TECHNICAL MEMORANDUM ◦ FEBRUARY 2017

Gold Butte – Mesquite Reach Ecohydrology Assessment

PREPARED FOR

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Suggested citation:
Stillwater Sciences. 2017. Gold Butte – Mesquite Reach ecohydrology assessment. Prepared by Stillwater Sciences, Berkeley, California for Desert Conservation Program, Las Vegas, Nevada.

Cover photo: View of the Virgin River looking upstream, near Hughes Middle School, Mesquite, NV. Photo taken by Stillwater Sciences on February 13, 2014.

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This reach-scale ecohydrology assessment of the lower Virgin River in the Gold Butte and Mesquite area was prepared by Stillwater Sciences for Clark County under the contract for the Virgin River Baseline Conditions Assessment (CBE 604156-16), with technical input from Dr. Tom Dudley, UCSB. This assessment follows the general approach used in 2013 for a similar assessment of the downstream Mormon Mesa reach (Project Number 2011-PIC-915B) (Orr et al. 2013a,b).

1 BACKGROUND

The assessment area includes the Gold Butte – Mesquite Reach (the Reach), which covers approximately 20 miles (32 km) along the lower Virgin River, from just upstream of the Nevada-Arizona state line downstream through Mesquite to the Gold Butte area in Nevada (Figure 1). The Reach comprises geomorphic reaches 2A, 2B, 2C, and 2D, as previously defined by Stillwater Sciences (2012) during the Phase 1 ecohydrology assessment funded by the Walton Family Foundation, and lies upstream of the Mormon Mesa Reach which was assessed previously (Orr et al. 2013a,b). The southwestern willow flycatcher (*Empidonax traillii extimus*) (SWFL) breeding population in both the Gold Butte-Mesquite Reach and Mormon Mesa Reach had declined in the past several years. This trend coincides with a general decrease in predicted suitable habitat along the Virgin River and in the western portions of the SWFL's range, which is correlated with the recent drought in the western United States and, in some areas such as the lower Virgin River, with shorter-term decreases in habitat quality associated with defoliation of tamarisk after arrival of the northern tamarisk beetle (*Diorhabda carinulata)*, a biological control agent. The recent reduction in tamarisk health and survival opens up physical space and resources, creating a valuable window of opportunity for more effective and efficient enhancement and restoration of native riparian vegetation. The potential for continued reduction in tamarisk biomass and adverse impacts to SWFL breeding habitat over the next few years due to drought and tamarisk defoliation by the beetle highlights both the need and the opportunity for rapid implementation of efforts to promote re-establishment of willows and other native riparian plants in the area.

Other sites within the assessment area have substantial potential to provide enhanced habitat for other native wildlife, such as the western yellow-billed cuckoo (*Coccyzus americanus*), Arizona Bell's vireo (*Vireo bellii arizonae*), and vermillion flycatcher (*Pyrocephalus rubinus*), if native riparian vegetation is restored. In addition, some areas have the potential to provide habitat for Yuma clapper rail (*Rallus longirostris yumanensis*) if suitable freshwater marsh habitat is restored.

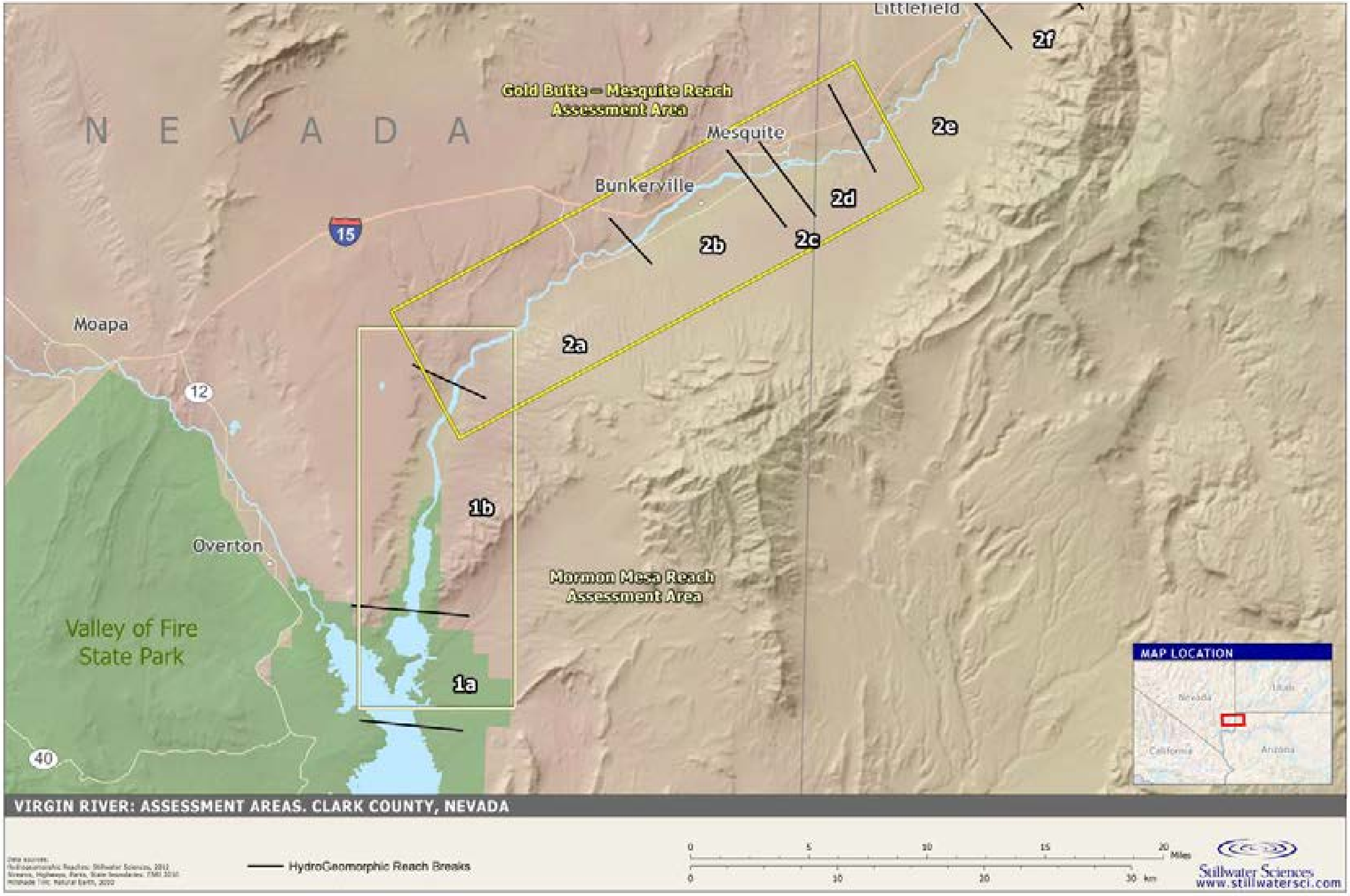

Figure 1. General location of the Gold Butte to Mesquite assessment area (=reaches 2a, 2b, 2c, and 2d as defined in Stillwater Sciences 2012) and the previous Mormon Mesa assessment area (= reaches 1a and 1b) on the lower Virgin River, Clark County, Nevada

2 PROJECT GOAL AND APPROACH

The goal of this project was to conduct an ecohydrological assessment which included developing new detailed maps of relative elevation, vegetation composition and structure, and potential sources of water associated with return flow from irrigation diversions, and then combining those data with existing information on vegetation types, soils, flood dynamics, and SWFL habitat to assess ecohydrological potential for restoration of native willow-cottonwood riparian habitat. This reach-scale assessment was required to: (1) provide an improved understanding of the key factors affecting restoration opportunities, constraints, and priorities on existing County-owned parcels (and on lands adjacent to these parcels); and (2) help the County (and other local partners, as appropriate) in evaluating additional parcels that might be considered for acquisition in the future for habitat restoration and conservation purposes.

To attain this goal, we conducted the following tasks (see Section 3 for more details on methods and results):

Ecohydrological Assessment: Ecological and hydrological factors affecting river and riparian habitat dynamics were assessed for the Reach using GIS analysis, combined with knowledge of the area from prior studies and a 1-day field reconnaissance of selected sites in November 2016 (see Figure 1 for map of the primary assessment area). This assessment included the following primary component subtasks:

- **Flood Scour:** prior mapping of historical changes in the river position and areas of scour and deposition in the floodplain were used to define the portion of the floodplain that is most likely to be "reset" in the next large flood events (= the flood reset zone).
- **Relative Elevation Mapping**: A GIS layer representing ground surface height above the low flow water surface of the river was generated from existing high-resolution LiDAR data collected by Utah State University's Remote Sensing/GIS Laboratory (USU RS/GIS) in November 2011. Relative elevation provides a very useful tool for restoration planning and can serve as a proxy for depth to groundwater.
- **Water Sources:** irrigation diversions and associated canal/ditch systems, and locations of potentially important return flows to the river, were mapped from recent aerial photography (as available in Google Earth), maps (USGS topographic quadrangles and Google Maps), and the relative elevation GIS layer. In addition, some areas of potential water sources from washes and urban runoff in Mesquite were also mapped.
- **Soils:** existing NRCS soils maps were reviewed to extract potentially useful information on soil salinity and texture.
- **Vegetation Type and Canopy Height:** A GIS layer representing vegetation canopy height was generated using the existing the November 2011 LIDAR data. Vegetation canopy height is very useful in characterizing existing habitat structure and suitability for wildlife species of interest, and in assessing vegetation growth potential.
- **Southwestern Willow Flycatcher Habitat:** documented historical SWFL habitat locations were mapped using available GIS data from the 2011 SWFL breeding surveys, and current SWFL habitat suitability was mapped using results of the Landsat-based model provided by Jim Hatten (USGS).
- **Synthesis:** A GIS analysis was conducted using multiple sources (historical flood-scour mapping, vegetation type and canopy height, relative elevation, modeled SWFL habitat suitability, historical SWFL habitat, distance to surface water, NRCS soils mapping, etc.) to identify various potential restoration sites in the assessment area and assign an initial level of priority for active restoration or site acquisition.

3 METHODS AND RESULTS

3.1 Flood Reset Zone

As part of our Phase I restoration planning efforts, we delineated flood-scour potential throughout the river corridor based on three of the most recent large flood events, as represented in aerial photography taken shortly after each event: 1989, 2005, and 2010 floods. Briefly, this entailed mapping flood-induced channel disturbance (typically scouring or burial of riparian vegetation) within the "hydrogeomorphically active channel"—that part of the mainstem channel bed that carried a significant part of the flood and sediment discharge during a given flood event. The frequency of flood disturbance to the river channel and floodplain was thus mapped to inform on potential future flood-scour risks during the next large event, which is particularly important for restoration planning in order to conserve limited resources and ensure re-vegetation success. The details of this analysis are summarized in Stillwater Sciences (2012).

The flood-scour mapping (Appendix A) was used to guide restoration planning in the Reach by delineating the "Flood Reset Zone," which was considered to include those areas of the active channel having >30% flood-scour frequency (i.e., approximately, scoured in 2 out of the 3 mapped floods),. This provides an indication of the risk or probability of future flood scour or reset that is appropriate for reach-scale planning (such as the restoration site near Hughes Middle School in Mesquite that was wiped out by the December 2010 flood). Additional field observations and review of recent channel migration and flood scour and deposition events by a geomorphologist should be conducted during individual site restoration feasibility assessment and design to provide more refined and site-specific evaluation of flood reset zones and potential risks and benefits associated with different restoration and management actions.

3.2 Relative Elevation

Existing information in the scientific literature and personal observations and unpublished data indicate that native riparian plant species tend to occur in particular topographic positions relative to the river channel. In particular, we have found that relative elevation above the low-flow, or baseflow, water surface in the river channel is a useful indicator for restoration potential. Relative elevation in a floodplain is generally correlated with depth to groundwater, and frequency of surface saturation and inundation.

Thus relative elevation, which combined with other GIS layers and field data, provides a powerful tool for assessing restoration potential via passive (natural recruitment processes) or active (horticultural restoration) approaches. Although successful germination of native riparian seedlings depends on a variety of hydrologic and geomorphic variables, seedling survival of phreotophytes such as cottonwoods and willows following germination (or of planted cuttings or container stock under horticultural restoration) is above all contingent on constant contact with the water table and/or its capillary fringe throughout the growing season (McBride and Strahan 1984, Stromberg et al. 1991). Research indicates that when the water table decline is more rapid over a long period than the rate of root growth, seedlings of phreatophytic species become isolated from their water source and suffer high mortality (McBride et al. 1989, Stromberg et al. 1996, Stella et al. 2010). In addition to the importance of groundwater levels for seedling survival, research indicates that groundwater levels play an integral role in determining sapling survivorship and adult riparian community composition (Smith et al. 1991).

Furthermore, comparative studies indicate that some non-native invasive plant species (such as tamarisk) tend to be more drought-tolerant than natives, and thus better able to compete along reaches with extreme inter- and intra-annual water table fluctuations (Smith et al. 1991, Freidman et al. 1995, Shafroth et al. 1998, 2000). Thus, in order to restore self-sustaining hardwood riparian forest, we need to better understand the role of groundwater in species survivorship across time and across species.

In the absence of data on groundwater depth, relative elevation can serve as a very useful proxy. Ideally, relative elevation mapping can be coupled with groundwater monitoring stations to increase our understanding of groundwater dynamics and increase rate of success when implementing riparian restoration, especially in areas where irrigation of new plantings may not be feasible (e.g., see Orr et al. 2014, and Orr et al. *in press).*

A relative elevation map was produced for the entire Reach using the bare-earth LiDAR data collected in November 2011 (Appendix B). The map displays topographic elevations relative to the low-flow channel elevation with the following categories: less than -3, -3 to -2, -2 to -1, -1 to -0.5, -0.5 to 0, 0–0.5, 0.5–1, 1–2, 2–3, 3–4, 4–5, 5–7.5, 7.5–10, 10–20, and greater than 20 m.

3.3 Water Sources

Irrigation diversions, primary irrigation canals or ditches, and return flow areas were mapped using available imagery and GIS layers, particularly relative elevation and recent Google Earth imagery. The objective was to capture potential sources of relatively reliable return flows (mainly surface flows, but potentially groundwater flows as well) that might be incorporated in riparian restoration planning and prioritization.

Three irrigation diversion and canal/ditch systems were mapped (Appendix B):

1. The Mesquite Ditch Diversion is located at the upstream end of the assessment area in Arizona, approximately 0.5 km upstream of Scenic Boulevard Bridge, and diverts water into an irrigation canal or ditch (the “Mesquite Ditch”) that runs along the base of the bluffs at the edge of the floodplain north of the river. According to USGS topographic quadrangles and Google Maps, the Mesquite Ditch flows through Mesquite and ends in the Pulsipher Wash, which provides return flows and runoff to the historically productive “Mesquite West” SWFL site downstream of the confluence of the wash and Virgin River (and adjacent to a golf course which has historically provided additional irrigation runoff or return flow). This site, along with the Bunkerville areas just downstream and across the river, support the best patches of current and potentially restorable SWFL habitat in the Reach. A few additional areas of potential return flow from washes and urban runoff from Mesquite have also been mapped.
2. The Bunkerville Ditch Diversion is located in Mesquite, NV, approximately 1 km upstream of Hughes Middle School, and diverts water into an irrigation canal or ditch (the “Bunkerville Ditch”) that runs along the toe of the bluffs at the edge of the floodplain on the south side of the river. According to USGS topographic quadrangles and Google Maps, the Bunkerville Ditch runs through Bunkerville and continues downstream for a bit. There are several mapped sites of return flow from the ditch in the upper portion (Mesquite) and lower portion (Bunkerville). The Bunkerville return flows, in particular, appear to support the best patches of current and potentially restorable SWFL habitat in the Reach.
3. The Riverside Ditch Diversion is located approximately 2 km upstream of the Riverside Bridge, and feeds into a canal or ditch (the “Riverside Ditch”) that runs along the toe of the bluffs at the edge of the floodplain on the south side of the river.

3.4 Soils

Analysis of soils data contributes to more realistic projections of potential woody riparian vegetation expected under various management scenarios, as we can exclude areas with soils unsuitable for hardwoods such as cottonwoods and willows (using NRCS/SCS info on salinity, soil texture, etc.). By linking our understanding of natural riparian vegetation recruitment processes and native woody plant life history requirements with soils information, our predictions of locations and total area suitable for passive revegetation (i.e., revegetation via restoration of natural seed dispersal/germination/root growth/inundation and water table recession processes) can be made more reliable. Our focus in the present analysis was to use soils data to explore the potential for both passive and active revegetation (i.e., horticultural restoration) to establish various native riparian trees, shrubs, and herbaceous species in the study area to restore or enhance suitable habitat for SWFL and other wildlife species of interest.

The NRCS SSURGO spatial dataset (produced before the 2010 flood event) was used to produce a soils map for the Reach displaying soil salinity and texture (Appendix A). Soil salinity and soil texture were based on the electrical conductivity and particle size categories, respectively, in the SSURGO dataset. Mapped salinity classes present within the Reach include only very slightly saline (2–4 mmhos/cm), which was mapped only in the lowermost portion of the Reach, and non-saline (soils <2 mmhos/cm were considered non-saline). This contrasts with the downstream Mormon Mesa Reach where many areas were classified as slightly saline (4–8 mmhos/cm) or strongly saline (>16 mmhos/cm) (Orr et al. 2013b). Soil texture classes present in the Reach include: not classified, fine-silty, fine-silty over sandy or sandy-skeletal, sandy, and sandy-skeletal. Within the assessment area, soil texture and salinity classes were not classified for substantial portions of the floodplain and the active channel.

Sampling and mapping soils in a dynamic alluvial reach with difficult access due to dense tamarisk vegetation is very challenging. Such is the case for the lower Virgin River in the assessment area. Given these challenges, and the patchy nature of the existing data, we only used NRCS soil map data, primarily soil salinity, as a secondary factor in determining restoration potential. The NRCS soils data should be used as a general indication of what soils might be like in a given restoration area, but final decisions on restoration priority and design should be based as much as possible on field data and soil samples collected on site (as was done for Virgin River Parcel 1 in the Mormon Mesa reach, Orr et al. 2013a).

3.5 Vegetation

The Reach is dominated by dense stands of tamarisk, with smaller patches of Fremont cottonwood (*Populus fremontii*), Goodding's willow (*Salix gooddingii*), and other native vegetation. The main patches of Fremont cottonwood and Goodding's willow can be identified in the GIS using vegetation canopy height information derived from the LiDAR data collected in November 2011. Mature trees of Goodding's willow tend to form an emergent crown greater than 7 m in height, which extends above the typically dense layer of tamarisk, so we can readily pick up individual trees and stands by mapping all vegetation >7 m in canopy height. Scattered mature cottonwood and willow trees occur primarily in the Mesquite and Bunkerville areas, and are generally absent from the lower portion of the Reach. Scattered patches of mesquite and other native vegetation, such as arrowweed (*Pluchea sericea*) and coyote or sandbar willow (*Salix exigua*) occur throughout the Reach, generally within a tamarisk-dominated matrix. Observations conducted in 2009 along the lower Virgin River in or near the assessment area indicated that some localized natural recruitment of cottonwood occurs in this area, but generally only near the low-flow channel margins and other wet or moist sites adjacent to mature individuals that serve as a source of seeds (Dudley and Bean 2012). Mature trees of Fremont cottonwood and Goodding's willow are scattered in the upper portion of the Reach near Mesquite and Bunkerville, but are quite sparse or absent in much of the lower portion of the Reach near Gold Butte. Aside from looking for areas most suitable for active restoration to enhance SWFL habitat, our ecohydrology assessment for the Reach also included identification of sites potentially suitable for establishment of patches of native riparian plants that could serve as "propagule islands" that provide seeds and vegetative propagules to facilitate natural (passive) revegetation processes (Dudley and Bean 2012, Orr et al. 2014).

Most tamarisk stands do not exceed 5 m in canopy height, but in the most productive sites taller plants are found and canopy height may be in the 5–7 m range. If other factors (such as relative elevation and soil salinity) are suitable, these taller, more productive tamarisk stands can be used as an indicator of areas likely to be suitable for revegetation by native woody species. The relationships between vegetation canopy height and presence of Fremont cottonwood, Goodding's willow, or other native vegetation, and likely restoration potential, are also supported by field observations and careful review of the classified vegetation from 2011 Appendix C) and recent natural color imagery (Google Earth).

A canopy-height map was produced for the entire Reach using the first-return LiDAR data collected in November 2011 (Appendix D). The map displays the following height categories: 0–1, 1–3, 3–5, 5–7, 7–10, 10–20, and >20 m.

3.6 SWFL Habitat

Historically occupied SWFL habitat patches were identified from a GIS layer associated with breeding surveys conducted in 2011 and earlier (for more information on survey methods and results from various years of surveys see McLeod, M. A., and A. R. Pellegrini. 2013), and mapped in Appendix E.

In addition, a GIS-based model (Hatten and Paradzick 2003; Hatten 2016) that identifies flycatcher breeding habitat suitability using Landsat Thematic Mapper imagery and 30-m resolution digital elevation models was applied to the Reach by James Hatten (USGS) using Landsat 8 imagery. Satellite-model output included a continuous probability grid, a five-class probability grid, and a binary habitat grid, with higher cell values in each case indicating relatively better SWFL habitat. Appendix E displays the results of the five-class probability grid, with green and yellow areas representing the greatest breeding habitat suitability (with most suitable sites shown in dark green [= class5], followed by lighter green [= class 4], and yellow [= class 3]) The highest quality areas are concentrated in Mesquite on the north side of the river just upstream of the Bunkerville Diversion and downstream near the confluence of Pulsipher Wash (which receives return from the Mesquite Ditch), and then near Bunkerville on the south side of the river near return flow sites from the Bunkerville Ditch.

4 ECOHYDROLOGICAL POTENTIAL AND VEGETATION RESTORATION PRIORITY AREAS

Potential priority restoration areas were then identified and mapped (Appendix F) based on suitable biophysical and ecohydrological characteristics (see Orr et al. 2014, Orr et al. in press a,b), primarily location relative to the Flood Reset Zone, relative elevation above baseflow, vegetation canopy height, existing vegetation patterns visible in the November 2011 natural color imagery and more recent Google Earth imagery. As described above (Section 3.3), NRCS soils map data were not used as a primary factor in identifying restoration potential. However, NRCS data or observations made during photographic interpretation suggest potential concerns regarding soil salinity in a few areas in the lower part of the Reach, as noted for a few of the mapped restoration polygons information is listed in Table 1. More detailed soils assessment should be considered in future refinement of priorities for field surveys (including surveys to collect site-specific soil samples) and restoration design (including the palette of native plant species to consider) and implementation. It is important to note that many other factors, including shade tolerance and other competitive abilities, proximity to seed source, intensity of livestock grazing or other herbivory, and presence of disease, can contribute to the success of plant establishment and species distributions within riparian zones.

The initial screening for restoration suitability and priorities was conducted by creating a restoration priority weighting score for each pixel based on relative elevation and canopy height:

Relative elevation (Appendix B)

- Relative elevation <= 1 m, score = 4
- Relative elevation 1.01 -2 m, score = 3
- Relative elevation 2.01-3 m, score = 2
- Relative elevation 3.01-4 m, score = 1
- Relative elevation > 4 m, score = 0

Canopy height (Appendix D)

- Canopy height > 10 m score = 4
- Canopy height 7-10 m score = 3
- Canopy height 5-7 m score = 2
- Canopy height 3-5 m score = 1
- Canopy height <3 m score = 0

The scores were then summed and results mapped showing the distributions of color-coded pixels along the entire Reach, with a score of 8 indicating the highest restoration priority and 0 the lowest (Figure 2 and Appendix F). The distributions displayed discrete groupings of suitable areas that were visually reviewed to identify appropriate areas with suitable biophysical characteristics for restoration and that were larger enough to provide a suitable patch of valuable wildlife habitat (generally > 10 acres), or, in the case of smaller areas, provide a suitable location for development of a “propagule island” through restoration to provide future source of native seeds and vegetative propagules to promote natural revegetation processes following floods. One useful indicator of site potential for developing areas is the presence of one or more mature specimens of desired native riparian species (especially cottonwood) that can serve as the focus of the propagule island.

In the next step, visual assessment of the pixel-based restoration priority weightings was conducted, along with a review of recent aerial imagery in Google Earth and the USU classified vegetation types (Appendix C) areas to identify areas likely having appropriate conditions for active or passive revegetation and restoration. Only areas within the floodplain that were outside or at the edge of the Flood Reset Zone (Appendix A) were included. These areas were delineated by manually encircling them with polygons and an initial priority ranking of high or medium was assigned to the polygon.

In the final step, high potential sites that included areas identified as having the most suitable SWFL habitat (based in historical SWFL habitat and on modeled habitat suitability, as shown in Appendix E) received additional emphasis and were classified as very high priority areas for restoration of native vegetation. We identified 41 potential restoration areas totally 1017.6 acres in the Reach: 4 Very High (123.9 acres), 8 High (160.8 acres), and 24 Medium priority areas (733 acres) (Table 1). Figure 2 shows the location of the 4 Very High priority sites near Bunkerville-. A full set of maps showing restoration priority areas for the full Reach is provided in Appendix F.

The Very High and High priority areas should be considered first for site restoration planning and implementation, or acquisition where appropriate. If restoration is considered in these areas, any adjacent medium priority areas, as well as adjacent areas in the flood reset zone that show high suitability for successful planting of willow cuttings, should be included in initial field assessment to see if they should also be included in site restoration design and implementation. As discussed in the Clark County Mormon Mesa Parcel Restoration Plan (Orr et al. 2013), small patch clearing and treatment of tamarisk and planting with Goodding's willow and other native plants is likely the most viable and effective rapid implementation option. Measures to restrict potential damage from trespass cattle would likely be required unless cattle are removed from the Reach.

Table 1. Characteristics of potential restoration (revegetation) priority areas in the Mormon Mesa Reach, beginning at the downstream end and working upstream (north).

Restoration area ID	Size (acres)	Priority	Notes[1]
1	30.77	Medium	Dominant tamarisk matrix, with patches of cottonwood-willow vegetation, plus other natives, and apparent marsh habitat. Potential return flow from Mesquite Ditch.
2	18.68	Medium	Dense tamarisk with some natives mixed in. Consider enhancement in conjunction with action in nearby polygons (3, 4, 5) to create propagule islands for cottonwoods, willows, and other natives..
3	10.35	Medium	Dense tamarisk with some natives mixed in. Consider enhancement in conjunction with action in nearby polygons (2, 4, 5) to create propagule islands for cottonwoods, willows, and other natives.
4	22.79	Medium	Scattered cottonwoods with tamarisk understory. Consider enhancement in conjunction with action in nearby polygons (2, 3, 5) to create propagule islands for cottonwoods, willows, and other nativis.
5	6.75	High	Currently supports a cottonwood-willow woodland with an understory of tamarisk. Consider enhancement in conjunction with action in nearby polygons (2, 3, 4) to create propagule islands for cottonwoods, willows, and other natives.

Restoration area ID	Size (acres)	Priority	Notes[1]
6	39.92	High (Very High?)	Dominant tamarisk matrix, with patches of cottonwood-willow vegetation, plus other natives, that appear to be supported by urban runoff and shallow groundwater (likely associated with the Bunkerville Diversion). Includes historical SWFL habitat and supports a good patch of modeled Class 3, 4, and 5. High to Very High restoration potential for SWFL, and possibly Yuma rail if combined with enhancement of marsh habitat in Polygon 7.
7	37.31	Medium (Medium – High or High?)	Mixture of tamarisk and native vegetation, plus open water and wetland habitats created by the Bunkerville Diversion dam. Hihg value habitat potential, especially in conjunction with the adjacent Polygon 6. Likely reset during larger floods, but conditions likely to be restored after each event as long as the Bunkerville Diversion remains in operation
8	6.52	Medium	Tamarisk matrix with patches of native vegetation, and some recent natural recruitment. Potential return flow from the Bunkerville Ditch.
9	27.41	High	Currently supports a cottonwood-willow woodland with an understory of tamarisk. Signs of recent natural recruitment of native vegetation (and tamarisk). Return flow from the Bunkerville Ditch.
10	21.34	Medium	Tamarisk matrix with patches of native vegetation, and some recent natural recruitment. Potential volunteer support in conjunction with the Partners In Conservation restoration efforts near Hughes Middle School.
11	4.24	Medium	Tamarisk matrix with patches of native vegetation, and some recent natural recruitment. Potential volunteer support in conjunction with the Partners In Conservation restoration efforts near Hughes Middle School.
12	6.08	High	Currently supports a cottonwood-willow woodland with an understory of tamarisk. Potential return flow from the Bunkerville Ditch.
13	36.00	Medium (Medium – High?)	Mix of habitat types, the middle portion of the polygon incudes higher priority habitat and overlaps with historical SWFL habitat.

Restoration area ID	Size (acres)	Priority	Notes[1]
14	36.36	Very High	This site, along with Polygon 21, provides the best current habitat and greatest restoration potential in the Reach. Overlaps with historical SWFL habitat and supports a good patch of modeled Class 3, 4, and 5 habitat. Air photos and field observations confirmation the presence of a large emergent wetland, mixed with tamarisk and native vegetation. Includes an open water pond/emergent marsh. Very good potential to restore high quality SWFL habitat, and potential Yuma rail habitat. Return flow from the Mesquite Ditch via the Pulsipher Wash appears to provide reliable perennial surface water. Site assessment should include evaluation of polygons 15 and 16, and investigations of the expected future reliability of return flow from the Wash and from irrigation of the golf course.
15	3.68	High	Potential for managed habitat adjacent to golf course that could enhance the value of SWFL habitat in the adjacent Polygon 14 and 16 areas.
16	12.12	Very High	Similar to Polygon 14. Supports a good patch of modeled Class 3, 4, and 5 SWFL habitat. Consider in conjunction with restoration of Polygons 14 and 15.
17	27.94	Medium (Medium – High?)	Supports patches of dense 5–7 m tall tamarisk vegetation, with a few scattered natives mixed in. Some lower relative elevation areas support mulefat scrub, along with tamarisk. Probably best considered restoring more for general native riparian biodiversity than SWFL habitat.
18	17.26	Medium	Supports patches of dense 5–7 m tall tamarisk vegetation, with a few scattered natives mixed in. Appears well protected from flood scour,
19	23.26	Medium (Medium – High, or High?)	Mix of tamarisk and native vegetation. Adjacent to very high value habitat (Polygon 20), and the downstream end of Polygon 19 support freshwater marsh that should be part of any restoration planned for Polygon 20. Suggest careful evaluation whenever Polygon 20 is assessed.
20	16.54	Very High	Overlaps with historical SWFL habitat and supports a good patch of modeled Class 3, 4, and 5 habitat. Air photos and field observations confirmation the presence of mature Fremont cottonwood and Goodding's willows, mixed with other native vegetation and tamarisk, including emergent marsh at the downstream end (and in adjacent Polygon 19). Very good potential to restore high quality SWFL habitat. Return flow from the Bunkerville Ditch appears to provide reliable perennial surface water.

Restoration area ID	Size (acres)	Priority	Notes[1]
21	58.88	Very High	This site, along with Polygon 14, provides the best current habitat and greatest restoration potential in the Reach. Overlaps with historical SWFL habitat and supports a good patch of modeled Class 3, 4, and 5 habitat. Air photos and field observations confirmation the presence of a large emergent wetland, mixed with tamarisk and native vegetation. Includes an open water pond/emergent marsh. Very good potential to restore high quality SWFL habitat, and potential Yuma rail habitat. Return flow from the Bunkerville Ditch appears to provide reliable perennial surface water.
22	24.80	Medium	Includes a pond and wetland, and borders a very high priority area (Polygon 21). Suggest site evaluation in conjunction with detailed assessment of Polygon 21.
23	15.92	Medium	Adjacent to very high priority area (Polygon 21), but with slightly drier and higher relative elevation conditions. Suggest site evaluation in conjunction with detailed assessment of Polygon 21.
24	38.13	High	Supports a mix of vegetation and habitat types, including some wetland/emergent marsh along with patches of tamarisk and native vegetation. Overlaps with historical SWFL habitat. See comments for Polygons 25 and 26.
25	62.48	Medium	Supports a patchy mix of vegetation and habitat types, including some wetland areas, but also includes some areas that might be prone to flood reset, including areas supporting historical SWFL habitat and modeled Class 3 habitat. Should be considered in combination with Polygon 24 and 26.
26	23.06	High	Supports patches of dense 5-7 m tall tamarisk vegetation, with a few scattered natives mixed in. Appears well protected from flood scour, and is adjacent to some wetland areas (in Polygon 25) at both upstream and downstream ends of the polygon. Field assessment of this site should include evaluation of restoration potential benefits and constraints in the adjacent Polygons 24 and 25, including areas supporting wetlands and sites in the flood reset zone that might be suitable for planting willow cuttings in the vicinity of the historical SWFL habitat.
27	7.18	Medium (Medium – High?)	Former high flow channel site that currently supports a wetland complex of open water and emergent marsh, suggesting high potential for restoring SWFL and Yuma rail habitat. Site historically within the flood reset zone, but assessment of recent flood flow paths suggest the site might be more resilient to the next few big floods. Field assessment is recommended, including evaluation of the adjacent upstream area that have previously burned, and the downstream area reset by the 2010 flood event.

Restoration area ID	Size (acres)	Priority	Notes[1]
28	6.80	Medium	Supports patches of dense 5–7 m tall tamarisk vegetation, with a few scattered natives mixed in. Appears well protected from flood scour, but is small so might be best suited for propagule island establishment.
29	25.90	Medium	Supports patches of dense 5–7 m tall tamarisk vegetation, with a few scattered natives mixed in. Other patches appear to be more dominated by natives. Portions of this polygon lie within the flood reset zone.
30	15.74	High	Supports a patch of dense 7–10 m tall tamarisk vegetation and other areas of 5–7 m tall tamarisk, with a few scattered natives mixed in. The site seems well protected from flood scour, and is a reasonable size so was given a high priority, but further field assessment is needed to confirm this ranking.
31	6.83	Medium	Supports dense 5–7 m tall tamarisk vegetation, with a few scattered natives mixed in. Appears well protected from flood scour, but is small so might be best suited for propagule island establishment. The area adjacent to the downstream portion of this polygon supports some wetland habitat within the flood reset zone that appears to be suitable for planting willow cuttings and should be considered during any future site evaluation.
32	21.98	Medium	Supports patches of 5–7 m tall vegetation that appears to be primarily tamarisk, with some willows or other natives mixed in. The area adjacent to the downstream portion of this polygon supports some wetland habitat within the flood reset zone that appears to be suitable for planting willow cuttings and should be considered during any future site evaluation.
33	24.97	Medium	Supports 5–7 m tall vegetation near channel that appears to be tamarisk mixed with willows or other natives. Some evidence of irrigation return flows that might be beneficial for restoration.
34	21.75	Medium (Medium – High?)	Includes some SWFL Suitability Class 3 and 4 habitat towards upstream end, near scattered cottonwoods and signs of surface moisture or saturated soils (likely supplemented by direct irrigation in some areas and irrigation return flow in adjacent unmanaged areas).
35	31.27	Medium	Areas of dense vegetation 5–7 m tall, of tamarisk plus some willows or other natives, suggests potentially productive revegetation zones. There appear to be one or two areas of potential irrigation return flow into this area that might facilitate successful restoration, including a return flow channel along and just outside of the western edge of the polygon that should be explored during any future site evaluation.

Restoration area ID	Size (acres)	Priority	Notes[1]
36	33.38	Medium	Includes wetland complex (open water and emergent marsh) at downstream end. Mix of tamarisk and some willows or other natives. Adjacent sites near channel lie in flood reset zone, but appear to be suitable for willow cuttings and should be considered during any future site evaluation.
37	46.97	Medium	Interesting mix of habitats and vegetation types – appears to include mesquite, tamarisk, willows or other natives, and patches of wetland. Some patches of dense vegetation 5-7 m tall suggests potentially revegetation productive zones.
38	16.75	Medium	Interesting mix of habitats and vegetation types – appears to include mesquite, tamarisk, willows or other natives, and patches of wetland. Includes some areas that may be more prone to flood scour, and soil salinity should be field checked
39	19.95	Medium	Supports 5-7 m tall vegetation near channel that appears to be tamarisk mixed with willows or other natives;
40	27.08	Medium	Interesting mix of habitats and vegetation types – appears to include mesquite, willows, tamarisk, and patches of wetland. Includes some areas that may be more prone to flood scour, and soil salinity should be field checked
41	82.40	Medium	Has a limited band of SWFL Suitability Class 3 habitat near channel in upstream end; bands of 5-7 m tall vegetation near channel that is likely mix of tamarisk and willow; NRCS maps soils as very slightly saline which suggests field sampling of soils would be useful to assess suitability for cottonwoods and willows
Total	**1017.55**		

[1] Notes include comments on soil salinity indicated in NRCS soils maps and other information sources such as SWFL survey reports and color aerial imagery, plus additional comments or suggestions regarding site assessment.

