APPENDIX 6B

EVALUATION OF TRIBUTARY SEDIMENT YIELDS FOR THE PACIFICORP KLAMATH PROJECT BASED ON DELTA SURVEYS

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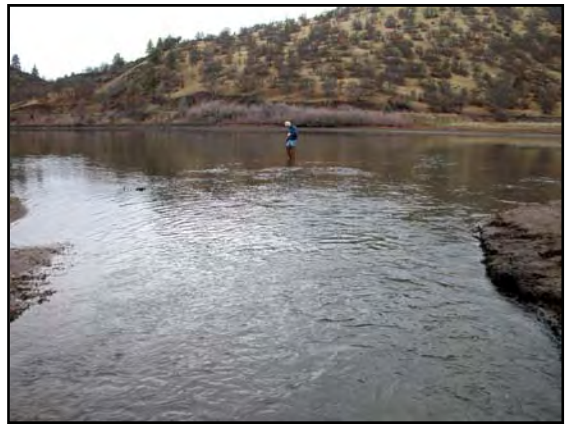

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CHAPTER 1.0 INTRODUCTION

1.1 PROJECT OVERVIEW

The Klamath Hydroelectric Project (Project), owned and operated by PacifiCorp, is currently conducting studies in support of a new license from the Federal Energy Regulatory Commission (FERC) for operation of the Project. The Project is located on the upper Klamath River in Klamath County, south-central Oregon, and Siskiyou County, north-central California. The Project consists of six hydroelectric developments on the upper Klamath River between River Mile (RM) 190 and RM 254, and one development on Fall Creek, a tributary to the Klamath River at about RM 196.

One of the studies being conducted as part of the relicensing process is titled “Analysis of Project Effects on Sediment Transport and River Geomorphology” (Study Plan 1.5). The purpose of this study is to characterize sediment transport and geomorphic conditions and controlling factors in the Project area. A component of this study was development of a sediment budget to help assess the effects of the Project on sediment transport and storage. Tributaries to the upper Klamath River in the Project area are considered important inputs to this sediment budget, and a key aspect of the sediment budget was to assess the character and quantity of sediments being retained in Project reservoirs.

This report describes the specific study of tributary sediment yields in the Project area based on tributary delta surveys. This study is used to assist in the development of the sediment budget by determining tributary watershed sediment yields to the upper Klamath River in the Project area. The measurement of tributary sedimentation involved detailed surveying and mapping of tributary deltas where they deposit into Project reservoirs. These surveys required a combination of detailed bathymetric and terrestrial surveys, as a considerable portion of the delta deposits occur above high-water level. Detailed field surveys of the entire delta deposit were completed and compared to the pre-dam topography. The process involved field surveys, preparation of digital terrain models for both sets of survey data, and computation of net change between the two surfaces. Attempts were made to ensure that a significant proportion of the computed volumes are not simply errors resulting from imprecision in the earlier, typically pre-dam mapping. To translate volumes into yield, the cubic yards were converted to tons using a multiplier by assuming a bulk density and then divided by the number of years since closure of the dam, and the drainage area. Obtaining several rates from different tributary drainage areas helped constrain the findings and added considerable confidence to the results.

The objectives of the surveys of tributary deltas and computation of sediment yields are to:

1. Describe the methods and approach used to measure selected tributary deltas in the reservoirs (Scotch, Camp/Dutch, and Jenny Creeks in Iron Gate Reservoir and Spencer Creek in Boyle Reservoir) of the Klamath Hydroelectric Project.

2. Describe the results of the field surveys and topographic maps developed of the deposits.
3. Investigate the sediment size distribution of the delta deposits using bulk samples and pebble counts in an effort to characterize the entire deposit and to estimate the percentage of coarse (>2mm) sediment within each deposit.
4. Present results of sediment yield analyses based on the field measurements and subsequent volumetric computations.

1.2 PROJECT SETTING AND BACKGROUND

The Klamath River drains a watershed of about 15,600 square miles (mi^2) in northwestern California and southern Oregon. The western half of the basin is mainly mountainous and rugged, draining the Siskiyou, Marble, Salmon, and Trinity Mountains. The eastern portion of the basin, much of which lies in southern Oregon, contains extensive lowlands. Annual precipitation varies from 20 inches in the dryer eastern portions to over 80 inches in the high mountain areas, with significant accumulations of snow in the higher elevations. Winter streamflow peaks are in response to intense precipitation events, either rain or rain-on-snow. Snowmelt run-off is typically of much lesser magnitude but longer duration, with peaks typically occurring between April and June. Land use in the basin has been focused around natural resources development, including timber harvest, mining, agriculture, fisheries, and recreation.

Extensive water resources development for agriculture, interbasin water transfer, and hydroelectric power generation has occurred in the basin, primarily in the upper basin and in the Trinity River sub-basin. The first mainstem impoundment in California was Copco No. 1, completed in 1922 with a capacity of 77,000 acre-feet. Copco No.2 was completed in 1925, 5.5 miles downstream. The primary purpose of these dams was power generation, and between 1925 and 1962 peaking operations at these facilities adversely affected the downstream fisheries resources. Iron Gate Dam, 8.2 miles downstream of Copco No. 2, was completed in 1962 with a capacity of 58,000 acre-feet. This reservoir acts to re-regulate the peaking flows from the upstream hydroelectric facilities. The combination of the upstream Klamath Project and the hydroelectric operations has significantly modified the flow regime of the river. Annual flows have been reduced by diversion for consumptive purposes, and seasonal redistribution of flows has also occurred. Although the changes in mean daily flows have been characterized, it has not yet been documented to what extent the Klamath Project and the hydroelectric reservoirs effect the peak discharges from the upper basin that are critical to natural morphologic function in downstream alluvial reaches.

Since 1922, almost all of the supply of sediment from the 4,300 mi^2 basin upstream of Copco No. 1 was cut-off, and since 1963 with the closure of Iron Gate Dam, the sediment generated by an additional 330 mi^2 has been trapped. Buer (1981) conducted surface and bulk sampling below Iron Gate and indicated that this section of river was generally armored by cobbles too large for salmon to move. The D_{50} parameter (the median diameter of the gravel size distribution) for his pebble counts and bulk samples show a wide range (from 12 mm up to 160 mm) but appear to average somewhere around 50 to 60 mm. They seem to be almost twice the size of the median grain size preferred by Chinook salmon, according to the extensive data set compiled by Kondolf and Wolman (1993).

2.1 CONTROL ESTABLISHMENT

An accurate comparison of the existing surfaces to the historic topography requires accurate control points within each of the delta sites from which all topographic and bathymetric surveys would be conducted. Survey-grade GPS equipment (Trimble 4700/4800 kinematic GPS system) was used to bring horizontal and vertical control to each site from existing benchmarks in the general vicinity (primarily vertical control), while the National Geodetic Survey's (NGS) Online Positioning User Service (OPUS) was used for position solution processing. A minimum of three permanent benchmarks were established at each site and linked together to create an accurate control network. In addition, temporary control points were established, as necessary, to allow full coverage of the sites and to work around the existing vegetation. All survey data were collected in the unit of US feet, based on the local California State Plane or Oregon State Plane coordinated systems and NAD 83 & NAVD 88.

2.2 TOPOGRAPHIC SURVEYS

2.2.1 Terrestrial Field Surveys

The focus of the field mapping was to provide a reasonably detailed topographic map of the delta deposits, though without the rigor needed to produce 1' contour maps that would meet national map accuracy standards. Much of the depositional areas in the deltas are heavily vegetated with willows, blackberries, and other vegetation and even in the early spring before leafing out, the thick net of stems and branches obscure satellite and visual observation thus making mapping difficult. The most effective means in those areas used a three person total station crew where the instrument (Topcon Robotic Total Station AP-L1A) was manually operated in conventional mode, set on a high point and the two rod people carried 25' (or 35') stadia rods with prisms mounted. Although we experimented with vegetation removal to open up survey corridors, it worked best to climb through the heavy brush with the rod collapsed and then raise it to an appropriate height. With directions radioed from the instrument person, the rod was moved until they could get a shot at the prism and the target height was radioed back to the instrument. The two rod people worked together roughly 30'-50' apart and moved in rough cross sections through the brush, making sure the main topographic breaks and enough ground surface points were surveyed to accurately characterize the topography. Key features such as vegetation margins, stream channel thalweg, water edges, and substrate sample locations were surveyed and appropriately coded. When vegetation became too thick to see through, we would survey new secondary control points on the hillslopes overlooking the deposition areas with the total station, move the instrument to the new control point, and continue surveying.

The more open areas surrounding the vegetated deposition areas were occasionally mapped with the three person crew, but were mostly surveyed by a single person, either using the robotic mode of the total stations or Real Time Kinematic GPS (RTK). The latter RTK method works around a Trimble 4700 GPS base station with radio, occupying a known control point. The Trimble 4800 rover unit with radio and TSC1 data collector is placed at the point to survey, receives location information by radio from the base and processes a survey grade solution for the new point within 5-10 seconds as long as at least 5 satellites are visible. Using either method, the main topographic breaks were surveyed along with additional ground surface points to accurately characterize the topography.

The reservoir margins were mostly surveyed with the robotic total station by a single operator. They surveyed the water edge and then waded out into the lake to map the lake bottom to a depth of approximately 2'.   Since the Scotch Creek and the Camp/Dutch Creek sites empty into a common cove, the lake portions of them were mapped as one site. The terrestrial and lake margin portions of the Irongate Reservoir sites (Scotch, Camp/Dutch and Jenny Creeks) were mapped between March 10 and March 22, 2003 when the reservoir level was relatively low.

2.2.2 Bathymetric Surveys

Heavy rains raised the lake and by the time the bathymetric surveying occurred on March 28-29, the lake had risen more than 4' in depth resulting in the fortuitous situation that considerable overlap existed between the bathymetric and terrestrial surveying.   The bathymetric data of the Irongate sites was collected using a small cataraft (10' tubes) powered with an electric trolling motor. On board was a combination of a Trimble 4800 GPS receiver aligned with a SonTek 3.0-Mhz Acoustic Doppler Profiler (ADP). The GPS receiver was set up in a continuous RTK mode where it communicates with the base station (Trimble 4700) and processes real time survey grade solutions for 1 point every second. The ADP unit is mounted directly below the GPS receiver at a known distance and measures depth below water surface every five seconds (as well as velocities). Both instruments relay their data to an onboard computer running Sontek River Surveyor software which coordinates the 1 point/second GPS data with the 1 point/5 second ADP data. After mapping, the combined data is processed – the GPS providing horizontal and vertical coordinates for the water surface and the ADP providing the depth at that point – into a single three dimensional coordinate for each point on the bed of the lake.

The ADP normally has a depth range of 2.5' to approximately 20' but we consistently lost return signals at depths approaching 20' in the Irongate reservoir. The shortened range may have been due to suspended algae throughout the water column and bottom rooted aquatic vegetation. We assumed that depths in that range likely represented areas that had experienced little deposition and therefore did not affect our results much. The shallow depth limit was not an issue since, as previously mentioned, water edges and wading shots were completed when the reservoir water level was several feet lower than when the bathymetry measurement occurred and there was considerable overlap between the two methods.

The Spencer Creek site exhibited little deposition and the delta section that could not be waded encompassed an area small enough to not warrant setting up the ADP apparatus. Instead, the bathymetry that was too deep to wade was mapped with a canoe and/or cataraft with two people aboard, one driving the boat and the other wielding a 15' prism rod with a robotic total station. This method resulted in far less number of points than using the ADP but enough to adequately describe the bathymetry out to the original river bottom.

2.2.3 Digital Terrain Modeling

The points collected using all methods (Total Station, RTK, ADP/RTK Bathymetry), were downloaded into AutoCAD Land Development Desktop 3 (LDD3) Digital Terrain Model (DTM) software to create surface topography models and produce the contour maps. During download points were separated into distinct point groups (TOPS, TOES, control points, etc) based on standard survey practice. Breaklines were created between points to define major topographic breaks (top of bank, etc). Breaklines and those points that describe the ground surface (e.g., as opposed to control points) were then used to create a DTM surface in LDD3 that was the basis for contours. Once built and edited, the DTM can be used to generate any contours desired.

2.3 PRE-DAM TOPOGRAPHY

The pre-dam topography was developed using two methods each with their own limitations: (1) from original topographic maps surveyed prior to dam construction and (2) from probing through the deposits with long rods to estimate original ground surface. The original topography for the three Irongate sites and the Spencer Creek site were supplied on CD ROM from the PacifiCorp GIS department.

The Irongate Reservoir pre-dam contours were supplied in several formats: a digital copy of the original 1957 blueprint portraying 10’ contours referenced to section corners and representing elevations in NGVD29 vertical datum; digitized contours from the original maps in .dxf and shapefile formats geo-referenced to UTM coordinates by the GIS department. The various coordinate systems were translated to the NAD83 (horizontal) coordinate system and NAVD1988 (vertical) datum, as necessary to allow comparison to the site survey data developed in this project.

The probe method used a ½” stainless steel rod with one end sharpened and the other with a T-handle, which could be lengthened in 3’ increments. This probe was pushed by hand into the alluvium until resistance was felt and then the rod depth measured. The resultant depth was assumed to represent original pre-dam ground surface. The existing ground elevation was then surveyed at each of the probe locations and coded with the depth reading. Later, on the computer, the elevation of these probe points was adjusted by the depth reading to yield 3 dimensional coordinates approximating the pre-dam surface.

Once the existing and pre-dam surfaces were built, we compared them to determine volumetric changes over time. In AutoCAD LDD3, a 2’ x 2’ grid was set over the surfaces and at each grid point, the software sampled the elevation of each surface and calculated the elevation change, using the pre-dam surface as the base. From those “elevation change” points, a new third surface was built which represents the change in volume and from which the cut, fill, and net changes were calculated. A useful method of demonstrating location and magnitude of site changes is by generating contours of change from the volumetric surface to produce an isopach plot.

2.4 SUBSTRATE

In an attempt to characterize the size distribution of the alluvial deposits, data were collected using both bulk sample and pebble count techniques. We took shovel bulk samples from various locations throughout each site. At each sample location, we dug a hole until we hit groundwater and in most cases continued to dig deeper, generally between 2'-3'. Each bulk sample hole was photographed to show depth of sample and layering. A 20-30 pound representative sample was bagged from each distinct layer and carried back to the lab for sieve analysis. We planned to conduct Wolman pebble counts (Wolman 1954) at each bulk sample location, but since the surface of most of the sites were composed of silt, only three of the sites have associated counts.

Typically, our aquatic bulk samples are oven (or sun) dried, and then run through automatic sieve shakers. Since most of the delta samples were composed of particles finer than 2 mm, we found it necessary instead to wet sieve those by hand through 12" brass sieves in full phi sizes and then sun or oven dry each fraction. For those bulk locations that exhibited more than one layer, each layer was sieved and weighed separately.

CHAPTER 3.0 RESULTS

3.1 SITE SELECTION

There are 4 significant tributaries to Iron Gate Reservoir: Scotch Creek, Camp Creek, Jenny Creek, and Fall Creek. In addition, there are several minor tributaries. There are no significant tributaries to Copco Lake, though there are a number of smaller or minor tributaries. Spencer Creek is the only significant tributary in the JC Boyle Reservoir. The original proposal was to map delta deposits in Iron Gate Reservoir only, consisting of those associated with Scotch, Camp, Jenny Creeks and two minor tributaries. We evaluated Fall Creek in our field reconnaissance in January 2003, but found that the effects of other site issues (hydroproject development and other grading in the vicinity of the delta deposits either affected the deposits directly, or compromised our ability to interpret the deposits. As a result, Fall Creek was dropped as a possible study site.

After review of the proposal by the technical committee, several changes in the sites were made. Smaller tributaries to Iron Gate were dropped and Spencer Creek was added. Figure 1 shows the locations of the selected sites. Figure 2A is an enlargement of the USGS quadrangle for the Iron Gate Reservoir sites, including Scotch, Camp, and Jenny Creeks. Note that Dutch Creek is a tributary to Camp Creek that joins the creek just upstream of the road embankment across the stream corridor. Figure 2B is an enlargement of the USGS quadrangle for the JC Boyle Reservoir site, Spencer Creek.

Figure 3 includes a series of photographs of the Scotch Creek site, showing the active delta at low water, the dense riparian vegetation occupying most of the delta deposits, and other site features. Figure 4 is a similar series of views of the Camp/Dutch Creek site. Figure 5 provides similar view of Jenny Creek, but at normal reservoir levels, thus hiding almost all of the actual delta deposits. Figure 6 includes views of the Spencer Creek site.

3.2 CONTROL

Development of the control network for all project surveys was completed in March 2003.
For control point markers, we used either 5/8” rebar with aluminum caps, rebar without caps, 2”x2” wooden hubs with tacks, or 12” galvanized iron spikes, depending on site characteristics and public access considerations. Initially we set a primary benchmark at each of the two main Iron Gate sites using rebar with aluminum cap stamped “GMA IG10” at the Jenny Creek site and “IG20” at the combined Scotch/Camp/Dutch Creek site. Horizontal and vertical coordinates were established for each point by setting up a Trimble 4700 GPS base station over the unknown point for a minimum period of two hours. The resulting two hour (or longer) receiver file was later downloaded into a computer running Trimble Geomatics Office (TGO) software, converted to a Rinex file type, and emailed to the National Geodetic Survey’s (NGS) Online Positioning User Service (OPUS) for processing. The OPUS service processed the file along with simultaneous files from the nearest three continuously operating reference stations (CORS) to arrive at a position solution for the unknown benchmark and then emailed that back. During the two plus hour occupation of IG10, we used a second GPS receiver (Trimble 4800 Rover) to collect GPS data at four benchmarks with known horizontal and/or vertical coordinates, at the

unknown IG20, and at one other secondary control point at each site. Next we occupied the IG20 point with the base station for a minimum of two hours (for OPUS) and used the rover at the other control points. Finally, at each of the two main sites, we set up a total station and surveyed angles and distance between the primary and secondary control points and established a third control point. The resultant network of GPS and terrestrial observations were downloaded and combined in the TGO software and, using the OPUS solutions and the established benchmarks, were processed to generate accurate coordinates for three control points at each of the two sites. The resultant positions used California State Plane Zone 1 Coordinates with the NAD83 horizontal datum (ft) and NAVD88 vertical datum (ft) (Table 1, Figures 7-9).

Using similar methods, a separate network of three new hubs and three known benchmarks were used to establish three control points at the Spencer Creek site using Oregon State Plane South Zone Coordinates, NAD83 (ft), NAVD88 (ft) (Figure 10).

3.3 EXISTING TOPOGRAPHY

Delta topography and bathymetry were developed from all of the survey data collected. Data values were downloaded into AutoCAD and Land Development Desktop 3 (LDD3) Digital Terrain Model (DTM) software to create surface topography models and produce the contour map. A digital terrain model (DTM) of all surveyed areas was created using the LDD3 software.

3.3.1 Point-Survey Area Coverages

Figure 7 shows the terrestrial survey points (black) and bathymetric survey points (red) collected at the Scotch Creek site during this study. Location and point number of the various control points, as well as their coordinates, are also shown. Similar presentations for the other sites are contained in Figure 8 (Camp/Dutch Creeks), Figure 9 (Jenny Creek), and Figure 10 (Spencer Creek). The figures depict the point density achieved at the sites despite often very difficult surveying conditions due to the dense riparian vegetation. The following table presents the survey areas in acres and the total number of survey points (combined from terrestrial surveys and bathymetric surveys) for each site.

SITE	SURVEY AREA (acres)	NUMBER OF SURVEY POINTS
SCOTCH	16.82	2,117
CAMP/DUTCH	25.43	1,921
JENNY	18.24	2,252
SPENCER	22.62	1,029

Table 2. Survey Area and Number of 2003 Survey Points by Site

3.3.2 Overlays on 2001 Aerial Photography

For reference, Figures 11-14 show the survey area boundary and control point locations overlain on 2001 aerial photography. These aerial photos were used to check horizontal alignments between the pre-dam and 2003 contour maps. The area of riparian encroachment on delta deposits above the normal reservoir level are readily apparent at each site.

3.3.3 Site Contour Maps

The 1’ contours maps for each site are shown in Figures 15-18. The maps include the reservoir perimeter road location for reference and show the waters edge (stream channels and reservoir edge) at the time of the surveys. The maps show 1’ contours in black with index (10’) contours in red.

The cut/fill associated with the reservoir perimeter road are not included to allow more direct comparison to pre-dam topography. Undisturbed areas on either side of the road cut/fill were surveyed, and then the topography extrapolated in these areas.

3.3.4 Pre-Dam Topography

Scanned or digitized pre-dam contour maps were provided by Pacificorp. For comparison to the existing topography, we translated them to NAD83 California State Plane Coordinates, Zone 1. To check horizontal alignment, we took scanned aerial photographs (supplied by PacifiCorp) from 1955 (representing pre-dam conditions) and 2001, and approximately scaled and translated them to real world coordinates using common points from the photos and geo-referenced USGS topographic quads. The Camp/Dutch Creek and the Jenny Creek site pre-dam contours aligned well with the quad but the Scotch Creek pre-dam contours had to be shifted approximately 90’ northerly with no rotation in order to line them up with the topo, photos, and existing topography. No explanation is available for why this was necessary, but the problem likely lay in the original surveys. Once aligned, the 10’ contour lines were shifted +3.428’ vertically to represent elevations in the NAVD88 datum (NGVD29 + 3.428 = NAVD88) and then used to build a pre-dam DTM to compare to the surveyed existing surface.

Figures 19-21 show the pre-dam topography developed for the Iron Gate Reservoir sites (Scotch, Camp, Jenny Creek sites). The 10’ (index) contours are shown in black, while extrapolated 2’ contours are shown in gray. Again, the maps include the reservoir perimeter road location for reference and show the waters edge (stream channels and reservoir edge) at the time of the surveys.

Also overlain on the pre-dam topography in Figures 19-21 are the results of probing performed on the delta deposits at each site. In general, probe points close to the edge of the deposits, or at least to depths of 10 feet or so, showed values reasonably close to the pre-dam topography. This was less true towards the upstream end of the deposits, likely due to the probe encountering coarse material that provided “refusal” conditions. Towards the center of the deposits, elevations obtained from probe depths were almost always at considerably higher elevations (shallower depths of deposit), suggesting that the rpobing was not an effective method at greater depths. For the reasons described here which apparently limited the effective use of probing, we were unable to build a pre-dam DTM surface simply from the probe data. However, the probe data appear to confirm that the general side slopes from the pre-dam topography were fairly accurate. The exception to the above discussion is the upstream end of the Jenny Creek deposit, where probing elevations at some locations are deeper than the pre-dam topography from the contour maps. Although it is possible that probing reached greater depths than the actual pre-delta surface by penetrating into that surface, this seems unlikely. Instead, the pre-dam topography for Jenny Creek appears suspect

The same approach used in Scotch, Camp, and Jenny Creeks could not be used for the Spencer Creek. We used the digitized 1959 10' contours and translated them from UTM to NAD83 Oregon State Plane Coordinates, South Zone and shifted them from NGVD29 to NAVD88 vertical datum by adding 3.786' (NGVD29 + 3.786 = NAVD88). Perhaps because the Spencer Creek delta area was very low gradient before Boyle Reservoir and the resolution with 10' contours did not adequately describe the pre-dam topography, the comparison between the existing and pre-dam topography was incorrect (shows net cut). Therefore for the Spencer Creek site, we used the second method of probing to describe the pre-dam condition.

The pre-dam DTM for the Spencer Creek site combined the adjusted 10' contours and the pre-dam probe points to add detail in the main depositional area. The resultant surface seems to much better represent the likely pre-dam topography than with the contours only.

3.3.5 Substrate

The locations of bulk samples and pebble counts at the four study sites are shown in Figures 23-26. Four samples each were collected at the Scotch and Camp/Dutch Creek sites, two at the Jenny Creek site, and one at the Spencer Creek site. The sample locations were generally distributed along the length of the deposit, although submerged portions of the sites (particularly Jenny Creek) could not be sampled due to normal reservoir water levels at the time of sample collection.

Figures 27 and 28 show photographs of each bulk sample site, while Figures 29-32 show the size distribution curves for the bulk samples and pebble counts (where applicable).

CHAPTER 4.0 ANALYSIS

4.1 DELTA CHANGES OVER TIME

To assess tributary delta changes over time, various aerial photographs were collected and provided by Dr. Matt Kondolf. We created viewports of the images in AutoCAD to show the same view of each delta in six different years for the Iron Gate tributaries (1955, 1963, 1965, 1979, 1989 or 1993, and 2001) and four different years (1952, 1968, 1994, and 2000) for Spencer Creek.

The development of the Scotch Creek delta is shown in Figure 33. The pre-dam aerial photograph from 1955 shows a wandering alluvial channel mostly hidden by a narrow riparian corridor. The reservoir had just been filled and the perimeter road constructed in the 1963 photo, with evidence of a small amount of sediment accumulation upstream of the road crossing. By 1965, a significant amount of sediment deposition had occurred, mostly as a result of the large December 1964 flood event, undoubtedly. No vegetation was present on the deposits yet. In 1979, continued growth of the delta into the reservoir is apparent, including a shift in the active channel location to the south. A significant amount of riparian vegetation had grown up on the deposits by this time. A similar pattern was visible in 1989, including delta growth and increased density of vegetation. By 2001, the entire delta deposit was covered with dense, tall riparian vegetation and the active channel had moved towards the north (not visible, but where it presently is located.

The development of the Camp/Dutch Creek delta is shown in Figure 34, and followed a similar sequence to that of Scotch Creek. After filling of the reservoir in 1963, the water level extended well upstream of the reservoir perimeter road, however by 1965, sediment had filled down past the road embankment. Initial construction of the boat launch and parking area could be seen in the 1965 photo. By 1979, vegetation had encroached onto most of the delta deposits. By 2001, all portions of the sediment deposit were covered with a dense, tall stand of riparian vegetation.

The development of the Jenny Creek delta is shown in Figure 35, and followed a similar sequence to that of the previous sites. In 1955, it is difficult to determine the course of pre-dam Jenny Creek, although it appears that the channel may have been up against the eastern hillslope, based on darker vegetation which is likely to be riparian forest species. Construction of the reservoir perimeter road and a large fill embankment had occurred by 1963. The creek channel was also realigned to a more westerly location, where a bridge was constructed over the channel. It also appears that there was some excavation upstream of the road embankment, in what is now the parking area. The December 1964 flood caused substantial change, including washing out the road bridge and depositing a large volume of sediment both upstream of the road embankment and southeast of the embankment into the reservoir. A temporary road is visible some distance upstream bypassing the washed out bridge. By 1979, the bridge had been rebuilt, the delta had continued to grown, and riparian vegetation has begun to become established on the sediment deposits. In the 1993 and 2001 photos, this process has just continued. Due to the normal reservoir levels in both of those photos, the main active part of the delta cannot be seen.

Development of a delta at the Spencer Creek site followed a fairly different sequence as is shown in Figure 36. The pre-dam channel of the creek was braided, except at the final approach to the river. It appears that a topographic control existed that created a braided, depositional reach upstream. This reach of the Klamath River was very low gradient prior to the dam, and with the construction of such a small dam, the inundation area above the pre-existing river level did not change a tremendous amount, seen in the differences between the 1952 and 1968 photos. Much of the braided nature of the creek channel has diminished over time, and only limited vegetation encroachment has occurred (due to the continued grazing in the area). It is not apparent from the photos that any appreciable amount of sediment has been deposited in a delta formation for this creek.

In general, with the exception of Spencer Creek, the growth and development of the tributary deltas followed a predictable pattern, with the only unusual event being the amount of change caused by the December 1964 flood event, obviously a very significant event in the Iron Gate area, similar to what is known about the event in the Klamath Mountains and indeed entire general region. Delta growth into the reservoir was rapid in the early years (much due to the 1964 event) in the shallower reservoir margin areas and has slowed since the mid to late 1970s as the deposits have been progressively moving into deeper water. In addition, encroachment of dense riparian vegetation onto the depositional surface has created a very hydraulically rough flow path. This helps to spread the flow out over much of the surface and leads to increased deposition on the older portions of the deposit.

4.2 DEPOSIT VOLUMES

Following completion of the development of both the pre-dam and existing digital terrain models, the two surfaces were overlaid and the net change computed. The resulting isopach maps (contours of net change, with green contours being fill areas and red contours showing cut areas) of the computed deposit volume are shown in Figures 37-40 for the four sites.

The Scotch Creek delta isopach (Figure 37) shows generally reasonable contours of net change, with shallow deposits (1-3’) upstream of the reservoir perimeter road crossing and increasingly deeper deposits until near the edge of the normal reservoir water level (blue lines). The maximum depth of deposit computed is 21 feet. A somewhat fan-shaped delta developing eblow the normal reservoir operating water level at the mouth of the existing channel is visible. The deposit then drops off down to very shallow thicknesses (1-2’) before rising again to the south to thicknesses of about 10 feet. This arrangement does not seem particularly reasonable unless the thicker deposit away from the active delta is actually caused by selective deposition of wash load, i.e. those finer-grained (silts and clays) portions of the sediment load which are not first deposited as the sediment laden flow reaches the reservoir. This would not seem likely unless there are currents, wind effects, or some other mechanism that would cause the wash load to be preferentially deposited in one area. It seems more likely that there is an error here in the pre-dam topography that results in the appearance of this depositional lobe. It is also apparent, that unless this lobe is an mapping error, the surveys of the existing delta did not quite reach the end of the deposit. One other issue that develops based on the analysis of the isopach map, is that from the pre-dam aerial photograph of Scotch Creek, it appears that the thalweg of the creek channel was up against the north hillslope (closer to the reservoir perimeter road alignment), however from the isaopach map, the deepest potion of the deposit is in the center of the deposit, rather than off to the north side. This issue relates primarily to the accuracy of the pre-dam topography, where, we believe, the greatest source of error in the volumetric is likely to occur. It is apparent from review of the pre-dam topography that substantial differences can be hidden between 10' contours. For example, there is no definition of a stream channel in the pre-dam topography, although clearly one existed.

The Camp/Dutch Creeks delta isopach map is shown in Figure 38. Evaluation of the deposit isopach is generally similar to Scotch Creek. The upstream end of the surveys on Camp Creek appears to have completely mapped all of the deposits, although this does not appear to be the case for Dutch Creek, where fill contours of over 6' are present at the upstream end of the surveys. Upstream of the raod embankment, the maximum deposit depth is about 19 feet, while deposit depths in the 21-22' range are found downstream. There is a fairly steep front on the active delta deposit about 75 feet to the west of the normal operating water level of the reservoir, with the deposit depth dropping from 19-20 feet to 10-11 feet. As one can see, the deposits of Scotch Creek and Camp/Dutch Creek merge in the reservoir and it is difficult to determine which portions of the deposit came from the different watersheds. The parcel boundary that we assumed to differentiate between the deposits is shown as a bold, dashed line in Figures 37 and 38, but we have no way to assess the accuracy of our sub-division. For this reason, as described in the next section, it is probably better to consider the entire Scotch-Camp-Dutch delta as a single deposit from which an average yield for the combined watersheds may be computed. Interestingly, a deposit feature that appears towards the south end of the Camp/Dutch delta isopach map, is similar to that described for Scotch Creek: a localized mound of considerably thicker deposits (up to 13' thick). Although this could be an actual portion of the deposit (and the presence of two at approximately similar locations on opposite sides of the original stream channel could indicate that a mechanism for creating these deposits may be present in the reservoir), we would still interpret these features to be artifacts of errors, or simply areas of lower accuracy on the pre-dam topography. Another interesting feature on the Camp/Dutch isopach map is the presence of a large area of "cut" (denoted by red contours) along the eastern shore of the reservoir and extending into the reservoir several hundred feet. From the aerial photos, we know that some grading occurred in this area after filling of the reservoir, in order to construct the boat launch and parking area, however, it is highly unlikely that the shape, depth, or extent of any excavation would match that on thye isopach map which covers a very large area, has depths of up to 18 feet and extends 250 feet into the reservoir. There is no evidence on the aerial photos that would indicate use of this area for a borrow pit for some aspect of reservoir and reservoir perimeter road construction, and instead, we believe there was a mapping error on the pre-dam topography.

