APPENDIX C

GEOMORPHIC ASSESSMENT

ANDERSON CONSULTING ENGINEERS, INC.
Civil • Water Resources • Environmental

August 7, 2014

Mr. Dave Jula, P.E.
Michael Baker Corporation, Inc.
165 South Union Boulevard
Suite 200
Lakewood, CO 80228

RE: St. Vrain Creek Watershed Master Plan: Quantification of Geomorphic Parameters
(ACE Project No. COMBJ01)

Dear Dave:

The week of September 13, 2013 unusually heavy and extended rainfall affected a large portion of the Colorado Front Range extending from Colorado Springs north to Fort Collins. Consequently many communities experienced unprecedented flooding and erosional damage. Unprecedented flooding was especially noted within the St. Vrain Creek watershed. In the report "Peak Flow Hydrology Investigation for the September 2013 Flood at Interstate 25," CDOT estimated peak flows for the 2013 flood using indirect methods. Correlating high water marks to HEC-RAS modeled water surface elevations, CDOT estimated that the discharge at the Interstate 25 crossing of St. Vrain Creek was 18,000 cfs (CDOT, 2014). CDOT's estimated discharge is approximately equivalent to the 130-year flood when comparing to flows presented in Rocky Mountain Consultant's (RMC) report "Floodplain Information, Flood Control and Floodplain Management Plan for St. Vrain Creek at Longmont Colorado" which were utilized as the effective flows published in the effective FIS.

Subsequent to the September 2013 flood, efforts to create a St. Vrain Creek Watershed Master Plan have commenced in order to provide post flood guidance and recommendations. In support of the St. Vrain Creek Watershed study, Anderson Consulting Engineers, Inc. (ACE) was contracted by Michael Baker Corporation, Inc. in June, 2014 to conduct a stream plan form evaluation and assist in the quantification of geomorphic parameters along St. Vrain Creek located in Northern Colorado. The results obtained from this assessment of geomorphic parameters will be interpreted and utilized by other project team staff to provide Boulder County with Master Plan guidance and recommendations.

St. Vrain Creek has its origins in the Rocky Mountains, in both Roosevelt National Forest and Rocky Mountain National Park, located west of the City of Longmont, Colorado. The main fork of the creek is formed by the confluence of the North and South St. Vrain Creeks near Lyons, Colorado. St. Vrain Creek conveys flows from the mouth of the Canyon, southeast to its confluence with the South Platte River near Platteville, Colorado.

The current study focuses on reaches of the South St. Vrain, Middle St. Vrain, North St. Vrain, and St. Vrain Creeks. The study reach for St. Vrain Creek extends from the confluence of the North and South St. Vrain Creeks, located near the mouth of the canyon, downstream to the confluence with the South Platte River, a stream distance of over 56 miles. The stretch of the St. Vrain Creek extending from the Boulder/Weld County Line up to Airport Road is highly urbanized with the channel being encroached by residential, commercial, and industrial development; while the land use throughout the upper and lower reaches s primarily agricultural, with the exception of the reach extending through the Town of Lyons.

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The current study reach also includes a 3.4-mile reach of the South St. Vrain, 5.0 miles of the Middle St. Vrain, and 10.2 miles of the North St. Vrain. The study reach of the South St. Vrain extends from the confluence with the North St. Vrain upstream to approximately the canyon mouth. The study reach for the North St. Vrain extends from the confluence with the South St. Vrain upstream to the Button Rock Reservoir. Finally, the 5-mile reach along the Middle St. Vrain Creek is approximately centered around the community of Raymond, Colorado. A vicinity map of the study reaches for the St. Vrain Creek is provided on page 3.

Historical Plan Form Evaluation

In an effort to evaluate historical behavior of St. Vrain Creek, a series of six sets of aerial photographs ranging from 1949 to 2013 were analyzed. Attached to the end of this letter are sixteen (16) sheets illustrating a plan form analysis for the study reaches identified in Section 1. The plan form analysis examines the historic location of St. Vrain Creek at six points in time between 1949 and 2013 (Post-Flood). The six points in time examined, and their sources of imagery utilized are identified below in Table 1.

Table 1. Aerial Photography Dates and Sources

Snapshot In Time	Boulder County		Weld County	
	Date of Photograph	Source	Date of Photograph	Source
1	1949	USGS	1949	USGS
2	1973	Boulder County	1972	USGS
3	2000	Boulder County	2002	USGS
4	2009	NAIP	2009	NAIP
5	2013 (Pre-Flood)	NAIP (Downstream of Lyons) 2012 Boulder County (Upstream of Lyons)	2013 (Pre-Flood)	NAIP
6	2013 (Post-Flood)	Google Earth	2013 (Post-Flood)	Google Earth

The plan form analysis demonstrates a number of trends which are identified below:

1. The 1949 plan form shows that historically the entire reach tended to be slightly more sinuous than indicated in the last 40 years. This is especially noticeable for the reach downstream of Sunset Street. It appears that the reach extending between Sunset Street and the Boulder/Weld County line was largely engineered/straightened during the 50's and 60's to accommodate City development. In the vicinity of Main Street the creek was confined by development which occurred prior to 1949 which reduced the sinuosity of the creek in that area.

2. For the South St. Vrain Creek, North St. Vrain Creek, Middle St. Vrain Creek, and reach of St. Vrain Creek between Lyons and the Boulder/Weld County line, a prominently stable plan form was observed between 1949 and 2013 (Pre-Flood).

3. For the reach between the Boulder/Weld County line and the confluence with the South Platte River, St. Vrain Creek demonstrated a natural tendency to meander across the floodplain. It is noted that although the river did meander through this reach, the extents of river migration noted appear to be reasonable for a river of this size, and should largely be considered natural/stable.

Vicinity Map of Geomorphic Study Reaches for the St. Vrain Creek Watershed Master Plan (Current Study Reaches are shown in Orange)

4. Over the entirety of the study reach, the 2013 Post-Flood channel largely follows the historic plan form of the river, with the exception of the locations where remnant gravel pit ponds have captured the river alignment, and in the vicinity of the confluence of the North and South St. Vrain Creeks. Locations where the remnant gravel pit ponds have captured the river corridor include:

   (a) right overbank ponds located between Union Road and 63rd Street; (b) both right and left overbank ponds just upstream of Hygiene Road; (c) the left overbank pond between Main Street and Martin Street, just north of the Harvest Junction shopping area; (d) right overbank ponds between the Boulder/Weld County Line and Highway 119; (e) the left overbank pond just downstream of Highway 119; and (f) the left overbank ponds for the approximately 2,000-foot reach downstream of I-25.