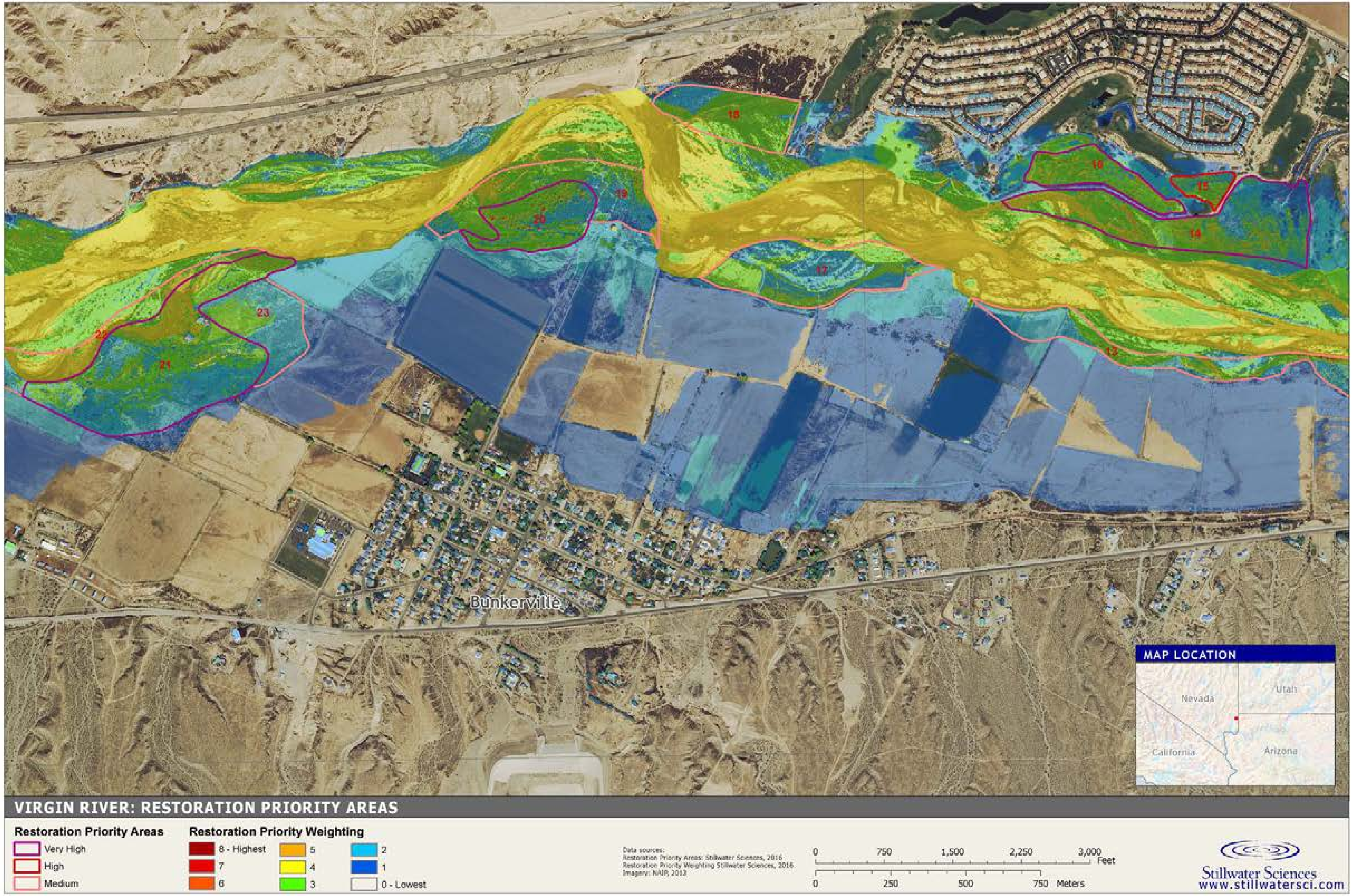

Figure 2. Location of restoration priority areas near Bunkerville, including all four of the Very High priority areas.

5 RECOMMENDATIONS

Based on the results of the ecohydrological assessment, we recommend the following:

- Conduct focused field assessments on the 4 Very High priority areas and adjacent areas as indicated in Table 1 to assess restoration feasibility and begin developing restoration designs for those sites that are determined to be both feasible (DCP-owned or willing landowner) and high value (high potential for restoration and enhancement to meet DCP riparian goals). This could be done in conjunction with site assessment of other existing DCP parcels in the Reach to maximize efficiency.
- After assessing the 4 Very High priority areas, conduct additional site surveys to refine boundaries and acquisition or restoration priorities for each High priority polygon being considered for acquisition or restoration implementation.
- Conduct intensive active riparian restoration using a phased, patch-work approach to remove tamarisk in lower quality habitat patches and then plant appropriate native plants suited to site conditions, thereby expanding existing patches of suitable habitat and establishing new sources of native plant propagules (i.e., creating “propagule islands”), while at the same time preserving some of the habitat benefits that might be provided by the existing taller tamarisk structure. As native vegetation matures in the initial treated patches, additional tamarisk removal and revegetation can be implemented in adjacent patches. The goal is not to actively treat the whole riparian-floodplain area, rather it is to do enough active restoration to put the site, and ultimately the whole riparian system, on a trajectory that is likely to create a more resilient, self-sustaining, and diverse riparian ecosystem into the future in the context of climate change and tamarisk biocontrol.
- Carefully locate tamarisk removal and revegetation actions to avoid inducing any undesirable channel instabilities (such as those that might erode important infrastructure or existing high quality native vegetation).
- Consider lower effort strategies in other areas where practical, including “disturbance contingency plans” such as spraying herbicide on re-sprouting tamarisk to promote natural recruitment process for willows and other native plants in areas disturbed by fires or floods, especially where much of the tamarisk biomass has been removed by the disturbance.
- Some sites that have not been disturbed by flood or fire in recent years may develop undesirable levels of tamarisk biomass that may impede restoration efforts or create a fire hazard that might put adjacent restoration or other high-value sites at risk. Such sites may provide opportunity for use of prescribed burning to remove tamarisk biomass and set the stage for successful, cost-efficient restoration of native species (Dudley and Bean 2012).
- Update the vegetation restoration priority coverage as new data (particularly field data on soils, depth to groundwater, and current vegetation) become available.
- Consider initiating groundwater monitoring on existing DCP parcels that overlap with any very high and high priority areas, and work with other landowners to establish additional groundwater monitoring sites in other high and very high priority areas.
- Conduct demonstration restoration projects on selected sites as appropriate and feasible, and then monitor to test our working hypotheses about physical site conditions, feasibility of restoration of native woody species and other plants, and site suitability for SWFL and other wildlife species of interest.
- Develop and implement an active adaptive management and monitoring program as restoration implementation progresses in the Reach (ideally in conjunction with similar efforts in the Mormon Mesa Reach).

Additional information on restoration design and strategies appropriate for the Reach can be found in Dudley and Bean (2012), Stillwater Sciences (2012), and Orr et al. (2013a,b; 2014; in press a,b)

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Appendices

(Available electronically as PDF files)

Appendix A

Flood Reset Zone and Soil Salinity and Texture

Appendix B

Relative Elevation and Potential Water Sources (Return Flows)

Appendix C

Classified Vegetation Types (from Utah State University)

Appendix D

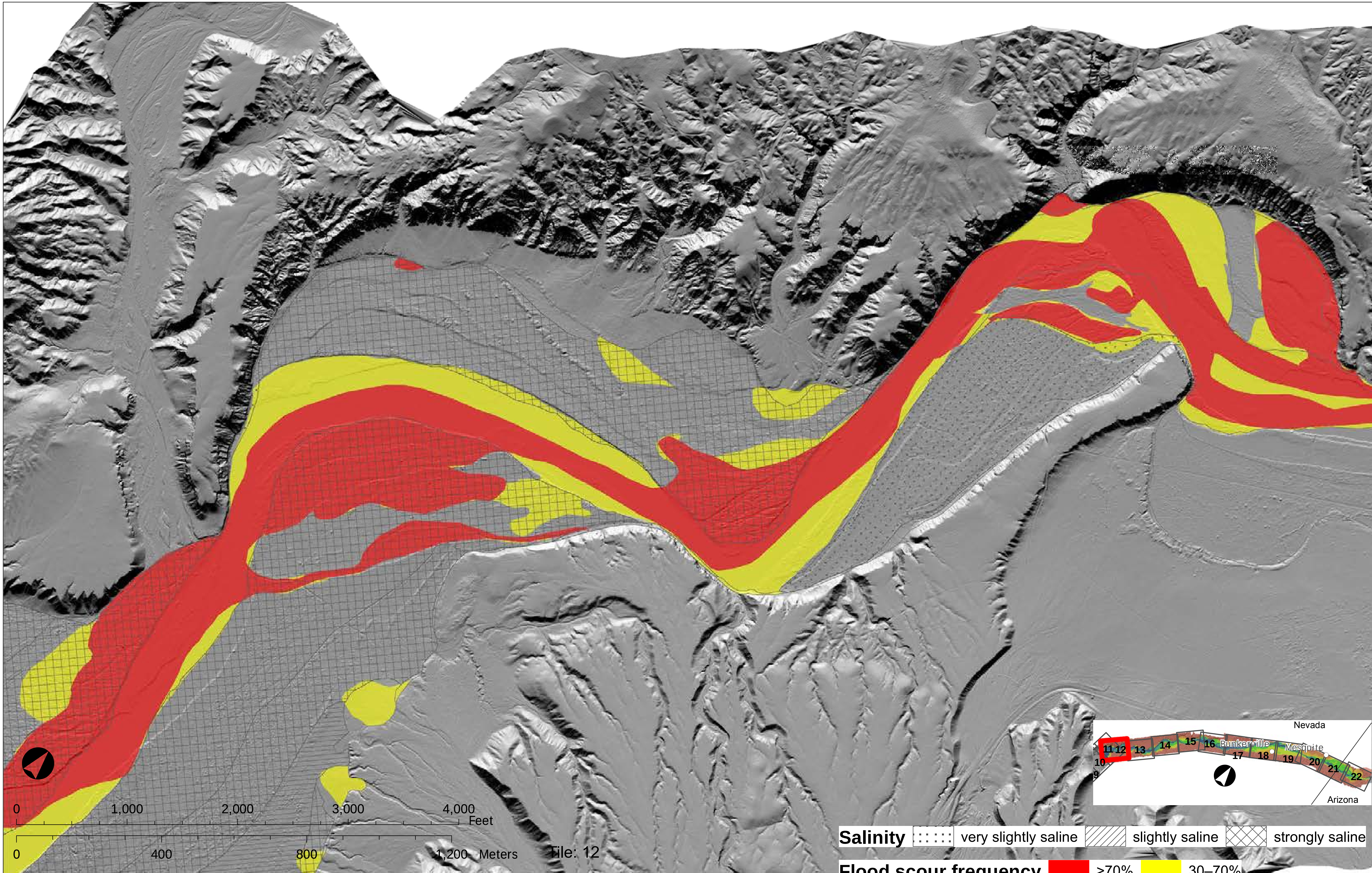
Vegetation Canopy Height

Appendix E

SWFL Historical Habitat and Modeled Habitat Suitability

Appendix F

Restoration Priority Areas



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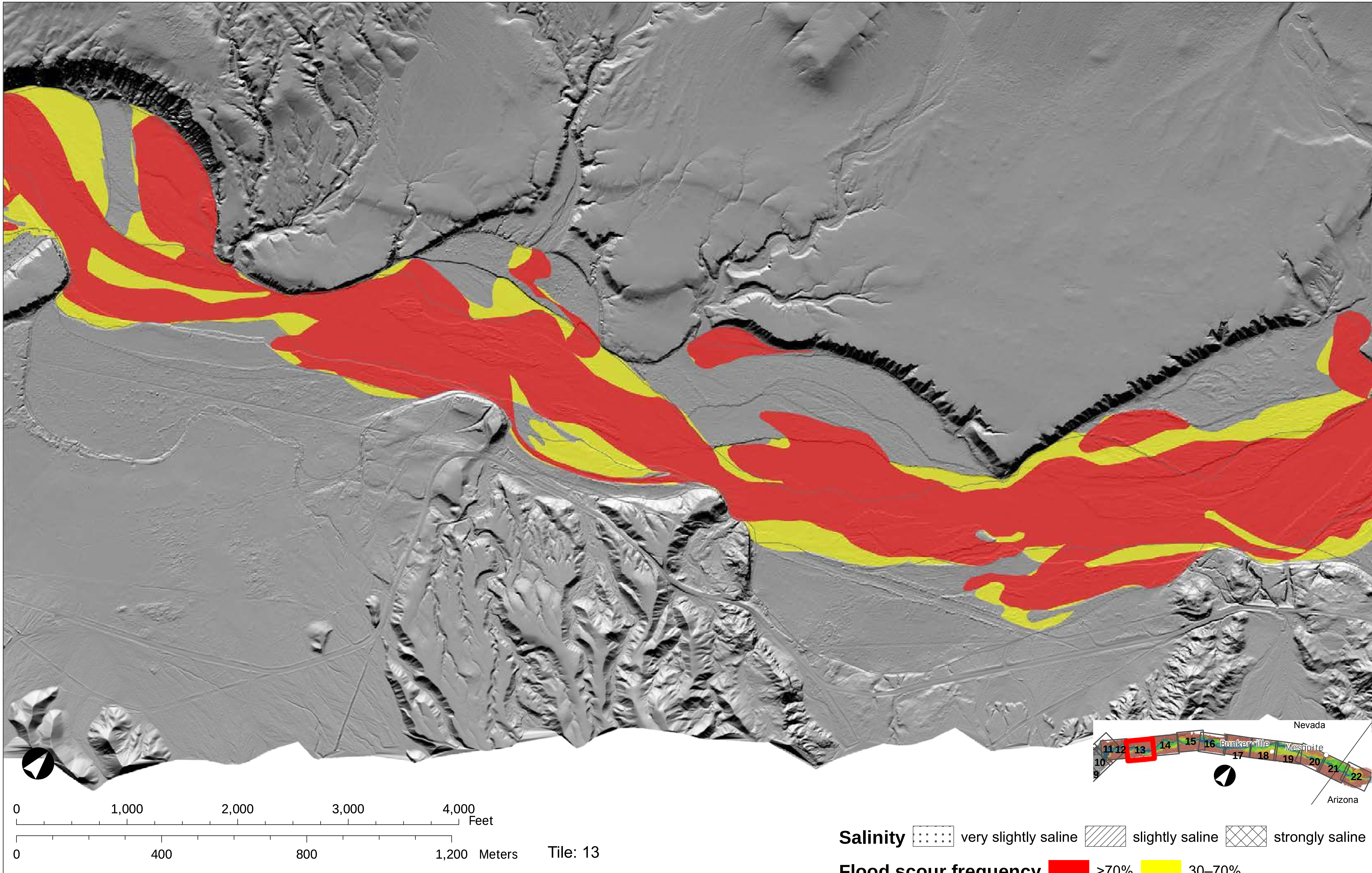

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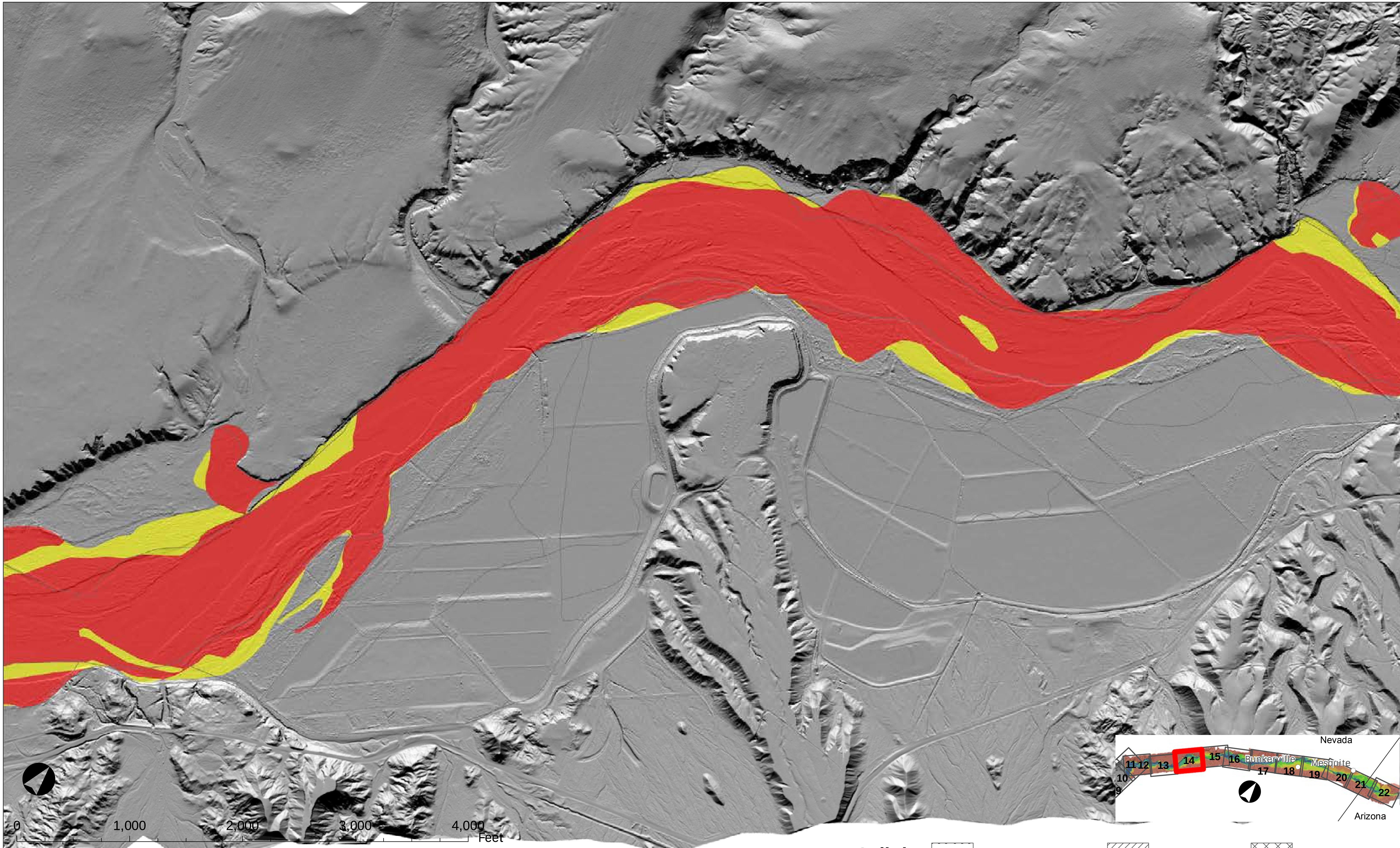

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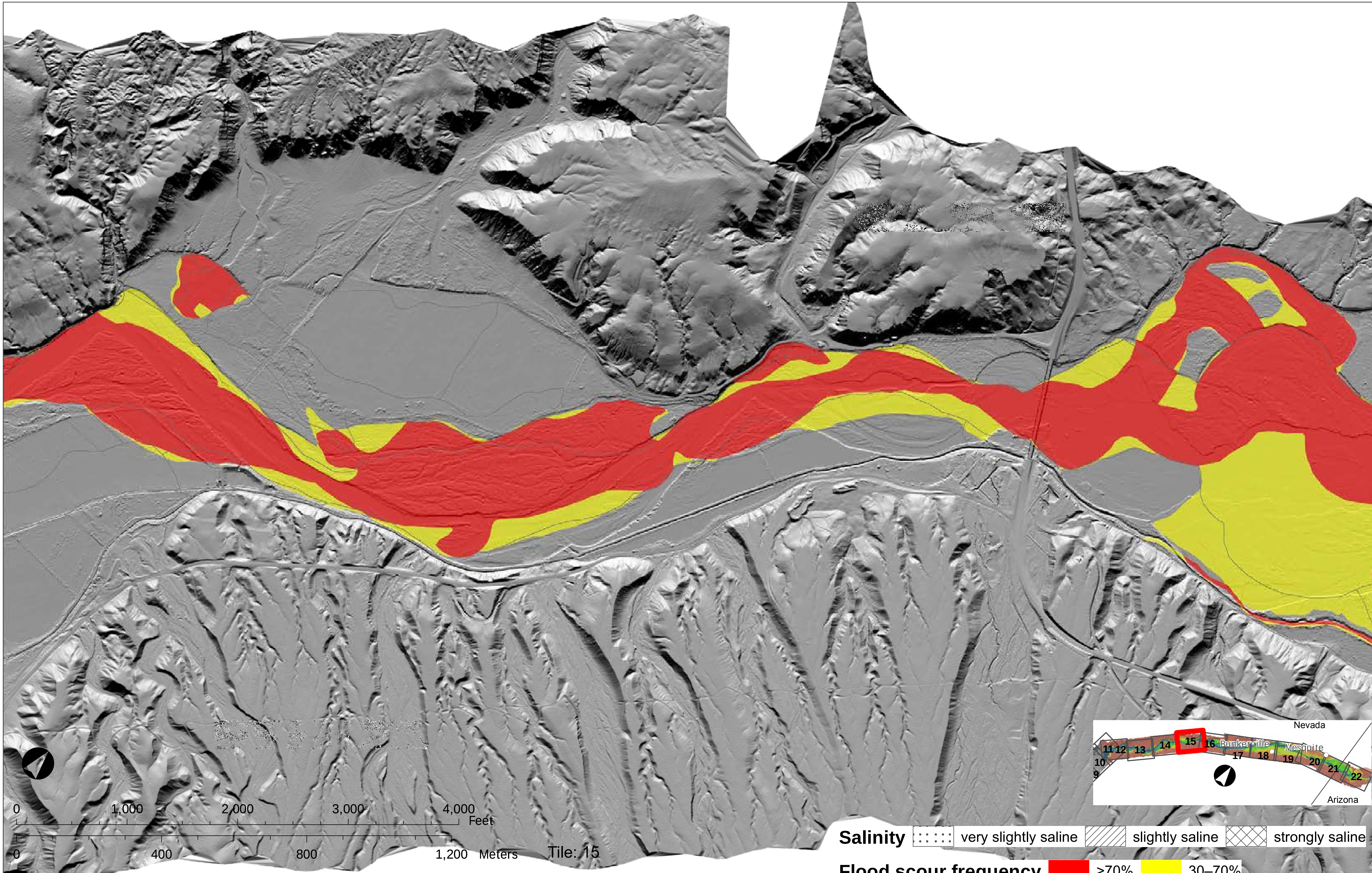

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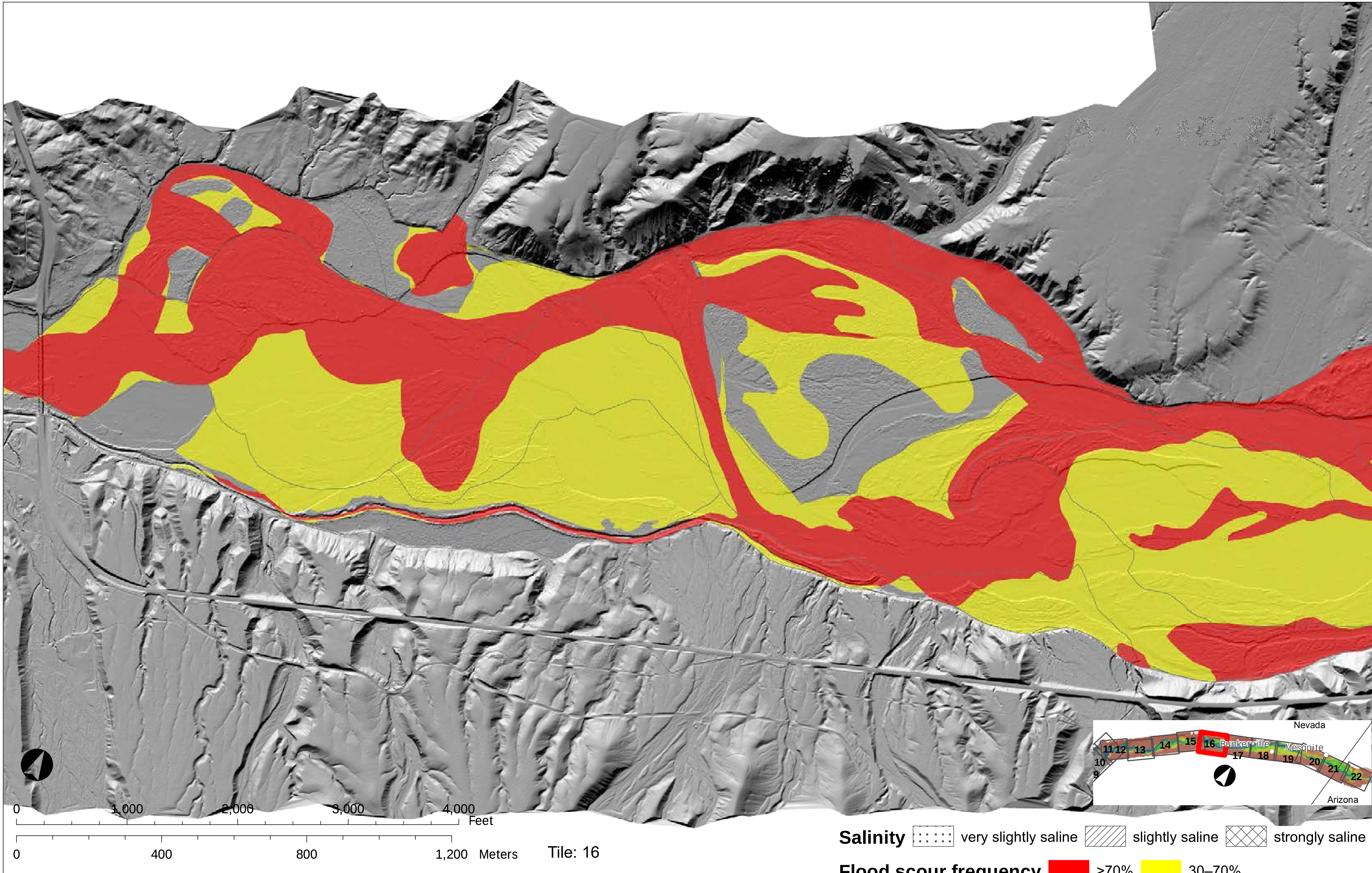
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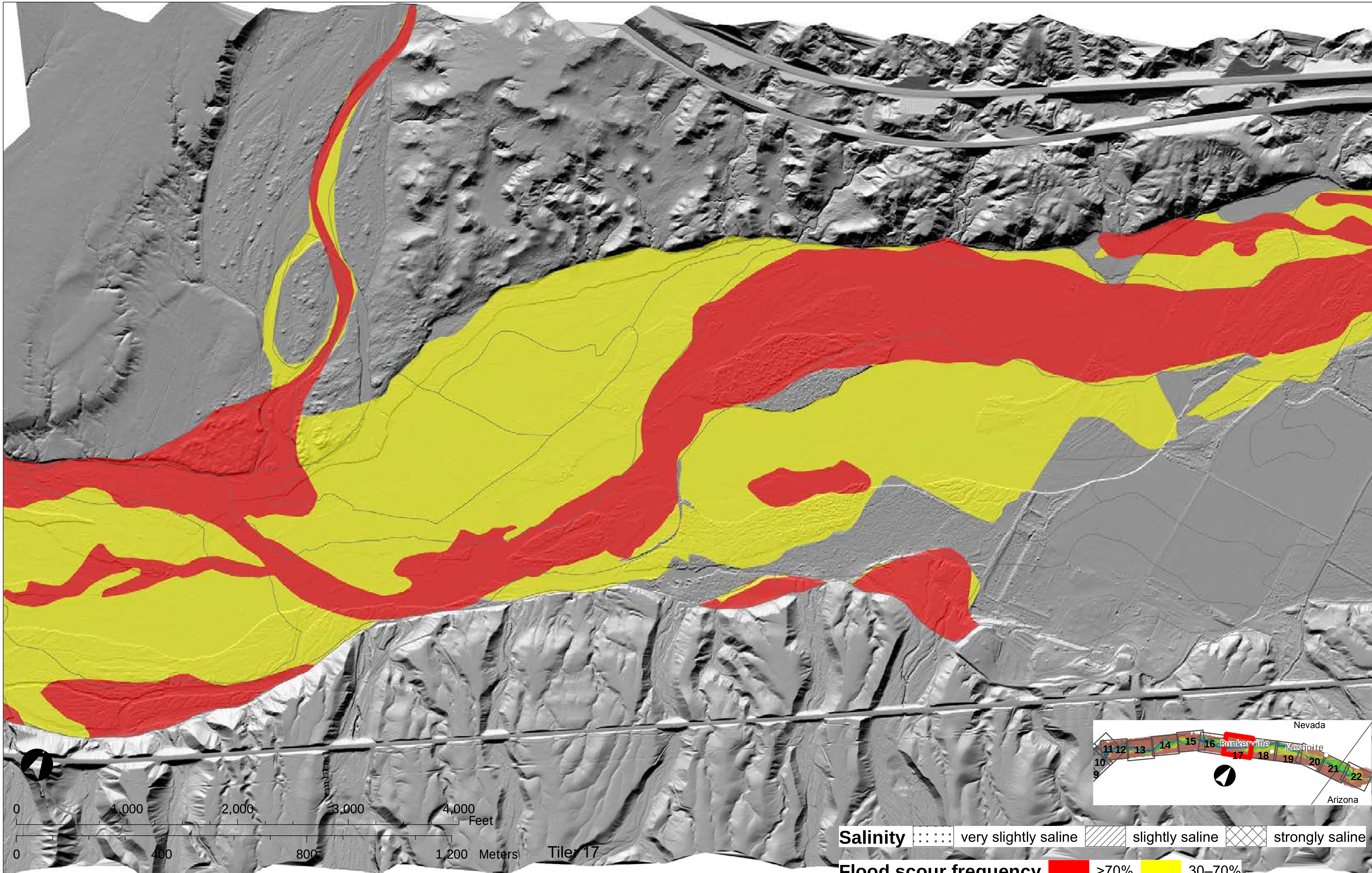

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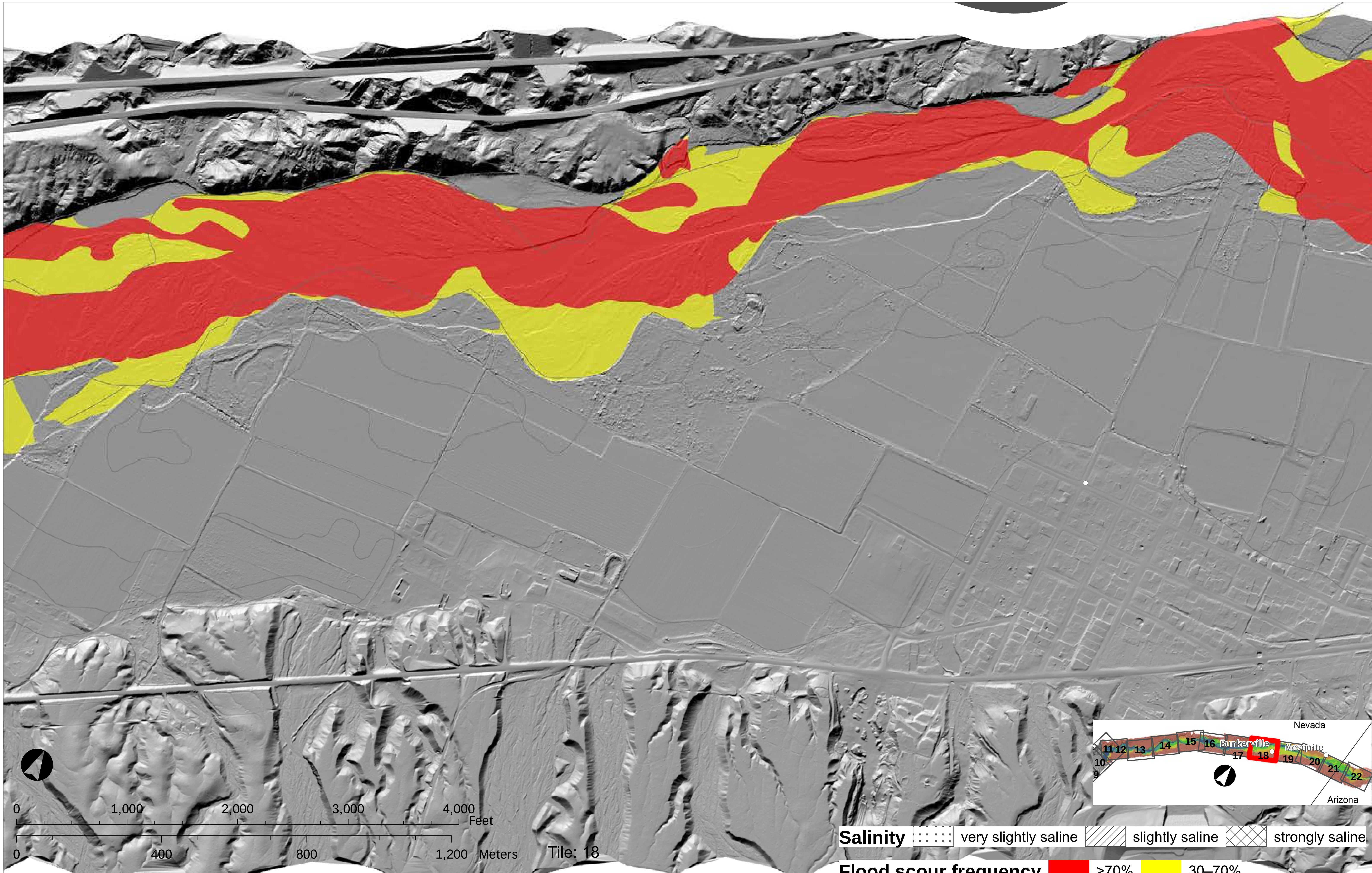