The Jenny Creek delta isopach is shown in Figure 39. At first glance, we see three areas of "cut" in the Jenny Creek deposit. The first and largest is upstream of the road crossing and embankment and would reflect the movement of the channel from up against the eastern hillslope towards the west as part of construction and then because of the 1964 flood. The extent of the cut in this area, of up to 7 feet, does not seem unreasonable for scour of a new stream channel on a watershed of this size. Depths of fill along the eastern hillslope are of this same magnitide 3-7 feet, although no stream channel was defined in this location in the pre-dam topographic surveys. The remaining two small cut areas are along a suspicious "ridge" alignment visible in the pre-dam topography. This ridge cut nearly all the way across the valley floor of Jenny Creek, leaving only a narrow slot for the stream to travel through. There is no evidence of such a “ridge” in the aerial photographs, so this feature is highly suspect from the pre-dam topography. To go from 9-13 feet of fill, shallow to 1-3 feet of fill plus areas of cut, and then deepen again to 16 feet of fill seems unlikely. In addition, portions of the area that show very shallow fill depths were exposed in January 2003 during the reservoir drawdown that coincided with our reconnaissance visit to the sites. Shovel excavations and shallow probing occurred in these areas but never were deposits that shallow found. The active face of the delta is well defined in the isopach plot and the thickness decreases by 8-9 feet in a short distance. The change contours indicate that if the pre-dam topographic data are reliable, then the 2003 surveys did not capture the entire deposit, as fill contours of 5-6 feet were present at the edge of the surveyed area. Overall, accuracy of the volume of sediment in Jenny Creek delta is judged to be lower than the Scotch-Camp sites.

The Spencer Creek delta isopach is shown in Figure 40. Surprisingly, this area shows very little deposition. The use of probe data in these shallow deposits should have prevented any substantial error in the pre-dam topography. No immediate esxplanation is available for the apparently very low sediment yields from this watershed.

The following table summarizes the deposit volumes for the four sites determined in this study:

SITE	DEPOSIT VOLUME (cubic yards)
SCOTCH	88,500
CAMP/DUTCH	73,500
JENNY	107,200
SPENCER	2,812

Table 4. Computed Tributary Delta Volumes by Site

Cross sections and a profile of both the pre-dam and the 2003 delta surface for each site are contained in Figures 41-48 to assist in review of the different surfaces and the isopach map. The first figure for each site is a location map of the 2003 site contour map with the cross section and profile locations shown. The second figure at each site contains the profile and the four cross sections.

Figures 41 and 42 are for the Scotch Creek site. The cross sections indicate that even some of the pre-dam hillslope topography do not match existing conditions all that well. Areas of cut or fill well outside the delta deposit were obviously excluded from any volumteric computations. In addition, in the deeper parts of the deposit it is apparent that the volume relative to the fill is far greater than any minor issues with alignment of the two surfaces, thus still providing a reasonable value. The upstream and downstream limits of the profile indicate that at least along that alignment, there was good agreement of both the pre-dam and existing elevations showing that essentially all of the deposit volume was included in the surveys.

Figures 43 and 44 cover the Camp/Dutch Creek site. Similar issues with cross section alignment of the hillslopes and other features (the ridge between Camp and Dutch Creeks) are visible at this site. Again, the ends of the profile indicate fairly complete surveys covering the extent of the deposit. The large volume of cut on the left side of cross section 4 is unlikely, as previously discussed.

Figures 45 and 46 present the cross sections and profiles for the Jenny Creek site. There are also issues at this site with hillslope alignment from the pre-dam topography, in addition to the doubtful topography (previously discussed) shown on cross section 3.

Figure 47 and 48 show the cross sections and profiles for the Spencer Creek site. Topographic issues occur at both ends of the profile and as shown in cross sections 1 and 4, where cut areas are shown.

4.3 COMPUTATION OF SEDIMENT YIELDS

Once a delta deposit volume has been determined, it is a relatively straight-forward process to translate that volume into a sediment yield. Several important assumptions are required during this process, however. First, the deposit volume needs to be converted from cubic yards to tons. This involves use of a bulk density factor for the deposit. Values from the literature have a fairly wide range, and vary based on geology, soil types, grain sizes present in the deposit, organic matter present in the deposit, and other factors. Values in other sediment budget studies have ranged from 85 to 125 pounds per cubic foot. Secondly, an assumption needs to be made regarding the percentage of wash load in the sediment supply, on the basis that much or most of the washload would not have been captured in the delta surveys and instead would have been deposited throughout the reservoir, and perhaps a small portion would even have been completely passed through the reservoir during storm flows. Thirdly, an assumption needs to be made regarding the percent coarse sediment (that which would be useful to creation and maintenance of salmonid spawning gravels, generally that greater than 8mm) that is present in the deposit.

Table 5 presents the results of our computation of sediment yields based on the field surveys and analysis conducted in this study. The table computes the Scotch and Camp/Dutch study sites individually and combined into a single site. In addition, Jenny Creek is computed individually and as a portion of all three Iron Gate tributaries combined.

The table presents the drainage area for each study site ranging from 17.9 mi^2 at Scotch Creek to 209.9 mi^2 at Jenny Creek, then converts deposit volumes in cubic yards to tons based on two different bulk density factors (1.485 tons/yd^3 and 1.2 tons/yd^3), and then computes the average unit yield (tons/mi^2/yr) based on the drainage area and the number of years since closure of the dam. Finally, an estimate of 20% washload is added to the yield to reflect very fine-grained sediments that would not likely be deposited in the delta. This percentage is simply an estimate based on limited suspended sediment size distribution data from the Shasta River (the nearest watershed with such data that drains mostly volcanic terrain) where approximately 20-30% of the suspended sediment load was in the clay and silt size classes. The only way to improve such an estimate would be to collect sediment transport data over a range of flows for the tributaries in question and perform size distribution analyses on those samples. In addition, the hydraulic roughness caused by the dense riparian vegetation on the delta deposits acts to trap some of these fine-grained sediments which would complicate any such analysis.

The computed yields range from 1.3 tons/mi^2/yr for Spencer Creek to 220 tons/mi^2/yr for Scotch Creek. It is difficult to determine why the sediment yields from Spencer Creek would be so low, and certainly that value does not seem reasonable. It is possible that other factors upstream in that watershed control sediment delivery to some extent, or that much of the sediment was trapped upstream of where we surveyed. The values for Jenny Creek (18-22 tons/mi^2/yr) also seem very low. There are several water supply reservoirs in the upper Jenny Creek watershed that undoubtedly trap some sediment, but we beileve that inaccurate pre-dam topography is the primary reason that sediment yields in Jenny Creek are much lower than Scotch and Camp/Dutch Creeks. Scotch and Camp/Dutch Creeks have generally similar yields ranging from 134 to 220 tons/mi^2/yr depending on bulk density values. As discussed earlier, we believe combining the two sites and computing a combined sediment yield is the most appropriate method. Given this, we believe that the long-term sediment yield from Iron Gate tributaries is in the 150-190 tons/mi^2/yr range, and probably should be weighted to the lower end as it is likely that the delta deposits incorporate a substantial amount of organic matter which will reduce the overall bulk density value.

CHAPTER 5.0 REFERENCES

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TABLE 1
CONTROL POINTS ESTABLISHED DURING THIS STUDY

NUMBER	NORTHING (NAD83, FT)	EASTING (NAD83, FT)	ELEVATION (NAVD88, FT)	DESCRIPTION	SITE
1	180106.35	4506723.58	3798.09	HUB	SPENCER
4	180463.62	4506708.89	3806.28	HUB	SPENCER
5	180962.35	4507134.01	3801.79	HUB	SPENCER
10	2603586.96	6453364.80	2376.38	CAP	JENNY
11	2603523.73	6452574.04	2365.03	REBAR	JENNY
12	2603242.93	6453267.45	2342.68	HUB	JENNY
20	2603001.01	6441905.07	2363.26	CAP	SCOTCH
21	2602021.41	6443008.54	2335.77	SPIKE	SCOTCH, CAMP/DUTCH
22	2603188.28	6442337.26	2361.71	HUB	SCOTCH
23	2602769.74	6442020.37	2364.53	REBAR	SCOTCH
24	2603253.86	6441847.70	2358.62	REBAR	SCOTCH
35	2602538.09	6442161.97	2355.64	REBAR	SCOTCH
36	2602870.13	6442786.44	2375.66	REBAR	SCOTCH, CAMP/DUTCH
37	2603369.61	6442151.64	2368.41	REBAR	SCOTCH
38	2603487.43	6442085.05	2368.88	REBAR	SCOTCH
39	2603105.19	6443006.54	2377.25	REBAR	CAMP/DUTCH
40	2602703.75	6443451.51	2348.27	SPIKE	CAMP/DUTCH
41	2603539.54	6443231.57	2423.78	REBAR	CAMP/DUTCH
42	2603023.00	6443773.71	2360.40	SPIKE	CAMP/DUTCH

NOTE: Spencer Creek site control uses Oregon State Plane South Zone horizontal coordinates while Irongate sites use California State Plane, Zone 1 coordinates

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TABLE 3
BULK SAMPLE SIZE PARAMETERS

	CAMP/DUTCH CREEK SITE							JENNY CREEK SITE			
SAMPLE #	**DC1**	**DC1**	**DC2**	**DC2**	**DC3**	**DC3**	**DC4**	**JC3**	**JC3**	**JC4**	**JC4**
DEPTH (in.)	**0-12**	**12-36"**	**0-24**	**24-36"**	**0-8**	**8-18"**	**0-24**	**0-6**	**6-27"**	**0-6**	**6-24"**
Dmean (Dg) =	0.75	0.32	1.05	5.13	0.66	31.02	0.88	1.25	4.44	0.78	
D90 =	1.63	0.63	1.51	14.08	1.21		2.00	2.74	11.86	1.64	Large Cobble
D84 =	1.31	0.45	0.95	10.45	0.97	56.43	1.34	1.54	8.57	1.03	and boulders
D65 =	0.79	0.27	0.71	4.64	0.71	39.92	0.71	0.48	3.30	0.48	
D50 =	0.54	0.20	0.59	2.42	0.59	32.07	0.50	0.36	1.66	0.39	
D35 =	0.33	0.15	0.48	1.08	0.43	9.19	0.38	0.26	0.91	0.31	
D16 =	0.16		0.17	0.27	0.14	0.27	0.24	0.13	0.40	0.17	
D10 =				0.19			0.17		0.27		

	SCOTCH CREEK SITE						SPENCER CREEK SITE	
SAMPLE #	**SC1**	**SC2**	**SC3**	**SC3**	**SC4**	**SC4**	**SPC**	**SPC**
DEPTH (in.)	**0-24**	**0-20**	**0-6**	**6-18"**	**0-6**	**6-24"**	**0-6**	**6-12"**
Dmean =	0.23	0.26	23.48	11.16	12.20	13.87	3.39	167.73
D90 =	0.39	0.41	55.14	29.58	26.13	35.79	15.56	
D84 =	0.33	0.35	45.81	22.64	22.23	23.95	8.22	
D65 =	0.22	0.26	29.26	11.29	15.46	10.31	0.32	38.30
D50 =	0.17	0.20	15.13	5.73	9.17	5.77	0.21	0.21
D35 =	0.13	0.16	5.04	2.15	4.29	3.03	0.17	
D16 =			0.48	0.55	0.78	0.77		
D10 =			0.29	0.36	0.38	0.42		

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TABLE

3

COMPUTATION OF SEDIMENT YIELDS BY STUDY SITE

SUB-WATERSHED NAME	AREA (acres)	AREA (sq. miles)
SCOTCH CREEK	11479.5	17.94
CAMP CREEK	12618.4	19.72
JENNY CREEK	134329.2	209.89
SPENCER CREEK		84.62

USING BULK DENSITY VALUE OF 1.485 TONS/YD^3 (110 POUNDS/CUBIC FT)

SITE	DEPOSIT VOLUME (yd3)	DEPOSIT VOLUME (tons)	AREA (mi^2)	PERIOD (years)	YIELD (tons/mi^2/yr)	Add 20% for washload (tons/mi^2/yr)
SCOTCH	88,500	131,423	17.94	40	183.2	219.8
CAMP/DUTCH	73,500	109,148	19.72	40	138.4	166.1
Combined Scotch/Camp/Dutch	162,000	240,570	37.65	40	159.7	191.7
JENNY	107,200	159,192	209.89	40	19.0	22.8
Combined All Irongate Tribs	269,200	399,762	247.54	40	40.4	48.4
SPENCER	2,812	4,176	84.62	36	1.4	1.6

USING BULK DENSITY VALUE OF 1.2 TONS/YD^3 (88 POUNDS/CUBIC FT)

SITE	DEPOSIT VOLUME (yd3)	DEPOSIT VOLUME (tons)	AREA (mi^2)	PERIOD (years)	YIELD (tons/mi^2/yr)	Add 20% for washload (tons/mi^2/yr)
SCOTCH	88,500	106,200	17.94	40	148.0	177.6
CAMP/DUTCH	73,500	88,200	19.72	40	111.8	134.2
Combined Scotch/Camp/Dutch	162,000	194,400	37.65	40	129.1	154.9
JENNY	107,200	128,640	209.89	40	15.3	18.4
Combined All Irongate Tribs	269,200	323,040	247.54	40	32.6	39.1
SPENCER	2,812	3,374	84.62	36	1.1	1.3

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TABLE 5

Vicinity Map

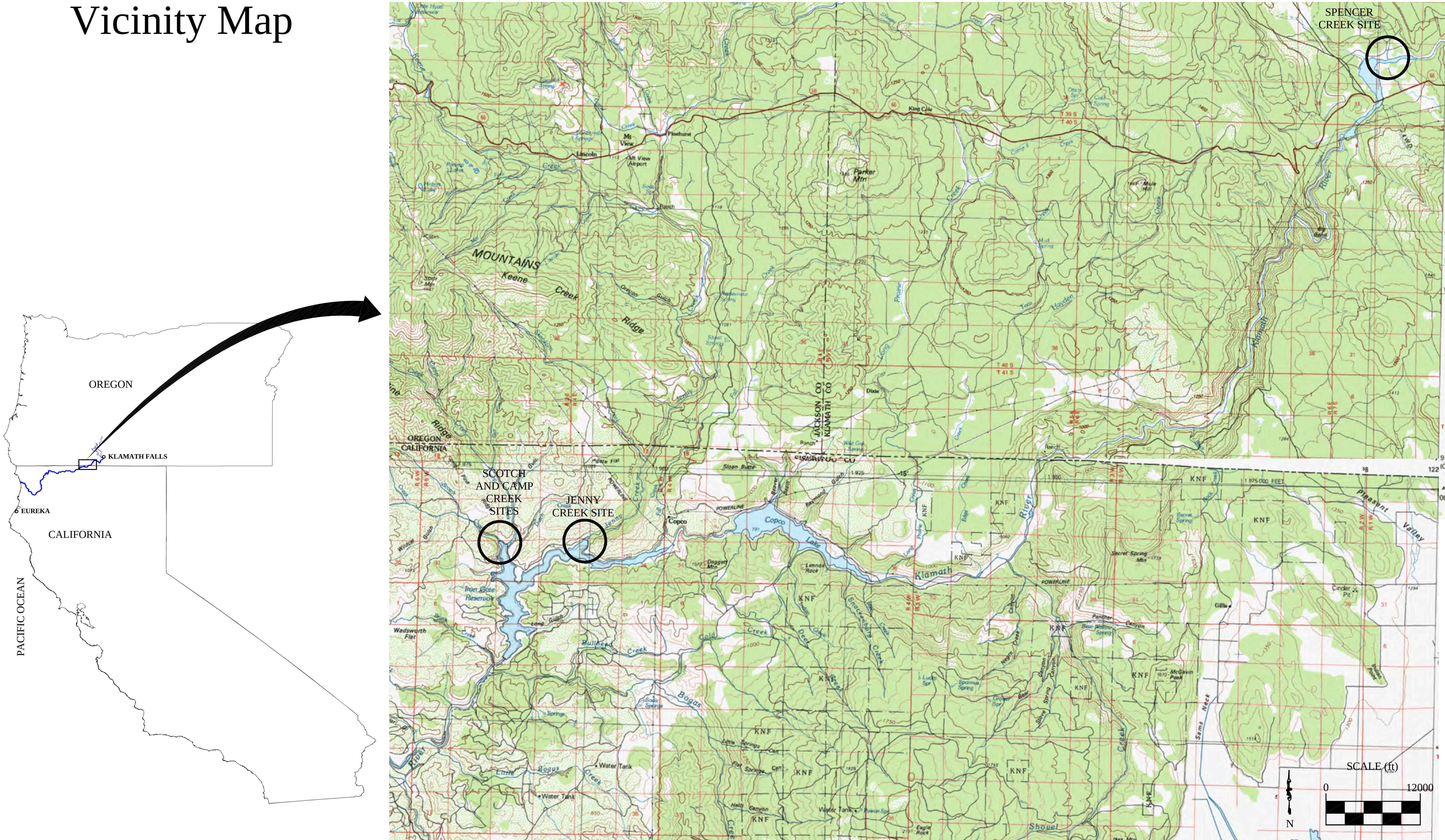

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FIGURE

1

SITE LOCATION MAP - USGS QUAD
SCOTCH, CAMP/DUTCH, AND JENNY CREEK SITES

SCALE (ft)
0 1200
N

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SITE LOCATION MAP - USGS QUAD
SPENCER CREEK SITE

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FIGURE

2B

GROUND PHOTOS OF PROJECT SITE – SCOTCH CREEK

Scotch Creek Delta deposit entering reservoir at low water

Middle of Dense Vegetation in Scotch Creek Delta

View Upstream of half buried Culvert in Delta

Sediment Deposition and Riparian Vegetation near upper end of Deposit

View of Riparian Encroachment onto Delta Deposit, Middle Reach

View of Active Delta Mouth at Confluence with Reservoir

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GROUND PHOTOS OF PROJECT SITE – CAMP/DUTCH CREEKS

Camp/Dutch Creek Delta deposit entering reservoir at low water

Channel as it exits Vegetation in Camp/Dutch Creek Delta

View of Delta Deposit below low Reservoir Water Level

Dense Riparian Vegetation falling into Channel

View across to Riparian Encroachment onto Camp/Dutch Delta Deposit

View of Dense Vegetation on Delta Deposit Upstream Road

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GROUND PHOTOS OF PROJECT SITE – JENNY CREEK

Jenny Creek Delta deposit entering reservoir at normal water

Entire area of Water in View has Delta Deposits a few feet below Surface

View of Delta Deposit upstream road near Campground

View Downstream of Jenny Creek near Upper end of Delta Deposit

View across submerged Jenny Creek Delta Deposit from Bridge

View of submerged Delta Deposit at Normal Reservoir Level

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GROUND PHOTOS OF PROJECT SITE
SPENCER CREEK

Spencer Creek looking downstream from
right bank towards Klamath River

Spencer Creek looking upstream from
right bank

Spencer Creek looking across the channel
from the right bank

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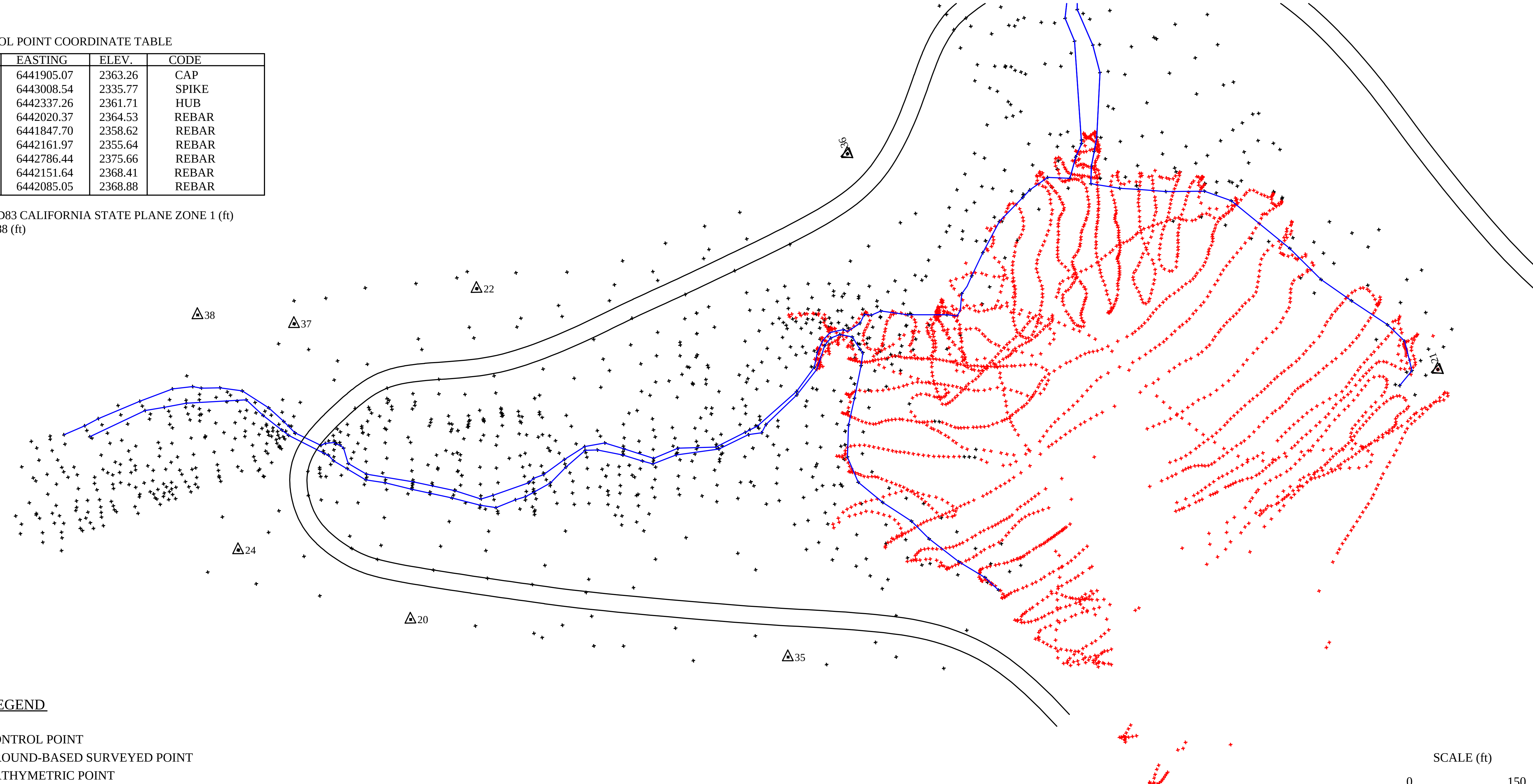
CONTROL AND SURVEY POINT MAP
SCOTCH CREEK

CONTROL POINT COORDINATE TABLE

POINT #	NORTHING	EASTING	ELEV.	CODE
20	2603001.01	6441905.07	2363.26	CAP
21	2602021.41	6443008.54	2335.77	SPIKE
22	2603188.28	6442337.26	2361.71	HUB
23	2602769.74	6442020.37	2364.53	REBAR
24	2603253.86	6441847.70	2358.62	REBAR
35	2602538.09	6442161.97	2355.64	REBAR
36	2602870.13	6442786.44	2375.66	REBAR
37	2603369.61	6442151.64	2368.41	REBAR
38	2603487.43	6442085.05	2368.88	REBAR

HORIZONTAL: NAD83 CALIFORNIA STATE PLANE ZONE 1 (ft)
VERTICAL: NAVD88 (ft)



LEGEND

35 CONTROL POINT
GROUND-BASED SURVEYED POINT
BATHYMETRIC POINT
WATER EDGE (3/10/03-3/21/03)
ROAD

SCALE (ft)
0 150

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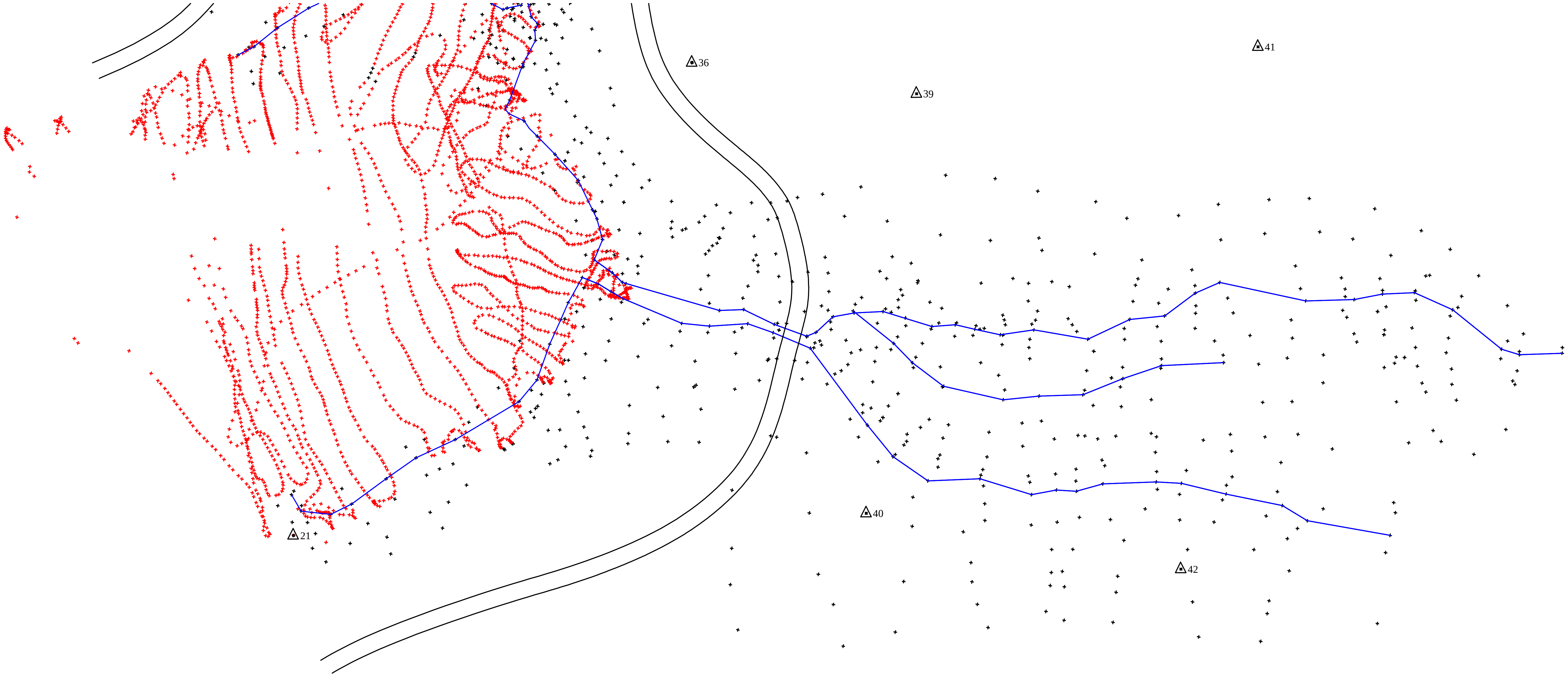
FIGURE 7

CONTROL AND SURVEY POINT MAP
CAMP/DUTCH CREEK



POINT COORDINATE TABLE

POINT #	NORTHING	EASTING	ELEV.	CODE
21	2602021.41	6443008.54	2335.77	SPIKE
36	2602870.13	6442786.44	2375.66	REBAR
39	2603105.19	6443006.54	2377.25	REBAR
40	2602703.75	6443451.51	2348.27	SPIKE
41	2603539.54	6443231.57	2423.78	REBAR
42	2603023.00	6443773.71	2360.40	SPIKE

HORIZONTAL: NAD83 CALIFORNIA STATE PLANE ZONE 1 (ft)
VERTICAL: NAVD88 (ft)

LEGEND

35 CONTROL POINT
GROUND-BASED SURVEYED POINT
BATHYMETRIC POINT
WATER EDGE (3/1/03-3/21/03)
ROAD

SCALE (ft)
0 150

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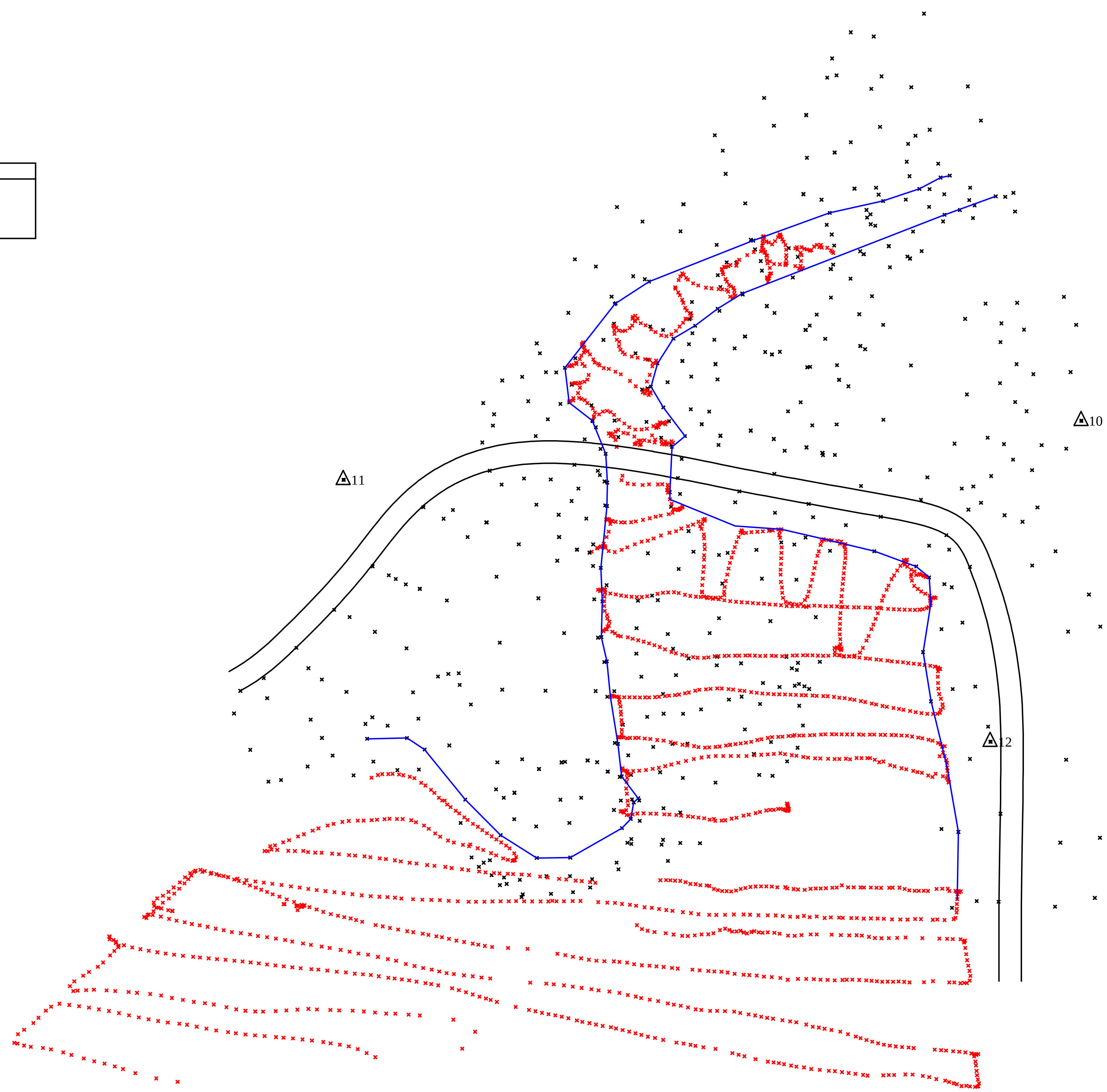
FIGURE
8

