PINE NUT CREEK
BASIN FEASIBILITY STUDY

Prepared for:

Douglas County, Nevada
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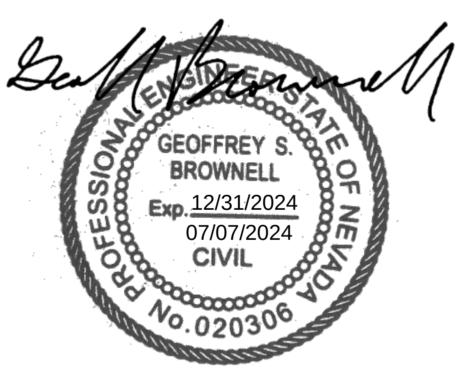

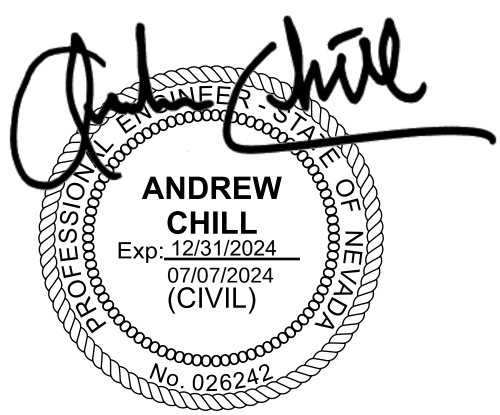

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July 2023

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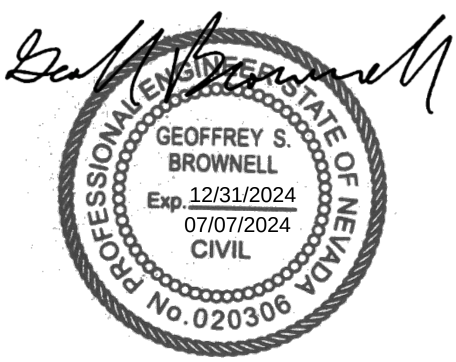
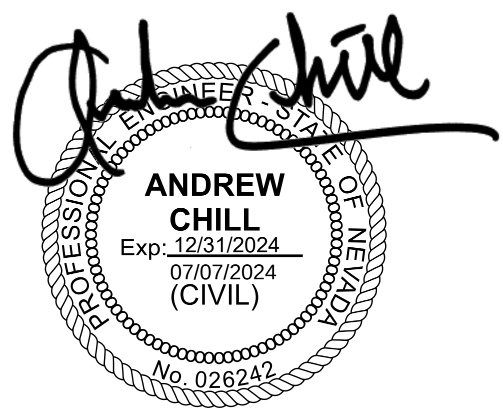
Douglas County, Nevada

DOUGLAS COUNTY
NEVADA





JULY 2023

Prepared By:

Kimley»Horn

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1.0 INTRODUCTION

1.1. PURPOSE OF STUDY

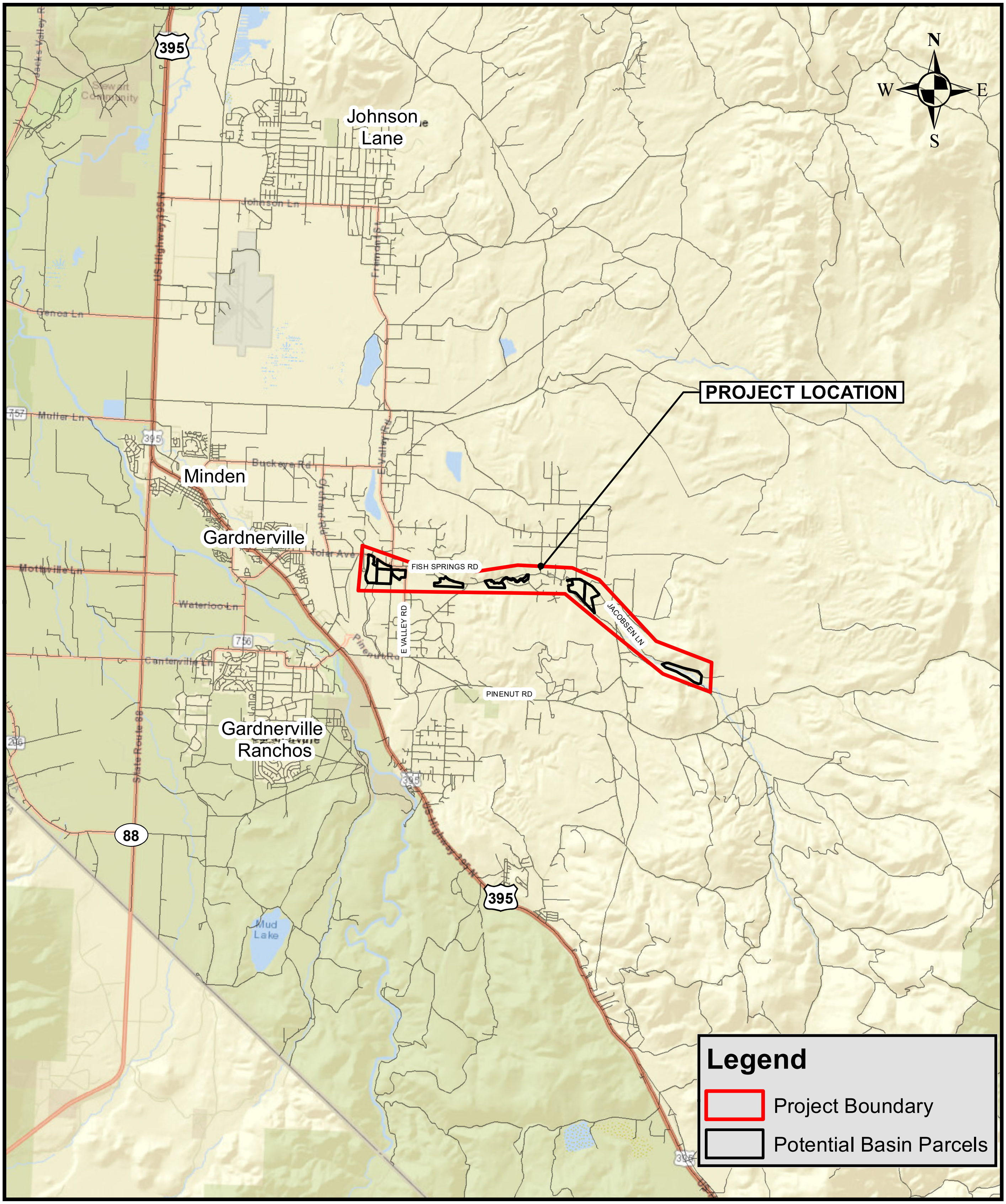
This basin study was initiated by Douglas County to determine the feasibility and cost of proposed drainage infrastructure along Pine Nut Creek upstream of Allerman Canal to reduce the risk of flooding downstream. The goal of the study was to determine the required storm water infrastructure upstream of Allerman Canal to limit Pine Nut Creek to the capacity of the Upper Allerman and Lower Allerman Canals and eliminate the breakout runoff west of the Lower Allerman Canal. The downstream limiting capacity of the canals is 100 cubic feet per second (cfs). The intent of this document is to provide a feasibility planning study for the proposed storm water infrastructure for Pine Nut Creek upstream of Allerman Canal.

1.2. LOCATION OF STUDY

Pine Nut Creek is located in unincorporated Douglas County, Nevada, east of State Route 395 and of Gardnerville. Parcels were identified by County staff that would be suitable for basin locations along the Pine Nut Creek Corridor. These parcel locations are provided in **Appendix B**. The general project location is also shown in **Figure 1** and **Figure 2**. A general description and priority as provided by County staff for each property is shown in **Table 1**.

Table 1: Identified Parcel Summary

Priority	Common Name	Parcel ID	Location	Description
1	Mel Basin Myers Basin	1221-06-001-038 1221-05-001-054	2089 Fish Springs Road	County owned parcels located approximately in the middle of the study reach.
2	The Dam	1221-00-001-001 1221-10-000-013 1221-10-000-012 1221-10-000-011	Near the end of Jacobsen Lane	BLM/Bently parcels near the City of Refuge. This is the furthest upstream parcel. Being the furthest upstream, this would help the greatest number of properties.
3	Bently 1 Basin Bently 2 Basin	1221-04-001-012 1221-04-002-001	South of Jacobsen Lane and east of Homestead Road	Bently parcels adjacent to Jacobsen Lane. This property is encumbered with FEMA floodplain and is planned to be developed.
4	Janelle Basin	1220-01-001-069	1923 Janelle Court	The landowner/developer has indicated they would be willing to provide storm water storage on this parcel.
5	Denmar Basin	1220-02-001-003 1200-02-001-012	Southwest of Toler Lane and Redhawk Lane	Den-Mar Associates parcels.
6	Redhawk Basin	1220-02-001-031	1766 Redhawk Lane	Southwest of Fish Springs Road and East Valley Road.
7	Syphus Basin	1220-02-001-029	East (upstream) of Allerman Canal	Landowner expressed interest to County staff about leasing land.

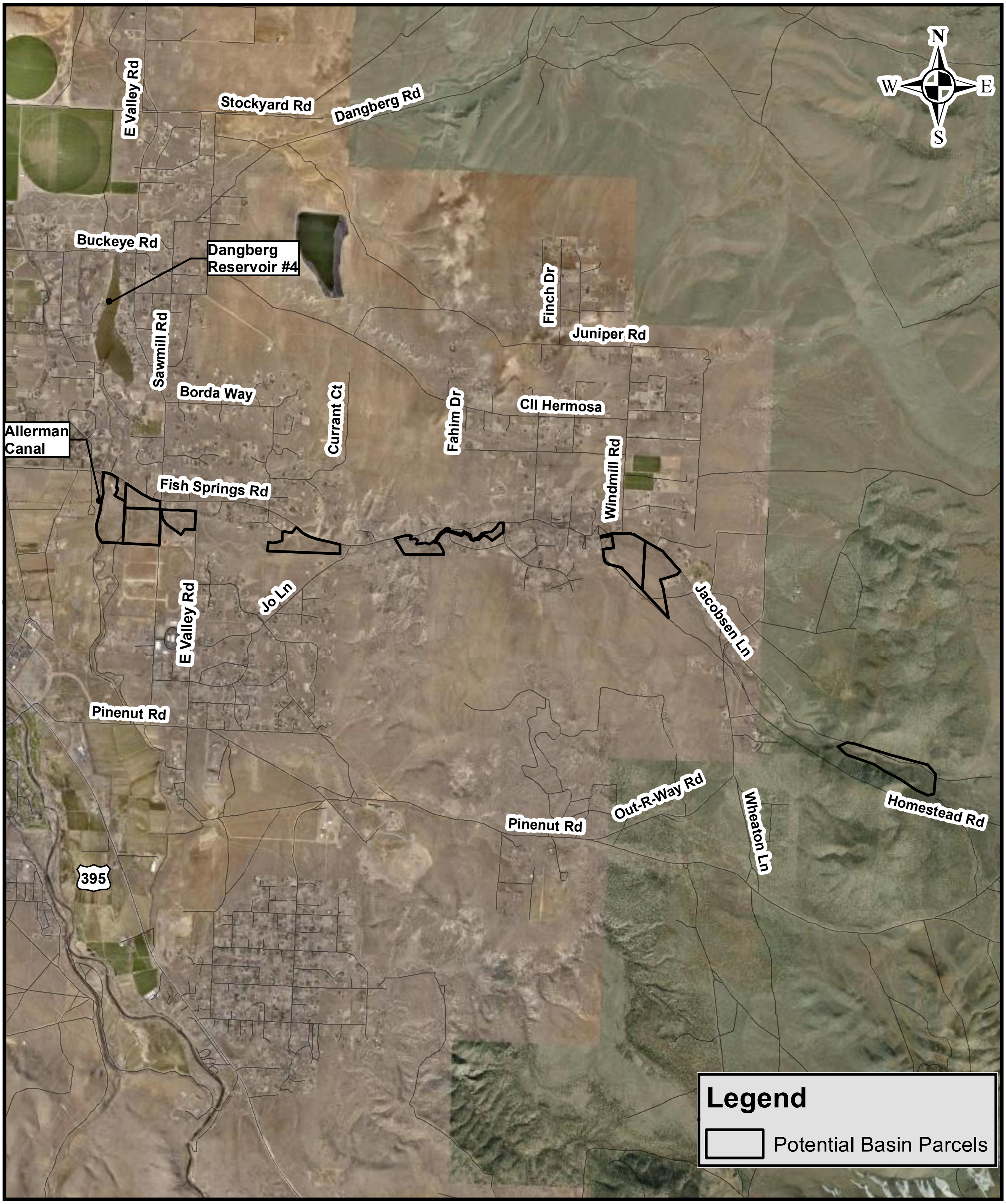


VICINITY MAP
PINE NUT CREEK BASIN FEASIBILITY
DOUGLAS COUNTY, NV

Figure 1

Kimley»Horn

Date: May 2023



LOCATION MAP
PINE NUT CREEK BASIN FEASIBILITY
DOUGLAS COUNTY, NV

Date: May 2023

Figure 2

Kimley»Horn

1.3. PREVIOUS STUDIES

As part of FEMA's Cooperating Technical Partners program (CTP) administered through Carson Water Subconservacy District (CWSD), a Letter of Map Revision (LOMR) was submitted to FEMA to remap Pine Nut Creek and contributing tributaries in Douglas County. This restudy included revised hydrology, hydraulics, and floodplain redelineation of Pine Nut Creek (HDR 2020). The hydrology was updated using the SCS Method in HEC-HMS. A HEC-RAS two-dimensional model with inflow hydrographs from the HEC-HMS model was used as the hydraulics model.

In addition to the LOMR application, there have been several additional studies including the Douglas County Pine Nut Mountain Flood Detention study spanning several watersheds draining from the Pine Nut Mountains including Pine Nut Creek. This study evaluated proposed detention storage along Pine Nut Creek (RO Anderson n.d.). Key excerpts from both studies have been included in **Appendix F**.

1.4. FEMA FLOODPLAIN

The FEMA Flood Insurance Rate Maps (FIRM) for Douglas County, Nevada, and incorporated areas show that Pine Nut Creek effective special flood hazard data as of the writing of this report is delineated as Zone A, AE, AO, and Shaded X. The pending Pine Nut Creek floodplain redelineation based on the LOMR Application shows that Pine Nut Creek is proposed to change to Zone AE with established base flood elevations. The effective and pending FEMA floodplain maps are provided in **Appendix A**. The pending FEMA floodplain data is being reviewed by FEMA and is anticipated to become effective soon. The proposed improvements shown in this report will require FEMA CLOMR applications during final design and a subsequent LOMR when the improvements are built.

1.5. SPECIAL CONDITIONS

The proposed improvements will need to evaluate special permitting such as environmental clearances, USACE Section 404 Clean Water Act permits, cultural impacts, state/federal dam permitting requirements, and local county permitting/coordination.

2.0 TOPOGRAPHIC DATA

2.1. HORIZONTAL AND VERTICAL DATUMS

The horizontal coordinate system of the topographic data used for this study is North American Datum of 1983 (NAD83) Nevada West State Plane. The vertical datum is North American Vertical Datum of 1988 (NAVD88). The units of measurement are US survey foot.

2.2. LIDAR DATA

LiDAR data was collected on February 27, 2019, for the LOMR study, and was used for these hydraulic modeling analyses. USGS has also completed LiDAR surveys for western Nevada (G17PD01257 NV Reno Carson City Urban (USGS n.d.)). This LiDAR dataset was obtained through FEMA from USGS and covered all the parcels of interest. **Appendix G** shows the key excerpts from these topographic datasets.

3.0 HYDROLOGY

3.1. METHOD DESCRIPTION

The detailed hydrology was completed by HDR for the Pine Nut Creek and associated tributaries LOMR of as a part of the CTP project with CWSD (LOMR Hydrology) (HDR 2020). The watershed is nearly 56 square miles and extends into the Pine Nut Mountain Range to the east. The project watershed is also shown in **Figure 4.** The LOMR Hydrology used the 100-year, 24-hour storm and duration, NOAA14 precipitation, SCS Curve Number, Rain on Grid transformation, and was compared to the Buckeye Creek Watershed and regional regression equations for calibration.

It is our understanding as of the writing of this report that the LOMR Hydrology has been submitted to FEMA, but it has not been approved. Kimley-Horn evaluated the LOMR Hydrology for basin routing and basin feasibility purposes. Kimley-Horn's evaluation focus on runoff volume for the total hydrograph as part of the basin feasibility analysis.

3.2. HYDROLOGY EVALUATION

For the initial evaluation, flow hydrographs and runoff volumes between Pine Nut Creek, Buckeye Creek (north of Pine Nut Creek) and Smelter Creek (south of Pine Nut Creek) were compared. The flow hydrographs are shown **Figure 3**. There is a significant difference in runoff volume and some differences in peak discharge between the watersheds. Pine Nut Creek has a greater peak discharge and runoff volume than Buckeye Creek which had a larger drainage area. Buckeye Creek was modeled in HEC-HMS using the Green-Ampt methodology for calculating rainfall losses. Smelter Creek was modeled in FLO-2D using Green and Ampt methodology as well. Pine Nut Creek was modeled in HEC-HMS using the SCS Curve Number methodology.

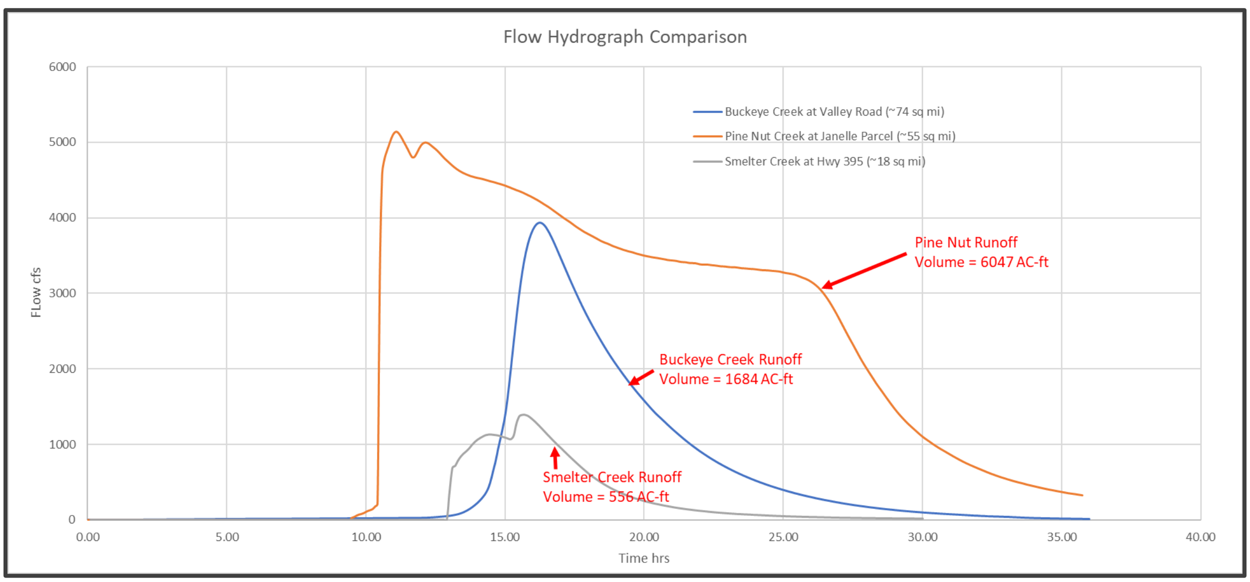
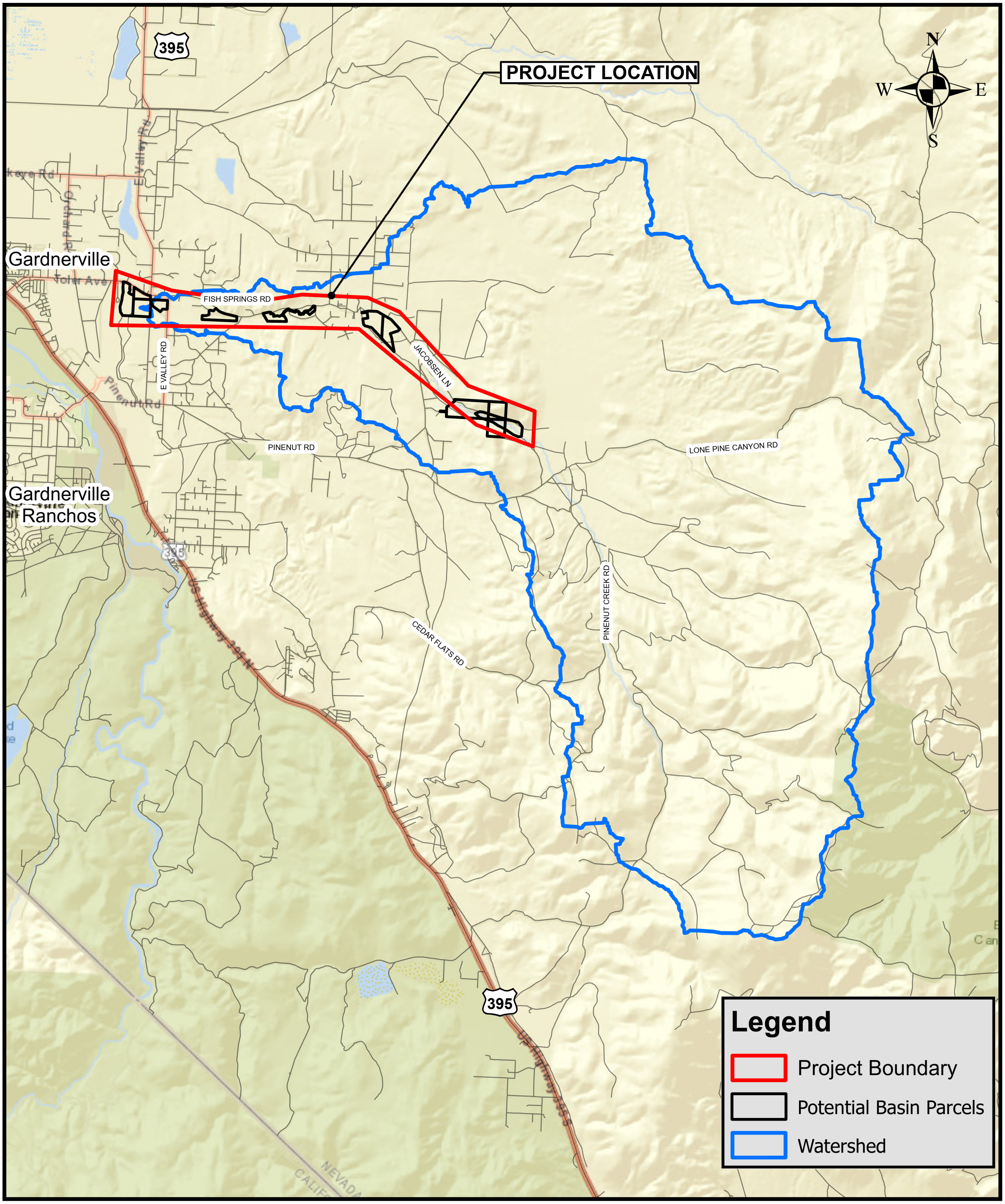


Figure 3: Flow Hydrograph Comparisons



WATERSHED MAP
PINE NUT CREEK BASIN FEASIBILITY
DOUGLAS COUNTY, NV

Figure 4

Date: July 2023

Table 2 shows the comparisons in a tabular format and includes peak discharge per square mile and runoff volume per square mile.

Table 2: Flow Comparison Table

Watershed	Drainage Area Size (sq mi)	100-year Peak Discharge (cfs)	Peak Discharge per Square Mile (cfs/mi)	100-year Runoff Volume (AC-ft)	Runoff Volume per Square Mile (AC-ft/mi)
Buckeye Creek	74	3,940	53	1684	23
Pine Nut Creek	55.5	5,150	93	6047	109
Smelter Creek	18	1,400	78	556	31

Based on the adjacent watersheds (Buckeye Creek and Smelter Creek), 1,400 – 1,700 AC-ft (23 to 31 AC-ft/mi) would be the anticipated runoff volume for Pine Nut Creek, whereas the LOMR hydrology results show over 6,000 AC-ft.

It is assumed that the biggest contributing factor to the runoff volume discrepancy is the hydrology methodology used, and more specifically the rainfall losses methodology. The Pine Nut Creek LOMR Hydrology used the SCS Curve Number approach, whereas the adjacent watersheds (Buckeye and Smelter Creeks) used Green-Ampt methodology for rainfall losses. In the SCS Curve Number approach, there is a trailing rainfall excess in the HEC-HMS model that is contributing to the extended hydrograph and runoff volume. **Figure 5** below is one of the upstream subbasins that shows the flow hydrograph with the rainfall excess. The rainfall excess of 0.01 inch over the 6.72 sq mi watershed over a 12-hour period is nearly 515 AC-ft and represents only 12% of the entire Pine Nut Creek watershed.

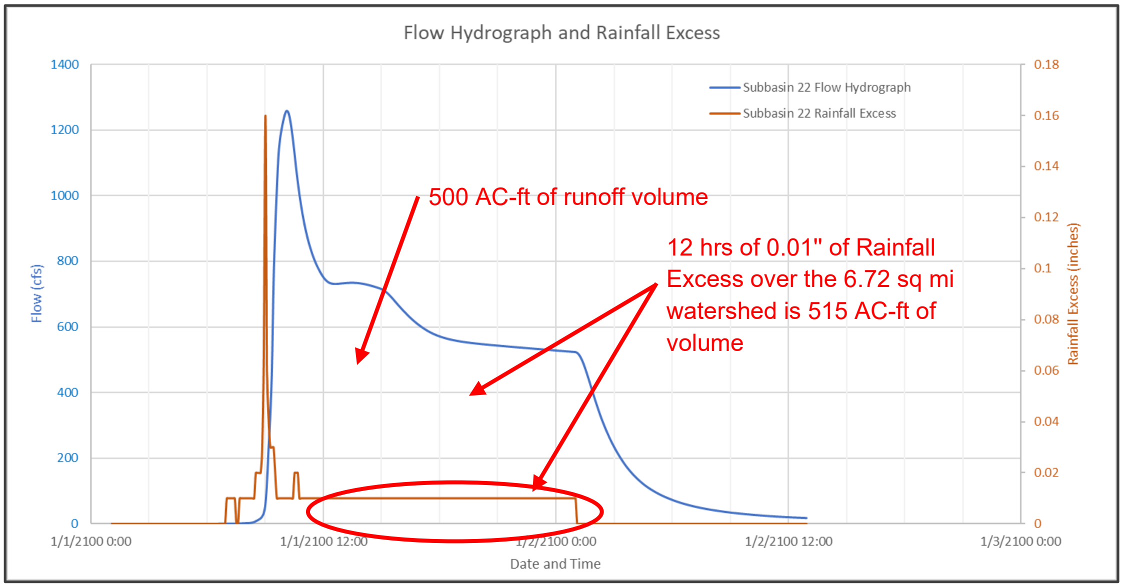


Figure 5: Flow Hydrograph and Rainfall Excess

3.3. MODIFIED HYDROGRAPH APPROACH

Based on the runoff volume being produced in the Pine Nut Creek LOMR hydrology with the SCS Curve Number methodology, it may be beneficial to evaluate the hydrology with Green-Apmt rainfall loss parameters similar to Buckeye and Smelter Creeks in the adjacent watershed. It is anticipated that the runoff volume will be substantially reduced, and the peak discharge may be reduced.

For the purposes of this basin feasibility study, the hydrograph from Buckeye Creek was used and scaled to the corresponding peak flow rate from the Pine Nut Creek LOMR hydrology. **Figure 6** below shows an example of this modified hydrograph approach. This flow hydrograph was taken near the Janelle Parcel (1220-01-001-069) for Pine Nut Creek. The modified flow hydrograph approach still generates 2,200 AC-ft for Pine Nut Creek at this location. Based on the adjacent watersheds, if the Pine Nut Creek watershed was modeled using Green and Ampt in HEC-HMS the peak flow and runoff volume could be furtherer reduced with volumes likely in the 1400-1700 AC-ft range.

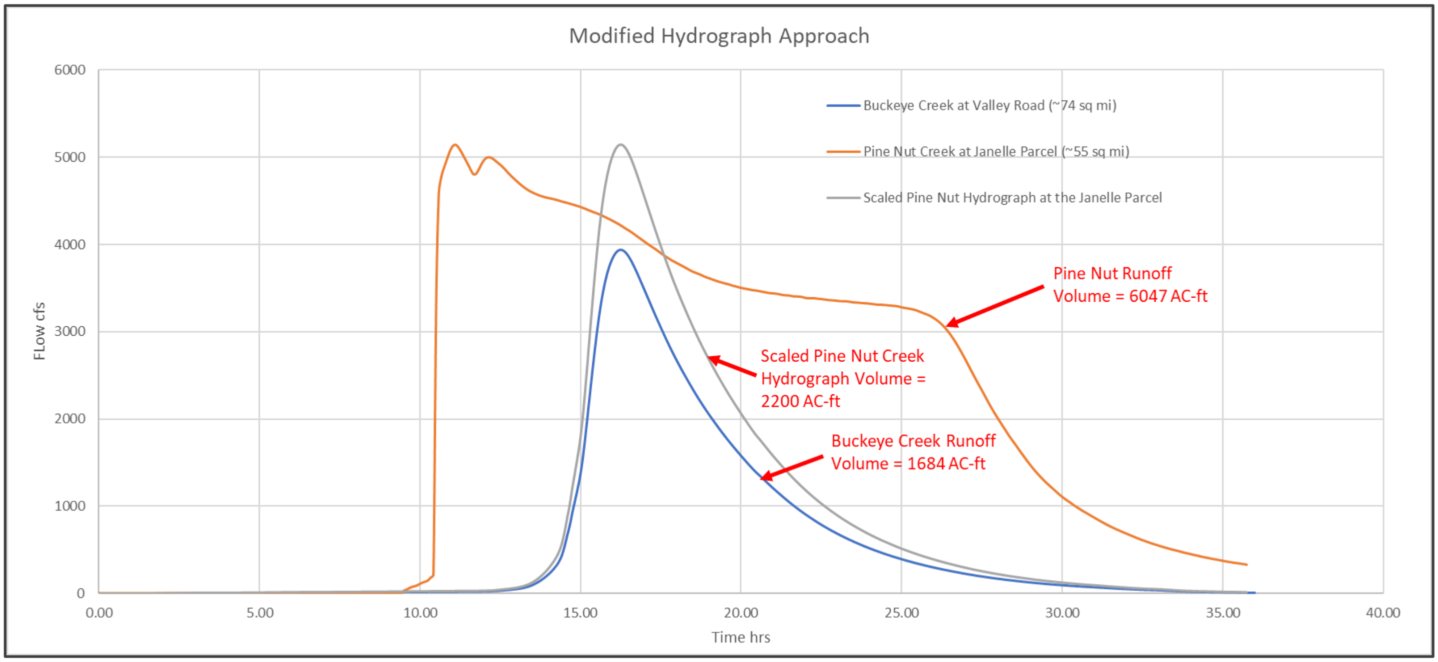


Figure 6: Modified Hydrograph Approach

With this modified hydrograph approach, the time of peak discharge was assumed to be the same for Pine Nut Creek and its tributaries. This was a conservative approach used for this feasibility study but could also be revised based on updated hydrology to further refine peak flow and volume estimates.

4.0 CONCEPTUAL DESIGN

For proposed conditions, a series of basins located on the identified parcels (**Table 1**) were analyzed to evaluate the effectiveness of retaining runoff from Pine Nut Creek to reduce peak discharge downstream. Due to the total estimated runoff volume generated for the Pine Nut Creek watershed, even using the modified hydrograph approach, the identified parcels did not provide enough detention volume to reduce downstream peak flows to the study goal levels. The proposed basins did reduce runoff downstream, but flow was still overtopping the Allerman Canal. Additional storage would be necessary such that identifying additional potential open space to construct a basin would likely not be feasible.

Based on discussion with County staff, a raised embankment or earthen dam was also evaluated to detain and attenuate runoff downstream. A dam has been considered in other adjacent areas in the County along the Pine Nut range such as in the Johnson Lane and Smelter Creek watersheds. RO Anderson completed the Pine Nut Flood Detention analysis that contemplated a dam in the similar location for Pine Nut Creek (RO Anderson n.d.).

The proposed dam is located upstream near BLM land. The dam location is shown in **Appendix B**. An initial dam location was placed based on the shortest dam length where Pine Nut Creek is restricted through a canyon. This location is on private land. An alternative dam location was considered further upstream and would be entirely located on BLM land. The alternative location is also shown schematically in **Appendix B**. This alternative dam location would have a smaller storage capacity as there is a breakover point to the north where flows could spill out of the dam pool and go into another tributary. The alternative dam location would have a longer dam length, but the height of the dam could be reduced.

Ultimately, the dam location will have to be further evaluated based on several factors; a few of which are the suitability of insitu soils, environmental & cultural constraints, sediment yield, landownership, outlet structure configuration, flanking, dam crest height, emergency response plan consideration, and local/state permitting requirements.

5.0 BASIN ROUTING

For the basin routing analysis, the County identified parcels were analyzed to determine potential maximum volume feasible based on grading and physical constraints. A proposed finished ground surface was developed for each parcel. This surface was used in the HEC-RAS two-dimensional LOMR model for basin routing purposes. All the basins were evaluated as inline basins with one basin cascading into the next basin. Due to the parcel/site topography, cascading basins were evaluated on some of the parcels to save earthwork costs. The modified flow hydrograph approach as discussed in **Section 3.3** was used in the basin routing.

The basins were generally graded to be 15 feet deep when space allowed with 4:1 side slope. The basins were offset from the property lines to provide a buffer to the surrounding parcels. Riprap or concrete spillways will be needed to transition the flow from the channel into the basin without eroding the basin side slopes. The basins can be landscaped to improve aesthetics, and it is recommended that the basin side slopes be seeded and allow vegetation to protect from rilling. Maintenance access roads are provided for maintenance crews to remove sediment/debris from the basins and for normal maintenance activities. The proposed concept drawing and cost estimates are provided in **Appendix C**. A summary of the volume provided per parcel is shown in **Table 3**.

Table 3: Basin Storage Summary

Priority	Common Name	Parcel ID	Location	Existing Conditions 100-year Runoff Volume Upstream of Basin (AC-ft) Modified Hydrograph Approach	Volume Provided (AC-ft)
1	Mel Basin Myers Basin	1221-06-001-038 1221-05-001-054	2089 Fish Springs Road	2,520	57.5
2	Pine Nut Creek Dam	1221-00-001-001	Near the end of Jacobsen Lane	2,150	2,200*
3	Bently 1 Basin Bently 2 Basin	1221-04-001-012 1221-04-002-001	South of Jacobsen Lane and east of Homestead Road	2,150	123.5
4	Janelle Basin	1220-01-001-069	1923 Janelle Court	2,700	181.1
5	Denmar Basin	1220-02-001-003 1200-02-001-012	Southwest of Toler Lane and Redhawk Lane	2,720	309.2
6	Redhawk Basin	1220-02-001-031	1766 Redhawk Lane		117.8
7	Syphus Basin	1220-02-001-029	East (upstream) of Allerman Canal		335.0

*The volume provided is dependent on how the outlet works of the dam is configured. The dam could store up to this amount.

For the Janelle Court Parcel (1220-01-001-069), Kimley-Horn and Douglas County coordinated with the property owner (developer) and engineering consultant which have expressed interest in utilizing this parcel for flood protection. The engineer provided a concept to retain Pine Nut Creek flows within the parcel. The proposed concept is shown in **Appendix D**. This concept contemplated essentially two inline raised embankment structures to retain runoff with a total volume provided of 120 AC-ft. This concept was considered but due to the amount of runoff volume in Pine Nut Creek (2200 AC-ft Modified Hydrograph Approach) the upstream dam concept described in this report was determined to be a more viable alternative.

5.1. SCENARIOS

Several proposed scenarios were evaluated for the dam upstream and basins downstream. The scenarios are summarized in **Table 4** and the results are provided in **Appendix E.**

Table 4: Scenario Summary

Scenario ID	Description	100-year Peak Discharge in Pine Nut Creek Upstream at Limit of Study (cfs)	100-year Discharge Downstream (west) of Lower Allerman Canal (cfs)	100-year Discharge in Upper and Lower Allerman Canal (cfs)
1	Existing conditions using the pending LOMR model and LOMR hydrology (SCS)	5,000	3,150	1,650
2	Existing conditions using the modified hydrograph approach (Green-Ampt)	5,000	4,100	1,800
3	Proposed basins without dam using the LOMR hydrology	5,000	2,420	1,750
4	Proposed basins without dam using the modified hydrograph approach	5,000	1,300	1,650
5	Proposed basins with dam release of 200 cfs using the modified hydrograph approach	200	0	200
6	Proposed basins with dam retaining the full 100-year, 24-hour storm (no dam release) using the modified hydrograph approach	0	0	0

If the dam upstream was constructed in the narrow configuration and to retain the entire 100-year runoff, the approximate height would be over 110 ft tall to provide 2,200 AC-ft of storage (Scenario #6). The downstream tributaries could then be completely retained in the proposed parcel basins with no discharge to either Upper or Lower Allerman Canal during a 100-year storm event. Additionally, the basins could potentially be reduced in size and cost from what is shown in **Appendix C**.