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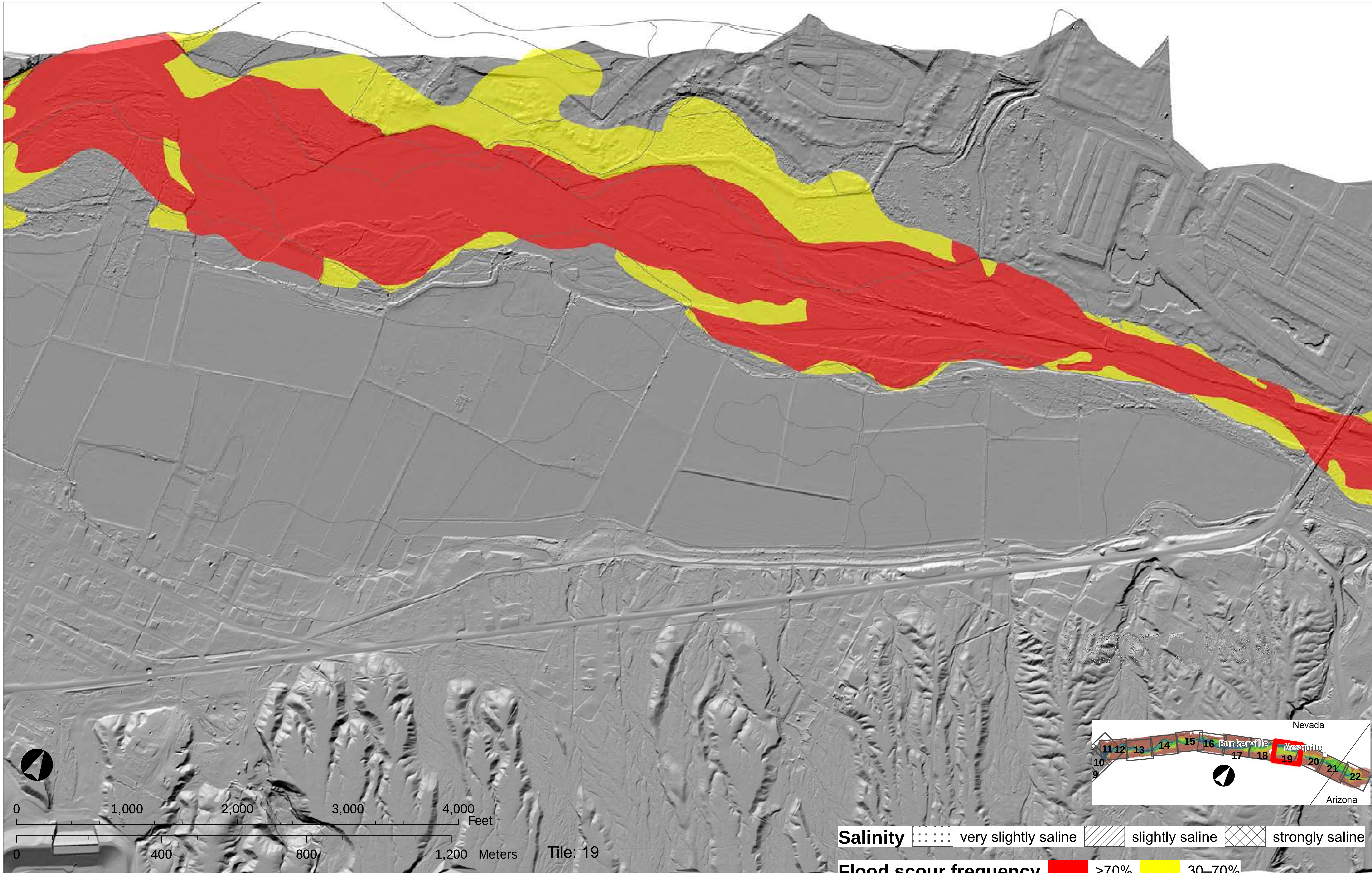
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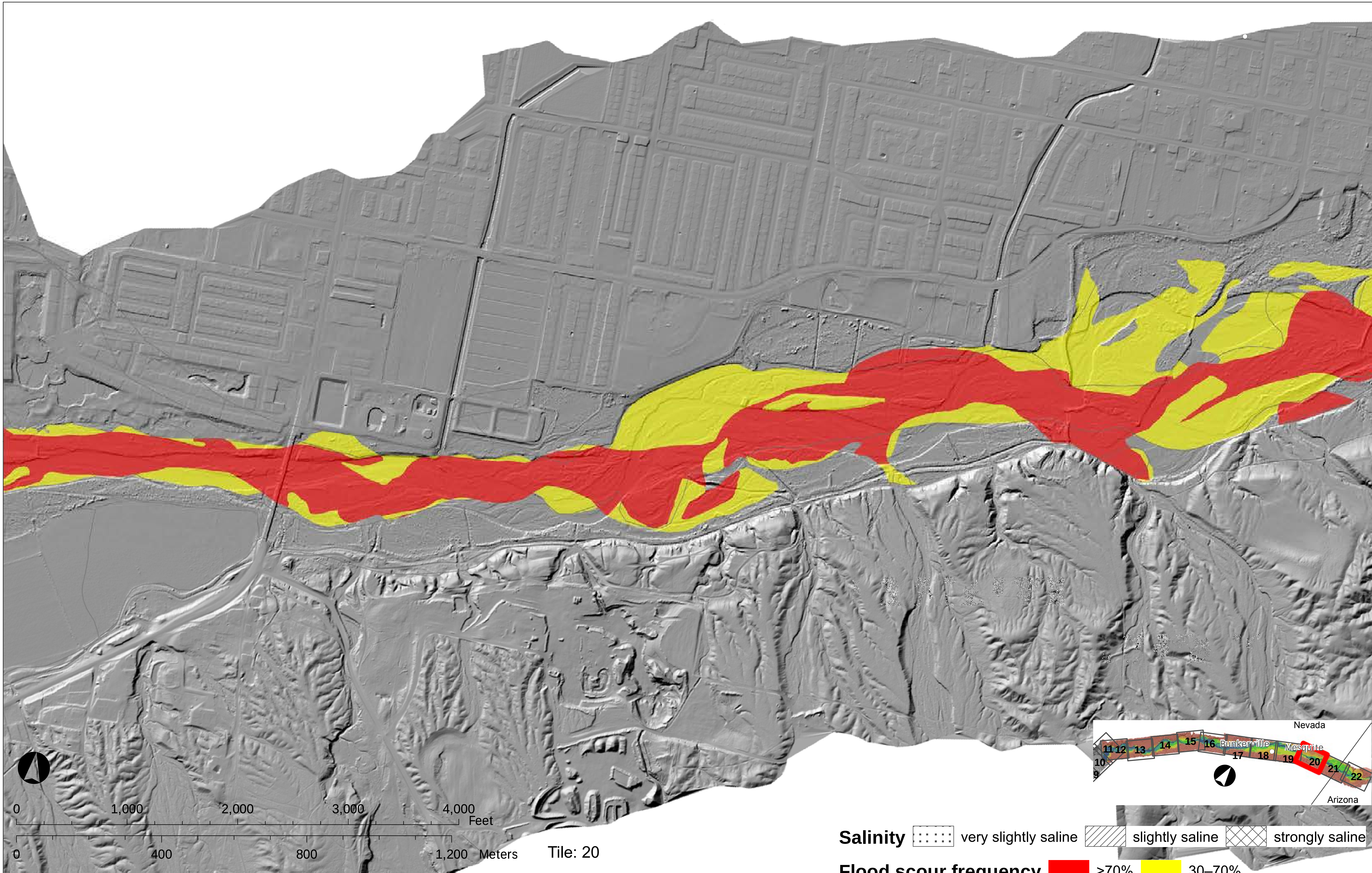
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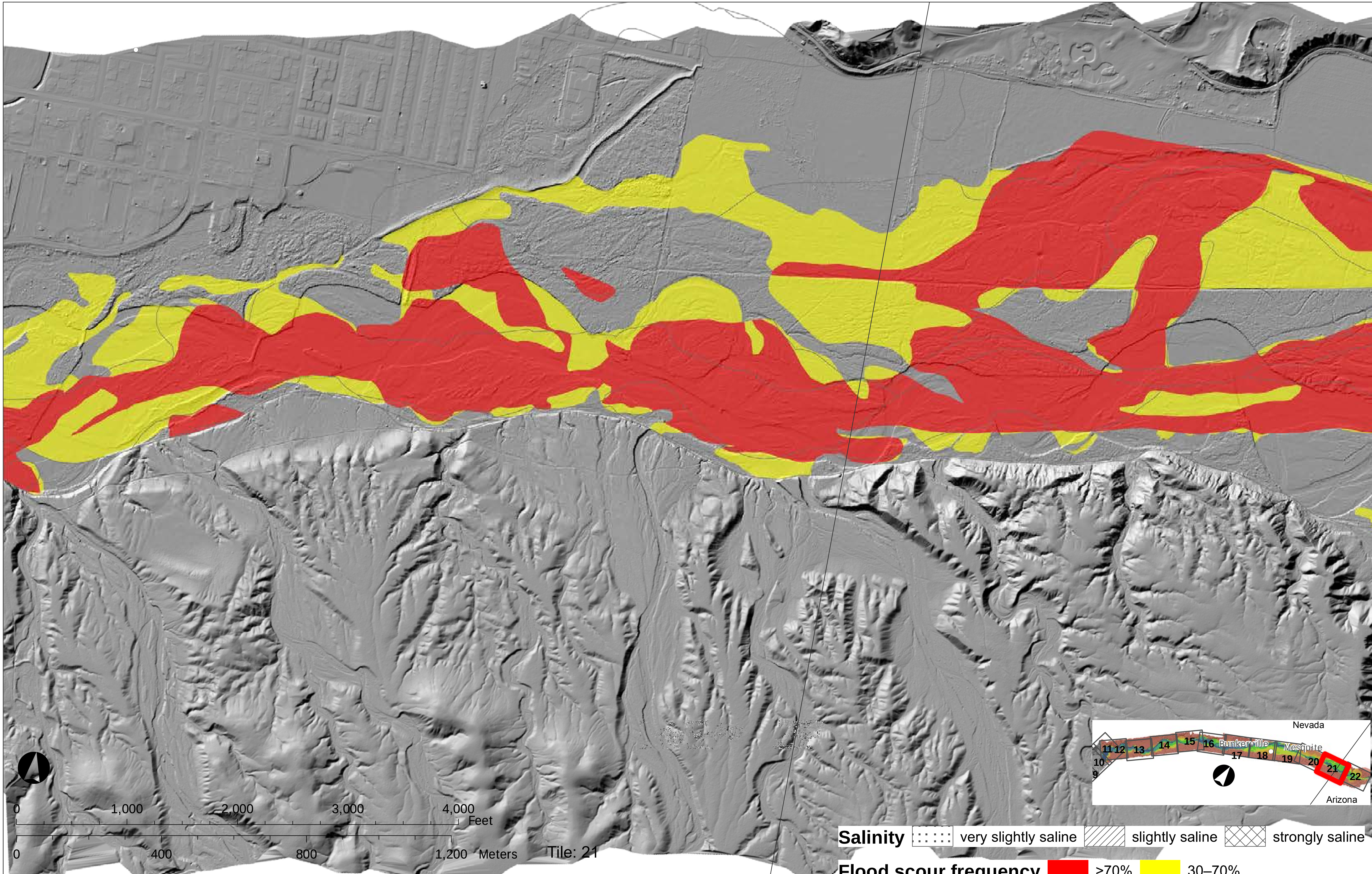
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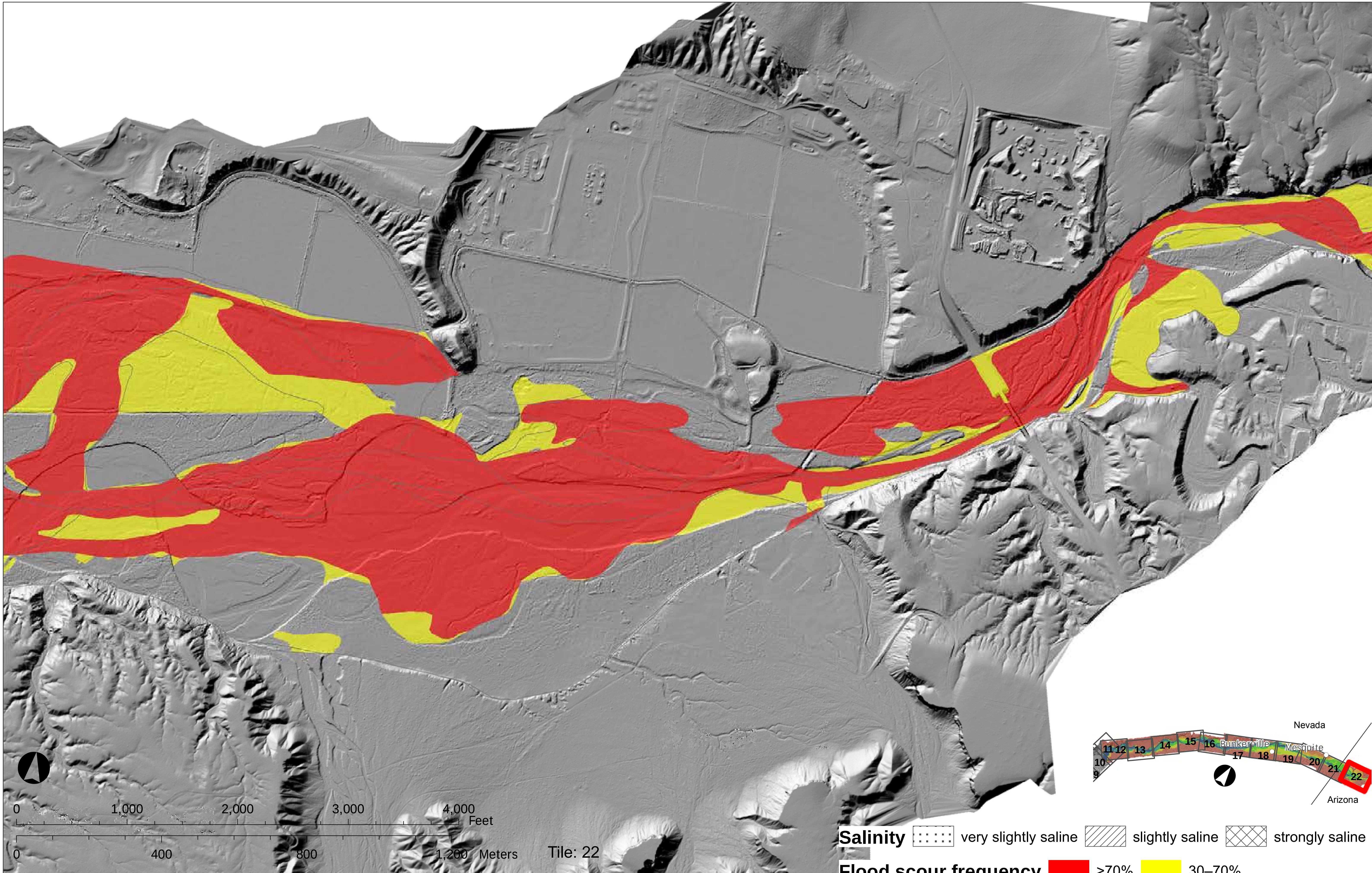

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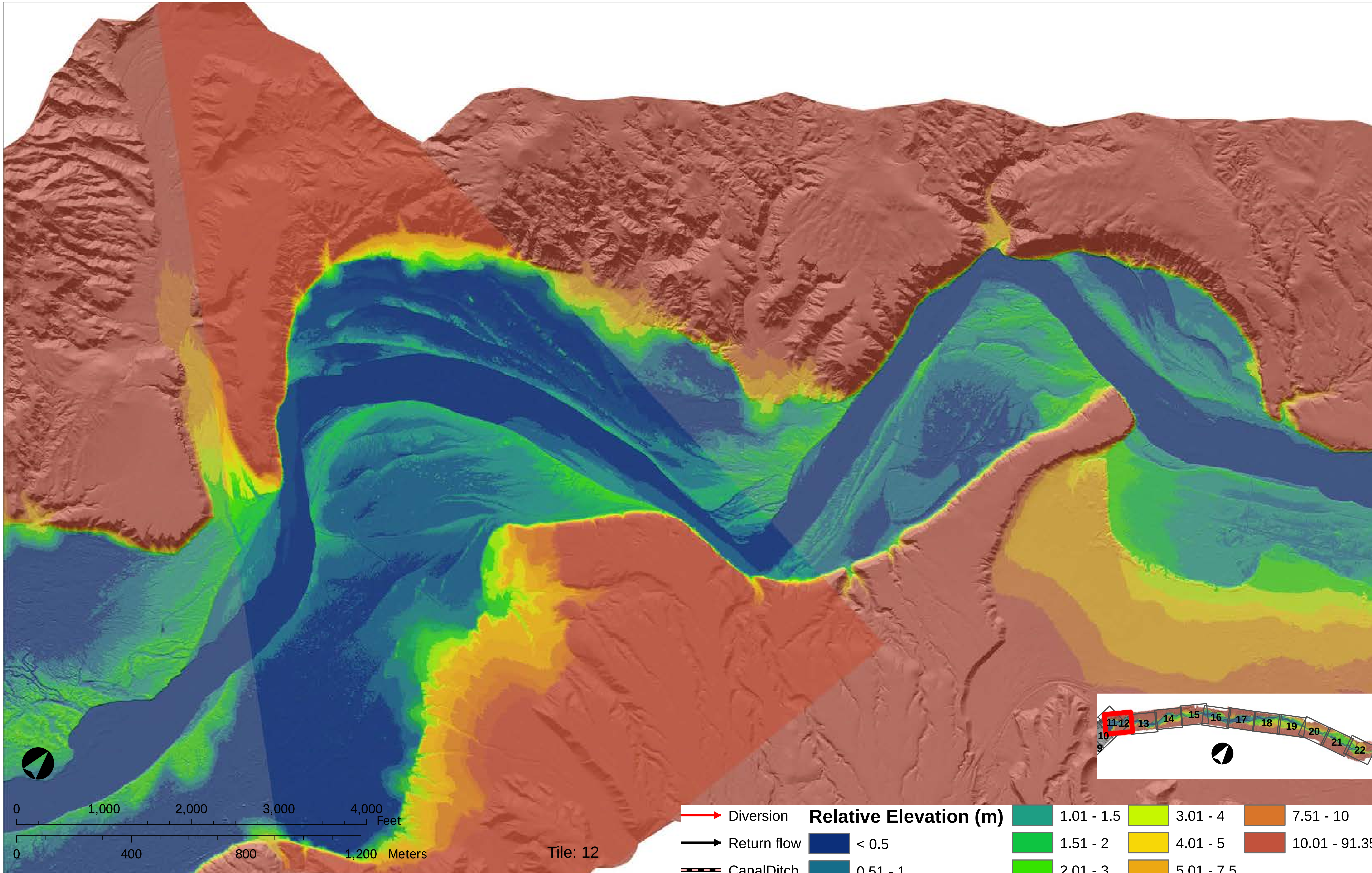

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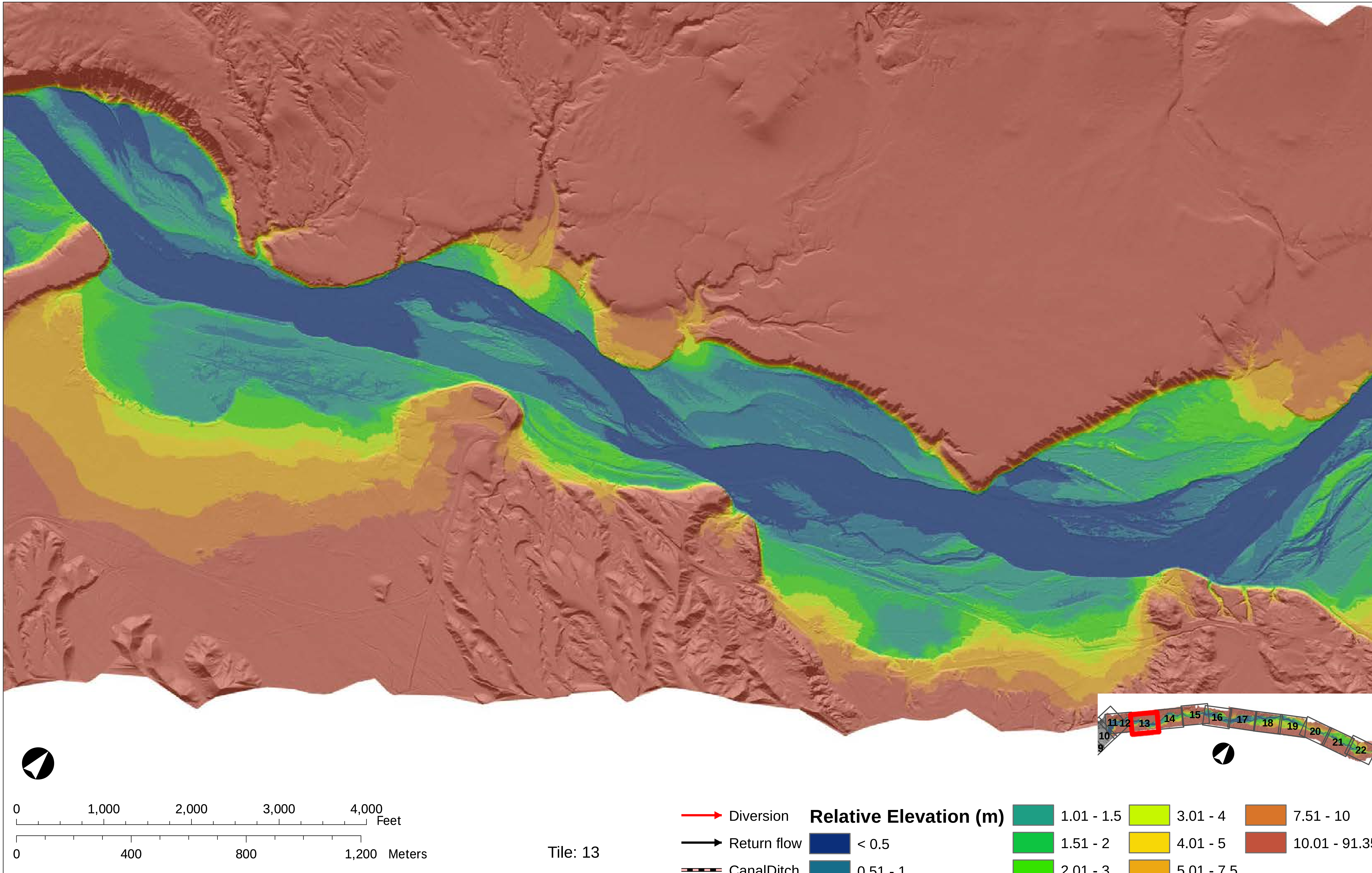

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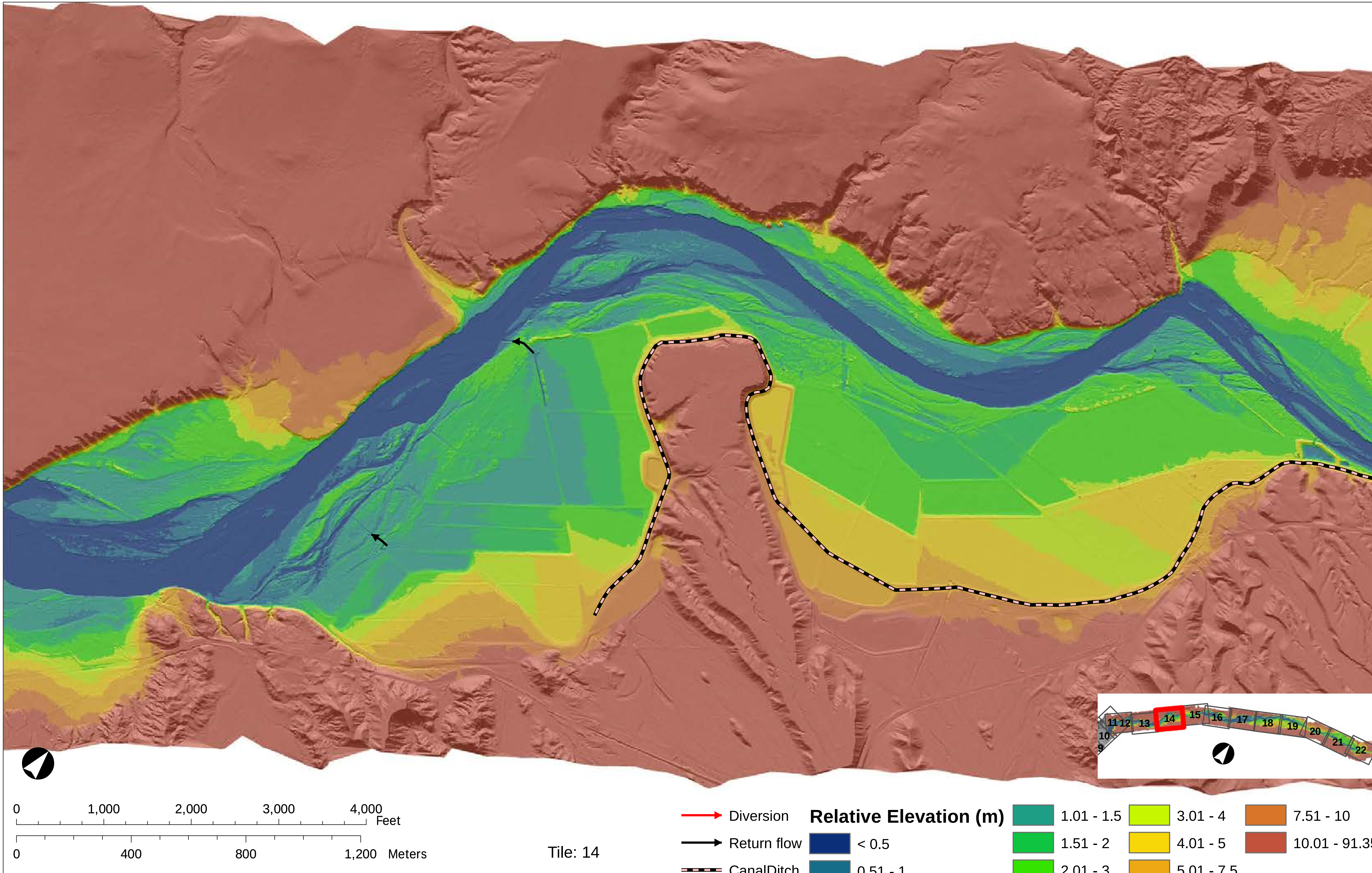
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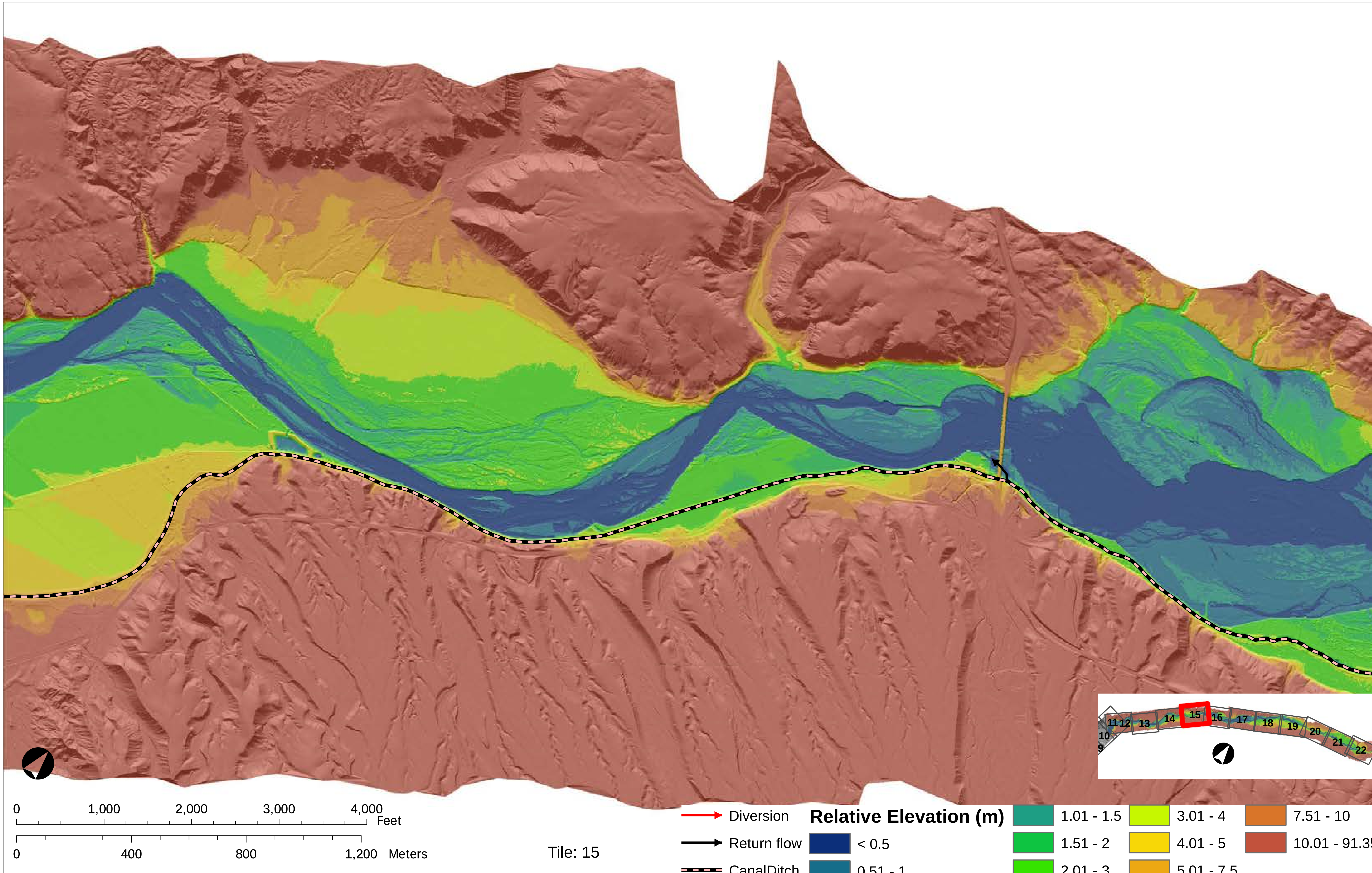
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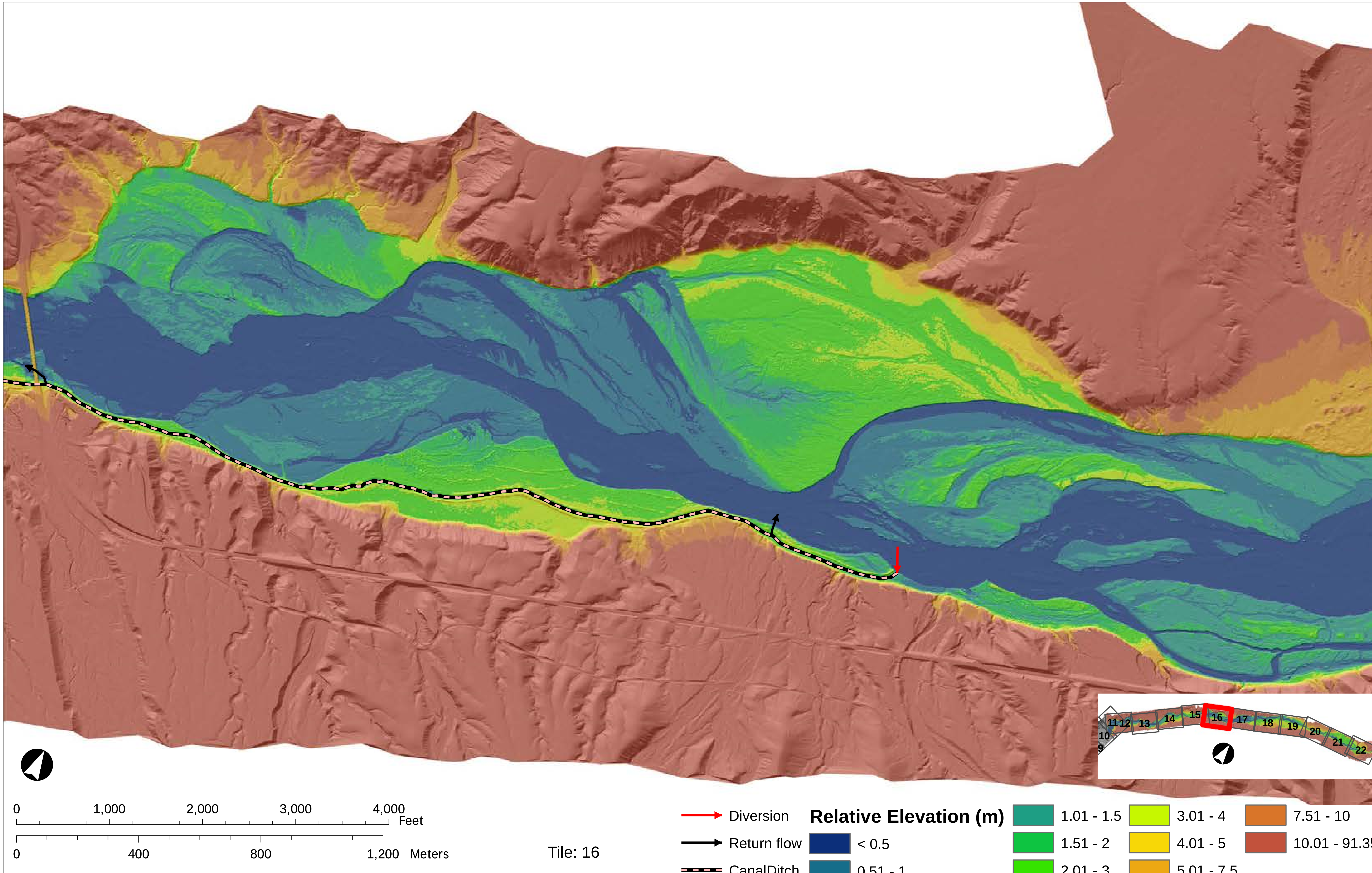

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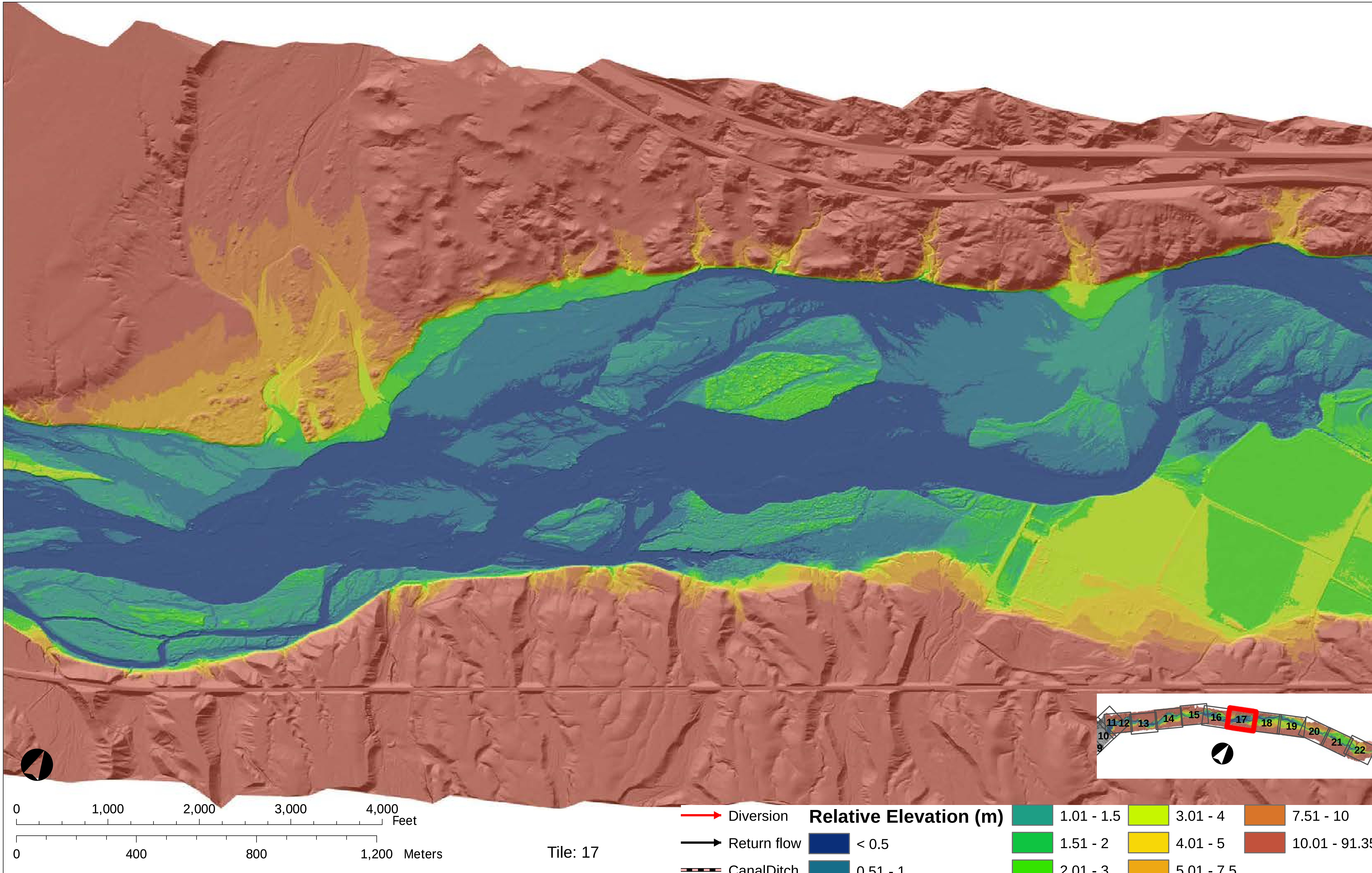

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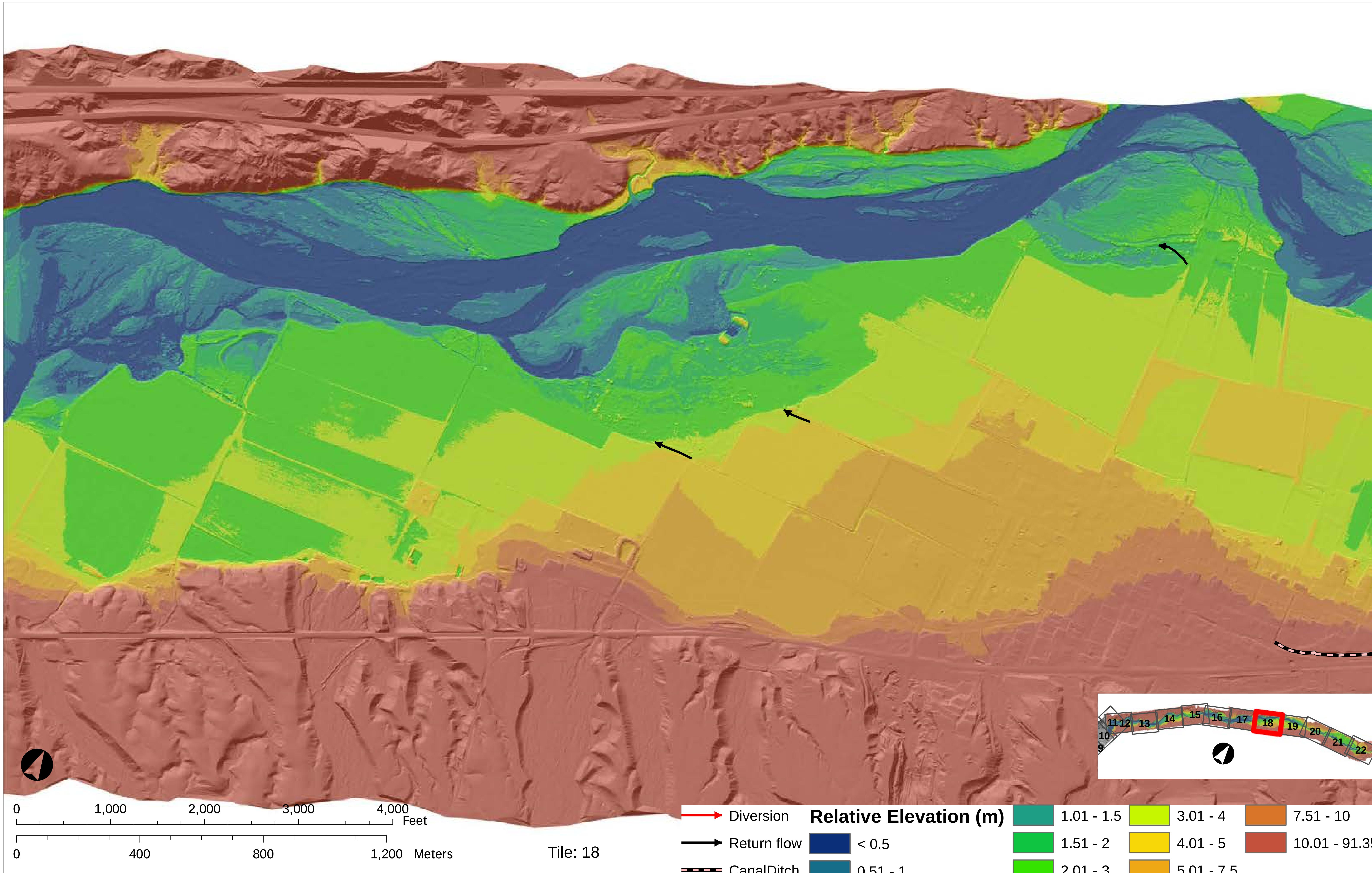

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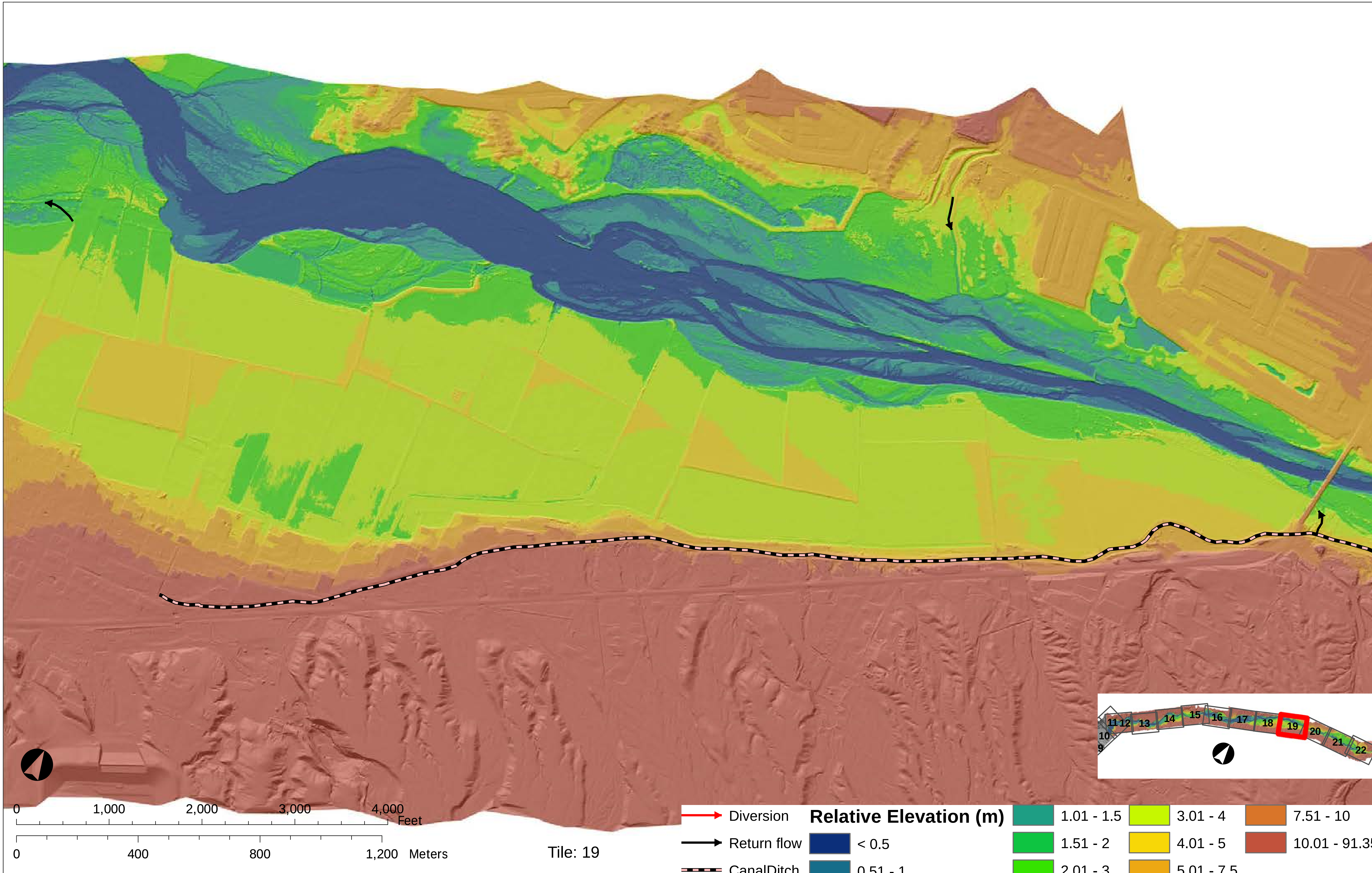