CONTROL AND SURVEY POINT MAP
JENNY CREEK

POINT COORDINATE TABLE

POINT #	NORTHING	EASTING	ELEV.	CODE
10	2603586.96	6453364.80	2376.38	CAP
11	2603523.73	6452574.04	2365.03	REBAR
12	2603242.93	6453267.45	2342.68	HUB

HORIZONTAL: NAD83 CALIFORNIA STATE PLANE ZONE 1 (ft)
VERTICAL: NAVD88 (ft)



LEGEND

35 CONTROL POINT
GROUND-BASED SURVEYED POINT
BATHYMETRIC POINT
WATER EDGE (3/1/03-3/21/03)
ROAD

SCALE (ft)
0 150

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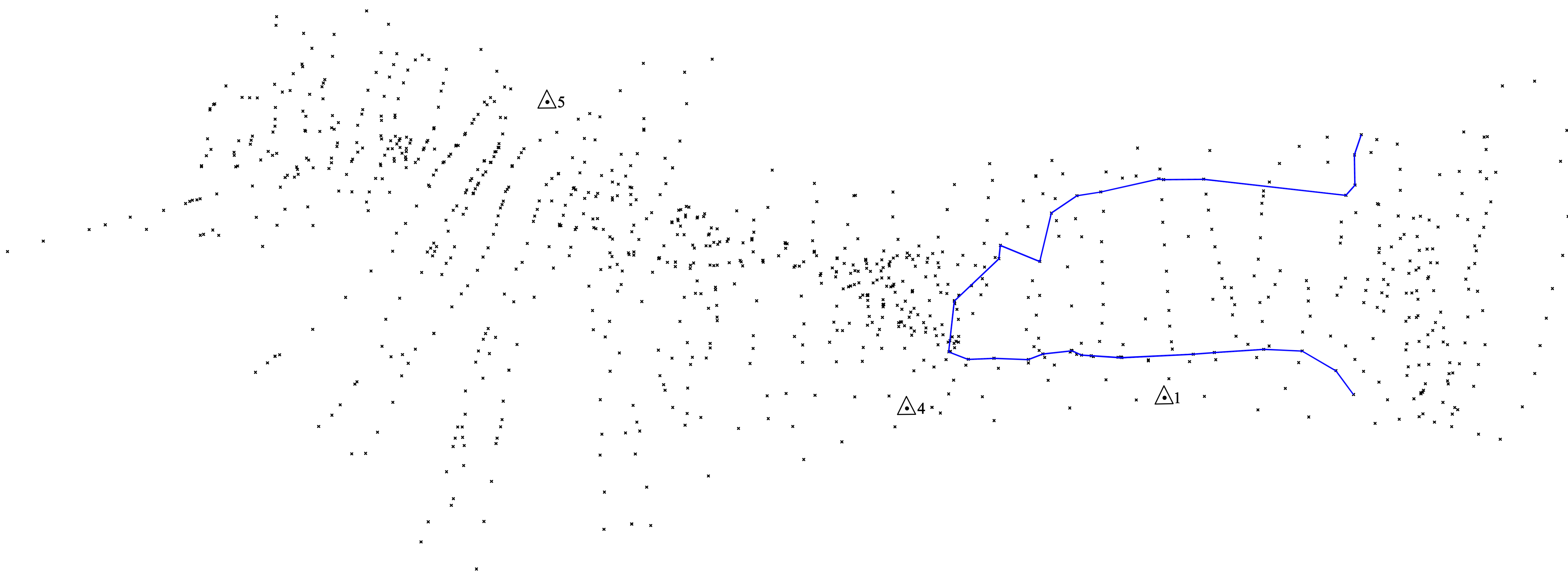
FIGURE
9

CONTROL AND SURVEY POINT MAP
SPENCER CREEK



POINT COORDINATE TABLE

POINT #	NORTHING	EASTING	ELEV.	CODE
1	180106.35	4506723.58	3798.09	HUB
4	180463.62	4506708.89	3806.28	HUB
5	180962.35	4507134.01	3801.79	HUB

HORIZONTAL: NAD83 OREGON STATE PLANE SOUTH ZONE (ft)
VERTICAL: NAVD88 (ft)

LEGEND

1 CONTROL POINT
GROUND-BASED SURVEYED POINT
WATER EDGE (3/30/03)

SCALE (ft)

0 150

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FIGURE

10

SURVEY BOUNDARY AND CONTROL ON 2001 AERIAL PHOTO - SCOTCH CREEK

LEGEND

35 CONTROL POINT
SURVEY BOUNDARY

SCALE (ft)
0 150

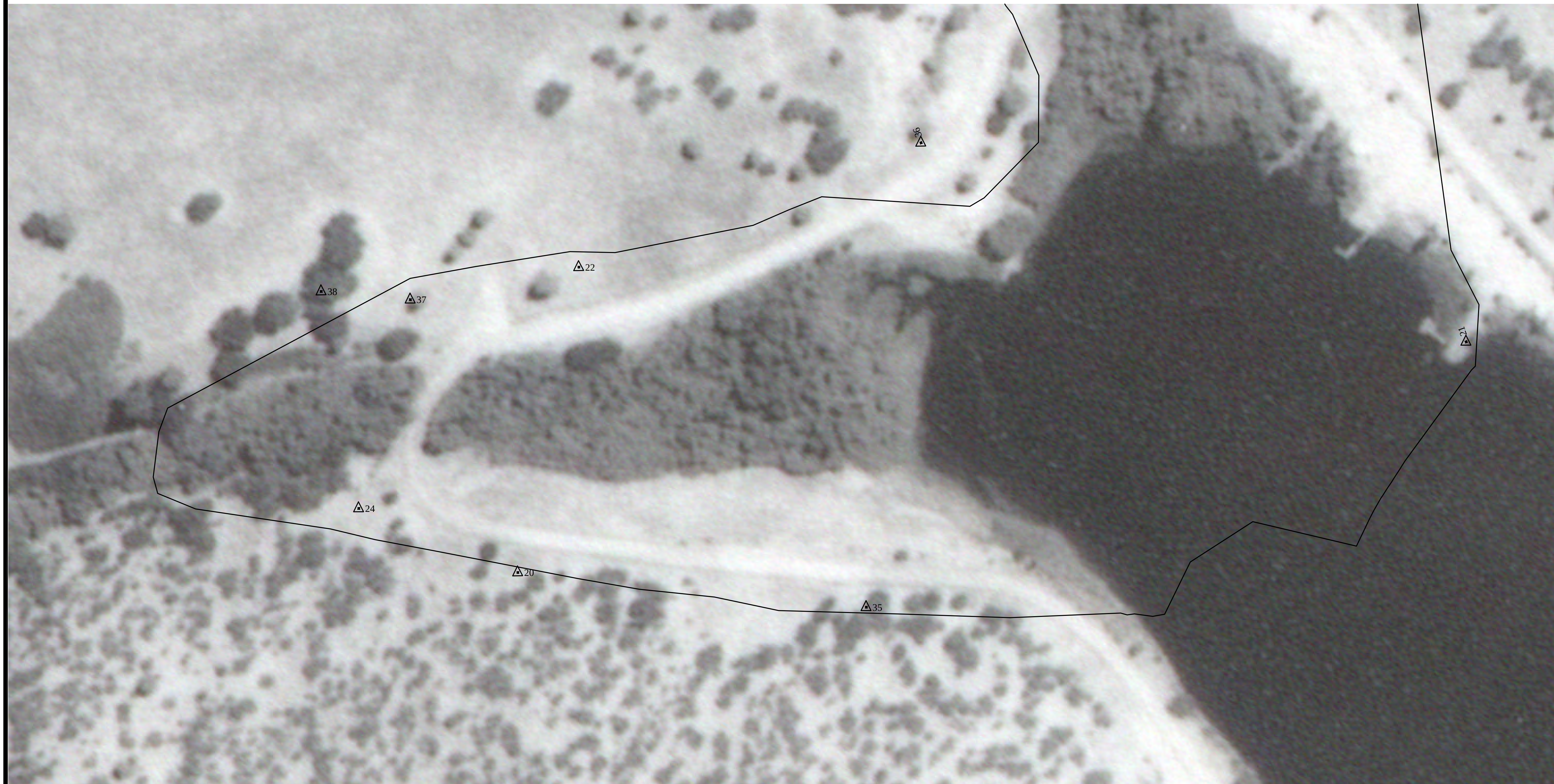

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FIGURE 11

SURVEY BOUNDARY AND CONTROL ON 2001 AERIAL PHOTO - CAMP/DUTCH CREEK

LEGEND

35 CONTROL POINT
SURVEY BOUNDARY

SCALE (ft)
0 150

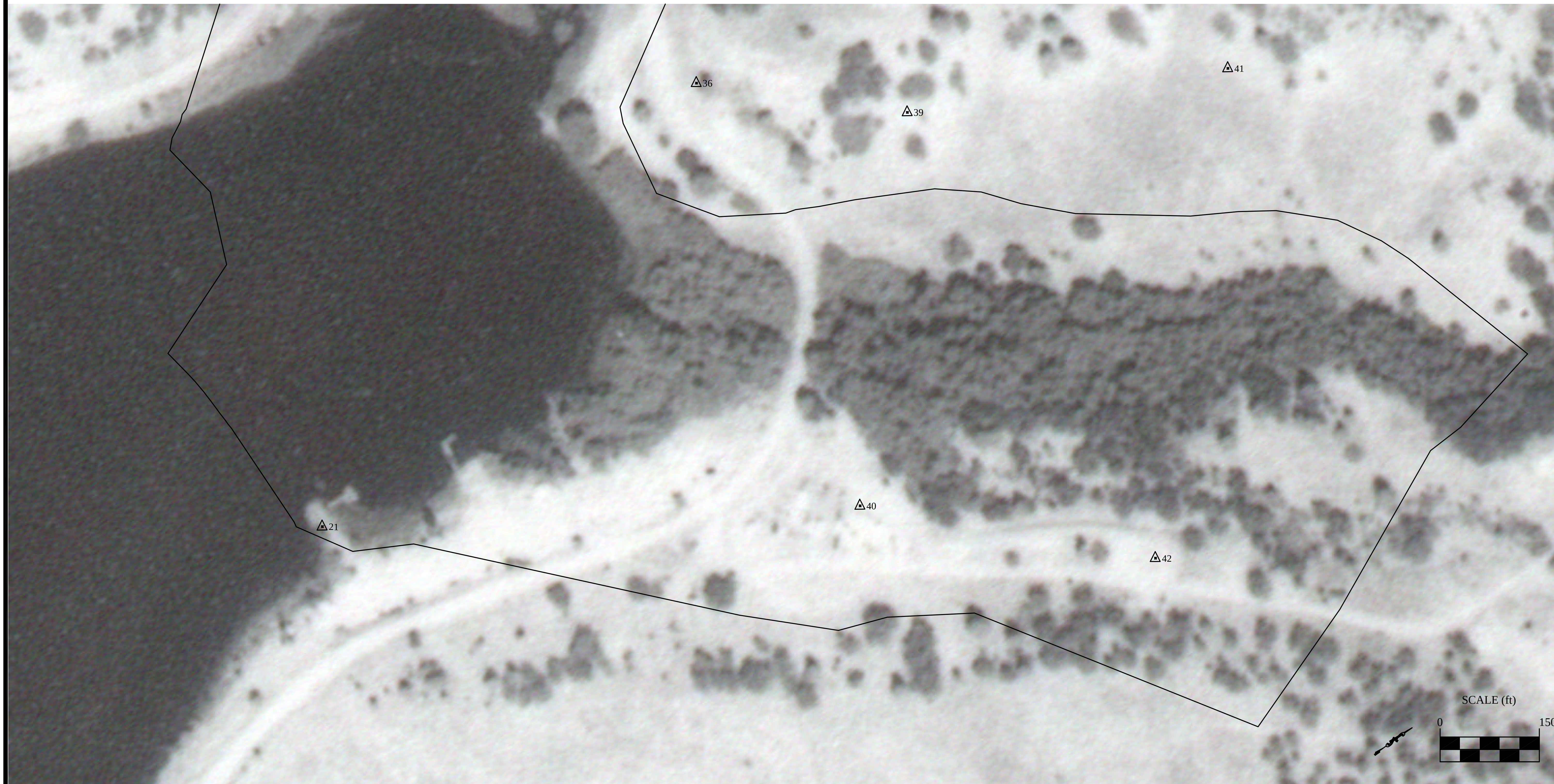

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FIGURE 12

SURVEY BOUNDARY AND CONTROL ON 2001 AERIAL PHOTO - JENNY CREEK

LEGEND

35 CONTROL POINT
SURVEY BOUNDARY

SCALE (ft)
0 150

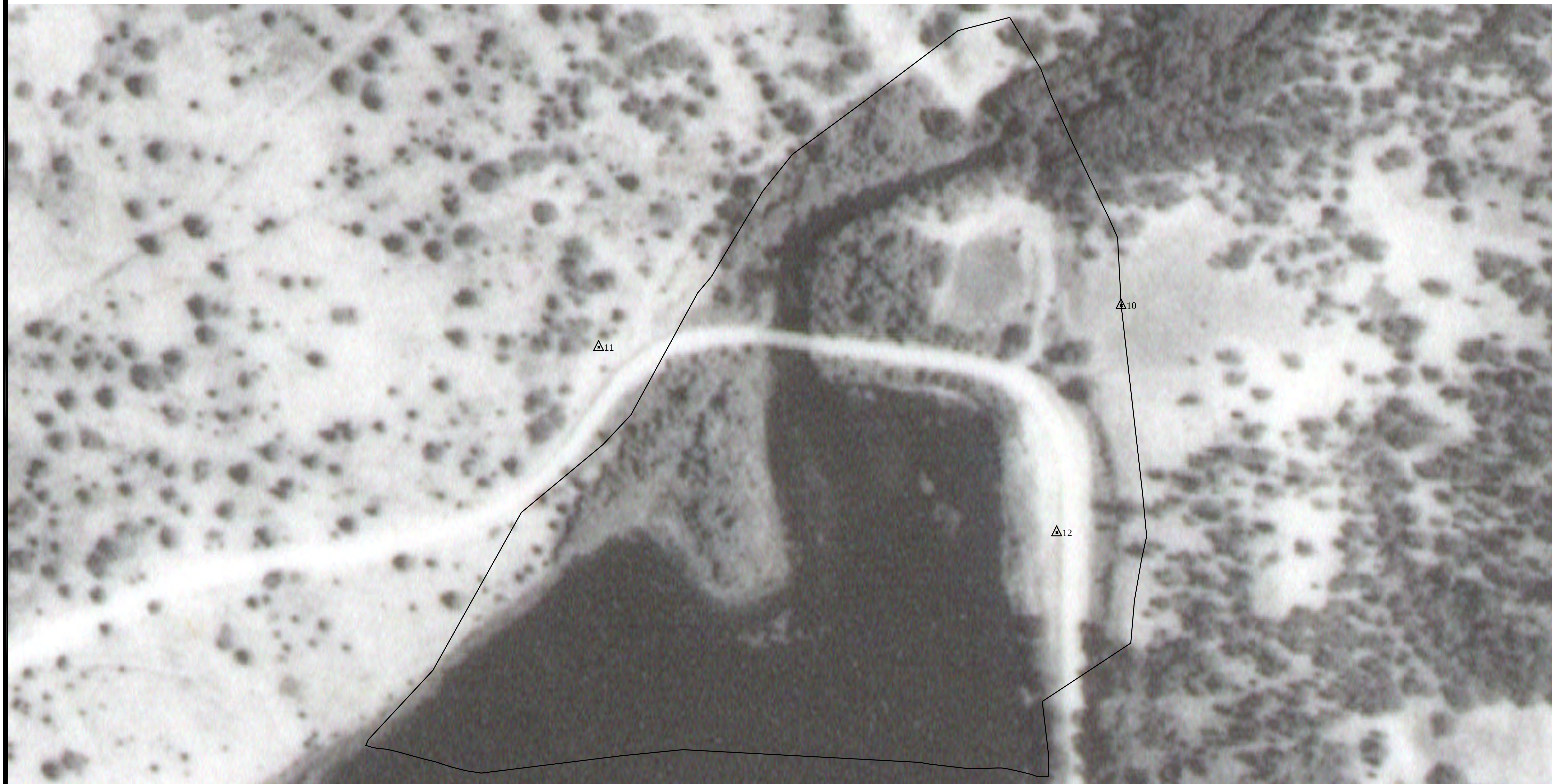

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FIGURE 13

SURVEY BOUNDARY AND CONTROL ON 2001 AERIAL PHOTO - SPENCER CREEK

LEGEND

△1 CONTROL POINT
SURVEY BOUNDARY

SCALE (ft)
0 200

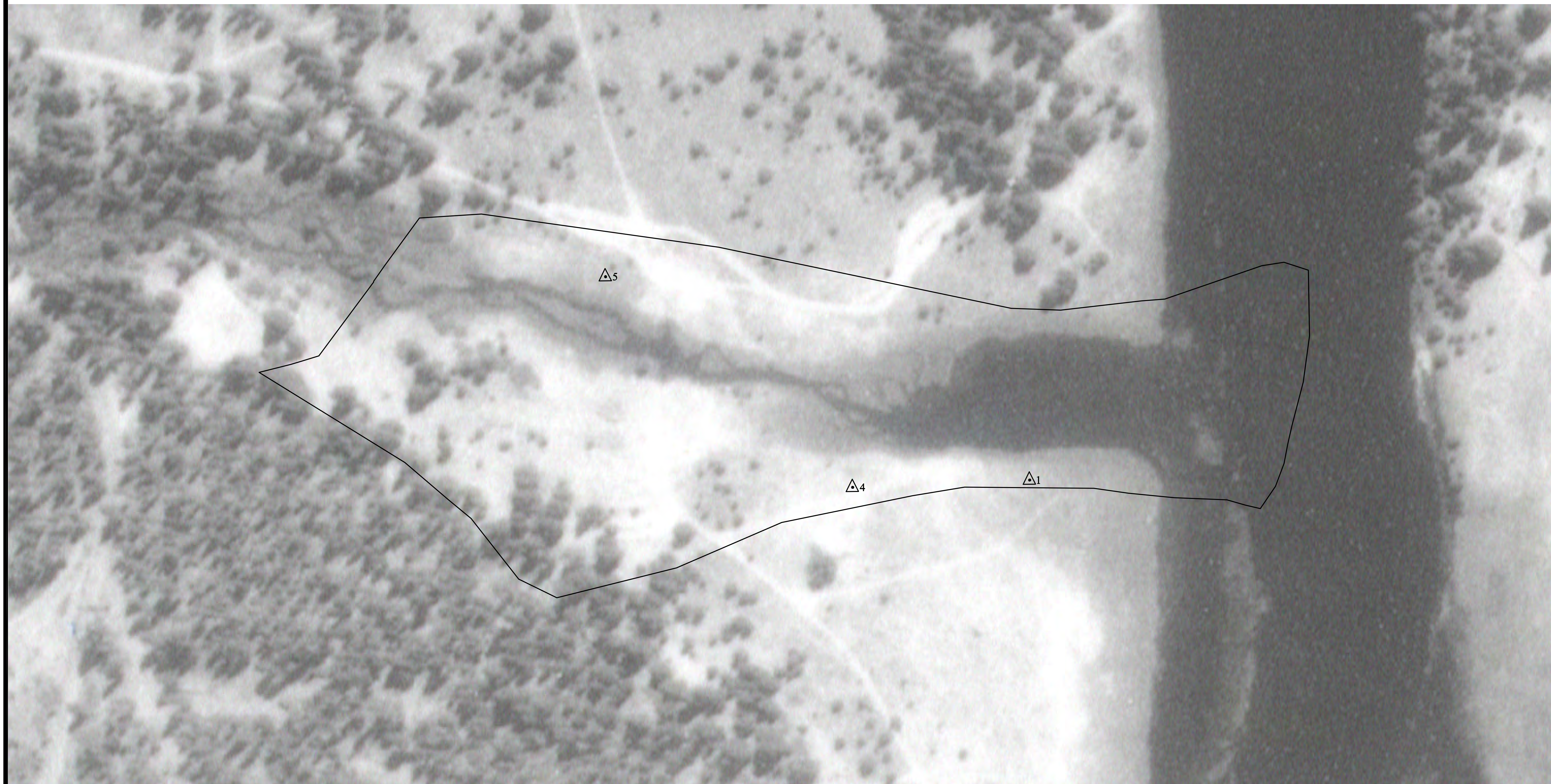

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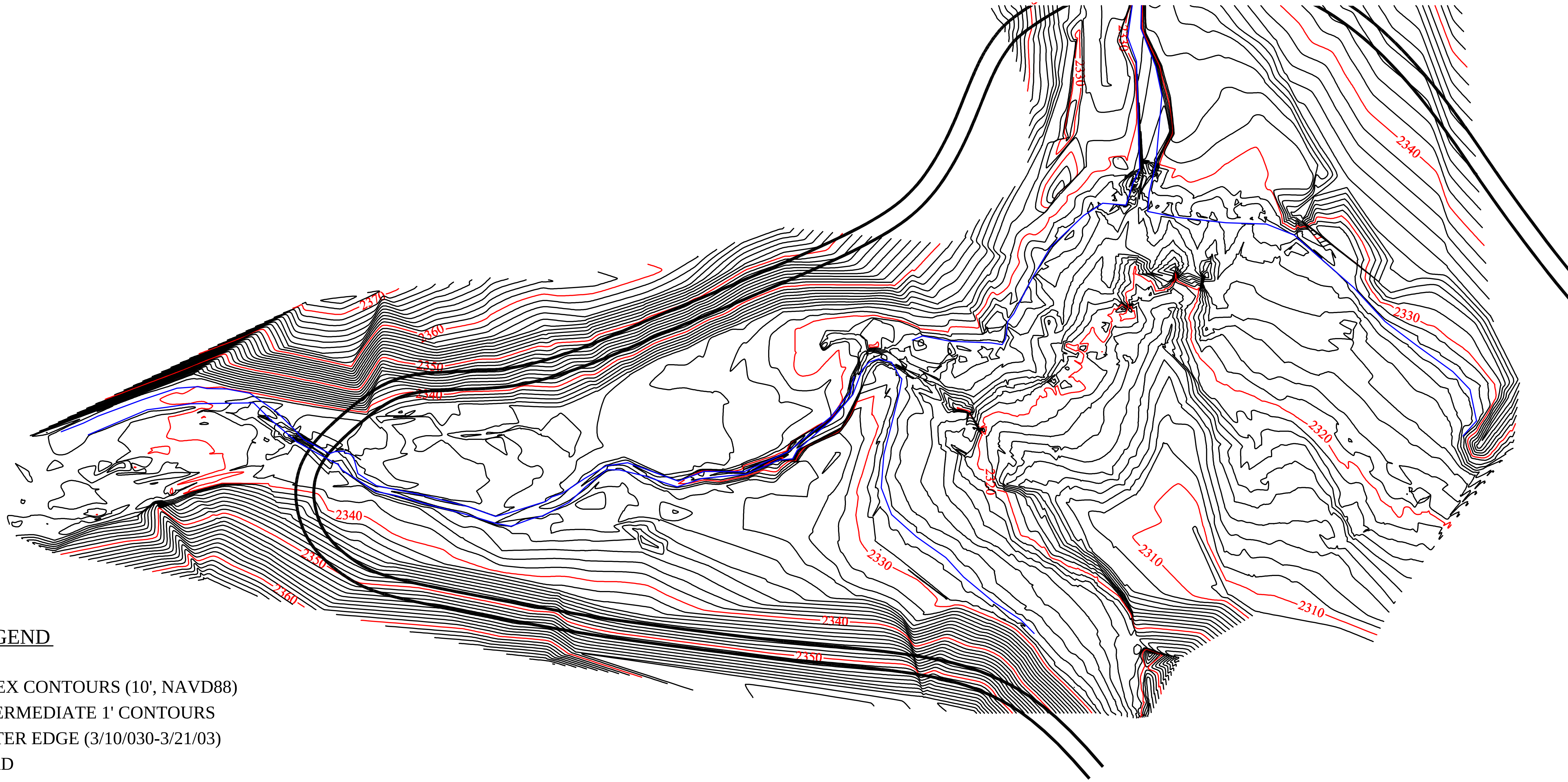
FIGURE
14

2003 TOPOGRAPHY - SCOTCH CREEK



LEGEND

- INDEX CONTOURS (10', NAVD88)
- INTERMEDIATE 1' CONTOURS
- WATER EDGE (3/10/030-3/21/03)
- ROAD

NOTE: TOPOGRAPHY REPRESENTS EXISTING CONDITIONS WITHOUT ROAD FILL IN ORDER TO BETTER COMPARE WITH PRE-DAM TOPOGRAPHY FOR VOLUME CHANGES.

SCALE (ft)

0 150

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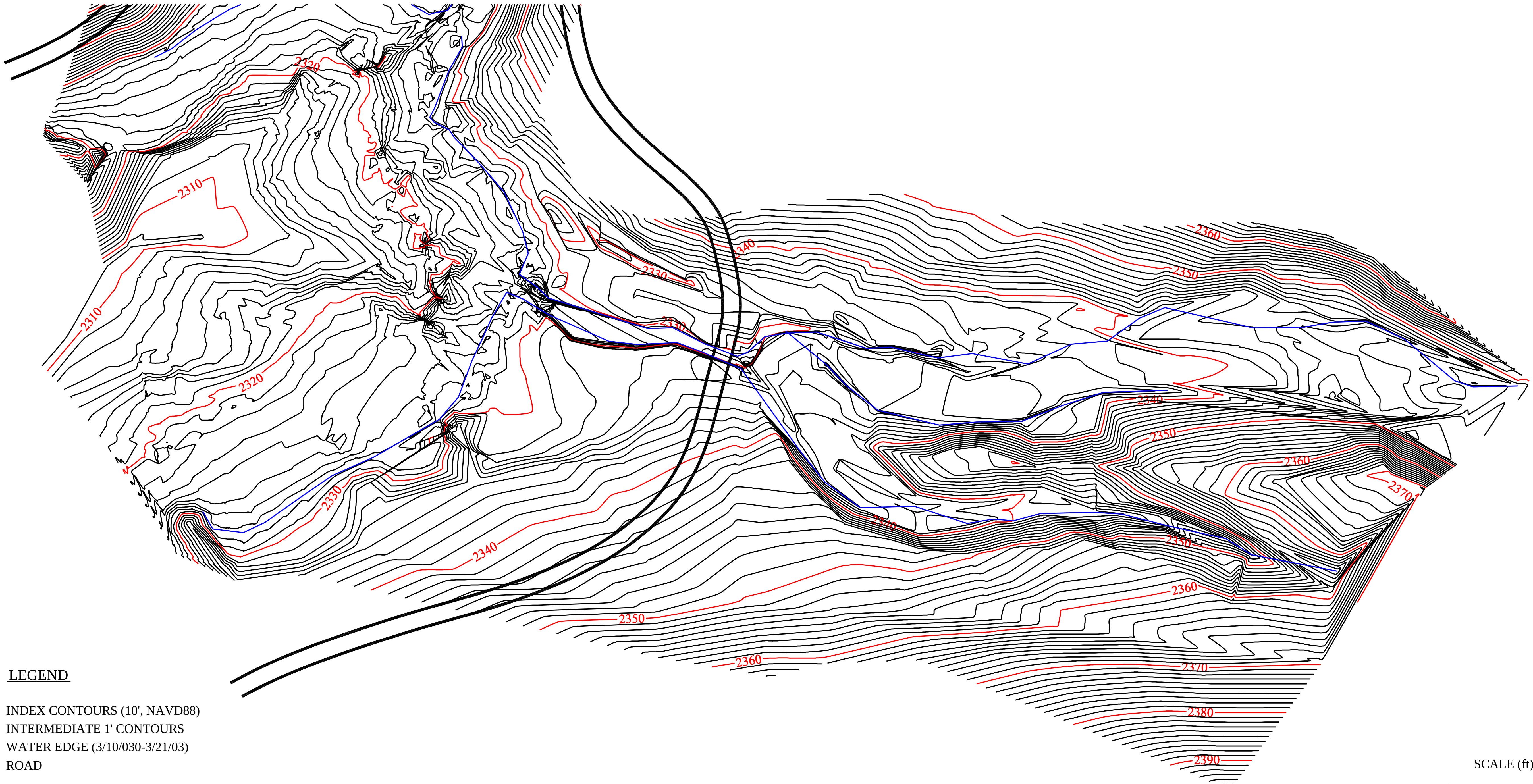
2003 TOPOGRAPHY - CAMP/DUTCH CREEK



LEGEND

INDEX CONTOURS (10', NAVD88)
INTERMEDIATE 1' CONTOURS
WATER EDGE (3/10/030-3/21/03)
ROAD

NOTE: TOPOGRAPHY REPRESENTS EXISTING CONDITIONS WITHOUT ROAD FILL IN ORDER TO BETTER COMPARE WITH PRE-DAM TOPOGRAPHY FOR VOLUME CHANGES.

SCALE (ft)
0 150

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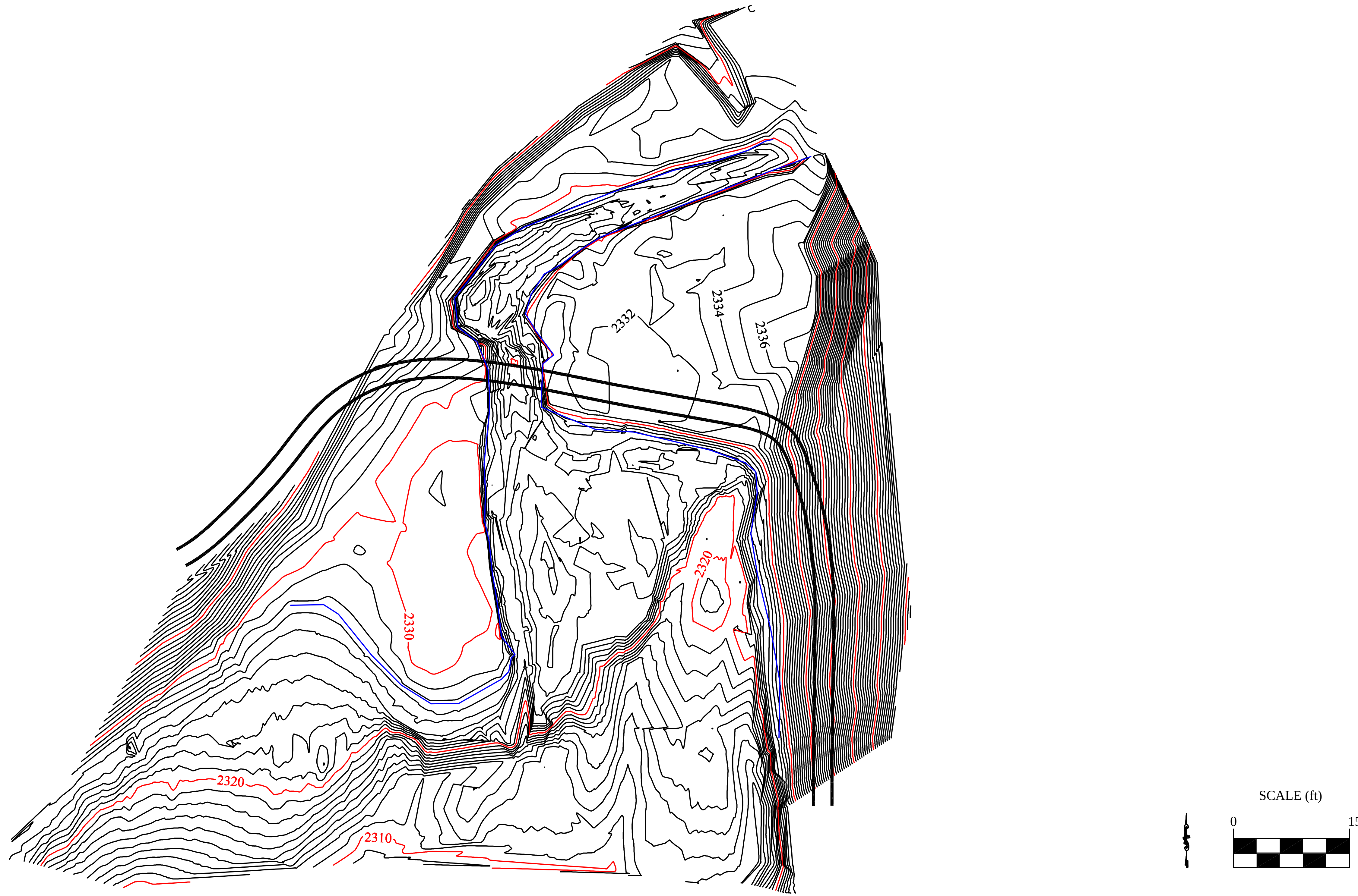
2003 TOPOGRAPHY - JENNY CREEK



LEGEND

INDEX CONTOURS (10', NAVD88)
INTERMEDIATE 1' CONTOURS
WATER EDGE (3/10/030-3/21/03)
ROAD

NOTE: TOPOGRAPHY REPRESENTS EXISTING CONDITIONS WITHOUT ROAD FILL IN ORDER TO BETTER COMPARE WITH PRE-DAM TOPOGRAPHY FOR VOLUME CHANGES.

