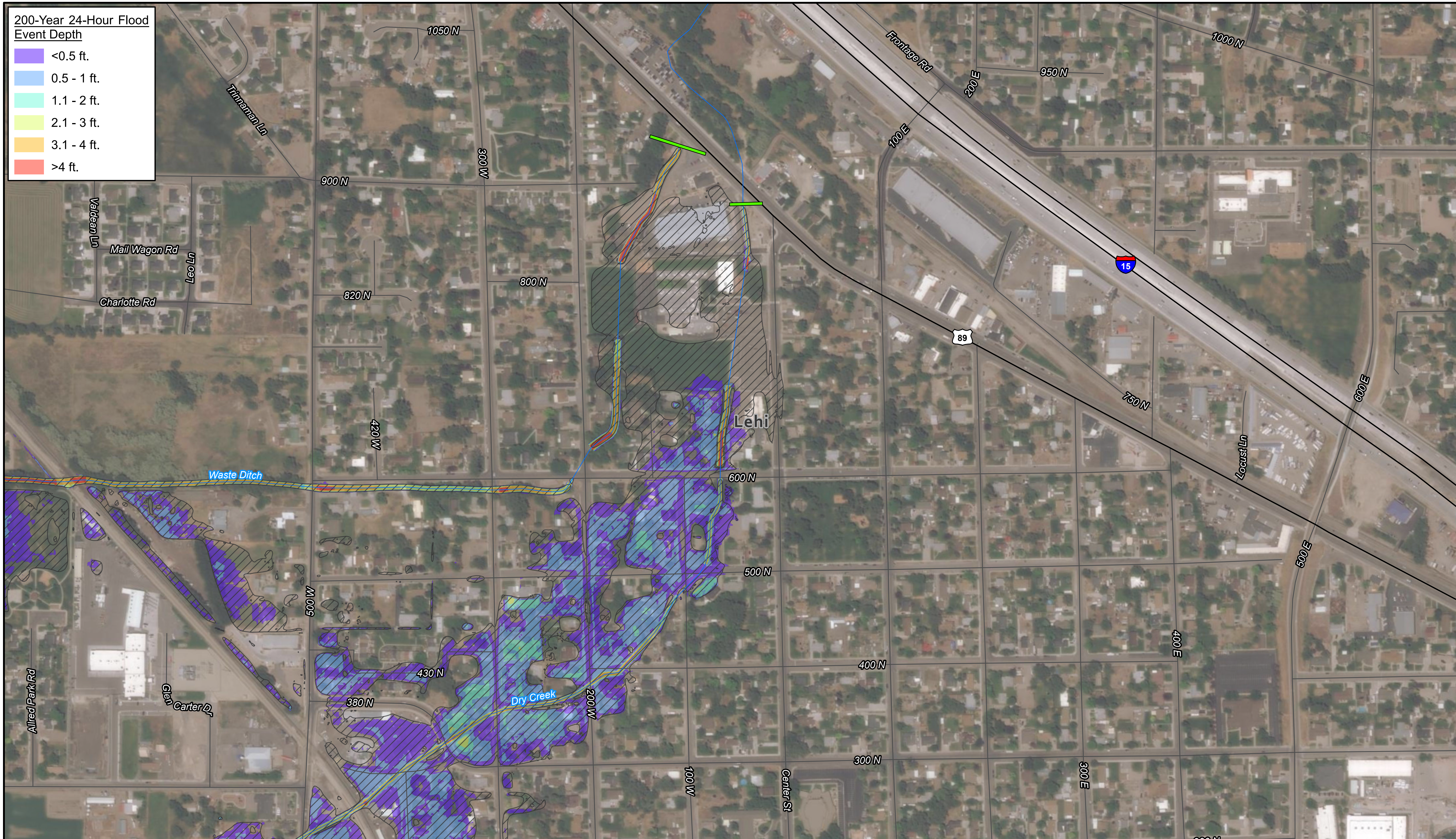
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 100-year 24-hour Flood Event 11x17L

Project Number: 2004-028	Drawn by: JWW 02-22	Last Edit: 02/22/2022

Utah County

Scale: 1" = 400'

8C



Boundary Condition - Flow Hydrograph
Municipal Boundary
Existing Conditions - 200-year Inundation Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Proposed Conditions - 200-year 24-hour Flood Event