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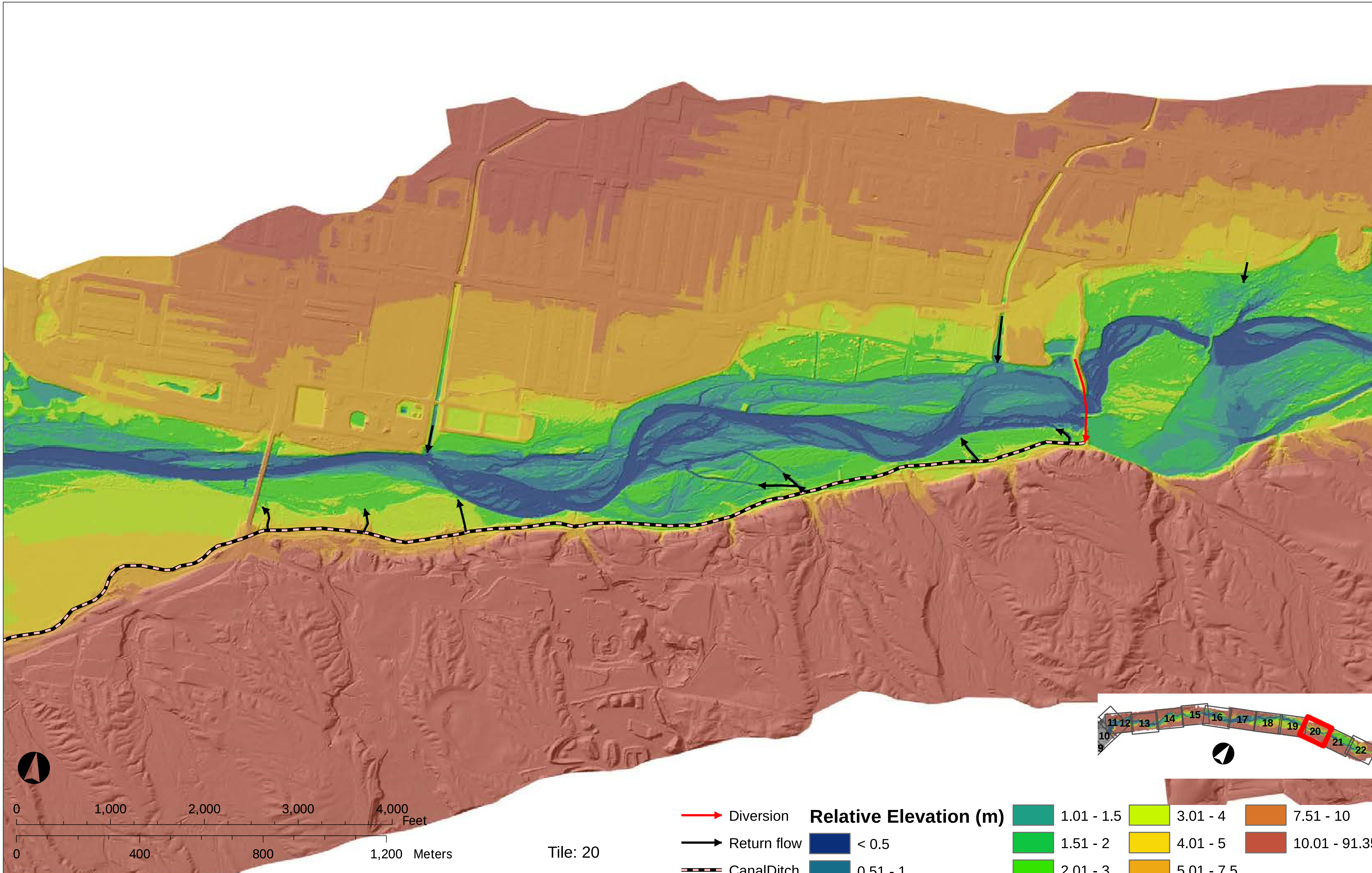
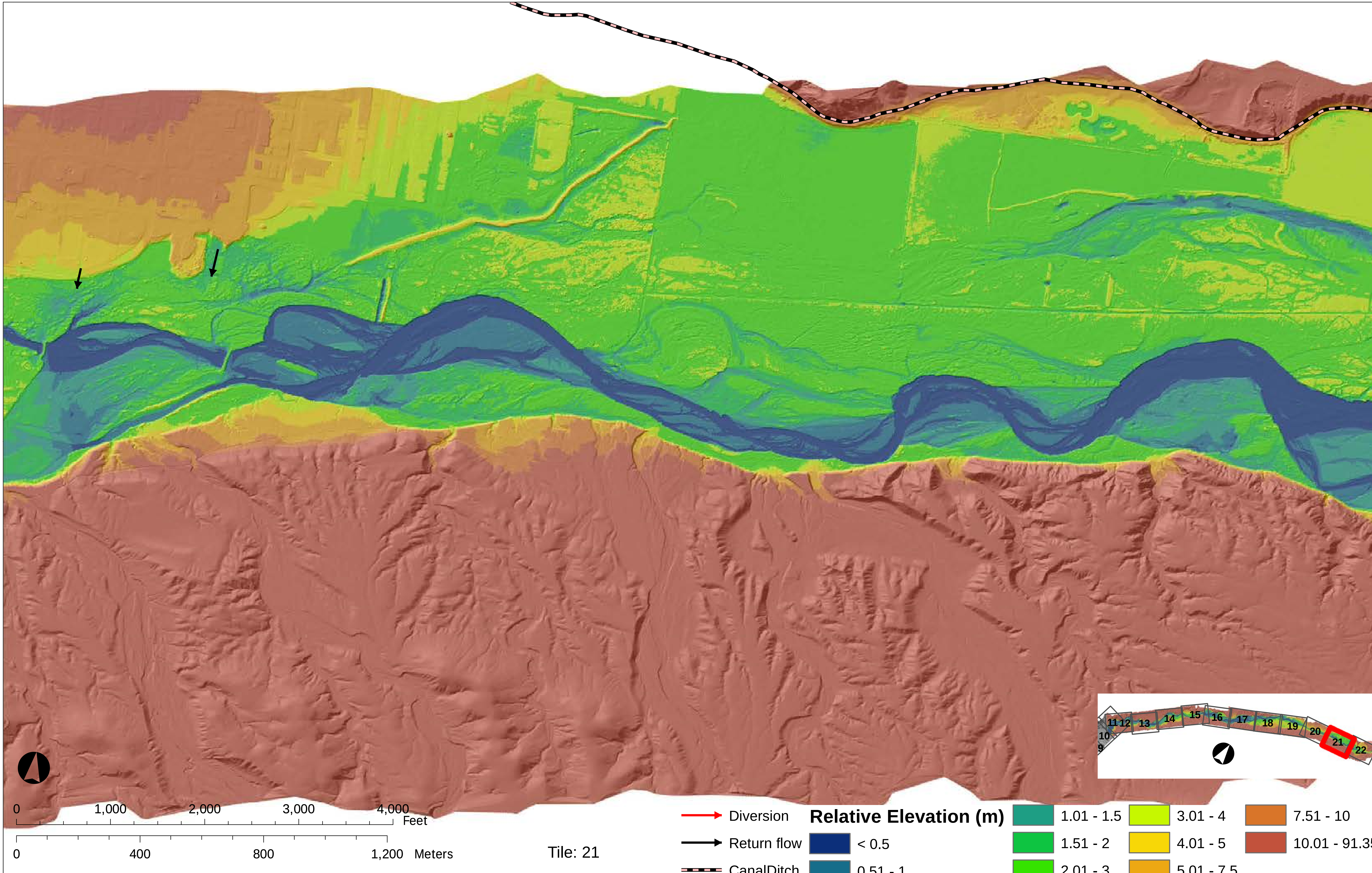
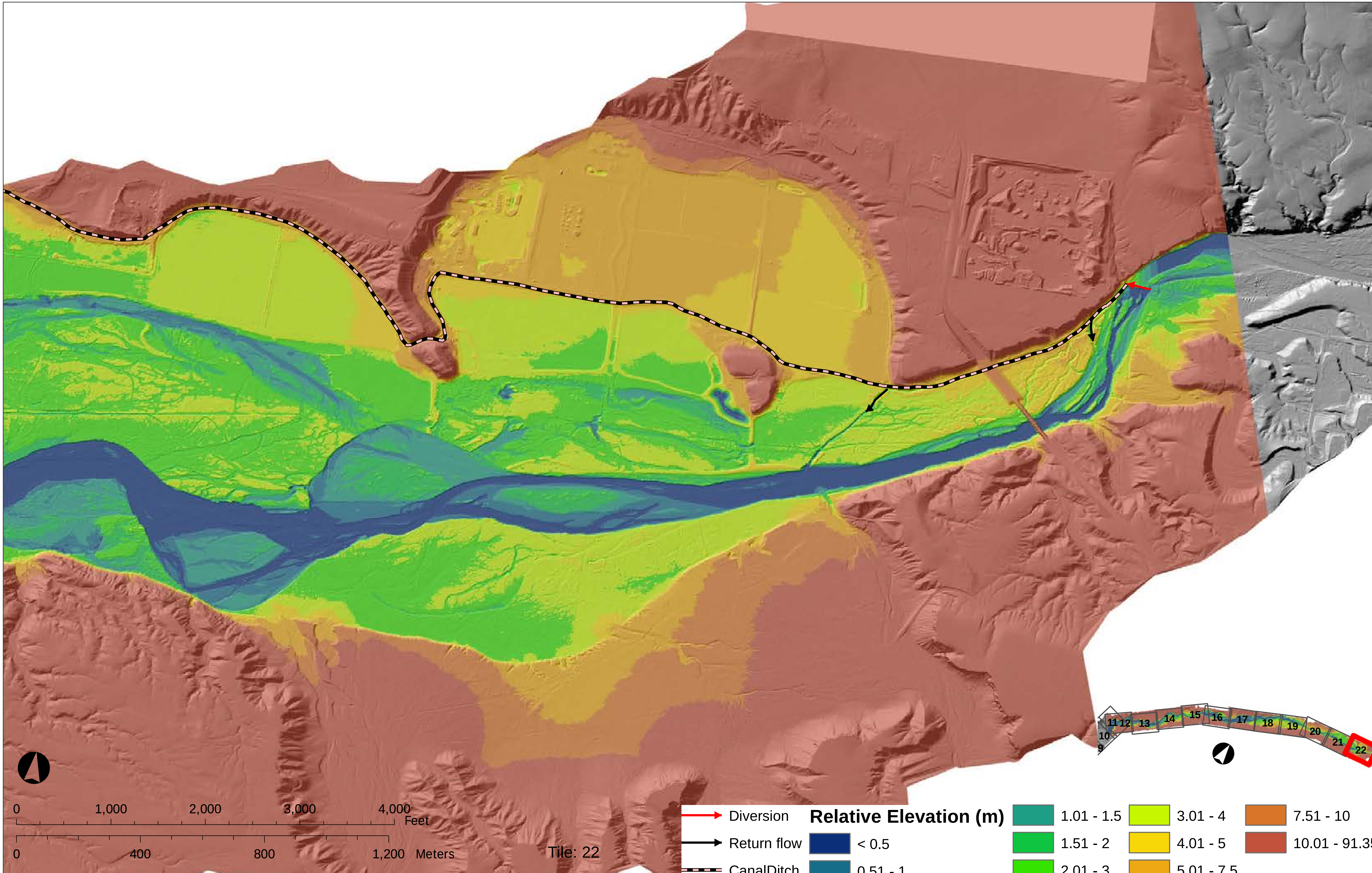
10.01 - 91.35



11 12 13 14 15 16 17 18 19 20 21 22
10
9
0 1,000 2,000 3,000 4,000 Feet
0 400 800 1,200 Meters
Tile: 20
Diversion
Return flow
CanalDitch
Relative Elevation (m)
< 0.5
0.51 - 1
1.01 - 1.5
1.51 - 2
2.01 - 3
3.01 - 4
4.01 - 5
5.01 - 7.5
7.51 - 10
10.01 - 91.35



11
12
13
14
15
16
17
18
19
20
21
22
10
9
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 21
Diversion
Return flow
CanalDitch
Relative Elevation (m)
< 0.5
0.51 - 1
1.01 - 1.5
1.51 - 2
2.01 - 3
3.01 - 4
4.01 - 5
5.01 - 7.5
7.51 - 10
10.01 - 91.35



0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 22
Diversion
Return flow
CanalDitch
Relative Elevation (m)
< 0.5
0.51 - 1
1.01 - 1.5
1.51 - 2
2.01 - 3
3.01 - 4
4.01 - 5
5.01 - 7.5
7.51 - 10
10.01 - 91.35
9
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21
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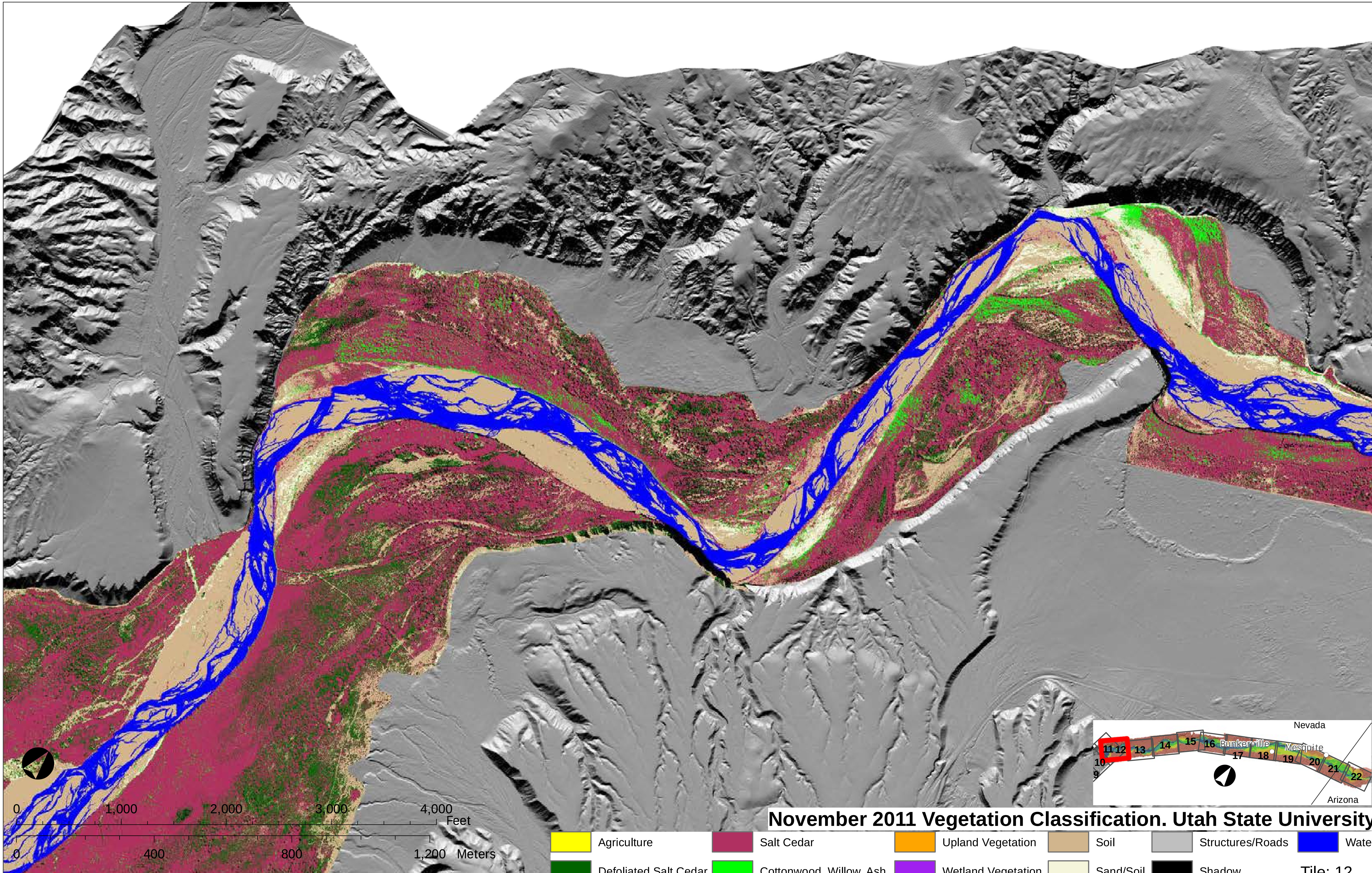
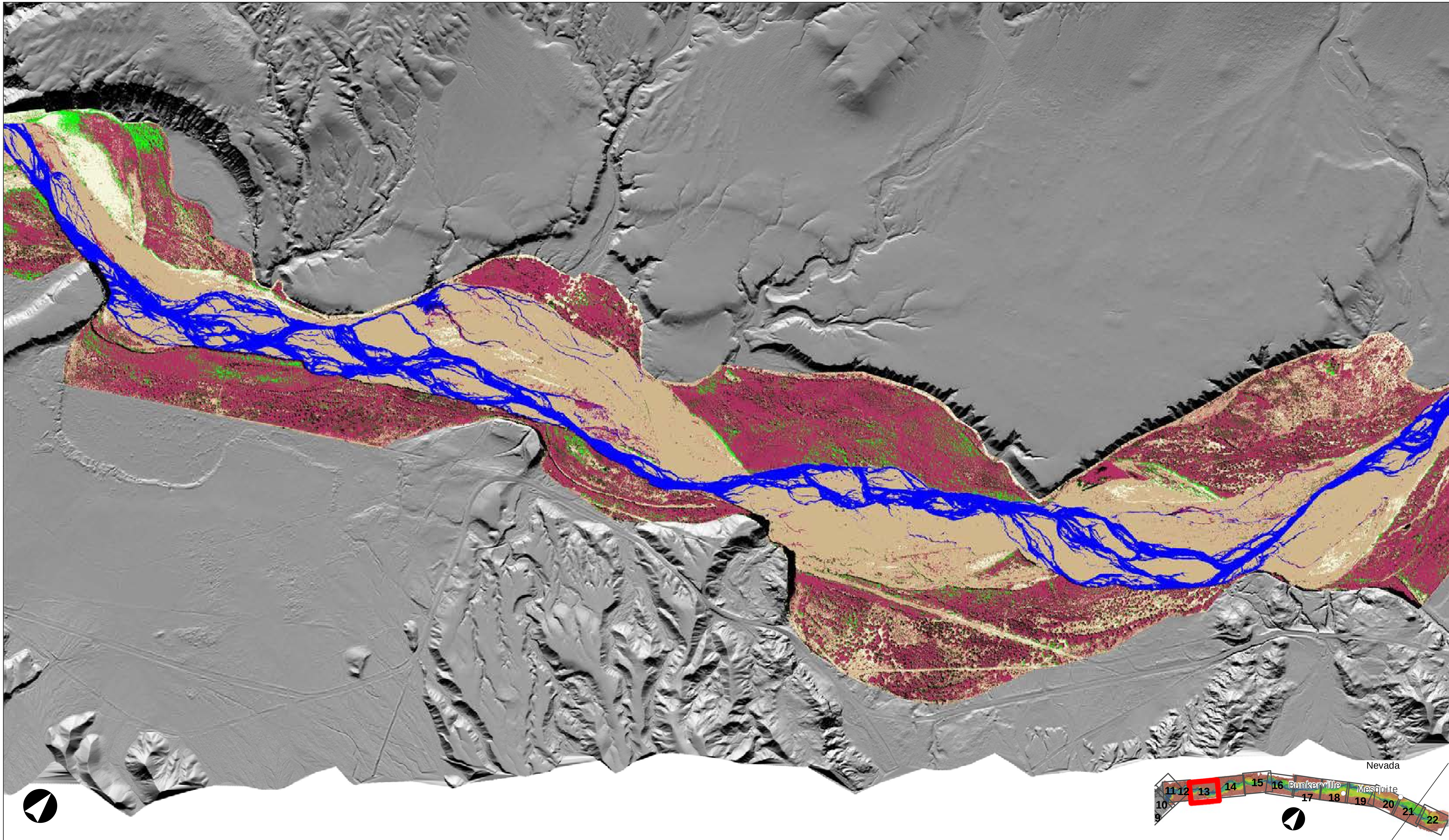


Nevada
11 12
13
14
15
16
Bunkerville
Mesquite
17
18
19
20
21
22
10
9
Arizona
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
November 2011 Vegetation Classification. Utah State University
Agriculture
Salt Cedar
Upland Vegetation
Soil
Structures/Roads
Water
Defoliated Salt Cedar
Cottonwood, Willow, Ash
Wetland Vegetation
Sand/Soil
Shadow
Tile: 12



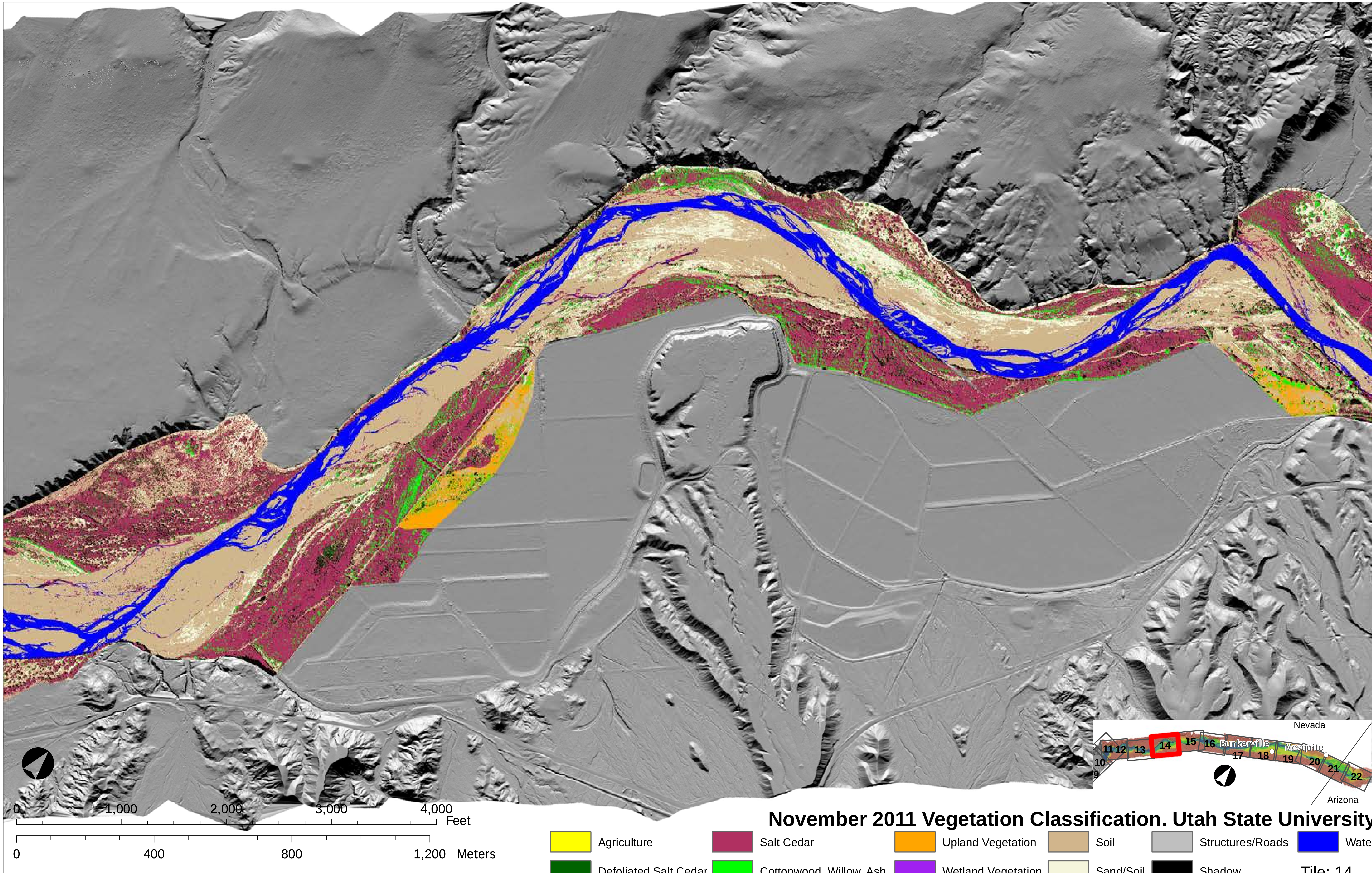
0 1,000 2,000 3,000 4,000 Feet

0 400 800 1,200 Meters

November 2011 Vegetation Classification. Utah State University

Agriculture	Salt Cedar	Upland Vegetation	Soil	Structures/Roads	Water
Defoliated Salt Cedar	Cottonwood, Willow, Ash	Wetland Vegetation	Sand/Soil	Shadow	

Tile: 13


November 2011 Vegetation Classification. Utah State University
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Agriculture
Defoliated Salt Cedar
Salt Cedar
Cottonwood, Willow, Ash
Upland Vegetation
Wetland Vegetation
Soil
Sand/Soil
Structures/Roads
Shadow
Water
Tile: 14
Nevada
Arizona
Bunkerville
Mesquite
9
10
11
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15
16
17
18
19
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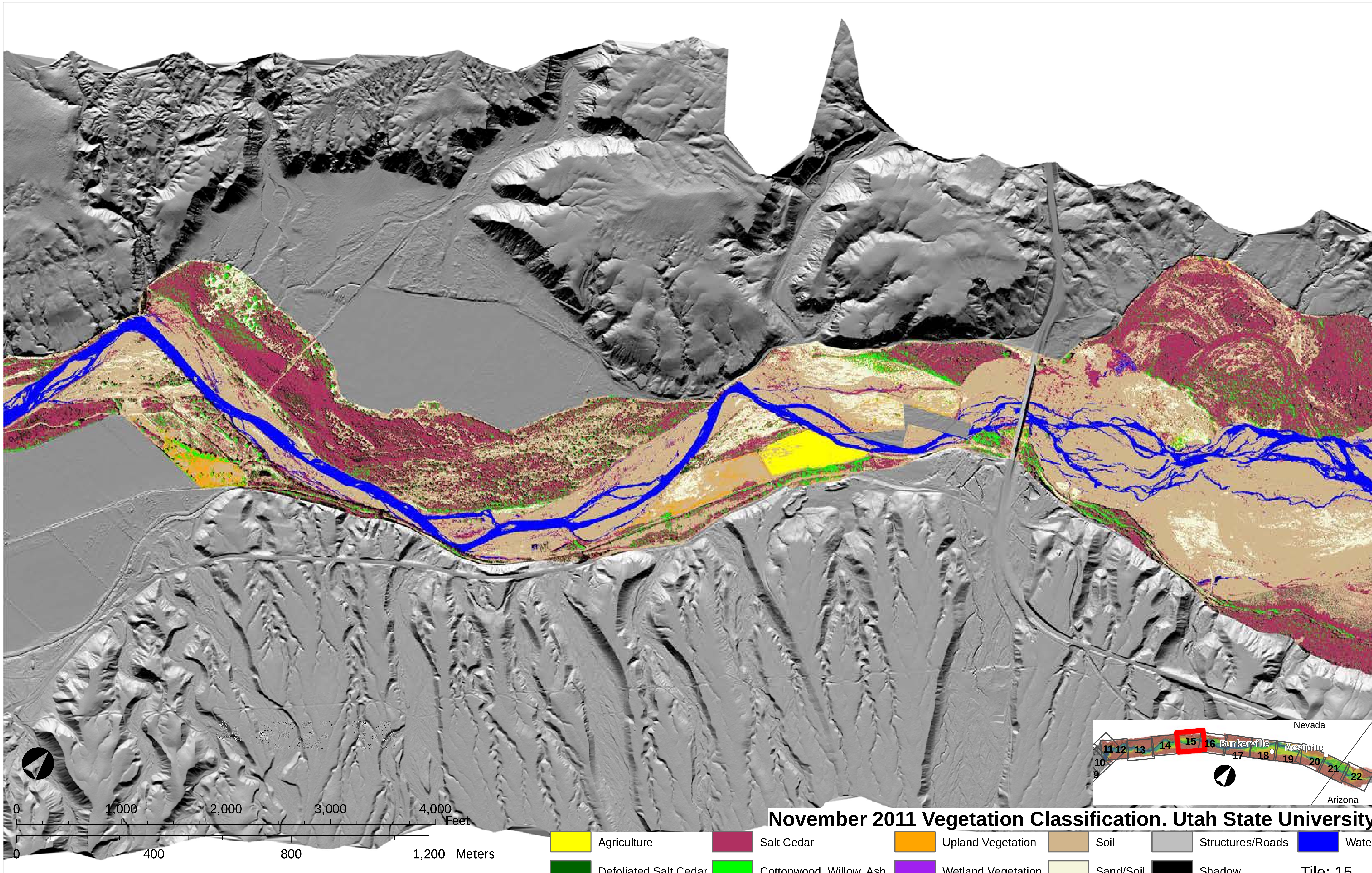
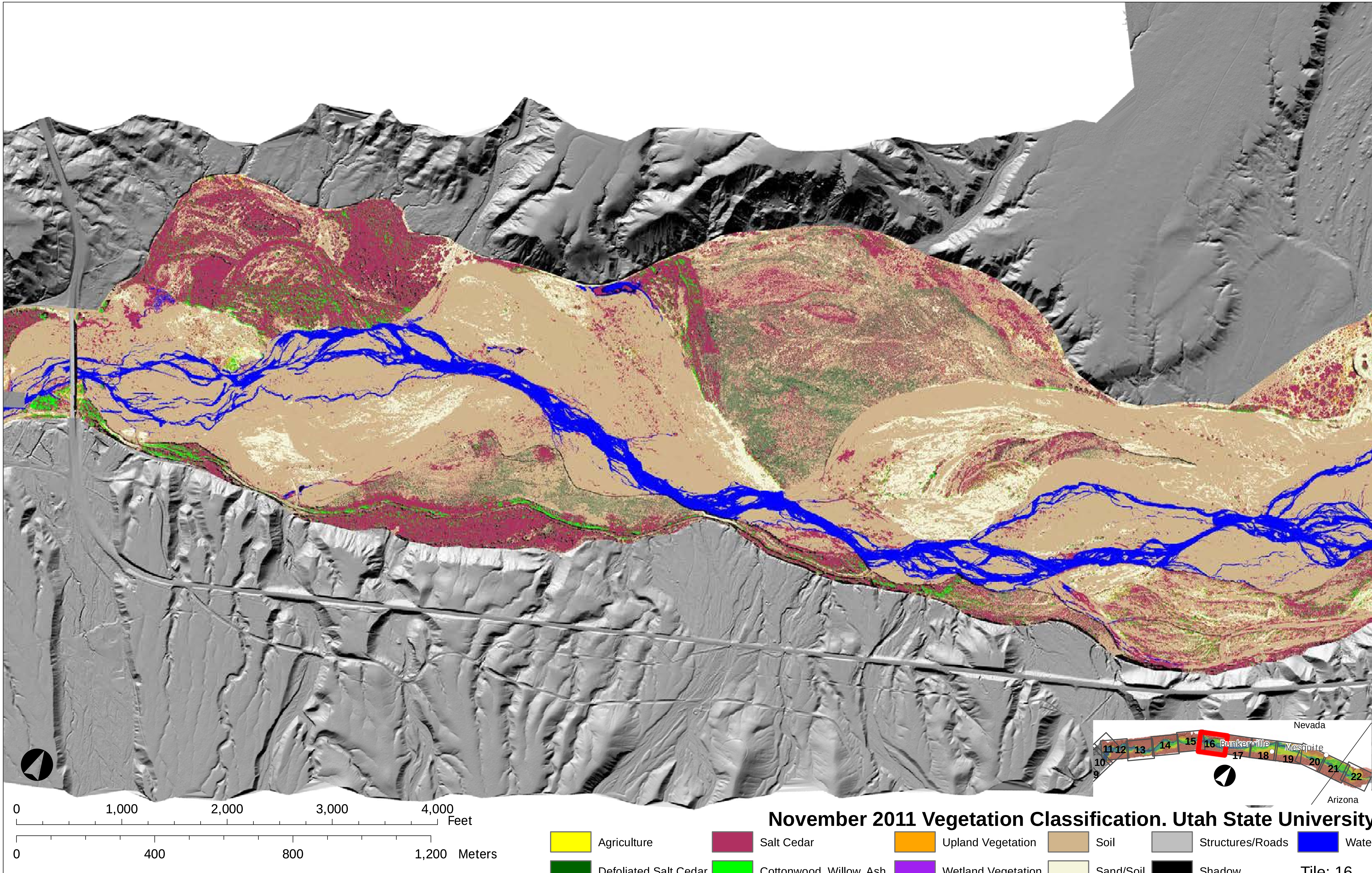
21
22


November 2011 Vegetation Classification. Utah State University
Agriculture
Salt Cedar
Upland Vegetation
Soil
Structures/Roads
Water
Defoliated Salt Cedar
Cottonwood, Willow, Ash
Wetland Vegetation
Sand/Soil
Shadow
Tile: 15
0 1,000 2,000 3,000 4,000 Feet
0 400 800 1,200 Meters
Nevada
Arizona
Bunkerville
Mesquite
9 10 11 12 13 14 15 16 17 18 19 20 21 22


November 2011 Vegetation Classification. Utah State University
Agriculture
Defoliated Salt Cedar
Salt Cedar
Cottonwood, Willow, Ash
Upland Vegetation
Wetland Vegetation
Soil
Sand/Soil
Structures/Roads
Shadow
Water
Tile: 16
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Nevada
Arizona
Bunkerville
Mesquite
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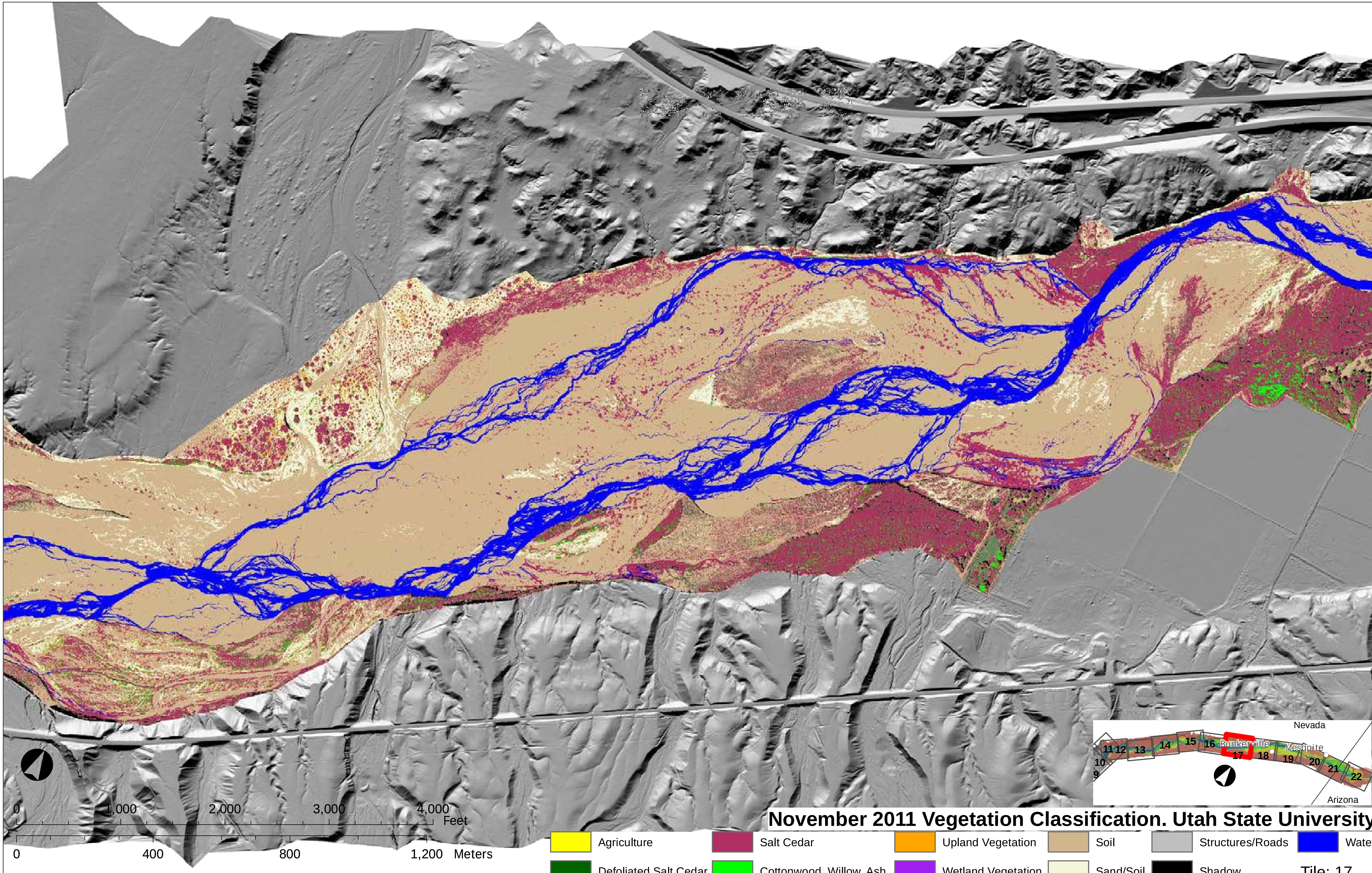
21
22