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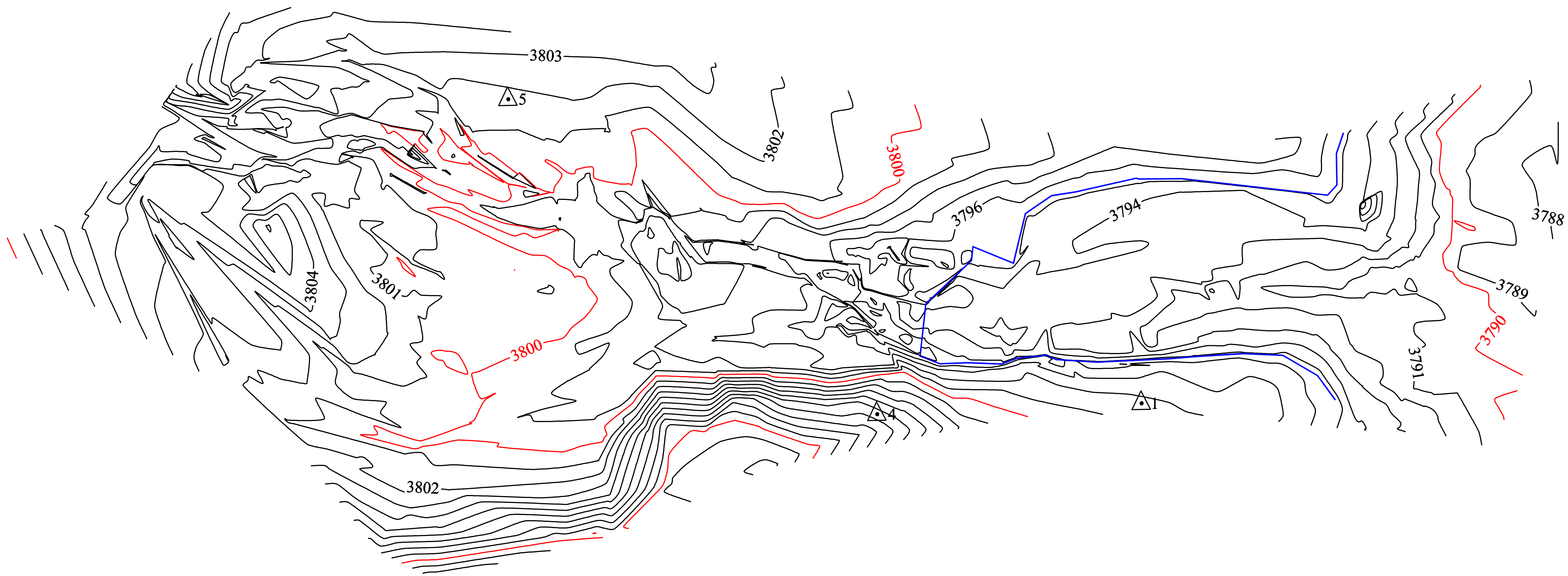
2003 TOPOGRAPHY - SPENCER CREEK



LEGEND

INDEX CONTOURS (5', NAVD88)
INTERMEDIATE 1' CONTOURS
WATER EDGE (3/30/03)
× 3900 PROBE POINTS WITH PRE-DAM ELE

NOTES: WATERLINE FROM 2003 MAPPING INCLUDED

SCALE (ft)
0 150

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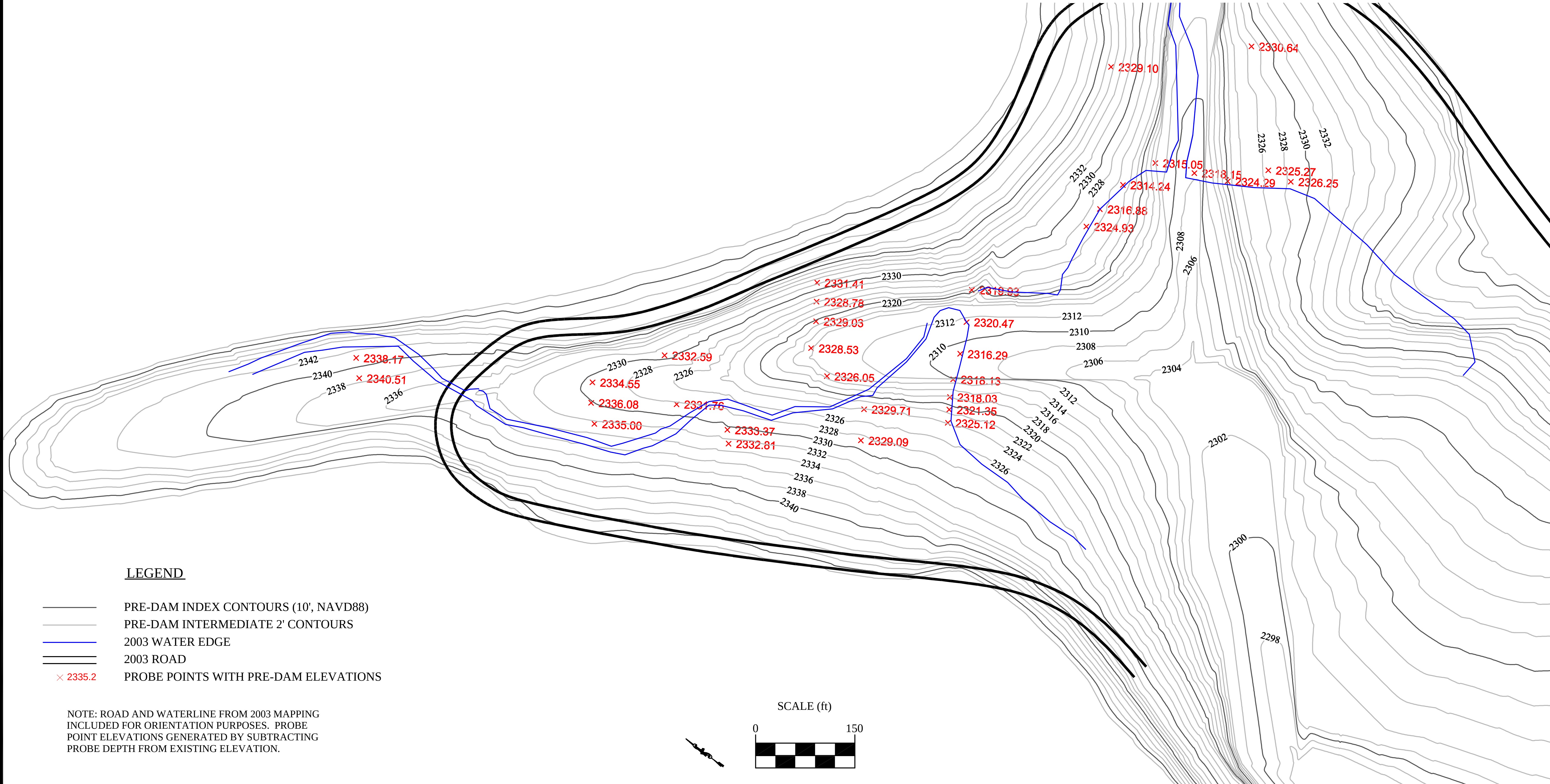
FIGURE
18

COMPARISON OF PRE-DAM TOPOGRAPHY WITH PROBING DATA - SCOTCH CREEK



LEGEND

—	PRE-DAM INDEX CONTOURS (10', NAVD88)
—	PRE-DAM INTERMEDIATE 2' CONTOURS
—	2003 WATER EDGE
=	2003 ROAD
× 2335.2	PROBE POINTS WITH PRE-DAM ELEVATIONS

NOTE: ROAD AND WATERLINE FROM 2003 MAPPING INCLUDED FOR ORIENTATION PURPOSES. PROBE POINT ELEVATIONS GENERATED BY SUBTRACTING PROBE DEPTH FROM EXISTING ELEVATION.

SCALE (ft)

0 150

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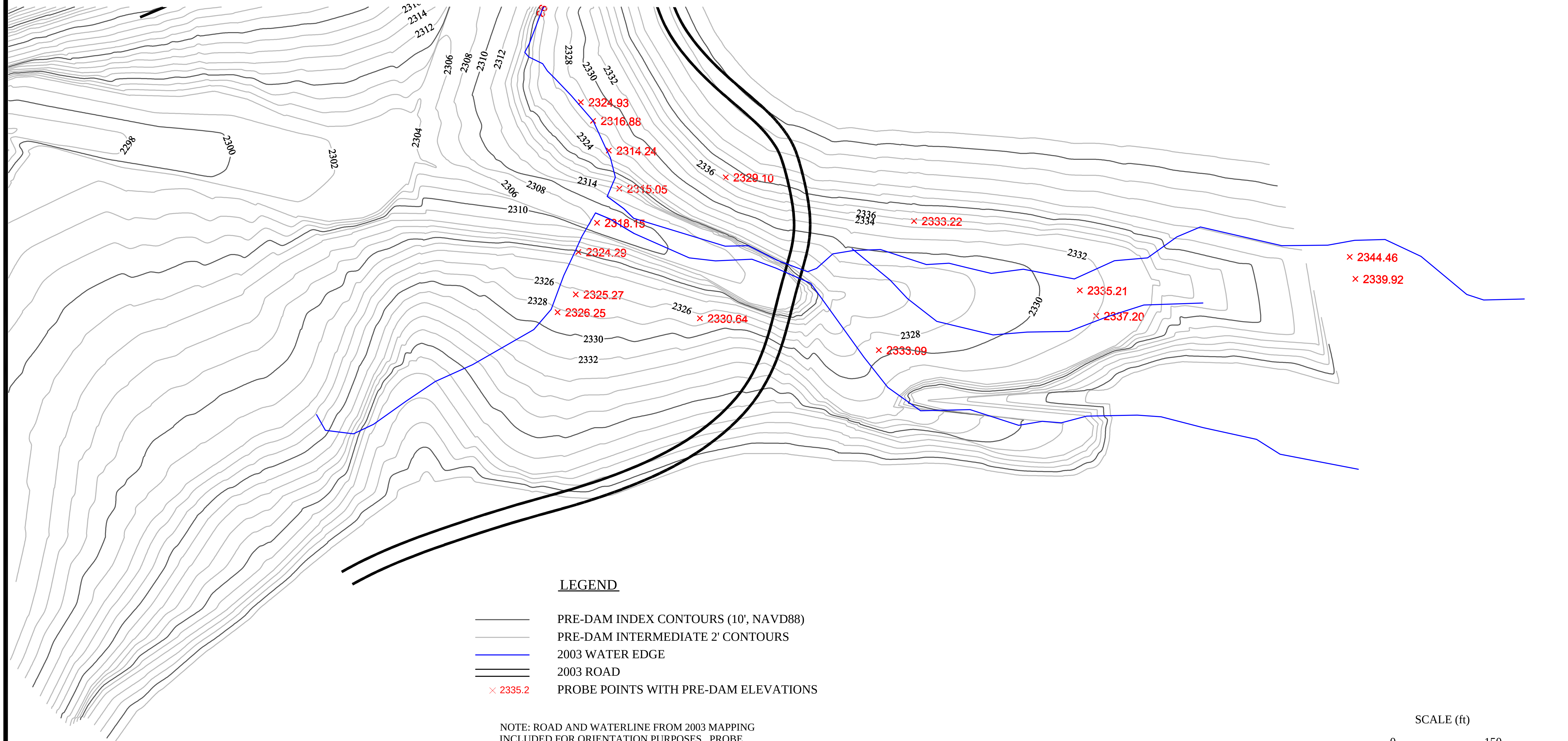
COMPARISON OF PRE-DAM TOPOGRAPHY WITH PROBING DATA - CAMP/DUTCH CREEKS



LEGEND

- PRE-DAM INDEX CONTOURS (10', NAVD88)
- PRE-DAM INTERMEDIATE 2' CONTOURS
- 2003 WATER EDGE
- 2003 ROAD
- × 2335.2 PROBE POINTS WITH PRE-DAM ELEVATIONS

NOTE: ROAD AND WATERLINE FROM 2003 MAPPING INCLUDED FOR ORIENTATION PURPOSES. PROBE POINT ELEVATIONS GENERATED BY SUBTRACTING PROBE DEPTH FROM EXISTING ELEVATION.

SCALE (ft)

0 150

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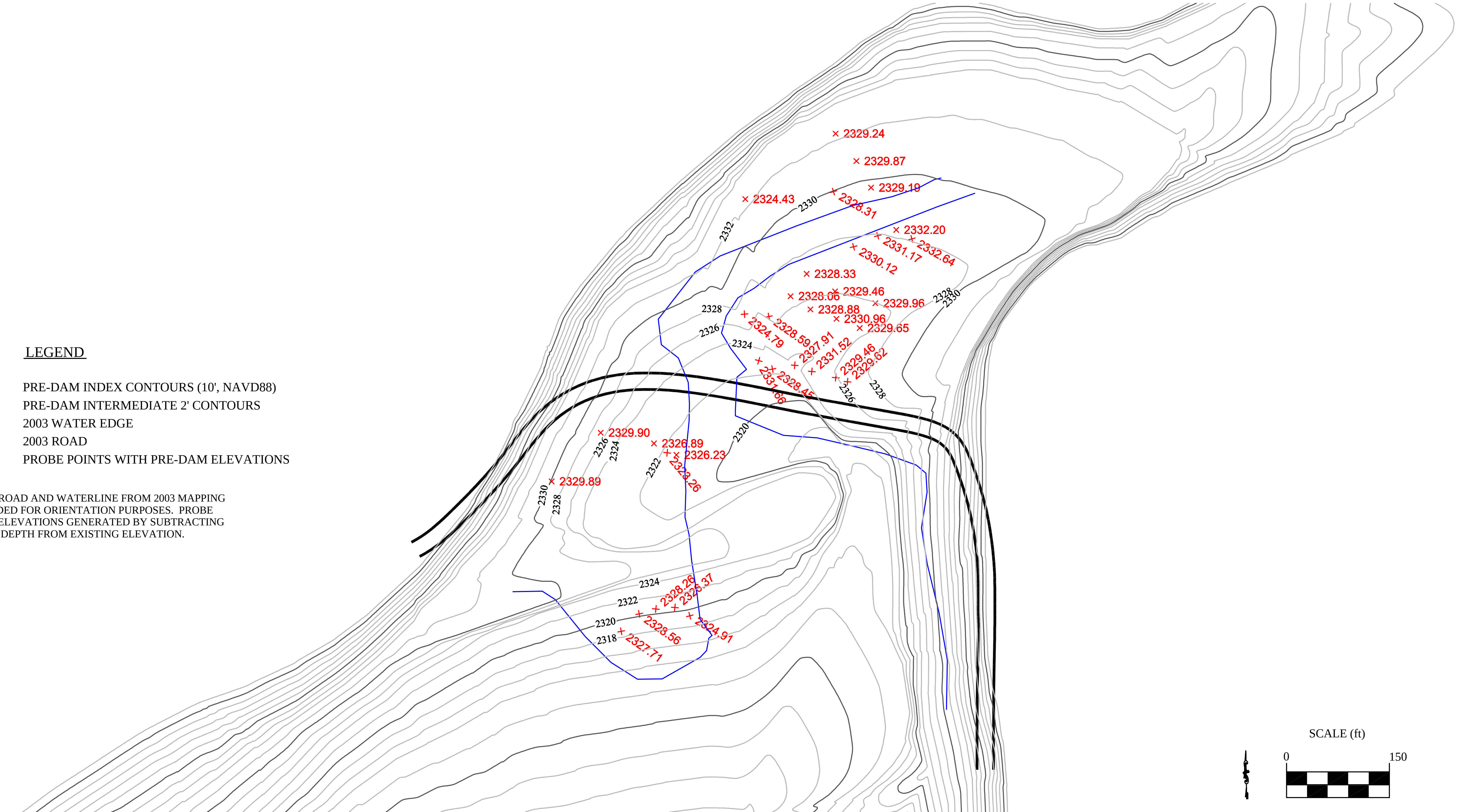
COMPARISON OF PRE-DAM TOPOGRAPHY WITH PROBING DATA - JENNY CREEK



LEGEND

PRE-DAM INDEX CONTOURS (10', NAVD88)
PRE-DAM INTERMEDIATE 2' CONTOURS
2003 WATER EDGE
2003 ROAD
× 2335.2 PROBE POINTS WITH PRE-DAM ELEVATIONS

NOTE: ROAD AND WATERLINE FROM 2003 MAPPING INCLUDED FOR ORIENTATION PURPOSES. PROBE POINT ELEVATIONS GENERATED BY SUBTRACTING PROBE DEPTH FROM EXISTING ELEVATION.

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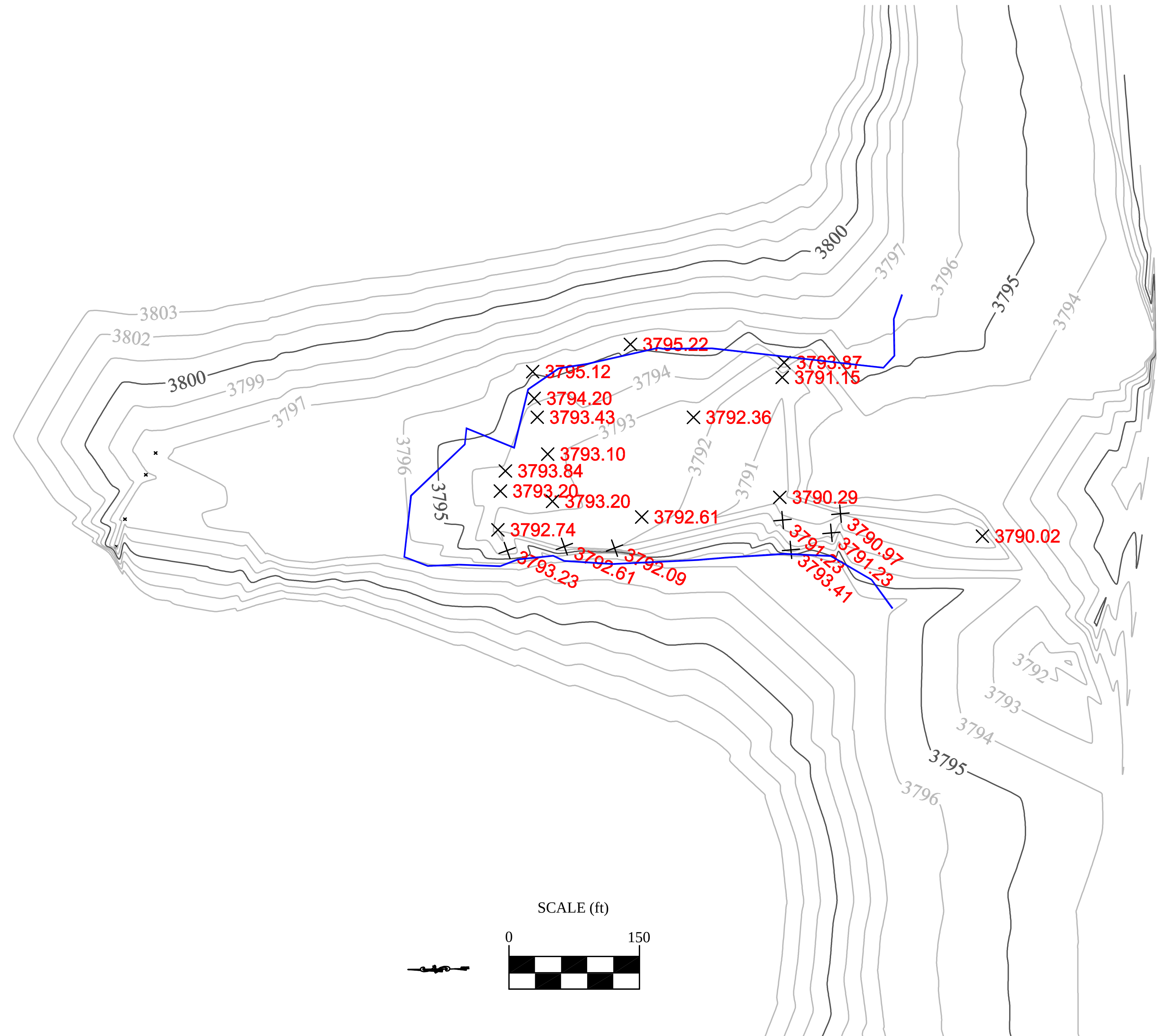
COMPARISON OF PRE-DAM TOPOGRAPHY WITH PROBING DATA - SPENCER CREEK



LEGEND

INDEX CONTOURS (5', NAVD88)
INTERMEDIATE 1' CONTOURS
WATER EDGE (3/30/03)
× 3900 PROBE POINTS WITH PRE-DAM ELEVATIONS

NOTES: WATERLINE FROM 2003 MAPPING INCLUDED FOR ORIENTATION PURPOSES. PROBE POINT ELEVATIONS GENERATED BY SUBTRACTING PROBE DEPTH FROM EXISTING ELEVATION. TOPOGRAPHIC SURFACE GENERATED FROM 10' HISTORIC CONTOURS AND PROBE POINTS TO IMPROVE RESOLUTION.

SCALE (ft)
0 150

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SUBSTRATE SAMPLING SITE MAP - SCOTCH CREEK

LEGEND

INDEX CONTOURS (10', NAVD88)
INTERMEDIATE 1' CONTOURS
WATER EDGE (3/10/030-3/21/03)
ROAD
JC3 SUBSTRATE SAMPLE SITES

SCALE (ft)
0 150

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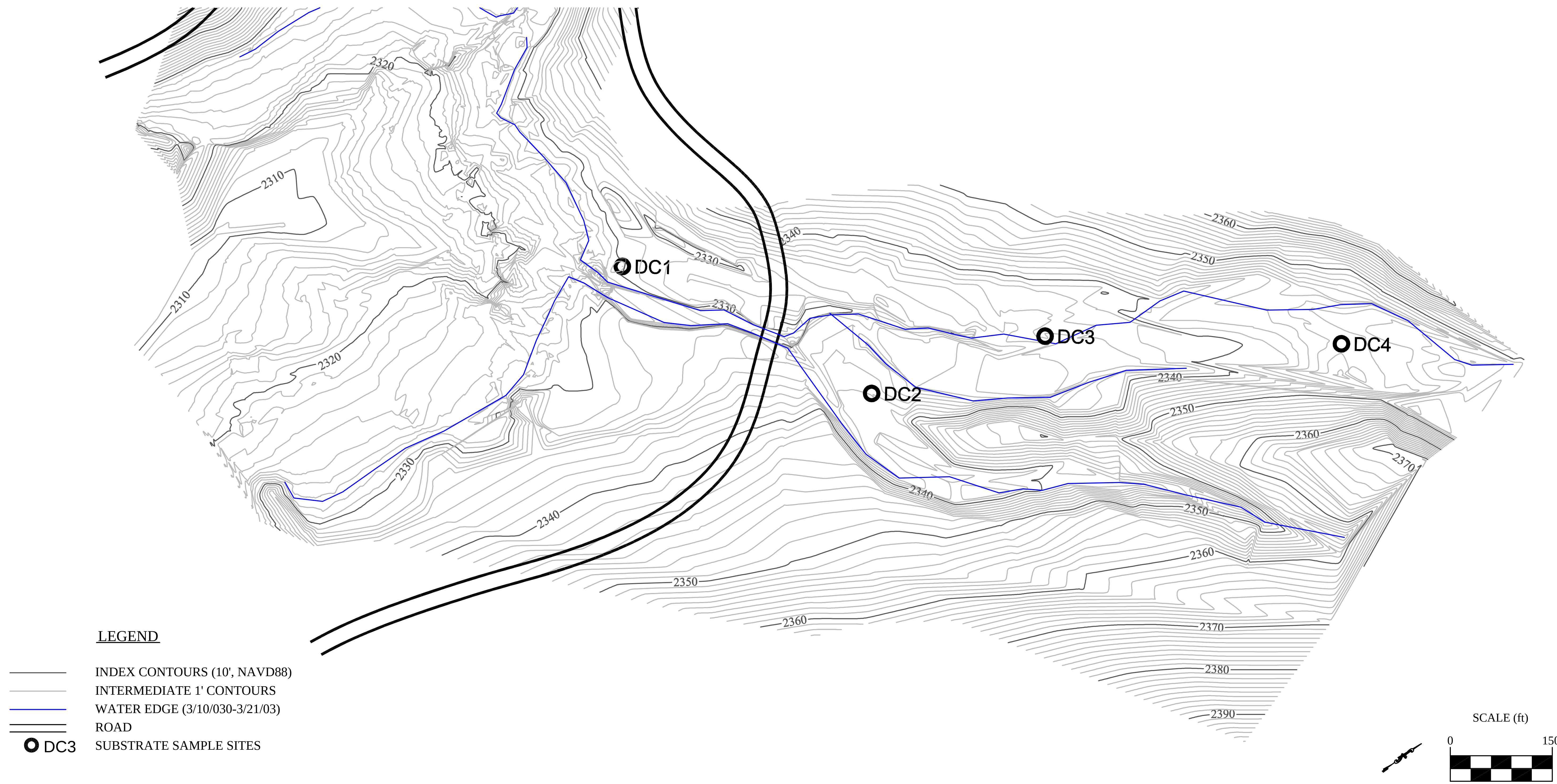
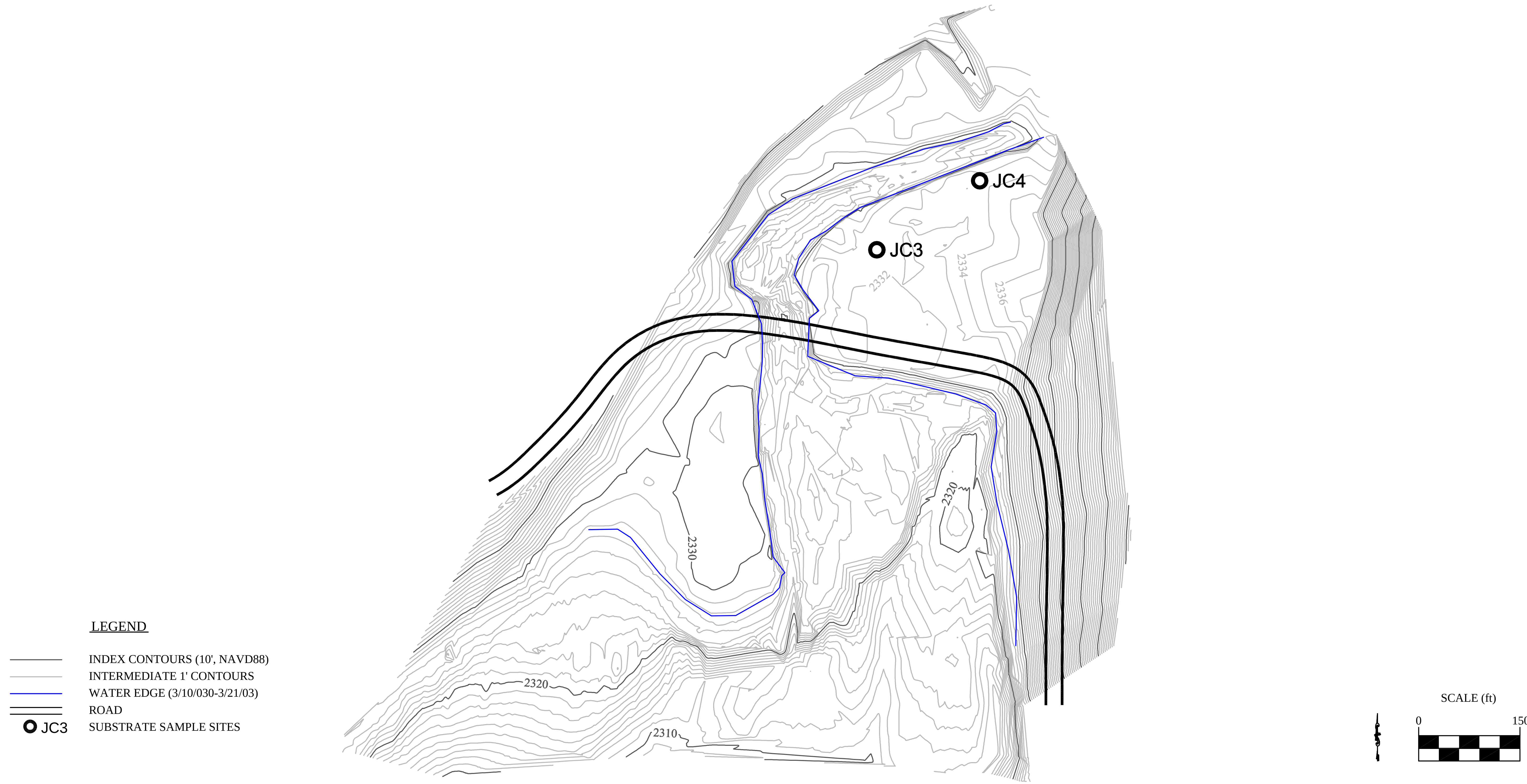
SUBSTRATE SAMPLING SITE MAP - CAMP/DUTCH CREEK



RESERVOIR TRIBUTARY DELTAS SURVEY PROJECT	KLAMATH HYDROELECTRIC PROJECT	GMA GRAHAM MATTHEWS & ASSOCIATES Hydrology · Geomorphology · Stream Restoration P.O. Box 1516 Weaverville, CA 96093-1516 (530) 623-5327 ph (530) 623-5328 fax	FIGURE 24