Based on the plan form analysis it appears that the main stem of St. Vrain Creek has exhibited a fairly stable plan form over the past 65 years, while the post-flood plan form has been largely influenced by the presence of numerous, near-channel remnant gravel pit ponds. Capturing of the river by these ponds significantly changes the sediment transport balance along the creek. Therefore, it is recommended that in most instances along the main stem of St. Vrain Creek the channel be returned to its' historic (2013 Pre-Flood) alignment; doing so will maximize the potential for the creek maintaining a stable plan form on a system-wide basis. Leaving St. Vrain Creek in its' 2013 Post-Flood alignment will likely result in a series of reaches along the creek operating with a sediment deficit which may result in an unstable system, manifested by: channel incision and headcutting; over-steepened banks and bank retreat; damage to infrastructure and loss of property; and the possible capturing of additional remnant gravel pit ponds. If the channel downstream of these gravel pit capture areas begins to incise, resulting in over-steepened banks, the width of the riparian corridor will likely become narrower. This combined with a lower adjacent groundwater table would result in a loss of riparian vegetation and habitat. In addition, flows through gravel pit ponds tends to be wider and shallower than in the native creek channel which, along with the reduced vegetative cover, can elevate water temperatures, thereby impacting aquatic species.

Restoration of the St. Vrain Creek main stem to its' Pre-Flood alignment will likely require excavation of materials deposited within the historic channel alignment, along with hardening of the channel bank at breach locations to control spills to the ponds. It is acknowledged that there are certain reaches where restoration of the channel alignment to its' Pre-Flood location may be prohibitive (either because of constructability issues or financial limitations). It is anticipated that these reaches may include the reach between the Boulder/Weld County Line and Highway 119, and the reach immediately downstream of I-25. In cases where the channel is not restored to its' pre-flood alignment, but rather remains captured in an overbank pond it is recommended that precautions be taken to limit channel instabilities, including: (a) the use of rock grade control structures upstream of the gravel pond to prevent headcuts from propagating upstream (it is noted that this concept was incorporated into the design of the Weld County Road 1 Bridge replacement); (b) armoring of banks in places where critical property and/or infrastructure may be threatened by channel migration; and (c) monitoring of downstream reaches for signs of future channel instabilities.

Due to the nature of the South St. Vrain Creek, North St. Vrain Creek, and Middle St. Vrain Creek reaches (slope, channel characteristics, bed material, etc.) the channel will tend to migrate and avulse for a range of hydrologic conditions. Absent of large flow events, the channel plan form for these reaches will likely remain reasonably stable once streambank vegetation has re-established. However, beyond some threshold discharge the channel plan form can be expected to change, and in some

instances change significantly due to avulsion and migration. Consequently, it is recommended that in most instances along Middle St. Vrain Creek, North St. Vrain Creek, and South St. Vrain Creek that the channel be left in the current (post-flood) alignment. The primary exception to this recommendation would be along the divided flow path south of South St. Vrain Creek, that has formed between Old St. Vrain Creek Road and McConnell Drive. It is recommended that this split flow path be eliminated, and that the channel be stabilized at the point of divergence. In areas where it may be necessary to reclaim limited amounts of private property or protect infrastructure (including bridges, roadways and utilities), minor realignment of the main channel may be necessary. In addition, the use of localized rock riprap bank protection is recommended to stabilize local sections of the channel where necessary. However, it should be recognized that in these reaches it will not likely be possible to stabilize the channel plan form over long reaches, for a range of high flow conditions.

Delineation of Reaches for Geomorphic Assessment

Reaches utilized in the geomorphic assessment were delineated and refined progressively for St. Vrain Creek on the basis of aerial photograph interpretation, inspection of bed profiles, field observations, and hydrologic, hydraulic and geomorphic analyses. Factors which influenced the selection of reaches included: channel bed slope, irrigation diversion structures, and significant grade control structures. Table 2 provides a summary of the reaches defined along South St. Vrain Creek, Middle St. Vrain Creek, North St. Vrain Creek, and the St. Vrain Creeks main stem.

Table 2. Summary of Geomorphic Assessment Reaches

Study Reach Name	Upstream Limit	Upstream Sta. (ft)*	Reach Length (ft)
St. Vrain Creek			
WC1	County Road 15	56,820	56,820
WC2	Interstate 25	78,770	20,950
WC3	County Road 1	110,900	33,130
BC1	Pedestrian Bridge Near Martin Street	123,680	12,780
BC2	Pedestrian Bridge Near Golden Ponds Park	139,220	15,540
BC3	N. 75th Street	151,050	11,830
BC4	Highland Dr.	175,870	24,820
BC5	Confluence with North St. Vrain Creek	184,830	9,960
South St. Vrain Creek			
BC6	Hall Ranch Parking Lot	193,180	8,350
BC7	Little Narrows	203,370	10,190
North St. Vrain Creek			
BC8	Apple Valley Road	20,530	20,530
BC9	Button Rock Reservoir	54,960	34,430
Middle St. Vrain Creek			
BC10	Mile 51 of Peak to Peak Hwy	28,090	28,090

*** Approximate station at upstream end of reach relative to the confluence with the South Platte River**

River Bed Profiles

The river bed profile is an indicator of the range of river conditions within the study area. Bed slope at any point represents the combined history of hydrology, hydraulics, sediment characteristics, geology and local anthropogenic influences. Therefore, bed slope is a useful indicator of changes in river characteristics.

Reach delineations for the St. Vrain Creek are superimposed on the plot of the Pre-Flood river bed profile through the study area provided in Figures 1 and 2. The profile for St. Vrain Creek was developed using a compilation of channel cross section data from two hydraulic studies. First, the 2008 hydraulic model prepared by Anderson Consulting Engineers, was utilized for the reach extending between County Line Road and Airport Road. Second, cross section data from the 1992 Love and Associates HEC-2 model for St. Vrain Creek were utilized for the upstream reach of St. Vrain Creek and North St. Vrain Creek. Finally, the bed profile for South St. Vrain Creek was defined based on bed profile/water surface profile figure published as part of the 1980 effective study (provided by the FEMA library).

River Plan Form Parameters

The plan form of each reach within the St. Vrain, North St. Vrain, South St. Vrain, and Middle St. Vrain study reaches was analyzed using GIS techniques to estimate reach sinuosity, meander wavelength, and meander amplitude, for both the pre-flood and post-flood conditions. The base mapping for the pre-flood condition of this work was the 2013 NAIP aerial photography, while Google Earth aerial photography was utilized for the 2013 post-flood condition. Results of the St. Vrain Creek plan form parameter evaluation for the pre- and post-flood conditions are summarized in Tables 3 and 4, respectively.