November 2011 Vegetation Classification. Utah State University
Agriculture
Salt Cedar
Upland Vegetation
Soil
Structures/Roads
Water
Defoliated Salt Cedar
Cottonwood, Willow, Ash
Wetland Vegetation
Sand/Soil
Shadow
Tile: 17
0
1,000
2,000
3,000
4,000
Feet
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400
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1,200
Meters
Nevada
Arizona
Bunkerville
Mesquite
9
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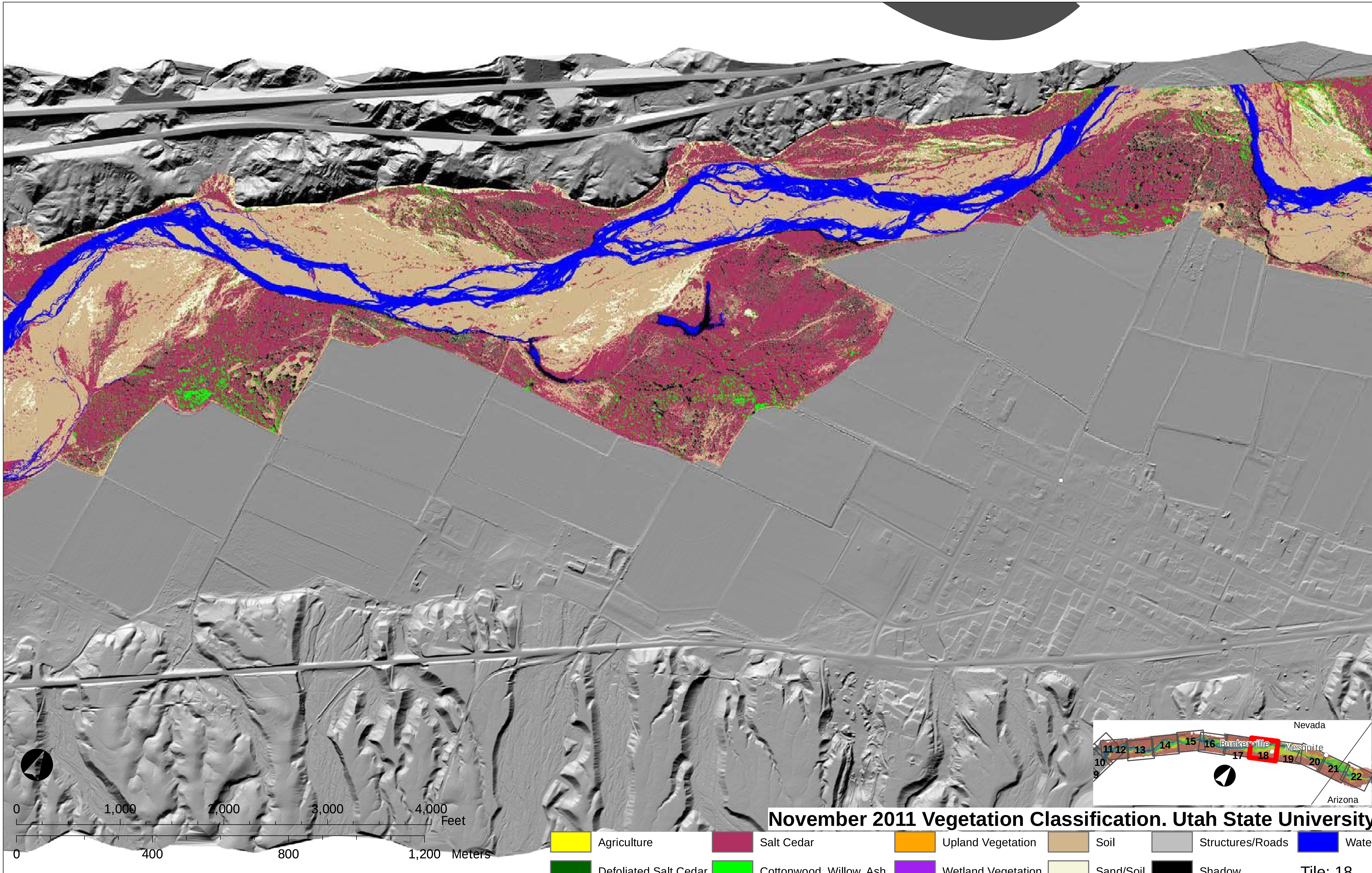
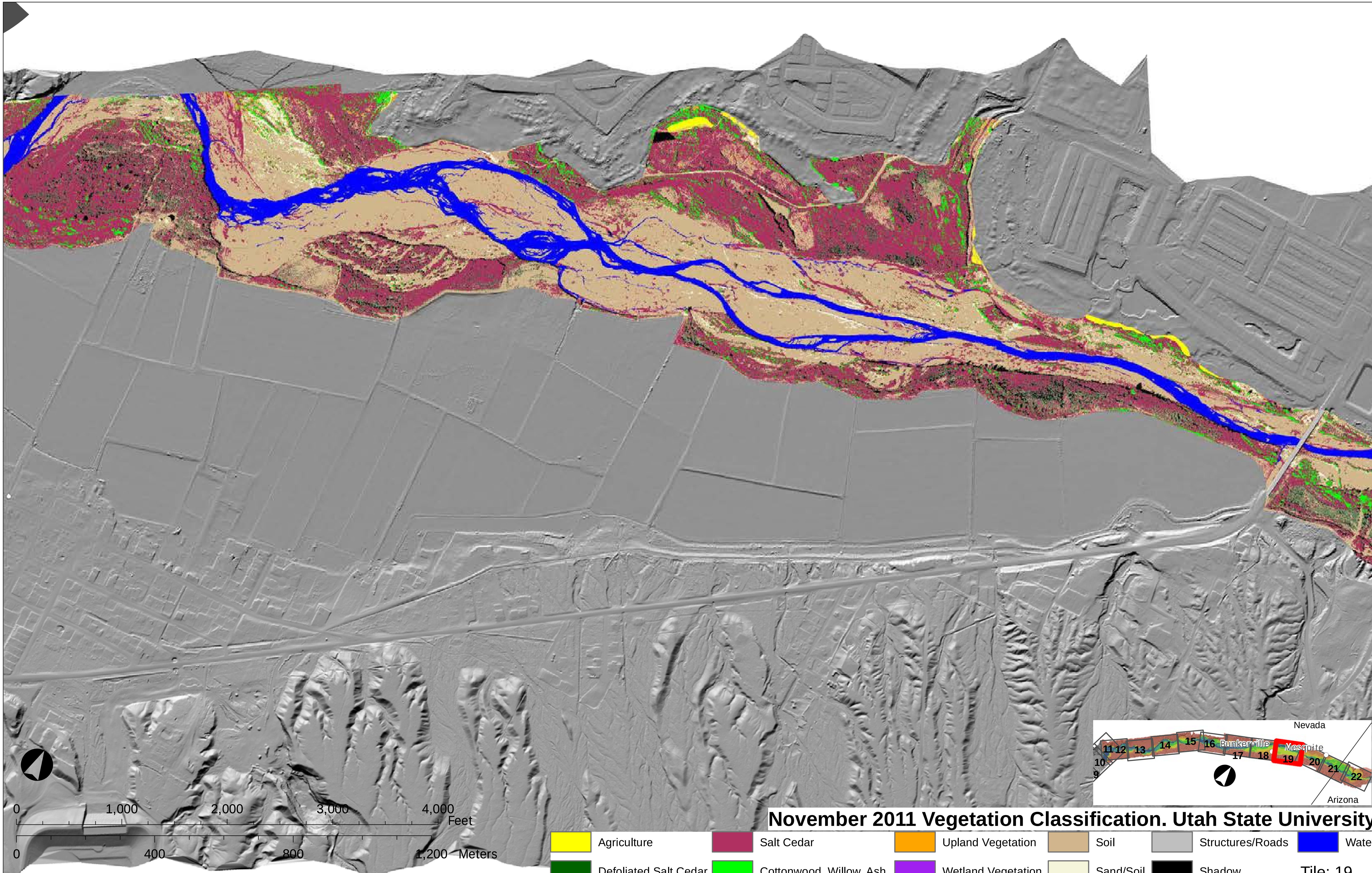

November 2011 Vegetation Classification. Utah State University
Agriculture
Salt Cedar
Upland Vegetation
Soil
Structures/Roads
Water
Defoliated Salt Cedar
Cottonwood, Willow, Ash
Wetland Vegetation
Sand/Soil
Shadow
Tile: 18
0 1,000 2,000 3,000 4,000 Feet
0 400 800 1,200 Meters
Nevada
Arizona
Bunkerville
Mesquite
9 10 11 12 13 14 15 16 17 18 19 20 21 22


November 2011 Vegetation Classification. Utah State University
Agriculture
Salt Cedar
Upland Vegetation
Soil
Structures/Roads
Water
Defoliated Salt Cedar
Cottonwood, Willow, Ash
Wetland Vegetation
Sand/Soil
Shadow
Tile: 19
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1,000
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Feet
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Meters
Nevada
Arizona
Bunkerville
Mesquite
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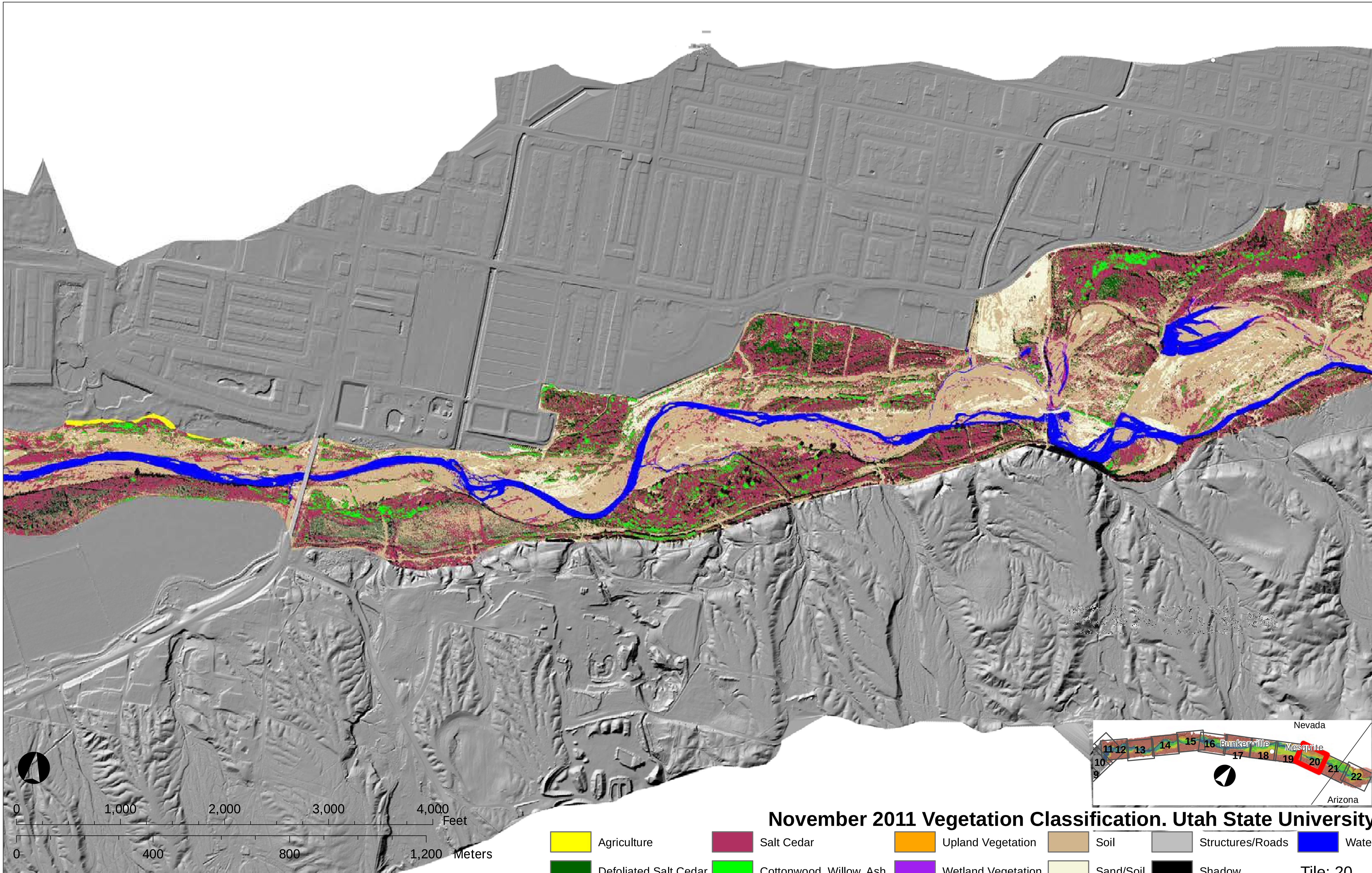

November 2011 Vegetation Classification. Utah State University
Agriculture
Salt Cedar
Upland Vegetation
Soil
Structures/Roads
Water
Defoliated Salt Cedar
Cottonwood, Willow, Ash
Wetland Vegetation
Sand/Soil
Shadow
Tile: 20
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Meters
Nevada
Arizona
Bunkerville
Mesquite
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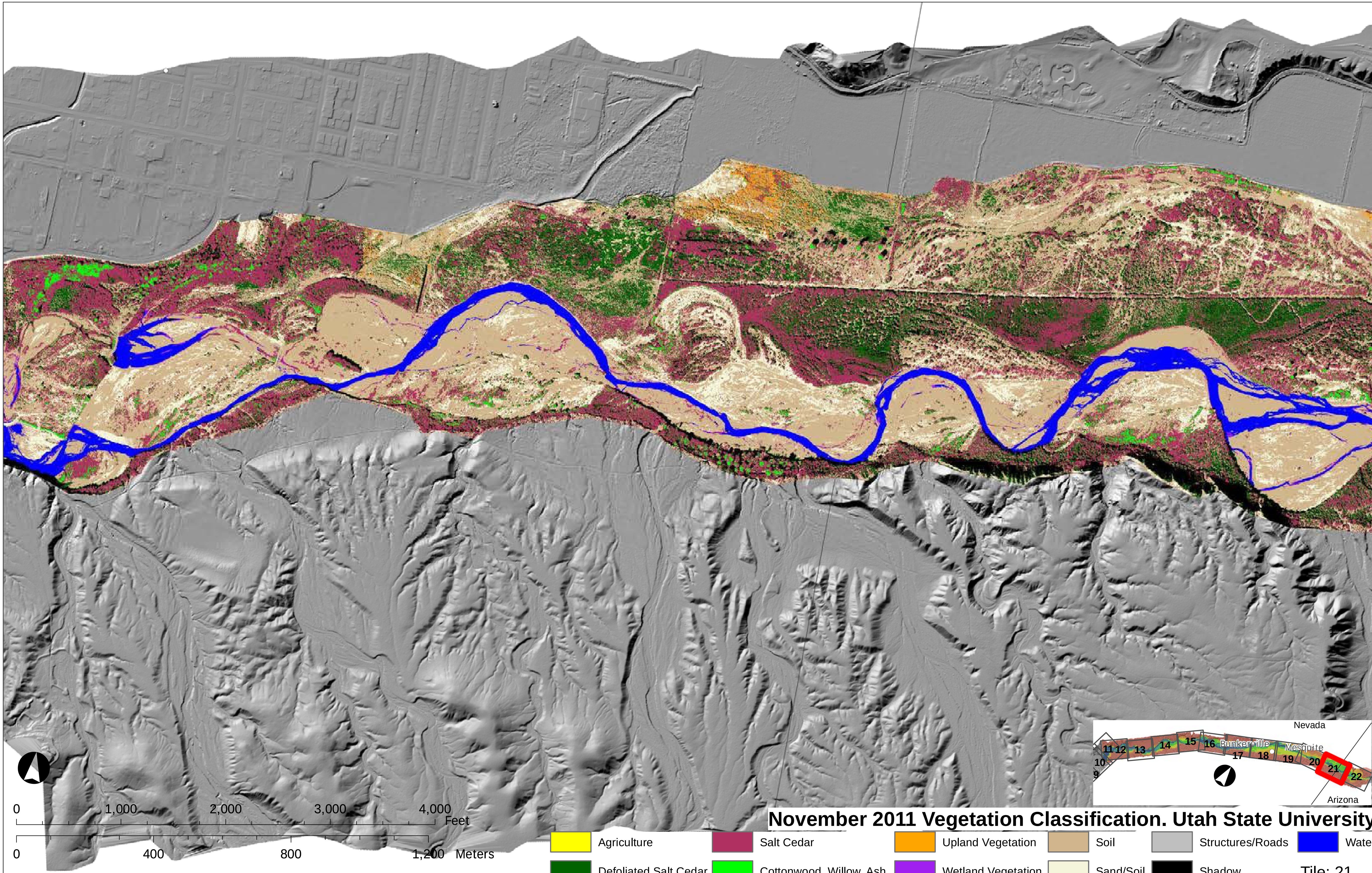

Nevada
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Bunkerville
Mesquite
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Arizona
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Feet
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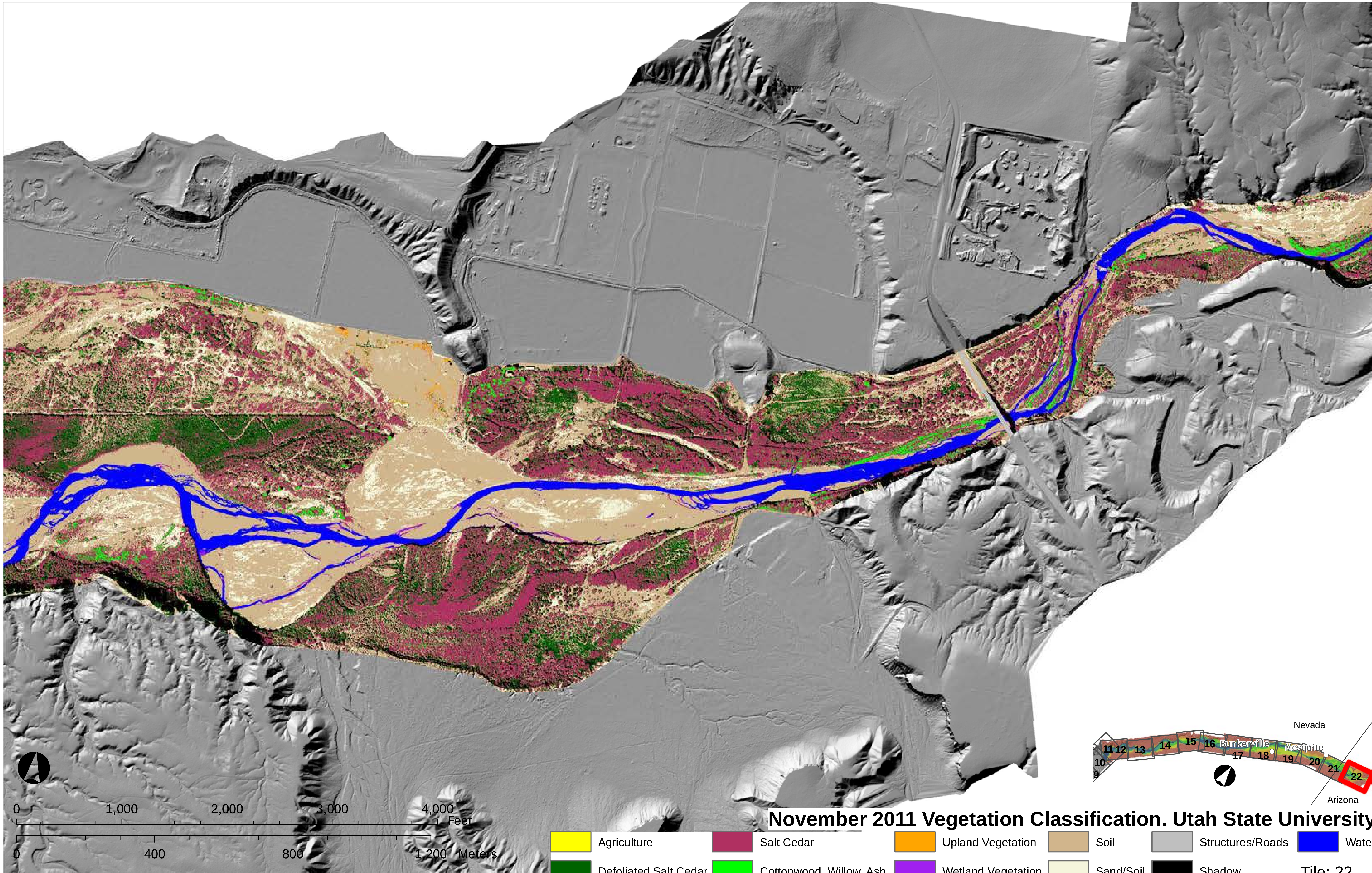
Meters
November 2011 Vegetation Classification. Utah State University
Agriculture
Salt Cedar
Upland Vegetation
Soil
Structures/Roads
Water
Defoliated Salt Cedar
Cottonwood, Willow, Ash
Wetland Vegetation
Sand/Soil
Shadow
Tile: 21


November 2011 Vegetation Classification. Utah State University
Agriculture
Salt Cedar
Upland Vegetation
Soil
Structures/Roads
Water
Defoliated Salt Cedar
Cottonwood, Willow, Ash
Wetland Vegetation
Sand/Soil
Shadow
Tile: 22
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1,000
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Feet
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Meters
Nevada
Arizona
Bunkerville
Mesquite
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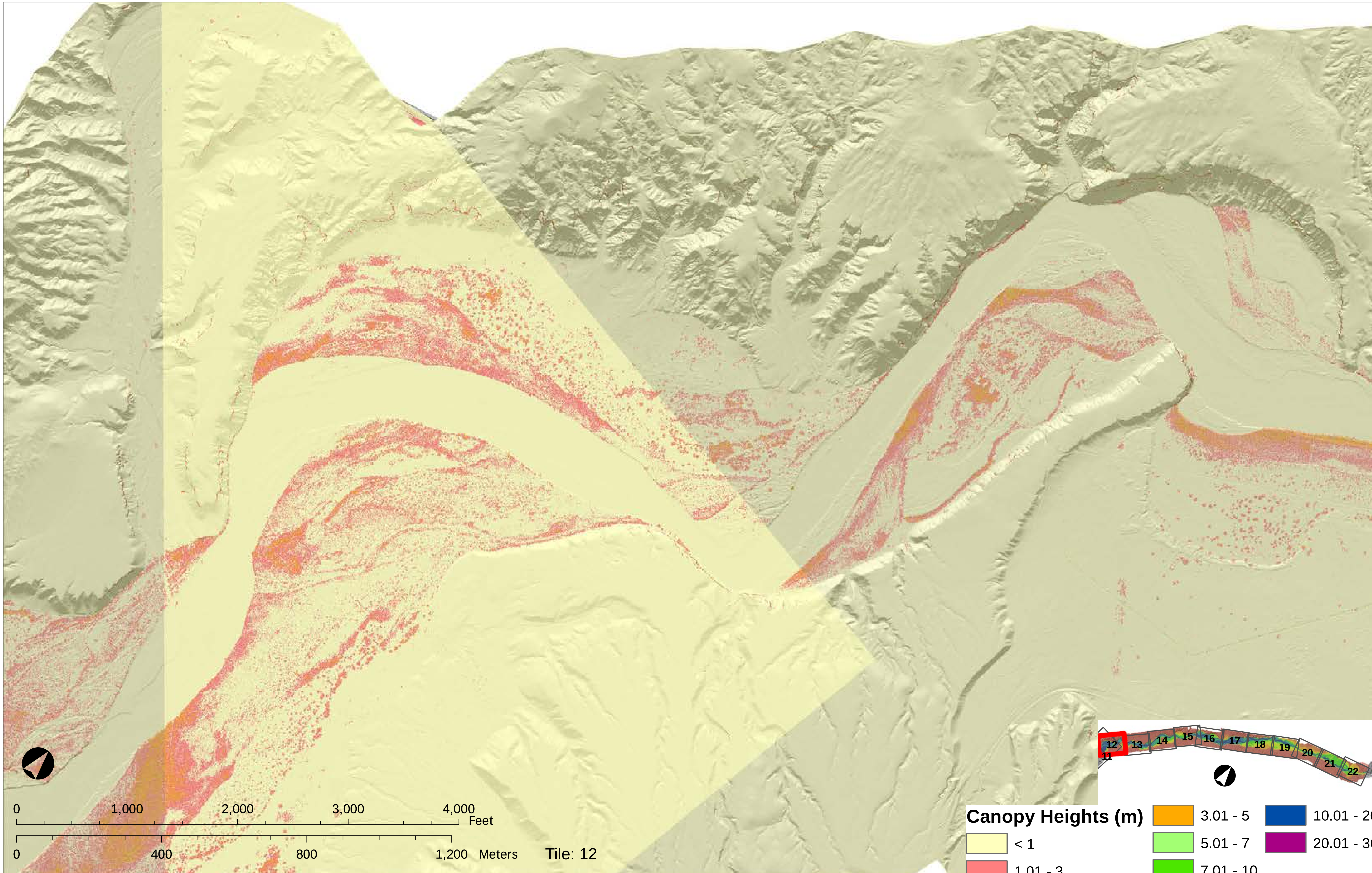

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Feet
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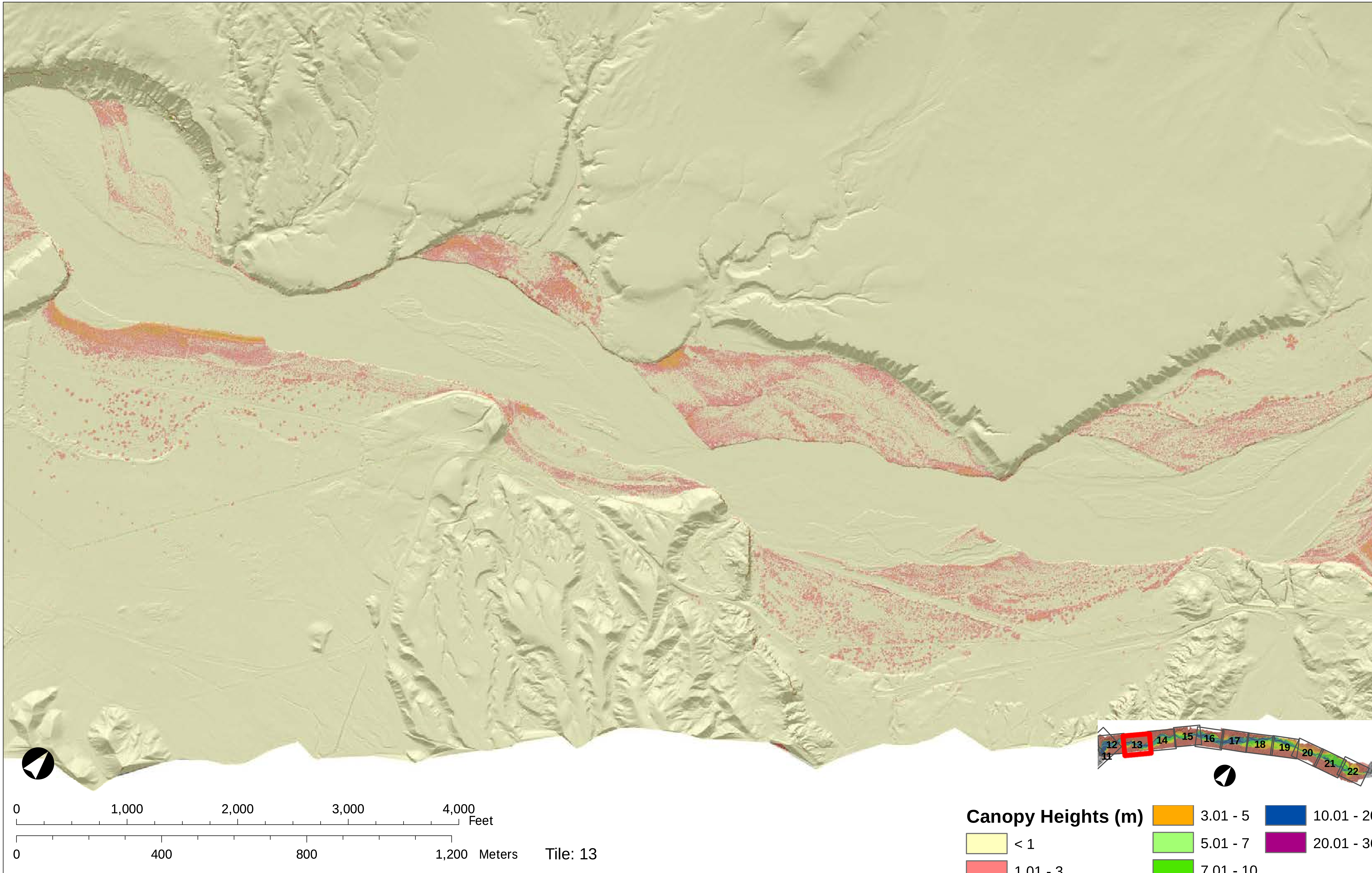
Meters
Tile: 12
Canopy Heights (m)
< 1
1.01 - 3
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36



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Meters
Tile: 13
Canopy Heights (m)
< 1
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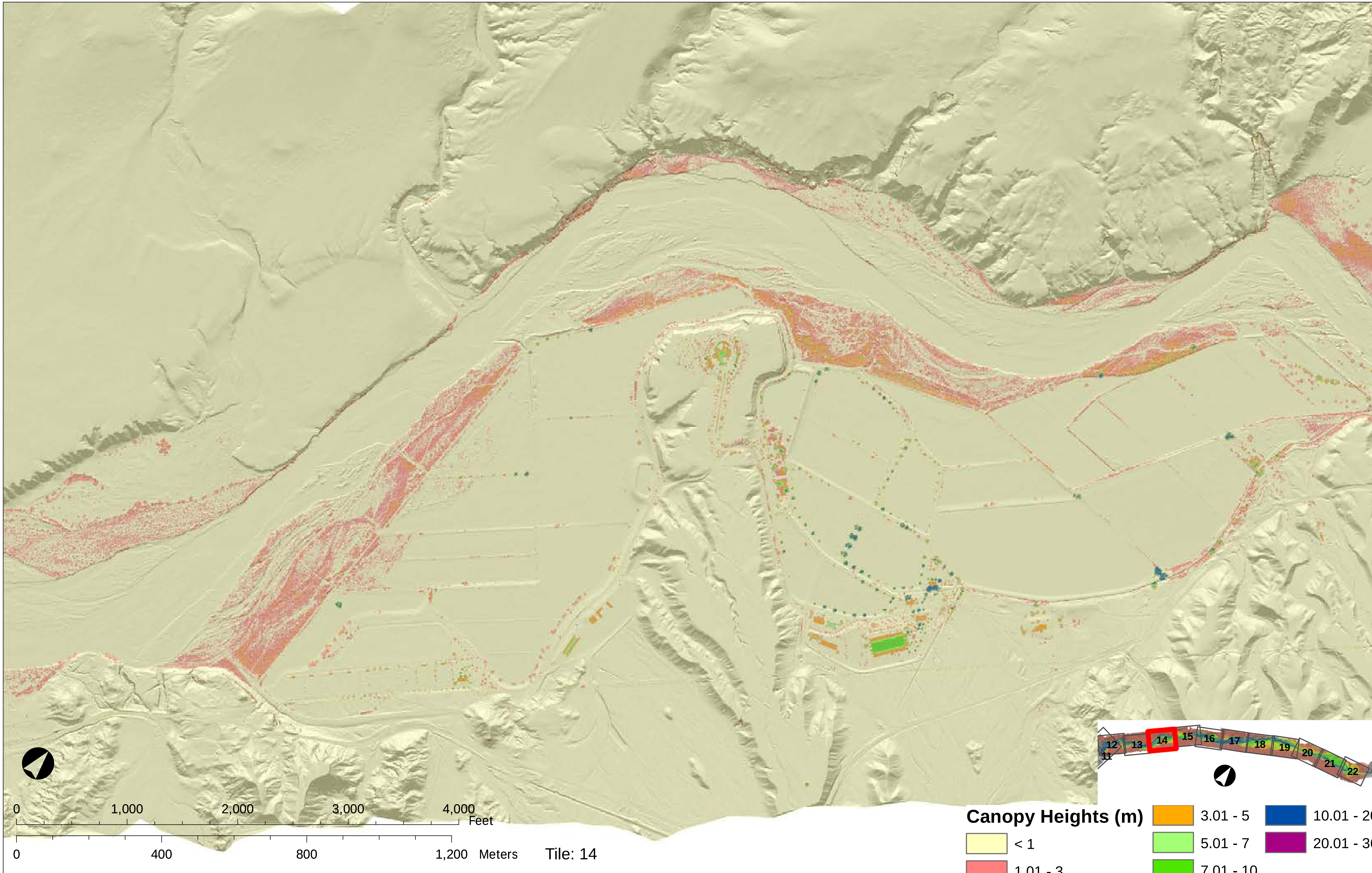
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36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4,000
Feet
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1,200
Meters
Tile: 14
Canopy Heights (m)
< 1
1.01 - 3
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36
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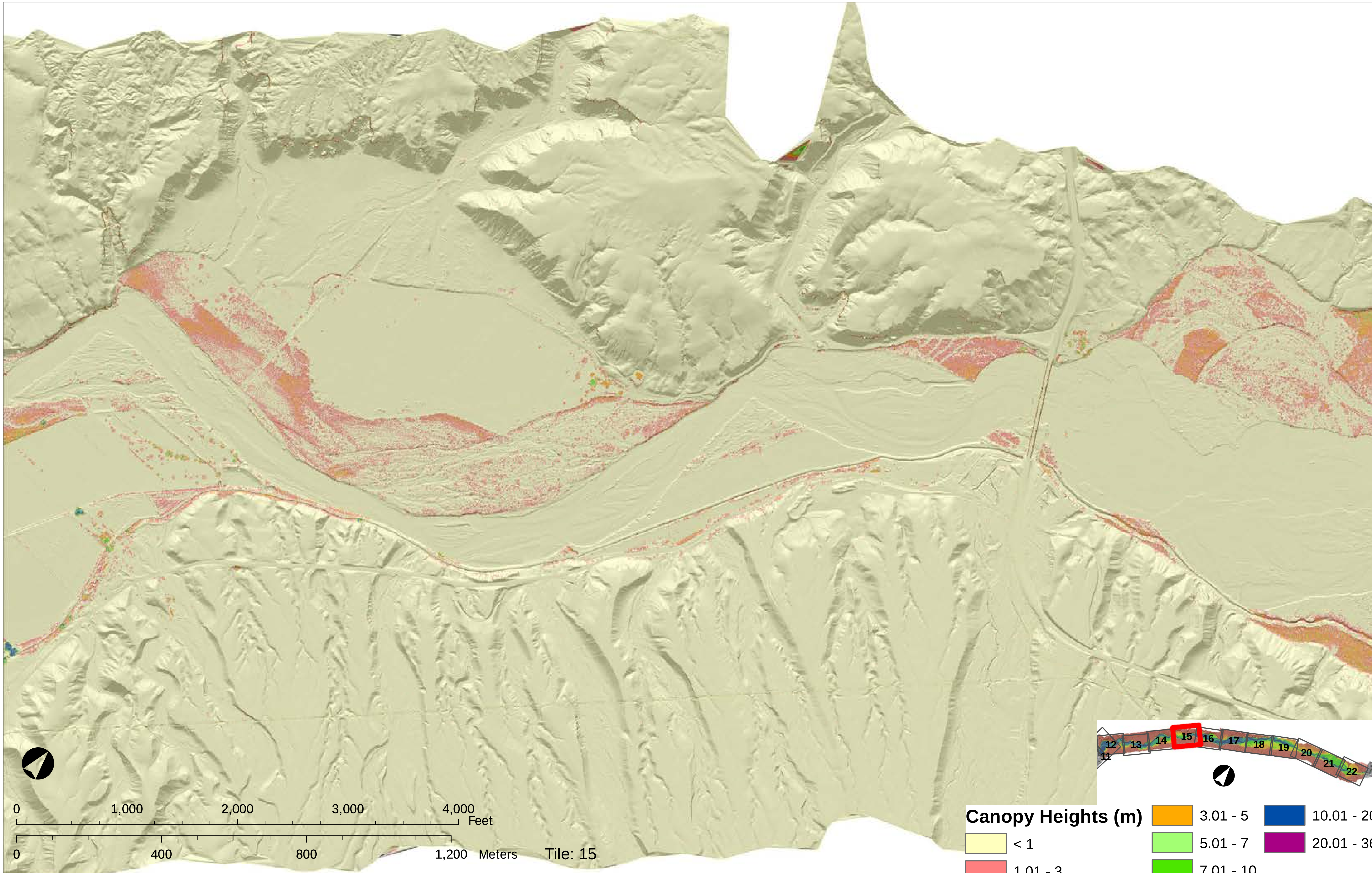