With the proposed parcel basins, the discharge from the dam can be approximately 200 cfs, reducing the dam height and cost, if downstream capacities in the Upper Allerman Canal (70cfs) and the Lower Allerman Canal (100cfs) are utilized. There could also be an opportunity to increase the capacity downstream for Upper Allerman Canal, Lower Allerman Canal, or west of the Lower Allerman Canal through the farm fields. By increasing the downstream capacity of Pine Nut Creek, the volume required in either the basins or dam upstream could be further reduced.

Another option to reduce the volume required would be to provide offline basins and routing the low flows around the basins instead of filling up some basin capacity with the low flow volume. This is further discussed in **Section 6.0**. The basins and dam should also be further evaluated independently of each other in the event of a phased construction as the funding becomes available.

5.2. DAM ANALYSIS

For the dam analysis, an approach was taken similar to the Johnson Lane (JE Fuller 2018) and Smelter Creek studies. The following summarizes the key design components:

100-year Outflow from the Dam -- A discharge of 200 cfs was determined to be the maximum release out of the dam during the 100-year storm event to meet the project goals. This flow will pass downstream and be routed to the subsequent parcel basins downstream. This discharge can be accomplished by using a 30'' or 42'' outlet pipe depending on the volume retained in the dam and the head on the discharge pipe. The head on this pipe would be over 90ft on the current dam location which would require special design considerations.

Spillway Crest -- The spillway crest was set a minimum of 1-ft above the 100-year, 24-hour event (controlling storm). The spillway should be designed for the probable maximum flood (PMF). The PMF as defined by the Code of Federal Regulations (CFR) as the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the drainage basin (CFR n.d.). There has not been a PMF analysis completed for Pine Nut Creek as of the writing of this report, so this would need to be completed as part of the next steps in the dam evaluation. For reference, the Smelter Creek PMF analysis computed a probable maximum precipitation (PMP) of approximately 10 inches of rainfall for the watershed, whereas the 100-year, 24-hour rainfall for the same watershed ranges from 3.5 to 5 inches.

In some dam cases, depending on the risk classification of the dam, the spillway can be designed to take ½ of the PMF flow but based on the Johnson Lane analysis there is not a significant cost increase or impact with constructing the spillway to the full PMF. Also, the Pine Nut Creek Dam is anticipated to be a high hazard dam due to the amount of volume to be stored and the height of the embankment. Based on this dam configuration, it is expected that the spillway be designed to the full PMF flow.

Dam Crest -- The dam crest shall be designed to have a minimum of 1-foot of freeboard during the PMF event and 3-feet of freeboard during a ½ PMF event.

Sediment -- The volume of the dam shall consider annual sediment yield that could be expected to accumulate in the dam flood pool and thereby reducing the storage volume. Per the Johnson Lane analysis, the sediment storage should account for five times the annual sediment yield plus the sediment delivered for one 100-year storm event (JE Fuller 2018).

Emergency Action Plan/Maintenance -- A raised embankment dam will bring additional risk to downstream properties, annual permitting, and considerable maintenance after construction. It will be required that state regulations be followed, and an emergency action plan and maintenance and operations plan be in place.

6.0 HYDRAULICS

The HEC-RAS two-dimensional model used in the Pine Nut Creek LOMR application was used for this basin feasibility study. The HEC-RAS model consists of inflow hydrographs for Pine Nut Creek and associated tributaries. The model's downstream limits extend west of Allerman Canal. The full model extents are shown in **Appendix E**. The Manning's n-values used from the LOMR model and key excerpts are provided in **Appendix F**.

Conceptual basin spillways, channel modifications, and culverts are provided for each basin design. These features are shown schematically for each parcel in **Appendix C** but shall be refined during final design. This applies especially to the downstream basins adjacent to the Upper and Lower Allerman Canals as shown in **Figure 7**. These basins will attenuate flow simultaneously through a culvert under the Upper Allerman Canal and then weir discharge to both canals.

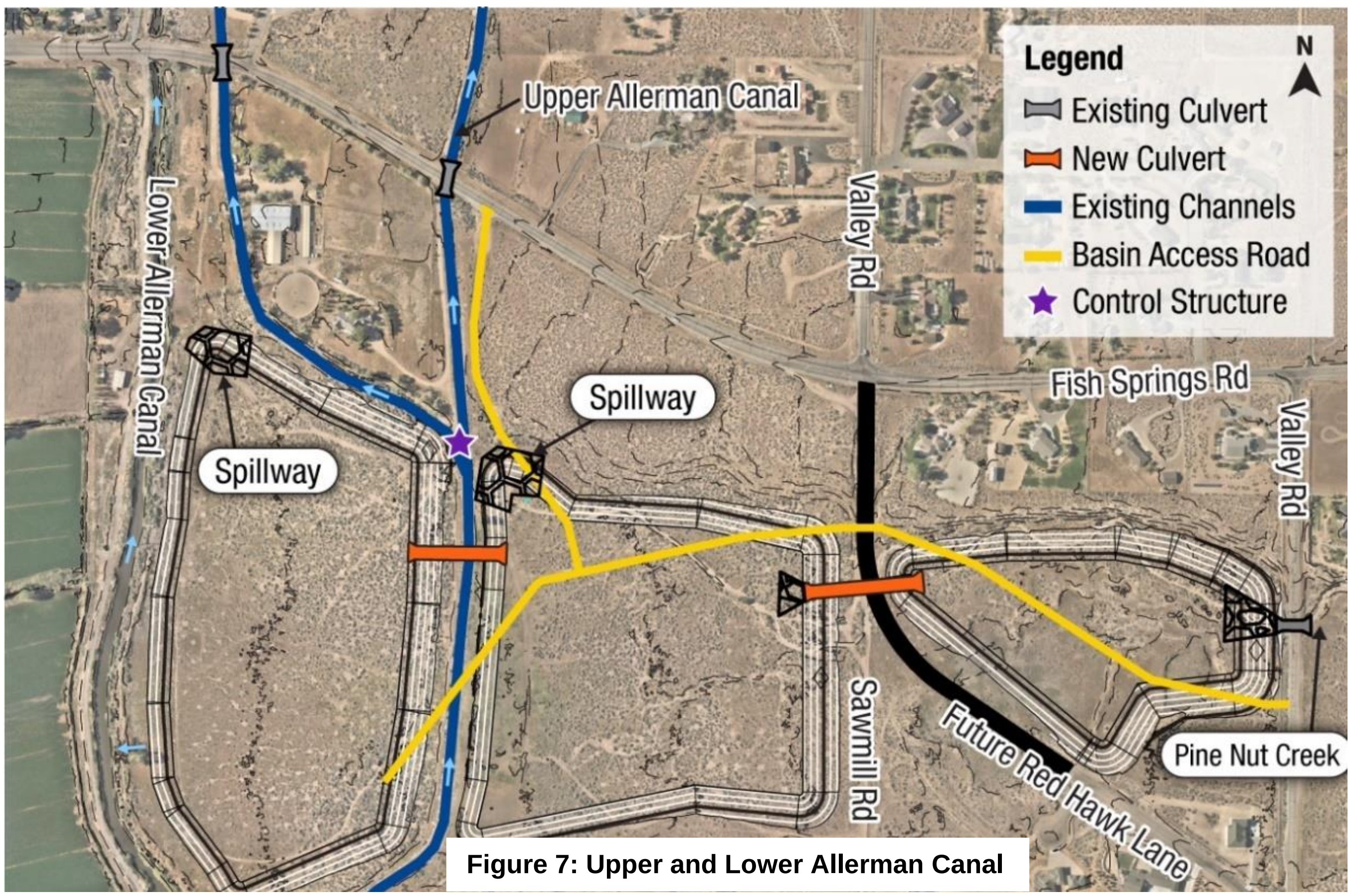


Figure 7: Upper and Lower Allerman Canal

Additionally, offline basins could be considered to route low flows (100-200 cfs) around the basin into the Upper and Lower Allerman Canals. This would save cost by reducing the volume required in the basins. Low flows would be conveyed through the parcel while lateral weir structures would direct higher flows into the adjacent basins when channel capacities are exceeded. This concept is shown schematically in **Figure 8**. The offline basin concept can potentially be applied to all proposed basins as a cost saving approach, but requires additional hydraulic analyses during design.

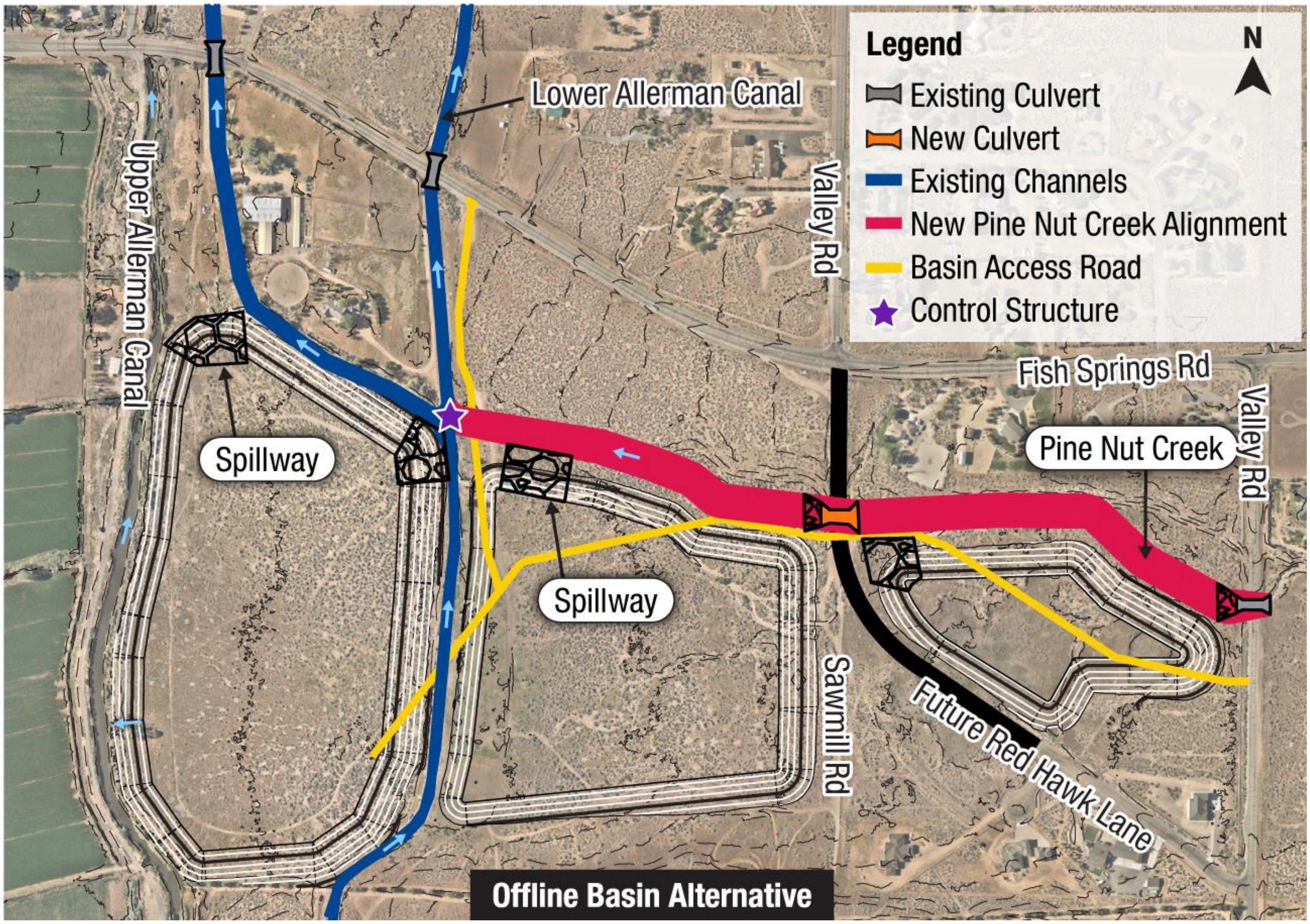


Figure 8: Offline Basin Alternative

7.0 BASIN DISSIPATION

A preliminary basin dissipation time was calculated for each basin based on the saturated hydraulic conductivity (KSAT) provided from the NRCS Soil Survey Geographic Database (SSURGO). KSAT is defined by NRCS as “the ability of a soil to transmit water or air. The hydraulic conductivity indicates the rate of water movement when the soil is saturated” (NRCS n.d.). An average KSAT value was found for each basin based on the SSURGO data. The average KSAT value was reduced by 50% to account for the degradation/silting in of the basin overtime. This reduction factor accounts for the decay in the basin infiltration overtime. The NRCS SSURGO data is the best readily available information; however, these soil surveys are very general and are based on a lot of different assumptions which might not be applicable for the specific sites. During final design, multiple soil infiltration tests such as the double ring infiltrometer test should be conducted for each basin to have site specific data. **Table 5** summarizes the KSAT, basin depth and anticipated time for the water in the basin to dissipate after the basin is full.

Table 5: Basin Dissipation Time

Common Name	Basin Depth (ft)	NRCS Soil Map Unit Symbol and Soil Name	Average Saturated Hydraulic Conductivity (in/hr)	Average Reduced (50%) Saturated Hydraulic Conductivity (in/hr)	Approximated Basin Drain Time
Mel Basin	15	6646 Saralegui Sand	4.0	2.0	90 hours 3.75 days
Myers Basin	15	6762 Turria Loam	1.0	0.5	360 hours 15 days
Bently 1 Basin	15	6261 Haybourne Fine Sandy Loam	4.0	2.0	90 hours 3.75 days
Bently 2 Basin	15	6261 Haybourne Fine Sandy Loam	4.0	2.0	90 hours 3.75 days
Janelle Basin	15	6261 Haybourne Fine Sandy Loam	4.0	2.0	90 hours 3.75 days
Denmar Basin	15	6261 Haybourne Fine Sandy Loam	4.0	2.0	90 hours 3.75 days
Redhawk Basin	15	6261 Haybourne Fine Sandy Loam	4.0	2.0	90 hours 3.75 days
Syphus Basin	15	6261 Haybourne Fine Sandy Loam	4.0	2.0	90 hours 3.75 days

8.0 EROSION AND SEDIMENT TRANSPORT

The parcel basins and dam will accumulate sediment with each storm. During final design, sediment yield analysis should be performed. The basins should also have engineered spillways and outfall weirs to protect from erosive velocities. Basin spillways could be configured as USBR baffle block spillway if standard riprap protection becomes too large. An example of this baffle block spillway is shown in the following figures.

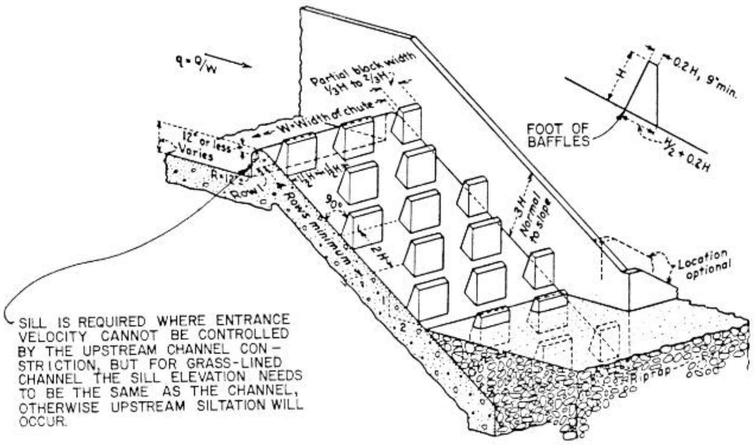


Figure 9: Baffle Chute Schematic

Figure 10: Baffle Chute

9.0 PRLEIMINARY COST ANALYSIS

A preliminary cost analysis was completed for the basin and dam features. The preliminary cost estimates include maintenance access roads, culverts, spillways, earthwork, land cost if the property is not already owned by the County, landscaping, removals, miscellaneous construction costs such as mobilization, construction staking, construction management, and planning/design costs. A summary of the cost estimates is provided in **Table 6**. The detailed cost estimates are provided in **Appendix C**.

Table 6: Preliminary Cost Estimate

Priority	Common Name	Parcel ID	Location	Construction Cost	Land Acquisition Cost	Planning/Design Cost	Total Cost Estimate
				$ in millions			
1	Mel Basin Myers Basin	1221-06-001-038 1221-05-001-054	2089 Fish Springs Road	$6.7	$0.0 (Owned by the County)	$0.9	$7.6
2	Pine Nut Creek Dam	1221-00-001-001	Near the end of Jacobsen Lane	$20.7	$0.4	$3.0	$24.1
3	Bently 1 Basin Bently 2 Basin	1221-04-001-012 1221-04-002-001	South of Jacobsen Lane and east of Homestead Road	$10.7	$0.5	$0.7	$11.8
4	Janelle Basin	1220-01-001-069	1923 Janelle Court	$10.9	$0.0 (Working with Developer)	$0.7	$11.6
5	Denmar Basin	1220-02-001-003 1200-02-001-012	Southwest of Toler Lane and Redhawk Lane	$12.2	$0.9	$0.8	$13.9
6	Redhawk Basin	1220-02-001-031	1766 Redhawk Lane	$6.5	$0.4	$0.7	$7.6
7	Syphus Basin	1220-02-001-029	East (upstream) of Allerman Canal	$11.9	$0.2	$0.8	$12.9

10.0 CONCLUSIONS/NEXT STEPS

- The Pine Nut Creek LOMR Hydrology used the SCS Curve Number Method, and seems to overestimate the total runoff volume based on a comparison with adjacent watershed studies using the Green-Apmt rainfall loss methodology. Revised hydrology using Green-Apmt for rainfall losses may yield lower total hydrograph volumes and peak flows.
- The upstream dam concept should continue to be refined based on state regulations, PMF analysis, earth work quantities, and cost.
- The proposed parcel basins and dam as described in this basin feasibility report will eliminate the overtopping of Allerman Canal during a 100-year storm event.
- The proposed improvements shown in this basin feasibility report will require FEMA CLOMR/LOMR permitting prior to construction.
- Environmental, geotechnical and cultural evaluations should be considered during final design, including USACE Section 404 Clean Water Act permitting. Other environmental permitting would likely be required depending on funding sources.
- During final design, the basins should account for erosion protection, basin side slope protection, and sediment yield when determining volume requirements.
- Basins should be evaluated independently for phased construction.

11.0 REFERENCES

CFR. n.d. "40 CFR SS 257.53."

HDR. 2020. "LOMR for Pine Nut Creek and Tributaries NV."

JE Fuller. 2018. "Johnson Lane Area Drainage Master Plan Technical Report."

NRCS. n.d. "NRCS SSURGO Douglas County Nevada."

RO Anderson. n.d. "Pine Nut Mountain Flood Detention."

USGS. n.d. "LiDAR Project Report G17PD01257 NV Reno Carson City Urban."

Appendix

Appendix A: FEMA

Appendix B: Parcel Locations

Appendix C: Proposed Exhibits and Cost Estimates

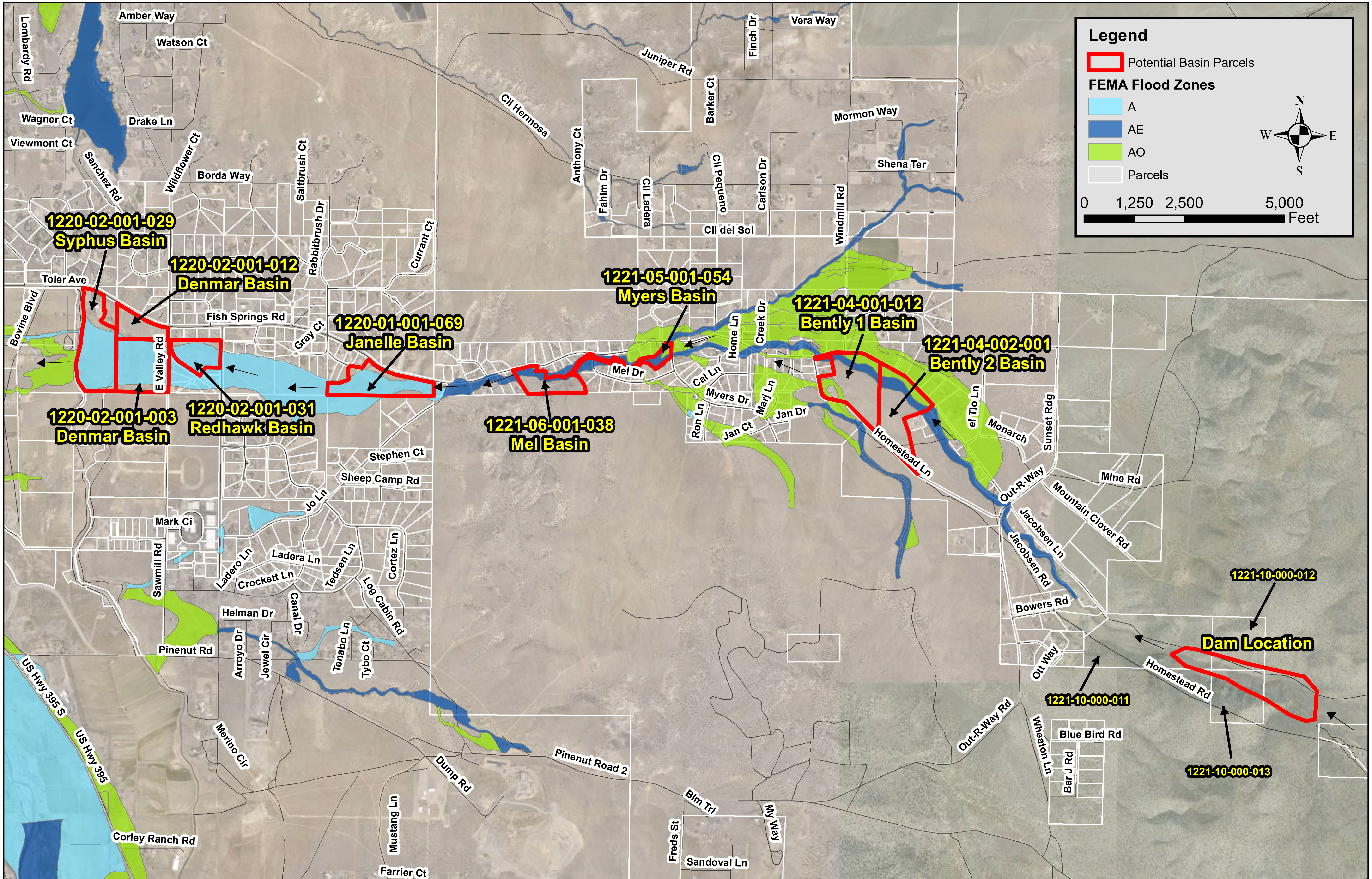
Appendix D: Janelle Court Parcel Dam Concept

Appendix E: Hydraulics

Appendix F: LOMR Excerpts

Appendix G: Topography Supporting Documentation

Appendix A: FEMA



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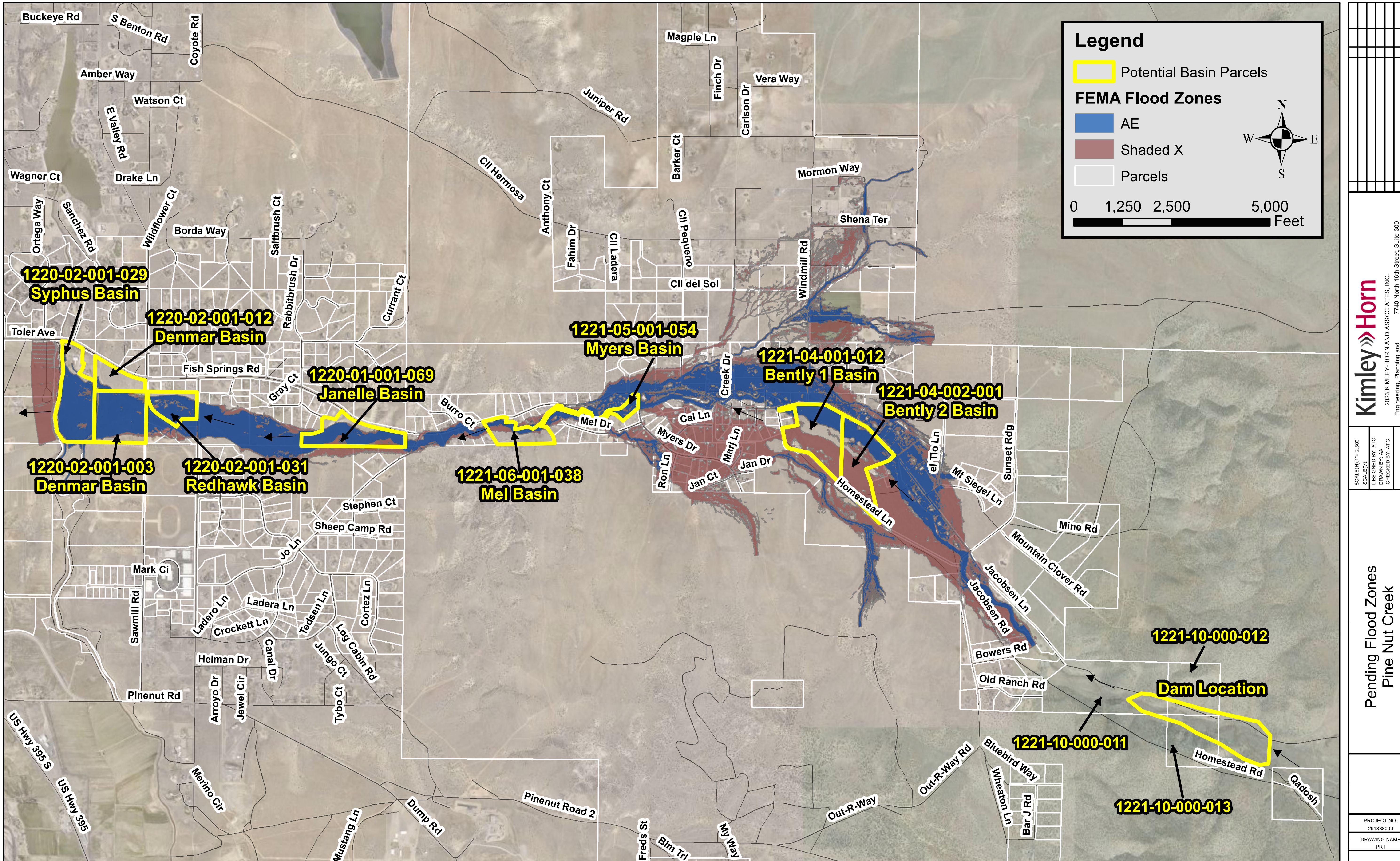
DATE: 5/9/2023

Effective Flood Zones
Pine Nut Creek

PROJECT NO.
291838000

DRAWING NAME
PR2



Legend
Potential Basin Parcels
FEMA Flood Zones
AE
Shaded X
Parcels
0
1,250
2,500
5,000
Feet
N
S
E
W
1220-02-001-029
Syphus Basin
1220-02-001-012
Denmar Basin
1220-01-001-069
Janelle Basin
1221-05-001-054
Myers Basin
1221-04-001-012
Bently 1 Basin
1221-04-002-001
Bently 2 Basin
1220-02-001-003
Denmar Basin
1220-02-001-031
Redhawk Basin
1221-06-001-038
Mel Basin
1221-10-000-012
Dam Location
1221-10-000-011
1221-10-000-013
Buckeye Rd
S Benton Rd
Coyote Rd
Amber Way
Watson Ct
E Valley Rd
Wagner Ct
Drake Ln
Ortega Way
Sanchez Rd
Wildflower Ct
Borda Way
Saltbrush Ct
Rabbitbrush Dr
Currant Ct
Toler Ave
Fish Springs Rd
Gray Ct
Burro Ct
Mel Dr
Cll Hermosa
Anthony Ct
Fahim Dr
Cll Ladera
Cll Pequeno
Cll del Sol
Barker Ct
Juniper Rd
Magpie Ln
Finch Dr
Carlson Dr
Vera Way
Mormon Way
Shena Ter
Windmill Rd
Creek Dr
Cal Ln
Myers Dr
Mari Ln
Jan Dr
Jan Ct
Ron Ln
el Tio Ln
Homestead Ln
Mt Siegel Ln
Sunset Rdg
Mine Rd
Mountain Clover Rd
Jacobsen Ln
Jacobsen Rd
Bowers Rd
Old Ranch Rd
Homestead Rd
Qadosh
Stephen Ct
Sheep Camp Rd
Jo Ln
Mark Ci
Sawmill Rd
Ladero Ln
Ladera Ln
Crockett Ln
Tedsen Ln
Cortez Ln
Log Cabin Rd
Jungo Ct
Canal Dr
Helman Dr
Arroyo Dr
Jewel Cir
Tybo Ct
Pinenut Rd
US Hwy 395 S
US Hwy 395
Merino Cir
Mustang Ln
Dump Rd
Pinenut Road 2
Freds St
Blm Trl
My Way
Out-R-Way
Out-R-Way Rd
Bluebird Way
Wheaton Ln
Bar J Rd
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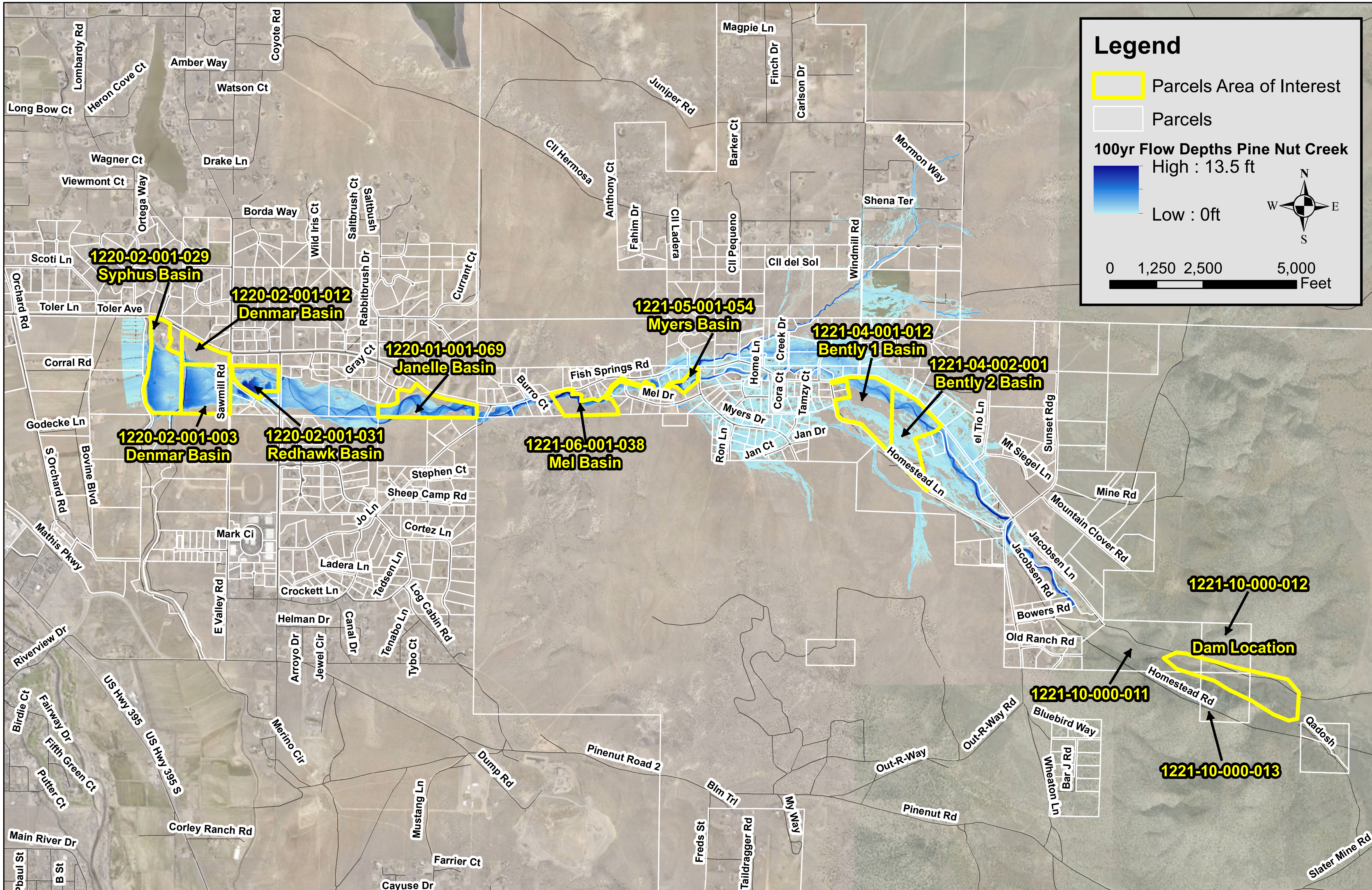
Pine Nut Creek
PROJECT NO.
291838000
DRAWING NAME
PR1

Appendix B: Parcel Locations



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DATE:

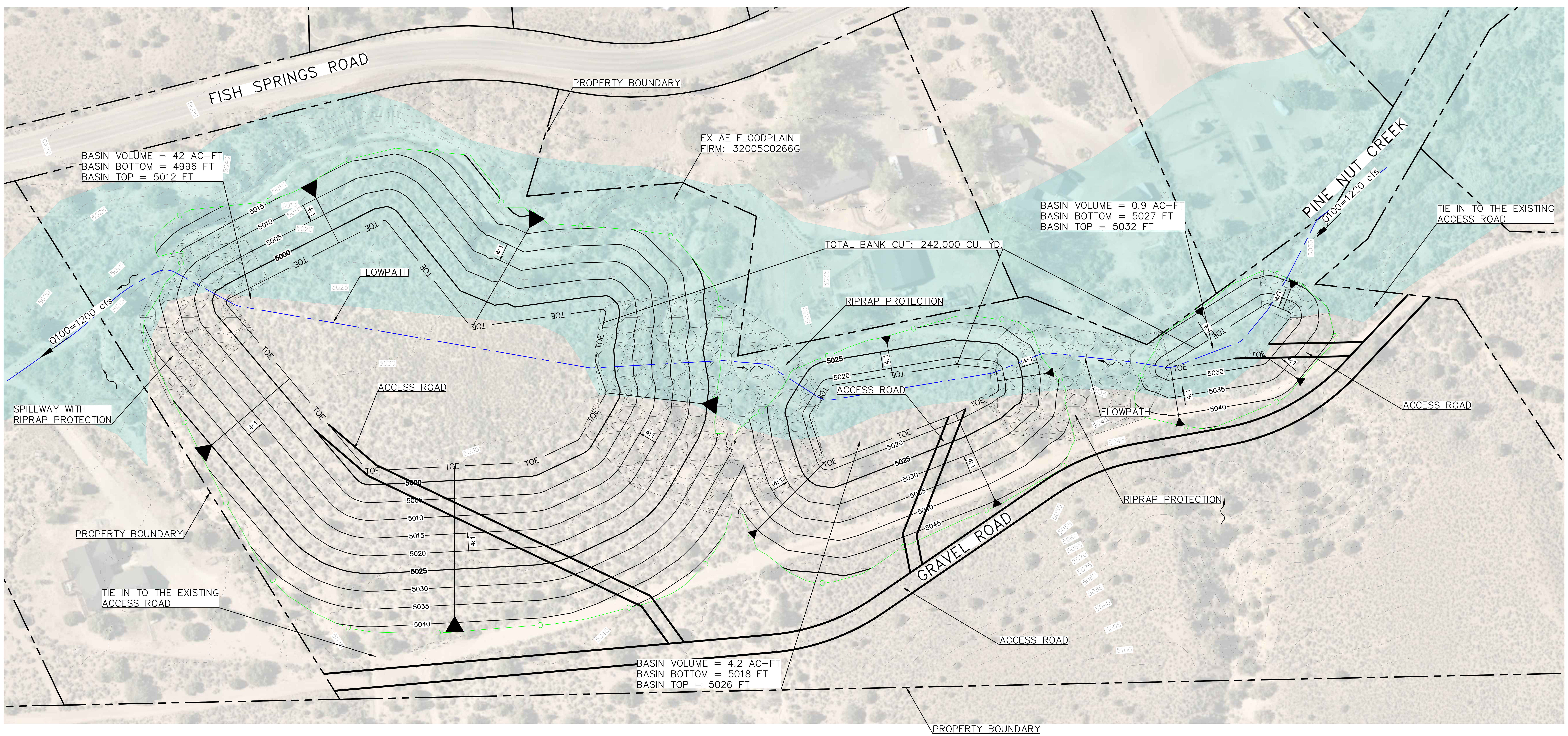
Parcel Areas of Interest
Pine Nut Creek

PROJECT NO.
XXX
DRAWING NAME
XXX

Appendix C: Proposed Exhibits and Cost Estimates

TOTAL VOLUME PROVIDED = 47.2 AC–FT
TOTAL BANK CUT VOLUME = 242,000 CY
COST ESTIMATE = $6.1 MILLION

0 60' 120'
SCALE: 1"=60'