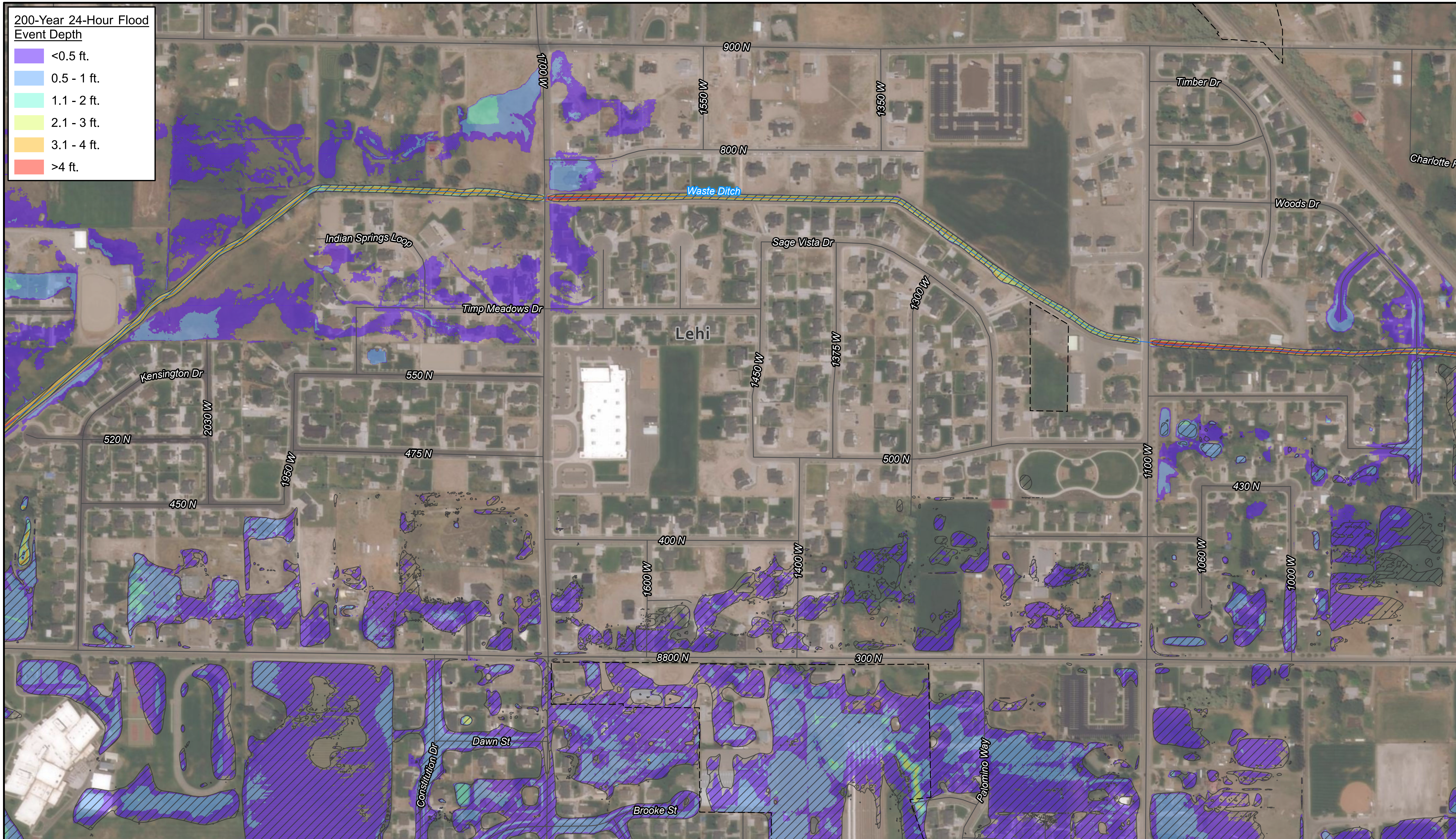
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 200-year 24-hour Flood Event 11x17L

Project Number: 2004-028	Drawn by: JWW 02-22	Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

9A



Municipal Boundary

Existing Conditions - 200-year Inundation Boundary

N

Feet
0 200 400

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Proposed Conditions - 200-year 24-hour Flood Event