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2,000
3,000
4,000
Feet
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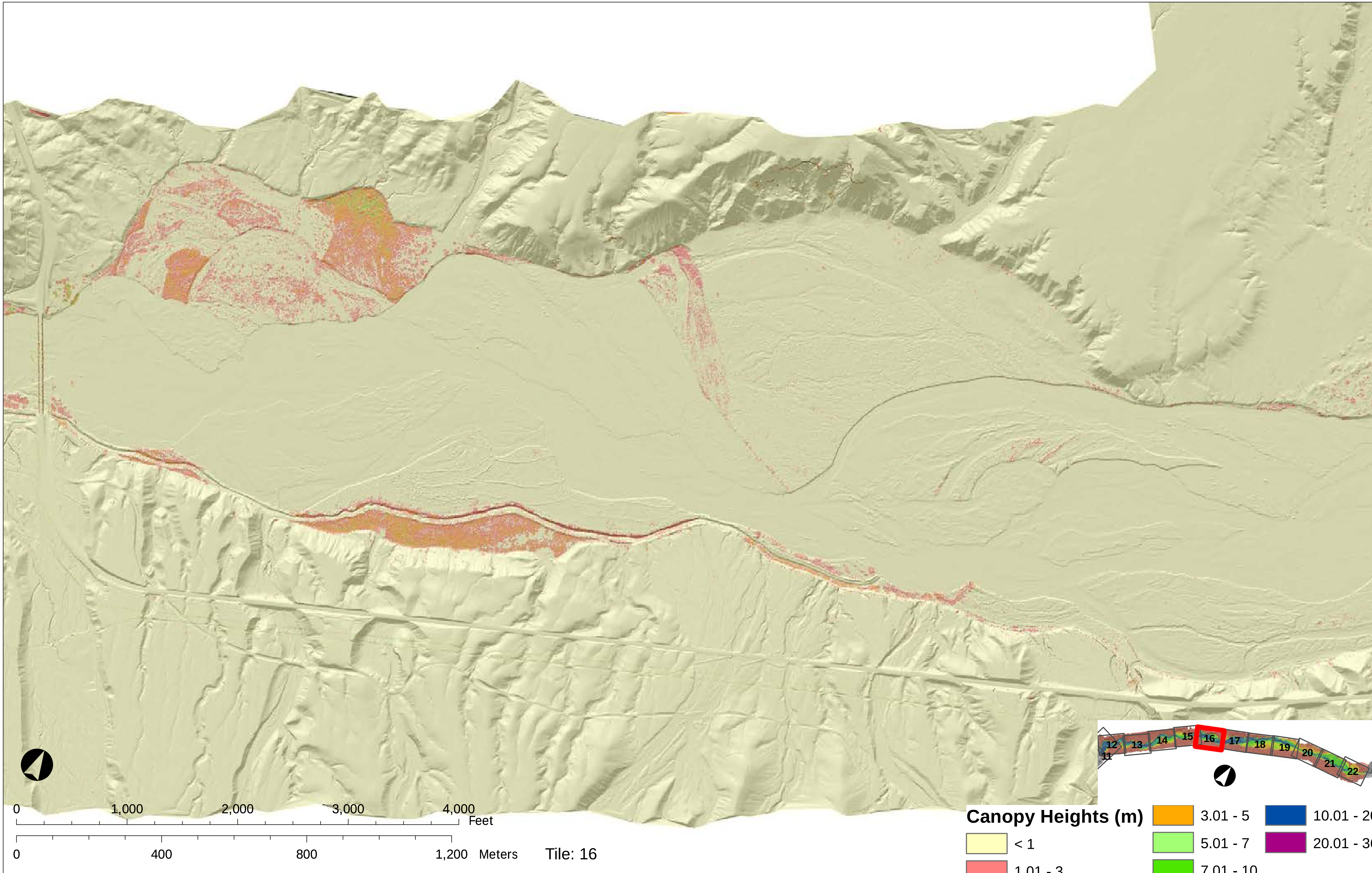
1,200
Meters
Tile: 15
Canopy Heights (m)
< 1
1.01 - 3
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36



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22
11
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2,000
3,000
4,000
Feet
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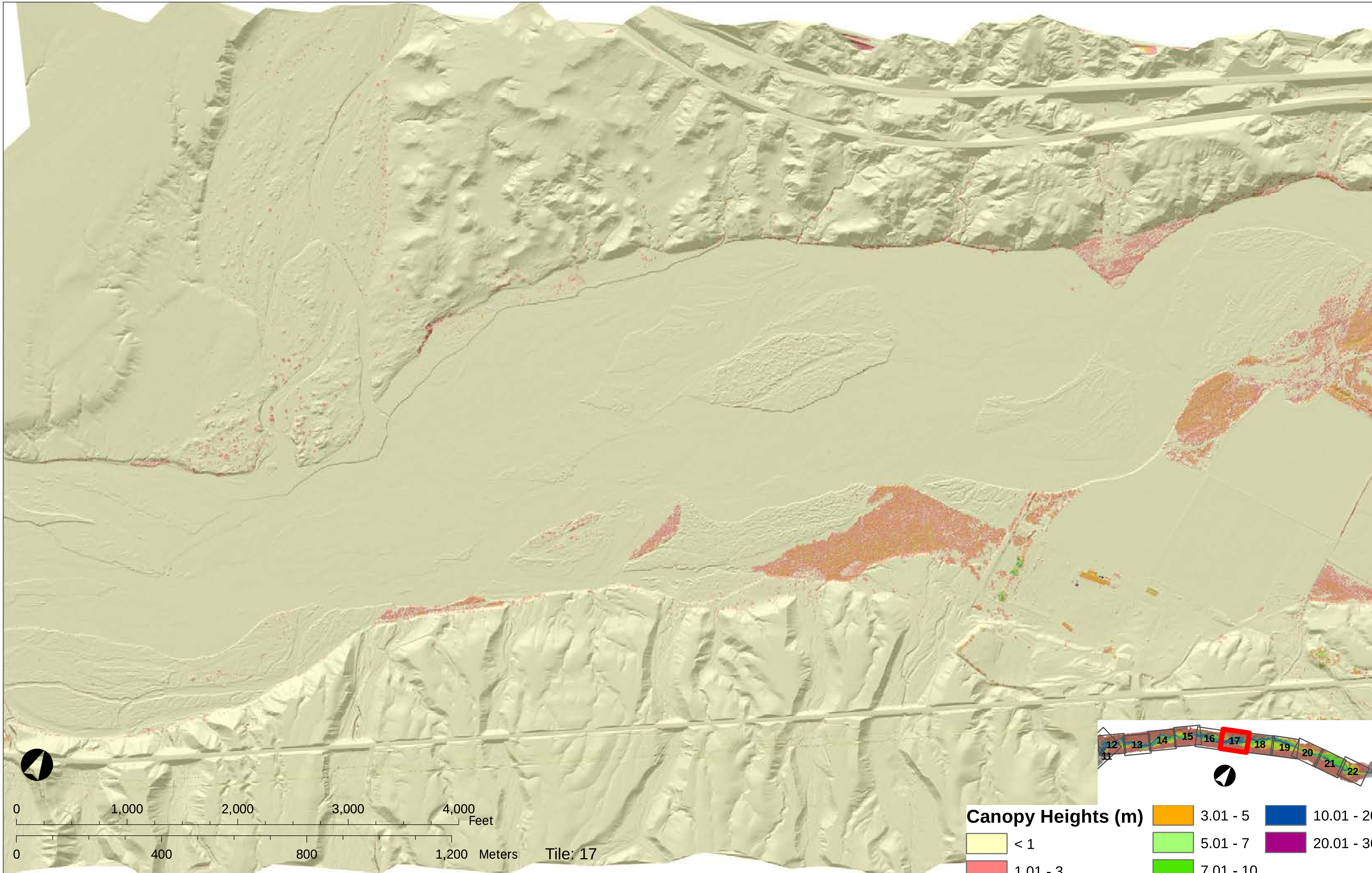
800
1,200
Meters
Tile: 16
Canopy Heights (m)
< 1
1.01 - 3
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36


12
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3,000
4,000
Feet
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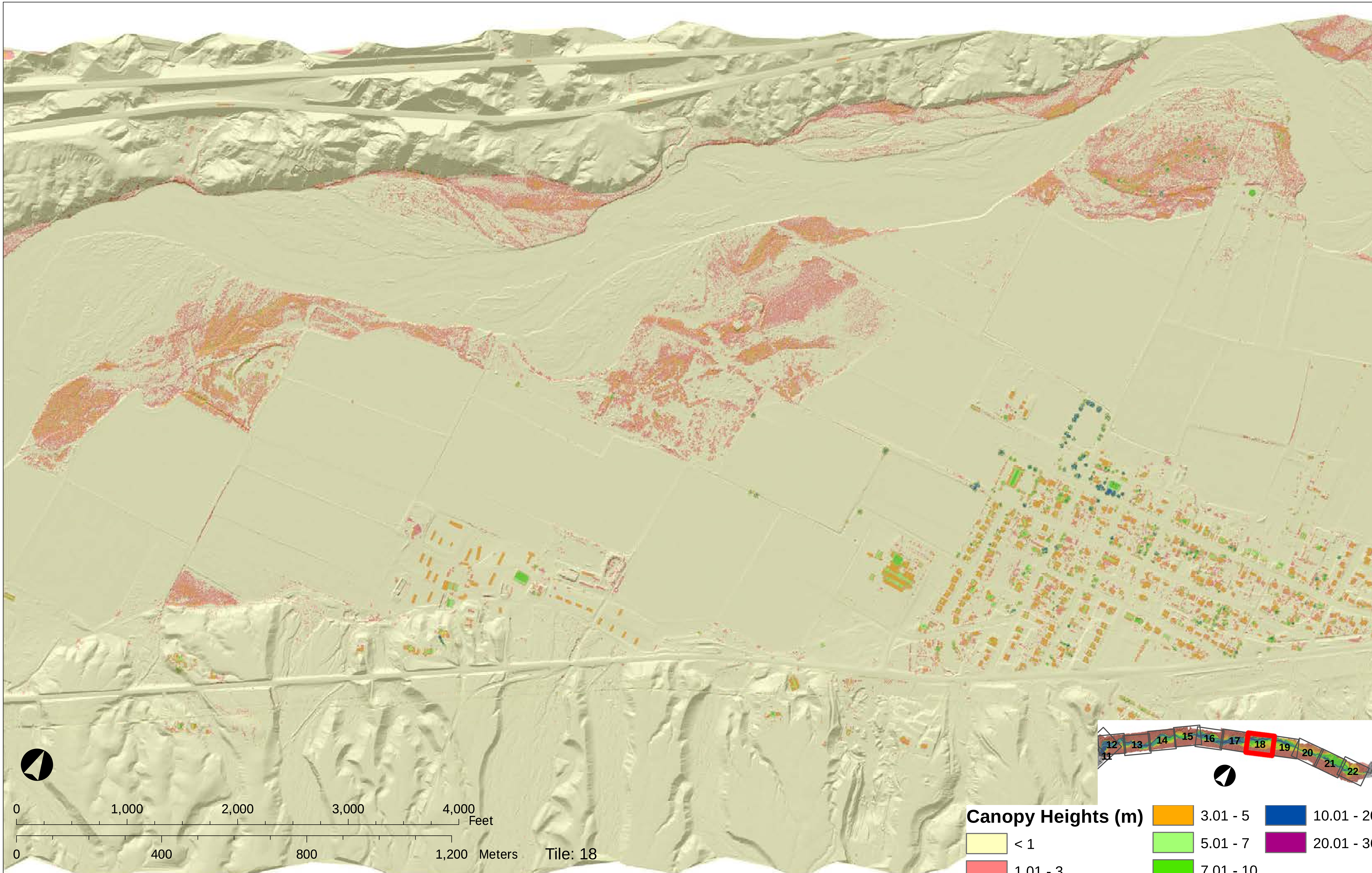
400
800
1,200
Meters
Tile: 17
Canopy Heights (m)
< 1
1.01 - 3
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36



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3,000
4,000
Feet
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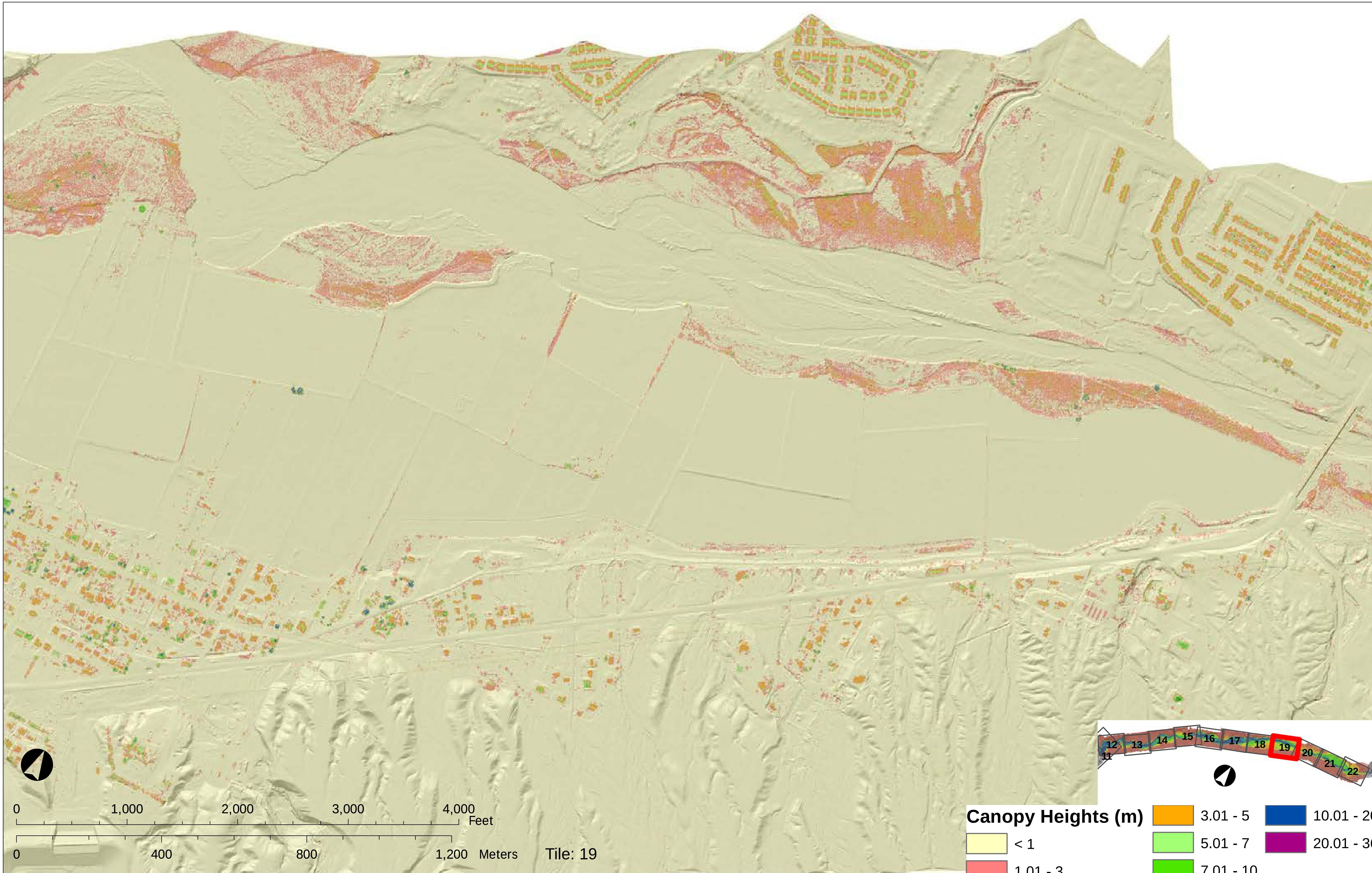
400
800
1,200
Meters
Tile: 18
Canopy Heights (m)
< 1
1.01 - 3
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36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21
22
11
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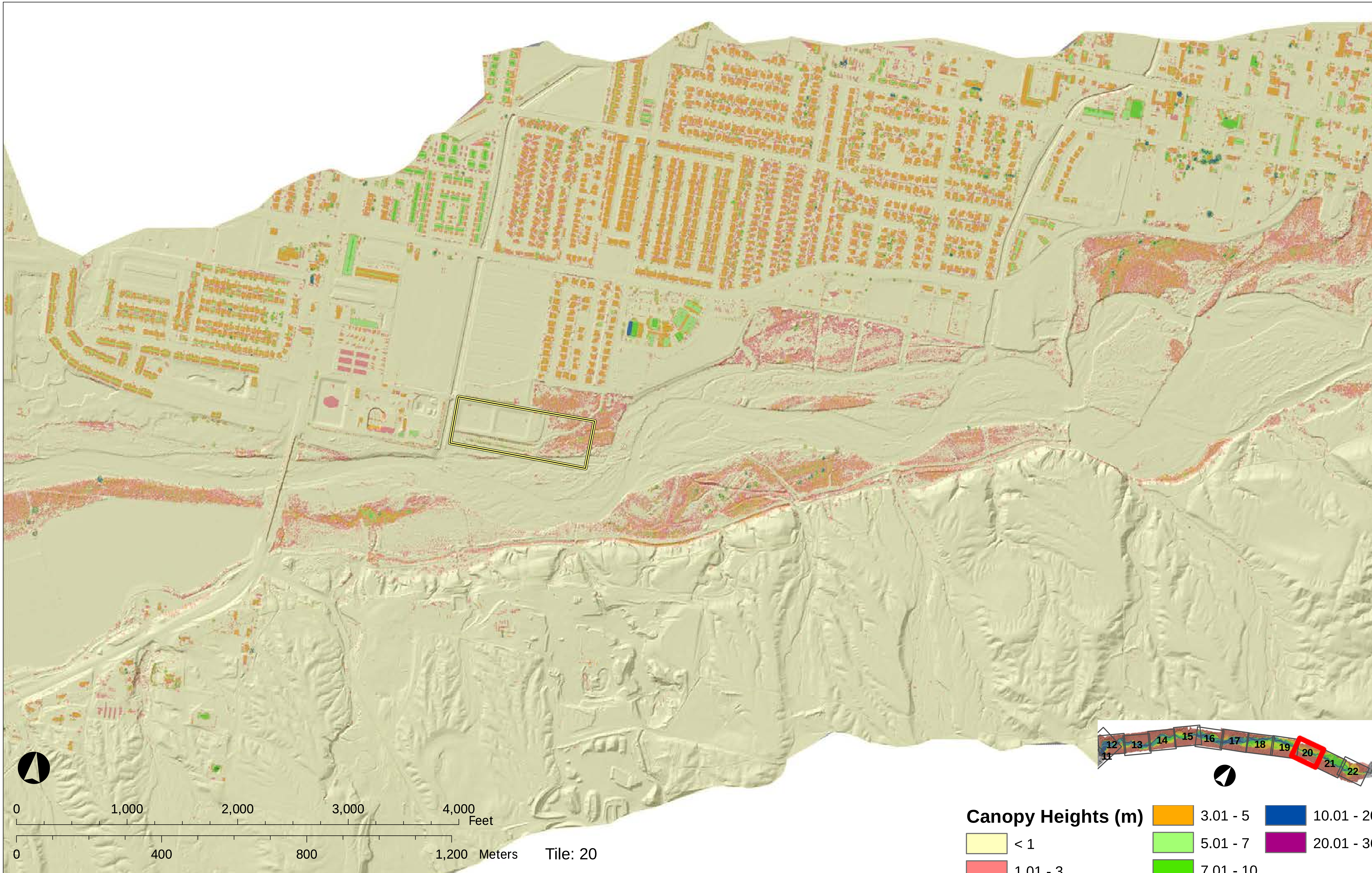
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 19
Canopy Heights (m)
< 1
1.01 - 3
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36



11
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21
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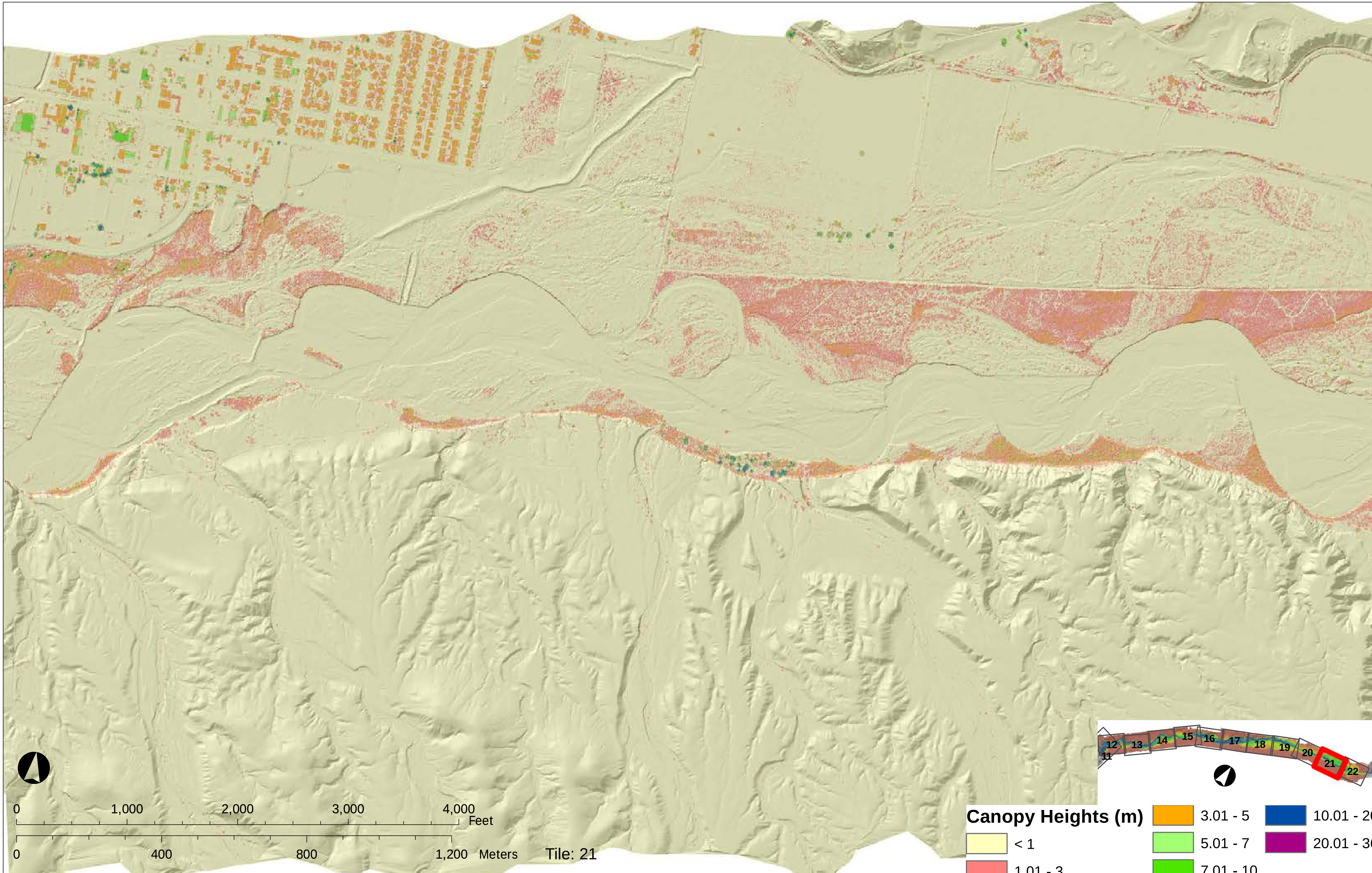
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 20
Canopy Heights (m)
< 1
1.01 - 3
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36



0
1,000
2,000
3,000
4,000
Feet
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400
800
1,200
Meters
Tile: 21
Canopy Heights (m)
< 1
1.01 - 3
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36
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12
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21
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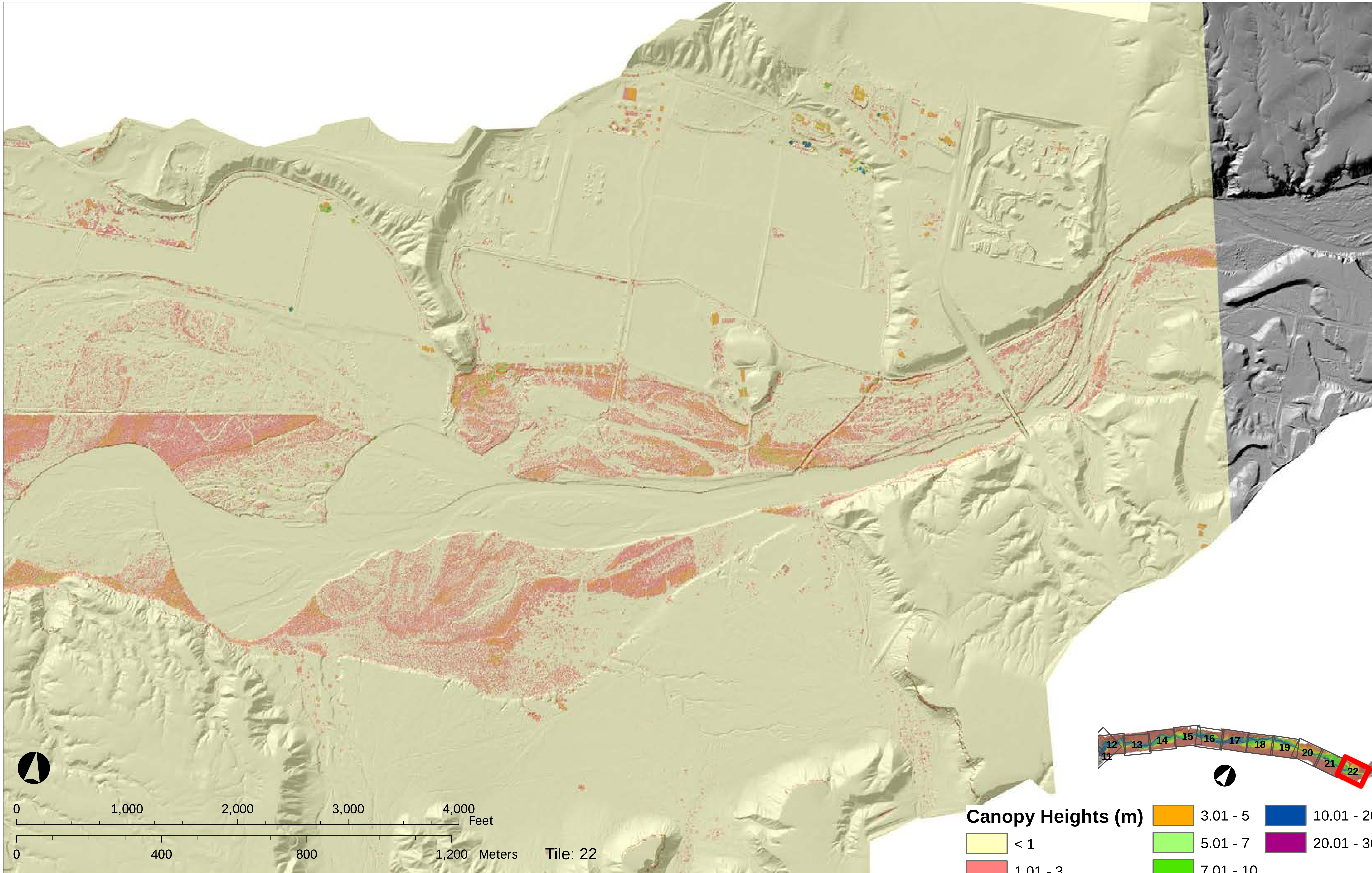
0
1,000
2,000
3,000
4,000
Feet
0
400
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1,200
Meters
Tile: 22
Canopy Heights (m)
< 1
1.01 - 3
3.01 - 5
5.01 - 7
7.01 - 10
10.01 - 20
20.01 - 36
11
12
13
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15
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19
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21
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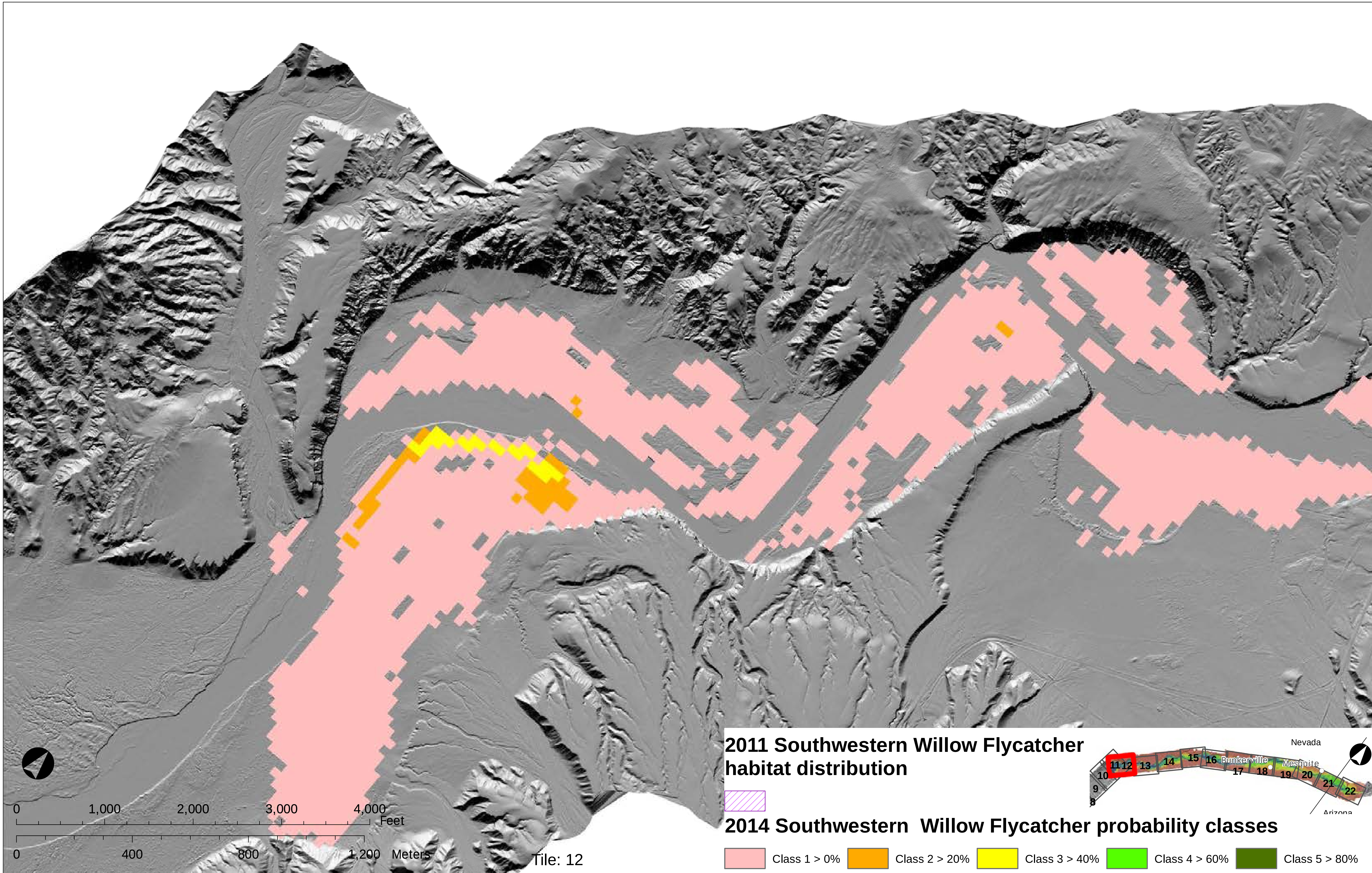

0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 12
2011 Southwestern Willow Flycatcher habitat distribution
2014 Southwestern Willow Flycatcher probability classes
Class 1 > 0%
Class 2 > 20%
Class 3 > 40%
Class 4 > 60%
Class 5 > 80%
Nevada
Arizona
Bunkerville
Mesquite
8
9
10
11
12
13
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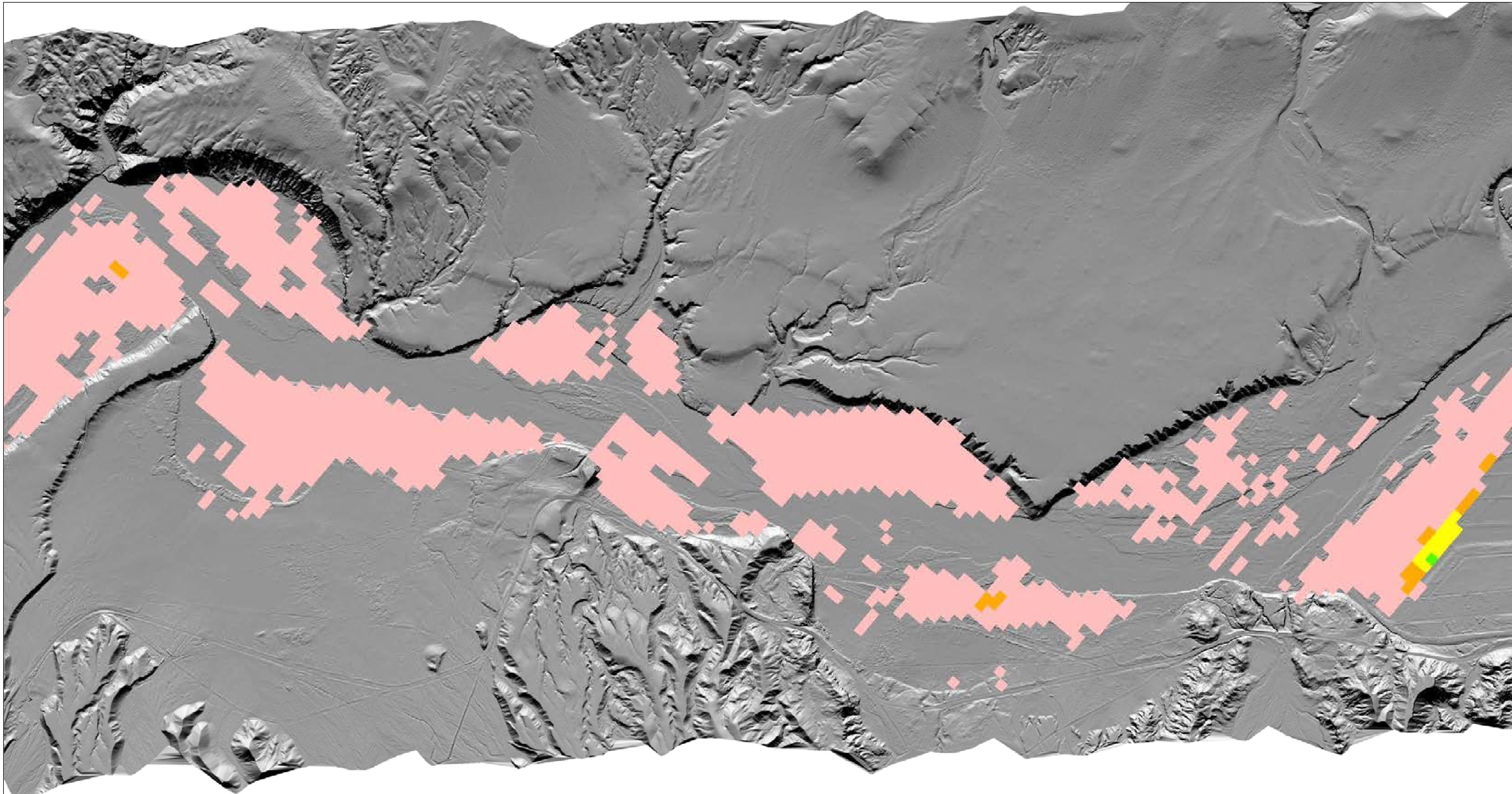
15
16
17
18
19
20
21
22