LEGEND

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KHA PROJECT	DATE	SCALE:	DESIGNED BY:	DRAWN BY:	CHECKED BY:
291838000	04/21/2023	1"=60'	AC	RJB	AC

MEL BASIN
PRELIMINARY DESIGN
IN-LINE BASIN

PINE NUT CREEK
BASIN FEASIBILITY
PARCEL 1221-06-001-038
DOUGLAS COUNTY, NEVADA

SHEET NUMBER
1

Kimley»Horn

Project:	***Pine Nut Creek Basin Feasibility***
Name	**Mel Basin**
Location	**Parcel 1221-06-001-038**
Level of Protection	**100-year**
Designed by:	**AA** Date: 7/6/2023
Checked by:	**ATC** Date: 7/6/2023

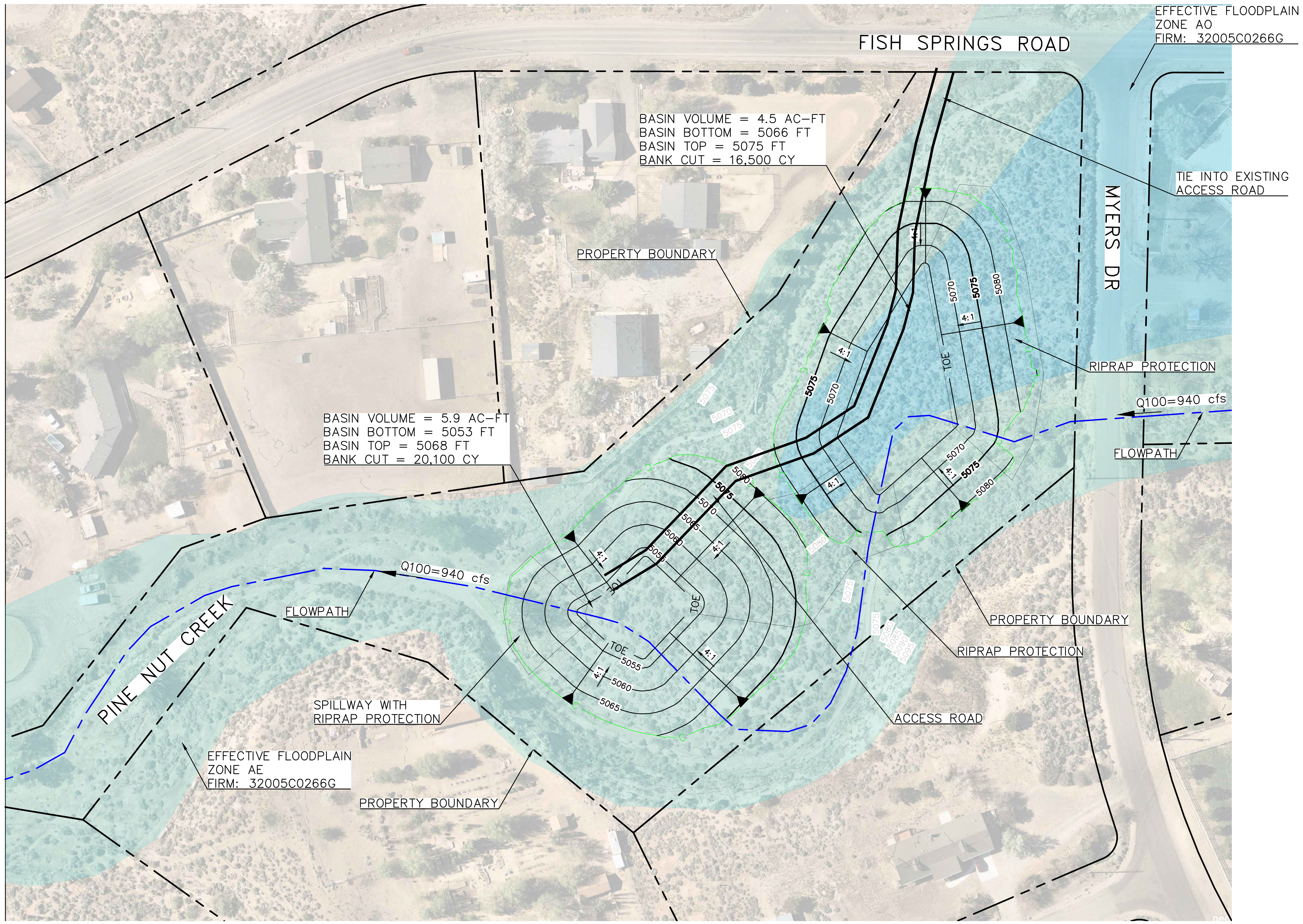
Item Description	Unit	Unit Price	Qty	Cost
Basin Earthwork	CY	$ 10	242,000	$ 2,420,000
Maintenance Roadway	SF	$ 1.10	324,000	$ 356,400
Riprap/Spillway	CY	$ 250	3,500	$ 875,000
Basin Landscaping	SF	$ 2	383,550	$ 767,100
Construction Subtotal				$ 4,419,000
Removals (5%)				$ 220,950
Miscellaneous Construction Costs (3%)[1]				$ 132,570
Contingency (15%)				$ 662,850
CONSTRUCTION TOTAL				**$ 5,435,370**
PLANNING/DESIGN TOTAL				**$ 650,000**
PRELIMINARY TOTAL PROJECT COST				**$ 6,086,000**

(1) Includes Mobilization, Traffic Control, Construction Staking, Quality Control, SWPPP, and Construction Management

SCALE: 1"=60'

0 60' 120'

TOTAL VOLUME PROVIDED = 10.3 AC–FT
TOTAL BANK CUT VOLUME = 36,642 CY
COST ESTIMATE = $1.5 MILLION



LEGEND

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- EFFECTIVE FLOODPLAIN, ZONE AO

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15% DESIGN

KHA PROJECT	DATE	SCALE:	DESIGNED BY:	DRAWN BY:	CHECKED BY:
291838000	04/21/2023	1"=60'	AC	RJB	AC

MYERS BASIN
PRELIMINARY DESIGN
IN-LINE BASIN

PINE NUT CREEK
BASIN FEASIBILITY
PARCEL 1221-05-001-054
DOUGLAS COUNTY, NEVADA

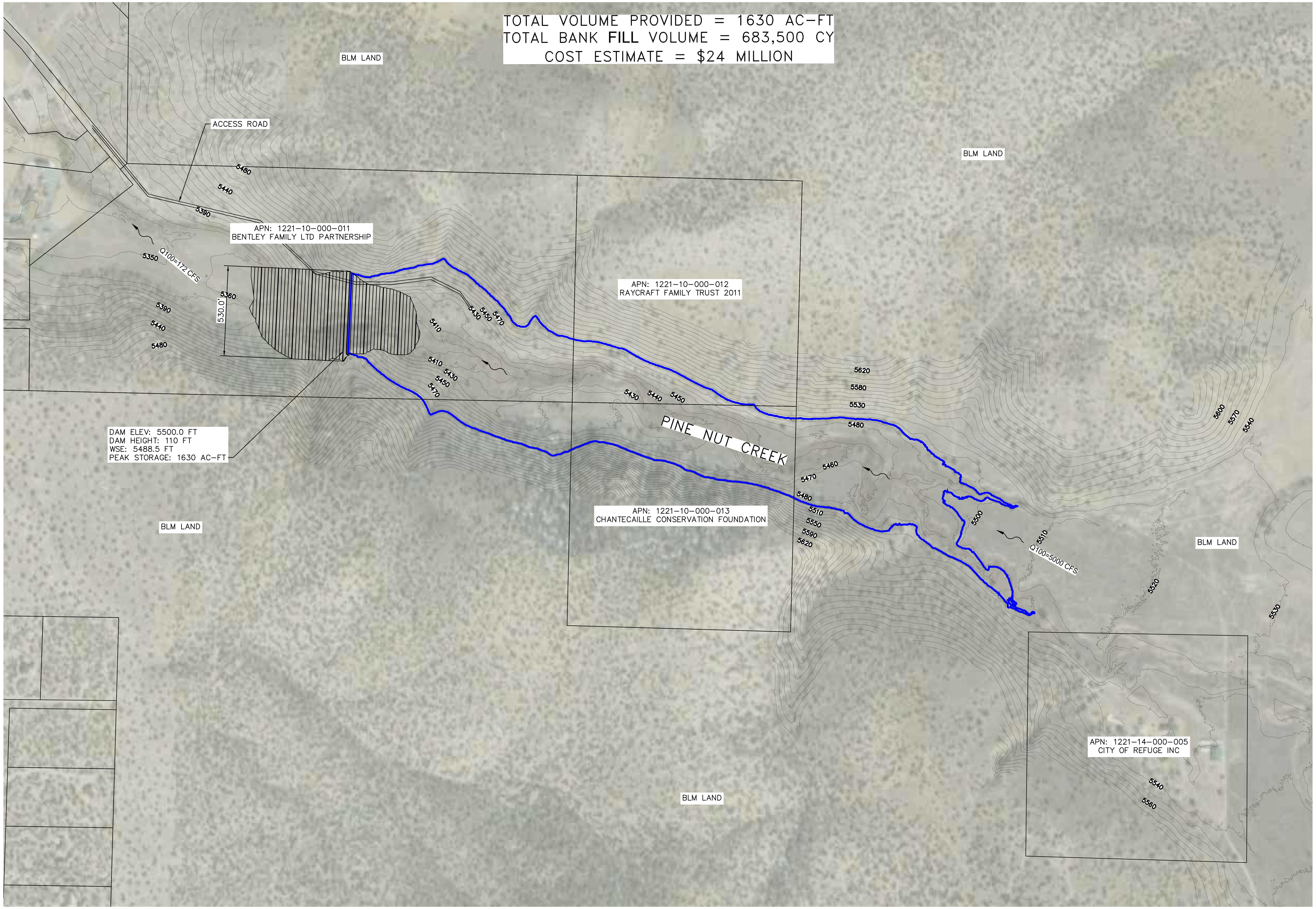
SHEET NUMBER
2

Kimley»Horn

Project:	***Pine Nut Creek Basin Feasibility***
Name	***Myers Basin***
Location	**Parcel 1221-05-001-054**
Level of Protection	**100-year**
Designed by:	**AA** Date: 7/6/2023
Checked by:	**ATC** Date: 7/6/2023

Item Description	Unit	Unit Price	Qty	Cost
Basin Earthwork	CY	$ 10	36,600	$ 366,000
Maintenance Roadway	SF	$ 1.10	7,200	$ 7,920
Riprap/Spillway	CY	$ 250	2,000	$ 500,000
Basin Landscaping	SF	$ 2	96,400	$ 192,800
Construction Subtotal				$ 1,067,000
Removals (5%)				$ 53,350
Miscellaneous Construction Costs (3%)[1]				$ 32,010
Contingency (15%)				$ 160,050
CONSTRUCTION TOTAL				**$ 1,312,410**
PLANNING/DESIGN TOTAL				**$ 200,000**
PRELIMINARY TOTAL PROJECT COST				**$ 1,513,000**

(1) Includes Mobilization, Traffic Control, Construction Staking, Quality Control, SWPPP, and Construction Management



0 400' 800'
SCALE: 1"=400'

LEGEND

- INUNDATION LIMITS
- PARCEL BOUNDARIES
- 10' CONTOURS

No. | REVISIONS | DATE

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KHA PROJECT 291838000
DATE 04/21/2023
SCALE: AS SHOWN
DESIGNED BY: AC
DRAWN BY: RJB
CHECKED BY: AC

DAM LOCATION
PRELIMINARY DESIGN
IN-LINE BASIN

PINE NUT CREEK
BASIN FEASIBILITY
DAM CONCEPT
DOUGLAS COUNTY, NEVADA

SHEET NUMBER
3

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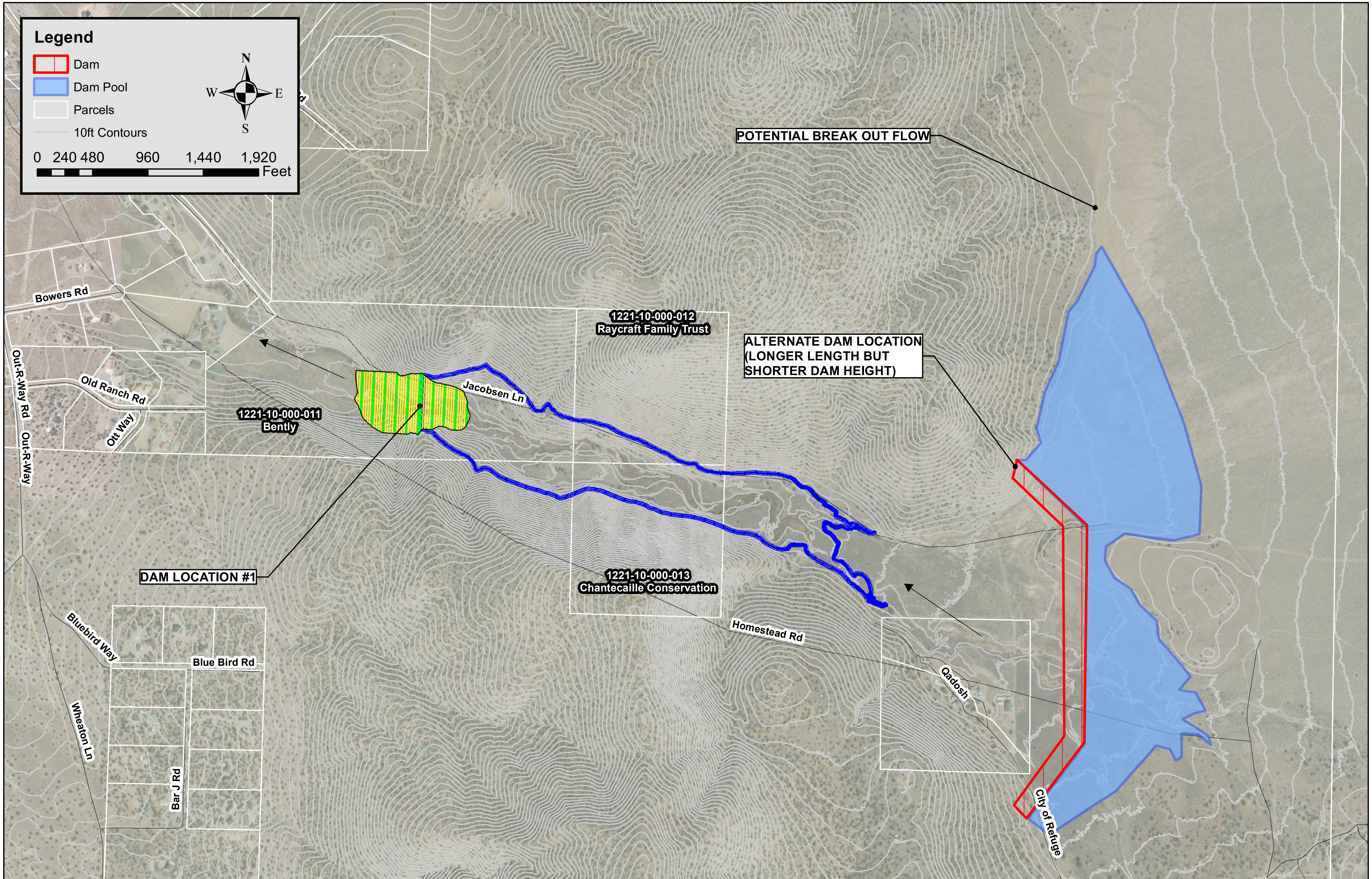

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SCALE(V):
DESIGNED BY: ATC
DRAWN BY: AA
CHECKED BY: ATC
DATE: 5/9/2023

Alternate Dam Location
Pine Nut Creek

PROJECT NO.
291838000
DRAWING NAME
ALT

Kimley»Horn

Project: ***Pine Nut Creek Basin Feasibility***
Location **Pine Nut Creek Dam**
Level of Protection **100-year**
Designed by: **AA** Date: 7/6/2023
Checked by: **ATC** Date: 7/6/2023

Item Description	Unit	Unit Price	Qty	Cost
Earthwork	CY	$ 18	683,500	$ 12,303,000
Spillway	LS	$ 1,500,000	1	$ 1,500,000
Outlet Structure/Pipe	LF	$ 650	1,000	$ 650,000
Maintenance Roadway	SF	$ 5.56	32,400	$ 180,000
Riprap/Energy Dissipation	LS	$ 900,000	1	$ 900,000
Construction Subtotal				$ 15,533,000
Removals (5%)				$ 776,650
Miscellaneous Construction Costs (3%)[1]				$ 465,990
Contingency (25%)				$ 3,883,250
CONSTRUCTION TOTAL				**$ 20,658,890**
LAND ACQUISITION (EASEMENT) TOTAL	AC	$ 5,500	80	**$ 440,000**
PLANNING/DESIGN TOTAL				**$ 3,000,000**
PRELIMINARY TOTAL PROJECT COST				**$ 24,099,000**

(1) Includes Mobilization, Traffic Control, Construction Staking, Quality Control, SWPPP, and Construction Management

BENTLY BASIN 1
VOLUME PROVIDED = 52.7 AC-FT
BANK CUT VOLUME = 209,000 CY
COST ESTIMATE = $5.4 MILLION

BENTLY BASIN 2
VOLUME PROVIDED = 70.8 AC-FT
BANK CUT VOLUME = 308,000 CY
COST ESTIMATE = $6.4 MILLION

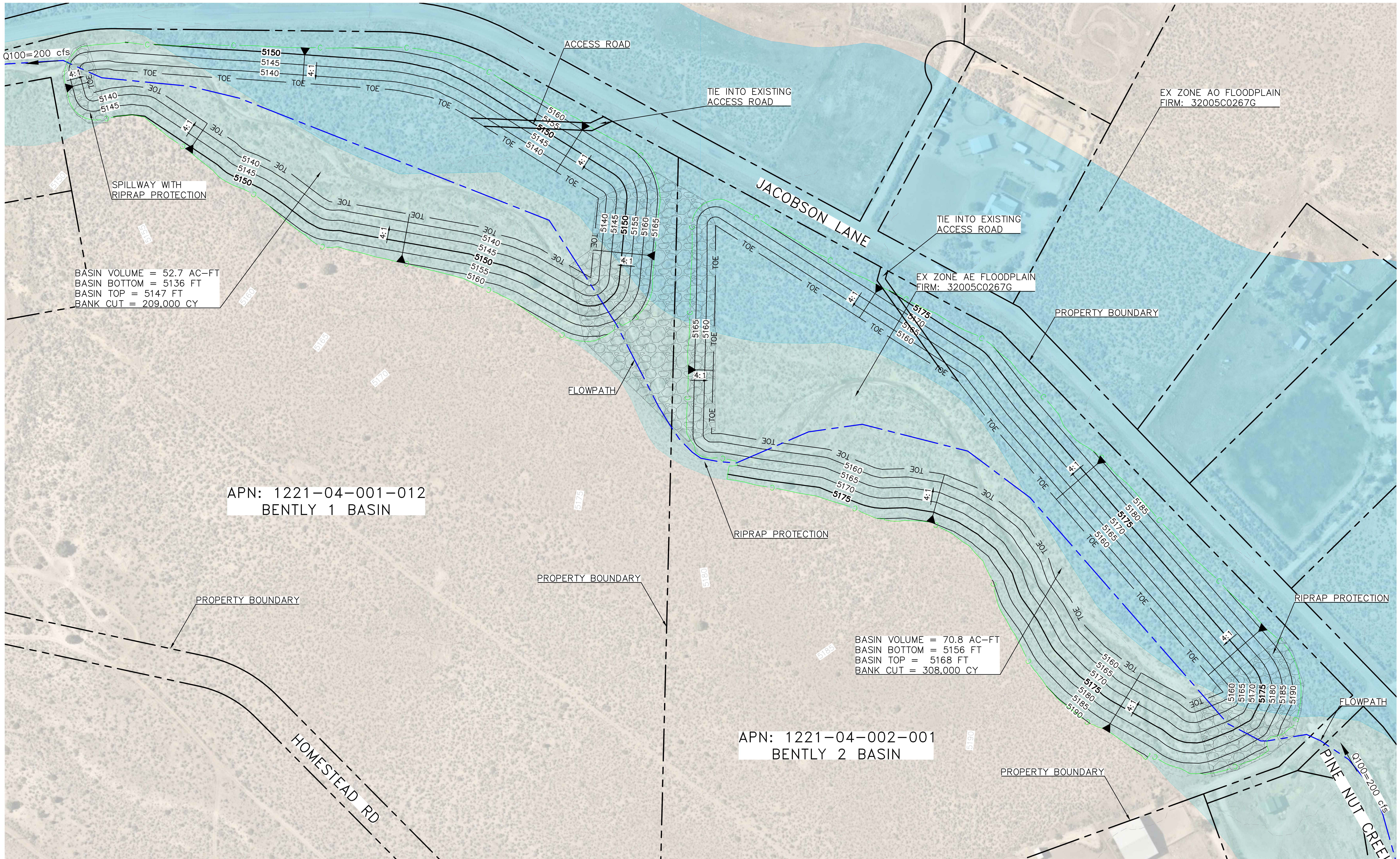
TOTAL VOLUME PROVIDED = 123.5 AC-FT
TOTAL BANK CUT VOLUME = 517,000 CY
COST ESTIMATE = $11.8 MILLION

0 100' 200'
SCALE: 1"=100'

LEGEND

EFFECTIVE FLOODPLAIN, ZONE AE

EFFECTIVE FLOODPLAIN, ZONE AO



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KHA PROJECT 291838000
DATE 04/21/2023
SCALE: 1"=100'
DESIGNED BY: AC
DRAWN BY: RJB
CHECKED BY: AC

BENTLY 1 & BENTLY 2 BASIN
PRELIMINARY DESIGN
IN-LINE BASIN

PINE NUT CREEK
BASIN FEASIBILITY
PARCELS 1221-04-001-012,
1221-04-002-001
DOUGLAS COUNTY, NEVADA

SHEET NUMBER
5

Kimley»Horn

Project:	***Pine Nut Creek Basin Feasibility***
Name	***Bently 1 Basin***
Location	**Parcel 1221-04-001-012**
Level of Protection	**100-year**
Designed by:	**AA** Date: 7/6/2023
Checked by:	**ATC** Date: 7/6/2023

Item Description	Unit	Unit Price	Qty	Cost
Basin Earthwork	CY	$ 10	209,000	$ 2,090,000
Maintenance Roadway	SF	$ 1.10	6,000	$ 6,600
Riprap/Spillway	CY	$ 250	4,350	$ 1,087,500
Basin Landscaping	SF	$ 2	380,000	$ 760,000
Construction Subtotal				$ 3,945,000
Removals (5%)				$ 197,250
Miscellaneous Construction Costs (3%)[1]				$ 118,350
Contingency (15%)				$ 591,750
CONSTRUCTION TOTAL				**$ 4,852,350**
LAND ACQUISITION TOTAL	AC	$ 22,000	9	$ 198,000
PLANNING/DESIGN TOTAL				**$ 350,000**
PRELIMINARY TOTAL PROJECT COST				**$ 5,401,000**

(1) Includes Mobilization, Traffic Control, Construction Staking, Quality Control, SWPPP, and Construction Management

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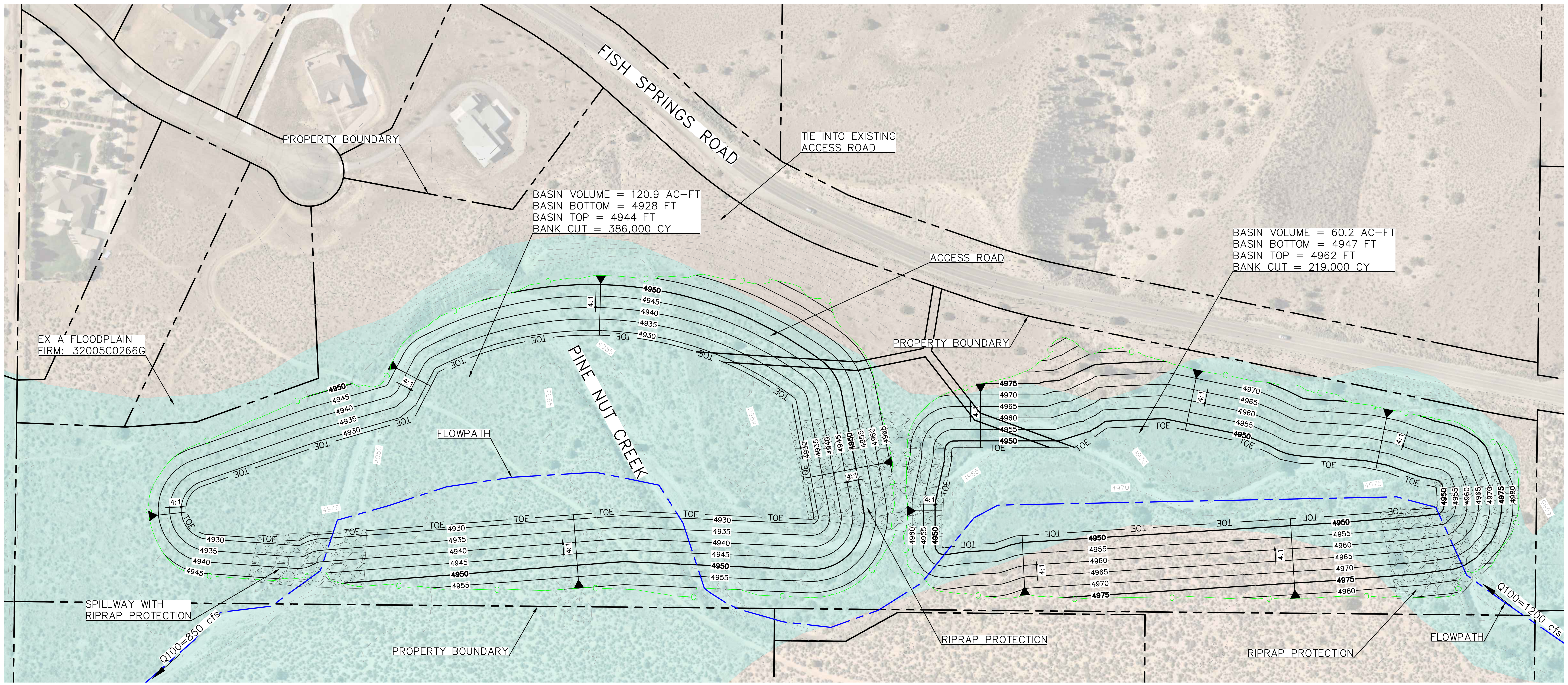
Project: ***Pine Nut Creek Basin Feasibility***
Name ***Bently 2 Basin***
Location **Parcel 1221-04-002-001**
Level of Protection **100-year**
Designed by: **AA** Date: 7/6/2023
Checked by: **ATC** Date: 7/6/2023

Item Description	Unit	Unit Price	Qty	Cost
Basin Earthwork	CY	$ 10	308,000	$ 3,080,000
Maintenance Roadway	SF	$ 1.10	3,180	$ 3,498
Riprap/Spillway	CY	$ 250	2,100	$ 525,000
Basin Landscaping	SF	$ 2	537,100	$ 1,074,200
Construction Subtotal				$ 4,683,000
Removals (5%)				$ 234,150
Miscellaneous Construction Costs (3%)[1]				$ 140,490
Contingency (15%)				$ 702,450
CONSTRUCTION TOTAL				**$ 5,760,090**
LAND ACQUISITION TOTAL	AC	$ 22,000	13	**$ 286,000**
PLANNING/DESIGN TOTAL				**$ 350,000**
PRELIMINARY TOTAL PROJECT COST				**$ 6,397,000**

(1) Includes Mobilization, Traffic Control, Construction Staking, Quality Control, SWPPP, and Construction Management

0 100' 200'
SCALE: 1"=100'

TOTAL VOLUME PROVIDED = 181.1 AC-FT
TOTAL BANK CUT VOLUME = 605,000 CY
COST ESTIMATE = $11.6 MILLION



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KHA PROJECT	291838000
DATE	04/21/2023
SCALE:	1"=100'
DESIGNED BY:	AC
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CHECKED BY:	AC

JANELLE BASIN
PRELIMINARY DESIGN
IN-LINE BASIN

PINE NUT CREEK
BASIN FEASIBILITY
PARCEL 1220-01-001-069
DOUGLAS COUNTY, NEVADA

SHEET NUMBER
6

Kimley»Horn

Project: ***Pine Nut Creek Basin Feasibility***
Name ***Janelle Basin***
Location **Parcel 1220-01-001-069**
Level of Protection **100-year**
Designed by: **AA** Date: 7/6/2023
Checked by: **ATC** Date: 7/6/2023

Item Description	Unit	Unit Price	Qty	Cost
Basin Earthwork	CY	$ 10	605,000	$ 6,050,000
Maintenance Roadway	SF	$ 1.10	9,660	$ 10,626
Riprap/Spillway	CY	$ 250	5,700	$ 1,425,000
Basin Landscaping	SF	$ 2	934,299	$ 1,401,449
Construction Subtotal				$ 8,888,000
Removals (5%)				$ 444,400
Miscellaneous Construction Costs (3%)[1]				$ 266,640
Contingency (15%)				$ 1,333,200
CONSTRUCTION TOTAL				**$ 10,932,240**
PLANNING/DESIGN TOTAL				**$ 700,000**
PRELIMINARY TOTAL PROJECT COST				**$ 11,633,000**

(1) Includes Mobilization, Traffic Control, Construction Staking, Quality Control, SWPPP, and Construction Management

SYPHUS BASIN
VOLUME PROVIDED = 335 AC-FT
BANK CUT VOLUME = 708,300 CY
COST ESTIMATE = $12.9 MILLION

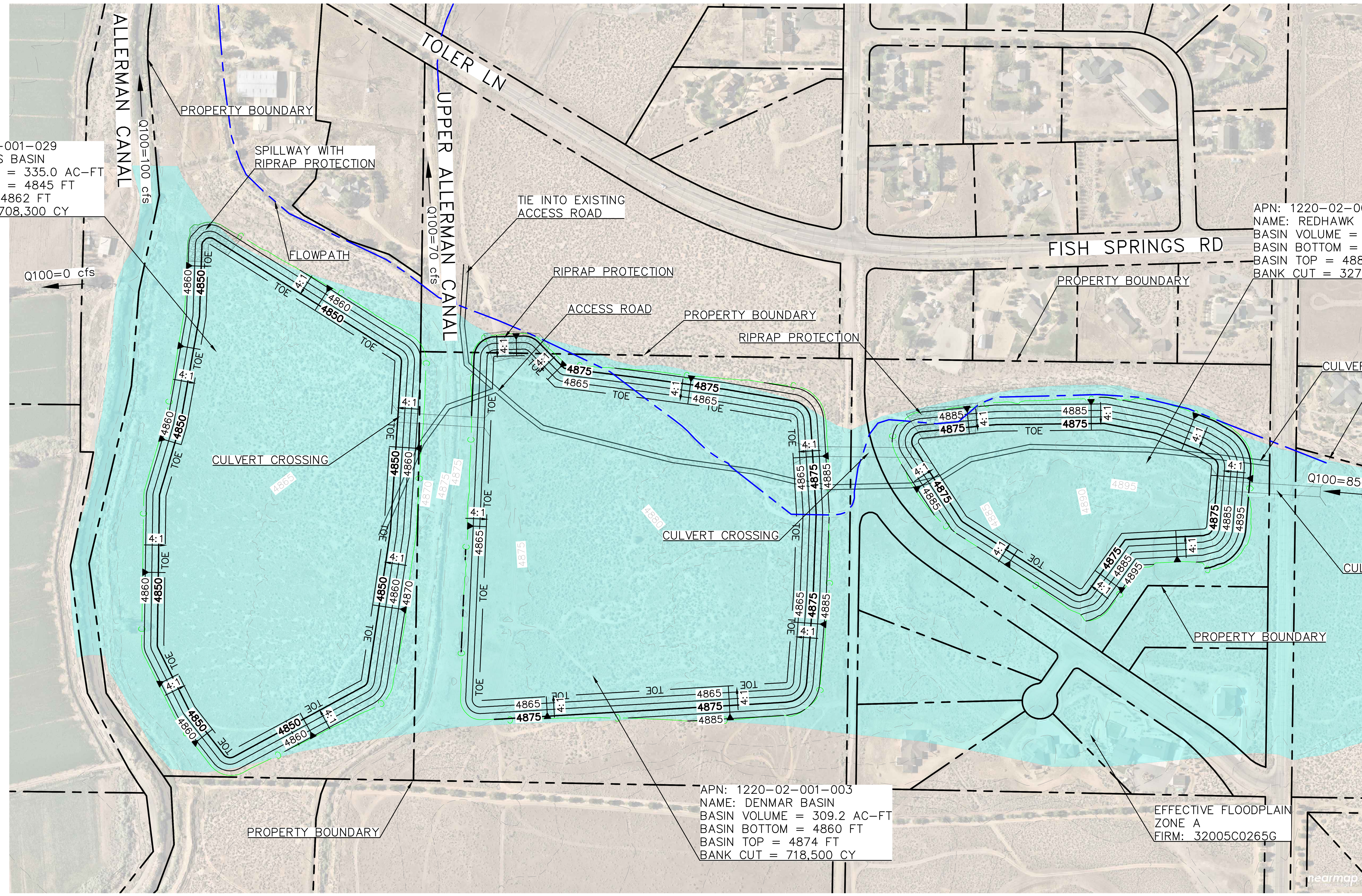
DENMAR BASIN
VOLUME PROVIDED = 309 AC-FT
BANK CUT VOLUME = 718,500 CY
COST ESTIMATE = $13.9 MILLION

REDHAWK BASIN
VOLUME PROVIDED = 118 AC-FT
BANK CUT VOLUME = 327,000 CY
COST ESTIMATE = $7.6 MILLION

TOTAL VOLUME PROVIDED = 762 AC-FT
TOTAL BANK CUT VOLUME = 1,753,800 CY
COST ESTIMATE = $34.4 MILLION

0 100' 200'
SCALE: 1"=100'

LEGEND
EFFECTIVE FLOODPLAIN, ZONE A



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No.	REVISIONS	DATE

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15% DESIGN

KHA PROJECT 291838000
DATE 04/21/2023
SCALE: 1"=100'
DESIGNED BY: AC
DRAWN BY: RJB
CHECKED BY: AC

SYPHUS, DENMAR, & REDHAWK BASIN
PRELIMINARY DESIGN
IN-LINE BASIN

PINE NUT CREEK
BASIN FEASIBILITY
PARCELS 1220-02-001-003,
1220-02-001-029 & 1220-02-001-031
DOUGLAS COUNTY, NEVADA

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SHEET NUMBER
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Project: ***Pine Nut Creek Basin Feasibility***
Name ***Syphus Basin***
Location **Parcel 1220-02-001-029**
Level of Protection **100-year**
Designed by: **AA** Date: 7/6/2023
Checked by: **ATC** Date: 7/6/2023

Item Description	Unit	Unit Price	Qty	Cost
Basin Earthwork	CY	$ 10	708,300	$ 7,083,000
Maintenance Roadway	SF	$ 1.10	5,400	$ 5,940
Culvert Crossing	EA	$ 700,000	1	$ 700,000
Riprap/Spillway	CY	$ 250	750	$ 187,500
Basin Landscaping	SF	$ 2	1,108,300	$ 1,662,450
Construction Subtotal				$ 9,639,000
Removals (5%)				$ 481,950
Miscellaneous Construction Costs (3%)[1]				$ 289,170
Contingency (15%)				$ 1,445,850
CONSTRUCTION TOTAL				**$ 11,855,970**
LAND ACQUISITION (EASEMENT/LEASE) TOTAL	AC	$ 5,500	36.0	$ 198,000
PLANNING/DESIGN TOTAL				**$ 800,000**
PRELIMINARY TOTAL PROJECT COST				**$ 12,854,000**

(1) Includes Mobilization, Traffic Control, Construction Staking, Quality Control, SWPPP, and Construction Management

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Project:	***Pine Nut Creek Basin Feasibility***
Name	***Denmar Basin***
Location	**Parcel 1220-02-001-003**
Level of Protection	**100-year**
Designed by:	**AA** Date: 7/6/2023
Checked by:	**ATC** Date: 7/6/2023

Item Description	Unit	Unit Price	Qty	Cost
Basin Earthwork	CY	$ 10	718,500	$ 7,185,000
Maintenance Roadway	SF	$ 1.10	21,312	$ 23,443
Culvert Crossing	EA	$ 700,000	1	$ 700,000
Riprap/Spillway	CY	$ 250	900	$ 225,000
Basin Landscaping	SF	$ 2	1,180,200	$ 1,770,300
Construction Subtotal				$ 9,904,000
Removals (5%)				$ 495,200
Miscellaneous Construction Costs (3%)[1]				$ 297,120
Contingency (15%)				$ 1,485,600
CONSTRUCTION TOTAL				**$ 12,181,920**
LAND ACQUISITION TOTAL	AC	$ 22,000	40.0	$ 880,000
PLANNING/DESIGN TOTAL				**$ 800,000**
PRELIMINARY TOTAL PROJECT COST				**$ 13,862,000**

(1) Includes Mobilization, Traffic Control, Construction Staking, Quality Control, SWPPP, and Construction Management

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Project: ***Pine Nut Creek Basin Feasibility***
Name ***Redhawk Basin***
Location **Parcel 1220-02-001-031**
Level of Protection **100-year**
Designed by: **AA** Date: 7/6/2023
Checked by: **ATC** Date: 7/6/2023

Item Description	Unit	Unit Price	Qty	Cost
Basin Earthwork	CY	$ 10	327,000	$ 3,270,000
Maintenance Roadway	SF	$ 1.10	15,024	$ 16,526
Culvert Crossing	EA	$ 700,000	1	$ 700,000
Riprap/Spillway	CY	$ 250	1,100	$ 275,000
Basin Landscaping	SF	$ 2	516,000	$ 1,032,000
Construction Subtotal				$ 5,294,000
Removals (5%)				$ 264,700
Miscellaneous Construction Costs (3%)[1]				$ 158,820
Contingency (15%)				$ 794,100
CONSTRUCTION TOTAL				**$ 6,511,620**
LAND ACQUISITION TOTAL	AC	$ 22,000	18.8	$ 410,000
PLANNING/DESIGN TOTAL				**$ 700,000**
PRELIMINARY TOTAL PROJECT COST				**$ 7,622,000**

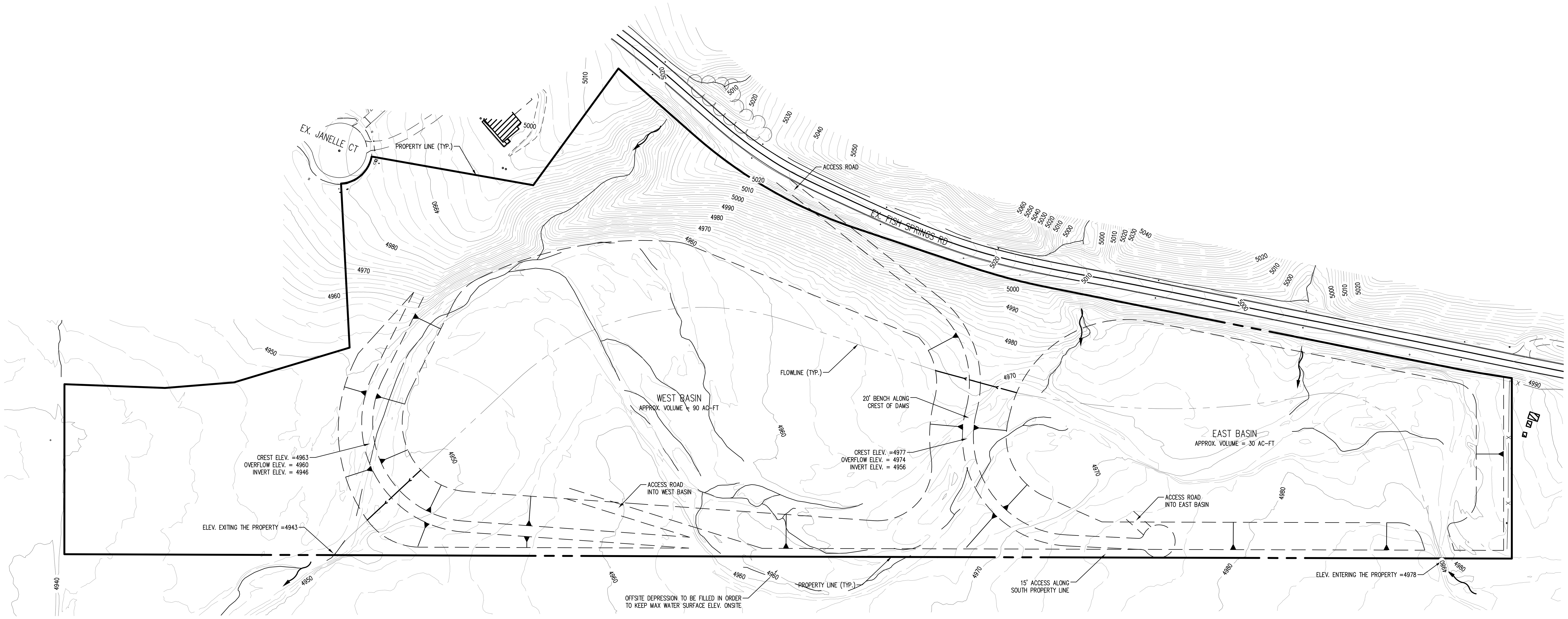
(1) Includes Mobilization, Traffic Control, Construction Staking, Quality Control, SWPPP, and Construction Management

Appendix D: Janelle Court Parcel Dam Concept

GRAPHIC SCALE

100 0 50 100 200 400

(IN FEET)
1 inch = 100 ft.