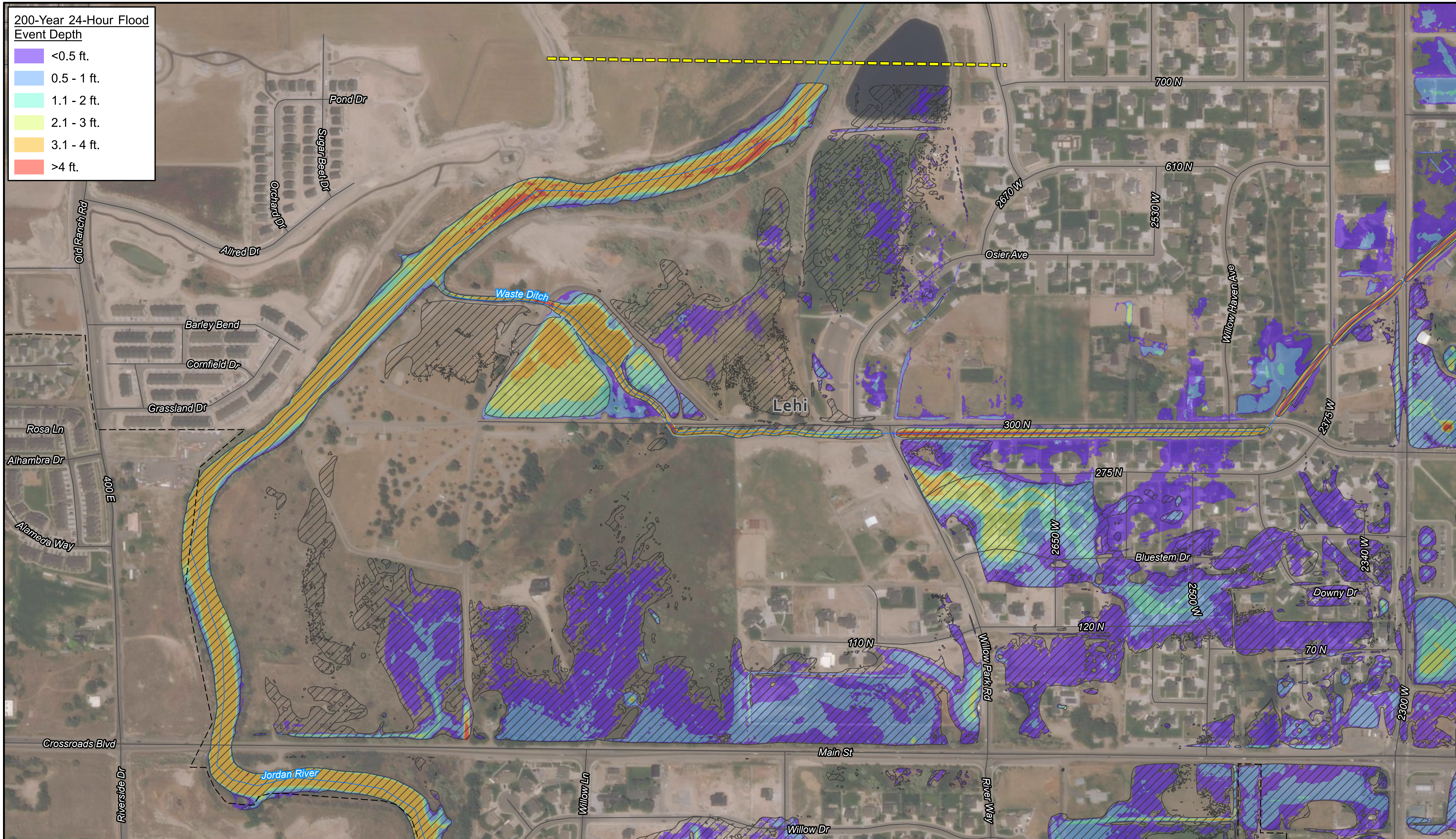
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 200-year 24-hour Flood Event 11x17L

Project Number: 2004-028 | Drawn by: JWW 02-22 | Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