Comparing the pre-flood and post-flood plan form characteristics, it is apparent that with only a few exceptions channel sinuosity decreased as a result of the 2013 flood. This behavior has been accompanied by an overall reduction in meander amplitude. Meander wavelength increased along North St. Vrain Creek, decreased along South St. Vrain Creek, and both increased and decreased along the St. Vrain Creek main stem depending on location. The Middle St. Vrain Creek experienced little to no change in channel sinuosity and meander wavelength as a result of the 2013 flood.

With respect to the main stem of St. Vrain Creek decreases in sinuosity are primarily attributed to the capture of the creek within overbank remnant gravel pit ponds. The decrease of sinuosity for the North St. Vrain Creek is primarily attributed to a large meander being cutoff approximately 650 feet downstream of Blue Mountain Drive. Finally, it is noted that there was a slight increase in sinuosity along the South St. Vrain Creek which occurred as new meander bends formed within the existing floodplain.

Bankfull Discharge and Cross Section Properties

The conveyance capacity of a river channel when it is flowing full (the bankfull discharge) is a good integrator of channel hydraulic properties including size, shape, roughness, sinuosity and slope and is therefore useful in delineating reaches of similar characteristics. Pre-flood bankfull conditions (when water is about to overflow the channel onto the floodplain) have been calculated throughout the study reach for the portions of St. Vrain Creek and North St. Vrain Creek for which detailed hydraulic models were available.

Using the one-dimensional steady state hydraulic models developed by Love and Anderson Consulting Engineers (HEC-2 and HEC-RAS), bankfull characteristics for St. Vrain Creek and North St. Vrain Creek were analyzed. Pre-flood bankfull discharges, top widths, and hydraulic depths for cross sections along St. Vrain Creek and North St. Vrain Creek are plotted in Figures 3 and 4 respectively. It is our understanding that other members of the project team will be interpreting these results in the context of the overall master plan.

Table 3. Summary of Pre-Flood Reach-Based Plan Form Characteristics for St. Vrain Creek

Study Reach Name	Average Bed Slope* (ft/ft)	Sinuosity	Meander Wavelength (ft)	Meander Amplitude (ft)
St. Vrain Creek				
WC1	0.0010	1.62	710	190
WC2	0.0013	1.11	1,140	110
WC3	0.0019	1.36	690	110
BC1	0.0030	1.13	460	50
BC2	0.0042	1.12	430	30
BC3	0.0057	1.08	520	50
BC4	0.0070	1.10	620	70
BC5	0.0083	1.13	980	90
South St. Vrain Creek				
BC6	0.0145	1.08	720	60
BC7	0.0151	1.09	1,110	90
North St. Vrain Creek				
BC8	0.0098	1.16	720	80
BC9	0.0235	1.35	330	60
Middle St. Vrain Creek				
BC10	0.0294	1.11	370	50

*** Estimated from the USGS 10-meter DEM**

Table 4. Summary of Post-Flood Reach-Based Plan Form Characteristics for St. Vrain Creek

Study Reach Name	Average Bed Slope* (ft/ft)	Sinuosity	Meander Wavelength (ft)	Meander Amplitude (ft)
St. Vrain Creek				
WC1	0.0010	1.53	720	60
WC2	0.0013	1.12	1,100	50
WC3	0.0021	1.17	1,230	40
BC1	0.0030	1.10	380	30
BC2	0.0043	1.06	560	20
BC3	0.0056	1.09	640	20
BC4	0.0069	1.10	620	30
BC5	0.0084	1.09	830	40
South St. Vrain Creek				
BC6	0.0135	1.08	480	20
BC7	0.0146	1.13	480	20
North St. Vrain Creek				
BC8	0.0100	1.13	790	30
BC9	0.0224	1.28	670	40
Middle St. Vrain Creek				
BC10	0.0295	1.12	370	20

*** Estimated from the USGS 10-meter DEM**

If you have any questions or comments concerning any of this information, please do not hesitate to contact me or Greg Koch.

Sincerely,
Anderson Consulting Engineers, Inc.

Jamis D. Darrow, P.E.
Senior Engineer I

Gregory J. Koch, P.E.
Vice President

Attachments

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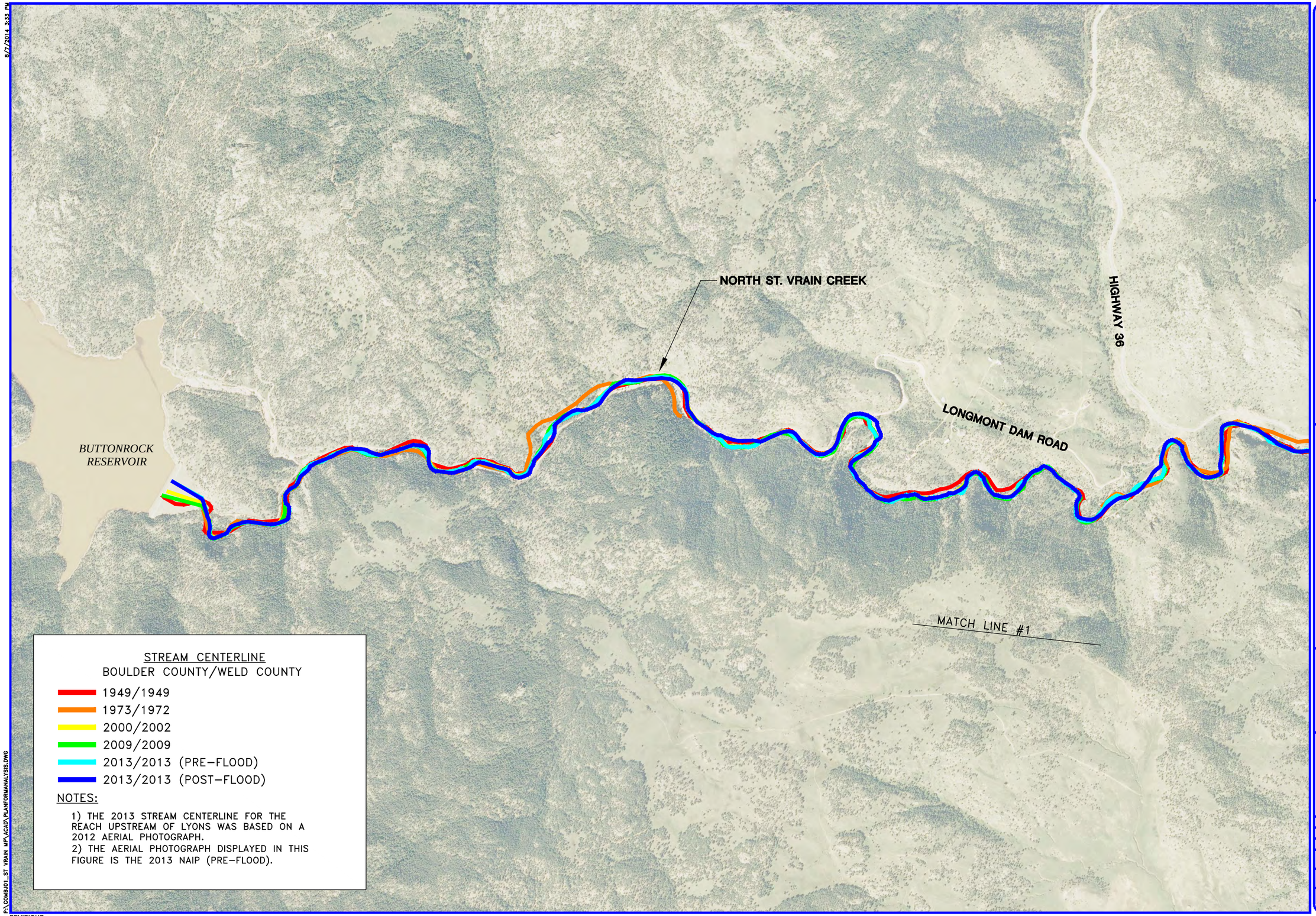