N

DATE	REVISIONS	DRAWN BY	CHECK BY

Manhard CONSULTING LTD

241 Ridge Street, Suite 400, Reno, NV 89501 ph:775-746-3500 fx:775.746.3520 manhard.com
Civil Engineers • Surveyors • Water Resource Engineers • Water & Wastewater Engineers
Construction Managers • Environmental Scientists • Landscape Architects • Planners

JANELLE CT DETENTION BASIN

DOUGLAS COUNTY, NEVADA

CONCEPTUAL DETENTION BASIN DESIGN

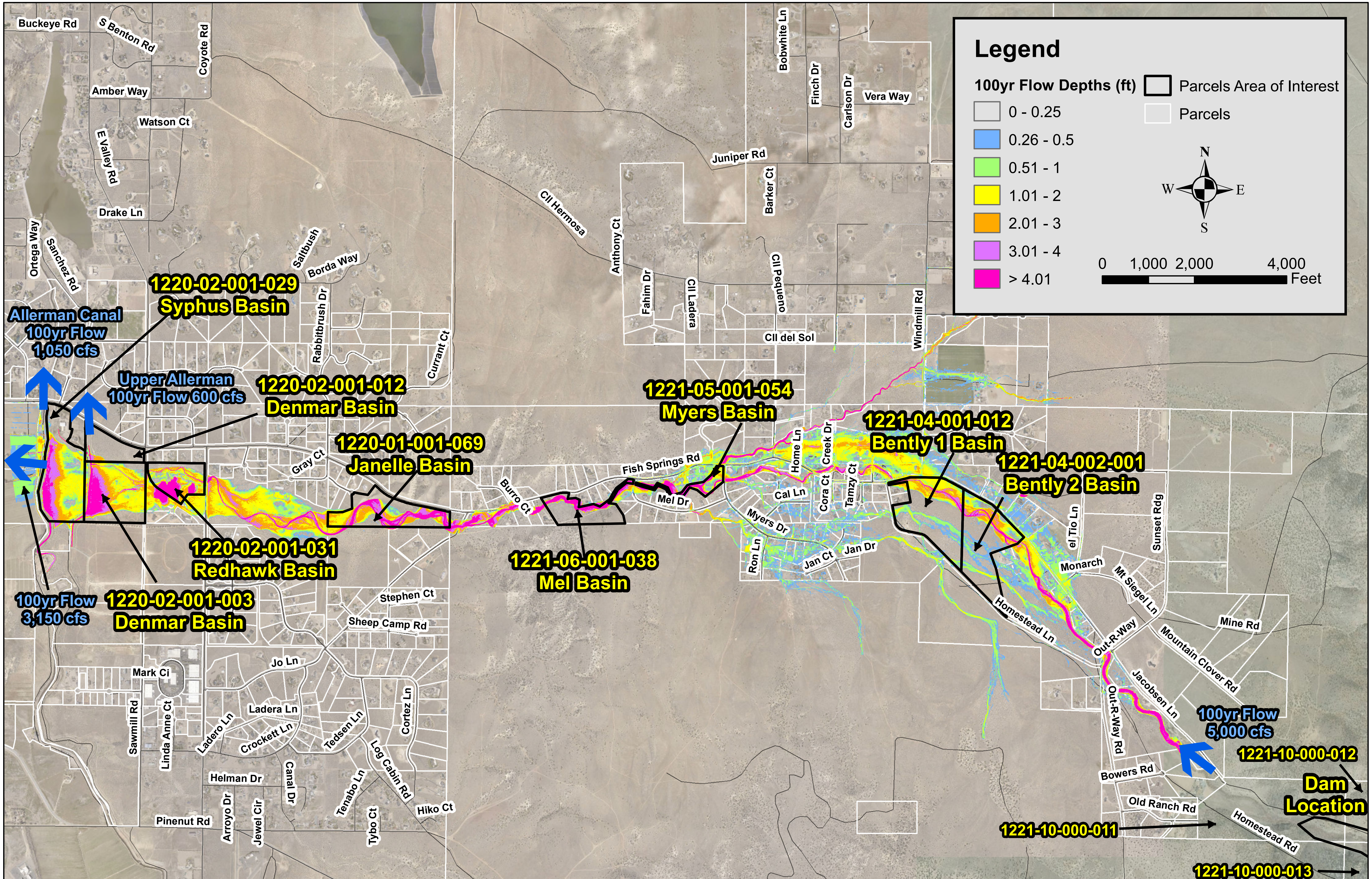
PROJ. MGR.:	DCB
PROJ. ASSOC.:	SDF
DRAWN BY:	SDF
DATE:	NOV 2022
SCALE:	AS SHOWN

SHEET 1 OF 1

LUC.DCNV01

EXHIBIT

Appendix E: Hydraulics



NO.	REVISION	BY	DATE	APPR.

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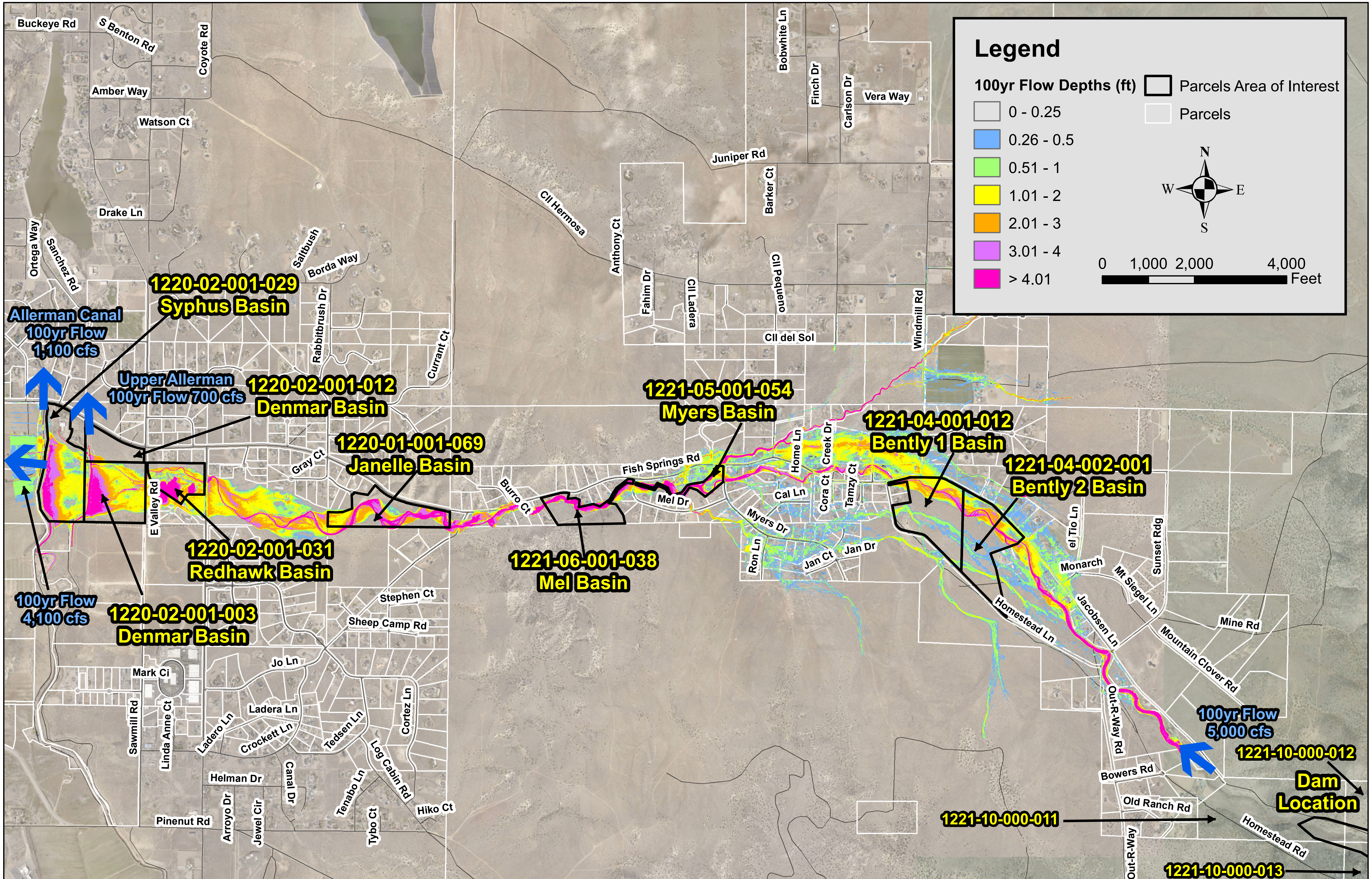
Engineering, Planning and Environmental Consultants
7740 North 16th Street, Suite 300
Phoenix, Arizona 85020 (602) 944-5500

SCALE(H):1"= 2000FT
SCALE(V): N/A
DESIGNED BY: ATC
DRAWN BY: ATC
CHECKED BY: GSB
DATE: APRIL 2023

Scenario 1 - LOMR Hydrology
Existing Conditions
Pine Nut Creek100-year Flow Depths

PROJECT NO.
291838000
DRAWING NAME
100YR



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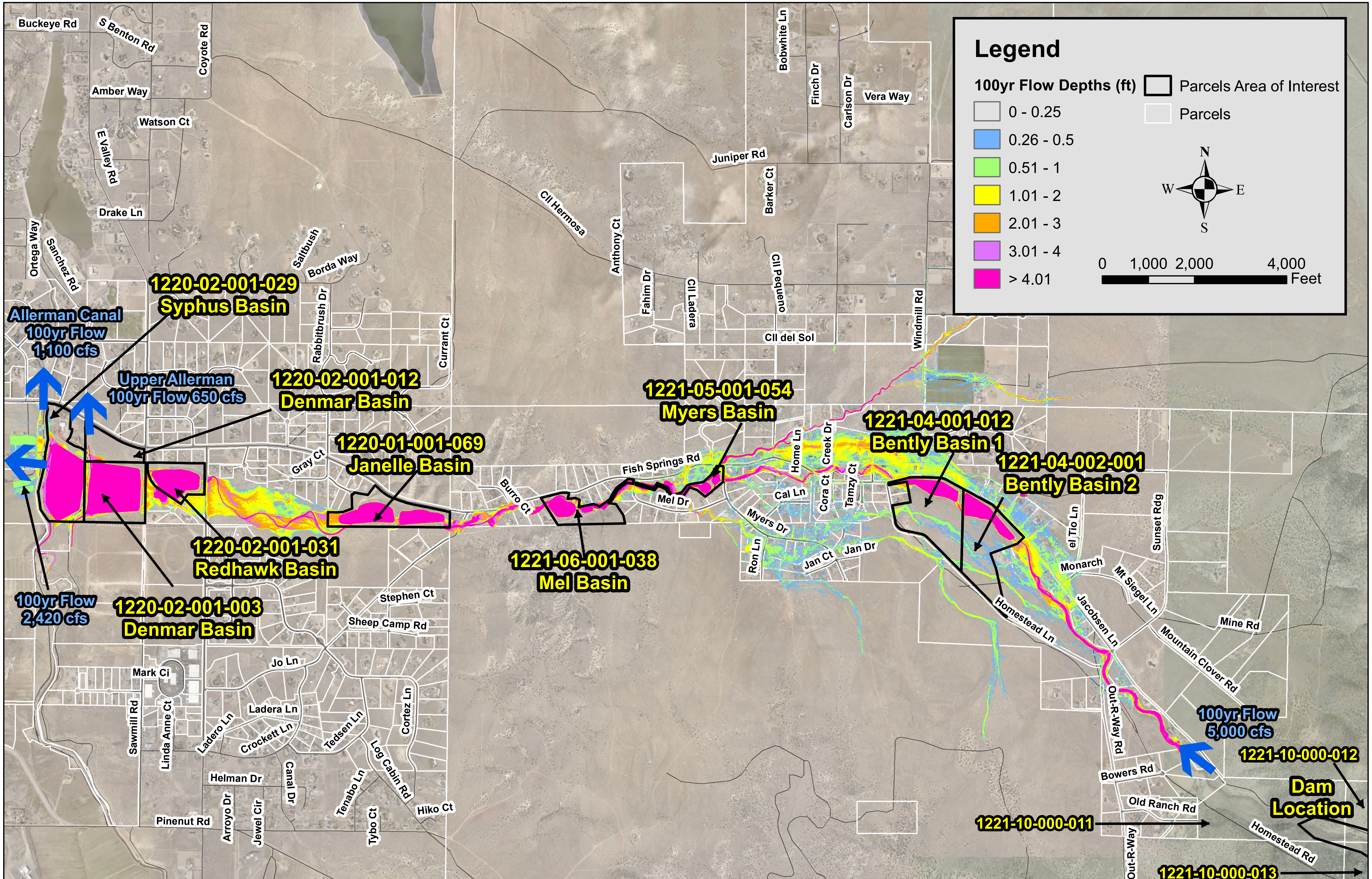
DRAWN BY: ATC
CHECKED BY: GSB
DATE: APRIL 2023

Scenario 2 - Modified Hydrology Approach
Existing Conditions
Pine Nut Creek100-year Flow Depths

PROJECT NO.
291838000
DRAWING NAME
100YR



Scenario 3 - LOMR Hydrology
Proposed Basins Without Dam
Pine Nut Creek100-year Flow Depths

SCALE(H):1"= 2000FT
SCALE(V): N/A
DESIGNED BY: ATC
DRAWN BY: ATC
CHECKED BY: GSB
DATE: APRIL 2023

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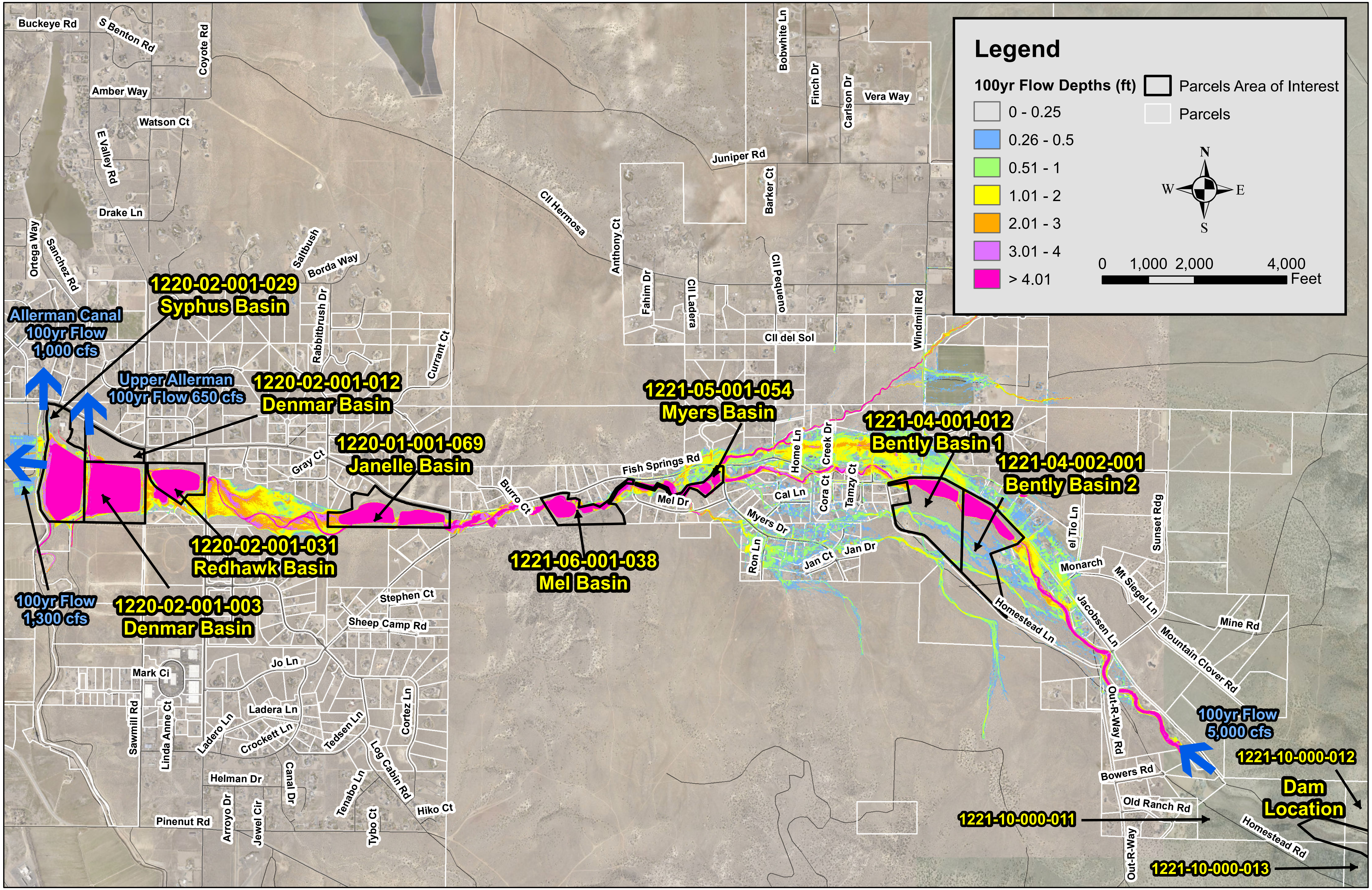
NO.	REVISION	BY	DATE	APPR.

PROJECT NO.
291838000
DRAWING NAME
100YR



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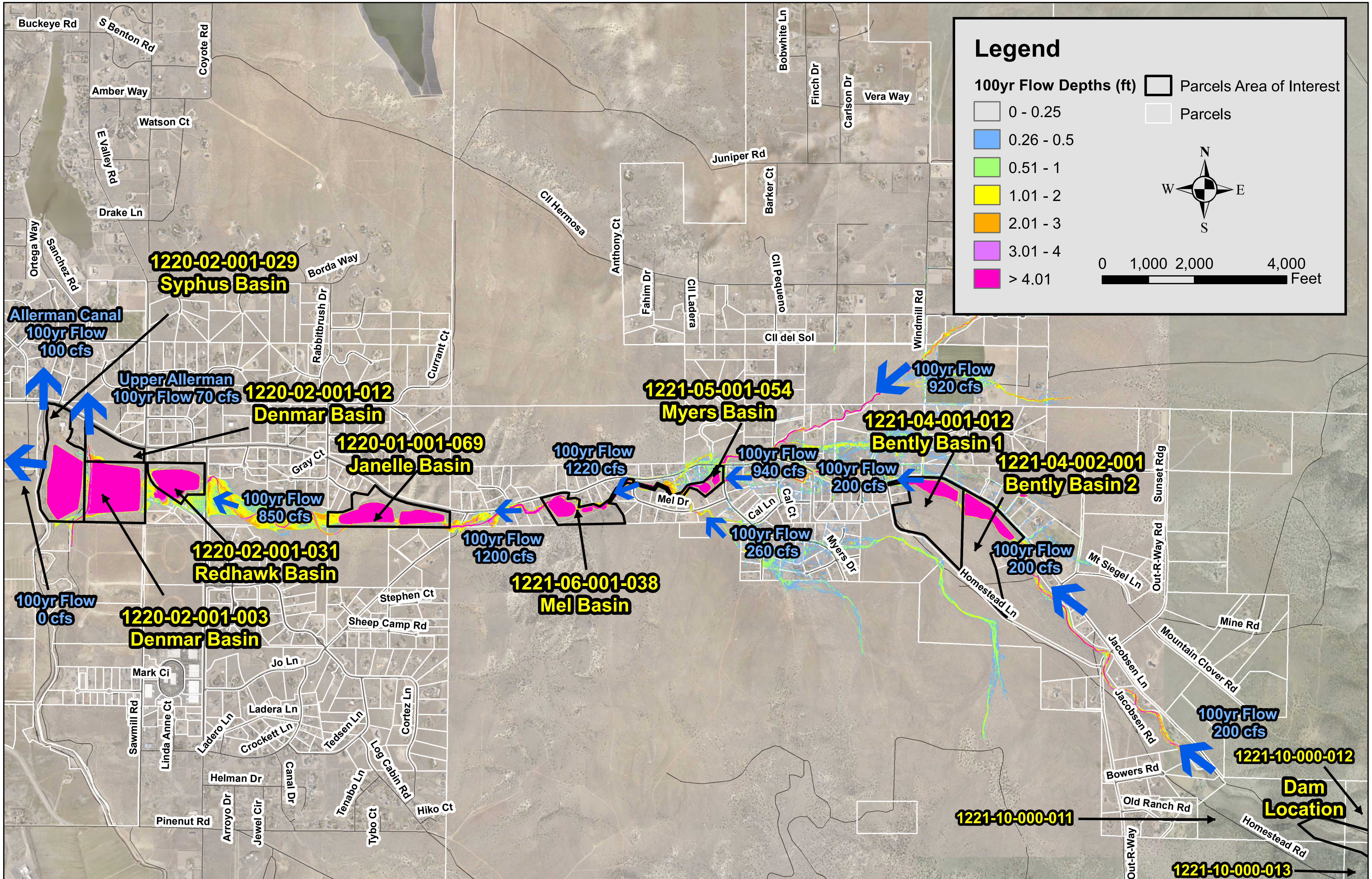
SCALE(V): N/A
DESIGNED BY: ATC
DRAWN BY: ATC
CHECKED BY: GSB
DATE: APRIL 2023

Scenario 4 - Modified Hydrograph Approach
Proposed Basins Without Dam
Pine Nut Creek100-year Flow Depths

PROJECT NO.
291838000
DRAWING NAME
100YR



Scenario 5 - Modified Hydrograph Approach
Proposed Basins with Dam Release
Pine Nut Creek100-year Flow Depths

SCALE(H):1"= 2000FT
SCALE(V): N/A
DESIGNED BY: ATC
DRAWN BY: ATC
CHECKED BY: GSB
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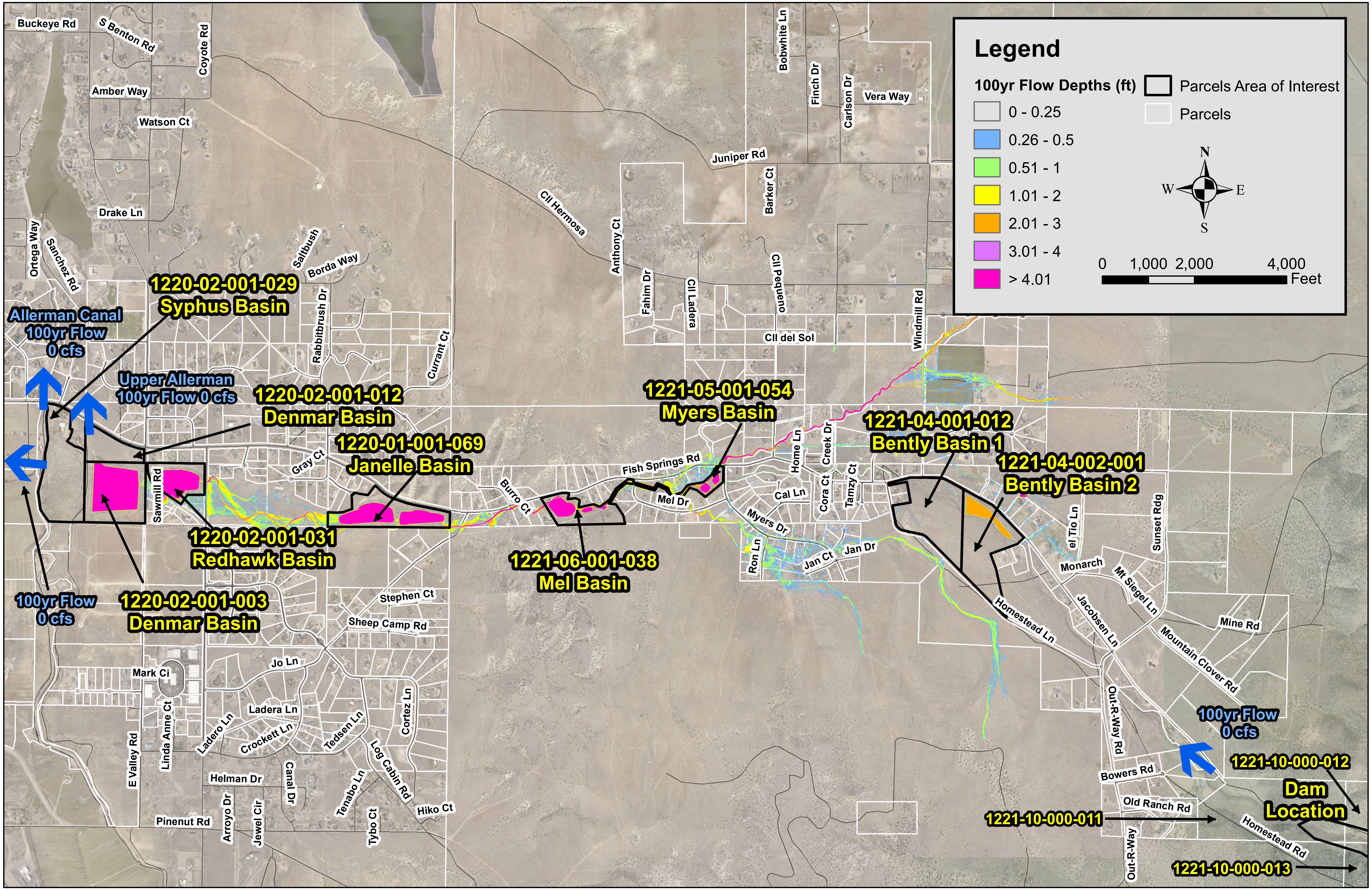
NO. | REVISION | BY | DATE | APPR.

PROJECT NO.
291838000
DRAWING NAME
100YR



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SCALE(V): N/A
DESIGNED BY: ATC
DRAWN BY: ATC
CHECKED BY: GSB
DATE: APRIL 2023

Scenario 6 - Modified Hydrograph Approach
Proposed Basins With Dam (No Release)
Pine Nut Creek100-year Flow Depths

PROJECT NO.
291838000

DRAWING NAME
100YR

NO.	REVISION	BY	DATE	APPR.

Appendix F: Previous Studies

HDR LOMR EXCERPTS

Letter of Map Revision Request for Pine Nut Creek and Tributaries, NV

PROFESSIONAL ENGINEER STATE OF NEVADA
MITCHELL L. BLUM
Exp: 12/31/20
CIVIL
No. 20804
10/06/2020

Douglas County, NV

October, 2020

Prepared for
Carson Water Subconservancy District

HDR Project Number: 10148141

Table of Contents

Figures

Tables

Appendices

Acronyms

BFE	Base Flood Elevation
cfs	cubic feet per second
DTM	digital terrain model
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
HEC-RAS	Hydrologic Engineering Center River Analysis System
LiDAR	Light Detection and Ranging
LOMR	Letter of Map Revision
NAD	North American Datum
NAVD	North American Vertical Datum
NHFL	National Flood Hazard Layer
RMSE	Root Mean Square Error
TIN	Triangulated Irregular Network representation of the terrain surface
USACE	United States Corps of Engineers

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Project Overview

Project Location

Pine Nut Creek is a 55.5 square mile high desert drainage originating in the Pine Nut Mountain Range on the east side of the Carson Valley in Douglas County, NV. The current Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRM) include the main stem Pine Nut Creek and 5 tributaries to be remapped (Figure 1). Watercourses included in this study include:

- Pine Nut Creek
- Pine Nut Creek Tributary
- Sheena Terrace Wash
- Fish Springs Creek
- Cody Wash
- Cody Wash Tributary

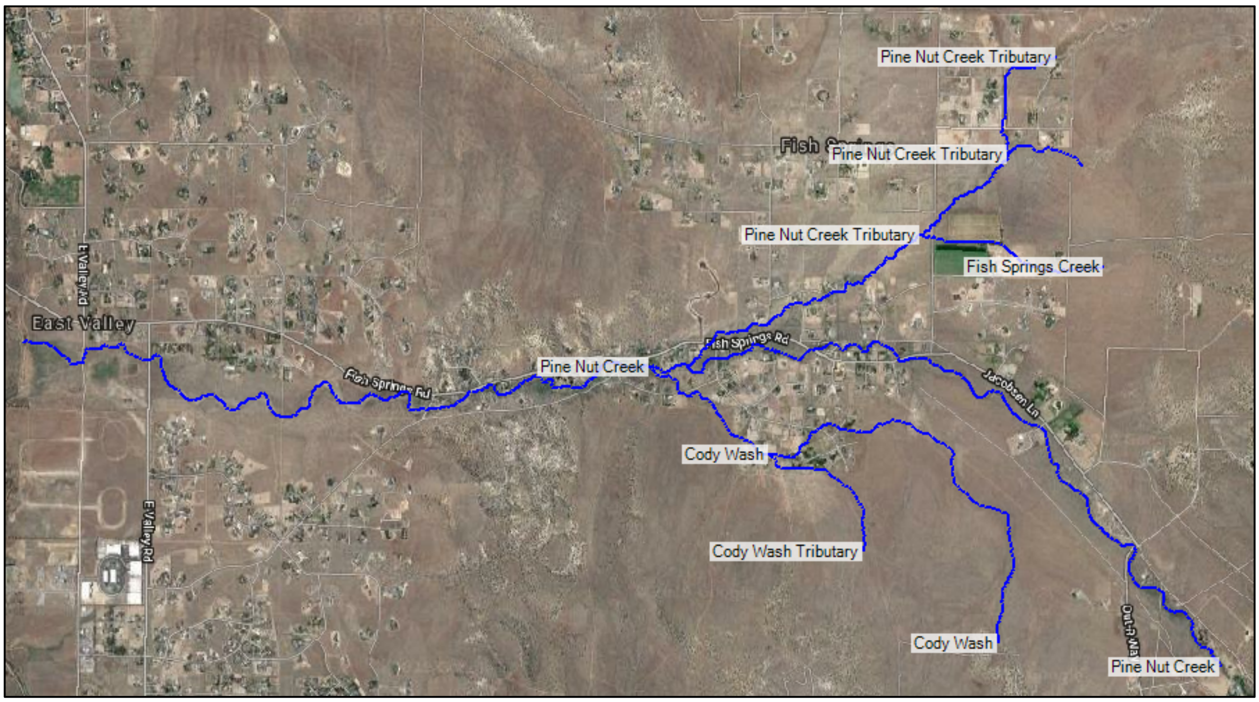


Figure 1: Study Reaches

The project area is shown on FEMA Flood Insurance Rate Panel Numbers 32005C0254H, 32005C0258H, 32005C0259H, 32005C0265G, 32005C0266G, 32005C0267G, and 32005C0286G. The project is located within Douglas County, NV; FEMA Community Number 320008 (Figure 2).