9B



Boundary Condition - Normal Depth

Municipal Boundary

Existing Conditions - 200-year Inundation Boundary

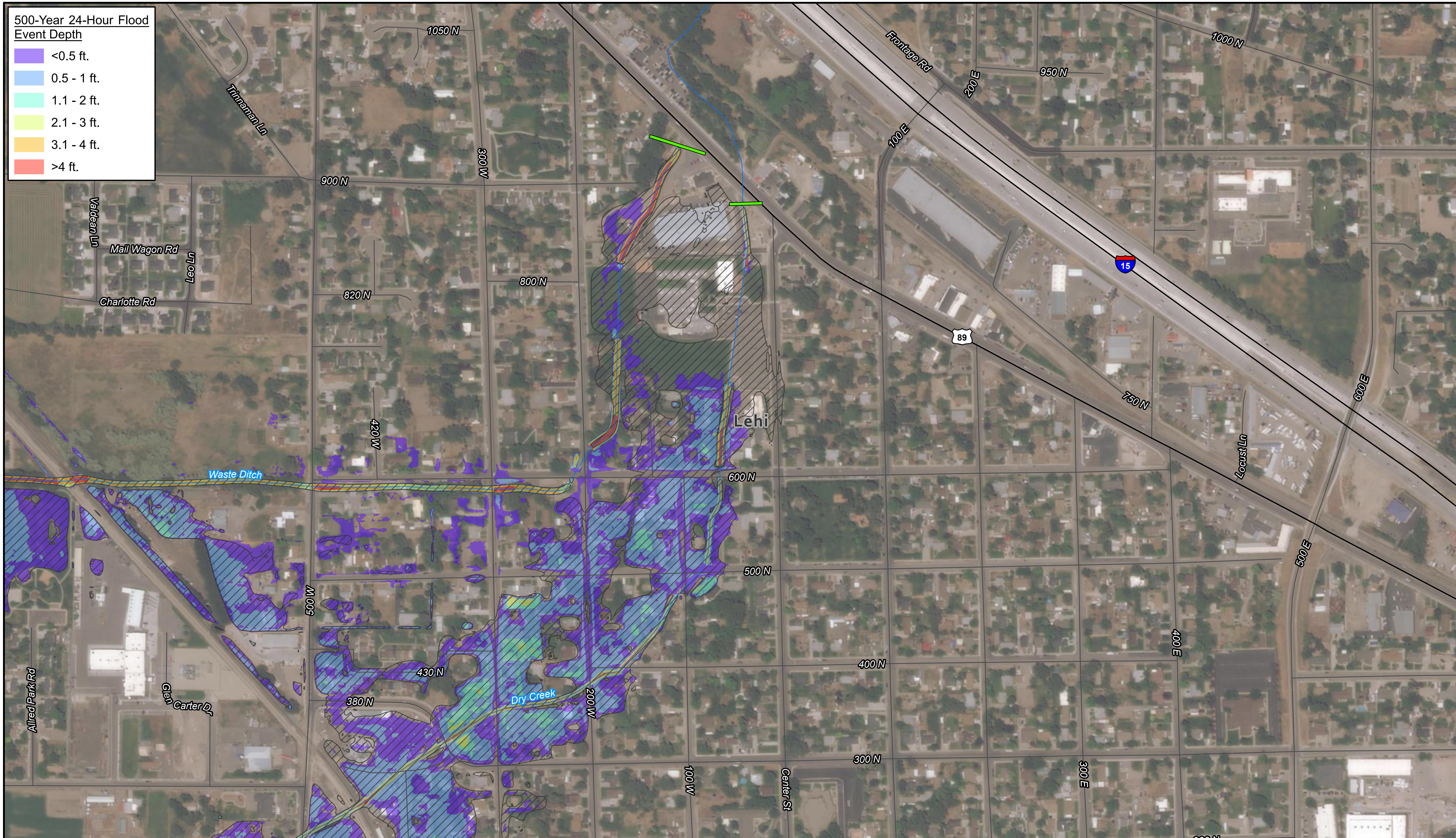
N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City	Utah County
Watershed Plan EA *Proposed Conditions - 200-year 24-hour Flood Event*	Scale: 1" = 400'
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 200-year 24-hour Flood Event 11x17L Project Number: 2004-028 / Drawn by: JWW 02-22 / Last Edit: 02/10/2022	9C