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Anderson Consulting Engineers, Inc
Civil / Water Resources / Environmental
373 East Waterin Street, Suite 100, Lyons, CO 80540
Phone (970) 256-0120 / Fax (970) 256-0121
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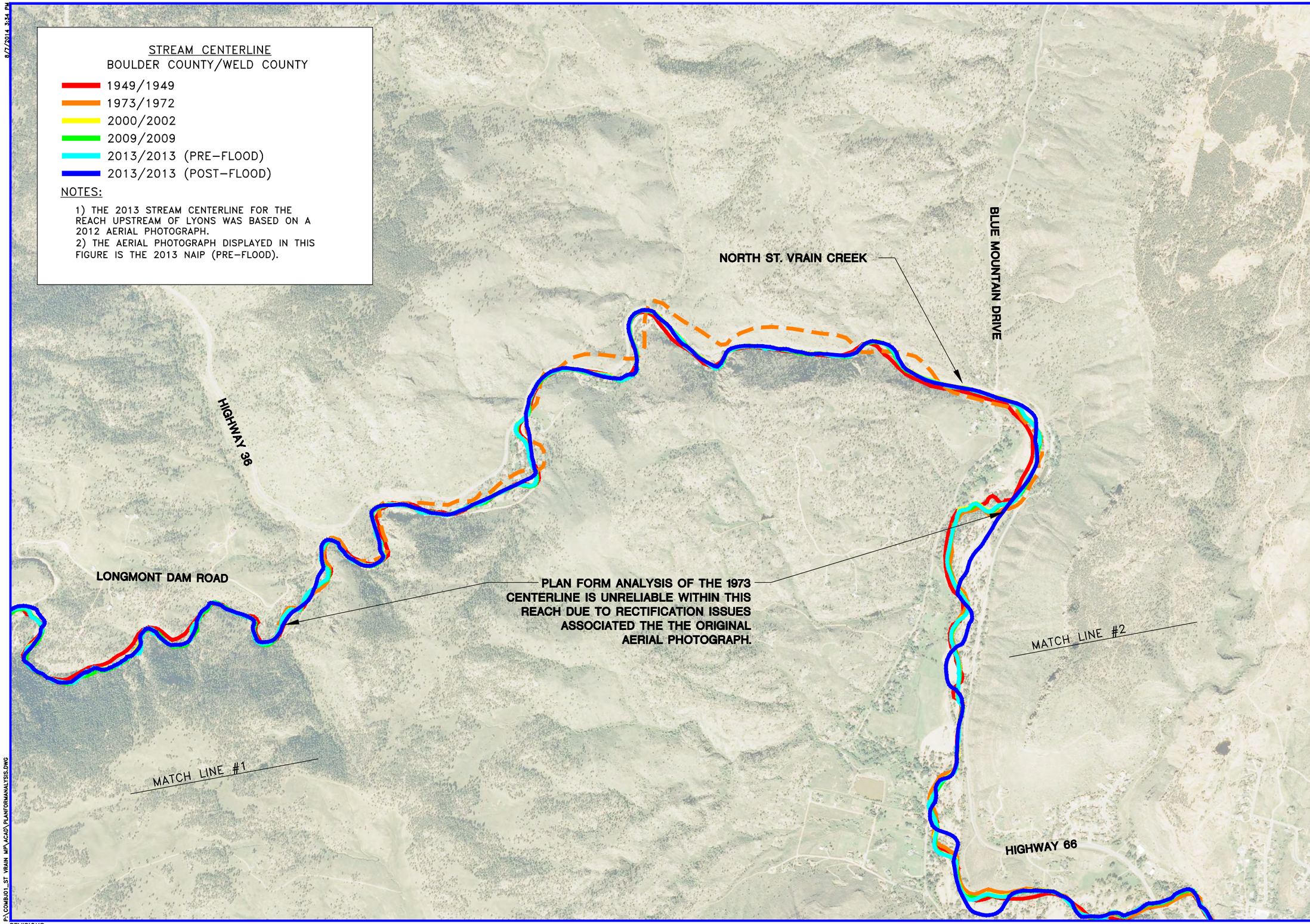