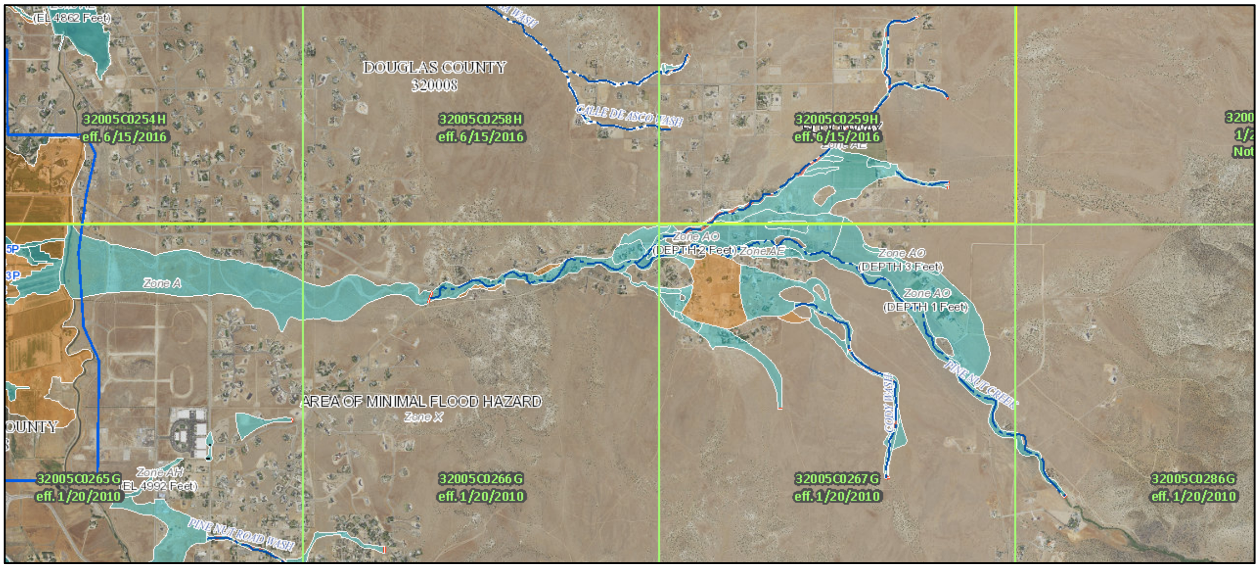


Figure 2: Effective FEMA Flood Hazard Areas

Study Purpose

The purpose of the Letter of Map Revision (LOMR) is to revise the current approximate and detailed 1-percent-annual-chance floodplain/floodway boundaries and the 0.2-percent-annual chance floodplain with new detailed boundaries and base flood elevations. The basis of this revision will be a map change based on flood hazard information meant to improve upon that shown on the flood map or within the flood study. This study uses better topographic data and improved modeling techniques to improve upon the current approximate information. This study has been initiated by the Carson Water Subconservancy District (CWSD), in conjunction with Douglas County, NV. These agencies wish to develop updated floodplain mapping that is based upon the most current available data, and that will allow the floodplain administrator to better assess potential flood risks to any existing or proposed development in the area. CWSD operates as a Cooperating Technical Partner (CTP) with FEMA, and has received a grant from FEMA under the CTP program that is intended to fund an update of the effective floodplain mapping in this area. In accordance with Section 72.5 of the NFIP regulations this study should be exempt from fees based on “map changes based on flood hazard information meant to improve upon that shown on the flood map or within the flood study”.

HDR Engineering, Inc. (HDR) contracted with CWSD to collect survey and LiDAR topographic data, develop hydrologic and hydraulic modeling for the study area, produce updated floodplain mapping and reporting for the region, and coordinate the necessary public notification of all land owners affected by the proposed map revisions.

Previous Flooding

Numerous flood events have taken place within the Pine Nut mountain range, on neighboring streams, and along Pine Nut Creek itself. One such large event took place on August 6, 2014. The National Weather Service (NWS) issued a flash flood warning for Douglas County on the evening of August 6, 2014. The NWS stated that a thunderstorm in the area was producing torrential rainfall of 1-inch or more in 45 minutes. Figure 3 provides a sample radar image of the event taken from the Reno Gazette-Journal website.

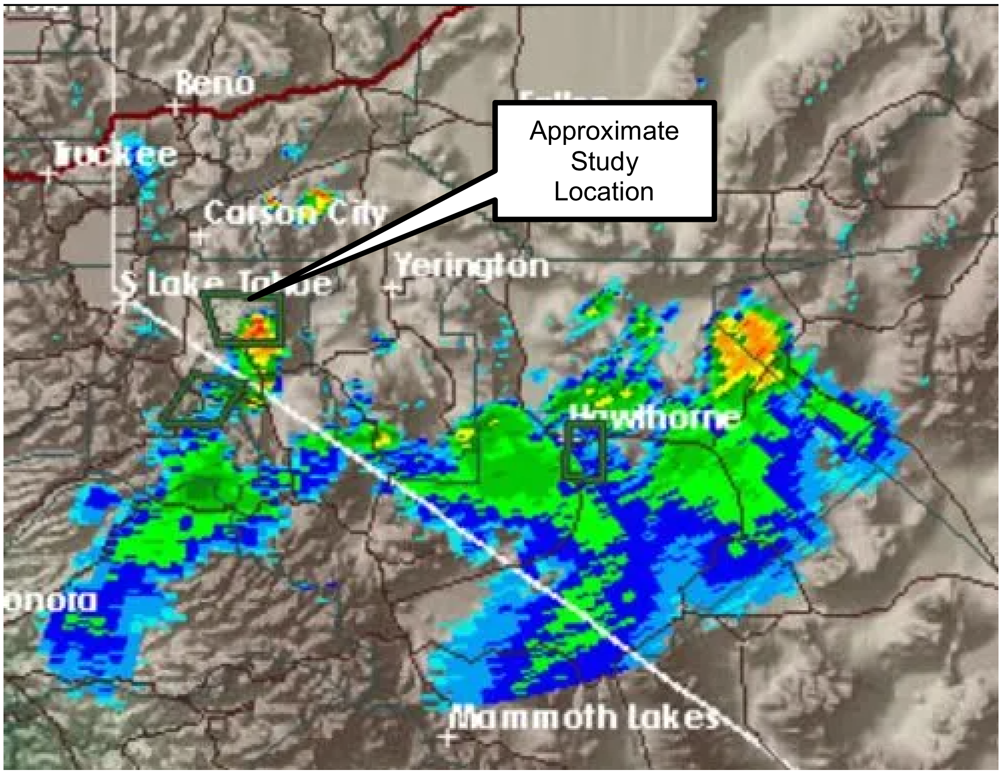


Figure 3: Doppler Radar Image of 8/6/2014 Thunderstorm That Produced Flash Flooding on Pine Nut Creek

At least 9 residences experienced flooding within the residential structure, and numerous yards, structures, and outbuildings were damaged by the flooding. This event demonstrates the intense precipitation that can occur within the study area, and the rapid runoff response that follows as the excess precipitation makes its way down the watershed. Several newspaper articles about this event were published immediately following the flooding, these include:

- https://www.nevadaappeal.com/news/amazing-flash-flood-hits-douglas/
- https://www.rgj.com/story/news/2014/08/06/flash-flood-warning-for-part-of-douglas-county/13707235/
- https://carsonvalleytimes.wordpress.com/2014/08/07/storm-sparks-fires-flooding-reported-in-pine-nut-creek/

Figure 4 displays one article about the flash flooding with a photo of a flooded home, along with a plan view of the HEC-RAS model 1% annual-chance event inundation extents at this location. The model results indicate significant flooding is likely to occur at this site during the event simulated.

Figure 4: Home Flooded During 8/6/2014 Flash Flood, Compared to HEC-RAS Model Results

Previous Studies

The study reaches were previously analyzed in the FEMA Flood Insurance Study (FIS) and designated as Zones A, AE, AO, and X. These inundation boundaries were developed using a combination of detailed and approximate methods. Cody Wash and Pine Nut Tributary both have existing floodways, while no floodway boundaries have been established for the other streams being updated in this study. The lower reach of Pine Nut Creek is currently mapped as Zone A, while the upper section of this channel and its tributaries have been mapped using detailed methods. This discrepancy, along with increasing development within the region, has led the local community to develop detailed flood mapping for the entire reach of Pine Nut Creek, as well as its tributaries.

Pine Nut Creek and its associated tributaries were initially studied in 1976/1977 by the Soil Conservation Service (SCS), under contract to FEMA. This analysis used WSP-2 and TR-20. In 1988, Pine Nut Creek and its tributaries were re-studied by the US Army Corps of Engineers

(USACE) Sacramento district for FEMA under Interagency Agreement No.EMW-86-E-2226, Project Order No. 19. This study established the currently effective hydrology and floodplain mapping. The hydrologic analysis was performed using HEC-1. The hydrologic modeling used a unit hydrograph transform method based on the “average mountain cloudburst” individual S-curves developed for the nearby Truckee River basin. This analysis assumed a 3-hour cloudburst storm event, with rainfall distribution patterned after Standard Project Storm criteria. Precipitation amounts and areal reduction factors were based upon NOAA Atlas 2 data. Loss rates used the standard and initial loss method, based on data previously adopted for a 1976 USACE review of a USGS study for a nearby region, as well as upon an analysis of soil cover. The hydraulic analysis that was used to develop the effective Zone AE and floodway boundaries was performed using HEC-2, using relatively coarse 5-foot topographic data as the basis of elevation information. The basis of the effective Zone AO mapping is unknown, as no supporting calculations for this mapping were received from FEMA following a data request for effective modeling and mapping information. At the time of the 1988 analysis, only limited stream gage data was available, so no meaningful validation of the flow rates calculated would have been possible.

In 2010, an HEC-HMS model was constructed to estimate peak discharge on Pine Nut Creek at Allerman Canal, for use in re-mapping Pine Nut Creek downstream from this location, as well as Cottonwood and Martin Sloughs. The 1%-annual recurrence interval peak discharge from this study is 5,510 cfs, which has been adopted as the effective FEMA discharge for Pine Nut Creek below Allerman Canal. This study did not perform any re-mapping on Pine Nut Creek upstream of Allerman Canal or any of its tributaries. This discharge value at Allerman Canal is based on an HEC-HMS model of the Pine Nut Creek watershed, utilizing the Green & Ampt infiltration estimation method, and the Snyder unit hydrograph transformation method. The study used NOAA Atlas 14 precipitation data, and simulated a 24-hour storm event.

The effective modeling and mapping products received from FEMA are attached in electronic format as an appendix to this report.

The existing effective 1%-annual-chance flows for the study reaches are as follows:

Table 1: Current effective 1%-annual-chance peak discharges.

Flooding Source	1% Annual Chance Peak Discharge (cfs)
Cody Wash	230
Cody Wash Tributary	190
Fish Springs Creek	595
Pine Nut Creek	5,510
Pine Nut Creek Tributary	685
Sheena Terrace Wash	265

Topographic Data Development

3DEP 1/3 Arc Second Data

Hydrologic modeling was conducted using 1/3 Arc Second (10-meter) resolution 3D Elevation Program (3DEP) topographic data published in 2018 by the US Geological Survey. The data was obtained from The National Map website and was collected in an ESRI arc grid format (USGS_NED_13_n39w120_ArcGrid.zip) in a NAD83 GRS80 horizontal projection and a NAVD88 metric vertical datum. These data were projected to NAD83 State Plane Nevada West FIPS 2703 (Feet) with a vertical datum of NAVD88 feet (Geoid12B) for modeling. The dataset was then clipped in ESRI's ArcMap software package to the extents of the project watersheds (Figure 5). The data and metadata is available through the USGS here: https://viewer.nationalmap.gov/basic/

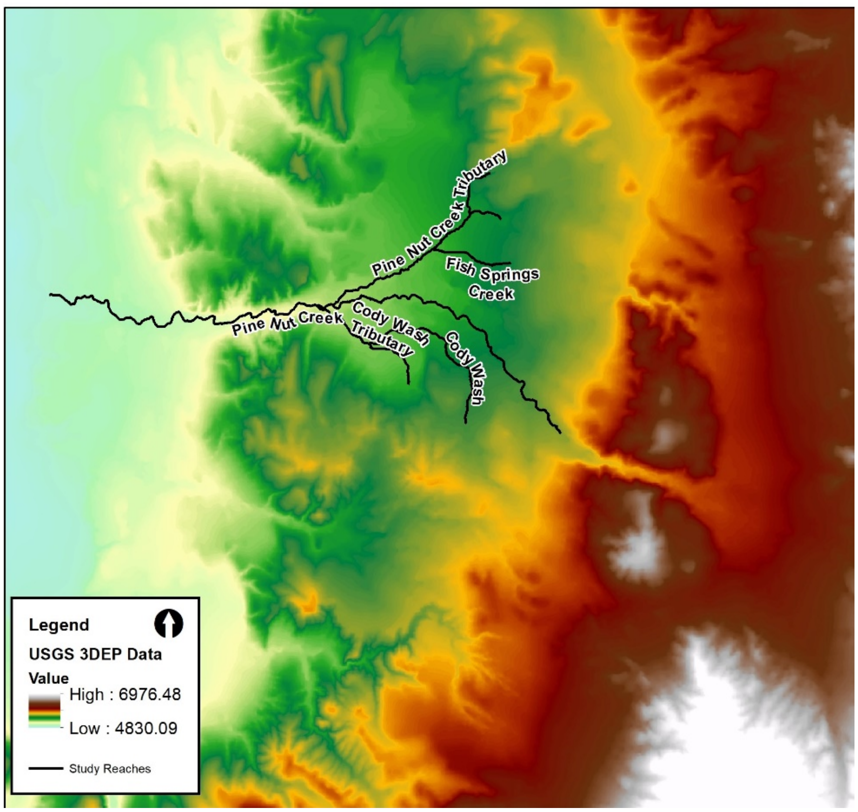


Figure 5: USGS 3DEP data used for hydrologic modeling.

LiDAR Data

Hydraulic modeling for this study was conducted using Light Detection and Ranging (LiDAR) data collected on February 27, 2019 specifically for this study. Quantum Spatial Inc. was contracted by HDR to collect aerial based LiDAR data and process that data into a series of classified LAS files to be used as the foundation of the modeling digital terrain model (DTM). Fifty Seven (57) las tiles were delivered as classified "ground" points in NAD83 State Plane Nevada West FIPS 2703 (Feet) with a vertical datum of NAVD88 feet (Geoid12B) (Figure 6).

Data accuracy standards were QL1 or better. Appendix A contains the LiDAR Technical Data Report and PLS Accuracy Letter.

LP360 software was used to convert the LiDAR LAS point files for the study area into a floating point grid file (*flt) at a 1-foot resolution. This float file was then ingested into HEC-RAS and a DTM was created for hydraulic modeling (Figure 7).

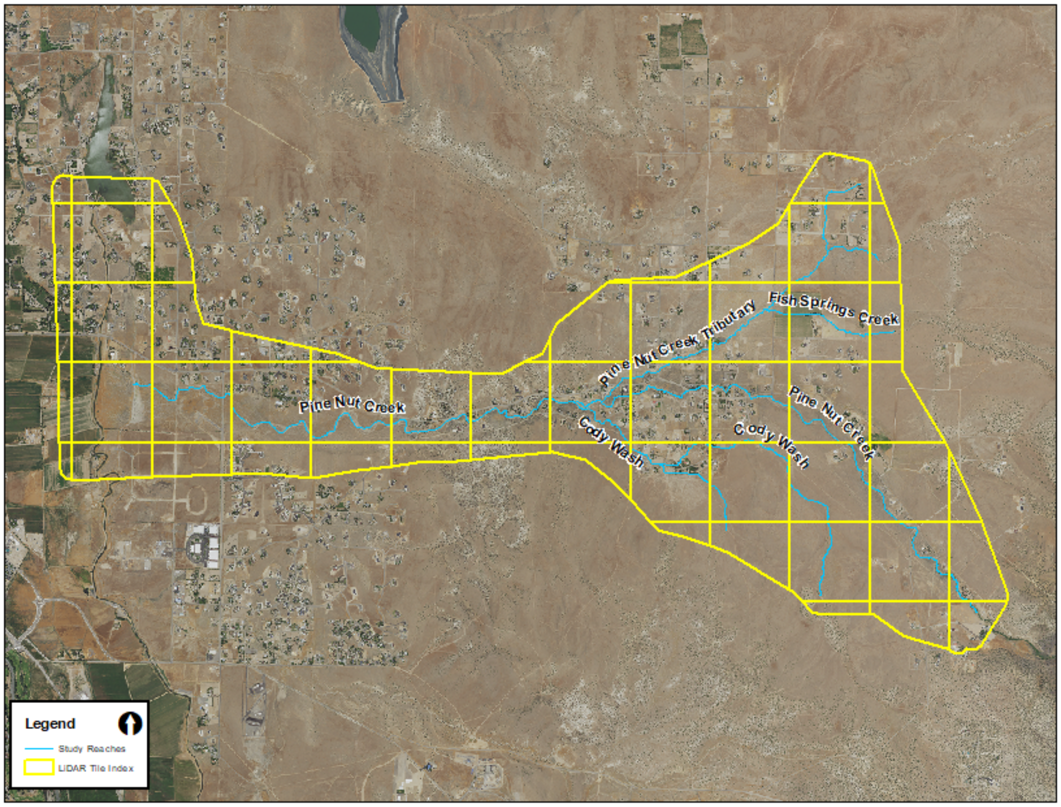


Figure 6: LiDAR Data Extents

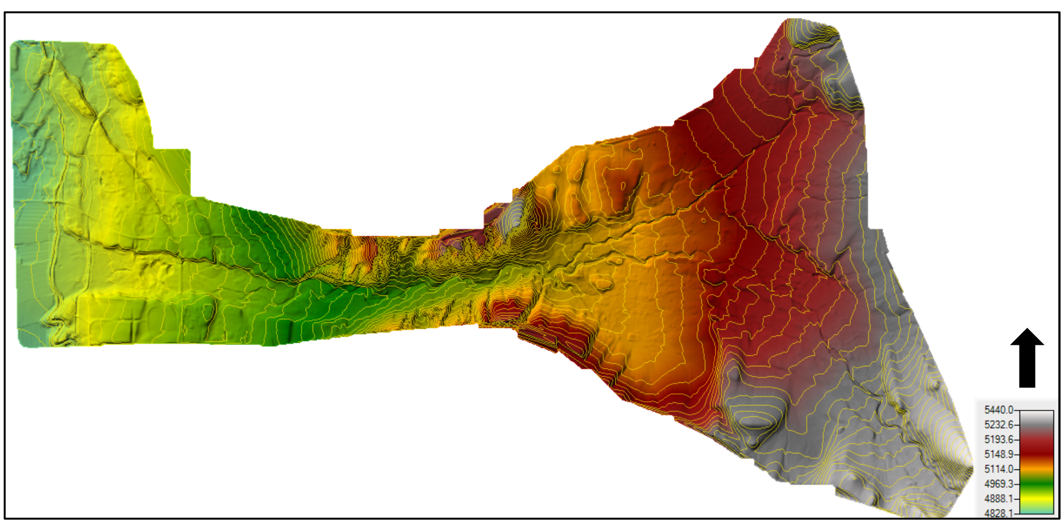


Figure 7: HEC-RAS DTM

The LiDAR data allows for the development of much higher resolution contour data than was used for the currently effective mapping. Figure 8 and Figure 9 provide a comparison of the effective mapping 5-foot contour interval topographic data and the updated 2-foot contour interval topographic data based upon the LiDAR.

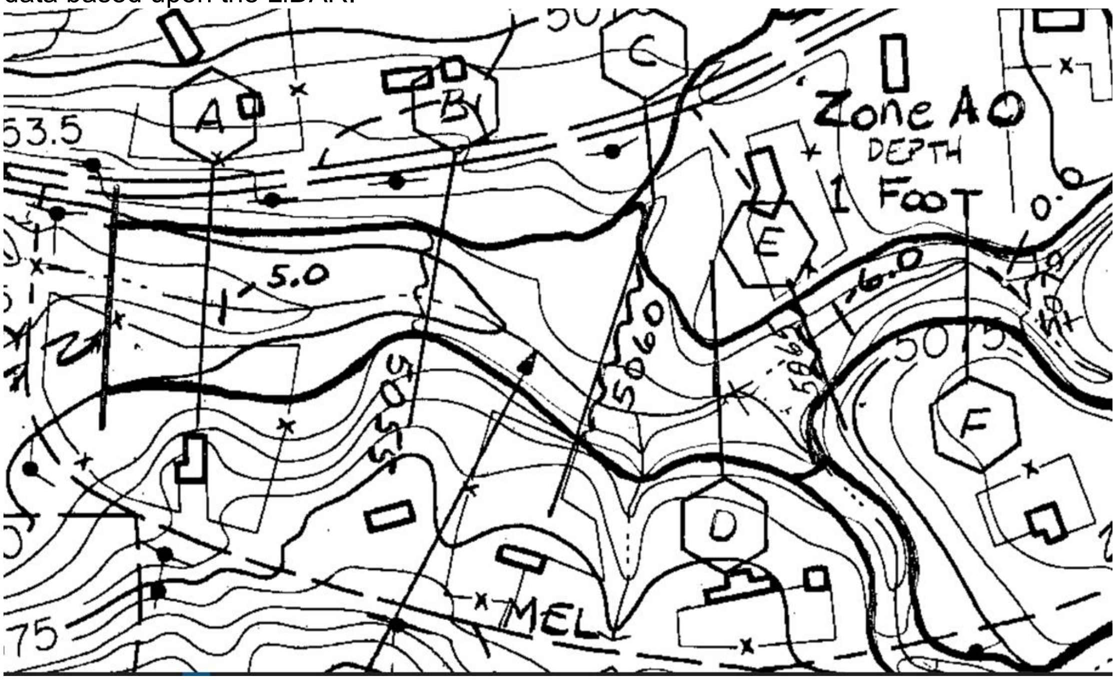


Figure 8: Effective Work Map Detail along Mel Drive

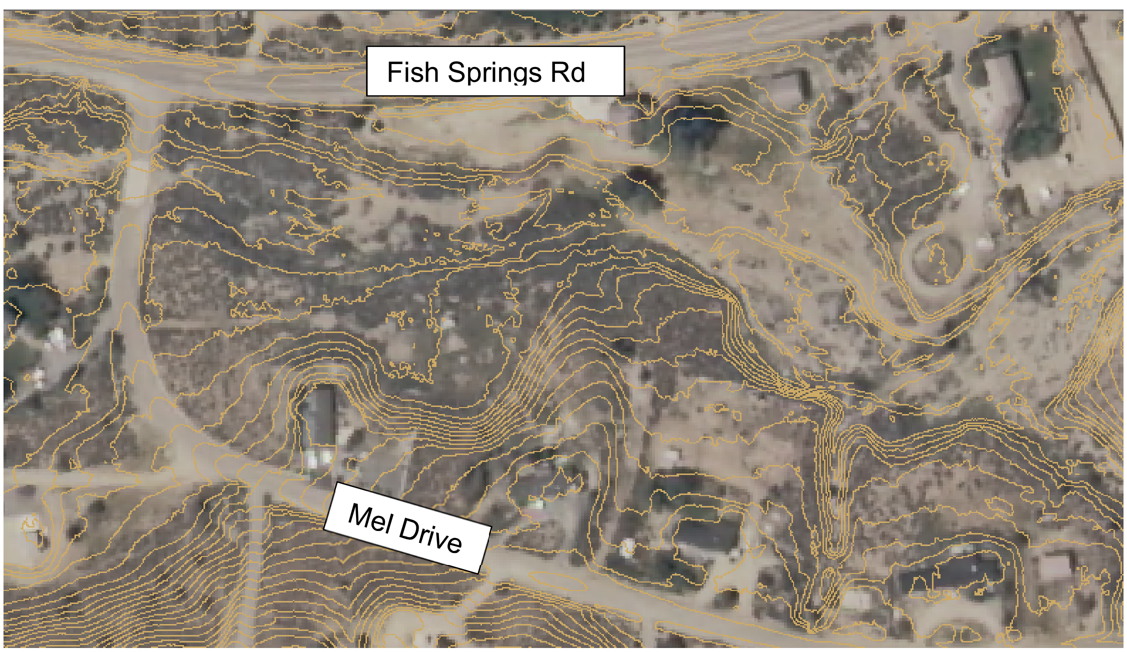


Figure 9: Updated LiDAR Topography Detail along Mel Drive

Hydraulic Structure Survey

All culverts and other hydraulic structures present on the watercourses analyzed were surveyed and photographed by Lumos & Associates. Structure dimensions and configurations were extracted from this information and used to populate the HEC-RAS hydraulic model. The survey data and photos are attached in Appendix F.

Analysis

Hydrology

Given the lack of stream gage data in the Pine Nut Watershed, a statistical analysis was done on the adjacent Buckeye Creek watershed as a basis of comparison. These watersheds are of very similar size, shape, and cover type, so it is reasoned that they will respond in a similar fashion to a given storm event. These basins also have similar average slopes, and they are both located on the western facing slopes of the Pine Nut Mountains, along the eastern edge of the Carson Valley. Unit discharges per area should therefore be similar. Figure 10 provides a comparison of these watersheds, based upon data from the National Hydrography Dataset.

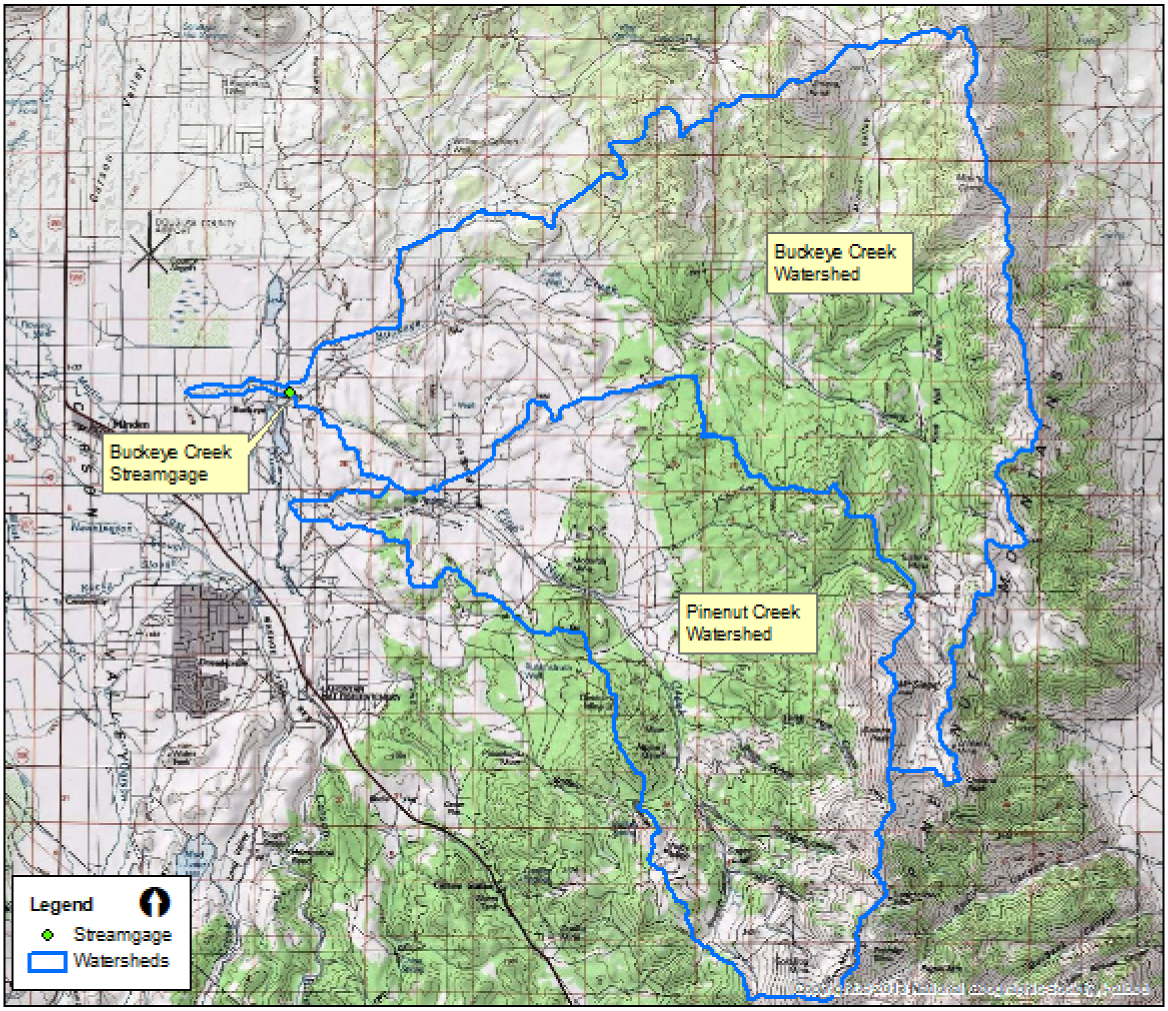


Figure 10: Buckeye Creek and Pine Nut Creek Basin Comparison

USGS peak discharge data for Buckeye Creek at East Valley Road (USGS gage #10309075) indicates that four of the five highest recorded peak flows at this location have occurred in the month of July, and the fifth highest took place in the month of September. Table 2 provides a summary of the annual peak streamflows recorded by the USGS gage on Buckeye Creek at East Valley Road. This data indicates that short duration summer time convective thunderstorm events driven by moist southwest monsoonal air flows pushing north along the east side of the Sierra Nevada range tend to generate the highest peak discharges in this basin. These monsoonal air masses typically occur between July and October. This hydrologic setting is quite different than the western side of the Carson Valley. In that portion of the valley, large-scale rain-on-snow atmospheric river events occurring during winter and spring have historically produced the highest peak flow events.

Table 2: Peak Streamflow Records at Buckeye Creek USGS Gage (#10309075).

Date	Peak Discharge (cfs)
Jul. 14, 1992	3000
Jul. 22, 1994	1300
Mar. 10, 1995	500
Jan. 02, 1997	200
Sep. 26, 1998	80
1999	0
2000	0
2001	0
2002	0
Jul. 20, 2003	140
Jul. 03, 2004	990
2005	0
Dec. 31, 2005	120
2007	0
2008	0
Jun. 08, 2009	1
Jan. 13, 2010	2
Jul. 30, 2011	67
Jul. 23, 2012	60
Sep. 14, 2013	1000
Jul. 20, 2014	2800
Jul. 08, 2015	85
Jan. 30, 2016	2
Feb. 10, 2017	359
Mar. 22, 2018	295
Feb. 14, 2019	20

Buckeye Creek Stochastic Analysis

The Buckeye Creek drainage is located immediately north of the Pine Nut creek drainage and is a similar size at 73.8 mi with similar land cover and ranges in elevation. A USGS stream flow gage located at East Valley Road near Gardnerville, NV (gage number 10309075) has peak flow estimates from 1992 to 2018. These peak estimates were used to do a Bulletin 17B analysis to estimate the 1-percent-annual-chance flood flow from a similar watershed.

The 17B analysis was conducted with the US Army Corps of Engineer's HEC-SSP V2.2 statistical package. Years with zero flow were not included in the dataset. Data was missing from years 1993, 1996, 2002, and 2008. A station skew of -0.278 was used with a median plotting position. In order to provide a better fit to the plot, values below 20 cfs were treated as low outliers (Figure 11). The 1-percent-annual-chance (1%) estimate was 7,498 cfs. This estimate yields a 1% peak flow rate per unit area of watershed of approximately 101.6 cfs. It was reasoned that the Pine Nut watershed could yield similar unit runoff for the 1% event and the hydrologic model was validated to yield a similar runoff per unit area. Comparison of these results to the FEMA effective hydrology for Buckeye Creek shows a good match to the previous 2010 effective flow rate of 6,891 cfs. It should be noted that the current 2016 Buckeye Creek 1% peak effective flow is 3,939 cfs.

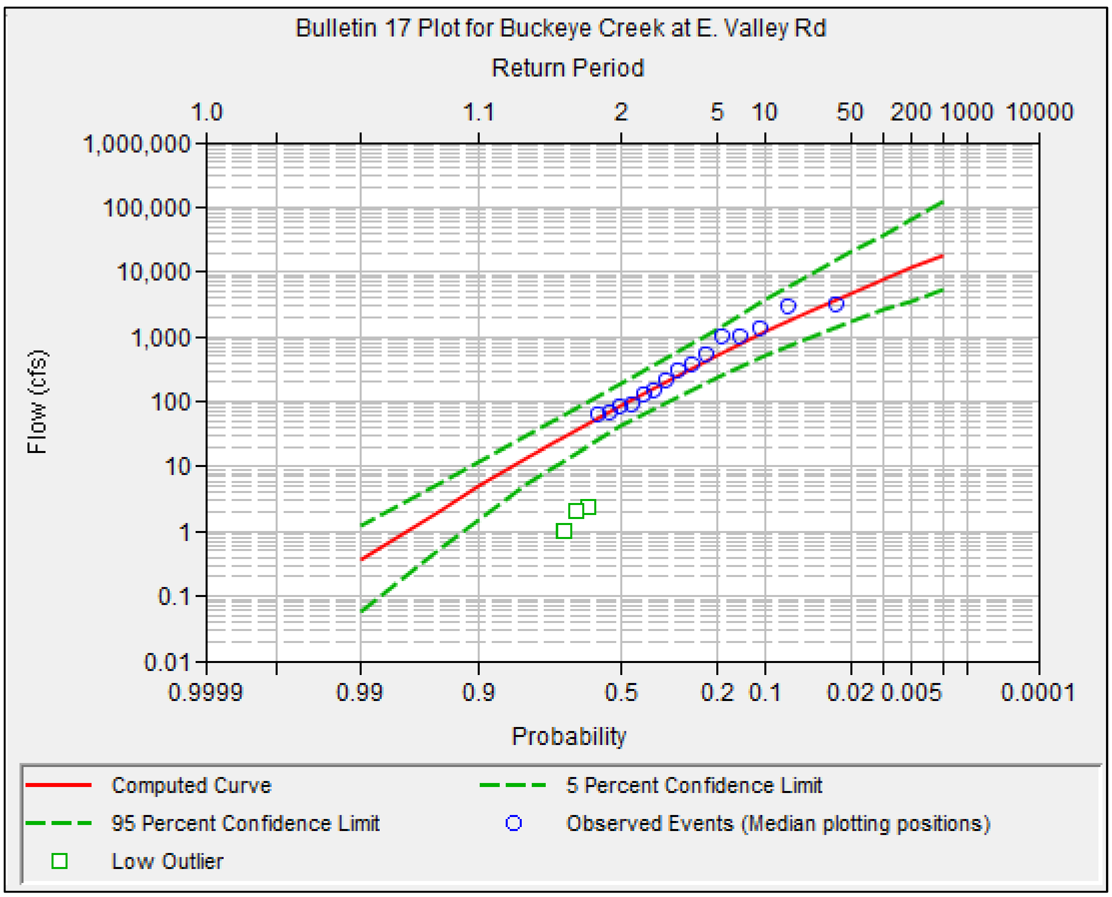


Figure 11: Buckeye Creek at E. Valley Rd. flow frequency curve

Watershed Delineation

The USGS 3DEP data described above was converted into state plane feet and then imported into ArcMap as an ESRI Grid. This grid was used to develop both Flow Accumulation and Flow Direction grids in ArcMap. Spatial Analyst hydrology tools were then used to do watershed delineation at desired concentration points for this study (Figure 12).These watersheds were then checked against aerial photos and other sources of data for reasonableness. Slight manual modifications were made to watershed boundaries. Nineteen (19) sub-basins were delineated ranging from 0.43 mi^2 to 6.72 mi^2.

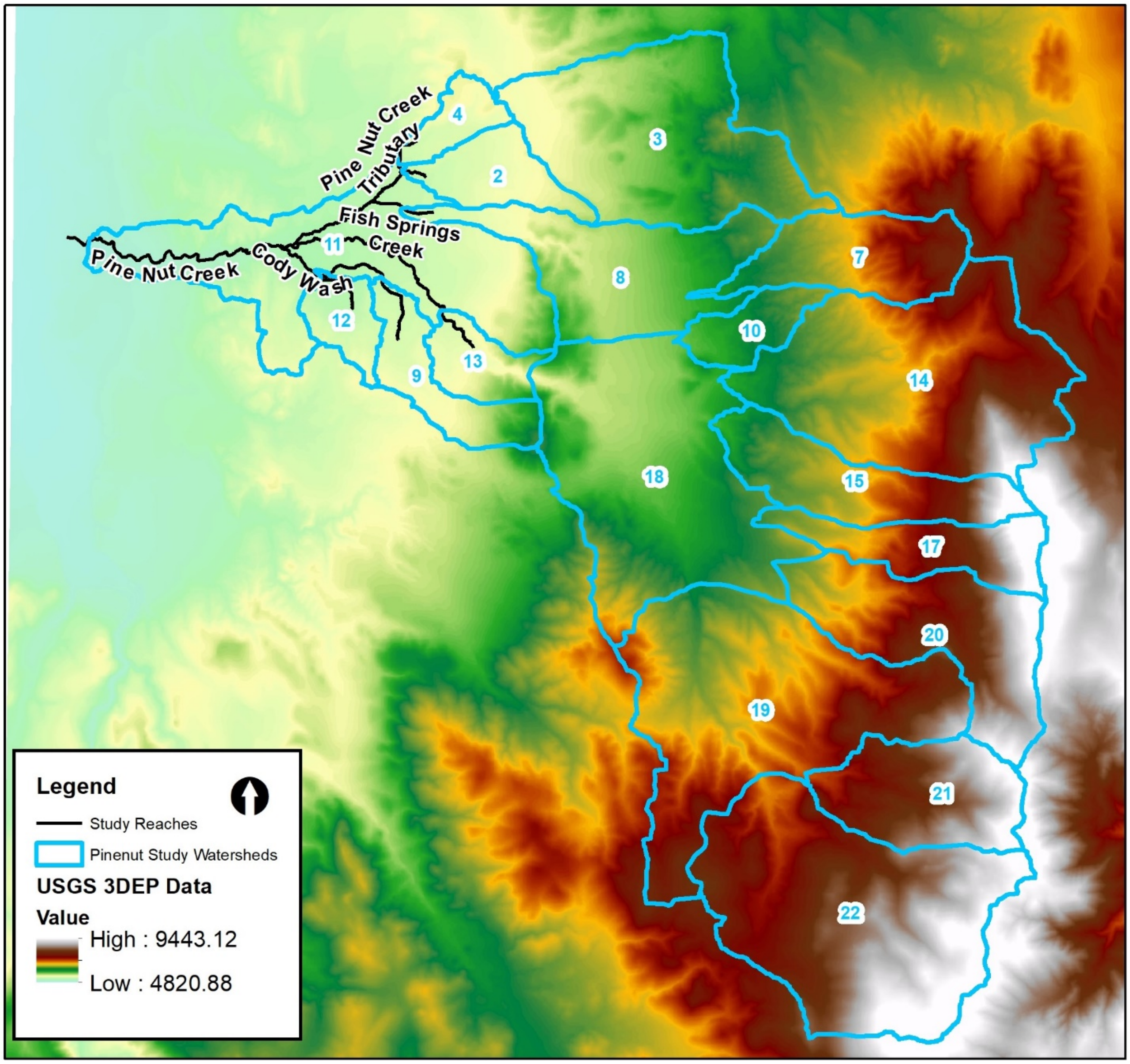


Figure 12: Pine Nut study watersheds.