Boundary Condition - Flow Hydrograph

Municipal Boundary

Existing Conditions - 500-year Inundation Boundary

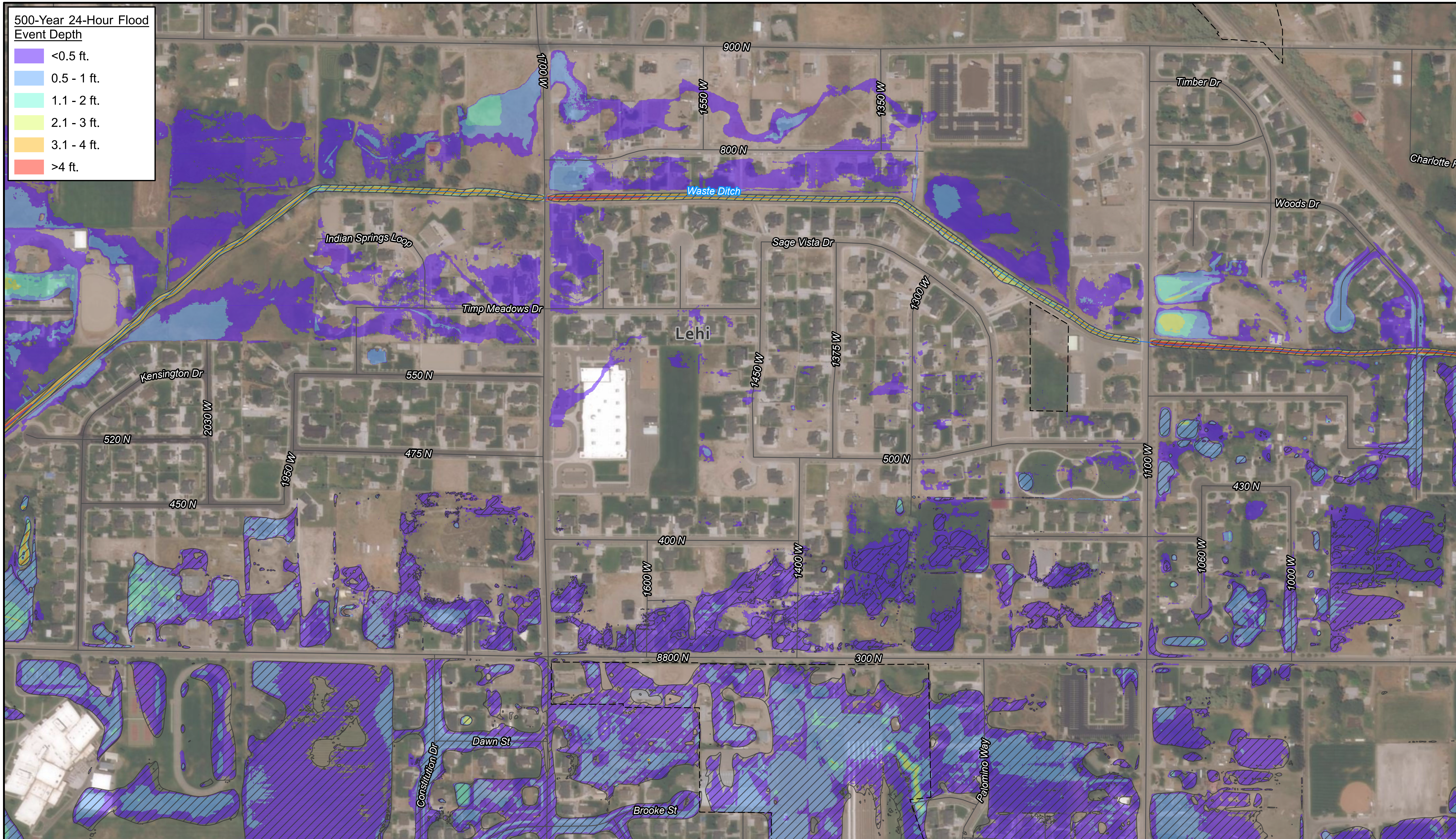
N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City	Utah County
Watershed Plan EA *Proposed Conditions - 500-year 24-hour Flood Event*	Scale: 1" = 400'
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 500-year 24-hour Flood Event 11x17L	10A
Project Number: 2004-028 · Drawn by: JWW 02-22 · Last Edit: 02/10/2022	