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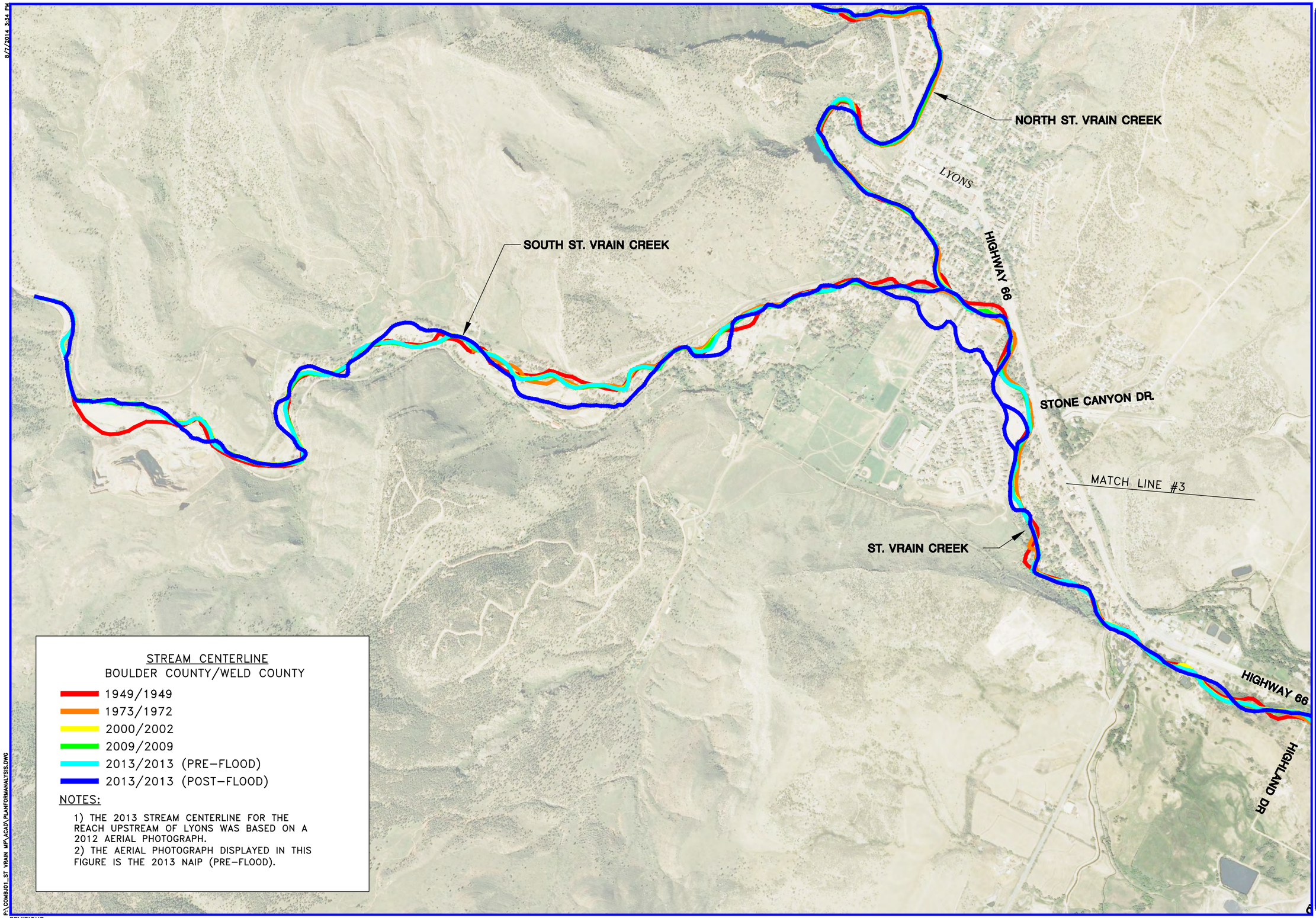

STREAM CENTERLINE
BOULDER COUNTY/WELD COUNTY

- 1949/1949
- 1973/1972
- 2000/2002
- 2009/2009
- 2013/2013 (PRE-FLOOD)
- 2013/2013 (POST-FLOOD)

NOTES:

1) THE 2013 STREAM CENTERLINE FOR THE REACH UPSTREAM OF LYONS WAS BASED ON A 2012 AERIAL PHOTOGRAPH.
2) THE AERIAL PHOTOGRAPH DISPLAYED IN THIS FIGURE IS THE 2013 NAIP (PRE-FLOOD).

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Civil / Water Resources / Environmental
373 East Elmer Street, Lyons, Colorado 80540
Phone (970) 236-0120 / Fax (970) 236-0121
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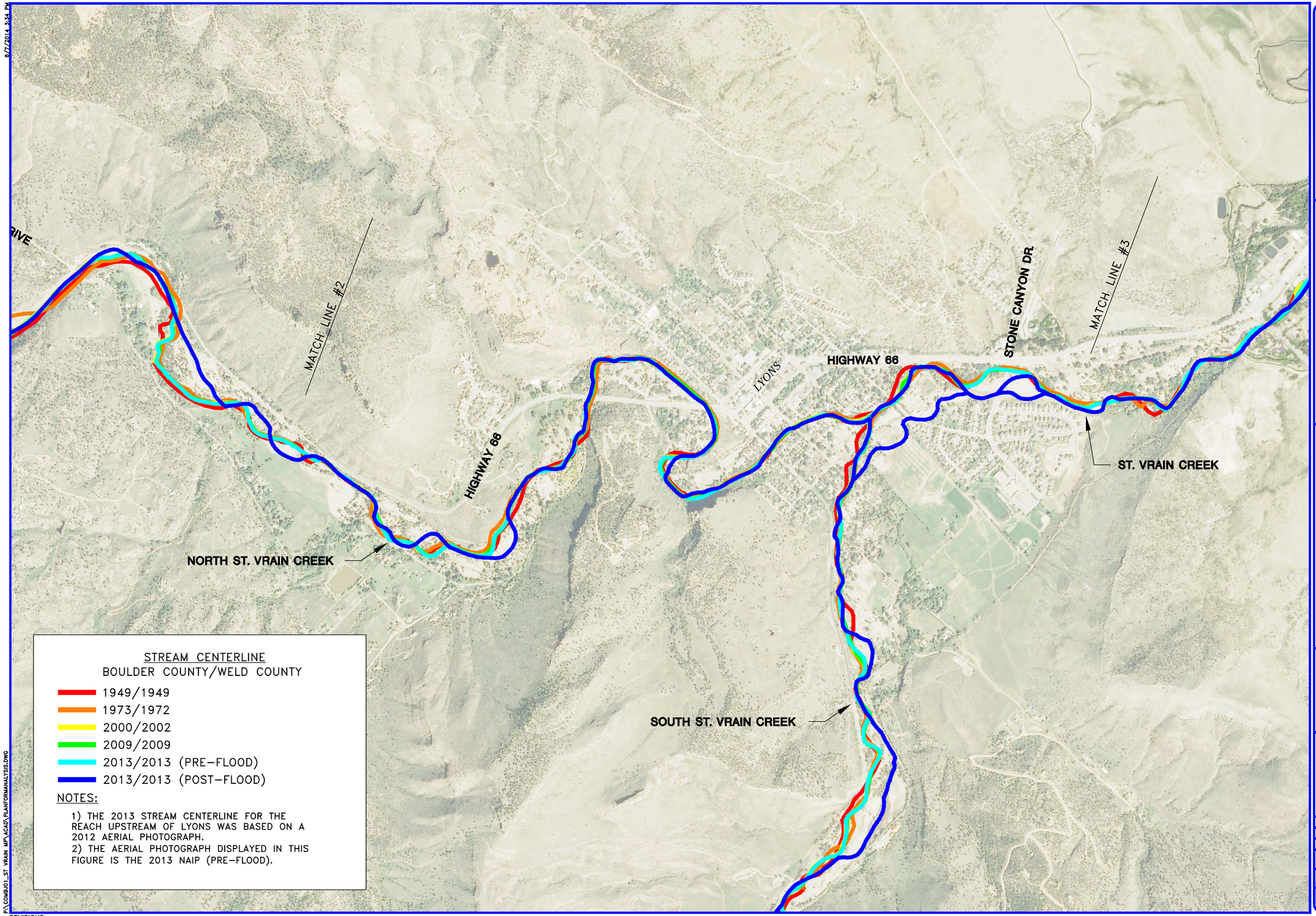