0 1,000 2,000 3,000 4,000 Feet

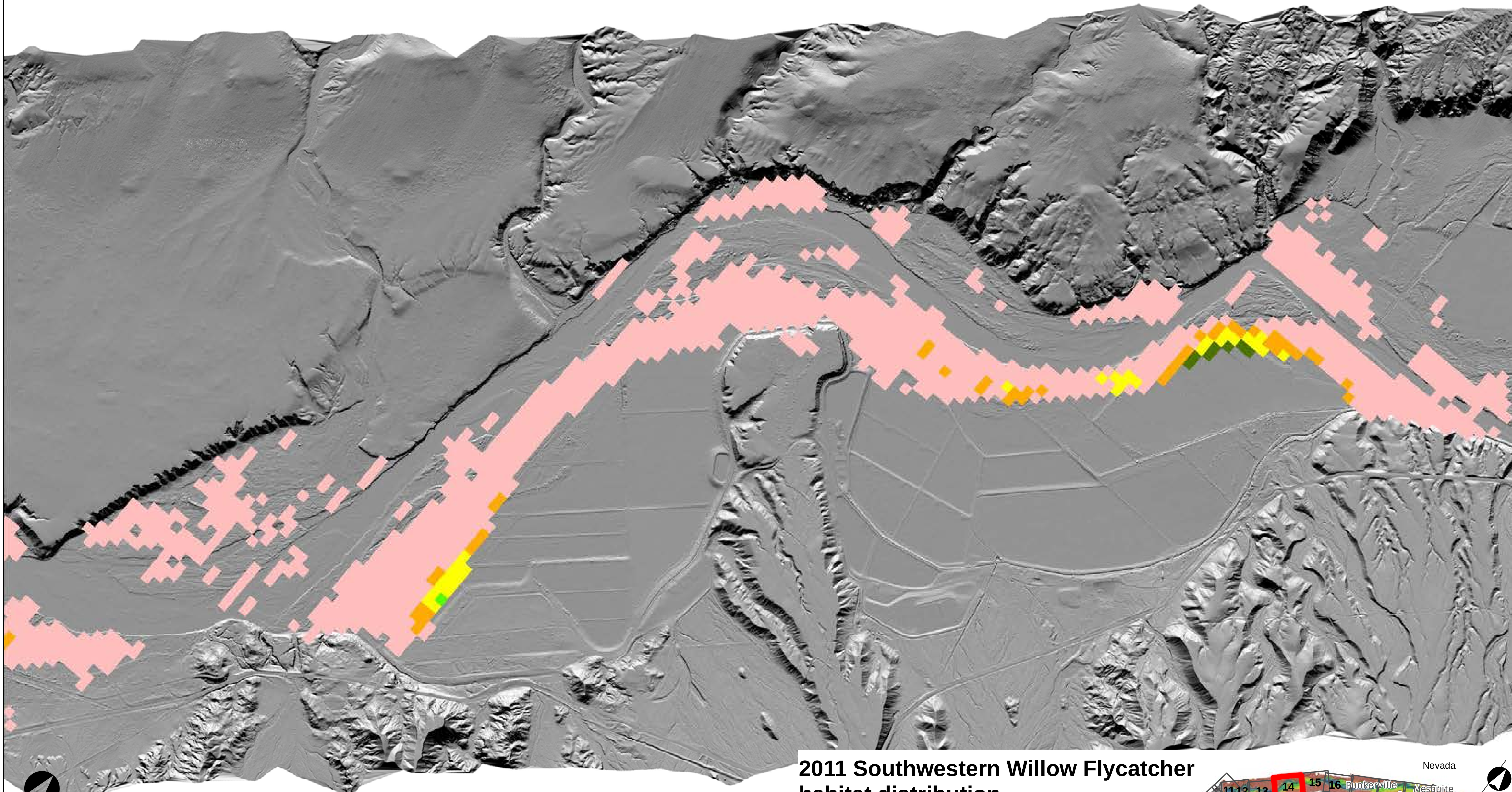
0 400 800 1,200 Meters

Tile: 13

2011 Southwestern Willow Flycatcher habitat distribution

2014 Southwestern Willow Flycatcher probability classes

Class 1 > 0% Class 2 > 20% Class 3 > 40% Class 4 > 60% Class 5 > 80%



0 1,000 2,000 3,000 4,000 Feet

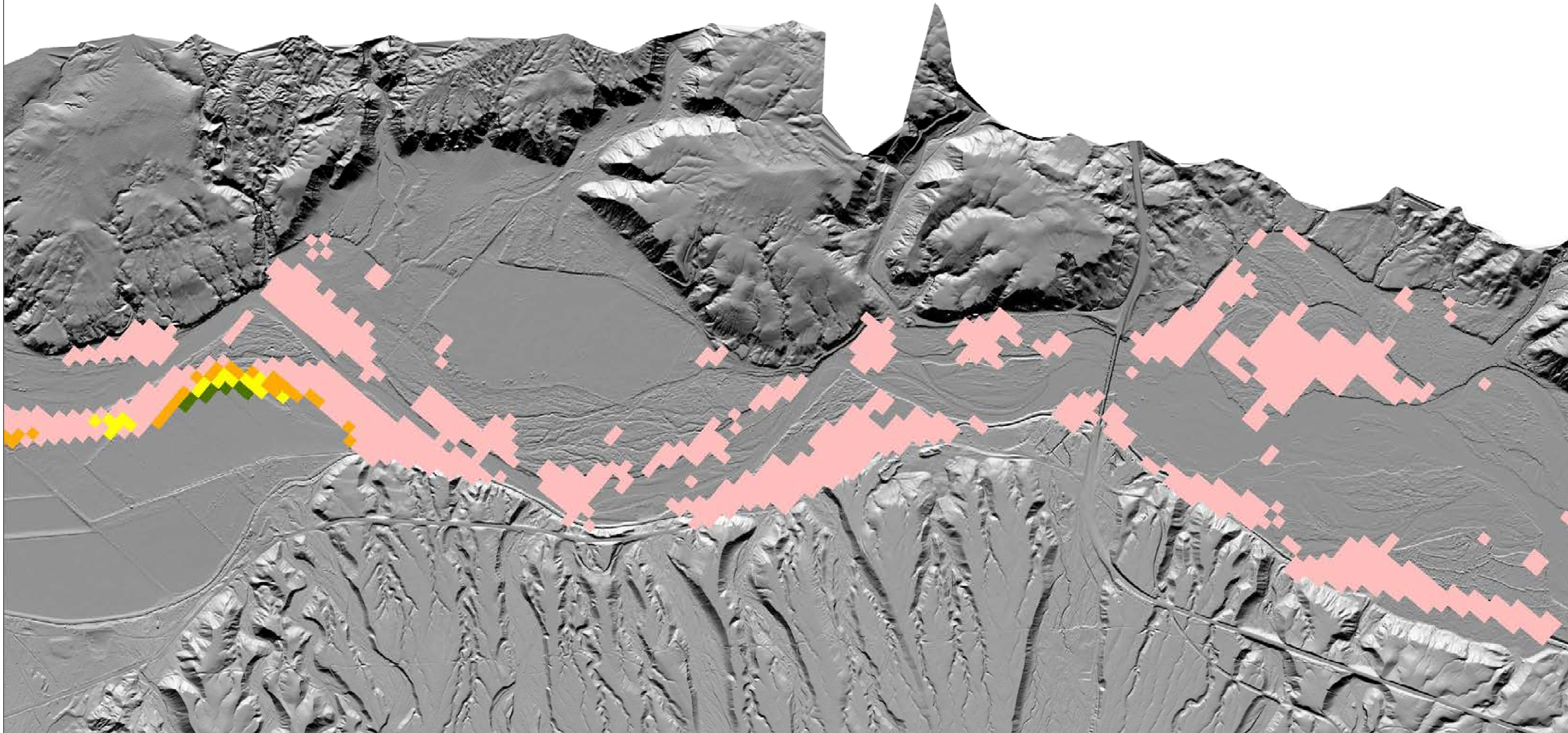
0 400 800 1,200 Meters

Tile: 14

2011 Southwestern Willow Flycatcher habitat distribution

2014 Southwestern Willow Flycatcher probability classes

Class 1 > 0% | Class 2 > 20% | Class 3 > 40% | Class 4 > 60% | Class 5 > 80%

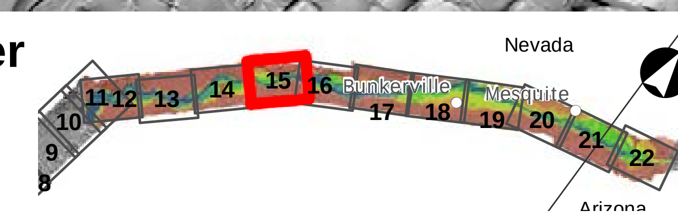


0 1,000 2,000 3,000 4,000 Feet

0 400 800 1,200 Meters

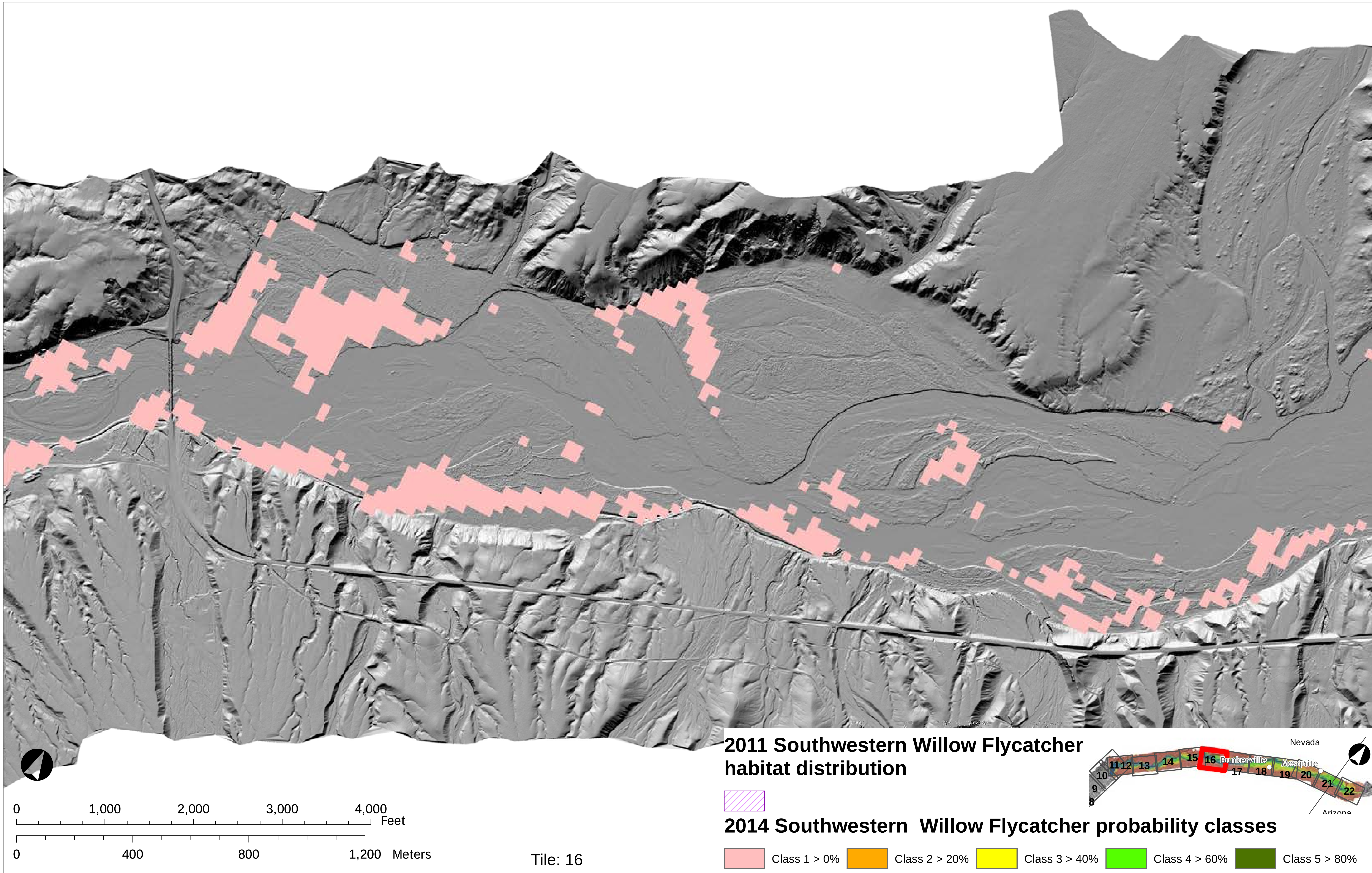
Tile: 15

2011 Southwestern Willow Flycatcher habitat distribution



2014 Southwestern Willow Flycatcher probability classes

Class 1 > 0% | Class 2 > 20% | Class 3 > 40% | Class 4 > 60% | Class 5 > 80%


2011 Southwestern Willow Flycatcher habitat distribution
2014 Southwestern Willow Flycatcher probability classes
Class 1 > 0%
Class 2 > 20%
Class 3 > 40%
Class 4 > 60%
Class 5 > 80%
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 16
Nevada
Arizona
Bunkerville
Mesquite
8
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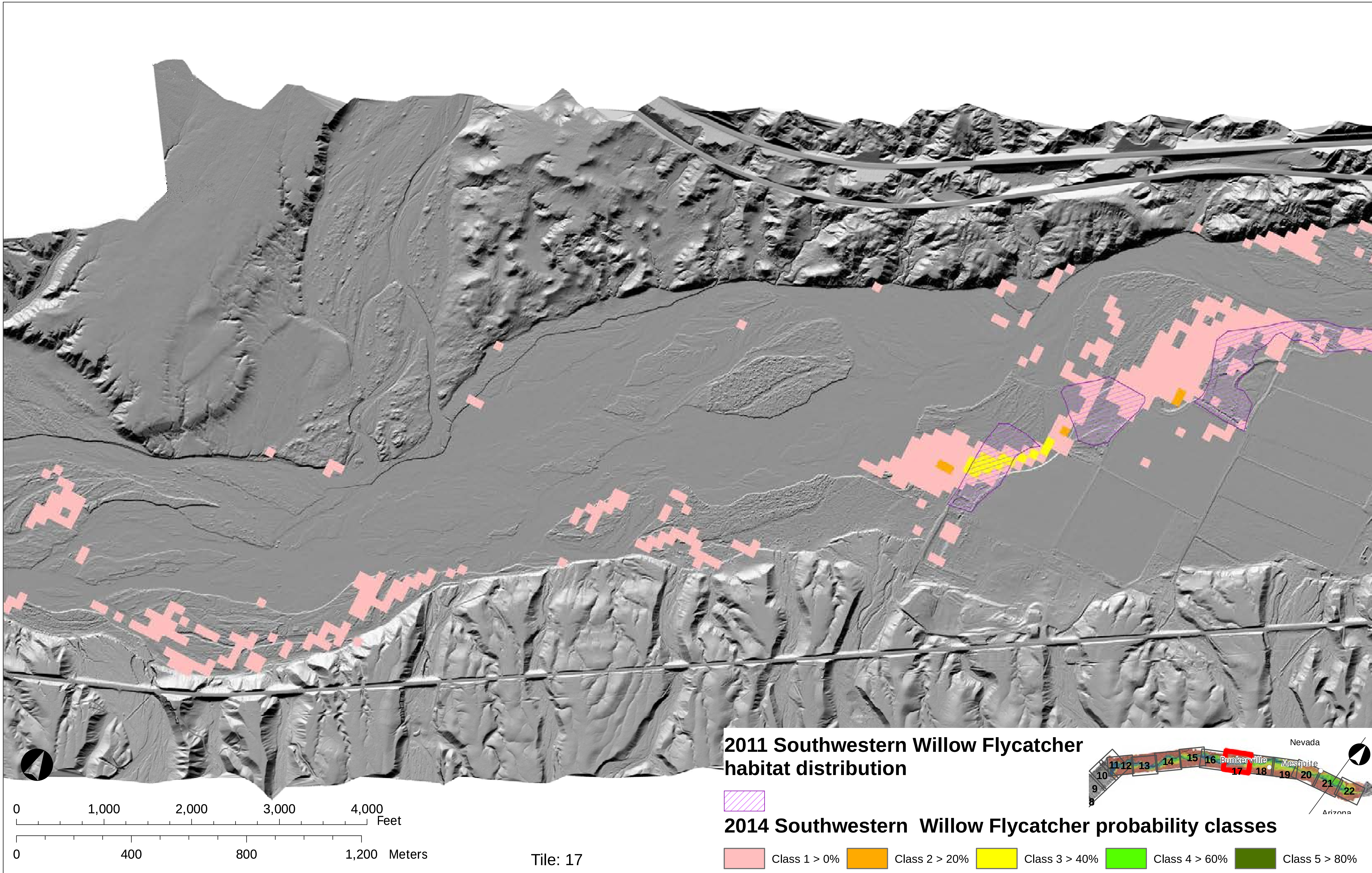
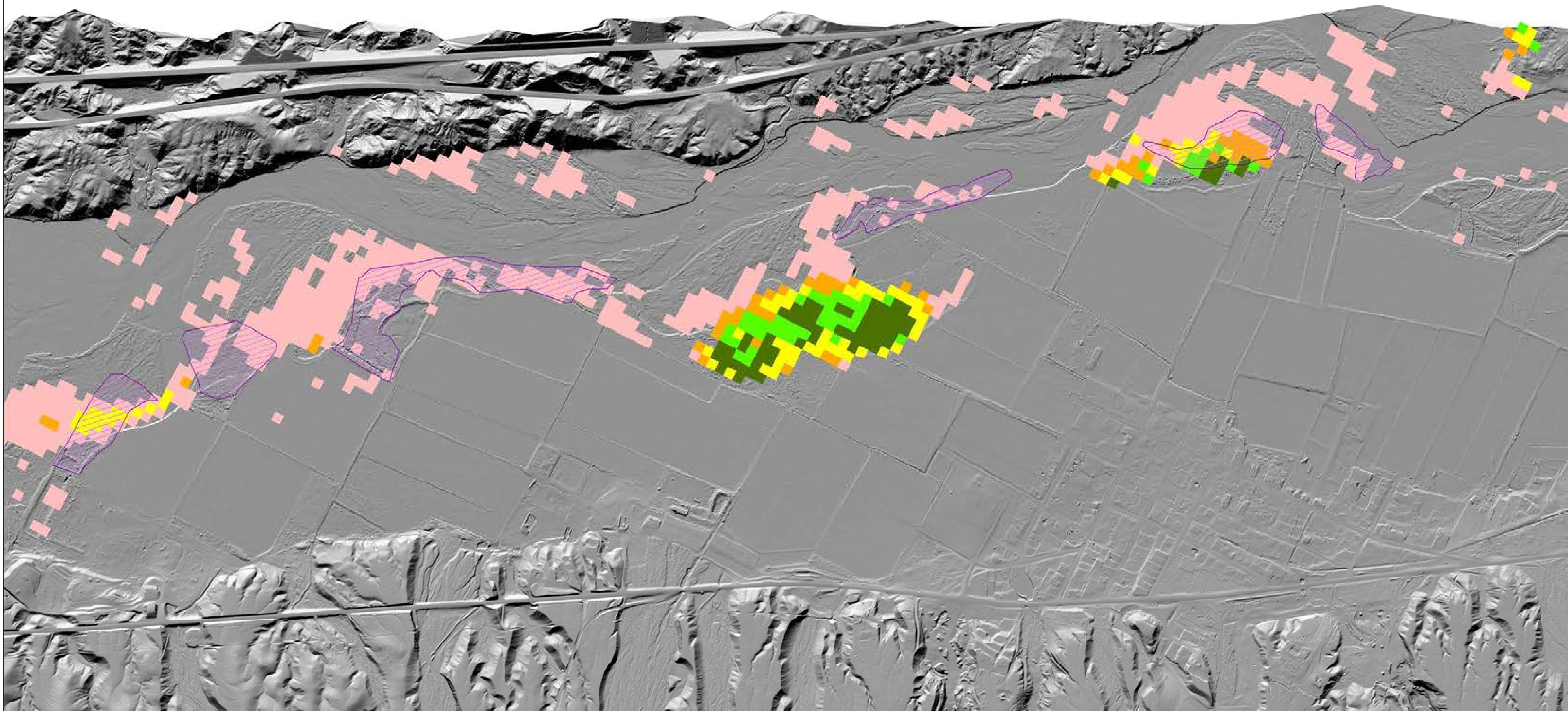
21
22


2011 Southwestern Willow Flycatcher habitat distribution
2014 Southwestern Willow Flycatcher probability classes
Class 1 > 0%
Class 2 > 20%
Class 3 > 40%
Class 4 > 60%
Class 5 > 80%
Nevada
Bunkerville
Mesquite
9 10 11 12 13 14 15 16 17 18 19 20 21 22
0 1,000 2,000 3,000 4,000 Feet
0 400 800 1,200 Meters
Tile: 17



2011 Southwestern Willow Flycatcher habitat distribution

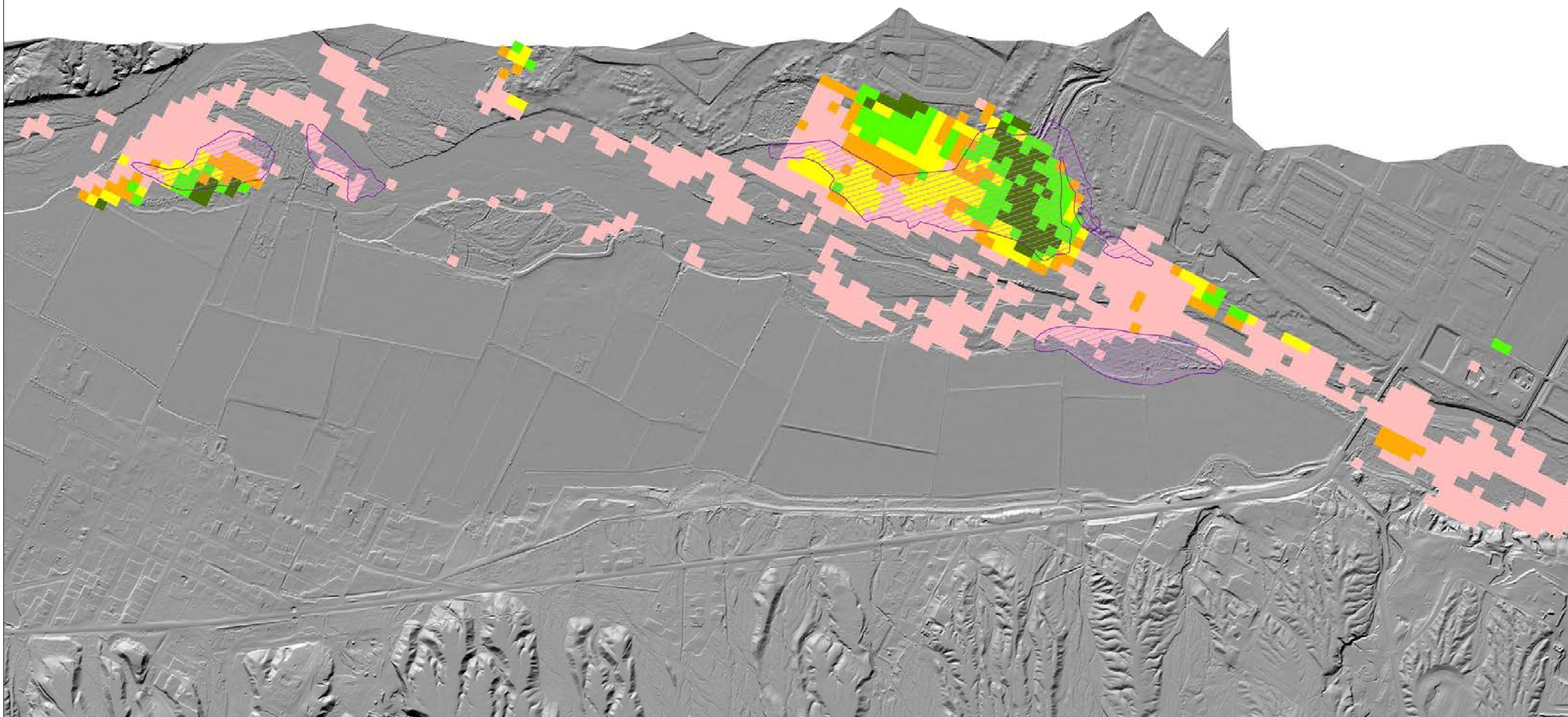
2014 Southwestern Willow Flycatcher probability classes

Class 1 > 0% | Class 2 > 20% | Class 3 > 40% | Class 4 > 60% | Class 5 > 80%

0 | 1,000 | 2,000 | 3,000 | 4,000 Feet

0 | 400 | 800 | 1,200 Meters

Tile: 18

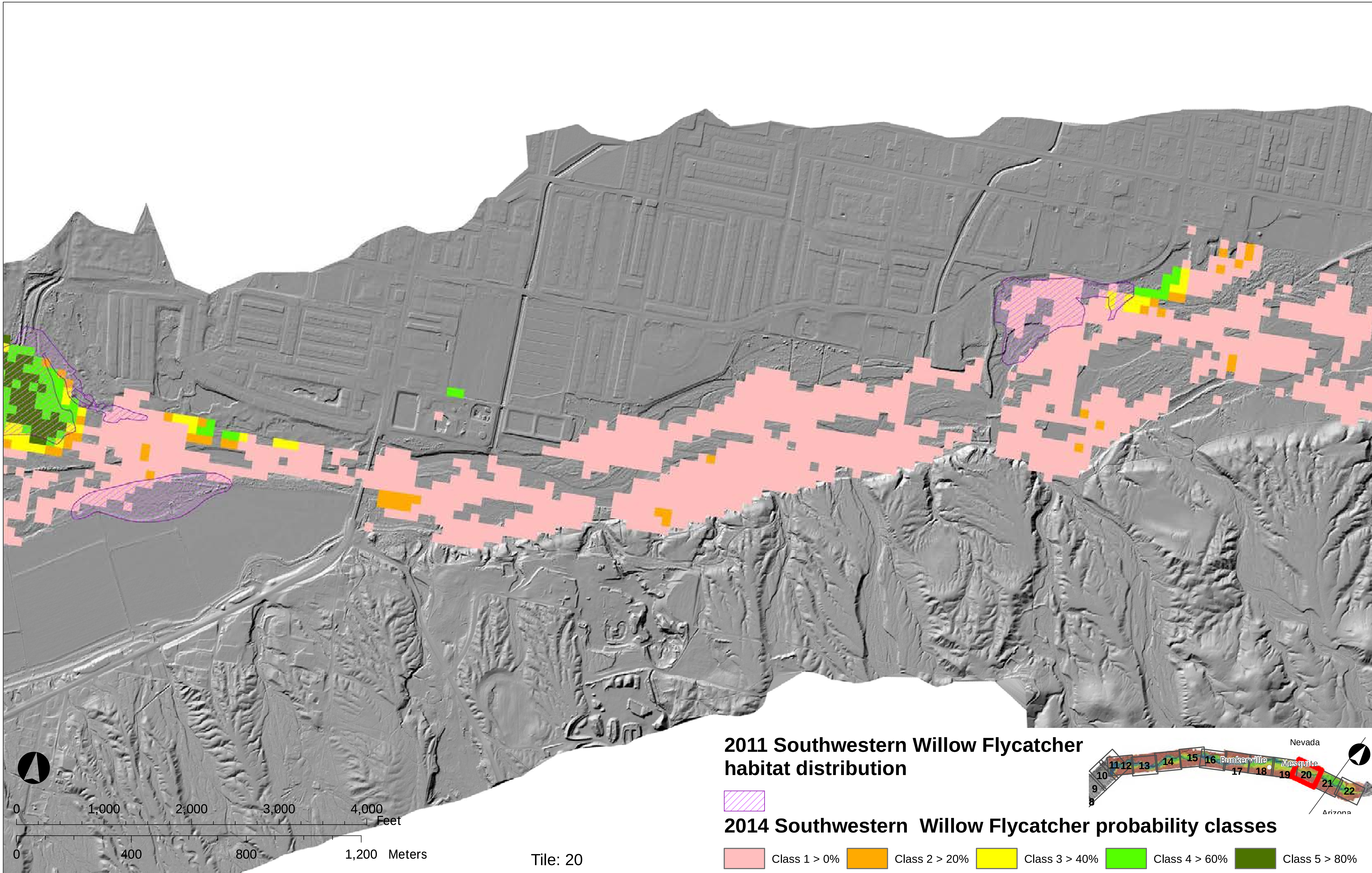


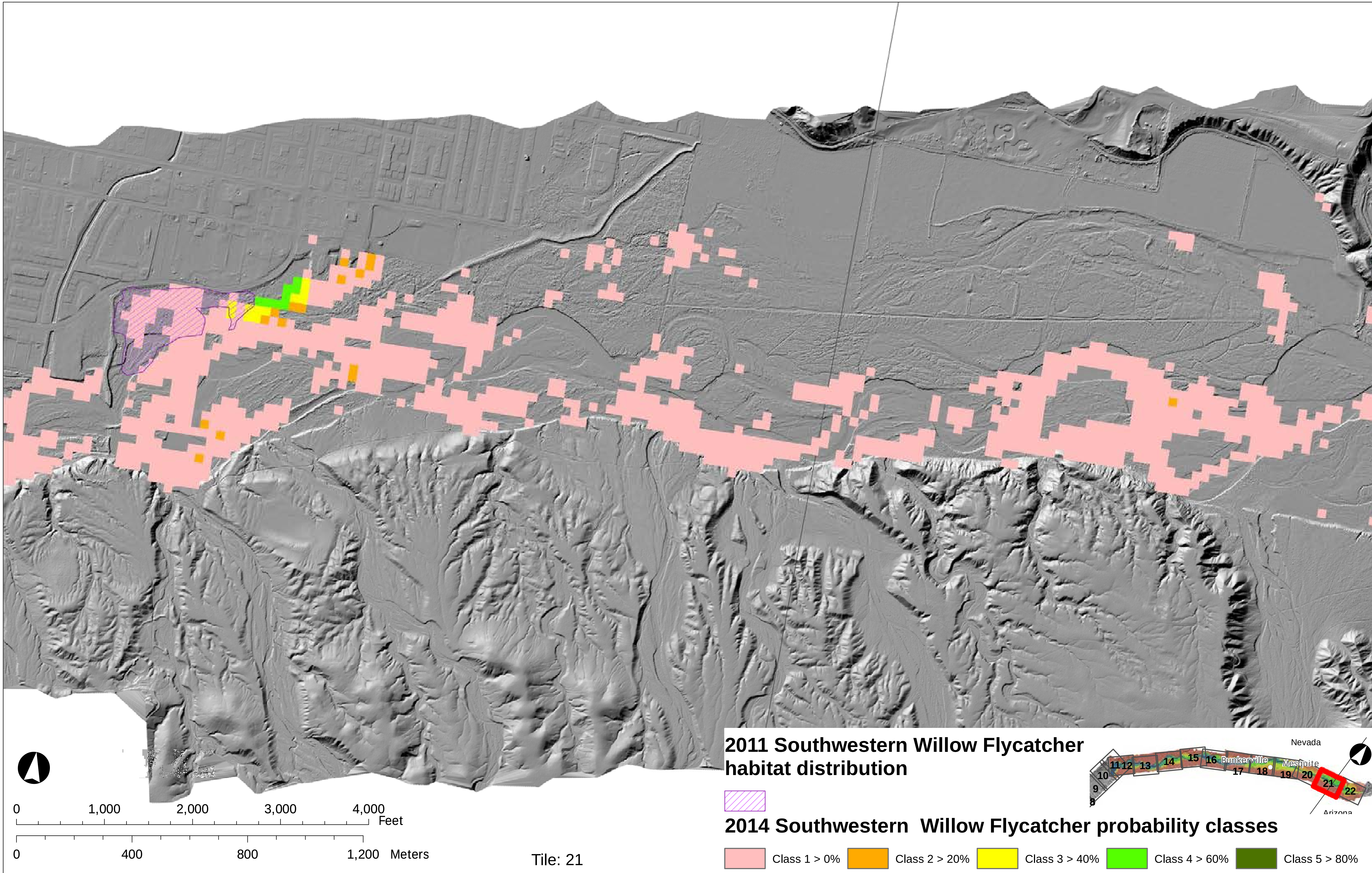
Tile: 19

2011 Southwestern Willow Flycatcher habitat distribution

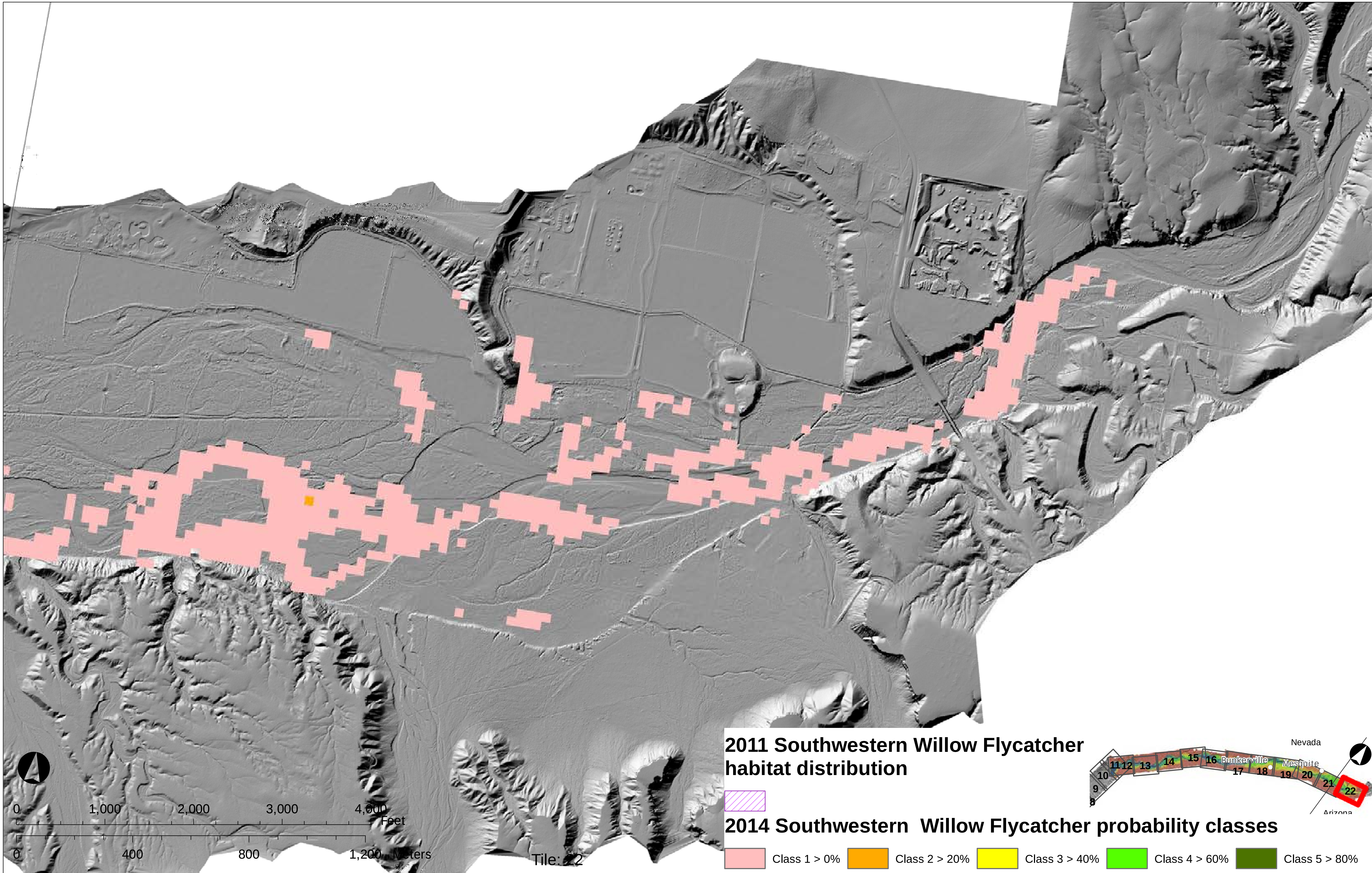
2014 Southwestern Willow Flycatcher probability classes

Class 1 > 0% | Class 2 > 20% | Class 3 > 40% | Class 4 > 60% | Class 5 > 80%

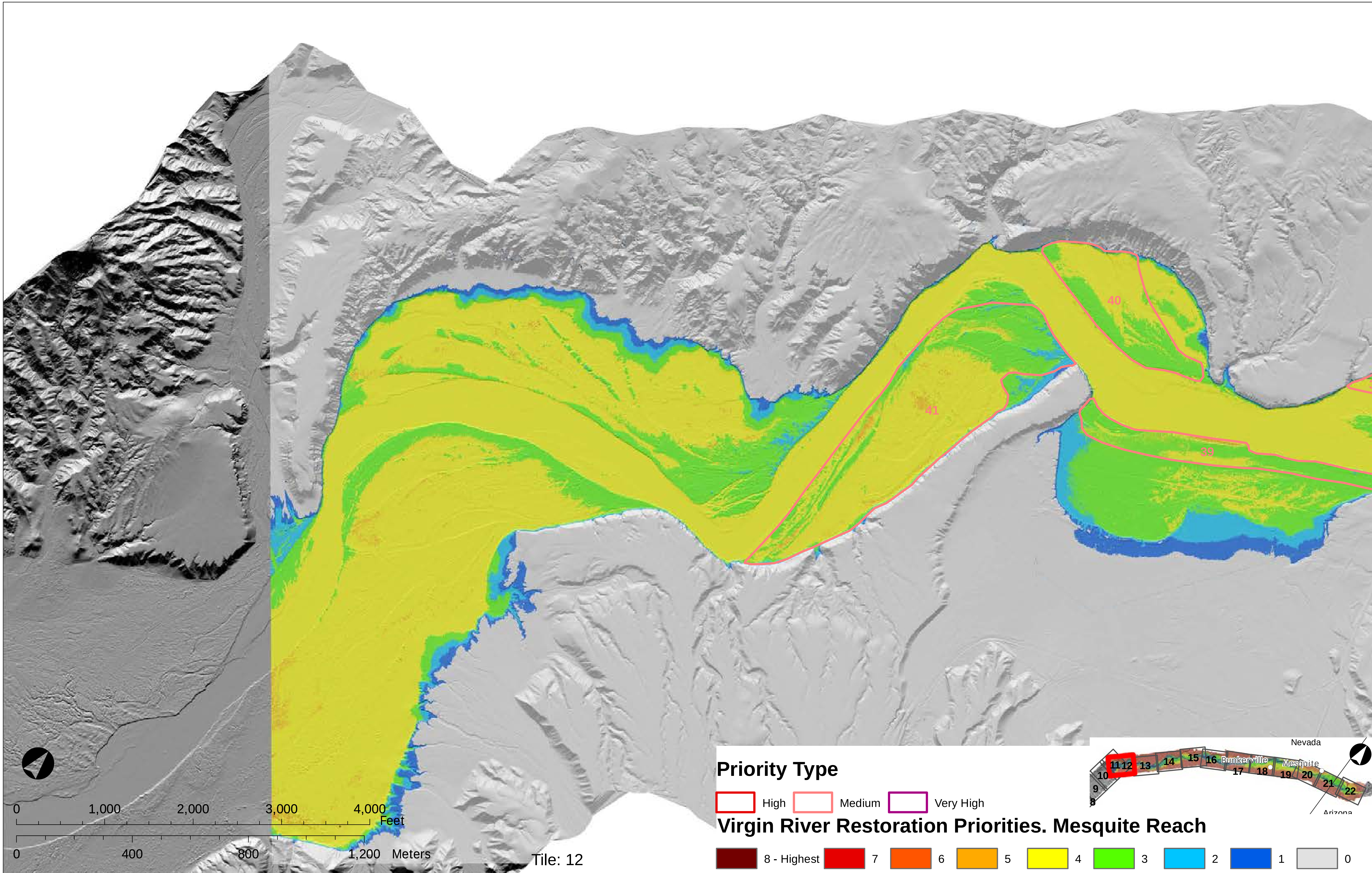

2011 Southwestern Willow Flycatcher habitat distribution
2014 Southwestern Willow Flycatcher probability classes
Class 1 > 0%
Class 2 > 20%
Class 3 > 40%
Class 4 > 60%
Class 5 > 80%
Nevada
Arizona
Bunkerville
Mesquite
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 20



2011 Southwestern Willow Flycatcher habitat distribution
2014 Southwestern Willow Flycatcher probability classes
Class 1 > 0%
Class 2 > 20%
Class 3 > 40%
Class 4 > 60%
Class 5 > 80%
Nevada
Arizona
Bunkerville
Mesquite
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 21



2011 Southwestern Willow Flycatcher habitat distribution
2014 Southwestern Willow Flycatcher probability classes
Class 1 > 0%
Class 2 > 20%
Class 3 > 40%
Class 4 > 60%
Class 5 > 80%
Nevada
Arizona
Bunkerville
Mesquite
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 22