Curve Number

Precipitation losses were estimated using the SCS Curve Number method. Development of runoff curve numbers followed methodology outlined in the US Department of Agriculture's (USDA) Technical Reference 55 (TR-55) Urban Hydrology for Small Watersheds. This procedure is based on a loss function that is described with a single parameter identified as the runoff curve number. The SCS, now known as the Natural Resources Conservation Service (NRCS), has developed curve numbers based upon empirical studies which are presented as tables of approximate values based upon soil type, relative soil moisture content, vegetation type, and vegetation cover density. Soil type is typically derived from the SCS soil surveys. These soil surveys classify all soils contained in the survey into one of four “hydrologic soil groups”: A, B, C, and D. Type A soils have a very low runoff potential and are typically very porous soils such as sand and cobbly soils. Type D soils have a high runoff potential, these include very rocky soils, soils with a well-developed desert pavement, or soils with a shallow impervious layer. Soil survey data was acquired in electronic format from the Web Soil Survey website (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm).

Another factor that impacts the curve number estimate is relative soil moisture content. This factor is described by the SCS using a relative term described as “antecedent moisture condition” (AMC). The NRCS has identified three different antecedent moisture conditions: AMC I, AMC II, and AMC III. AMC I is a condition in which the soil moisture has been depleted by a relatively long period of no rainfall and is assumed to be the condition when soil has its highest infiltration rate. AMC II is an average condition and is the condition usually assumed to be present in the watershed for most hydrologic studies for drainage design. AMC III is the condition in which soil moisture is high due to recent rainfall or snowmelt. This condition is assumed to be the condition in which the soil infiltration capacity is at its lowest point and is usually used for probable maximum discharge studies. AMC II is the condition used for this study.

Vegetation type refers to the land use or plant community which occupies the watershed. The SCS identified curve numbers for various typical plant communities and typical land use types. The vegetation types which best describe the plant communities encountered in the study area include sage-grass and juniper-grass cover types.

Composite curve numbers were derived for each of the 19 sub-basins using hydrologic soil group data and land cover estimates. Standard curve number values for each cover type were adjusted for variation in cover density, based upon Figure 9-6 from NEH-4 (SCS, 1972) (Figure 13). This document did not include curve numbers for hydrologic soil group D, which does occur within the study domain. Standard curve numbers for D type soils were added to the data set in TR-55 (NRCS, 1999). The lines shown in red on Figure 13 represent recommended curve number values for D type soils. These lines were developed based upon Table 2-2D in TR-55 and added manually to the chart.

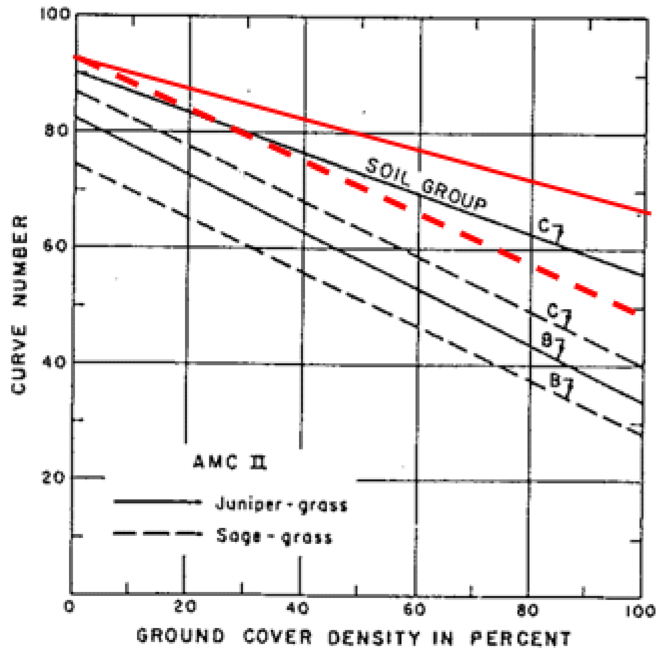


Figure 13: Ground Cover Density vs Curve Number (from SCS NEH-4), D Type Soils Shown in Red (from NRCS TR-55, 1999)

Vegetation cover type and cover density was estimated using aerial photos in ESRI's ArcMap software. Vegetation cover density estimates for the juniper-grass cover type range from 20-40%, while the sage-grass estimated cover density ranges from 20-45%. Figure 14 presents an overview of the delineated vegetation cover types. Polygons of homogeneous land cover and cover density were delineated for use in hydrologic calculations. Land cover data was intersected with the hydrologic soils group coverage from the soil survey data and a weighted curve number layer was developed in ArcMap and using Microsoft Excel (Table 3).

Table 3: Curve number estimates for the Pine Nut subbasins

Subbasin ID	Final Curve Number
Basin 2	78
Basin 3	77.6
Basin 4	75.6
Basin 5	66.9
Basin 7	76.2
Basin 8	70.7
Basin 9	79.1
Basin 10	70.2
Basin 11	76
Basin 12	76.8
Basin 13	76.6
Basin 14	69.8
Basin 15	69.7

Subbasin ID	Final Curve Number
Basin 17	67.8
Basin 18	71.1
Basin 19	78
Basin 20	72.9
Basin 21	59.8
Basin 22	70.6

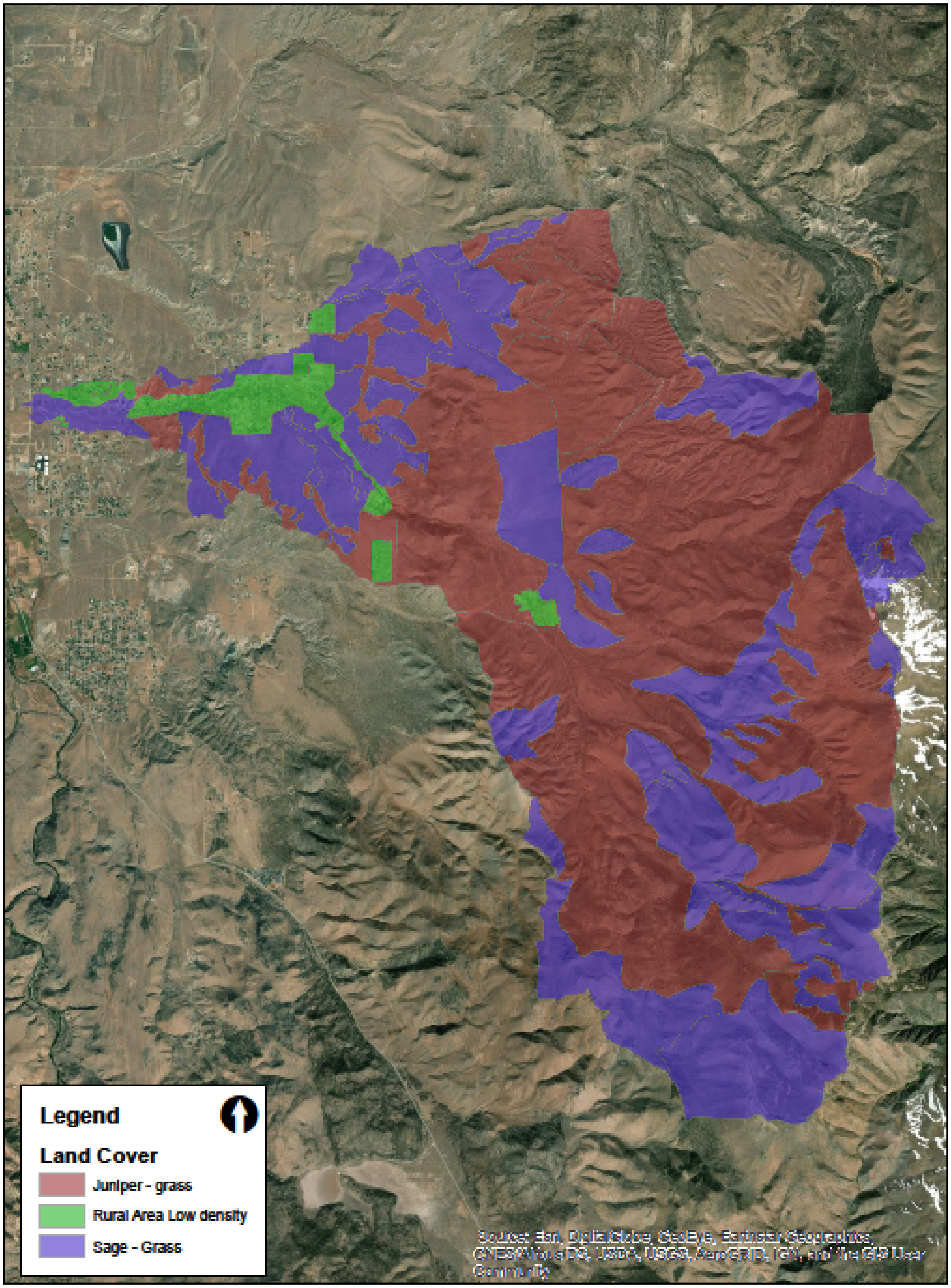


Figure 14: Land cover for Pine Nut Watershed

Precipitation

It was decided to use the 100-year 24-hr frequency storm for hydrologic analysis of the study area. The National Oceanic and Atmospheric Administration (NOAA) Atlas 14 precipitation data has the short duration storm embedded in the precipitation data and this was considered to be a reasonable approach since the peak flows in the study area would likely occur from the more intense short duration rainfall. This storm pattern is more comparable to the convective events that produce the highest peak flows in the drainage basins along the eastern edge of the Carson Valley.

Precipitation for hydrologic analyses was derived from the NOAA Atlas 14 Precipitation-Frequency Atlas of the United States Volume 1 Version 5.0 Semiarid Southwest (NOAA 2011). Depth-Duration-Frequency data were extracted for the 100-year, 24-hour event at the centroid of each of the 19 sub-basins. Sub-basins were then analyzed independently, each with a unique precipitation amount using the 5-minute through 24-hour durations as “frequency storms” in the hydrologic model.

It is assumed that no snow is present in the watershed at the time of the storm event. The peak discharges in this portion of the Carson Valley are generally produced by cloudburst events occurring during the summer months, so no consideration was made of the potential for snowpack to influence the basin response to the rainfall event.

Due to the size of the overall study area it was necessary to add a depth area reduction factor (DARF) to each sub-basin based on appropriate storm areas. Standard elliptical pattern storm isohyets were applied to the study area watersheds with an assumed storm centering and orientation aligned with the bulk of the overall watershed (Figure 15). A depth area reduction factor was then applied to each sub-basin based on its centroid location and DARF factors outlined in the US Department of Commerce Weather Bureau’s Technical Paper No. 40 (TP-40) (1961). This area of the Pine Nut Mountains experiences flooding primarily from shorter-duration, “flashier”, localized storm events. During these events, the majority of the precipitation volume tends to arrive during the early portion of the storm event. This is in contrast to the larger regional atmospheric river events in the Sierra Nevada Mountains, in which the highest intensity precipitation tends to occur later during the storm. Given the nature of the storms affecting the study area and the results of the stochastic analysis for the proximal Buckeye Creek watershed, precipitation in the model was set to have a 33% intensity position. The use of this intensity position resulted in a unit discharge per basin area that best matched to the frequency analysis, which confirms the selection of this option.

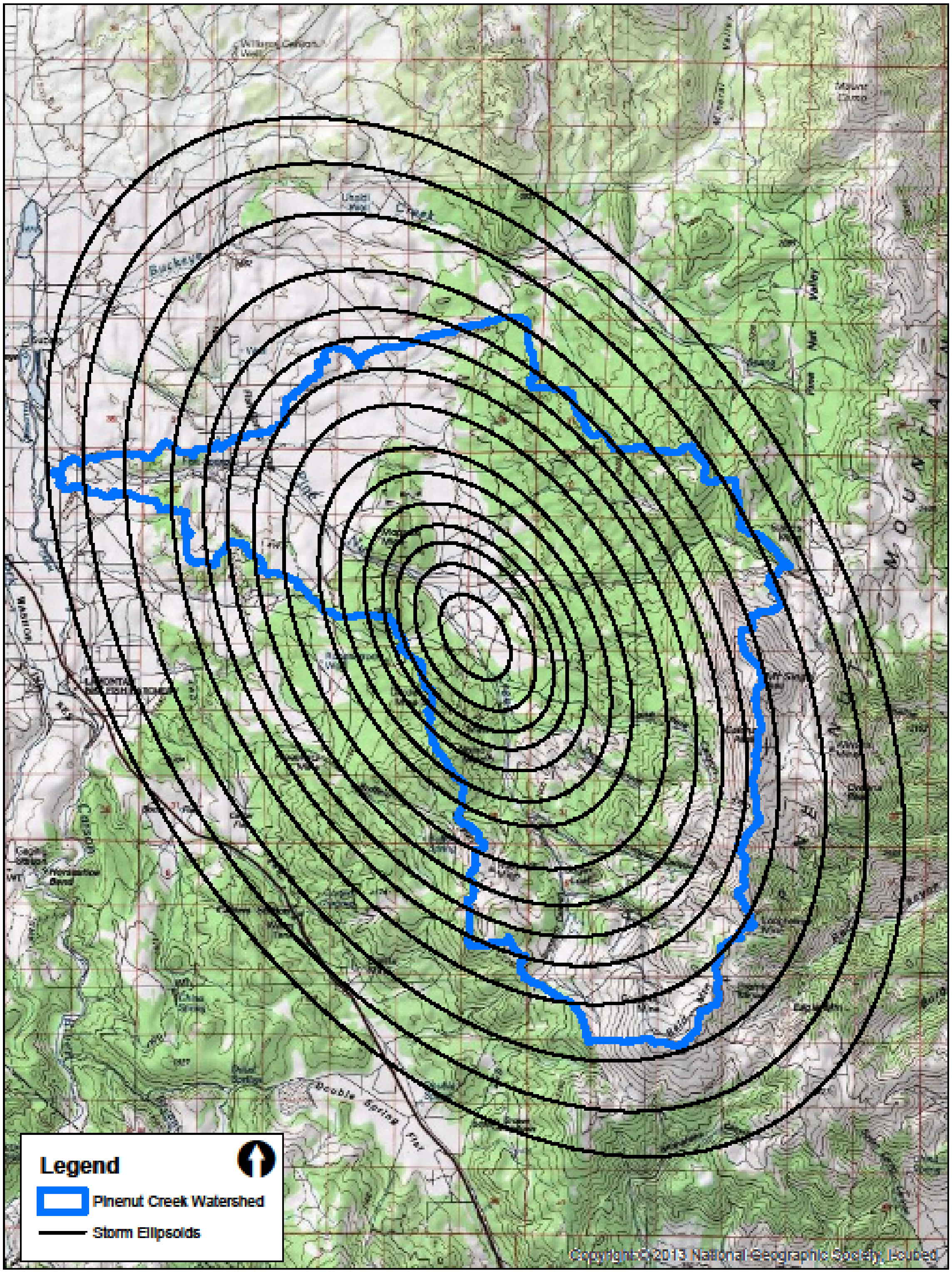


Figure 15: Pine Nut Watershed storm centering

Precipitation Excess

Precipitation excess was determined using the US Army Corps of Engineers' HEC-HMS hydrologic model. A simplified HEC-HMS V4.4 model was developed using the above curve numbers and precipitation parameters. No runoff routing is done in this model, therefore no routing reaches are included in the model configuration. All routing was performed with an HEC-RAS model, utilizing the rain-on-grid option. Each of the 19 above watersheds were input into the HEC-HMS model and run with individual depth area reductions. This yielded the appropriate excess precipitation hyetograph for each of the sub-basins. Figure 16 is an example of the precipitation excess calculated for Subbasin 20.

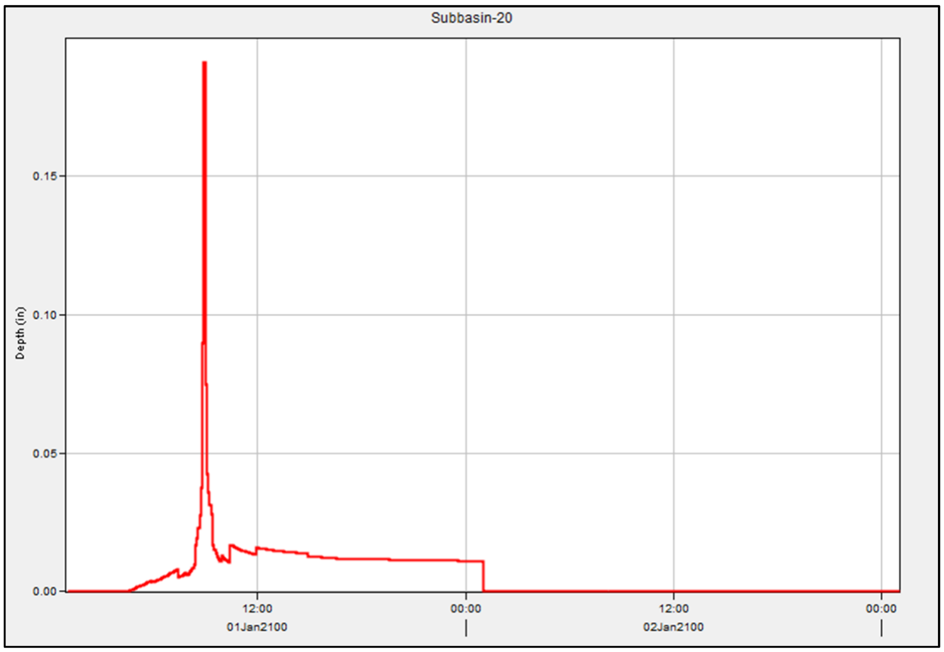


Figure 16: Example precipitation excess from basin 20

Rain on Grid Direct Transformation

Traditional transformation methods using lag time and unit hydrographs were not used for this hydrologic analysis. Hydrologic transformation was calculated explicitly using an HEC-RAS 2D "rain on grid model". The explicit representation of all overbank and channel features that exist in the study domain yields a more realistic assessment of rainfall-runoff response than that provided by traditional transform methods. This method allows for a more accurate simulation of the runoff response of a specific watershed to a given storm event, rather than relying on the simplifying assumptions inherent in all unit hydrograph transform methods. The DEM dataset mentioned above was converted to a floating point grid (*flt) file using ArcMap capabilities and imported in HEC-RAS Mapper. The 19 watershed boundaries were also brought into HEC-RAS Mapper and converted to 2D model domains. Appropriate breaklines were added to the model grid layout including those for stream centerlines.

Manning's n values were delineated based on aerial photos and a lower channel n value was applied to major drainage ways using an n value override polygon in HEC-RAS. Channel values were set to 0.04, while overland n values ranged from 0.1 to 0.15. These values are higher than those typical of a deeper water floodplain as most of the flow is shallow overland flow. 2D hydraulic connections were added at watershed concentration points to allow flow to move downstream from one subbasin to the next (Figure 17). The HEC-RAS 2D equation option was selected for these connections, rather than using the weir equation option. Using the rainfall excess based upon a 33% intensity position and the rain on grid direct transform, the Pine Nut 55.5 mi^2 watershed yielded 5,128 cfs at the outlet. This is a similar unit discharge (92 cfs/mi^2) to the Buckeye Creek stochastic analysis (101.6 cfs/mi^2). This value is also relatively close to the effective flow rate at this location, which is 5,510 cfs.

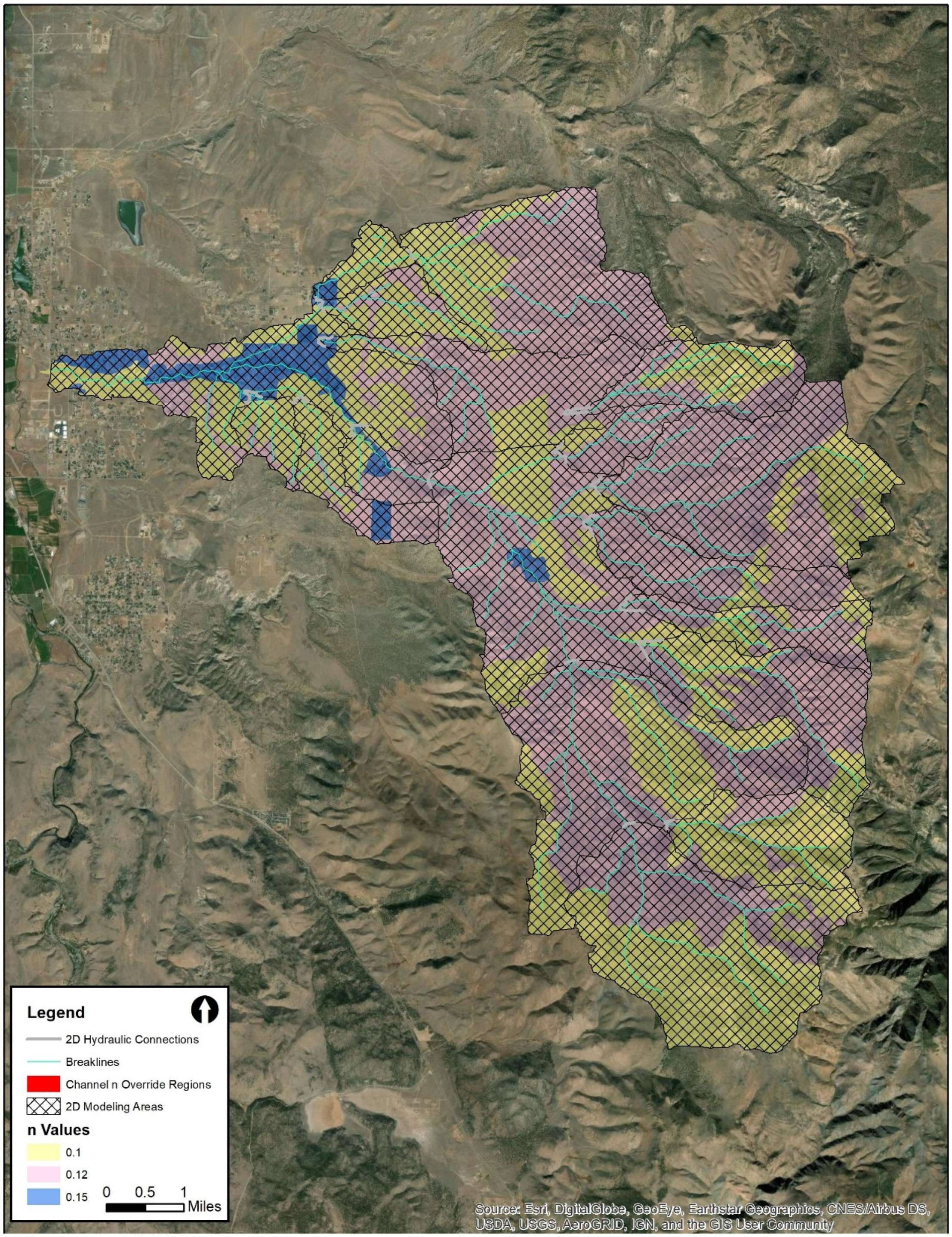


Figure 17: HEC-RAS rain on grid model setup

Regression Analysis

The USGS has developed regional regression equations that are intended to provide an estimate of the magnitude and frequency of floods in a given region. These equations use easily obtained watershed physical parameters to allow an engineer to calculate a peak discharge for a given recurrence interval flood event. The equations are developed for relatively large regions, and can fail to account for large variations in hydrologic setting that can occur over relatively small regions. The basins analyzed for this report are an example of such an issue. The USGS report (USGS, 1997) detailing the regression equations for the study area shows that the applicable equations to be used are intended for use on both the eastern and western sides of the Carson Valley. The study area falls within Study Zone 5 in the USGS report (Figure 18). This figure indicates that the analysis used to develop these equations combined watersheds where peak discharges are controlled by longer-term atmospheric river rain-on-snow events with basins where peak discharges occur due to convective cloudburst storm events. The regression equation for the 100-year recurrence interval event in this region has a reported average standard error of prediction of 95%. Since the regression equations are not able to account for the variable hydrologic setting in the study area, and because error bands for the equations in this region are so large, no regression analysis was performed for this study. It should be noted that the 2010 study which established the effective hydrology for Pine Nut creek below Allerman Canal did include an analysis of the USGS regression equations, using the USGS National Flood Frequency (NFF) Program software. That report stated that the NFF program estimated a 100-yr peak discharge for Pine Nut Creek at Allerman Canal of 5,020 cfs, which is quite close to the peak discharge results at that location found by this study.

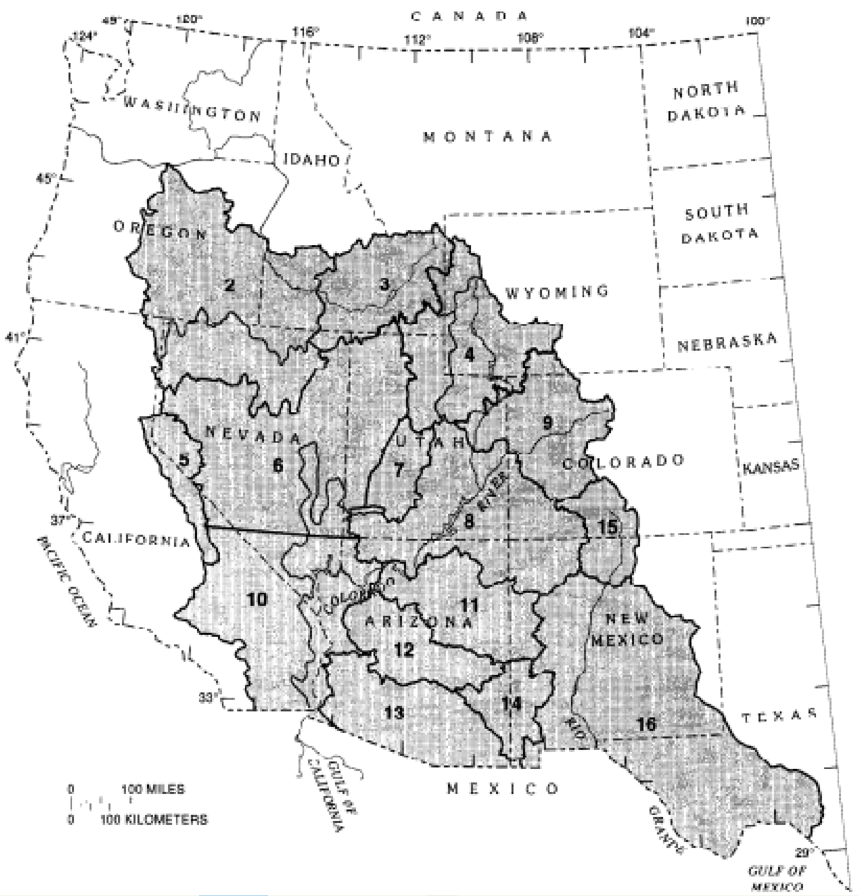


Figure 18: USGS Regression Equation Zones

Hydraulic Model

In order to assess hydrodynamic behavior and determine base flood elevations for detailed reaches, HDR Engineering chose to develop a two dimensional (2D) hydrodynamic model of the study area using the US Army Corps of Engineers' HEC-RAS Version 5.0.7. A 2D model was chosen due to the study area having bifurcated flow with different water surface profiles in the overbanks compared to the channel. This approach allows for a much more detailed and accurate assessment of possible flooding conditions in the study area than the methods applied by the effective modeling. In particular, the shallow flooding areas can be simulated more realistically than has previously been possible with 1D modeling software.

A fully 2D model geometry of the study area was developed using HEC-RAS Mapper capabilities. Culverts were modeled using 2D connections based on survey data collected in 2019 for this effort. A nominal model grid cell sizing of 25-foot square was chosen to allow for sufficient detail to capture flood wave dynamics, with smaller cells being used as needed to capture complex flow conditions. Model "breaklines" were added at hydraulically significant high features in the modeling domain to capture terrain features that influence flow behaviors. Figure 19 illustrates the HEC-RAS 2D model layout.

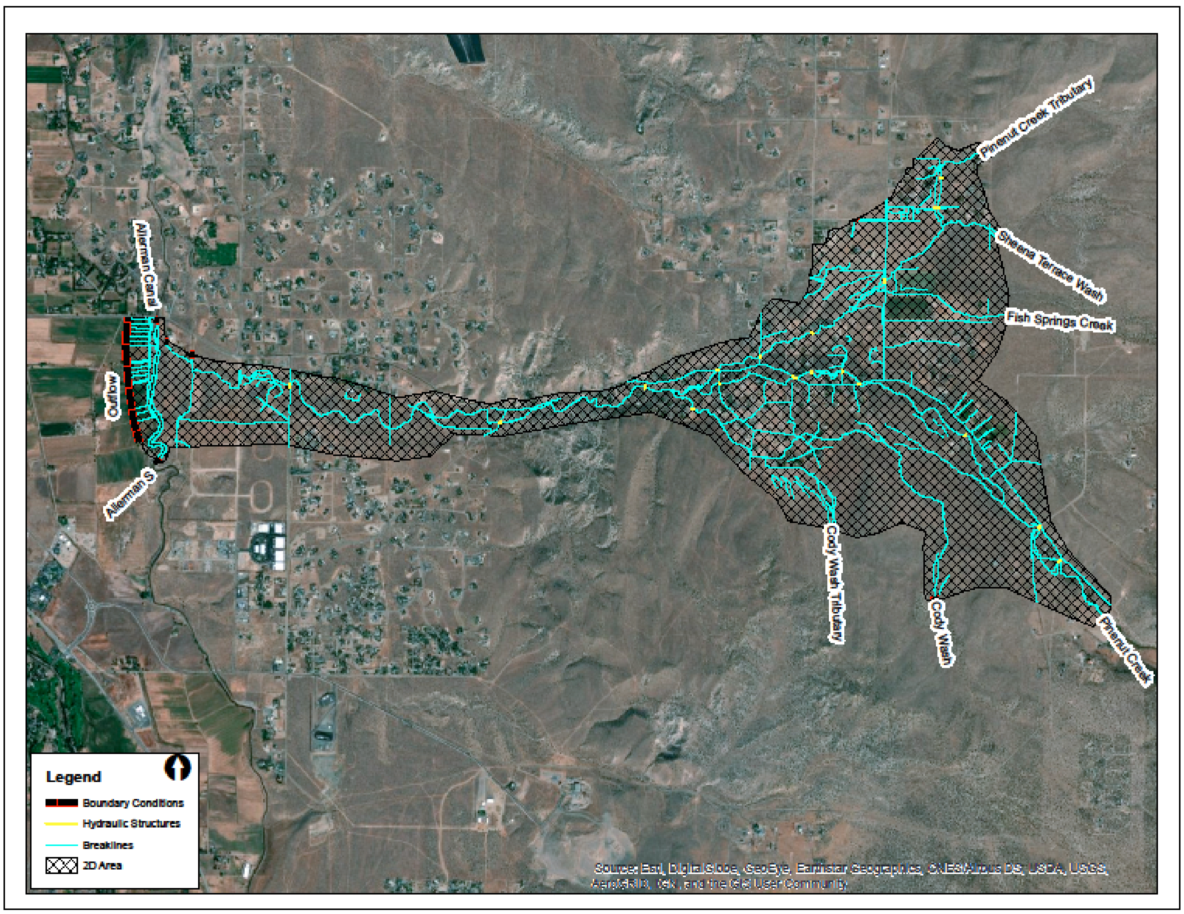


Figure 19: HEC-RAS 2D Model Setup

Manning's n hydraulic roughness values were delineated based on examination of aerial photos from 2010, 2012, and 2017 using ArcMap editing tools. In addition, oblique aerial photos from the Pictometry online resource, ground photography from the survey missions, and Google Street View were used in the development of the hydraulic roughness polygon layer. The following land use designations and n values were given to polygons of homogeneous land use: Barren Ground (0.025), Channel (representing the Allerman Canal, n=0.03), Developed Low Intensity (0.06), Developed Medium Intensity (0.08), Developed Open Space (0.045), Dirt Roads (0.03), High Grass Pasture (0.045), Mature Row Crops (0.035), Paved Roads (0.017), Sage-Grass (0.07), Sage-Grass2 (more dense vegetation than Sage-Grass, n=0.075), Sage-Pinion (0.08), and Short Grass (0.04). Figure 20 provides a map showing the level of detail of the roughness polygons. Examination of the effective models showed that the prior modeling used similar values, with the Pine Nut Creek channel regions generally using n=0.075, and overbanks using n=0.1. Roughness values used in the effective tributary models were similar, but often slightly higher than those used in the Pine Nut Creek effective model. The proposed modeling uses n values somewhat lower than the values used in the effective models due to the fact that a 2D model is able to more accurately represent wetted perimeter, and to explicitly capture hydraulic losses due to terrain undulations and ineffective flow areas.

Homes, garages, and large outbuildings that were inundated were represented using the roughness override option in HEC-RAS Mapper with a high n value (n=10,000) in order to block flow from passing through these structures. This approach provides a more accurate representation of flow conditions around these structures. Aside from the structures, the developed areas generally do not have extensive landscaping with large areas of grass. This results in a hydraulic roughness only slightly lower than the surrounding rangeland, which is dominated by the Sage-Grass land use type. Due to this, the developed regions use higher roughness values than would be used to represent a suburban setting with established yards. Roadways were delineated as separate roughness polygons and the refinement region option in HEC-RAS Mapper was used to create grid cell faces along these linear features.

The roughness override region option was also used to represent some hydraulically important regions of bare soil (n=0.03), and the channel of Pinenut Creek below the East Valley Road crossing (n=0.05). The streams in the study area are ephemeral washes that do not carry flow on a regular basis. Examination of aerial and ground photographs indicate that these channels are very narrow, and do not differ significantly in hydraulic roughness from the surrounding overbank regions. Since the peak discharges are generally not contained within the stream channels, the channels form a relatively small percentage of the entire flow conveyance during the peak of the flood. Aside from the lower portion of Pinenut Creek, the stream channels are not separated out from the overbank regions with a different roughness value.

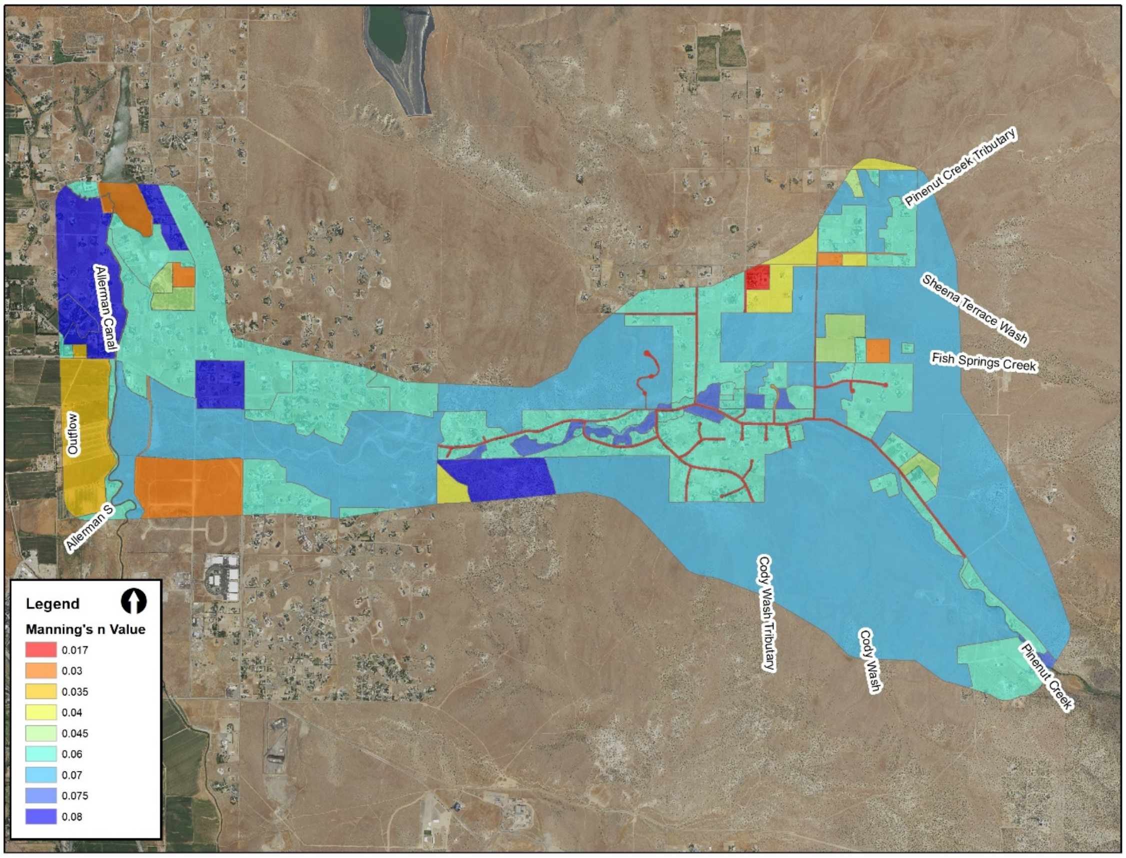


Figure 20: Manning's n Hydraulic Roughness

Inflow hydrographs were extracted from the rain-on-grid hydrologic model and added to the channel reaches within the hydraulic model at appropriate locations for each stream reach. The results of the rain-on-grid model were examined to determine locations where it was appropriate to introduce additional flow into the model domain to account for subbasins that do not report at the top of the stream reach being analyzed, but that could impact results farther down the reach. This was only necessary at one location along lower Pine Nut Creek, one along Cody Wash Tributary, and one on upper Pine Nut Creek.