ANDERSON CONSULTING ENGINEERS, INC
Civil / Water Resources / Environmental
373 East Elmer Street, Lafayette, CO 80026
Phone (970) 226-0120 / Fax (970) 226-0121
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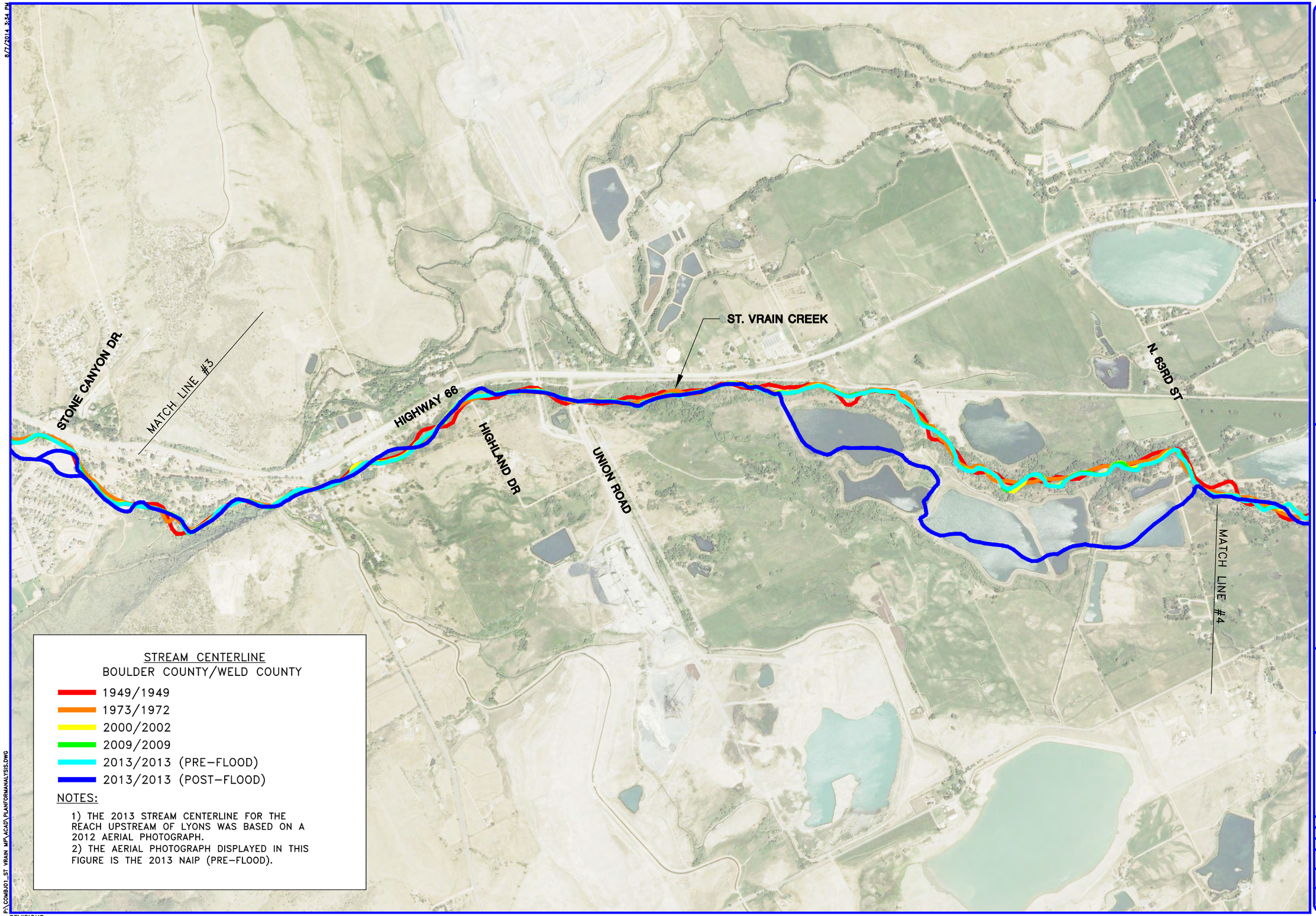

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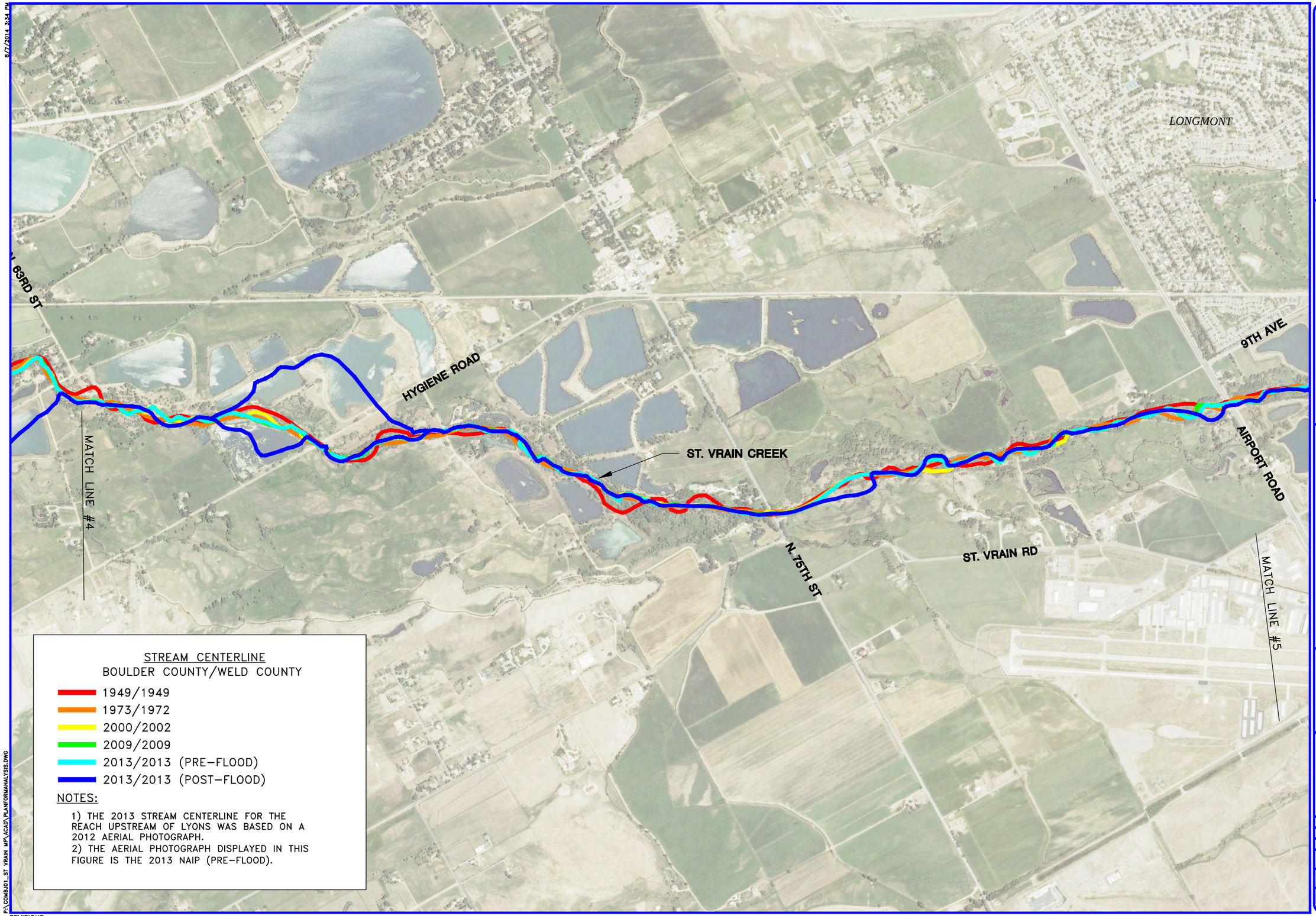