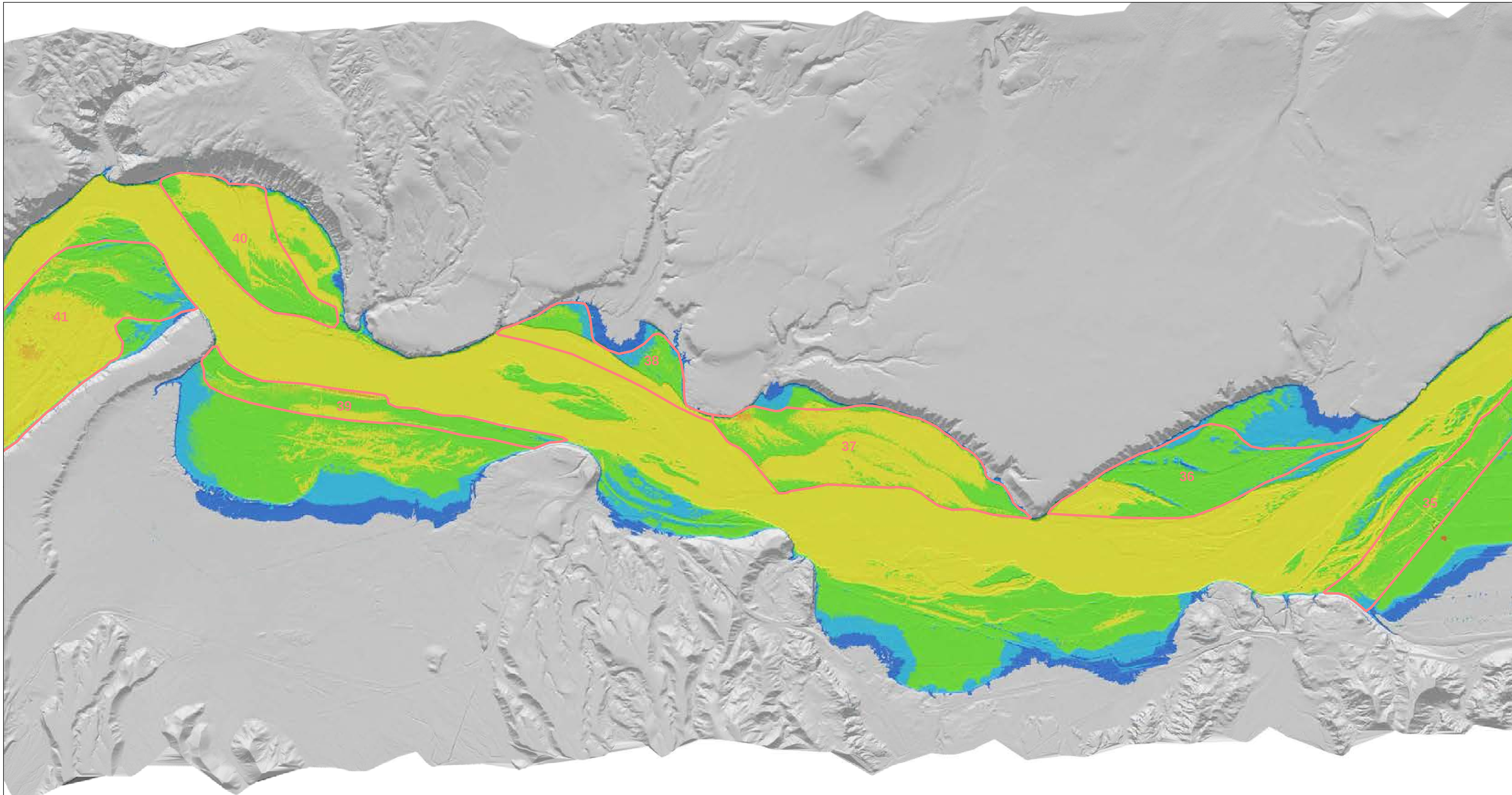
Tile: 12

Priority Type

High | Medium | Very High

Virgin River Restoration Priorities. Mesquite Reach

8 - Highest | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0



0 1,000 2,000 3,000 4,000 Feet

0 400 800 1,200 Meters

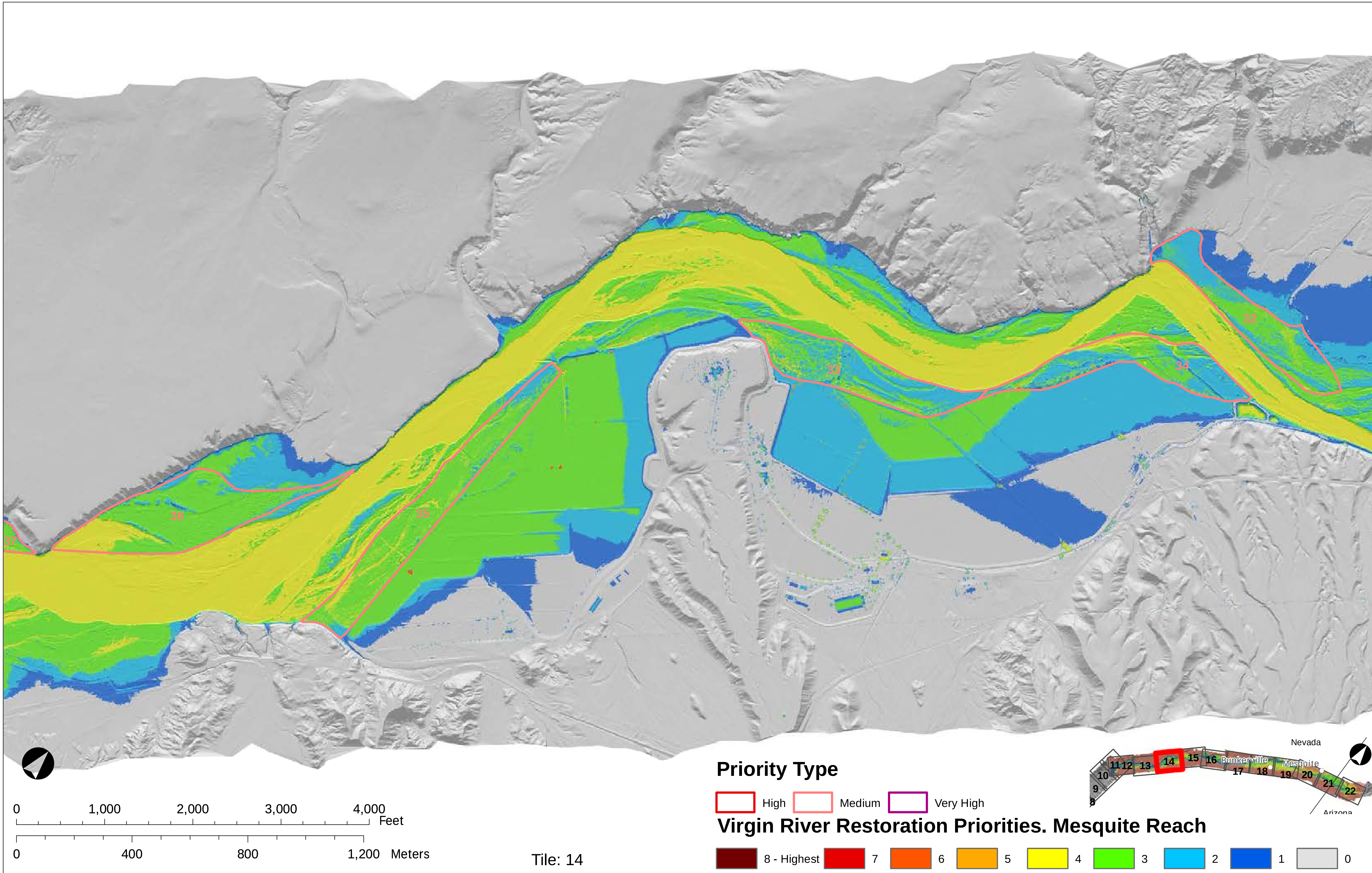
Tile: 13

Priority Type

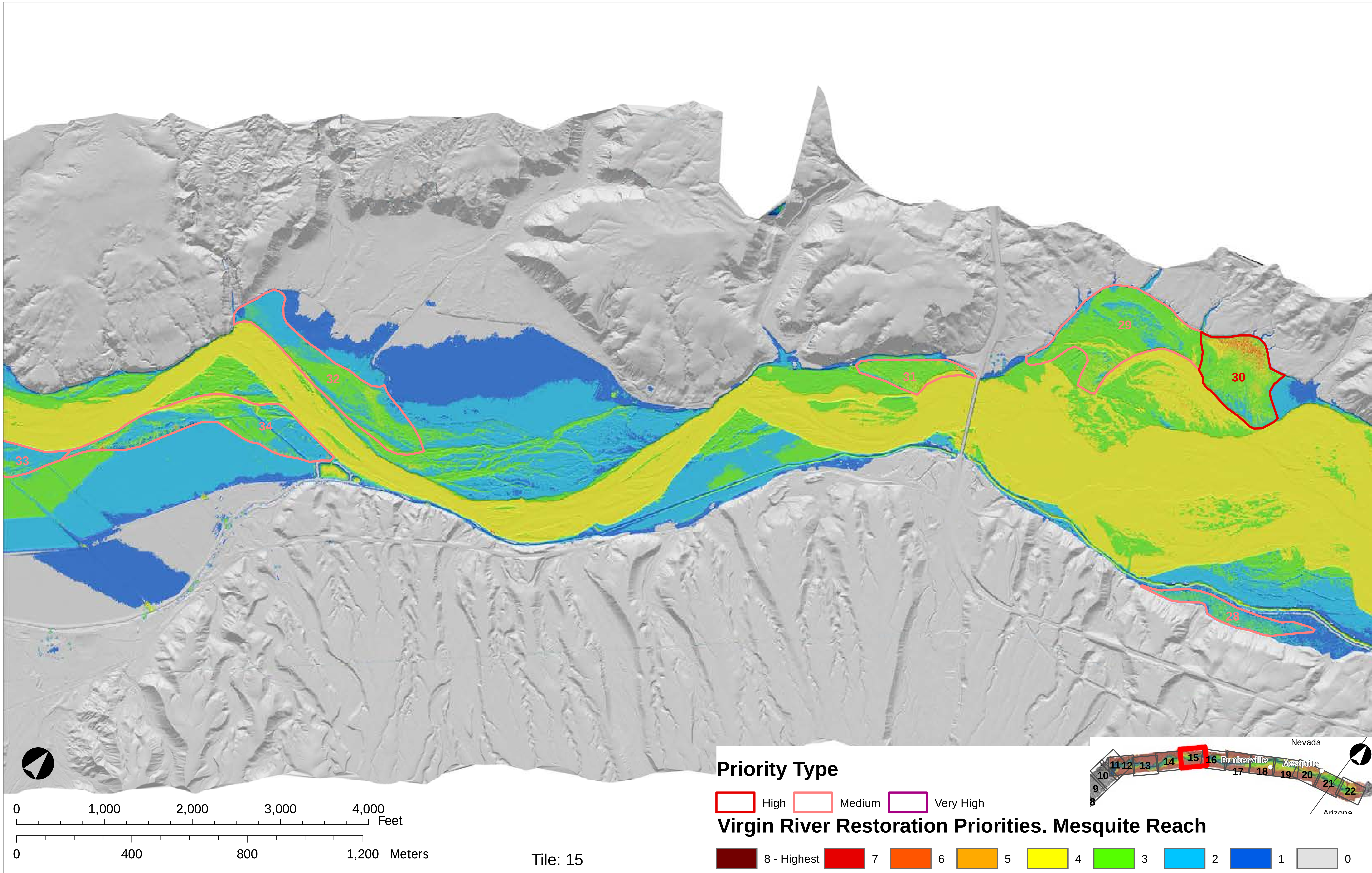
High | Medium | Very High

Virgin River Restoration Priorities. Mesquite Reach

8 - Highest | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0



37
36
35
33
34
32
Priority Type
High
Medium
Very High
Virgin River Restoration Priorities. Mesquite Reach
8 - Highest
7
6
5
4
3
2
1
0
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 14
Nevada
Arizona
Bunkerville
Mesquite
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22


29
30
31
32
33
34
28
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 15
Priority Type
High
Medium
Very High
Virgin River Restoration Priorities. Mesquite Reach
8 - Highest
7
6
5
4
3
2
1
0
Nevada
Arizona
Bunkerville
Mesquite
8
9
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11
12
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15
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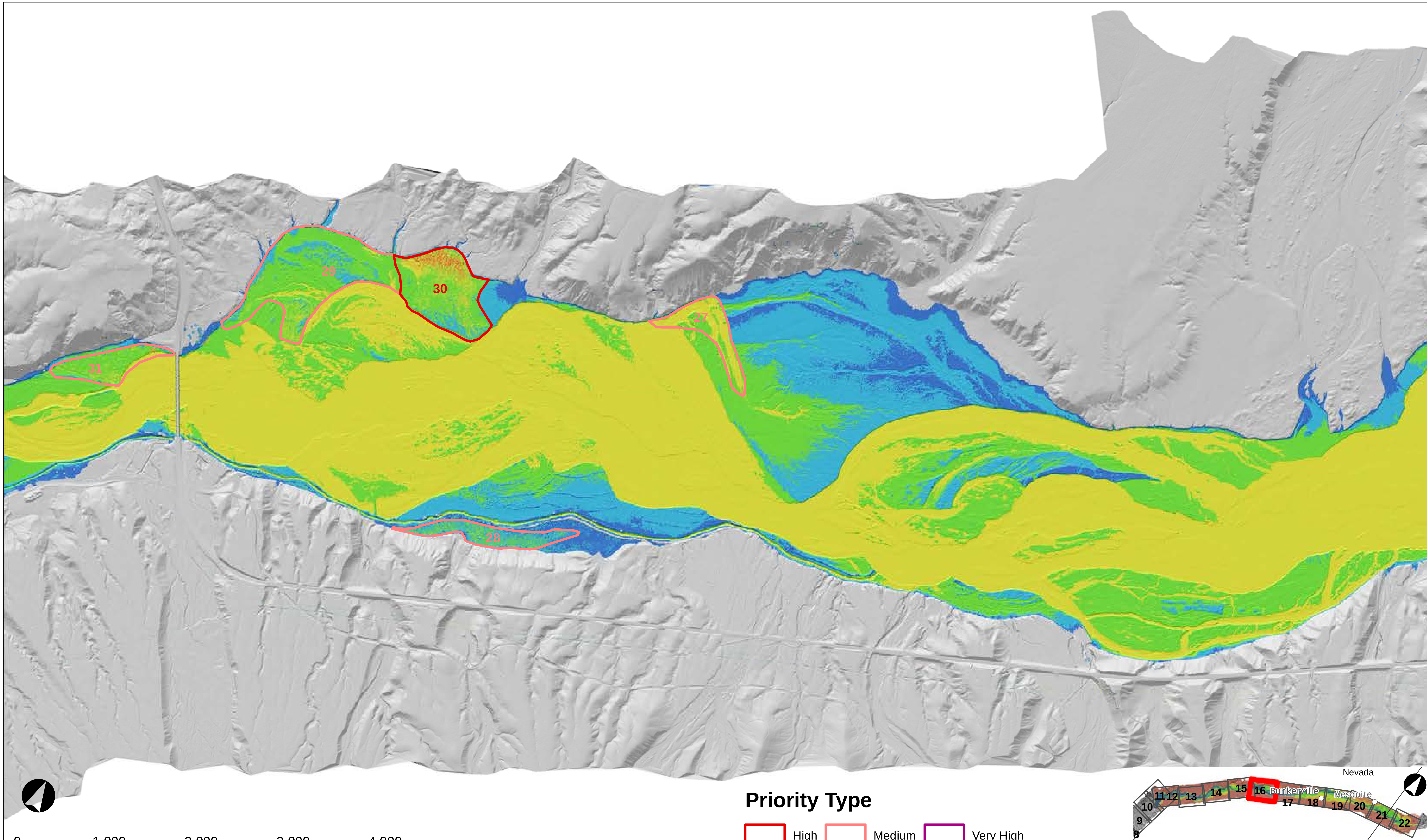
20
21
22



0 1,000 2,000 3,000 4,000 Feet

0 400 800 1,200 Meters

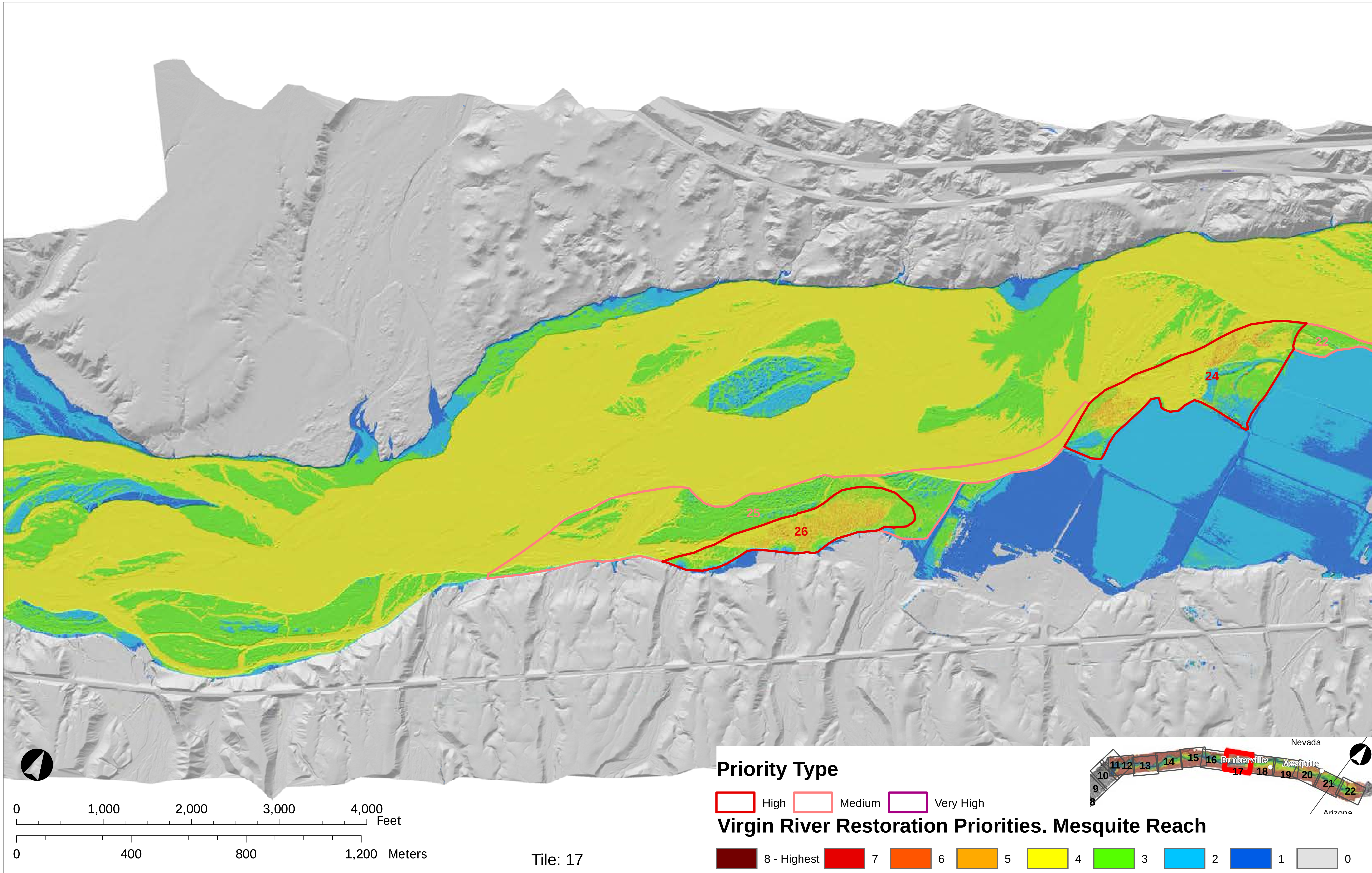
Tile: 16

Priority Type

High | Medium | Very High

Virgin River Restoration Priorities. Mesquite Reach

8 - Highest | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0


24
25
26
23
Priority Type
High
Medium
Very High
Virgin River Restoration Priorities. Mesquite Reach
8 - Highest
7
6
5
4
3
2
1
0
Nevada
Arizona
Bunkerville
Mesquite
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9
10
11
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15
16
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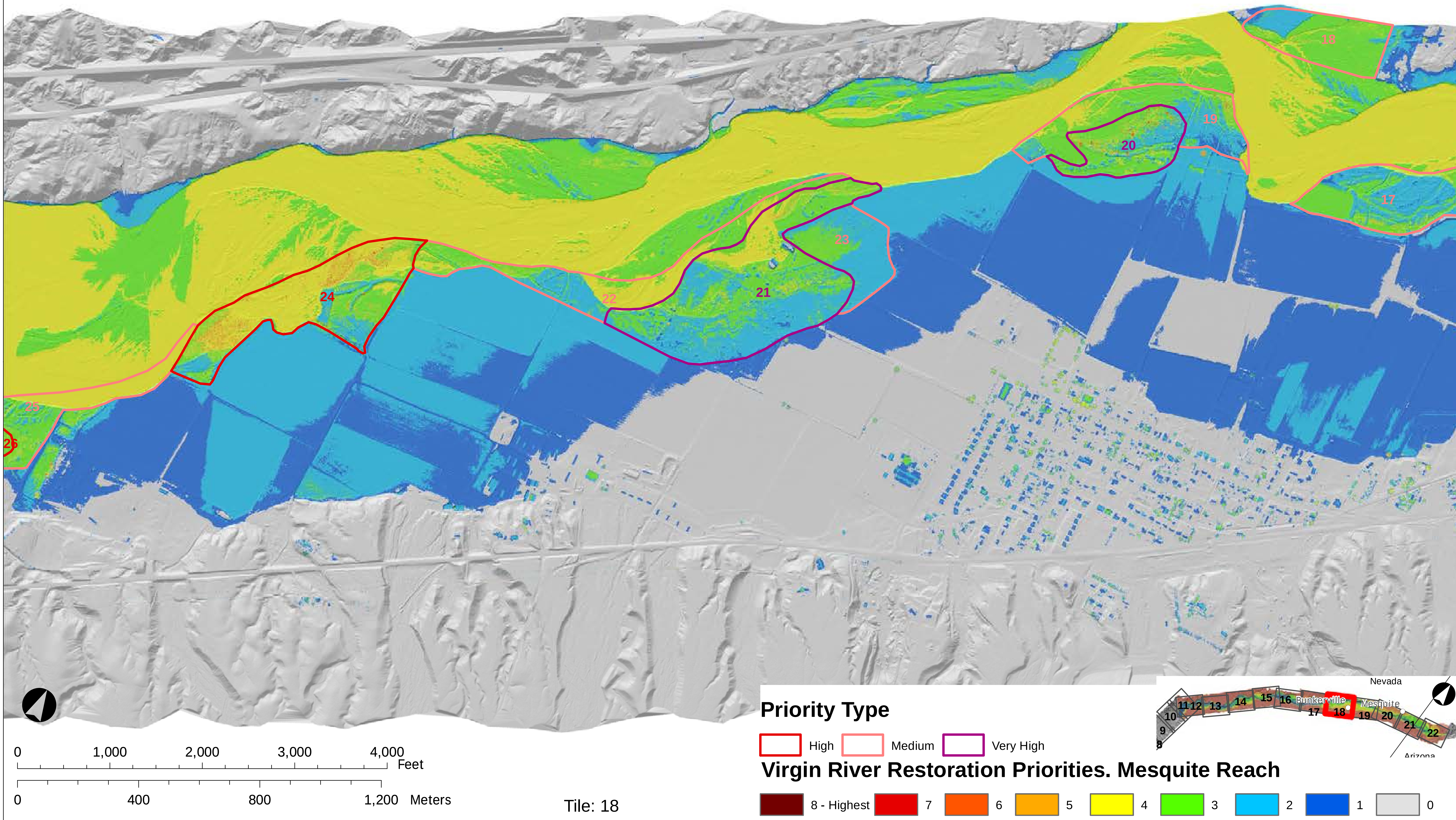
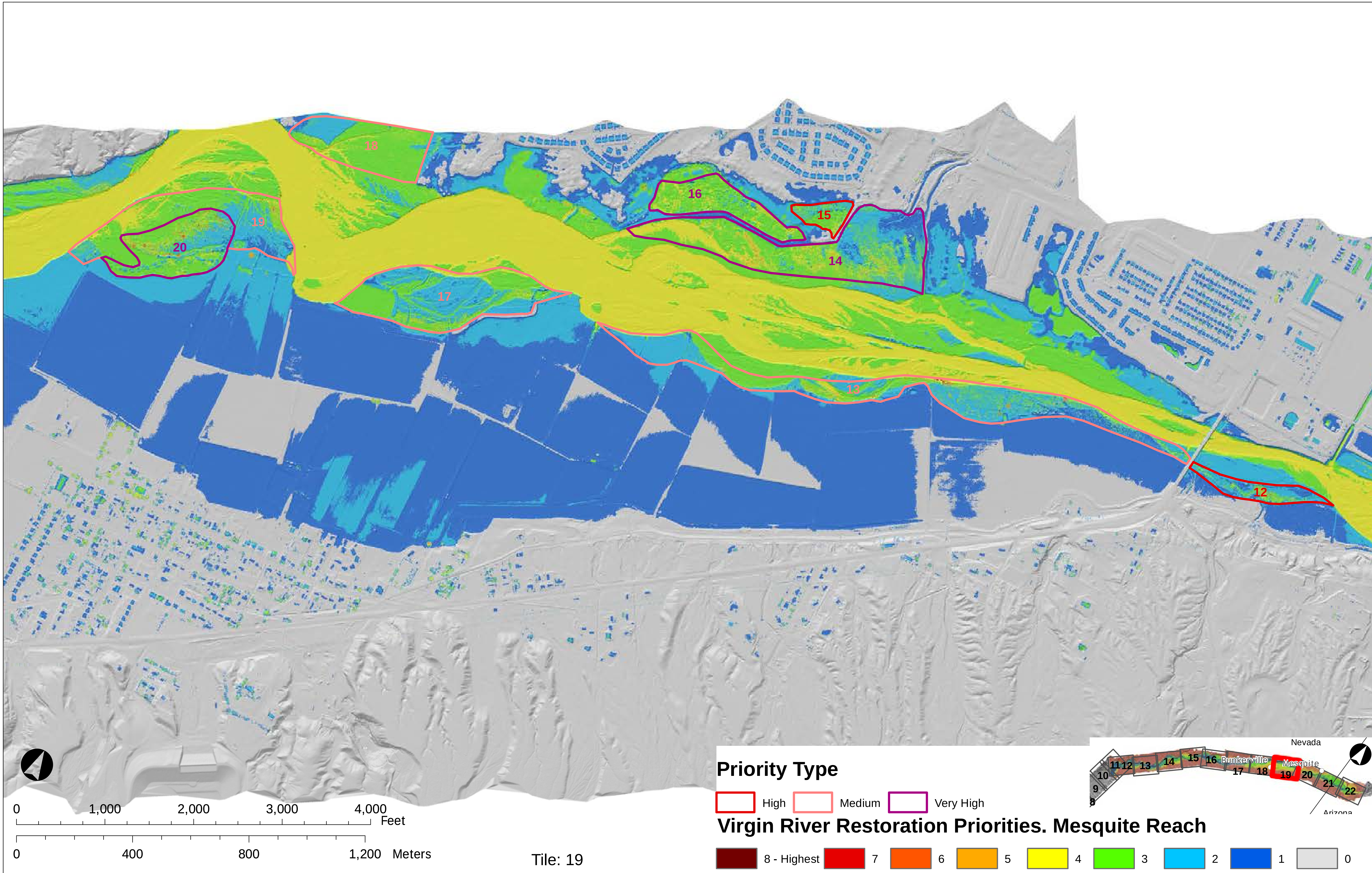
19
20
21
22
0
1,000
2,000
3,000
4,000
Feet
0
400
800
1,200
Meters
Tile: 17



Virgin River Restoration Priorities. Mesquite Reach

Tile: 18



Virgin River Restoration Priorities. Mesquite Reach
Tile: 19
Priority Type
High
Medium
Very High
8 - Highest
7
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3
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0
1,000
2,000
3,000
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Feet
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Nevada
Arizona
Bunkerville
Mesquite
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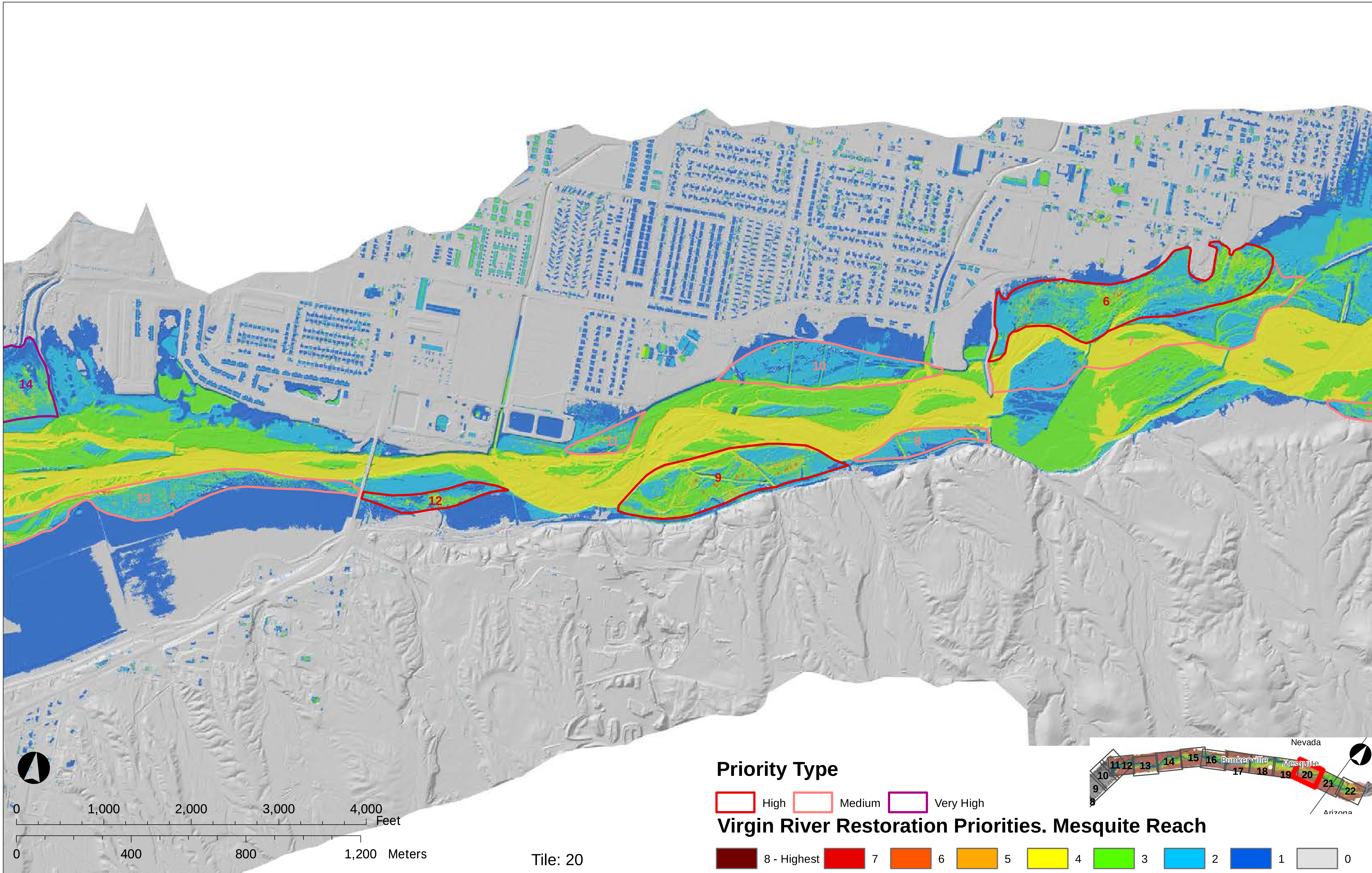

14
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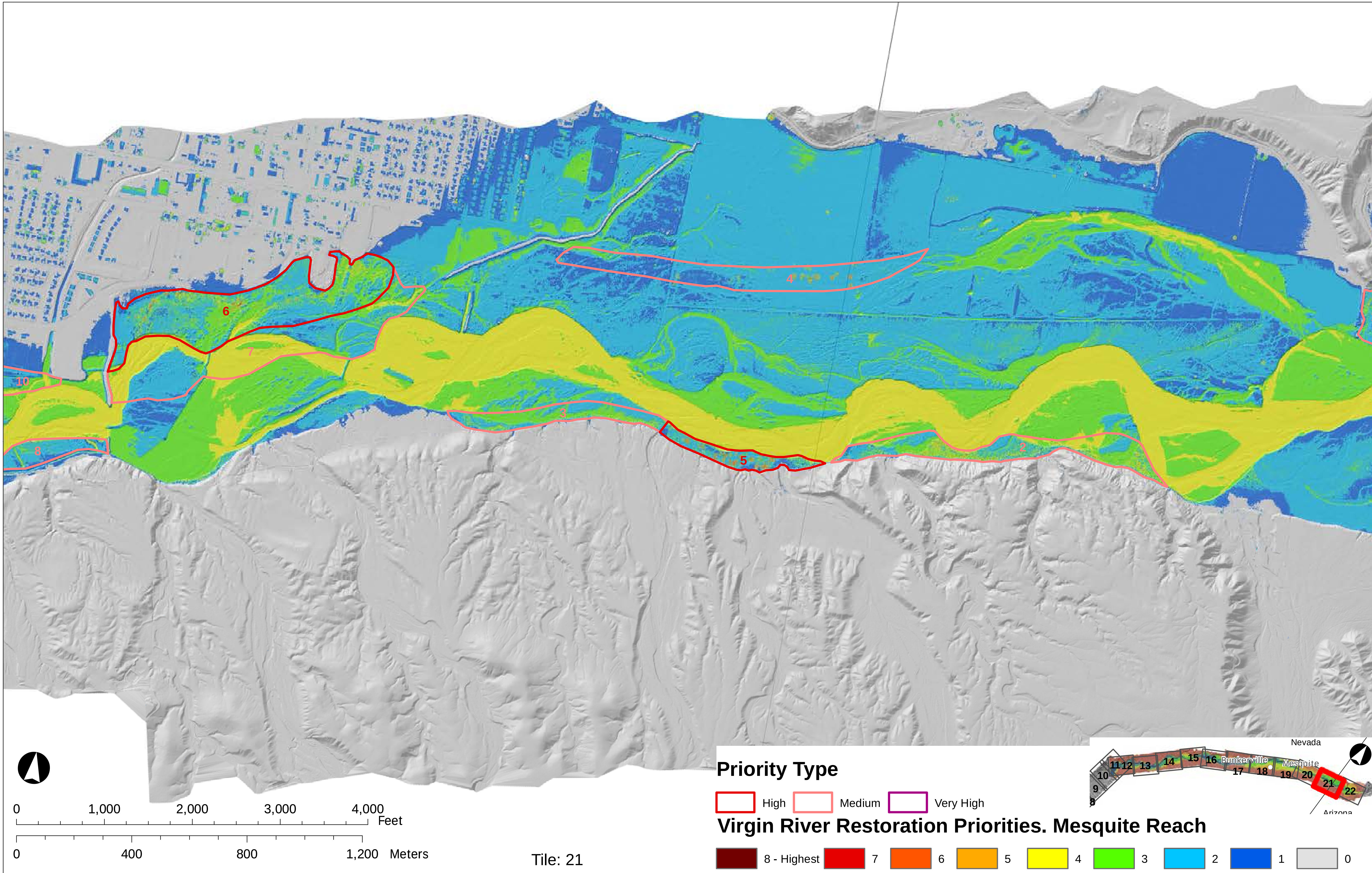
Nevada
Bunkerville
Mesquite
Arizona
8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
0 1,000 2,000 3,000 4,000 Feet
0 400 800 1,200 Meters
Tile: 20
Priority Type
High
Medium
Very High
Virgin River Restoration Priorities. Mesquite Reach
8 - Highest
7
6
5
4
3
2
1
0



Priority Type
High
Medium
Very High
Virgin River Restoration Priorities. Mesquite Reach
8 - Highest
7
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1,000
2,000
3,000
4,000
Feet
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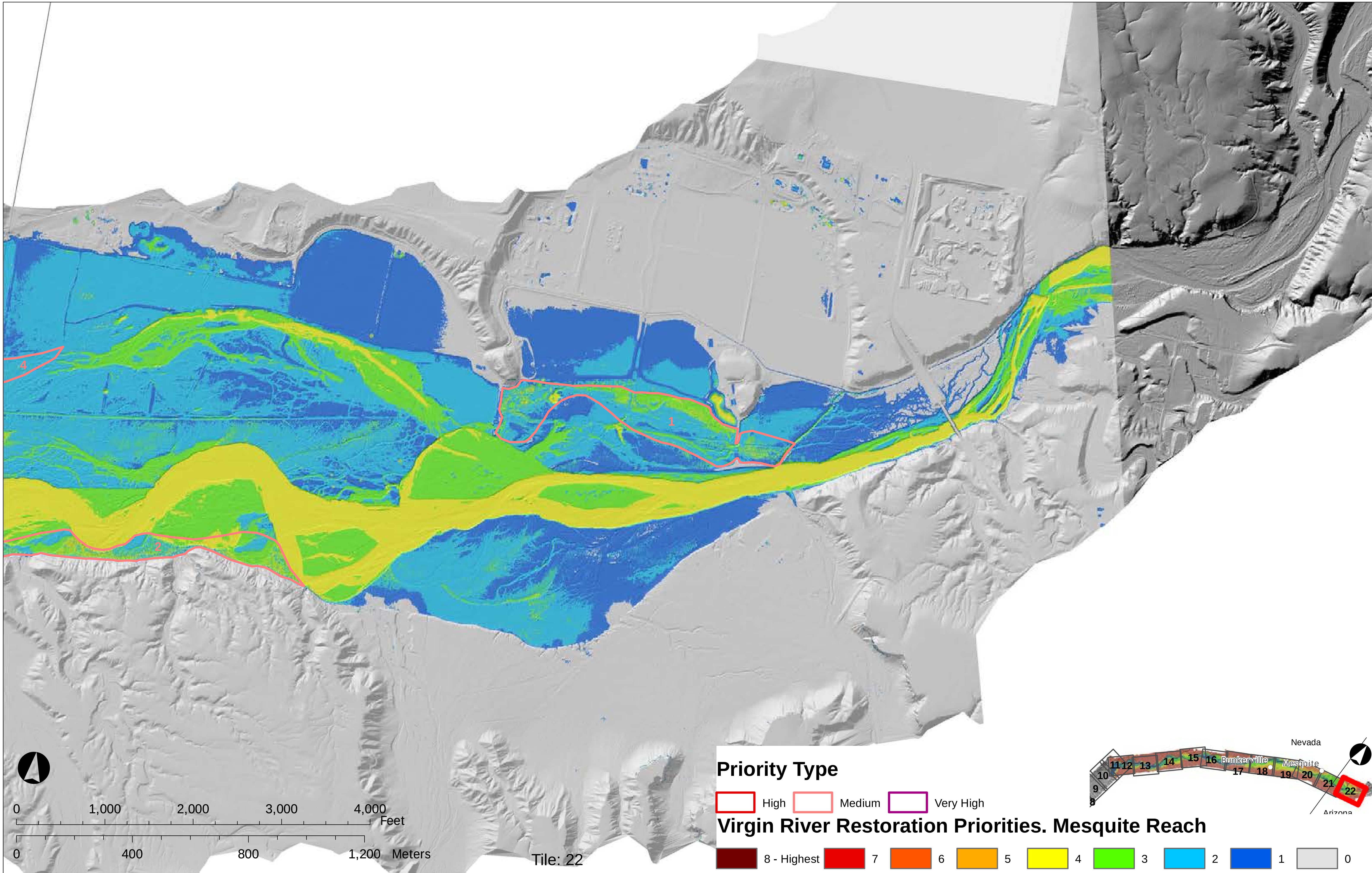
400
800
1,200
Meters
Tile: 21
Nevada
Arizona
Bunkerville
Mesquite



4
1
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1,000
2,000
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Feet
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1,200
Meters
Tile: 22
Priority Type
High
Medium
Very High
Virgin River Restoration Priorities. Mesquite Reach
8 - Highest
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Nevada
Arizona
Bunkerville
Mesquite
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