Municipal Boundary

Existing Conditions - 500-year Inundation Boundary

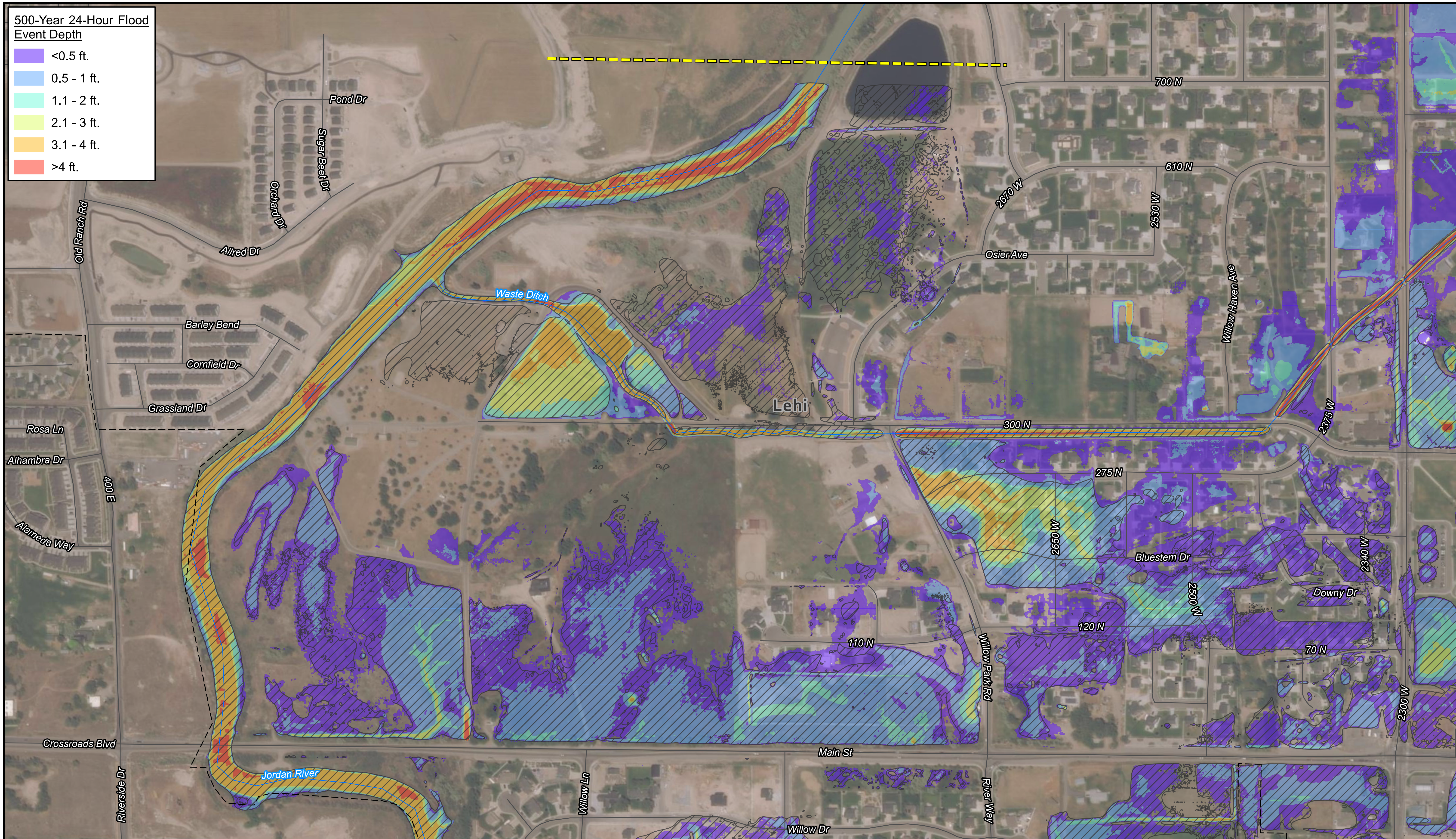
N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City	Utah County
Watershed Plan EA *Proposed Conditions - 500-year 24-hour Flood Event*	Scale: 1" = 400'
Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 500-year 24-hour Flood Event 11x17L	10B
Project Number: 2004-028 · Drawn by: JWW 02-22 · Last Edit: 02/10/2022	



Boundary Condition - Normal Depth

Municipal Boundary

Existing Conditions - 500-year Inundation Boundary

N

0 200 400 Feet

FRANSON CIVIL ENGINEERS

Jones & DeMille Engineering

Lehi City

Watershed Plan EA
Proposed Conditions - 500-year 24-hour Flood Event

Map Name: H:\JD\Proj\2004-028\Design\GIS\Projects\Water\2004-028_Water.aprx - Exh Lehi Proposed Conditions - 500-year 24-hour Flood Event 11x17L

Project Number: 2004-028	Drawn by: JWW 02-22	Last Edit: 02/10/2022

Utah County

Scale: 1" = 400'

10C