Outflow boundary condition lines were placed at each location where ditches or canals leave the model domain. In addition, flow that overtops the Allerman Canal leaves the domain in the form of sheet flow moving in the westerly direction. The outflow boundaries use a normal depth condition, the energy grade slope specified is based upon channel slope measurements taken from the model terrain downstream of the outflow location.

HEC-RAS plans were run in unsteady-state using the inflow hydrographs for a 37.75-hour duration to ensure peak flows traveled through the whole consequence area. The models were run using the Full Momentum equation set using an adaptive time step ranging from 0.25 sec to 8.0 sec. The maximum Courant condition was set to 1.0 with a minimum of 0.45. Continuity error for the 1% annual chance run was 0.05668% with minimal water surface elevation errors.

The effective and revised peak discharges for each stream reach are summarized in Table 4, along with associated drainage areas. Variations in drainage area between the effective and proposed modeling are due to revisions in watershed delineations, based upon updated topography. The updated peak discharges for the tributaries show some discrepancies when compared to the effective hydrology, it is assumed that these are due to the updated topography, hydrology, and improved modeling methods utilized by this study. In general, the updated results indicate a reduction in peak flow rate for the tributary channels as compared to the effective hydrology. The updated peak flow rate for Pine Nut Creek at Allerman Canal compares quite well to the effective peak discharge. The effective hydrology at this location is based upon results of the 2010 study, which used much more modern data and methodologies than the effective studies of the tributary channels.

Table 4: Effective and Revised HEC-RAS 2D model inflows

Stream Name & Location	Effective Peak Flow 1% (cfs)	Effective Peak Flow 0.2% (cfs)	Effective Drainage Area (sq mi)	Revised Peak Flow 1% (cfs)	Revised Peak Flow 0.2% (cfs)	Revised Drainage Area (sq mi)
Fish Springs Creek 1500 ft U/S of Windmill Rd	595	N/A	3.34	425	903	3.2
Cody Wash 0.5 mi U/S of Marj Ln*	230	N/A	1.26	155	346	1.3
Pine Nut Creek Tributary At Sheena Terrace	685	N/A	4.95	410	798	3.2
Cody Wash Tributary At Ron Ln	190	N/A	0.71	78	186	0.7
Pine Nut Creek At Allerman Canal	5510	N/A	54.0	5128	14031	55.5
Sheena Terrace Wash At Mouth	265	N/A	1.27	119	267	3.3

*Cody Wash flows extracted ~2,600 ft upstream due to converging flows in 0.2% event at original check point

Floodway Development

Updated floodway boundaries were developed for those stream reaches that have current effective floodway boundaries. These are Pinenut Creek Tributary and Cody Wash. No new floodways were delineated on the other reaches analyzed, as much of the study area experiences shallow, bifurcated flow where the floodway concept is not easily implemented or managed. This bifurcated condition does also exist within portions of the reaches where updated floodway boundaries are being proposed, but FEMA regulations generally prohibit eliminating floodways from reaches with a previously identified floodway boundary. If current floodways did not exist along Pinenut Creek Tributary and Cody Wash, the bifurcated nature of portions of the floodplains along these reaches would suggest that floodways not be developed for these reaches. Determination of the floodway reaches and extents produced was finalized following coordination with CWSD and Douglas County. The floodway extents are largely confined to the boundaries of the existing washes, as the 1% base run results are often contained by the gully within the stream reaches analyzed where floodways have been developed.

The proposed floodway boundaries are similar in downstream extent to the effective boundaries, except that the Cody Wash floodway extent was extended downstream to a point just upstream of the intersection of Marj Lane and Myers Drive. This location was chosen because the floodplain has largely been developed downstream of this point, and because flow was largely confined to the channel and near overbank regions upstream of this area.

Several alternative methods exist that may be utilized when developing a with-floodway HEC-RAS 2D model. These include:

- Use of extremely high roughness values (range of n=10,000) to prevent conveyance in the fringe. This option forces the base flood discharge to be conveyed in the region to be defined as floodway. But, this option still allows floodplain storage to occur in the fringe and will not be representative of a future encroached condition. This option also requires care in representing the change in roughness to be clearly defined at the proposed floodway boundary which may require mesh refinements to make this happen.
- Use of a “wall” at the floodway boundary that can be done with HEC-RAS using a storage area/2D connection line that is artificially raised above the floodway elevation. This blocks all storage in the floodway and requires mesh modifications to enforce the connection line that may differ from the base profile unless the same mesh refinements are included in both the with- and without-floodway models. In an unsteady solution this will also change the magnitude of the base flood as you proceed downstream.
- Limiting the 2D domain for the floodway model to the floodway polygon. This option requires that the tributary inflow boundary conditions be moved to the revised boundary. In an unsteady solution this will also change the magnitude of the base flood as you proceed downstream.

The floodway analysis presented is based upon the final alternative mentioned above, which uses a revised 2D domain boundary to define the floodway polygon. This option was selected as it provides a relatively straightforward method that does not require modification of the without-floodway condition, and because it does not represent flood volume storage outside of the floodway boundary. The with-floodway model was developed by duplicating the “base run” HEC-RAS geometry that was used for the floodplain development. Two duplicate geometries were developed, one for each channel for which a floodway simulation was performed. The 2D grid representing the reach being studied was truncated to only cover the reach of the stream for which a floodway was developed. Flow was constrained to the proposed floodway extent by reducing the 2D grid extent to match the intended floodway boundary. This approach allows for a relatively straightforward simulation of encroachment along the channel being analyzed. This method assumes complete development of the floodway fringe, which is not completely realistic, but it avoids issues related to the other analysis methods mentioned above.

In numerous places, the 1% base run indicated that the 100-year flow would be contained within the stream channel or its associated gully. In these areas, the floodway boundary was configured to be coincident with the floodplain boundary. In areas where the 1% inundation boundary extended outside of the natural channel, the proposed floodway boundary is generally similar to the width of the overall gullies that carry smaller flows along these reaches. No other changes were made to the HEC-RAS 2D grid layout for the floodway run, in order to provide comparable results between the model runs.

Flow hydrographs input to the top of the reaches analyzed for floodways are identical to the inputs used for the base run. Tributary inflows that were seen in the base run to move overland from other channels and flow into the reaches being analyzed were added to the floodway grids at appropriate locations within the floodway reaches. In addition, the flow from Fish Springs Creek that enters Pinenut Creek Tributary at the confluence of these streams near Windmill Drive was introduced into the Pinenut Creek Tributary 2D grid in the area of that confluence. Along Cody Wash, two overland flow hydrographs were introduced to the floodway grid along the right side of the channel. The grid extent was increased at these locations to avoid artificially increasing maximum water surface elevation within the channel by adding the flow directly the channel in the encroached region. This has resulted in a floodway boundary with minor increases in extent outside the Cody Wash channel at the locations of these inflows. Following development of the floodway model runs, flow hydrographs from the base run and the floodway runs were extracted near the downstream end of each floodway reach in order to ensure that the inflows added to the floodway models were similar to those used for the base run. For Pinenut Creek Tributary, the peak flow seen in the floodway run was within 0.9% of the peak discharge from the base run, while the peak flows for Cody Wash matched to within 2.6%.

Because the tabular outputs normally utilized to quantify floodway surcharges in a 1D HEC-RAS model are not available from a 2D HEC-RAS model, comparison of the maximum WSE results rasters is the only way to accurately assess floodway surcharges throughout a 2D HEC-RAS model domain. Floodway surcharges were evaluated by exporting maximum WSE raster files for the floodway runs at a 2-foot cell resolution using ArcMap tools. The maximum WSE base run results were subtracted from the floodway maximum WSE results using the ArcMap raster math tools. This analysis provides a gridded representation of the surcharges occurring throughout the proposed floodway extents. The raster files representing the surcharges for both floodway reaches are included as electronic files in Appendix G.

For the Cody Wash floodway, the range of surcharges that occurred were between -0.68 and 1.03 feet. The FEMA draft guidance on 2D floodway analysis (FEMA, 2020) indicates that negative surcharges are acceptable in some portions of the 2D floodway, to a maximum value of -0.5 feet, and that maximum surcharge up to 1.5 feet is acceptable. The regions of negative surcharge exceeding -0.5 feet are very small and occur only at two locations, both of which are along the edges of the floodway inundation area. The floodway and floodplain boundaries are nearly coincident in these areas and revisions to the floodway boundary did not alleviate these minor pockets of excessive negative surcharge. It appears that these results are related to the floodway analysis method. The intent for the floodway run is to use identical grid cell faces as those seen in the floodplain run. However, some cell faces had to be truncated in order to reduce the floodway grid layout when compared the base run geometry. This alters the conveyance characteristics of these cell faces, as well as the distribution of flow through these regions. In some locations, this results in increased velocities and negative surcharges. Because the floodway boundary is essentially identical to the floodplain boundary in these small areas, no further effort was made to eliminate the negative surcharges.

For the Pinenut Creek Tributary floodway, the range of surcharges seen extends from -2.23 feet to 1.04 feet. The areas of excessive negative surcharges along this channel are relatively small, and occur along the floodway edges, for similar reasons as the areas of excessive negative surcharge that were seen along the Cody Wash floodway.

The draft FEMA Floodway Analysis and Mapping guidance document (FEMA, 2020) discusses presenting 2D modeling surcharge results using evaluation lines with the reported surcharge being calculated based upon a suitable weighting method. The guidance document suggests developing surcharge values for each 2D grid cell along an evaluation line. One difficulty with this approach is that WSE can vary along a single grid cell face, requiring averaging even within this small span.

Following the development of the floodway run results, it was found that the orientation of the base run and floodway water surface contours are often quite different. See Figure 21 for an example of this issue along Cody Wash. The draft guidance document appears to recommend evaluation lines that are based upon base run water surface contours. Due the complexity and difficulty associated with the evaluation line approach, no quantitative surcharge results, other than the raster comparison results included in Appendix G, are included in this document. The production of floodway data tables based on 2D modeling is also problematic due to these issues. Along with the problems described above, several of the parameters required for floodway data tables which are easily extracted from a 1D HEC-RAS model in tabular form are not available from 2D modeling results. Due to these issues, no floodway data tables have been produced for this report. Following initial review of this document, further coordination with CWSD, Douglas County, and FEMA personnel may be necessary to determine the most appropriate way to present surcharge results.

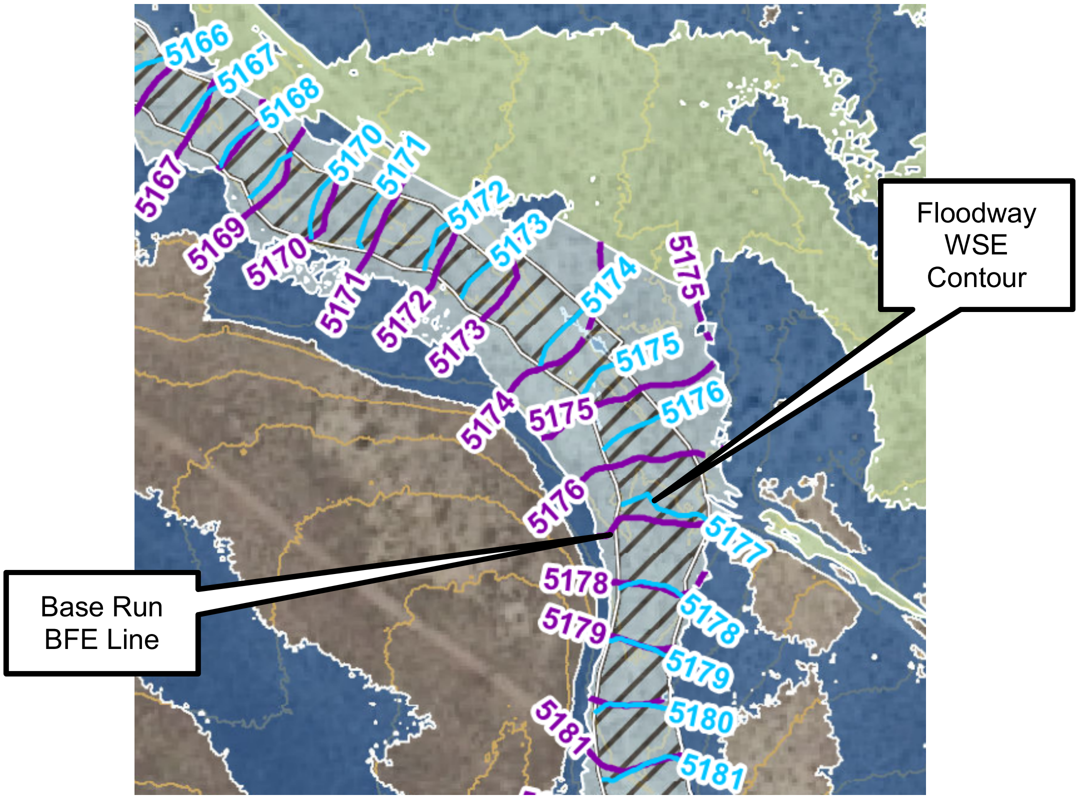


Figure 21: Comparison of Cody Wash BFE lines and Floodway WSE contours

Mapping and Base Flood Elevations

Mapping

After the model runs were complete, HEC-RAS Mapper was used to process both the 1%- and 0.2%-annual-chance water surface elevations and floodplain extents. The raw floodplain and floodway boundaries were then refined using topographic information and engineering judgment to eliminate “stranded” pockets of water and elevated “islands” in the floodplain. Due to the size and complexity of the floodplain inundation boundary, it was necessary to use a GIS smoothing routine to allow the final inundation boundary shapefile to be processed. Special Flood Hazard areas and tie-ins are shown on Workmaps and Annotated FIRMs (Appendix A).

Effective flood zone mapping along Pine Nut Creek and its tributaries represents these streams as being within several different flood hazard area types. The revised flood hazard designations are based upon the detailed hydraulic modeling results developed as part of this re-mapping effort. Areas subject to shallow flooding are designated as Shaded Zone X (average depth of flooding is less than one-foot). Although a few minor pockets of flooding greater than one-foot in depth are seen within these regions proposed to be mapped as Shaded Zone X, these areas do not warrant designation as Zone AO or Zone AE.

Areas of deeper flooding have been designated as Zone AE with associated Base Flood Elevations being established. Table 5 provides a summary of the effective and revised flood zone designations along each of the streams to be re-mapped.

Floodway modeling results are presented in a set of two additional floodway workmaps, similar in format to the standard workmaps, that present the base run BFE lines along with the floodway run maximum WSE contours. These are intended to allow reviewers and floodplain mangers to determine floodway surcharge at any location within the floodway reach. This approach allows the user to assess surcharge across the channel without the need for averaging across evaluation lines.

The HEC-RAS model used for the analysis presented here is based upon a rigid boundary assumption, as are most hydraulic modeling software packages. This approach assumes that no change to the channels, overbanks, or structures will take place during a flood event. Based upon the high velocities calculated by the model, it is likely that lateral migration as well as channel erosion and/or deposition could take place during a flood event. In addition, the velocities seen along several of the roadways within the model domain indicate that significant damage or complete destruction of those roads could take place. The inundation extents, water surface elevations, and depths presented here could change based on the potential for erosion and channel movement.

Table 5: Effective and Revised Flood Zone Designations for Stream Reaches

Stream Name	Effective Flood Zones	Revised Flood Zones
Cody Wash	Floodway, AE, AO, A, Shaded Zone X	Floodway, AE, Shaded Zone X
Cody Wash Tributary	AO	Shaded Zone X
Fish Springs Creek	AE, AO	AE, Shaded Zone X
Pine Nut Creek	AE, A, AO, Shaded Zone X	AE, Shaded Zone X
Pine Nut Creek Tributary	Floodway, AE, AO, Shaded Zone X	Floodway, AE, Shaded Zone X
Sheena Terrace	AE	AE

Comparison of the updated modeling results with the effective workmaps shows that in many locations the floodplain boundaries are quite similar, although the proposed flood zone type may differ from the effective mapping. See Figure 22 and Figure 23 for an example in the region of the intersection of Mel Drive and Fish Springs Road.

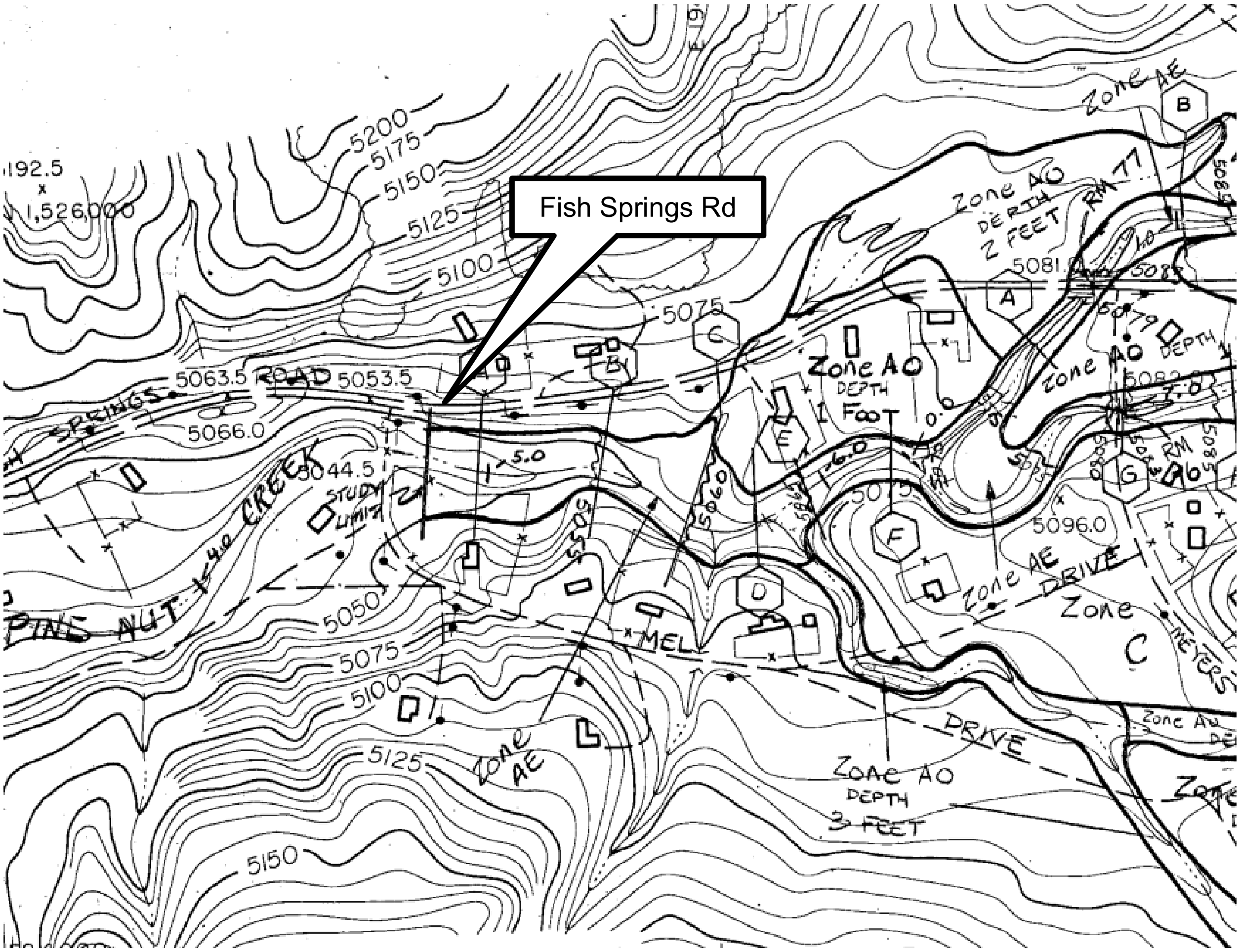


Figure 22: Effective Workmap Example

![HDR logo]

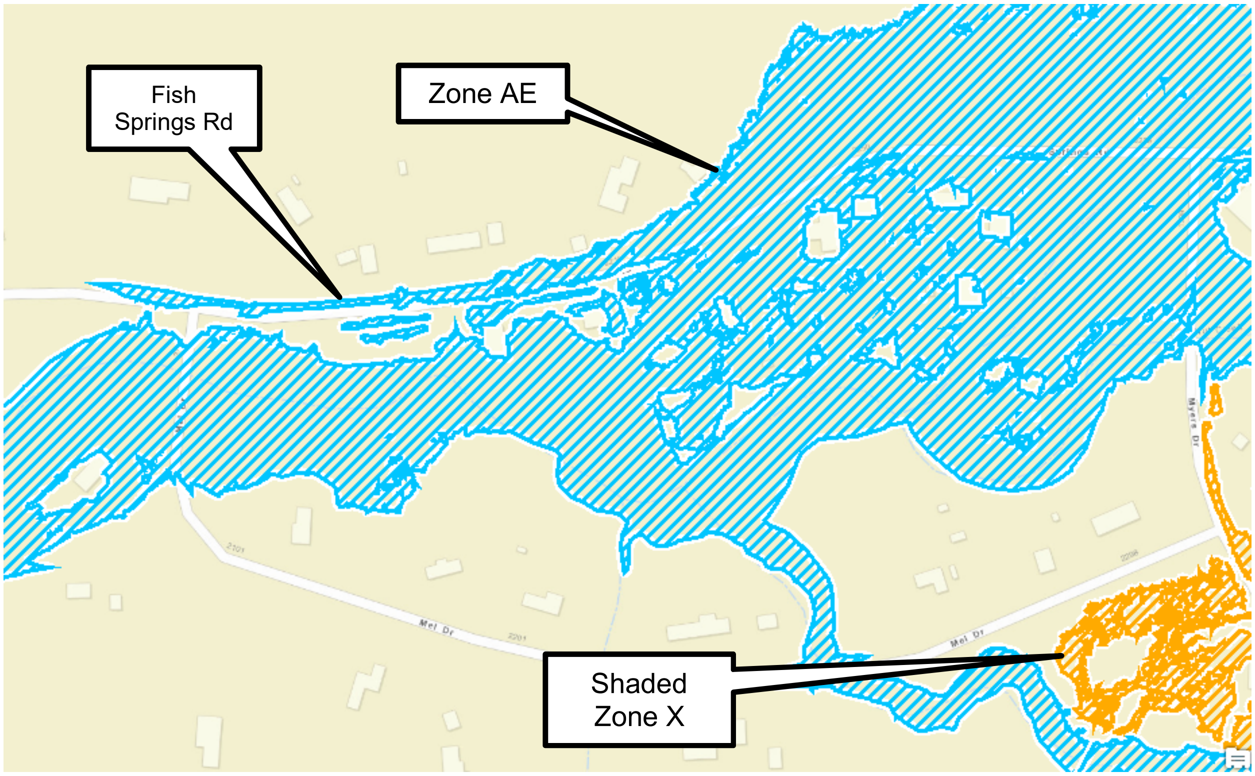


Figure 23: Updated Mapping Example

Base Flood Elevations

Base flood elevations (BFE) were determined for the 1%- annual-chance floodplain for those portions of the 6 study reaches that are proposed to be re-mapped as Zone AE. Base flood elevations range from 4859.8 ft. up to 5321.2 ft. (NAVD88) over the entire study extent. A maximum WSE raster file was created in RAS Mapper and exported to a final result file with a 2-foot cell size resolution using ESRI ArcMap. BFE contour lines were developed from the maximum WSE raster using the ArcMap contour tool. An initial set of BFE lines using a one-foot contour interval were created for use in the work maps and annotated FIRMs.

Examination of the maps indicated that in some areas, the complex water surface profile would not be sufficient to allow proper interpolation of maximum WSE between the one-foot BFE lines to a 0.1-foot level of accuracy. Based upon the “Mapping Base Flood Elevations on Flood Insurance Rate Maps” draft FEMA guidance document (FEMA, 2020), additional BFE lines using a 0.2-foot contour interval were developed in ArcMap. These lines were added to the work maps where the 0.2-foot interval BFEs indicated the slope of the maximum WSE profile between the one-foot interval BFEs was not linear, or where more detail was needed to define the maximum WSE profile. To avoid “crowding” of labels upon the work maps, these 0.2-foot BFE lines are not labeled on the work maps, and are symbolized with a different line color and weight than the one-foot interval BFEs.

Profiles

The use of a 2D model to simulate and map complex hydraulic settings with highly bifurcated flow patterns such as the Pine Nut Creek watershed provides a challenge in developing traditional flood hazard profiles. The use of 2D models such as HEC-RAS 5.0.7 does not lend itself to the selection of a single profile for each frequency as water surface elevations may not be consistent across the channel as in a 1D model. Areas that experience super elevation around a bend, for example, have variable water surfaces across the channel. It is difficult therefore to select a single water surface profile in a 2D setting. This issue is discussed in the draft FEMA Flood Profiles Guidance document (FEMA, 2020). Based on these issues, flood profiles have not been developed for the reaches being re-mapped.

Limitations

It should be noted that several sources of uncertainty in the physical setting, modeling assumptions, and modeling methodologies exist that could impact the accuracy of the results presented in this report.

A recent wildfire, referred to as the “Numbers” fire, began on July 6, 2020, and burned a total of 18,380 acres in an area within and near the region analyzed in this study. The fire was reported as being fully contained on July 13, 2020. See Figure 24 for an approximate location and extent of this wildfire with the Pinenut Creek watershed overlain to indicate how much of the basin was impacted by this fire. The base map used for this figure was obtained from inciweb.nwcg.org.

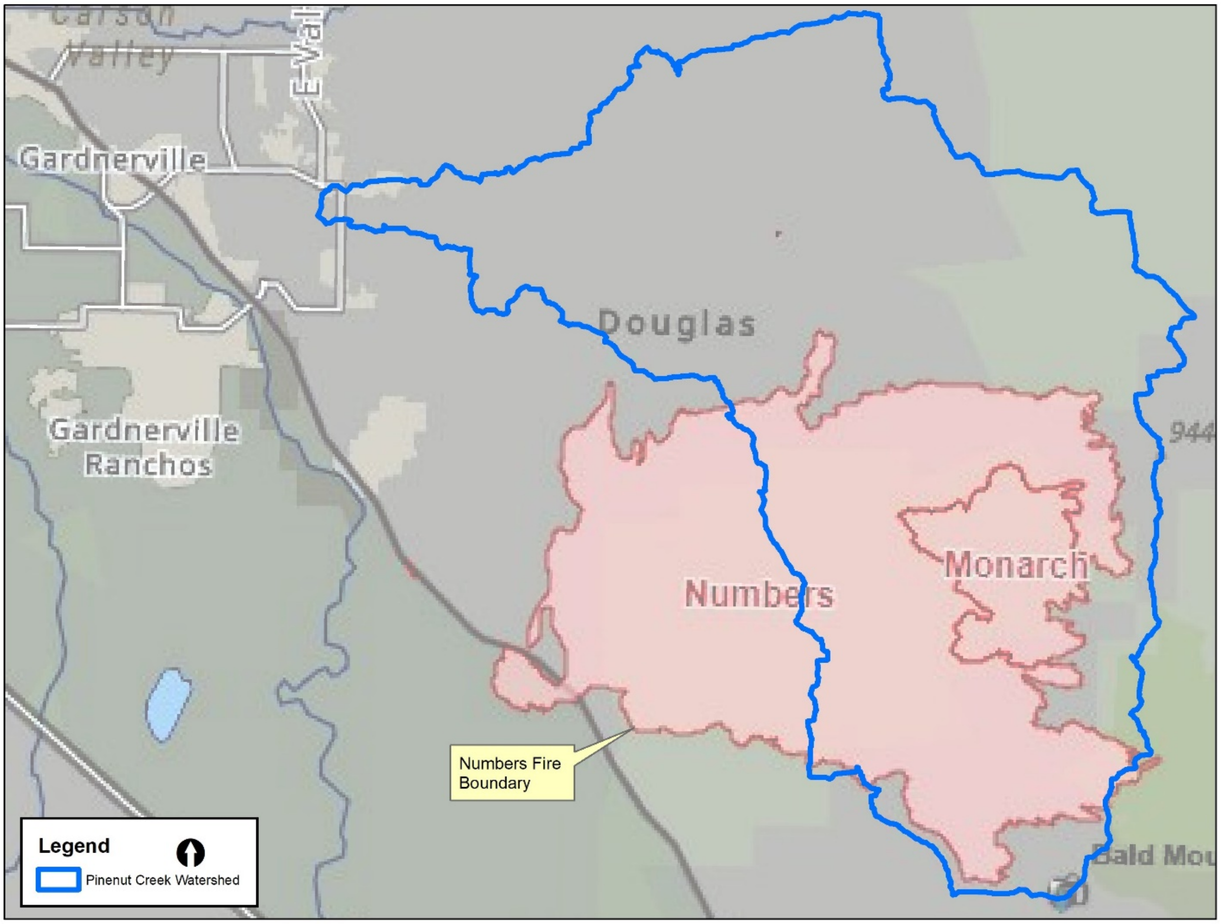


Figure 24: Approximate location and extents of the Numbers fire. This fire took place between July 6, 2020 and July 13, 2020.

The potential impact of the fire upon land cover within the study domain has not been explicitly assessed, but it is assumed that loss of vegetation and possible alteration of the runoff characteristics of the soils in the watershed would be likely to increase peak discharges produced in the basin when compared to the pre-burned condition. Given the arid climate, it is likely that vegetation in the region will take decades to fully recover. Damage to pinion pines would be especially long-lasting, as these trees grow quite slowly. Sagebrush and other shrub/brush vegetation will tend to recover more rapidly than the pinions.

No assessment has been made of the potential impact of climate change upon the hydrology of the region. Climate change could tend to increase the intensity of storm events in this area, which would increase the peak discharge rates occurring in these drainages. In addition, it should be recognized that the NOAA Atlas 14 precipitation data, along with the stochastic analysis of Buckeye Creek, assume a homogeneous period of record. This assumption may not be valid due to changes in storm frequency and intensity that may occur due to climate change.

The hydraulic modeling conducted assumes a rigid boundary of the streams being analyzed. No estimate was made of the potential for erosion or lateral migration to occur along these waterways. It would be prudent for floodplain managers to consider the use of erosion setback zones when developing future floodplain management policies.

Erosion of roadways and berms could alter the flow behaviors in the shallow flooding areas within this region, resulting in different flooding patterns and depths than those presented here.

Impacted Properties and Property Owner Notification

Individual notification requirements as indicated in 44CFR60 will be followed. All property owners impacted by increases to the base flood elevations, floodway, and/or Zone AE floodplain boundaries within the new detailed study reach will be notified by mail. In addition, a public notice describing the changes to the flood zones will be published in the local newspaper. A GIS analysis was conducted to identify parcels impacted by increases to the flood zones, and a spreadsheet was created to catalog each parcel affected by the changes and what impacts will occur on that property. This spreadsheet, along with sample letters for each impact scenario, are included in Appendix C. Appendix C also includes maps showing the proposed flood mapping, along with effective FEMA flood zones, overlaid with the Assessor's parcel base. These maps are intended to allow Douglas County to provide each impacted property owner with a graphic representation of the effective and proposed flood hazard mapping at their property. The impacted parcels spreadsheet includes a column that indicates the map panels that each impacted parcel is displayed upon. This can be used to create a packet for each property owner that will include appropriate impact notification letter, and the impact map(s) that will show the proposed changes to their property.

Community Coordination

The Carson Water Subconservancy District contracted with HDR Engineering for this re-mapping effort, under a Cooperating Technical Partners (CTP) grant from the Federal Emergency Management Agency. Only properties within unincorporated Douglas County will be affected by this map revision, no other communities fall within the study area. As described above, public notification of the map revision will be provided by notification published within the local newspaper, as well as by notification letters and maps sent to individual property owners affected by the revisions.

MT-2 Forms

The following forms are included in Appendix D of this document:

- Overview and Concurrence Form
- Riverine Hydrology & Hydraulic Forms. This LOMR includes the following streams:
    - Cody Wash
    - Cody Wash Tributary
    - Fish Springs Creek
    - Pine Nut Creek

- Pine Nut Creek Tributary
- Sheena Terrace Wash

- Riverine Structures Forms. This LOMR includes the following:
    - Bray Way
    - Cll Pequeno
    - Creek Drive
    - E. Valley Road
    - Jacobsen Lane
    - Jacobsen Lane 2
    - Jacobsen Lane 3
    - Jo Lane
    - Lupo Lane
    - Mel Drive
    - Mel Drive 2
    - Myers Drive
    - Mormon Way
    - Out-R-Way
    - Sheena Terrace
    - Springs Road
    - Unnamed Crossing
    - Windmill Drive

Survey/Topographic Data

LiDAR data collected by Quantum Spatial, Inc. was used as the basis of the topographic data for this re-mapping effort. This data is included in Appendix E, along with supporting metadata files and the technical data report provided by Quantum Spatial.

All hydraulic structures present along the streams being re-mapped were surveyed by Lumos & Associates prior to the hydraulic modeling effort. This data was used to accurately represent these structures within the hydraulic model. The survey data was provided in csv format, and has also been compiled into a single Excel spreadsheet, titled “Master Survey List.xlsx”. This data is included in Appendix E.

Field Photos

Field Photos were obtained during the hydraulic structure survey to assess the current conditions in the reach and verify culvert configurations. Site photos were used to assess Manning's n hydraulic roughness values and to identify any hydraulic anomalies in the reach. Field photos are included in Appendix F.

Electronic Files

The following supporting electronic files are included in Appendix G:

- Effective models and workmaps
- GIS Data
  - Manning's n layer (Mannings_n_Polygons.shp)
  - 1-percent annual chance floodplain (in S_FLD_HAZ_AR.shp)
  - Floodway boundaries (in S_FLD_HAZ_AR.shp)
  - 0.2-percent annual chance floodplain (in S_FLD_HAZ_AR.shp)
  - BFEs (1-foot contour interval, in S_BFE.shp)
  - Supplemental BFEs at a 0.2-foot contour interval (in Supplemental_1_PCT_Max_WSE_0_pt_2_Ft_Contours.shp)
  - 100-Year maximum water surface elevation raster file (100Yr_Max_WSE.tif)
  - 100-Year maximum depth raster file (100Yr_Max_Depth.tif)
  - Floodway maximum WSE Contours (1-foot contour interval, in Floodway_1_Ft_WSE_Contours.shp)
  - Cody Wash floodway maximum water surface elevation raster file (Cody_Wash_Floodway_Max_WSE.tif)
  - Cody Wash floodway maximum depth raster file (Cody_Wash_Floodway_Max_Depth.tif)
  - Cody Wash floodway surcharge raster file (Cody_Wash_Floodway_Surcharge.tif)
  - Pinenut Tributary floodway maximum water surface elevation raster file (Pionenut_Trib_Floodway_Max_WSE.tif)
  - Pinenut Tributary floodway maximum depth raster file (Pinenut_Trib_Floodway_Max_Depth.tif)
  - Pinenut Tributary floodway surcharge raster file (Pinenut_Trib_Floodway_Surcharge.tif)
  - Stream centerlines (S_Profil_Basln.shp)
  - 2-foot Topographic Contours (2ft_contours.shp)

- Modeling
    - HEC-HMS Model Files
    - HEC-RAS Hydraulic Model Files
    - HEC-RAS rain-on-grid Model Files
    - HEC-SSP Model Files
- Mapping
    - Workmaps
    - Floodway Workmaps
    - Annotated FIRMs
- Reporting
    - Electronic PDF version of the LOMR report

Submittal File Structure:

- Appendix A - Mapping
- Appendix B - WSE Profiles
- Appendix C - Notification
- Appendix D - MT-2 Forms
- Appendix E - Survey Data
- Appendix F - Photos
- Appendix G - Modeling & Results
    - Effective Models & Workmaps
    - GIS Data
    - HEC-HMS Model
    - HEC-RAS Hydraulics Model
    - HEC-RAS Rain_on_Grid Model
    - HEC-SSP Model
- Report

References

Federal Emergency Management Agency (2015). Guidance for Flood Risk Analysis and Mapping. Federal Emergency Management Agency, November 2015.