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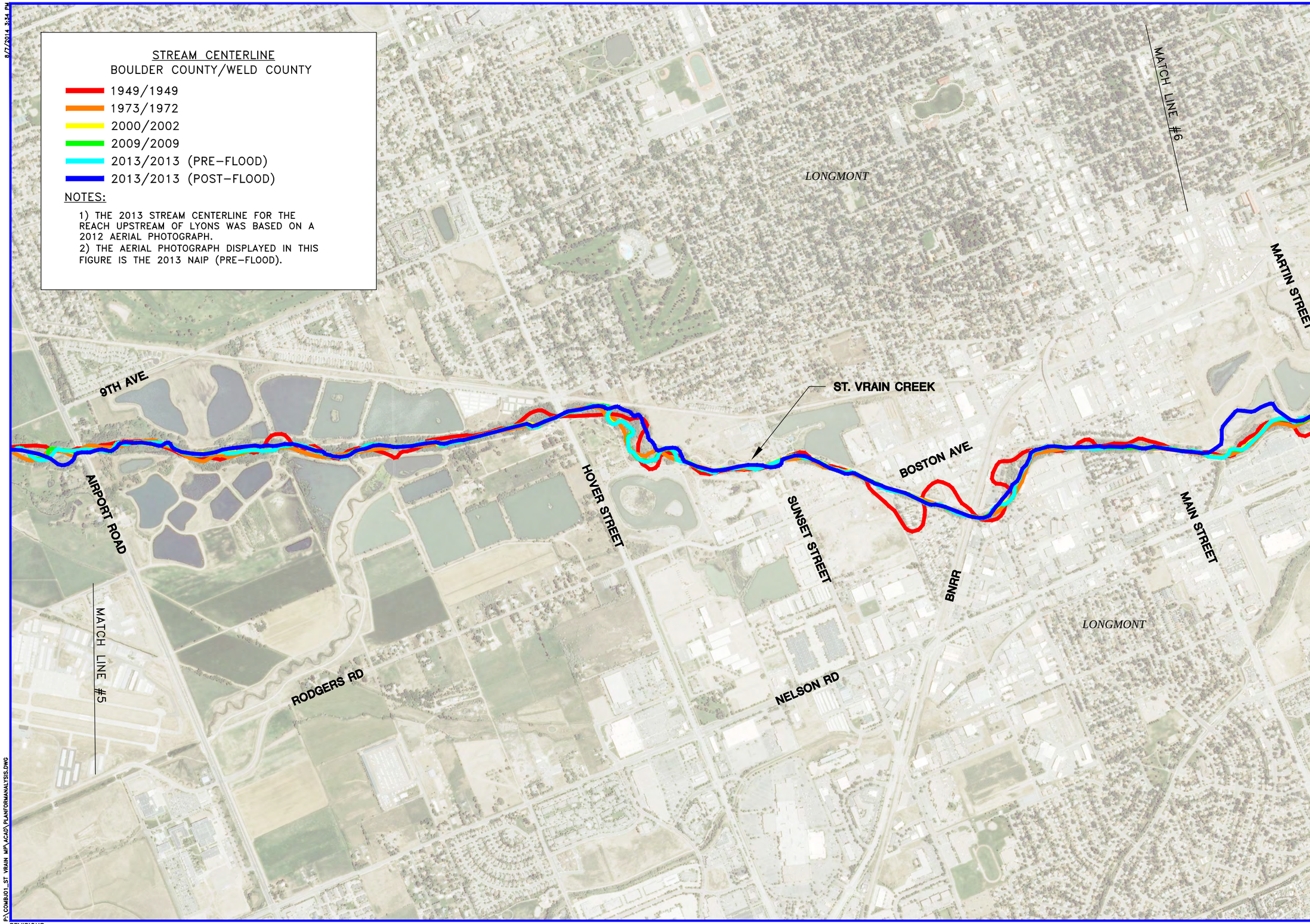