SUBSTRATE SAMPLING SITE MAP - JENNY CREEK



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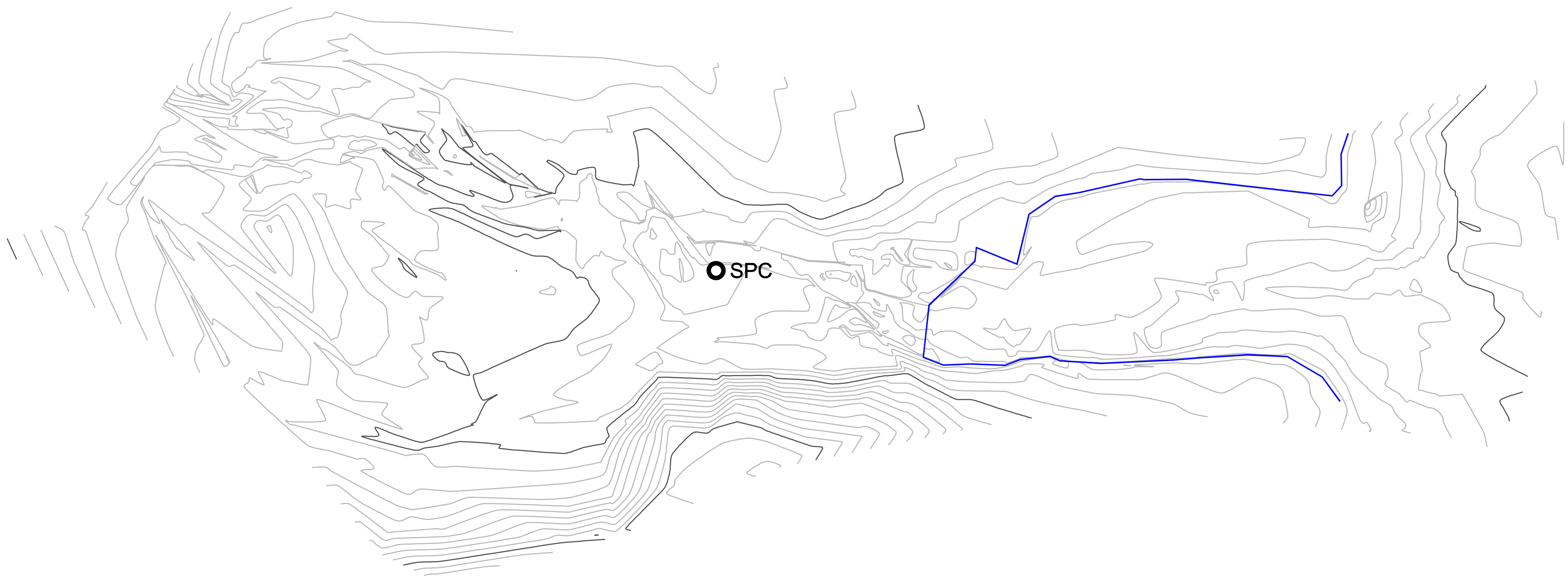
SUBSTRATE SAMPLING SITE MAP
SPENCER CREEK



LEGEND

INDEX CONTOURS (10', NAVD88)
INTERMEDIATE 1' CONTOURS
WATER EDGE (3/10/030-3/21/03)
SPC SUBSTRATE SAMPLE SITES

SCALE (ft)
0 150

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PHOTOGRAPHS OF SUBSTRATE SAMPLE PITS - SCOTCH AND JENNY CREEKS

SCOTCH CREEK


SC1


SC2


SC3


SC4

JENNY CREEK


JC3


JC4

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FIGURE 27

PHOTOGRAPHS OF SUBSTRATE SAMPLE PITS - CAMP/DUTCH AND SPENCER CREEKS

CAMP/DUTCH CREEK


DC1


DC2


DC3


DC4

SPENCER CREEK


SPC

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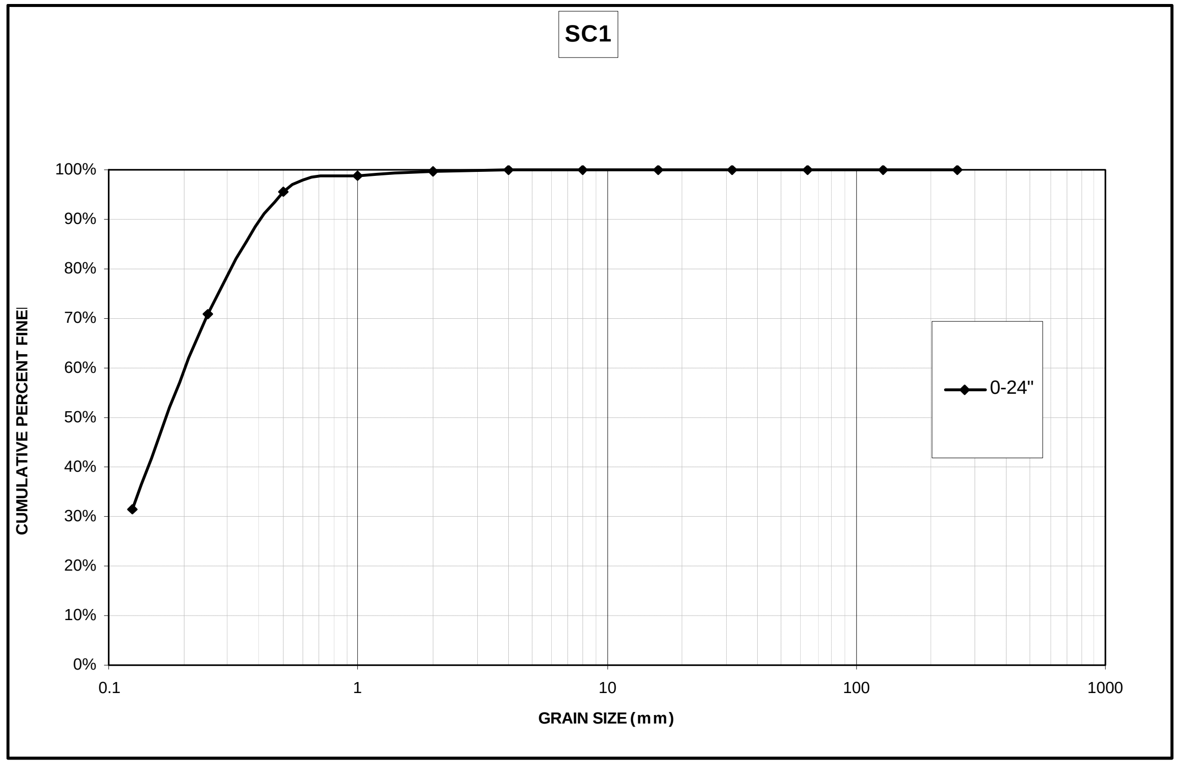
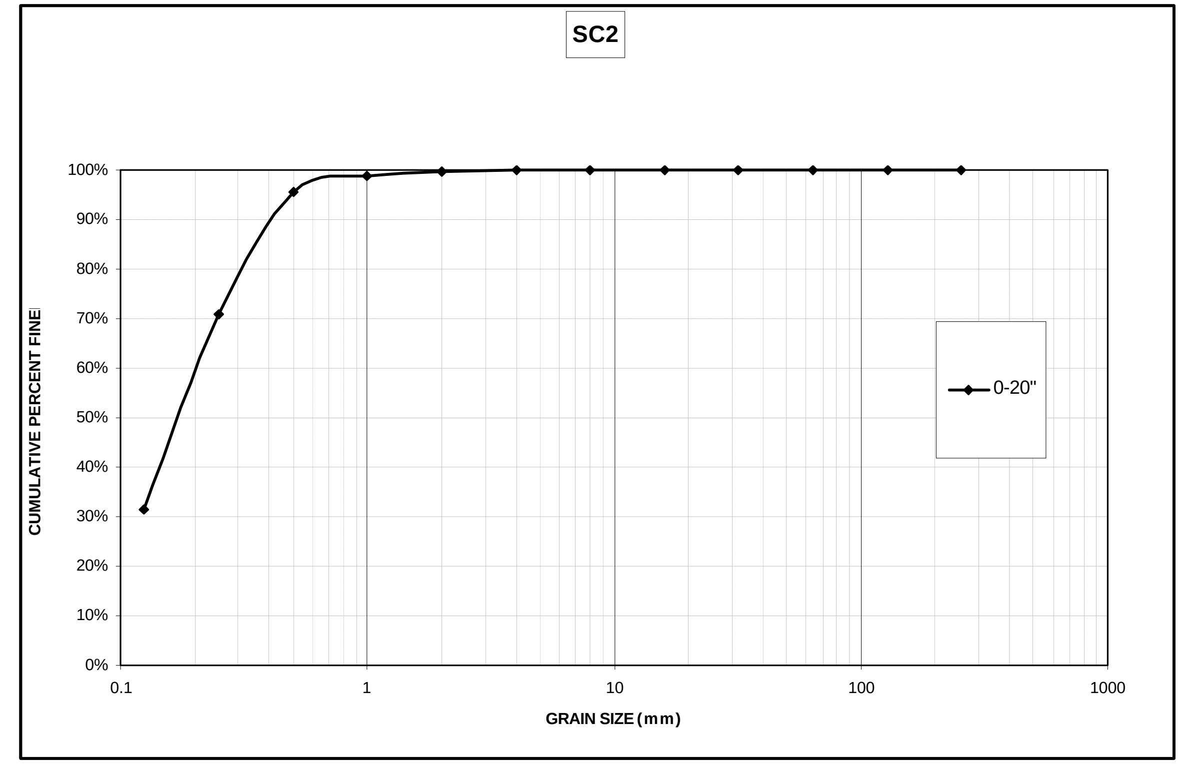
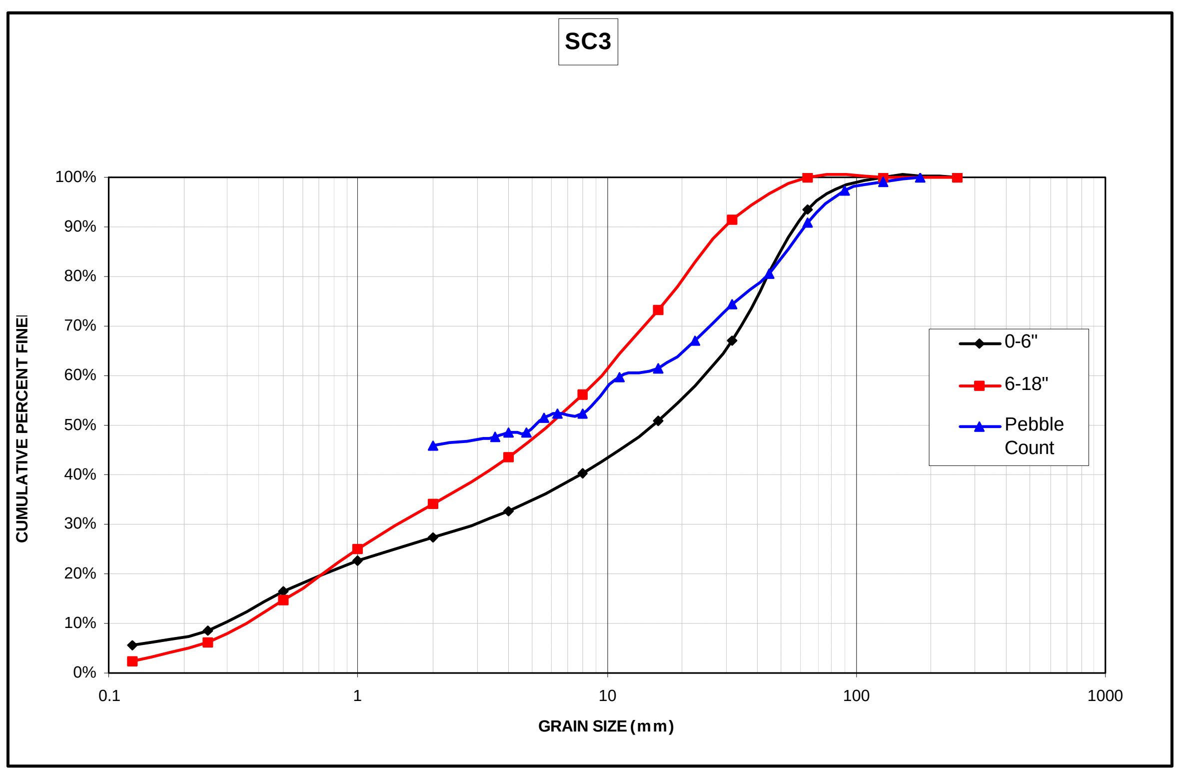
FIGURE 28

SUSBSTRATE SIZE DISTRIBUTION - SCOTCH CREEK







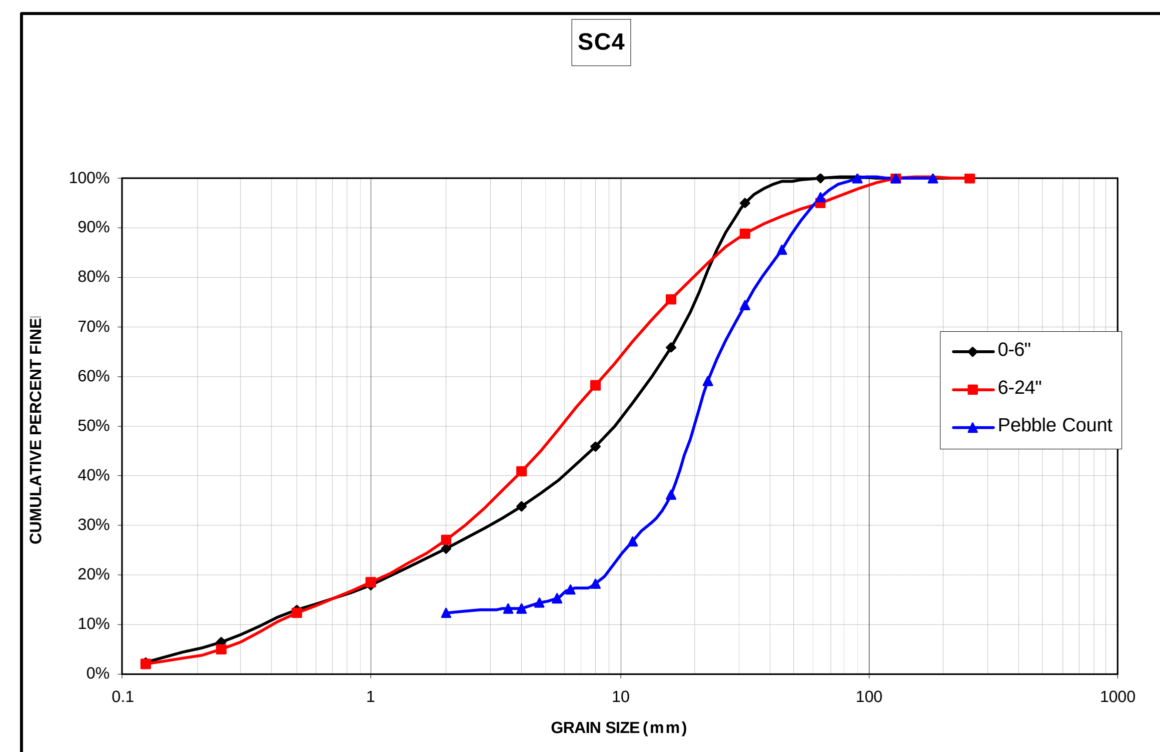


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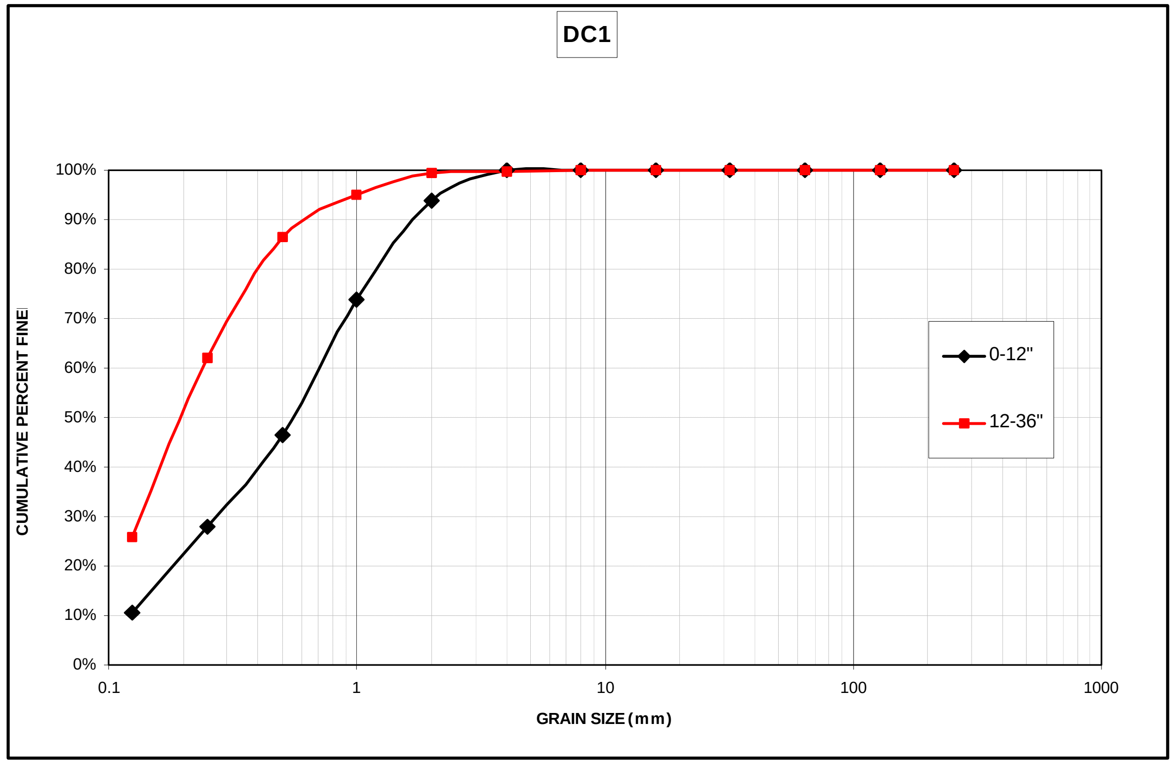
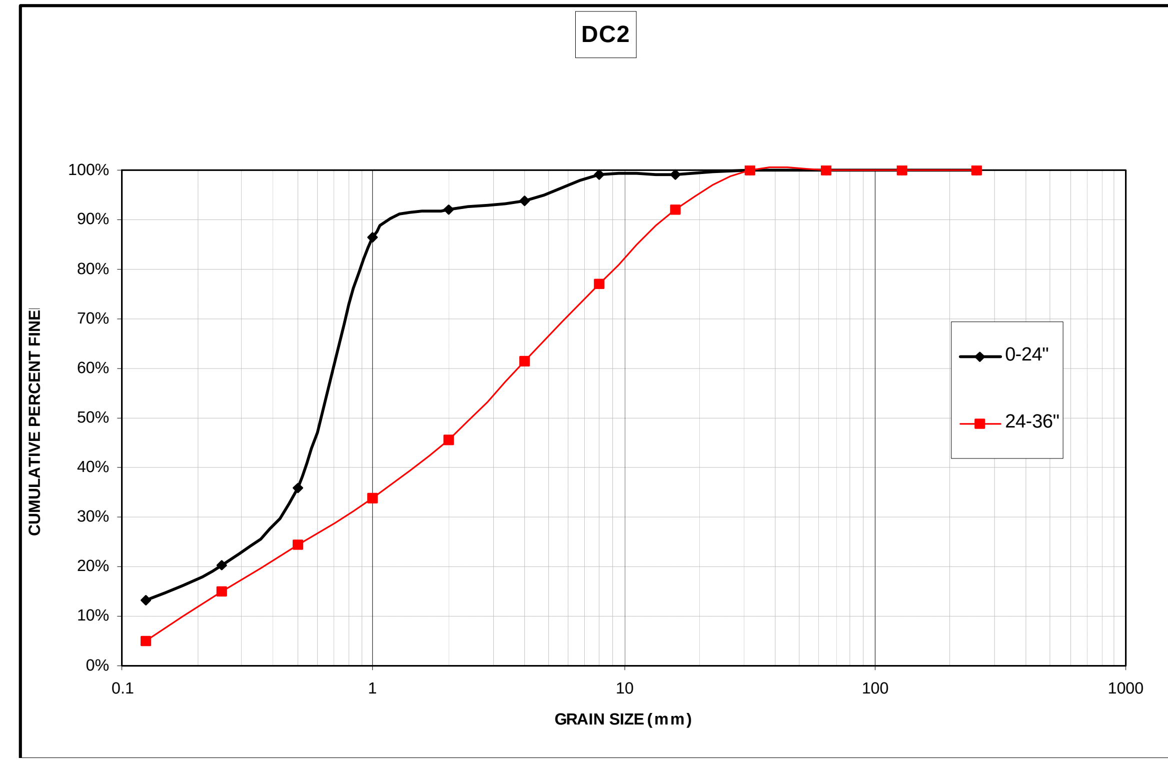
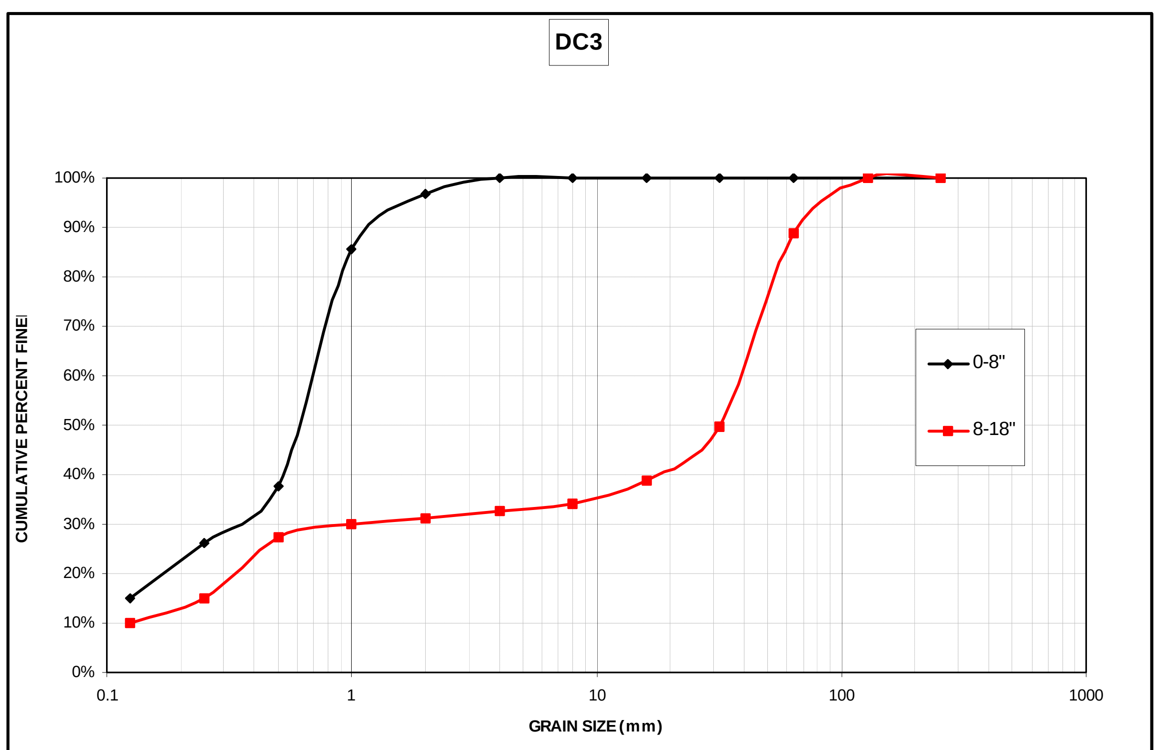
FIGURE 29

SUSBSTRATE SIZE DISTRIBUTION - CAMP/DUTCH CREEK







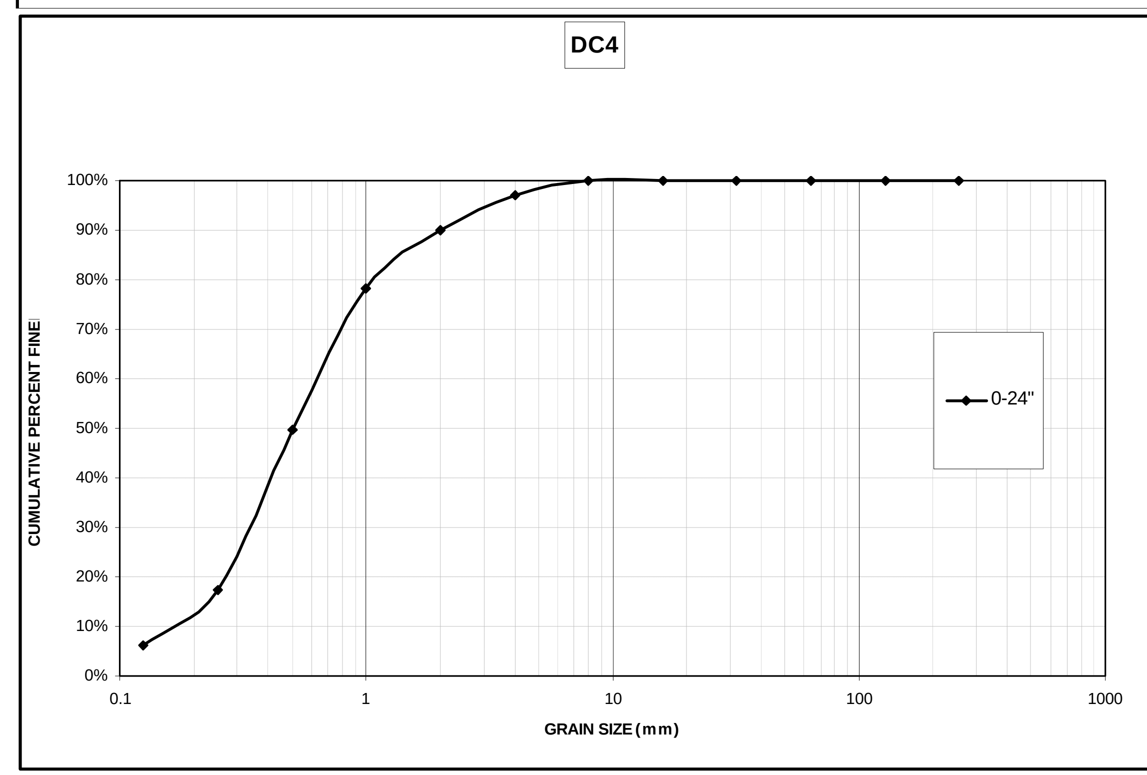


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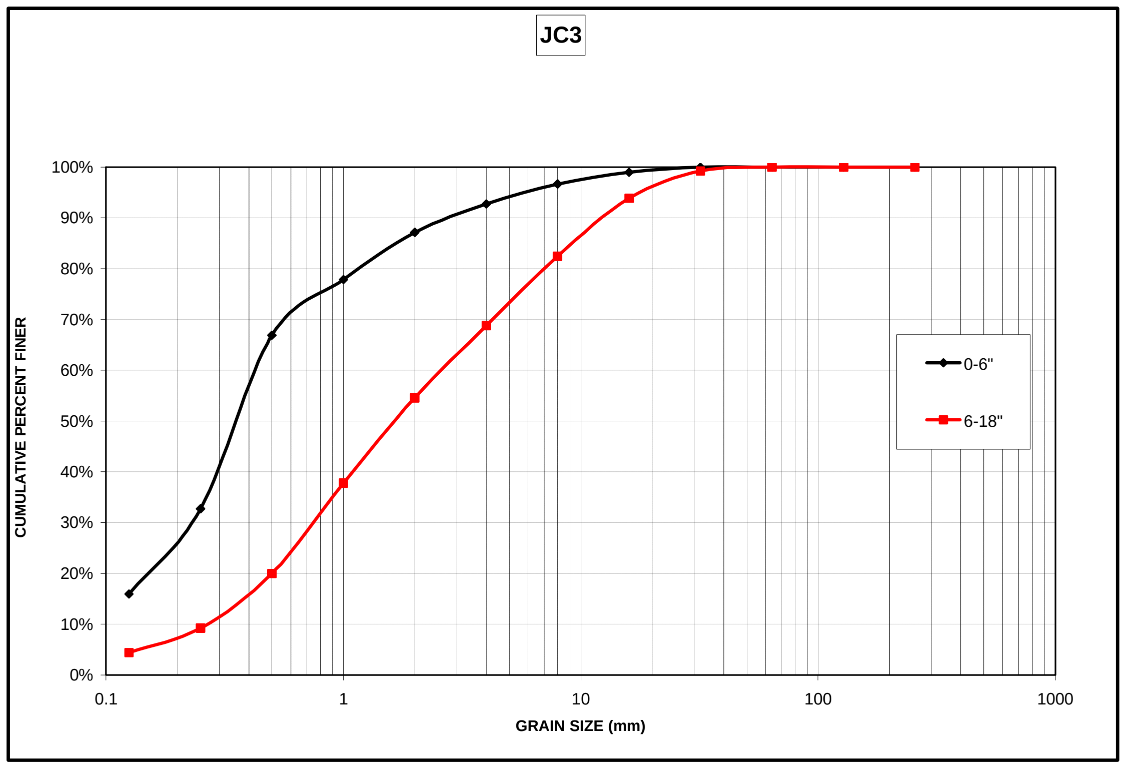
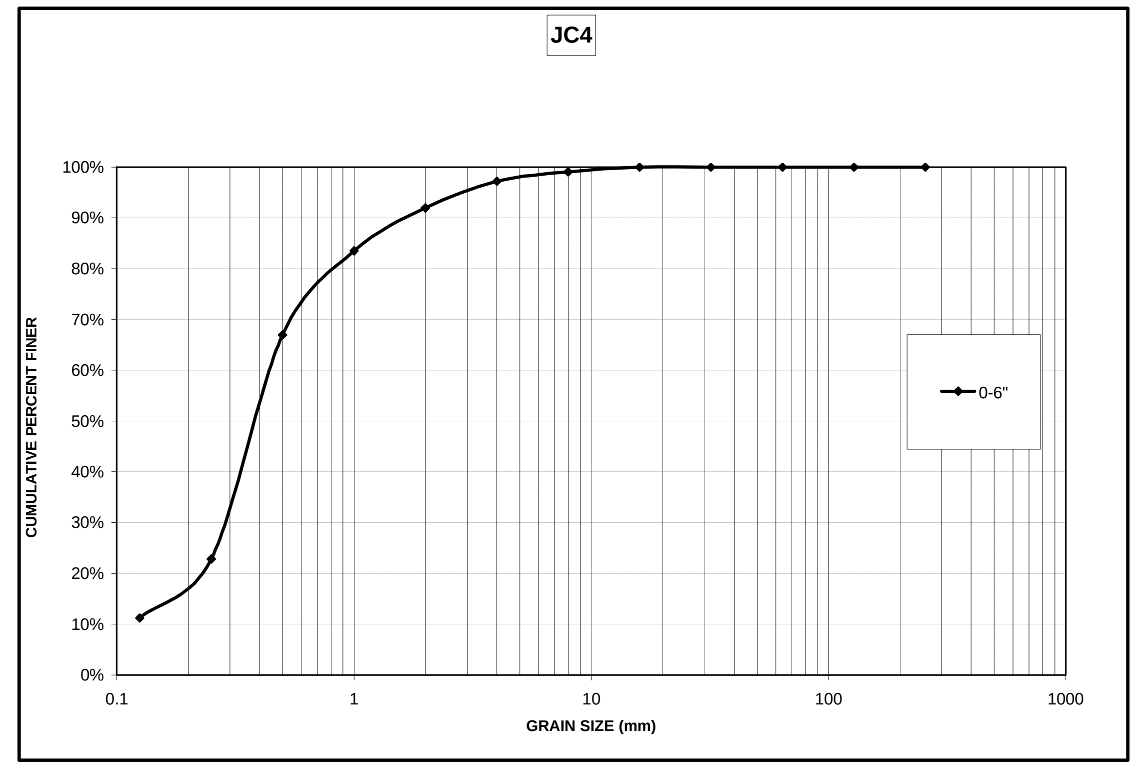
FIGURE 30