Federal Emergency Management Agency (2016). Flood Insurance Study Douglas County, Nevada and Incorporated Areas. Flood Insurance Study number 32005CV000B, Revised: June 15, 2016.

Federal Emergency Management Agency (2020). Guidance for Flood Risk Analysis and Mapping. Flood Profiles. Federal Emergency Management Agency, November 2020.

Federal Emergency Management Agency (2020). Guidance for Flood Risk Analysis and Mapping. Floodway Analysis and Mapping. Federal Emergency Management Agency, November 2020.

Federal Emergency Management Agency (2020). Guidance for Flood Risk Analysis and Mapping. Mapping Base Flood Elevations on Flood Insurance Rate Maps. Federal Emergency Management Agency, November 2020.

U.S. Army Corps of Engineers (1980). Hydrology Office Report Truckee River California and Nevada, February 1980.

U.S. Army Corps of Engineers (2016). HEC-RAS Users Manual Version 5.0 and Hydraulic Reference Manual Version 5.0.

U.S. Department of Agriculture, Soil Conservation Service (1972). SCS National Engineering Handbook, Section 4, Hydrology. August 1972.

U.S. Department of Agriculture, Natural Resources Conservation Service (1999). Urban Hydrology for Small Watersheds, Technical Release 55, January 1999.

U.S Department of Commerce, National Oceanic and Atmospheric Administration (2011). Precipitation-Frequency Atlas of the United States, Volume 1, Version 5.0: Semiarid Southwest (Arizona, Southeast California, Nevada, New Mexico, Utah), 2011.

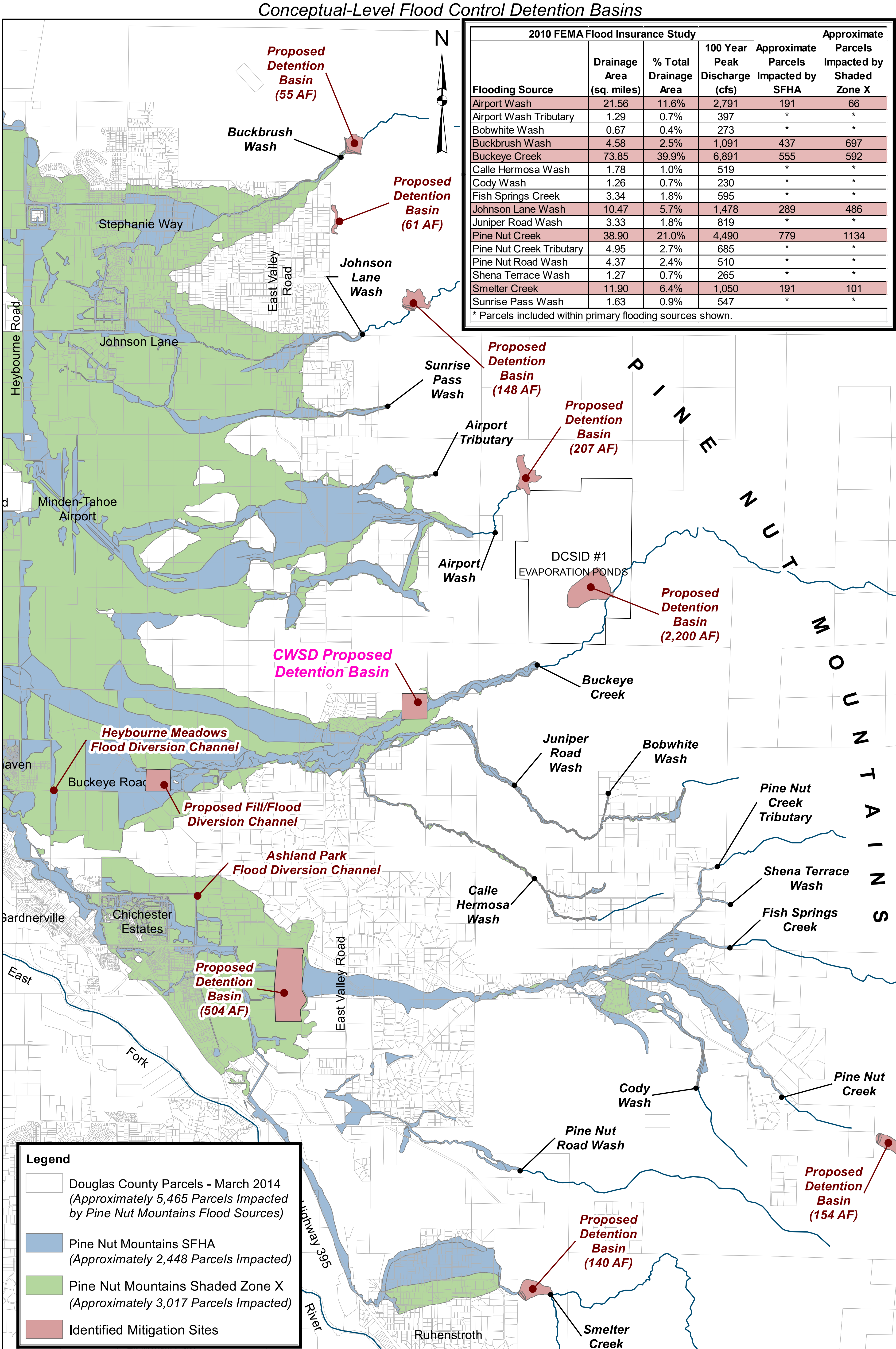
U.S. Geological Survey (1997). Methods for Estimating Magnitude and Frequency of Floods in the Southwestern United States. Water-Supply Paper 2433. 1997.

RO ANDERSON

Douglas County, Nevada: Pine Nut Mountains Flood Sources

PARCEL FLOOD IMPACT ANALYSIS

Conceptual-Level Flood Control Detention Basins



2010 FEMA Flood Insurance Study				Approximate	Approximate
Flooding Source	Drainage Area (sq. miles)	% Total Drainage Area	100 Year Peak Discharge (cfs)	Parcels Impacted by SFHA	Parcels Impacted by Shaded Zone X
Airport Wash	21.56	11.6%	2,791	191	66
Airport Wash Tributary	1.29	0.7%	397	*	*
Bobwhite Wash	0.67	0.4%	273	*	*
Buckbrush Wash	4.58	2.5%	1,091	437	697
Buckeye Creek	73.85	39.9%	6,891	555	592
Calle Hermosa Wash	1.78	1.0%	519	*	*
Cody Wash	1.26	0.7%	230	*	*
Fish Springs Creek	3.34	1.8%	595	*	*
Johnson Lane Wash	10.47	5.7%	1,478	289	486
Juniper Road Wash	3.33	1.8%	819	*	*
Pine Nut Creek	38.90	21.0%	4,490	779	1134
Pine Nut Creek Tributary	4.95	2.7%	685	*	*
Pine Nut Road Wash	4.37	2.4%	510	*	*
Shena Terrace Wash	1.27	0.7%	265	*	*
Smelter Creek	11.90	6.4%	1,050	191	101
Sunrise Pass Wash	1.63	0.9%	547	*	*

* Parcels included within primary flooding sources shown.

1 0.5 0 1 Miles

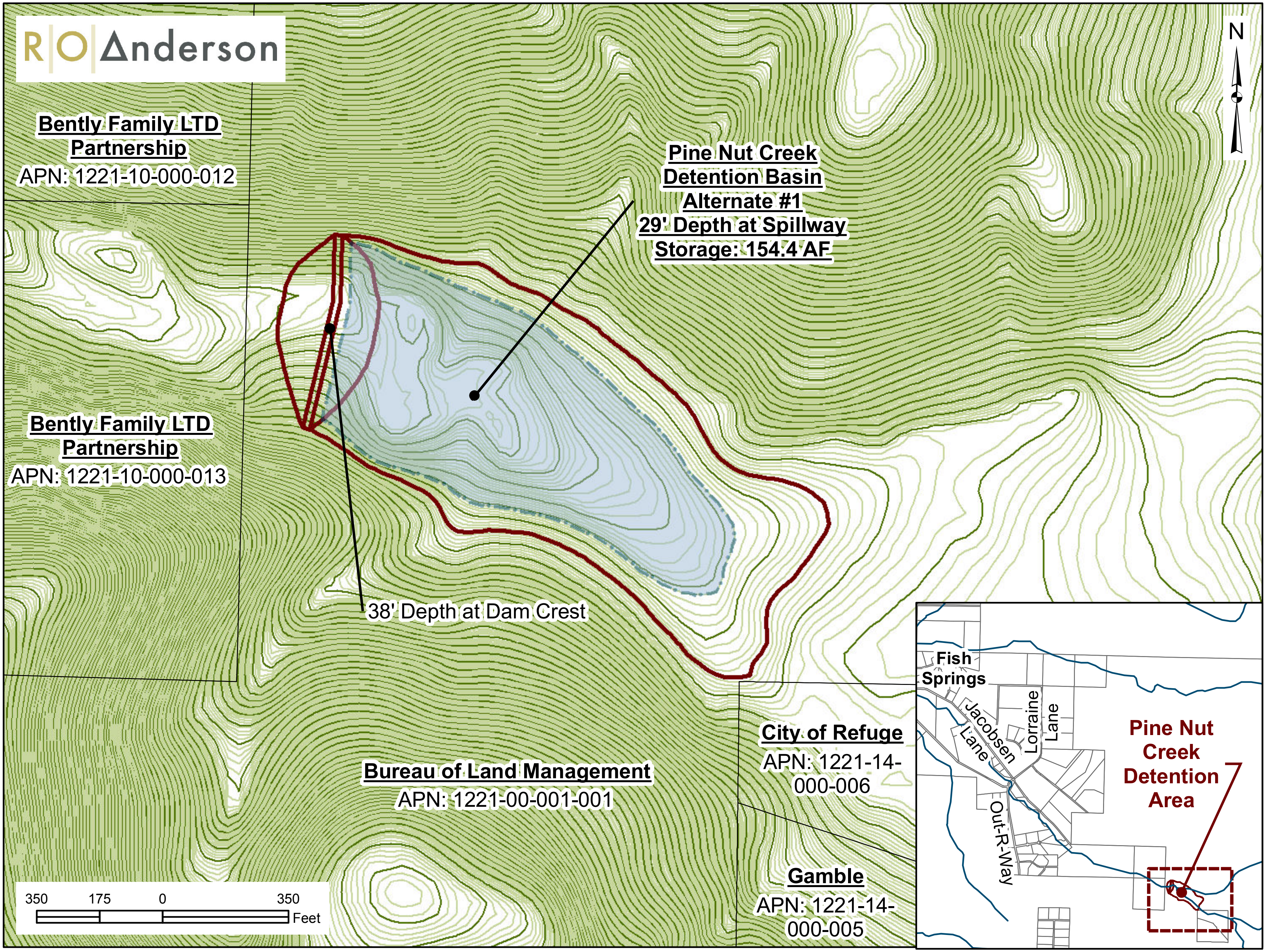
Scale: 1" = 1 Mile

R|O Anderson

EXHIBIT A

Print Date:11/19/2021

File Name: L:\Processed\NV\ROA\Carson River Basin\FloodZones.mxd


R|O Anderson
N
Bently Family LTD Partnership
APN: 1221-10-000-012
Pine Nut Creek Detention Basin Alternate #1
29' Depth at Spillway
Storage: 154.4 AF
Bently Family LTD Partnership
APN: 1221-10-000-013
38' Depth at Dam Crest
City of Refuge
APN: 1221-14-000-006
Bureau of Land Management
APN: 1221-00-001-001
Gamble
APN: 1221-14-000-005
350 175 0 350
Feet
Fish Springs
Jacobsen Lane
Lorraine Lane
Out-R-Way
Pine Nut Creek Detention Area

Appendix G: Topography Supporting Documentation

LiDAR Project Report

G17PD01257, NV Reno Carson City Urban

Prepared For:

United States Geological Survey

Prepared By:

Digital Aerial Solutions, LLC

CONTRACT: # G16PC00044
CONTRACTOR: DIGITAL AERIAL SOLUTIONS
TASK ORDER: # G17PD01257

Project Report
LiDAR Collection, Processing, and QA/QC

G17PD01257, NV Reno Carson City
Urban

Prepared For:
US Geological Survey
1400 Independence Road
Rolla, MO 65401
Phone: (573) 308-3759

Prepared By:
Digital Aerial Solutions, LLC
4027 Crescent Park Drive
Riverview, FL
33578
Phone: (813) 628-0788

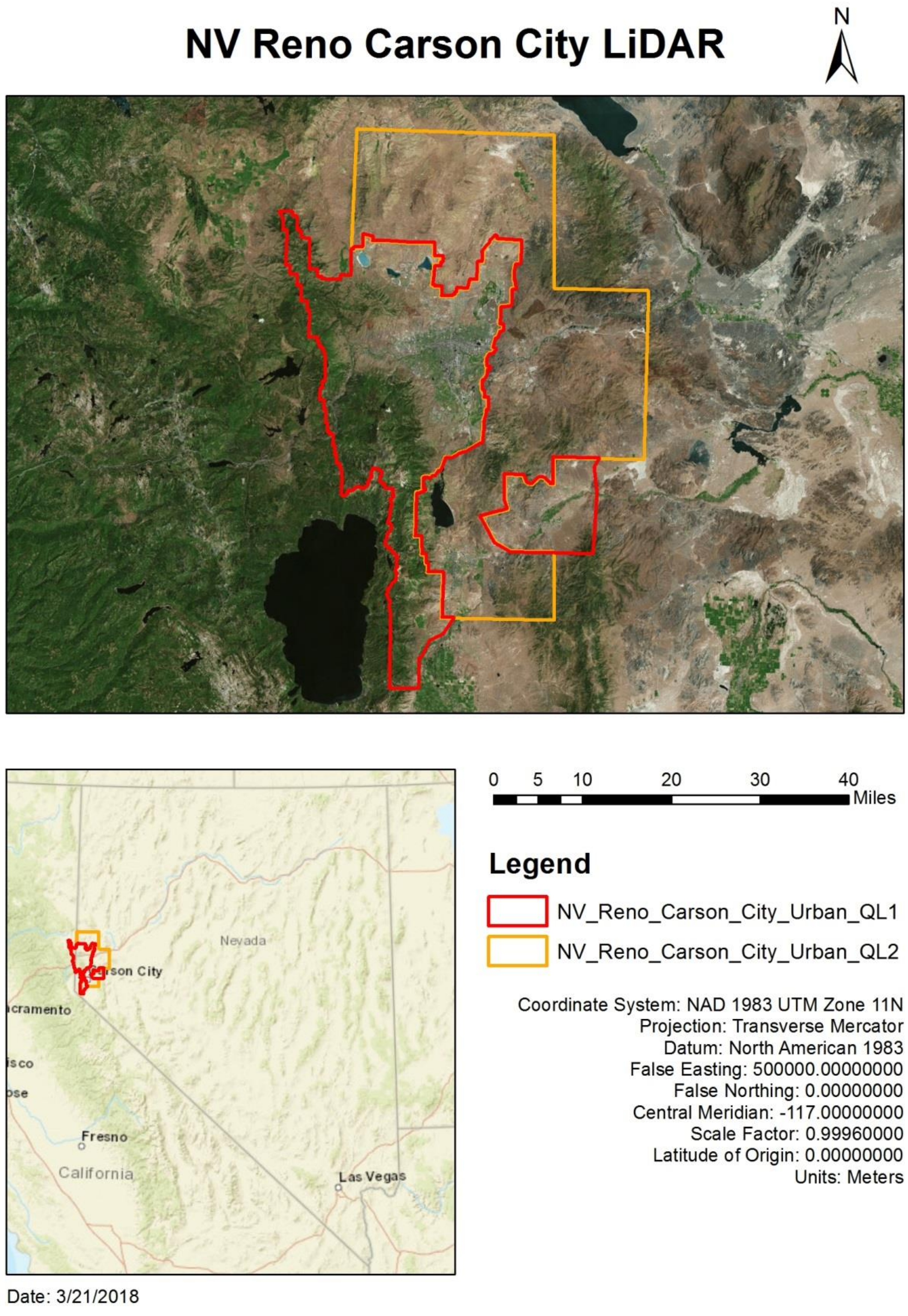


Image 1: NV Reno Carson City Urban LiDAR AOI

Table of Contents

1 Introduction and Specifications

Digital Aerial Solutions, LLC (DAS) was tasked to collect and process a Light Detection And Ranging (LiDAR) derived elevation dataset for the G17PD01257, NV Reno Carson City Urban LiDAR. The area encompasses approximately 1534 square miles Aerial LiDAR data was collected utilizing a Leica ALS80. The ALS80 is a discrete return topographic LiDAR mapping system manufactured by Leica Geosystems. LiDAR data collected for the G17PD01257, NV Reno Carson City Urban LiDAR survey has an Aggregate Nominal Pulse (ANPS) spacing of (QL1 0.35 meters) and (QL2 0.7 meters), and includes up to 4 discrete returns per pulse, along with intensity values for each return.

LiDAR datasets were post processed to generate elevation point cloud swaths for each flight line. Deliverables include the point cloud swaths, tiled point clouds classified by land cover type, breaklines to support hydro-flattening of digital elevation models (DEM)s, intensity tiles, and bare-earth DEM tiles. The point cloud deliverables are stored in the LAS version 1.4, point data record format 6. The tiling scheme for tiled deliverables is a 1000 meter x 1000 meter grid. Tile number is the appropriate cell number values found in the USNG index. All deliverables were generated in conformance with the U.S. Geological Survey National Geospatial Program Guidelines and Base Specifications, Version 1.3.

2 Spatial Reference System

The spatial reference of the data is as follows:

Horizontal Spatial Reference

- Coordinates: UTM Zone 11 N, Meters (to 2 decimal places)
- Datum: North American Datum 1983 (2011), Meters (to 2 decimal places)

Vertical Spatial Reference

All datasets are available with orthometric elevation; point cloud datasets are also available with ellipsoid heights.

- Datum: North American Vertical Datum of 1988 (GEOID12B)

3 LiDAR Acquisition

3.1 Survey Area

The NV Reno Carson City Urban LiDAR survey covers approximately 676 square miles for the QL1 area of interest and 858 square miles for the QL2 area of interest. Totaling 1534 square miles covering all of Washoe, Storey, Carson City and Lyon counties in NV. The flight plan consisted of 610 survey lines and 4 control lines.

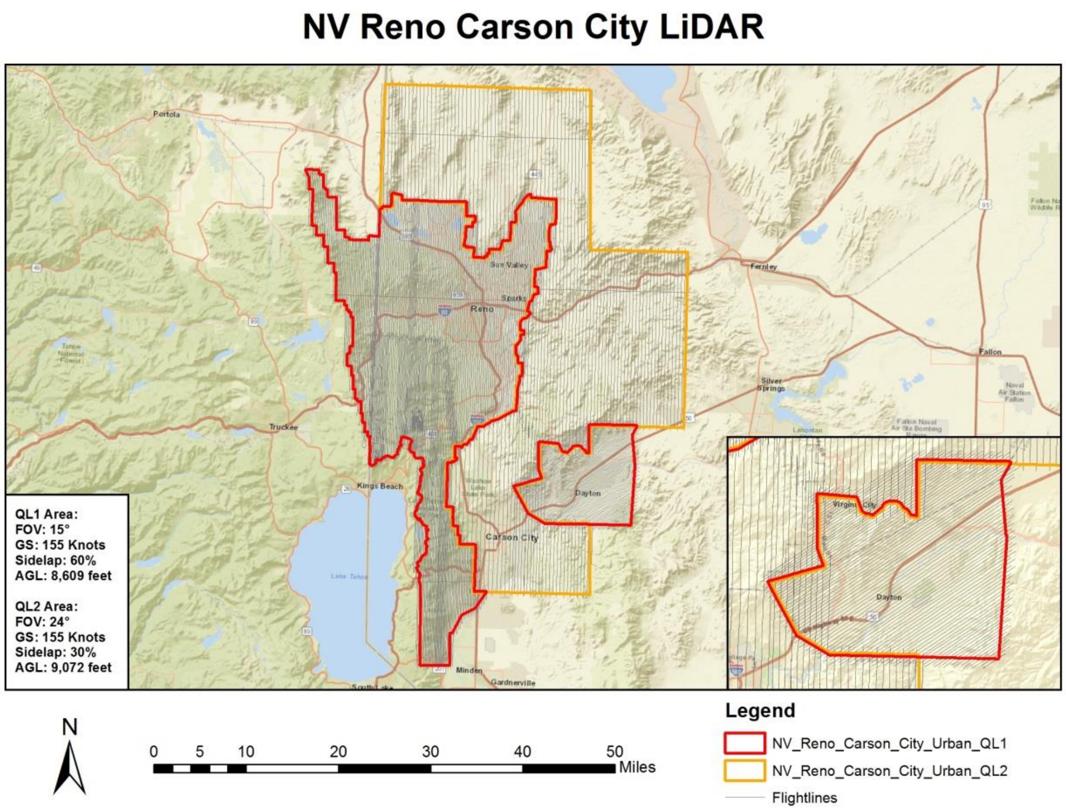


Image 2: NV Reno Carson City Urban LiDAR Flightlines

3.2 Acquisition Parameters

Acquisition parameters include the sensor configuration and the flight plan characteristics, and are selected based on a number of project specific criteria. Criteria reviewed include the required accuracies for the final dataset, the land cover types within the project survey area, and the required nominal pulse spacing. Aggregate Nominal Pulse Density (ANPD) for QL1 AOIs are no less than 8ppsm and for the QL2 AOIs are no less than 2ppsm. The project parameters are summarized below.

Parameter	QL1	QL2
Flying Height Above Ground Level:	8,609 feet	9,072 feet
Nominal Sidelap:	60%	30%
Nominal Speed Over Ground:	155 Knots	155 Knots
Field of View:	15°	24°
Laser Rate:	220.2 kHz	206.2 kHz
Scan Rate:	65.2 Hz	49.2 Hz
Maximum Cross Track Spacing:	1.22 meters	1.62 meters
Maximum Along Track Spacing:	0.61 meters	0.81 meters
Average point Spacing:	0.50 meters	0.67 meters

Table 1: Flight Parameters

3.3 Acquisition Mission

The acquisition mission for the G17PD01257, NV Reno Carson City Urban LiDAR survey was coordinated for optimal collection conditions and was acquired within 6 weeks. Collection began on September 19, 2017 and was completed on October 27, 2017.

3.4 Airborne GPS/IMU

Airborne global positioning system (GPS) and inertial measurement unit (IMU) data was collected on the aircraft during the acquisition mission, providing sensor position and orientation information for geo- referencing the LiDAR data. Airborne GPS observations were collected at a frequency of 2Hz, and IMU observations are collected at a frequency of 200Hz.

Aircraft	Sensor	GPS Lever Arm (m)	IMU Lever Arm (m)
C421-N12RF	ALS80 SN# 8137	X: -0.153, Y: -0.055, Z: -1.361	X: -0.219, Y: 0.297, Z: 1.192

Table 2: Aircraft and Lever Arms

GPS data was collected with ground base stations during the acquisition missions, providing corrections to support differential post-processing of the airborne GPS. Base stations were setup at

Minden-Tahoe Airport NV. Ground GPS observations were collected at a frequency of 2Hz. The use of three CORS stations was also employed to support data acquisition for the project area. The following table's list the positions used in to post-process the airborne GPS.

Name	Latitude	Longitude	Ellipsoid (m)
Minden-Tahoe Airport – KMEV	38° 59' 52.40797"	-119° 45' 22.01331"	1409.811
Minden-Tahoe Airport – KMEV1	38° 59' 52.32560"	-119° 45' 22.16652"	1409.803
CORS – COF1	39° 36' 18.05072"	-119° 14' 26.22857"	1252.459
CORS – DOT1	39° 09' 22.30087"	-119° 45' 48.33047"	1416.299
CORS – P143	38° 45' 36.58657"	-119° 45' 53.35851"	1734.123

Table 3: Base Stations locations

4 LiDAR Processing

4.1 Acquisition Post-Processing

For each mission, airborne GPS was differentially corrected using the ground base station GPS for the corresponding day in Leica's IPAS software. The resulting solution is check to assure an accuracy of +/- 3 cm combined separation for north, east and height position difference between the forward and reverse processing solutions.

Differentially corrected airborne GPS data was merged with the airborne IMU dataset in Leica's IPAS software through Kalman filtering techniques. IPAS applies the reference lever arms for the GPS and IMU measurement systems during processing to determine the trajectory (position and orientation) of the LiDAR sensor during the acquisition mission. Estimated lever arm values reported posteriori validate the measurements made during sensor installation in the aircraft.

Raw LiDAR sensor ranging data and the final sensor trajectory from IPAS were processed in Leica's ALSPP software to produce the LiDAR elevation point cloud swaths for each flight line, stored in LAS version 1.2 file format. Quality control of the swath point clouds was performed to validate proper function of the sensor systems, full coverage of the project AOI, and point density consistent with the planned nominal pulse spacing.

Swath point clouds were assigned a unique File Source ID within the LAS file format before further processing. Swath files for the G17PD01257, NV Reno Carson City Urban LiDAR project were numbered in chronological order of acquisition.

4.2 Geometric Calibration

Geometric and positional accuracy of the LiDAR swath point clouds is highly dependent on accurate calibration of the various subsystems within the LiDAR sensor system. Sensor calibration parameters fall into two categories, one being those parameters proprietary to the manufacturer's sensor design, and the other being parameters common to most commercial airborne LiDAR sensors, the IMU to laser reference system alignment angles (bore-site), and mirror deformation constants (scaling).

The manufacturer specific calibration parameters are applied in Leica's ALSPP software for the Leica ALS80 sensor system. Terrasolid's Terramatch software was used to calculate the IMU bore-site and mirror scale parameters for the G17PD01257, NV Reno Carson City Urban LiDAR. Within the TerraMatch software, the Tie- line workflow was used to solve for the parameters. The Tie-line workflow involves automated selection of numerous 'tie-lines', which represent a linear segment fit to the data that should have the same slope, azimuth, position and elevation, within the overlap sections of the survey lines and control lines. The tie- lines provide observations for algorithms within TerraMatch to solve for the bore-site and mirror scale parameters for the lift.

The Tie-line workflow is dependent upon well distributed tie-lines throughout the swath point clouds to effectively solve for bore-site and mirror scale parameters with the automated algorithms.

Manual estimation of the bore-site and mirror scale parameters was performed using the observed tie-lines in overlap areas.

The final step of geometric calibration is to determine elevation (z) offset corrections to be applied to the swath point clouds. The Z values calculated during the course of the acquisition mission can vary at the centimeter level as the GPS satellite constellation observed in the survey area changes with satellites moving through their orbits over the course of the mission. Baseline length from the ground base station GPS to the airborne GPS can also impact the z values calculated for the swath point clouds. The Z offset corrections are calculated in two steps; a relative step, where individual lines are corrected one to another using the adjusted tie-lines from the bore-site and mirror scale calculation step; and an absolute step, where groups of lines are leveled to project ground control.

For G17PD01257, NV Reno Carson City Urban LiDAR project, the control lines were used to determine relative z offset corrections in areas of discernible ground. The ground control points listed below were used to adjust the LiDAR by an average of -0.180 cm.

Point Id	Easting	Northing	Orth. Height
04.GCP.BG.01	620192.726	5064157.33	891.6397
08.GCP.BG.01	625950.124	5081209.372	920.0333
08.GCP.BG.01A	602777.4524	5031062.218	1066.0656
GCP.BG.01	260969.099	4338273.65	1423.118
GCP.BG.10	277392.198	4356378.341	1648.38
GCP.BG.11	277392.199	4356378.343	1648.371
GCP_NVA.BG.02	256020.902	4329290.092	1528.339
GCP_NVA.BG.03	250244.158	4318040.241	2163.541
GCP_NVA.BG.04	272152.037	4347496.544	1554.815
GCP_NVA.BG.06	271231.517	4353733.3	1907.229
GCP_NVA.BG.07	271263.717	4359012.689	2074.733
GCP_NVA.BG.11	252561.759	4358148.771	2308.951
GCP.HP.01	258003.661	4344308.104	1550.248
GCP.HP.02	272445.392	4375771.769	1338.888
GCP.HP.11	282521.926	4353104.002	1323.601
GCP.HP.12	257558.262	4403563.812	1563.345
GCP_NVA.HP.03	259189.646	4332992.955	1480.408
GCP_NVA.HP.06	263293.752	4332298.771	1438.997
GCP_NVA.HP.08	270245.594	4344174.034	1481.727
GCP_NVA.HP.09	256091.814	4362654.773	1771.648
GCP_NVA.HP.16	260442.59	4341638.183	1442.508
GCP_NVA.HP.24	280973.185	4381806.092	1308.072
GCP_NVA.LV.10	261848.55	4352267.561	1569.989
GCP.PS.01	248807.55	4392717.7	1520.357
GCP.PS.02	256445.016	4416808.361	1513.873
GCP_NVA.PS.04	256325.956	4333359.564	1631.584
GCP_NVA.PS.06	252854.437	4332996.338	1824.366
GCP_NVA.PS.08	265773.119	4332626.121	1415.375
GCP_NVA.PS.13	265301.972	4372050.22	1347.786
GCP_NVA.PS.18	252471.425	4400483.183	1575.459
GCP_NVA.PS.28	264254.101	4412809.06	1476.773
GCP_NVA.PS.30	269039.062	4400110.38	1434.329
GCP_NVA.PS.31	267592.54	4391765.602	1372.906

Table 5: Ground Control Points

The final geometrically calibrated swath point clouds were compared to the bare-earth profile survey data. The data fit the profile surveys within the vertical accuracy tolerance specified for the project. Full documentation of the vertical accuracy checks maybe found in section 5.1.

4.3 Point Cloud Classification

Georeference information was applied to the swath point cloud LAS files. Geometrically calibrated swath point clouds were cut into USNG index, 1000 meter x 1000 meter LAS 1.2 format tiles for point cloud classification and derived in LAS 1.4 format for product creation.

Tiled point cloud data was processed in Terrasolid's Terrascan software to assign initial classification values. The Terrascan software provides a number of routines to algorithmically detect and assign points to their appropriate class. Points left unclassified by the algorithmic routine remain as Class 1

– Processed, but unclassified. Automated classification routines assigned points to one of the following classes:

```
Class 1 – Processed, but unclassified
Class 2 – Bare-earth ground
Class 7 – Low Noise (low, manually identified, if necessary)
Class 9 — Water
Class 17 — Bridge Decks
Class 18 – High Noise (high, manually identified, if necessary)
Class 20 — Ignored Ground (Breakline Proximity)
```

Automated classification results were reviewed for each tiled point cloud, and manual edits made where necessary to correct for misclassified points. Points remaining in Class 1 after the automated classification routines were run were left in Class 1. Points falling outside of a 100 meter buffer of the project AOI polygon were excluded from the tiled point clouds.

4.4 Breakline Collection

Manual breakline collection was performed to support the hydro-flattening requirements of the project's DEM deliverables. Breaklines were collected directly from the classified point clouds and from triangulated irregular network (TIN) surface models built from the classified point clouds, in Terrasolid's Terrascan and Terramodeler software. Breakline features were collected as design file elements in Bentley's Microstation software. Breaklines were converted to ESRI 3D shapefile format for the breakline deliverable, and tiled to USNG index.

The data collected for the G17PD01257, NV Reno Carson City Urban LiDAR survey maintained significant point density in the water, marsh, and swamp, limiting the usefulness of point density as guiding factor in breakline placement.

Points classified as Class 2 – Bare-earth ground, falling within a one meter buffer of the collected breaklines, were reassigned to Class 20 – Ignored Ground. These points are excluded from the surface model during DEM generation to preserve the hydro-flattening characteristics of the breaklines.

4.5 DEM Generation

The final classified point clouds and collected breaklines were reviewed for completeness and conformance to the task order scope of work. Within the Terramodeler software, points in Class 2 – Bare- earth ground and the breaklines were combined to generate TIN elevation models for each tile, from which the bare-earth DEM tiles were interpolated and exported as ERDAS Imagine 32-bit floating point raster format ".img" format.

5 Quality Control

5.1 Point Clouds

Accuracy and completeness of the LiDAR point clouds directly impacts the quality of all other derived LiDAR derived products. Ensuring a quality LiDAR dataset begins with proper mission planning and execution. Ground GPS base stations are located such that GPS baselines between the ground and airborne receivers do not exceed 30km. For the G17PD01257, NV Reno Carson City Urban LiDAR project, two base stations were run to meet this requirement, one at the field operations airport and one within the survey area. Static alignment is performed both before take-off and after landing to allow for GPS integer ambiguity resolution. Sensor operators carefully monitor the LiDAR unit and its various subsystems during the acquisition mission to ensure proper function. Airborne GPS positional dilution of precision (PDOP) estimates are monitored to ensure they remain less than 3.The optical system is monitored to ensure there are no ranging errors encountered during the flight lines.

During acquisition post-processing estimates of the trajectory data accuracy are reviewed to ensure they will support the required accuracies of the point cloud data. The trajectory accuracy is a function of the differentially corrected GPS data and the IMU data.

The raw swath point clouds generated from ALSPP are reviewed as another check for proper sensor function. The point clouds are reviewed for full coverage of the AOI, required point density and nominal pulse spacing, clustering, proper intensity values, full swath coverage within the planned field of view, and planned survey line overlap.

Geometric calibration quality control validates that the positional accuracy requirements of the project are met, and includes relative accuracy assessments for intra-swath (within) and inter-swath (between) accuracy, along with absolute accuracy assessments against project ground control.

Image 3: NV Reno Carson City Urban LiDAR QL1 Intensity Image

Relative vertical accuracy assessments are normally made using the tie-lines generated in the Terramatch software, as these lines provide positional observations throughout the extent of individual swaths, and between neighboring swaths.

This data set was produced to meet ASPRS "Positional Accuracy Standards for Digital Geospatial Data" (2014) for a 22.6 (cm) RMSEx / RMSEy Horizontal Accuracy Class which equates to Positional Horizontal Accuracy =+/- 78.3 cm at a 95% confidence level.

Estimated LiDAR Horizontal:	(cm)
Error Per Point ($RMSE_R$)	32.0
Error Per Point ($RMSE_X$/$RMSE_Y$)	22.6
Per Point at 95% confidence level	78.3

Table 6: Estimated LiDAR Horizontal Accuracy

Absolute vertical accuracy assessments for the point cloud data are made against ground check point data. For the G17PD01257, NV Reno Carson City Urban LiDAR, ground check point data consisted of the ground GPS base station and real-time kinematic (RTK) GPS techniques.

Check point locations were collected at 1 – second intervals during the RTK survey. Points collected during the static pre-initialization and post-initialization was removed from the assessment so as not to bias the assessment.

Local TIN models of the elevation points are built around each ground check points. The tin model elevation is sampled at the horizontal position of the ground check point. The TIN model elevation and ground check point survey elevation values were used to calculate the Non-vegetated Vertical Accuracy (NVA) of the swath point clouds. The NVA of the TIN tested RMSEz 0.051 meters and 0.100 meters at the 95% confidence level in open terrain. NVA of the DEM tested at an RMSEz of 0.053 meters and 0.104 meters at the 95% confidence level in open terrain. The full calculations for all check points can be found in Appendix B.

NVA of TIN		
$RMSE_Z$ =	0.051	meters
NSSDA =	0.100	meters

Table 7: Tested NVA of tin from Classified Point Cloud.

NVA of DEM		
$RMSE_Z$ =	0.053	meters
NSSDA =	0.104	meters

Table 7: Tested NVA of Digital Elevation Model.

The tiled point cloud products were reviewed for full coverage of the AOI and proper classification. As part of the QC process, TINs are built in the Terramodeler software for each tile using the ground class and the hydro-flattening breaklines. The TINs are reviewed for non-ground features, and edited where necessary to remove any remaining non-ground features. Points were also reviewed for absolute elevation, and points falling below the selected orthometric elevation for water were removed from the ground class.

5.2 Breaklines

The final breaklines in ESRI 3D shapefile format were reviewed for topological consistency and correct elevation. Breaklines features are continuous and do not have overlaps or dangles.

5.3 Digital Elevation Models

Digital elevation models (DEMs) were reviewed for conformance with the SOW and the Base Mapping Specification version 1.3 guidelines. DEM files were loaded in the Global Mapper software and inspected visually for edge matching between tiles, void areas within the project AOI, and proper coding of the NODATA values. DEM file naming was verified for consistency with the USNG index.