SUSBSTRATE SIZE DISTRIBUTION - JENNY CREEK





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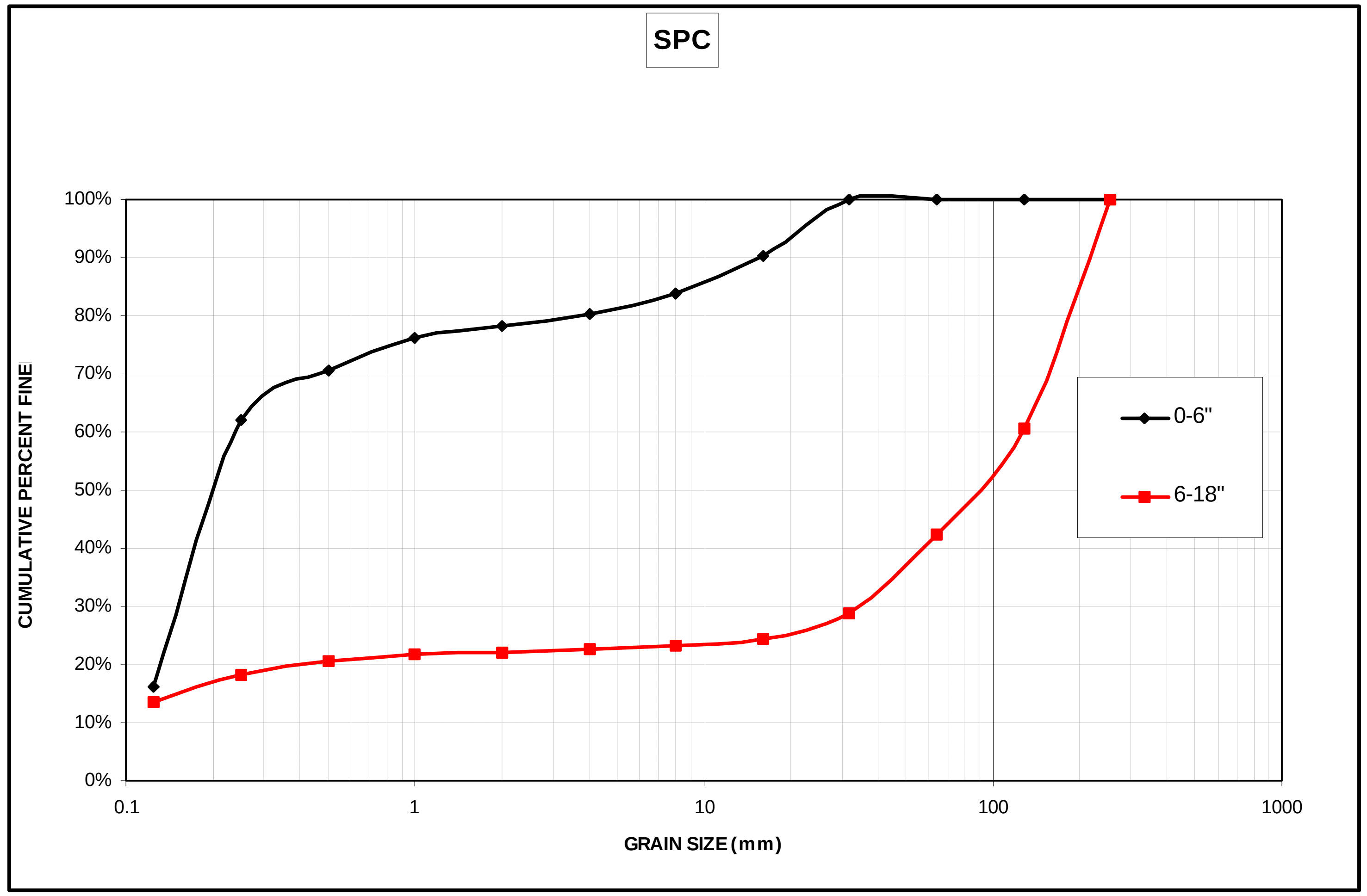
SUSBSTRATE SIZE DISTRIBUTION - SPENCER CREEK



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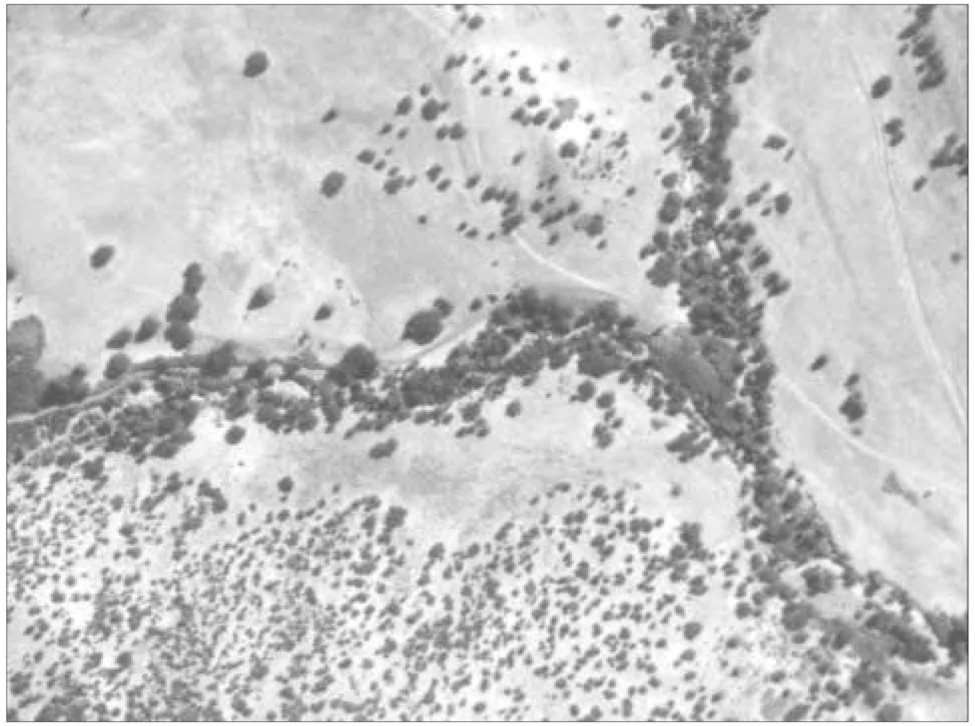
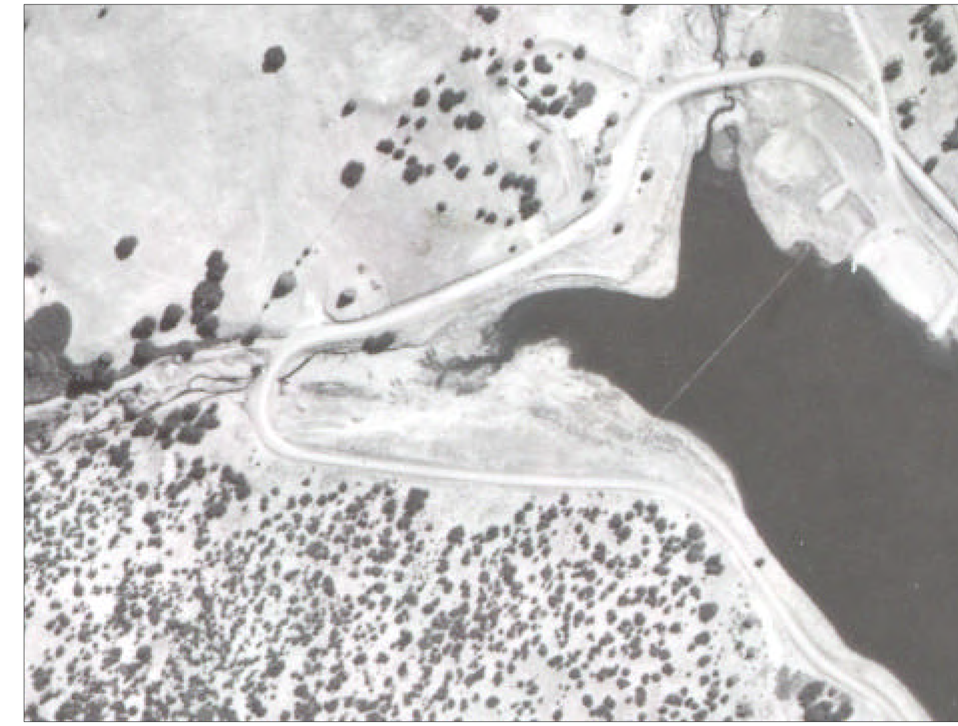
DELTA CHANGES OVER TIME
SCOTCH CREEK

SCALE (ft)
0 450

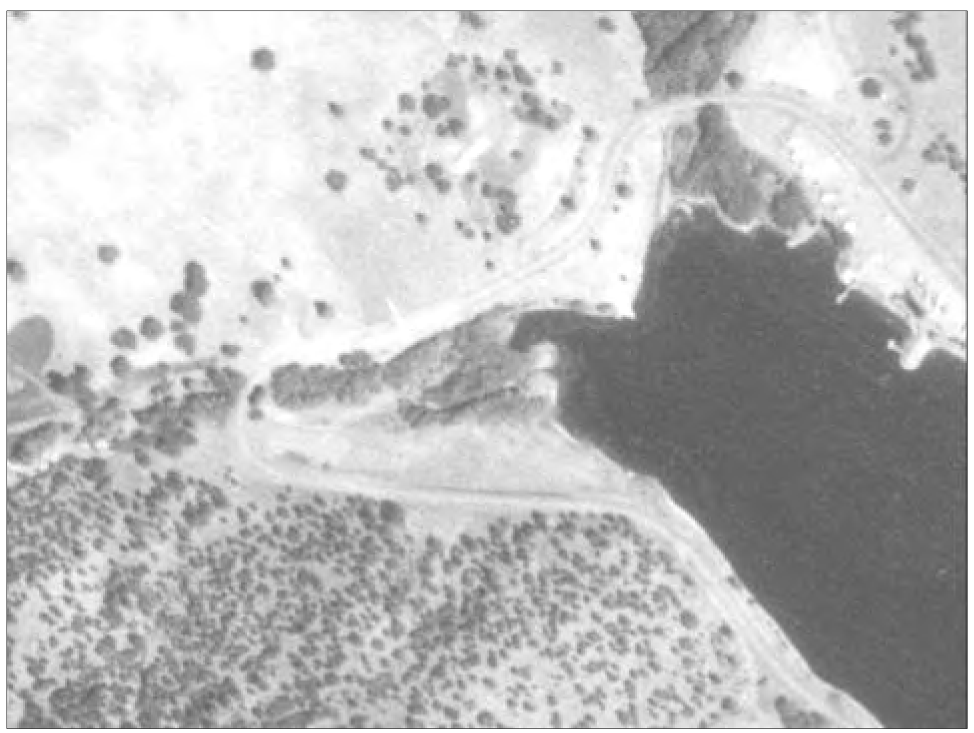


1955

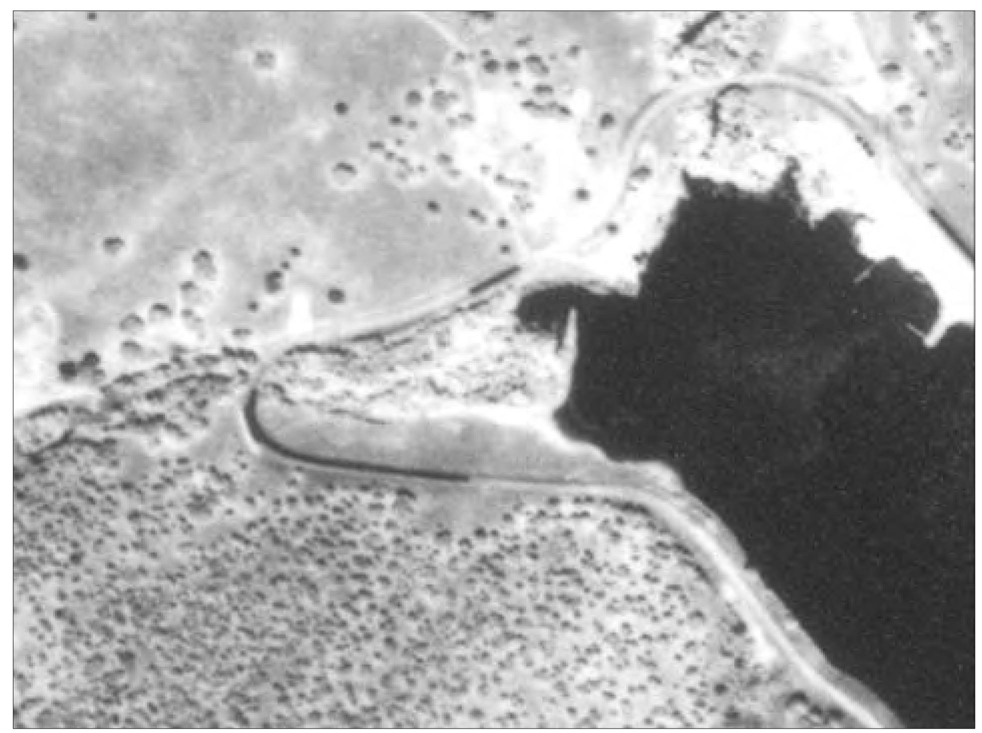
1963



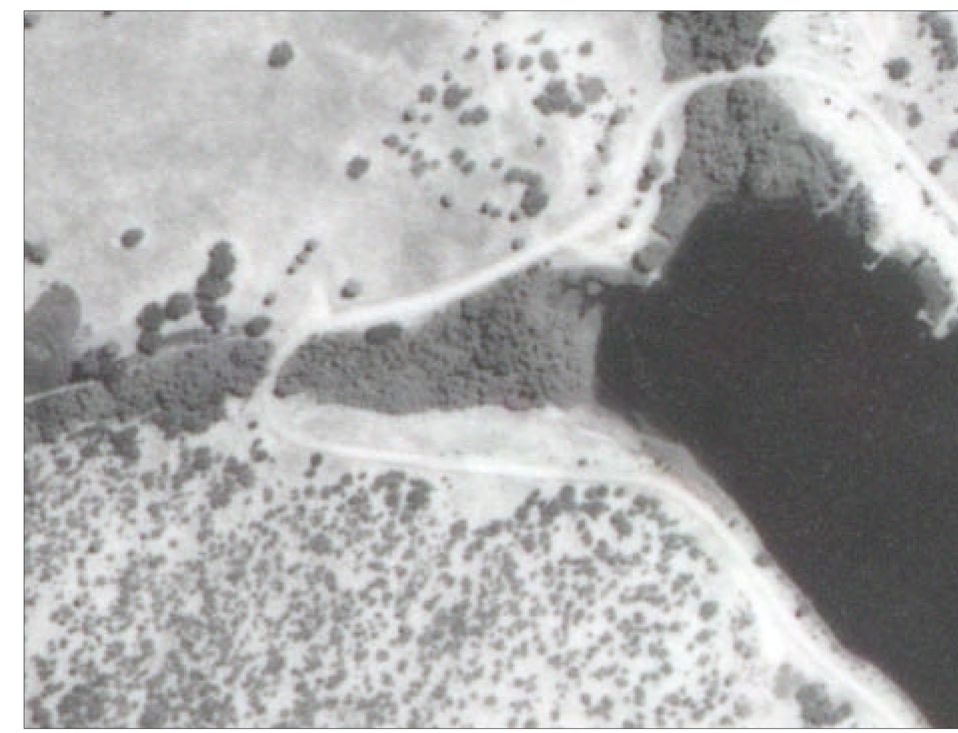
1965



1979



1989



2001

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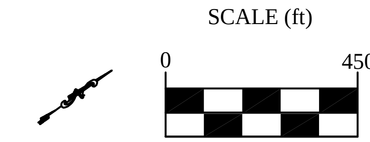
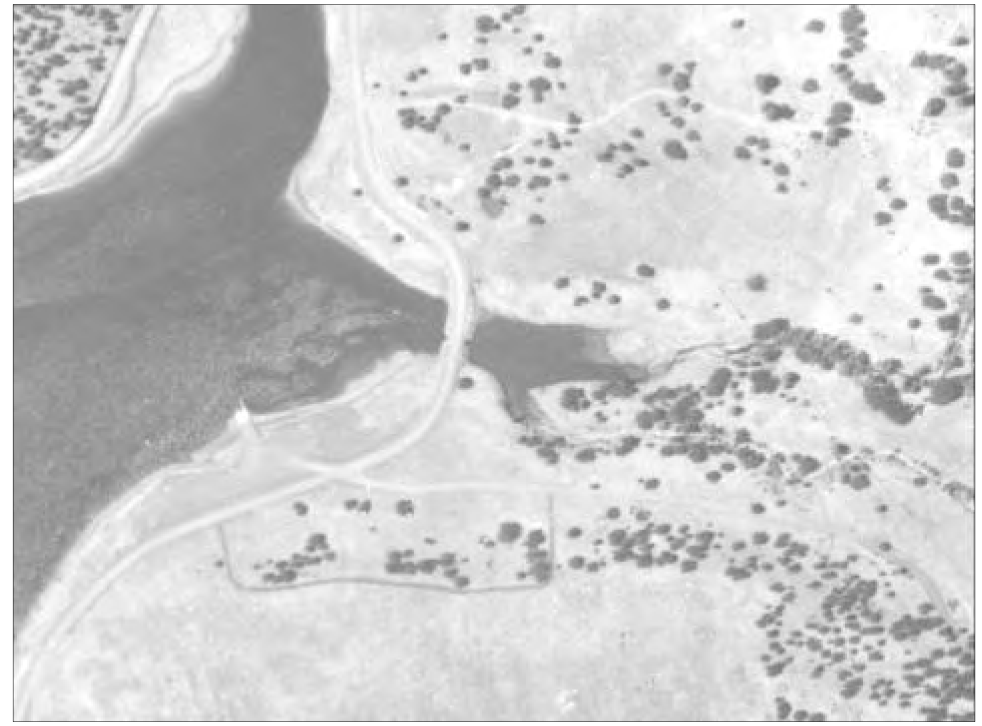
FIGURE 33

DELTA CHANGES OVER TIME
CAMP/DUTCH CREEKS

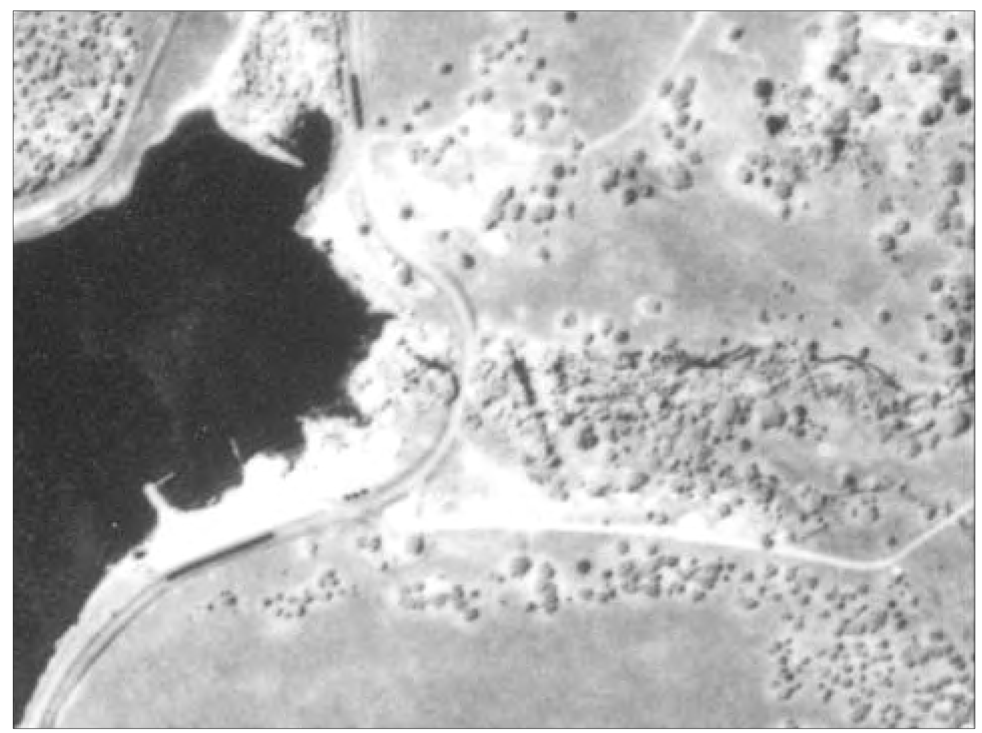


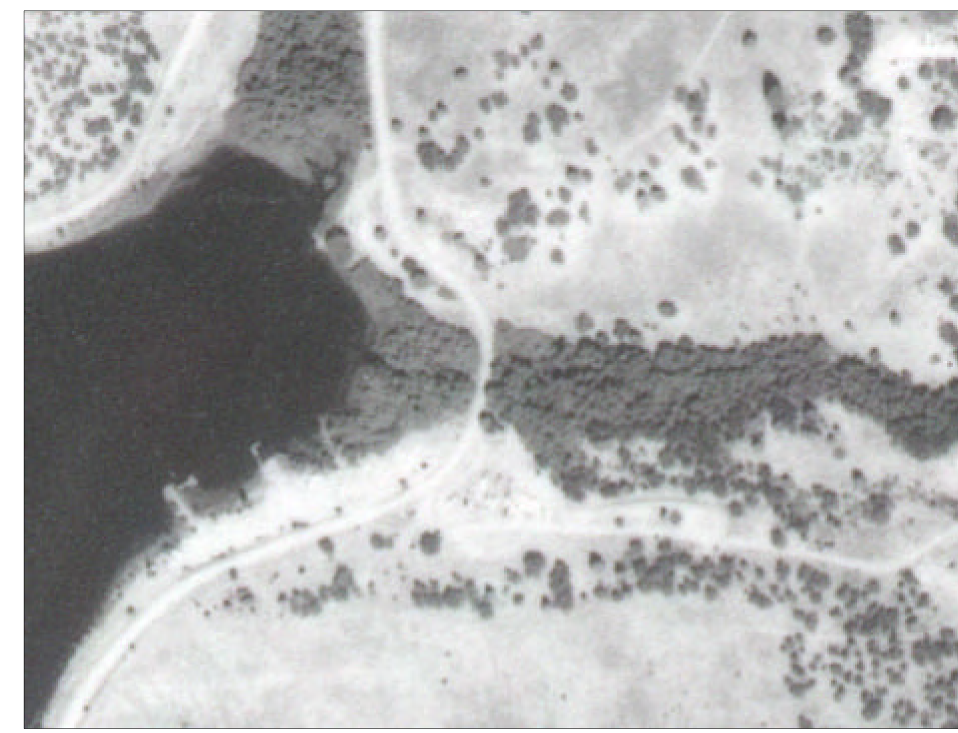

1955


1963


1965


1979


1989


2001

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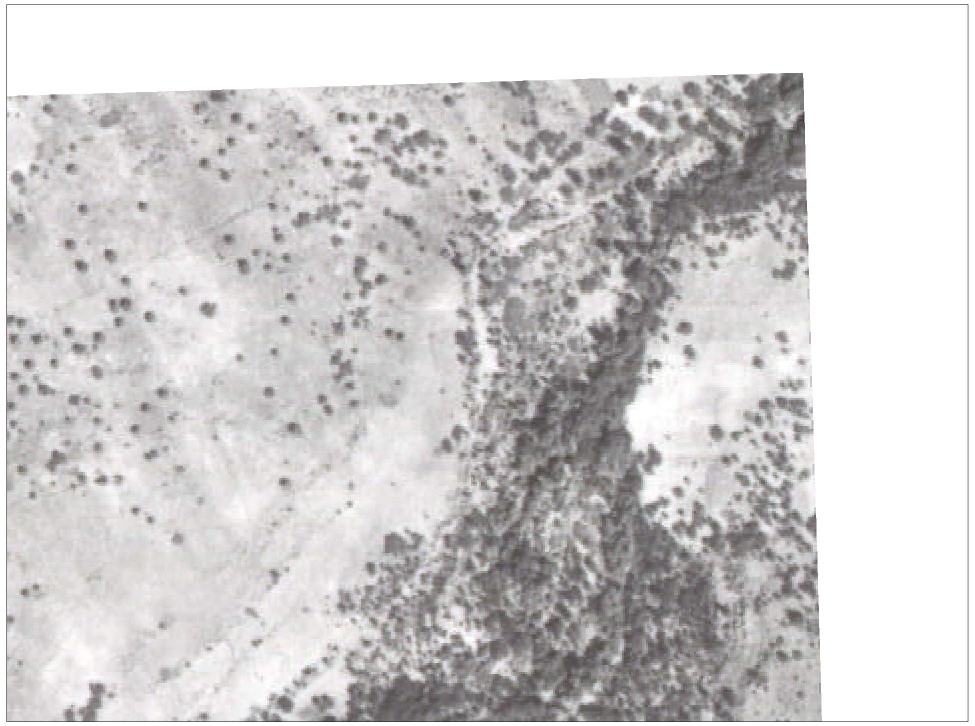
DELTA CHANGES OVER TIME
JENNY CREEK

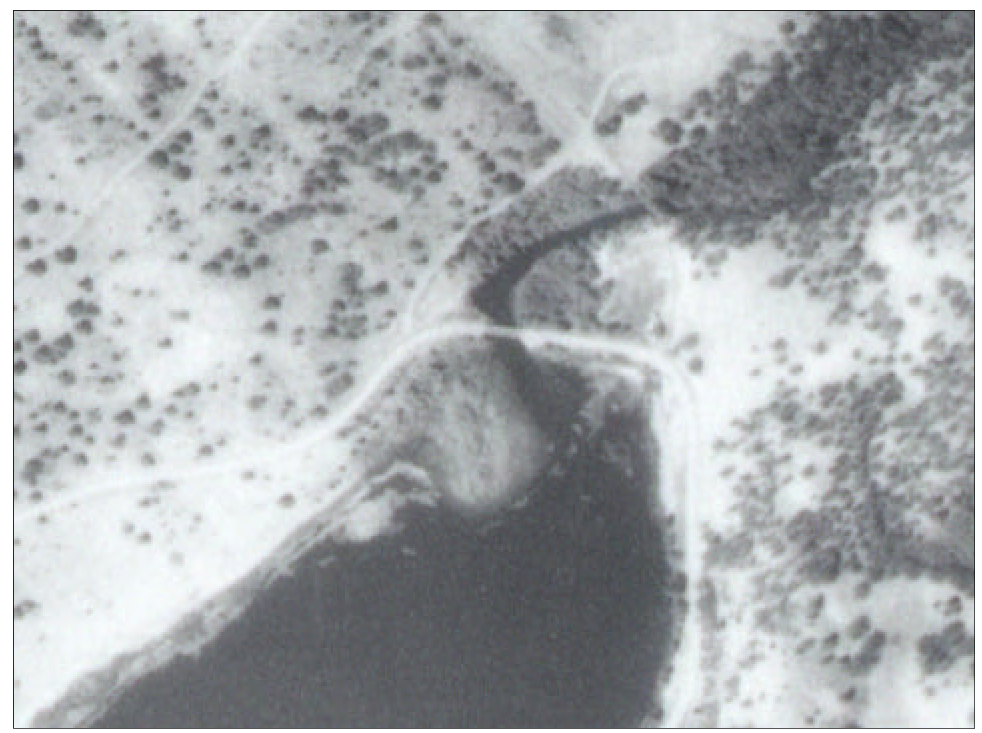
SCALE (ft)
0 450


1955


1963


1965


1979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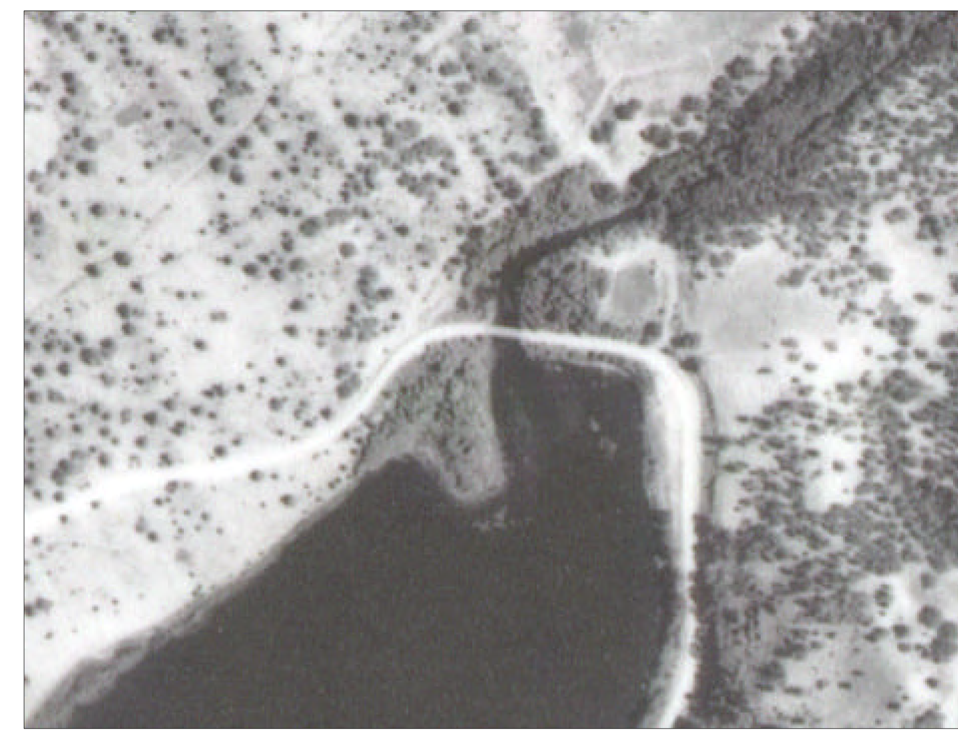
2001

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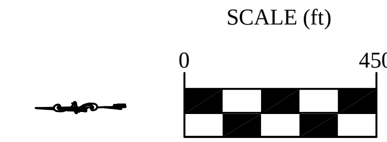
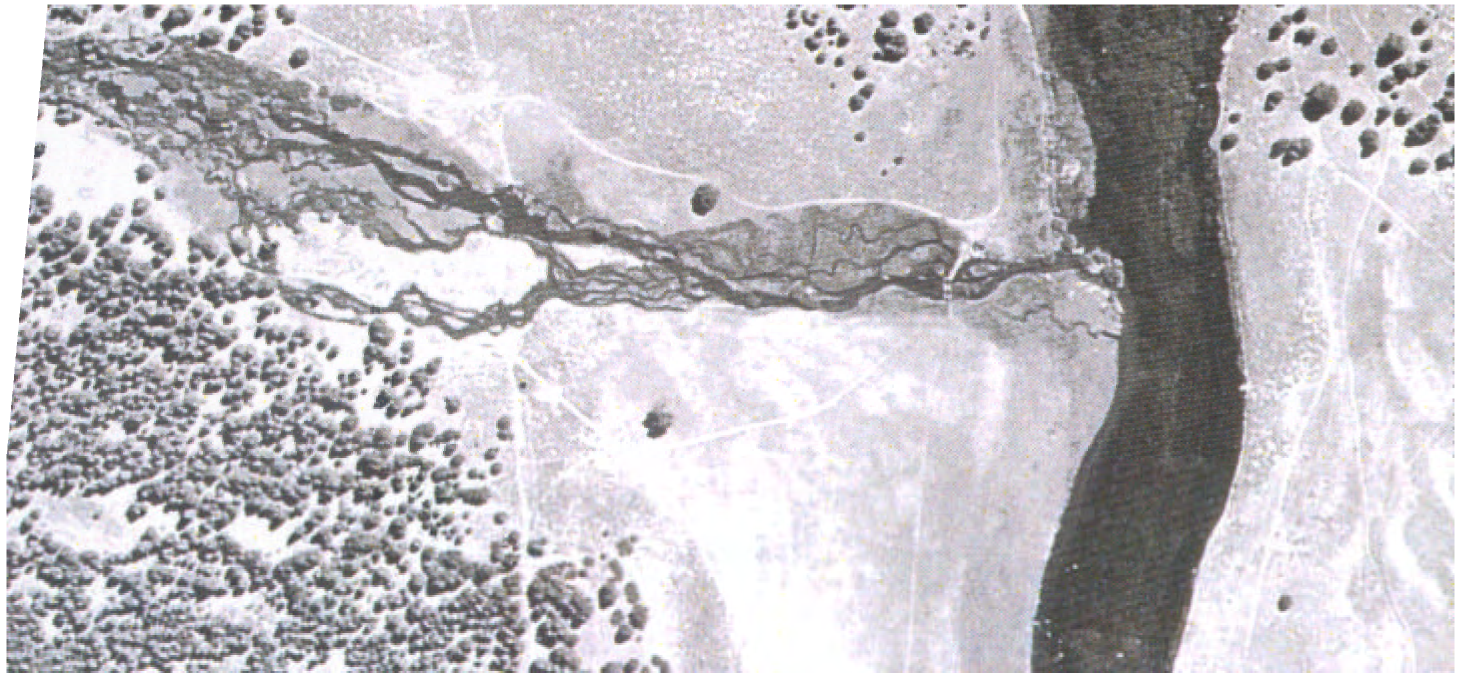
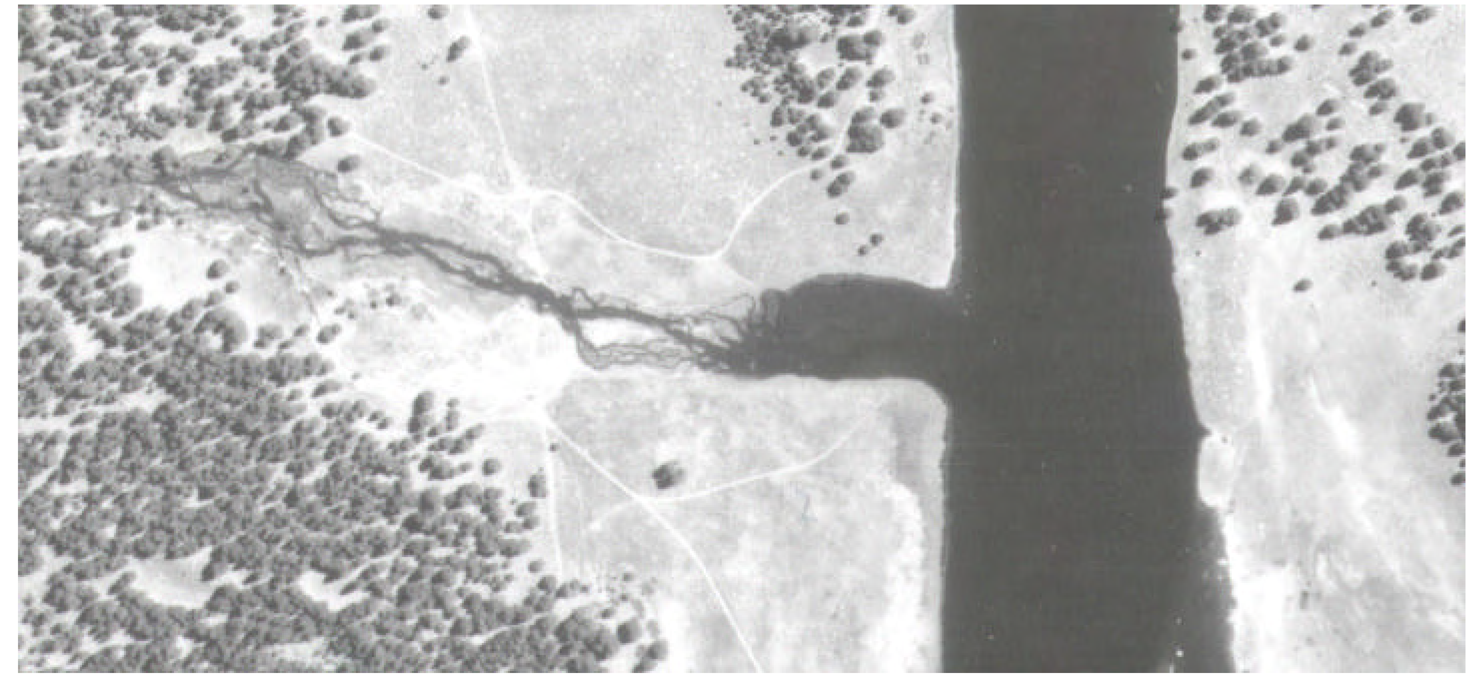
FIGURE 35

DELTA CHANGES OVER TIME
SPENCER CREEK



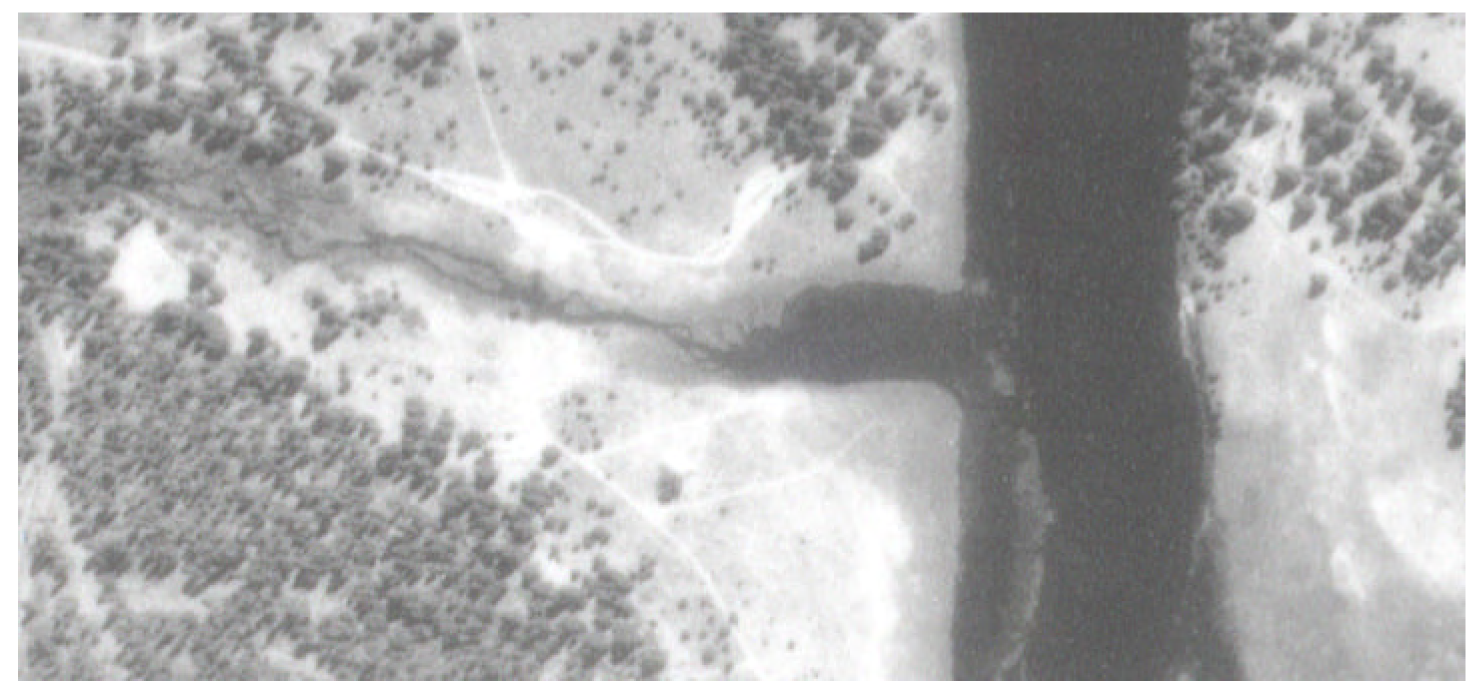


1952



1968

1994



2000

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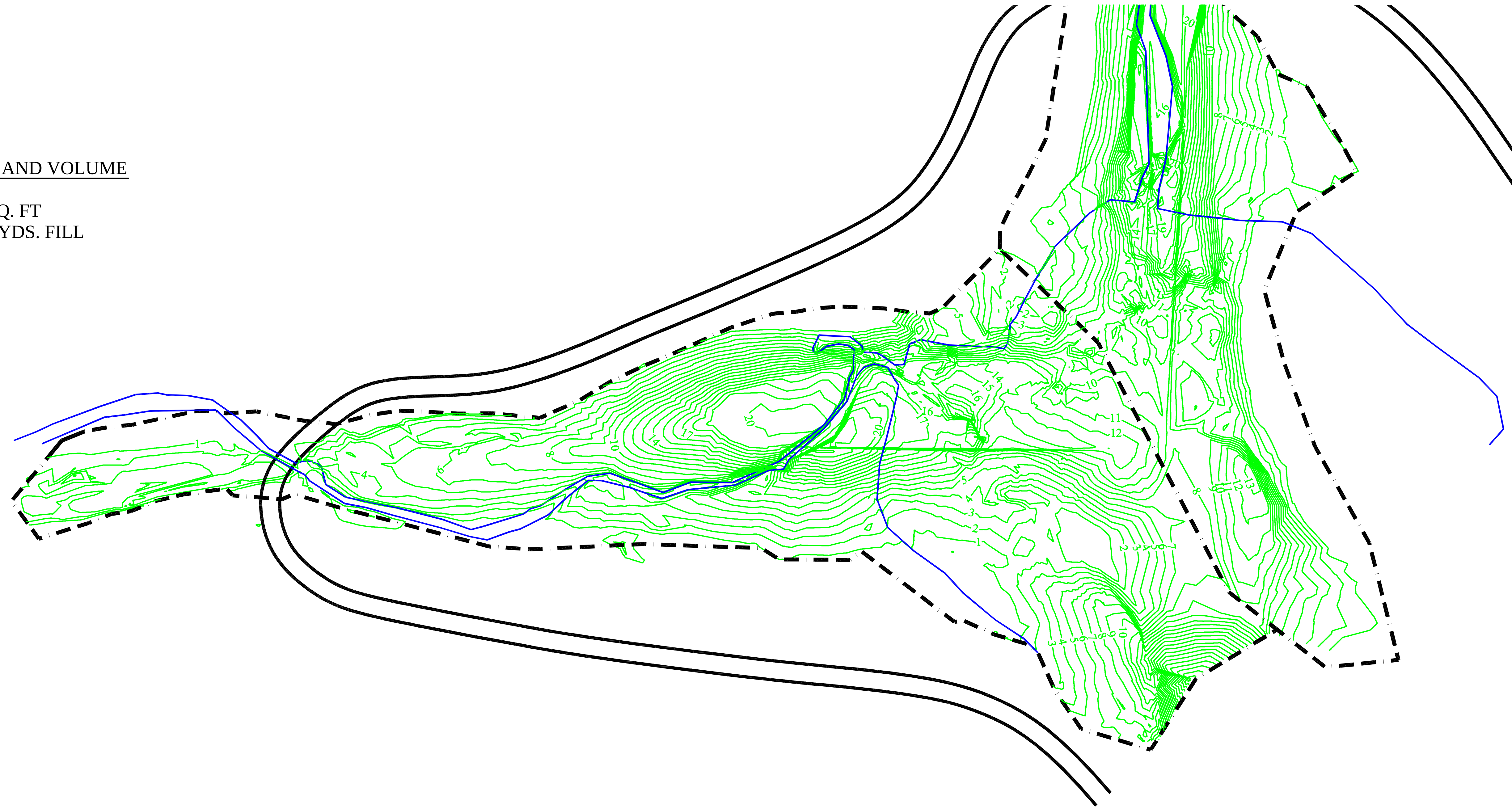
FIGURE

36

ISOPACH MAP OF DEPOSIT VOLUME - SCOTCH CREEK

SCOTCH CREEK DEPOSITION AREA AND VOLUME

PARCEL AREA = 363,490 SQ. FT
PARCEL VOLUME = 88,500 CU. YDS. FILL



LEGEND

FILL 1' CONTOURS
PARCEL BOUNDARY
2003 WATER EDGE
2003 ROAD

NOTE: THE PARCEL BOUNDARY ENCLOSES THE AREA USED TO GENERATE THE FILL VOLUME AND REPRESENTS THE EDGE OF HEAVY RIPARAIAN VEGETATION AND THE AREA UNDERWATER ESTIMATED TO DERIVE FROM SCOTCH CREEK.

SCALE (ft)
0 150

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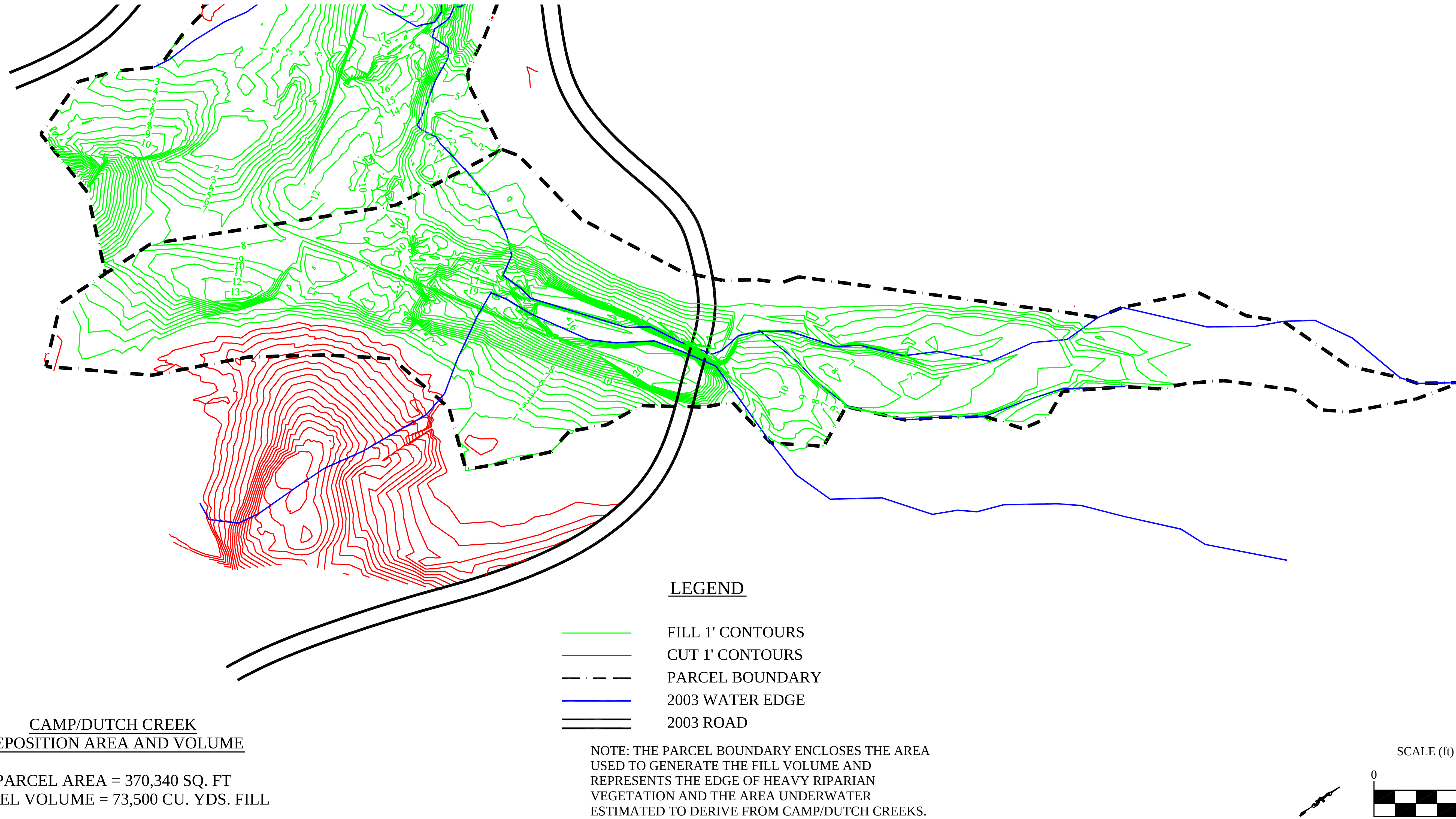
ISOPACH MAP OF DEPOSIT VOLUME
CAMP/DUTCH CREEK



CAMP/DUTCH CREEK
DEPOSITION AREA AND VOLUME

PARCEL AREA = 370,340 SQ. FT
PARCEL VOLUME = 73,500 CU. YDS. FILL

NOTE: THE PARCEL BOUNDARY ENCLOSES THE AREA USED TO GENERATE THE FILL VOLUME AND REPRESENTS THE EDGE OF HEAVY RIPARIAN VEGETATION AND THE AREA UNDERWATER ESTIMATED TO DERIVE FROM CAMP/DUTCH CREEKS.

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ISOPACH MAP OF DEPOSIT VOLUME - JENNY CREEK

JENNY CREEK DEPOSITION AREA AND VOLUME

PARCEL AREA = 537,900 SQ. FT

PARCEL VOLUMES:
CUT 4300 CU. YDS.;
FILL 111,500 CU. YDS.
NET FILL 107,200 CU. YDS.

LEGEND

- FILL 1' CONTOURS
- CUT 1' CONTOURS
- PARCEL BOUNDARY
- 2003 WATER EDGE
- 2003 ROAD

NOTE: THE PARCEL BOUNDARY ENCLOSES THE AREA USED TO GENERATE THE FILL VOLUME AND REPRESENTS THE EDGE OF HEAVY RIPARIAN VEGETATION AND THE PRE-DAM TOE OF THE HILLSLOPES.

SCALE (ft)
0 150

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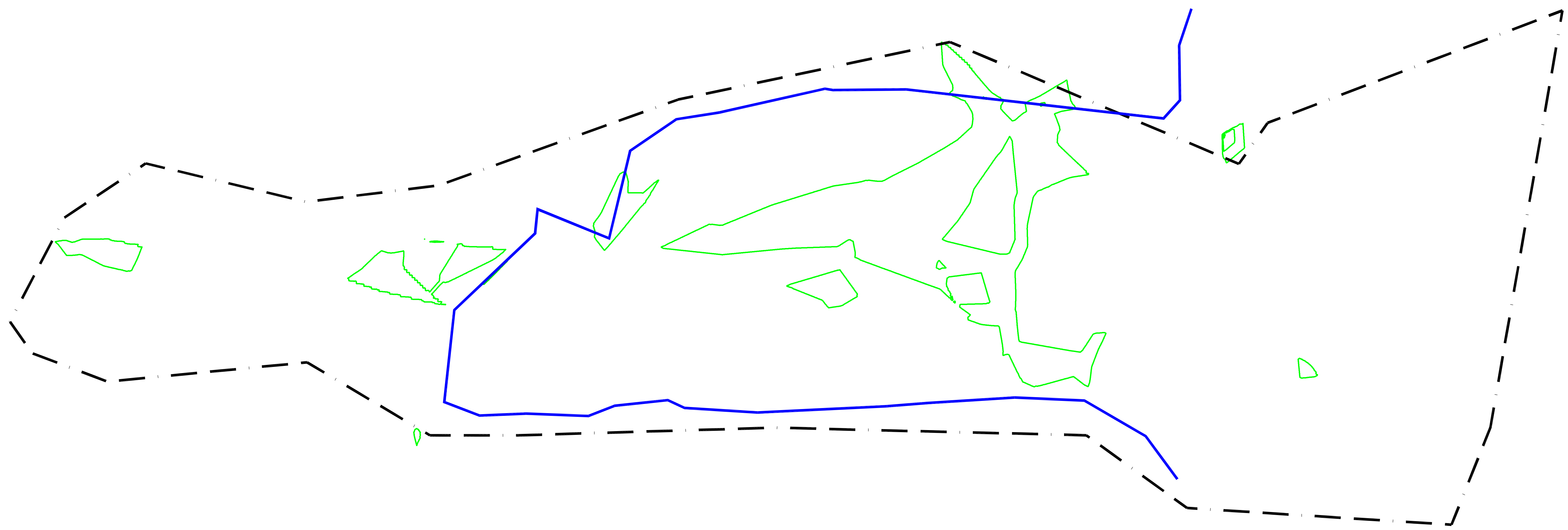
ISOPACH MAP OF DEPOSIT VOLUME - SPENCER CREEK



LEGEND

FILL 1' CONTOURS
PARCEL BOUNDARY
2003 WATER EDGE

NOTE: THE PARCEL BOUNDARY ENCLOSES THE AREA USED TO GENERATE THE FILL VOLUME.

SPENCER CREEK
DEPOSITION AREA AND VOLUME

PARCEL AREA = 274,820 SQ. FT
PARCEL VOLUME = 2812 CU. YDS. FILL

SCALE (ft)
0 100

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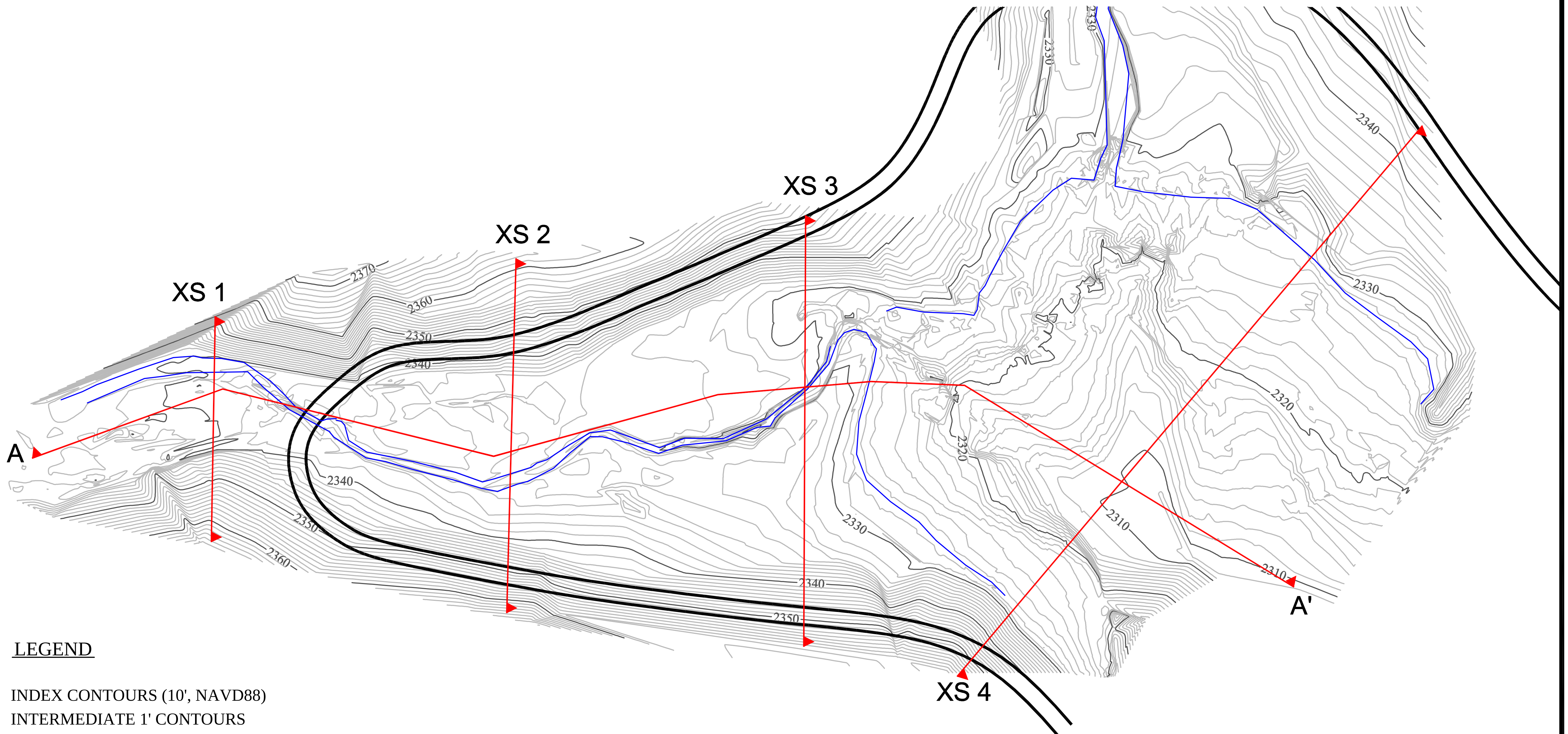
FIGURE 40

LONGITUDINAL ALIGNMENT AND CROSS SECTION LOCATIONS - SCOTCH CREEK



LEGEND

INDEX CONTOURS (10', NAVD88)
INTERMEDIATE 1' CONTOURS
WATER EDGE (3/10/030-3/21/03)
ROAD
XS1 CROSS SECTION LOCATIONS
A LONGITUDINAL ALIGNMENT

SCALE (ft)
0 150

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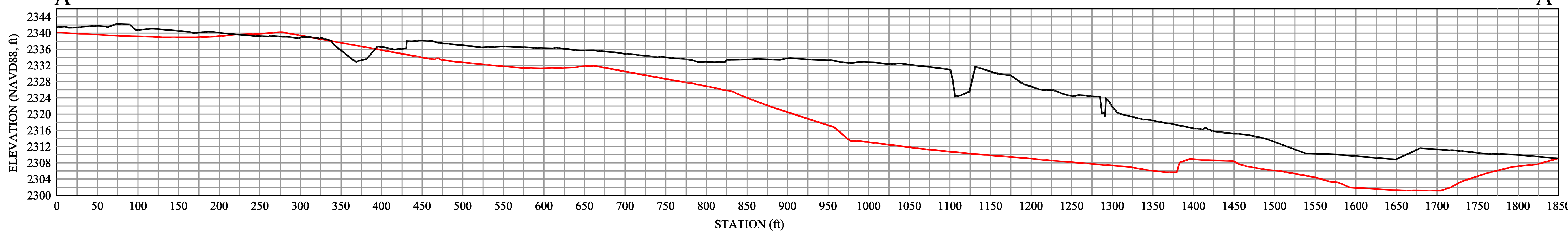
PROFILE AND CROSS SECTIONS - SCOTCH CREEK

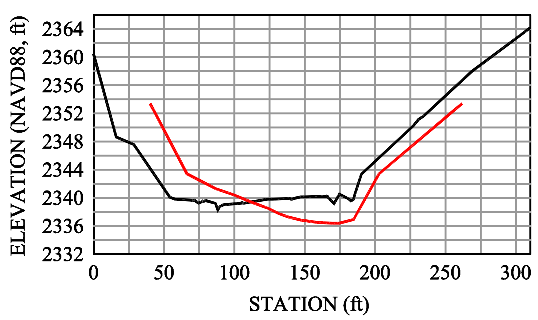
LONGITUDINAL PROFILE

A

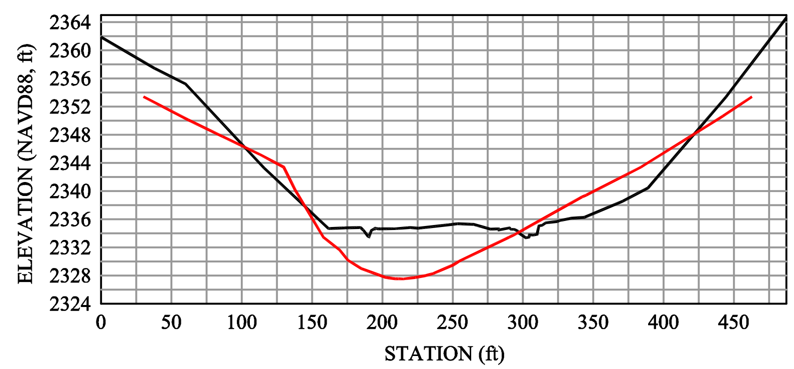
A'



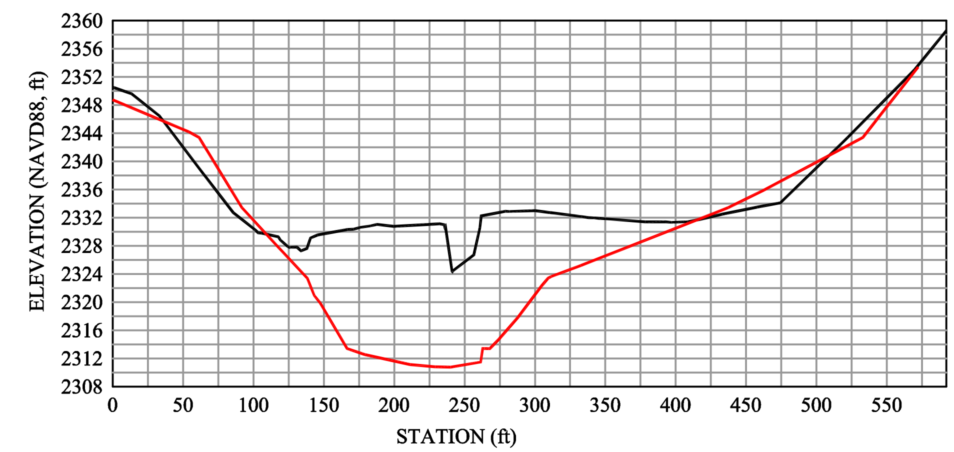
CROSS SECTION 1



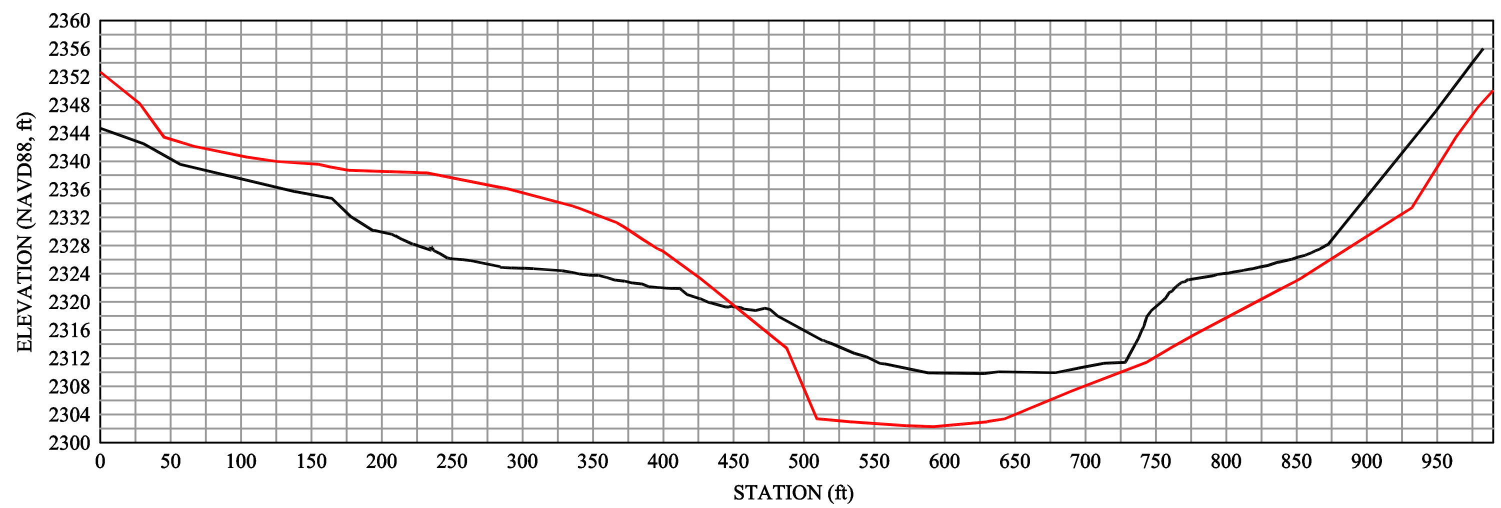
CROSS SECTION 2



CROSS SECTION 3



CROSS SECTION 4



LEGEND

EXISTING SURFACE (3/03)

PREDAM SURFACE

5X VERTICAL EXAGGERATION

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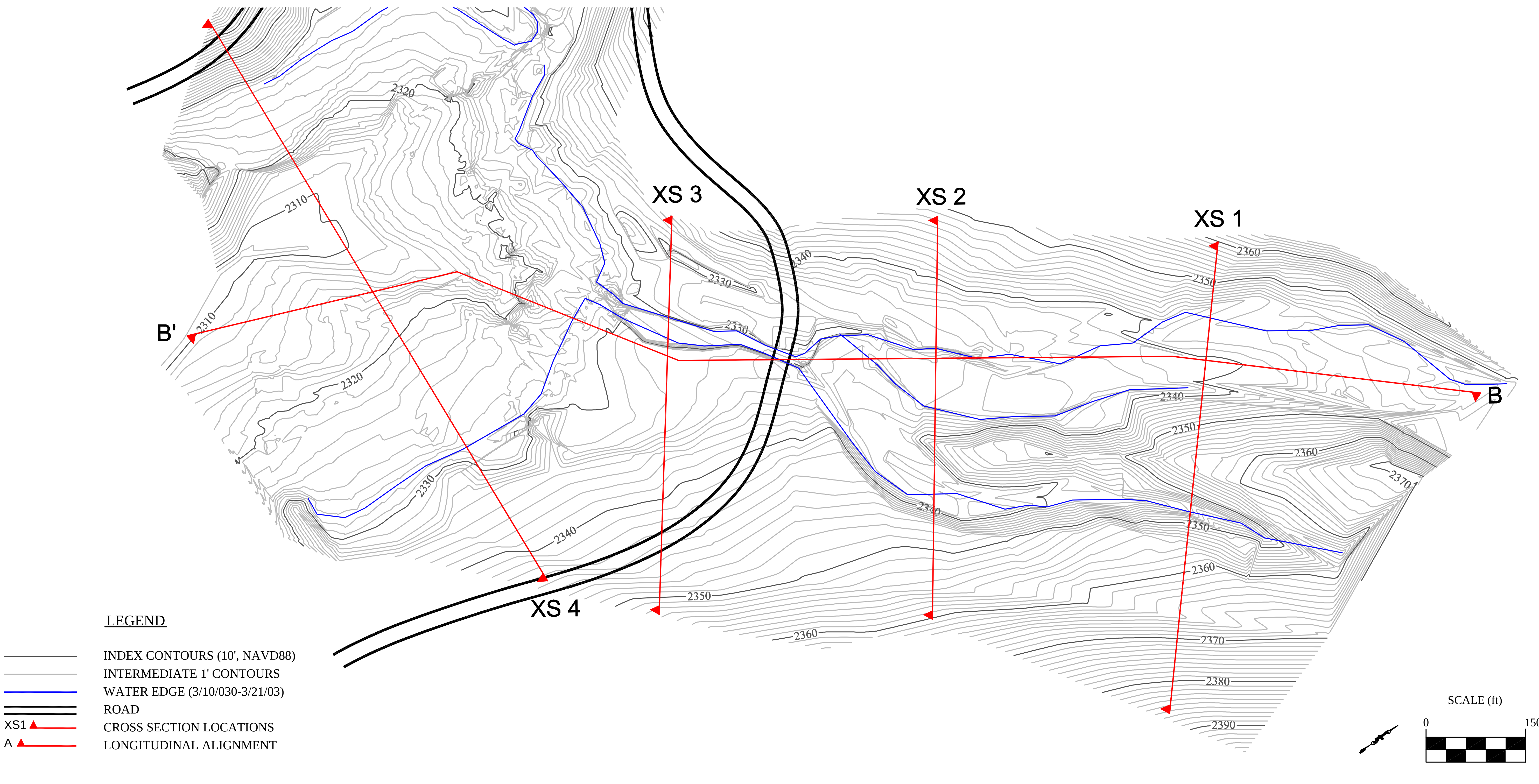
FIGURE

42

LONGITUDINAL ALIGNMENT AND CROSS SECTION LOCATIONS - CAMP/DUTCH CREEKS



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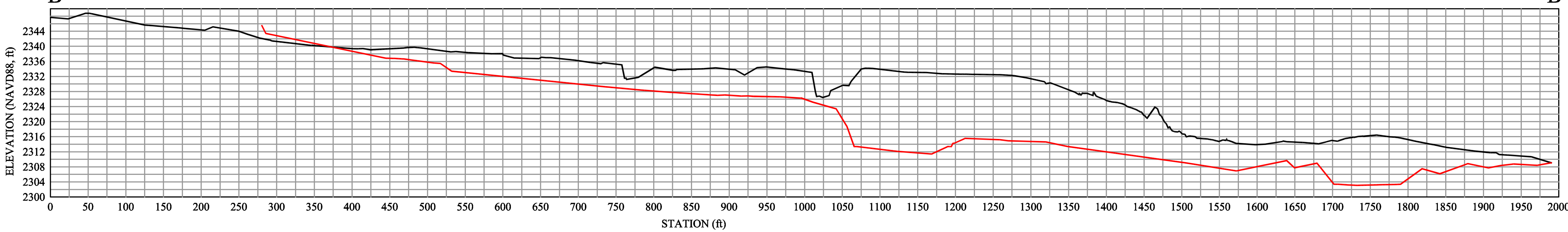
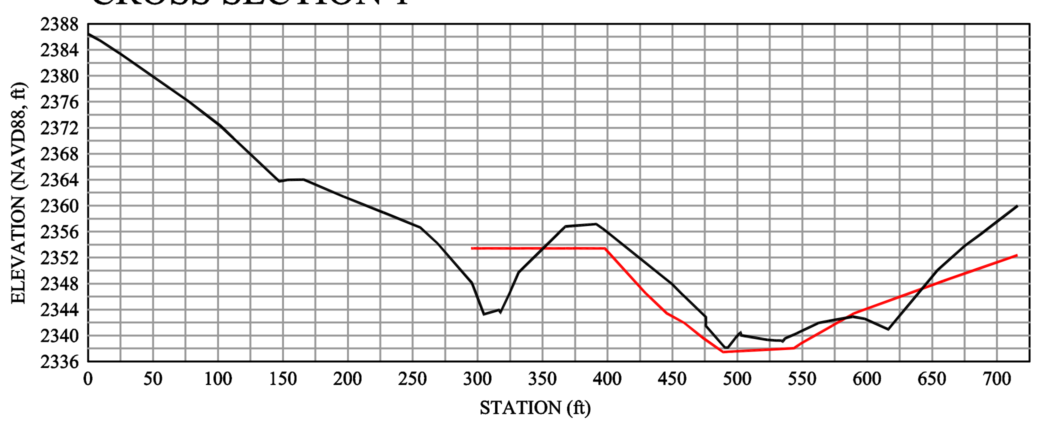
PROFILE AND CROSS SECTIONS - CAMP/DUTCH CREEKS

LONGITUDINAL PROFILE

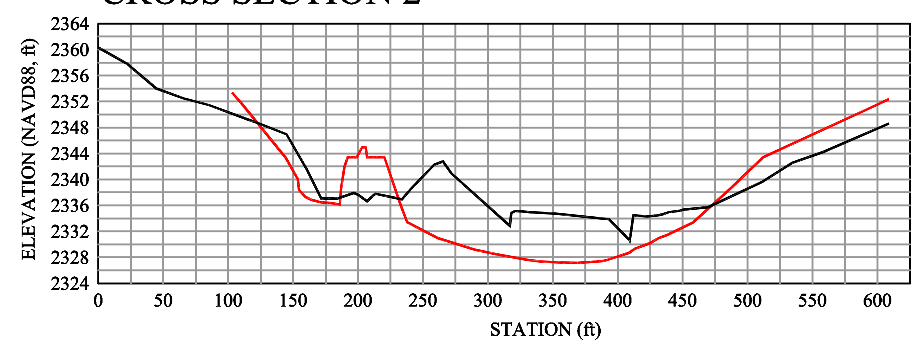
B B'



CROSS SECTION 1



CROSS SECTION 2



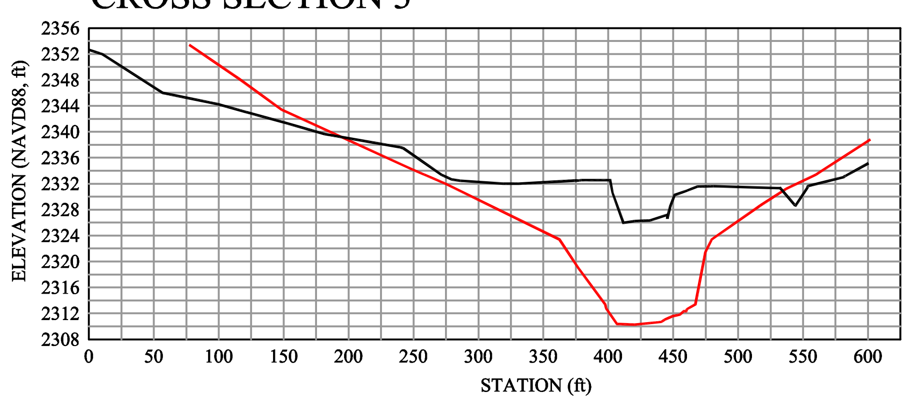
LEGEND

EXISTING SURFACE (3/03)

PREDAM SURFACE

5X VERTICAL EXAGGERATION

CROSS SECTION 3



CROSS SECTION 4

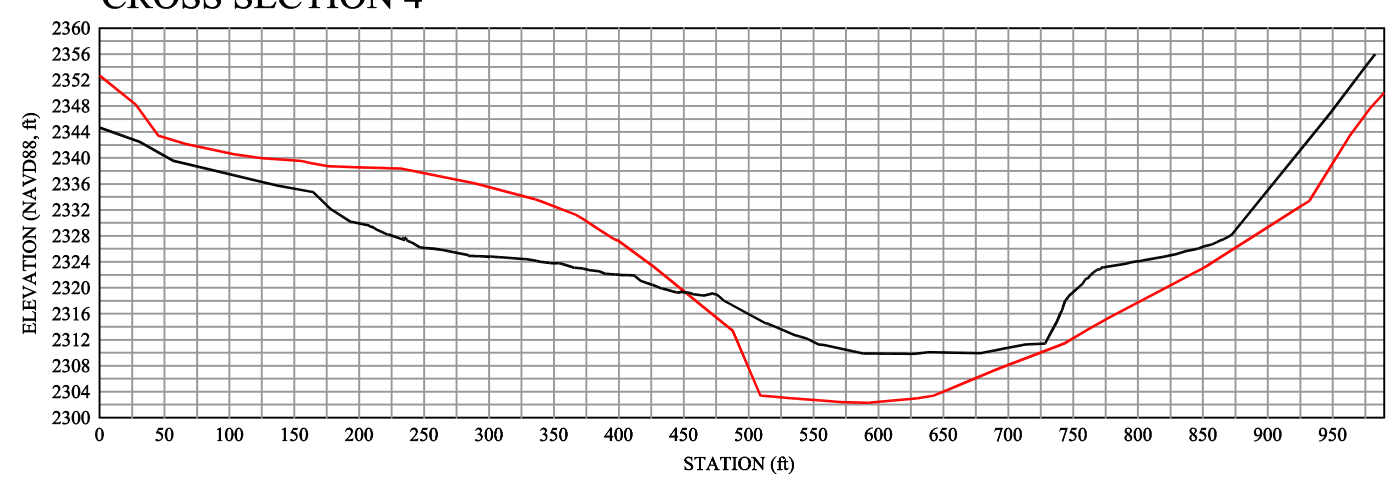


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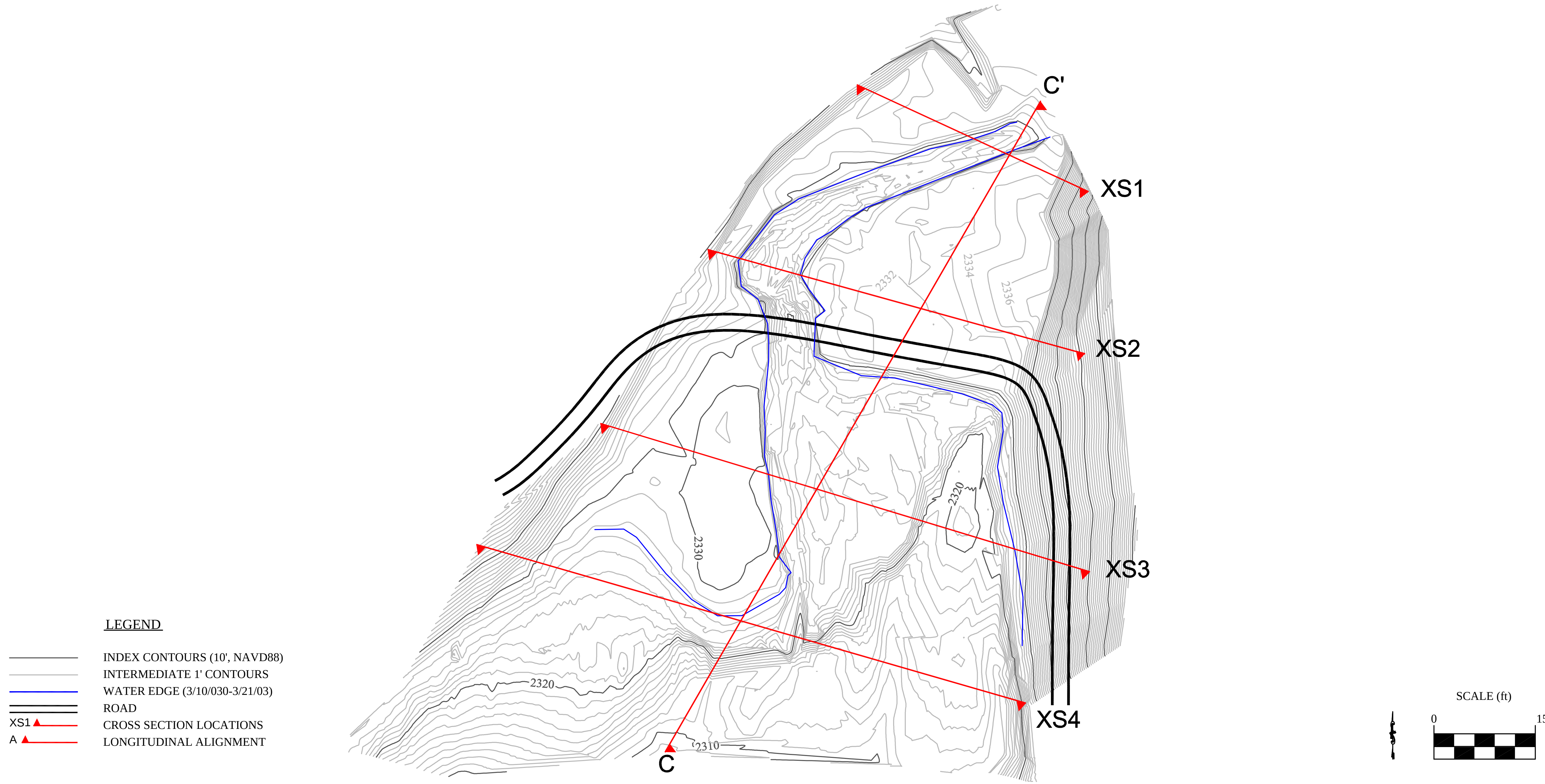
FIGURE

44

LONGITUDINAL ALIGNMENT AND CROSS SECTION LOCATIONS - JENNY CREEK



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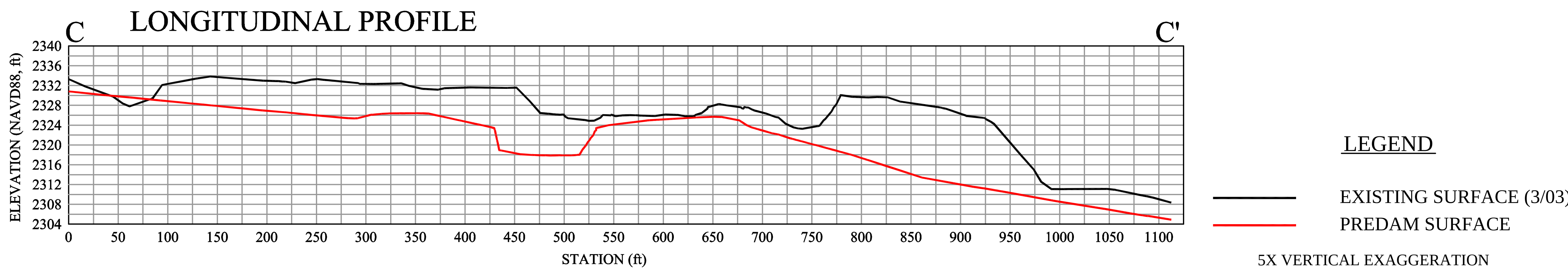
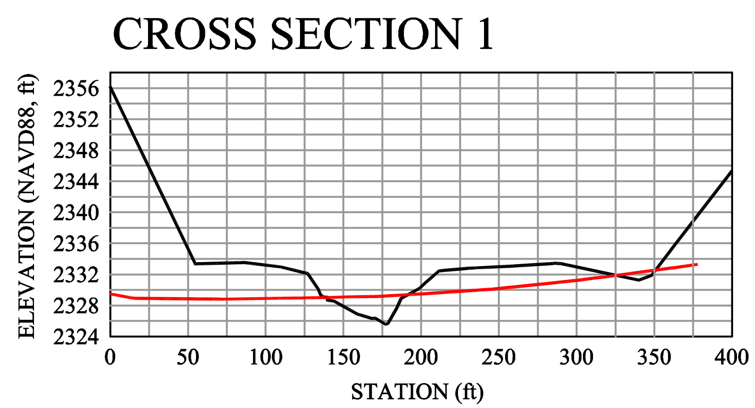
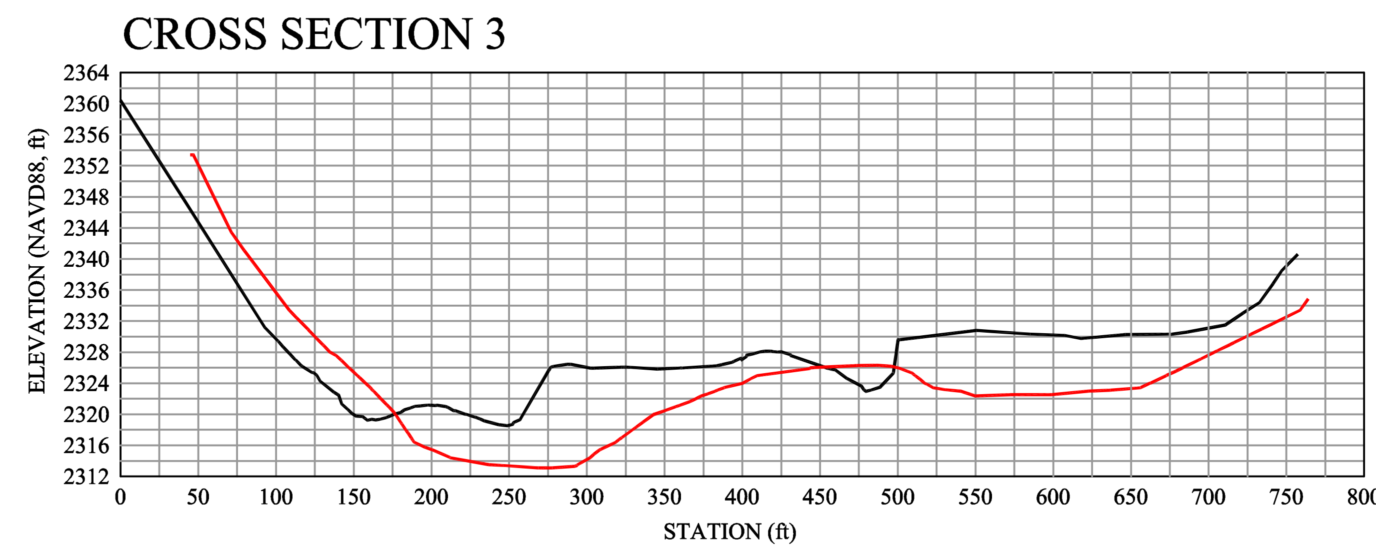
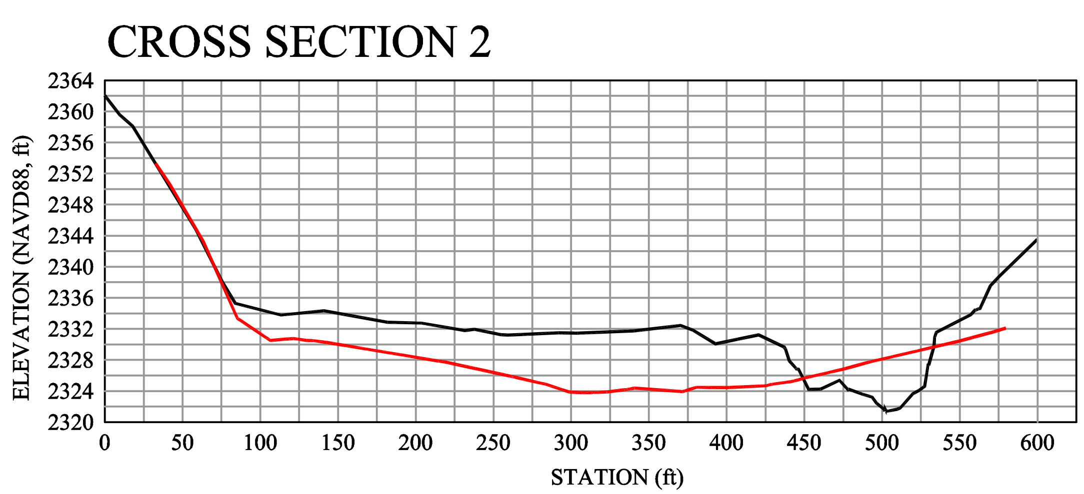
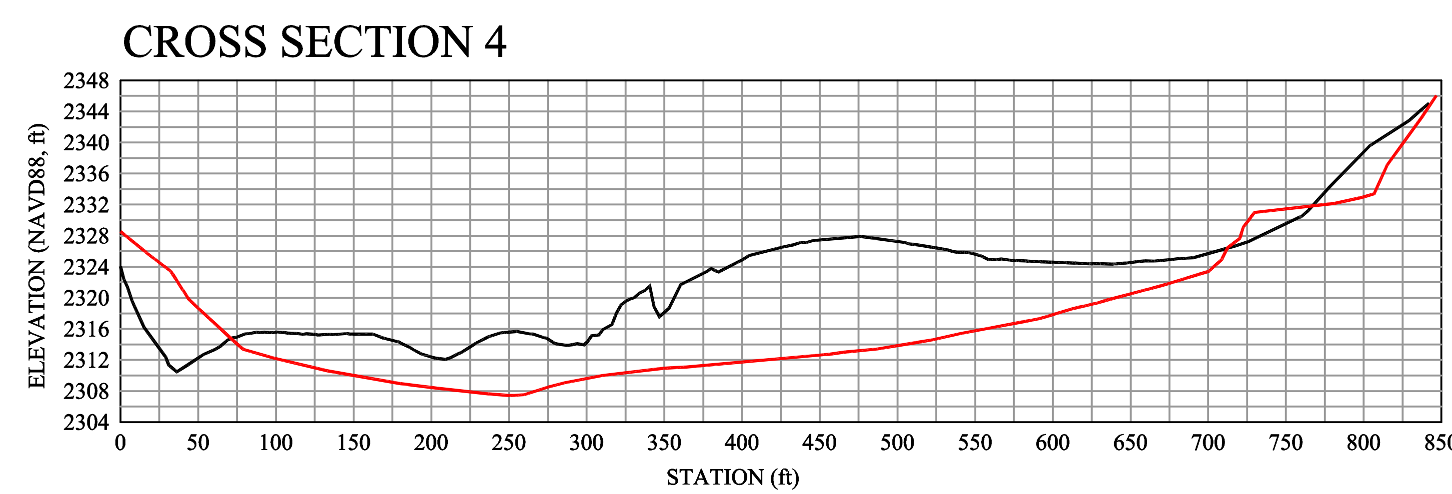
PROFILE AND CROSS SECTIONS - JENNY CREEK











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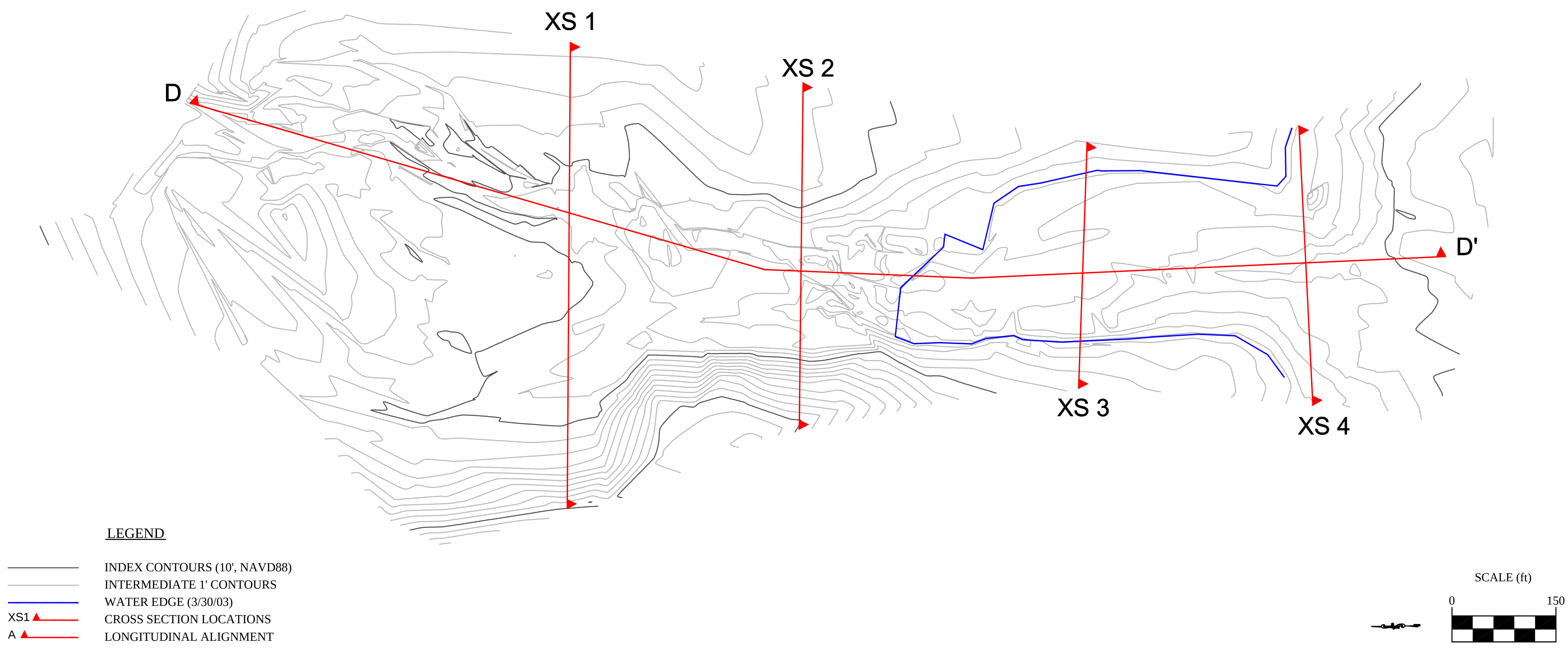
LONGITUDINAL ALIGNMENT AND CROSS SECTION LOCATIONS - SPENCER CREEK



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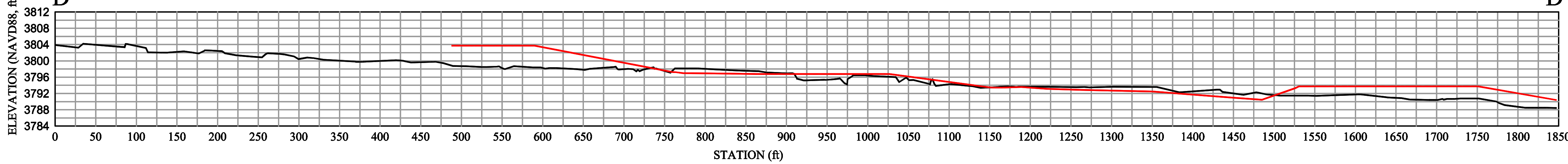
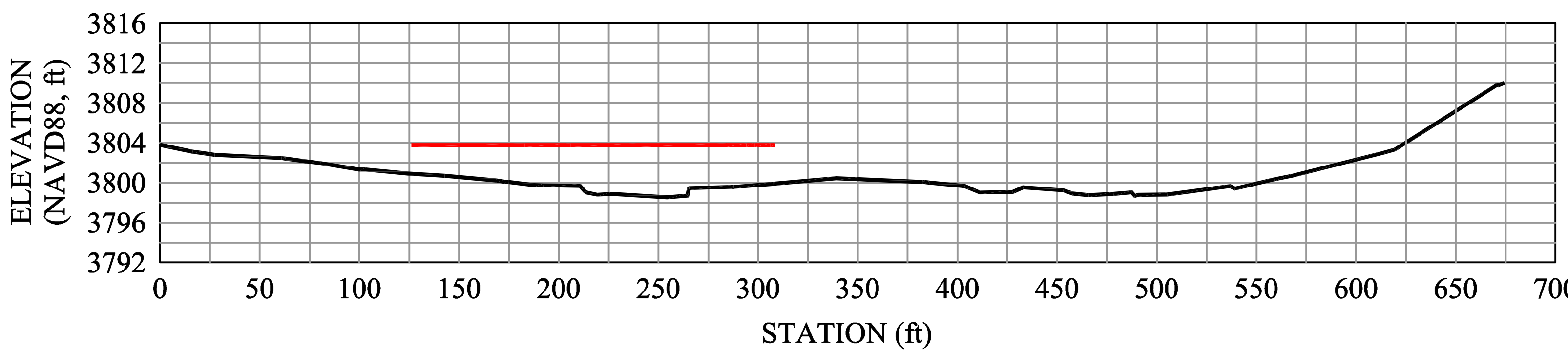
PROFILE AND CROSS SECTIONS - SPENCER CREEK

D LONGITUDINAL PROFILE D'



CROSS SECTION 1



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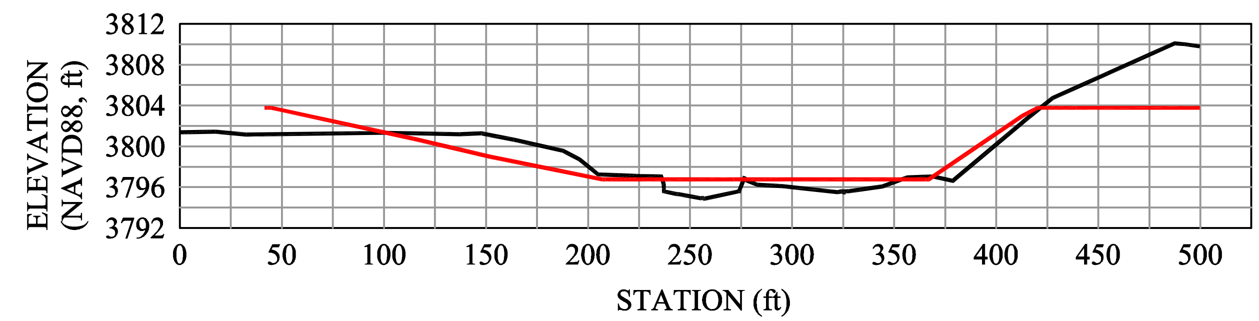
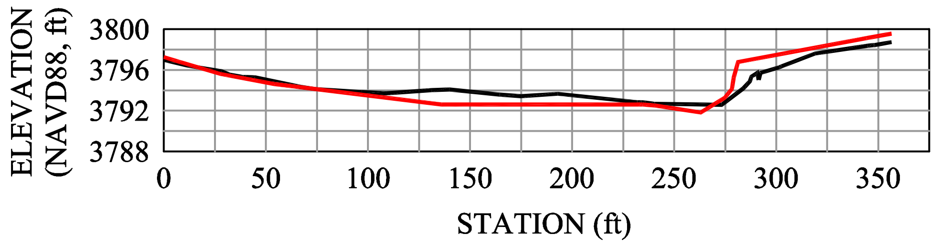
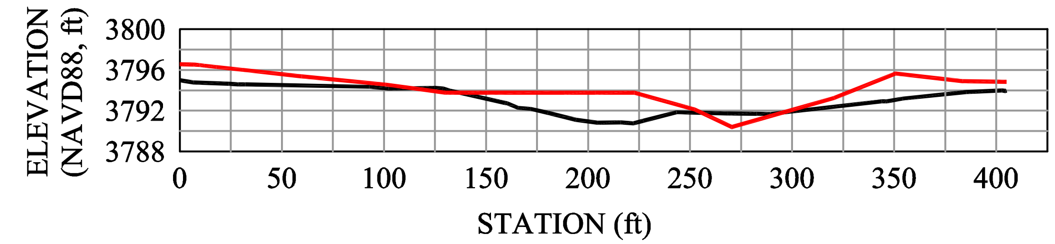


CROSS SECTION 3



CROSS SECTION 4



LEGEND

EXISTING SURFACE (3/03)
PREDAM SURFACE

5X VERTICAL EXAGGERATION

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FIGURE
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