Anderson Consulting Engineers, Inc
Civil / Water Resources / Environmental
5715 Ute Highway, Longmont, Colorado 80503
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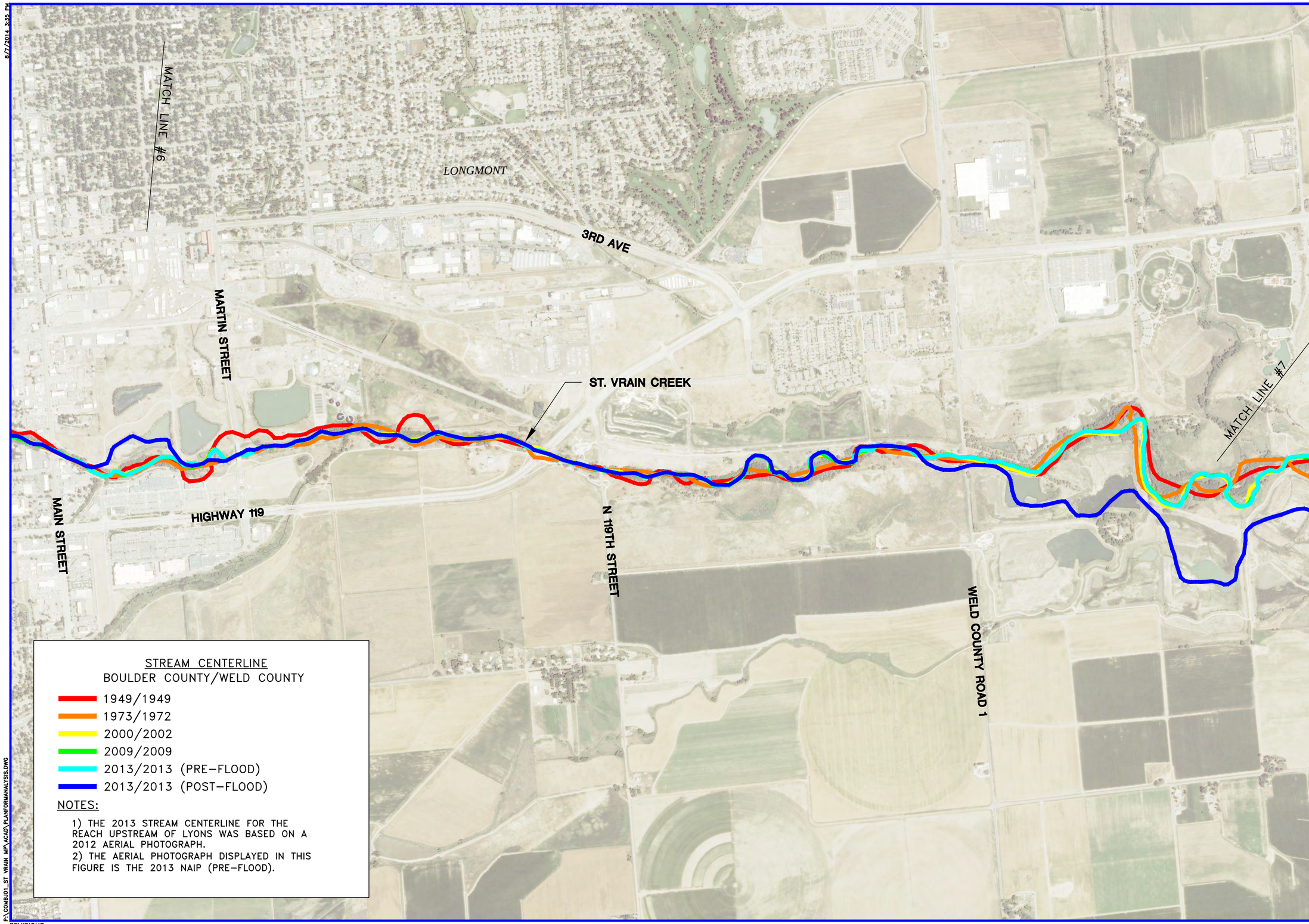

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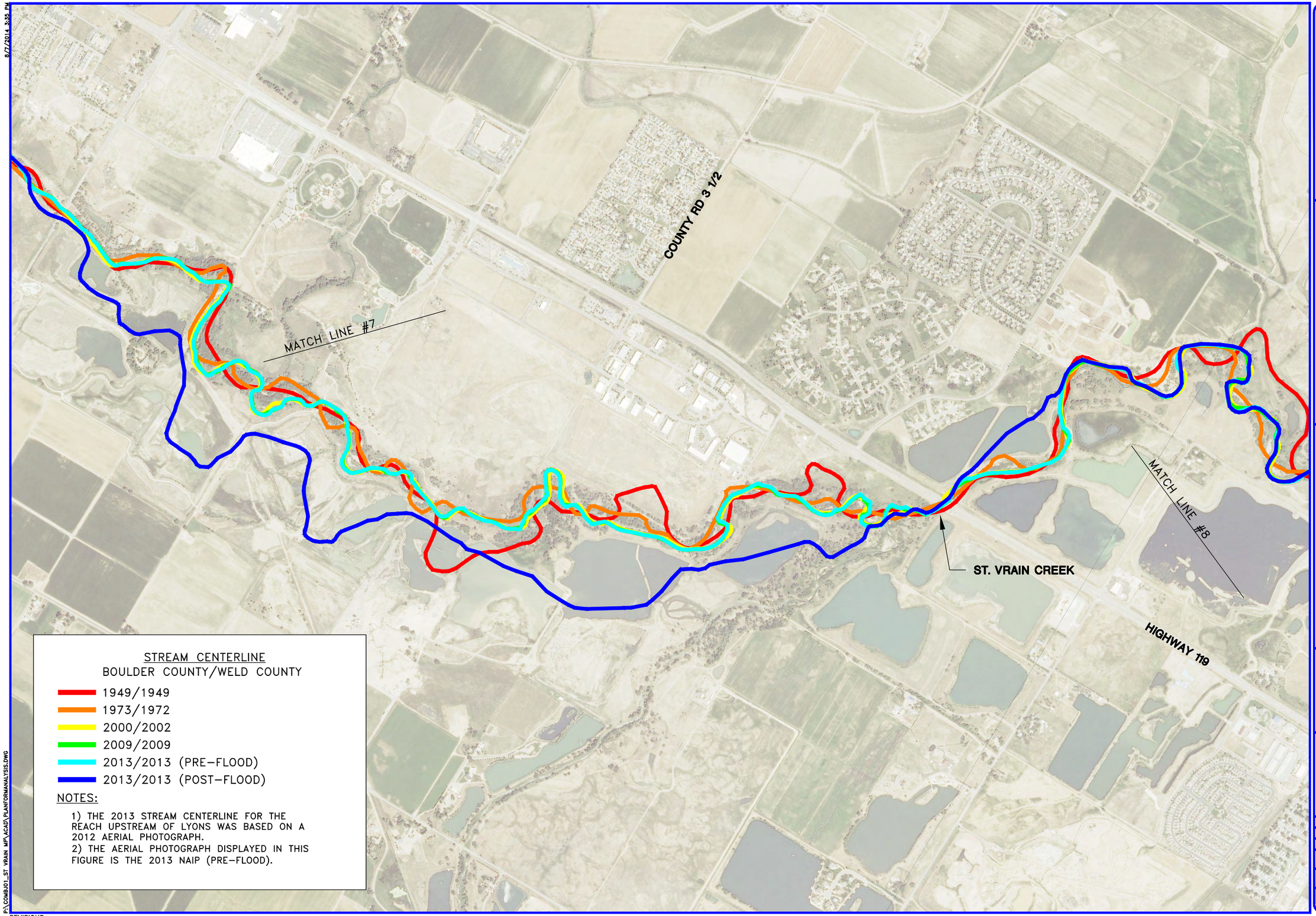

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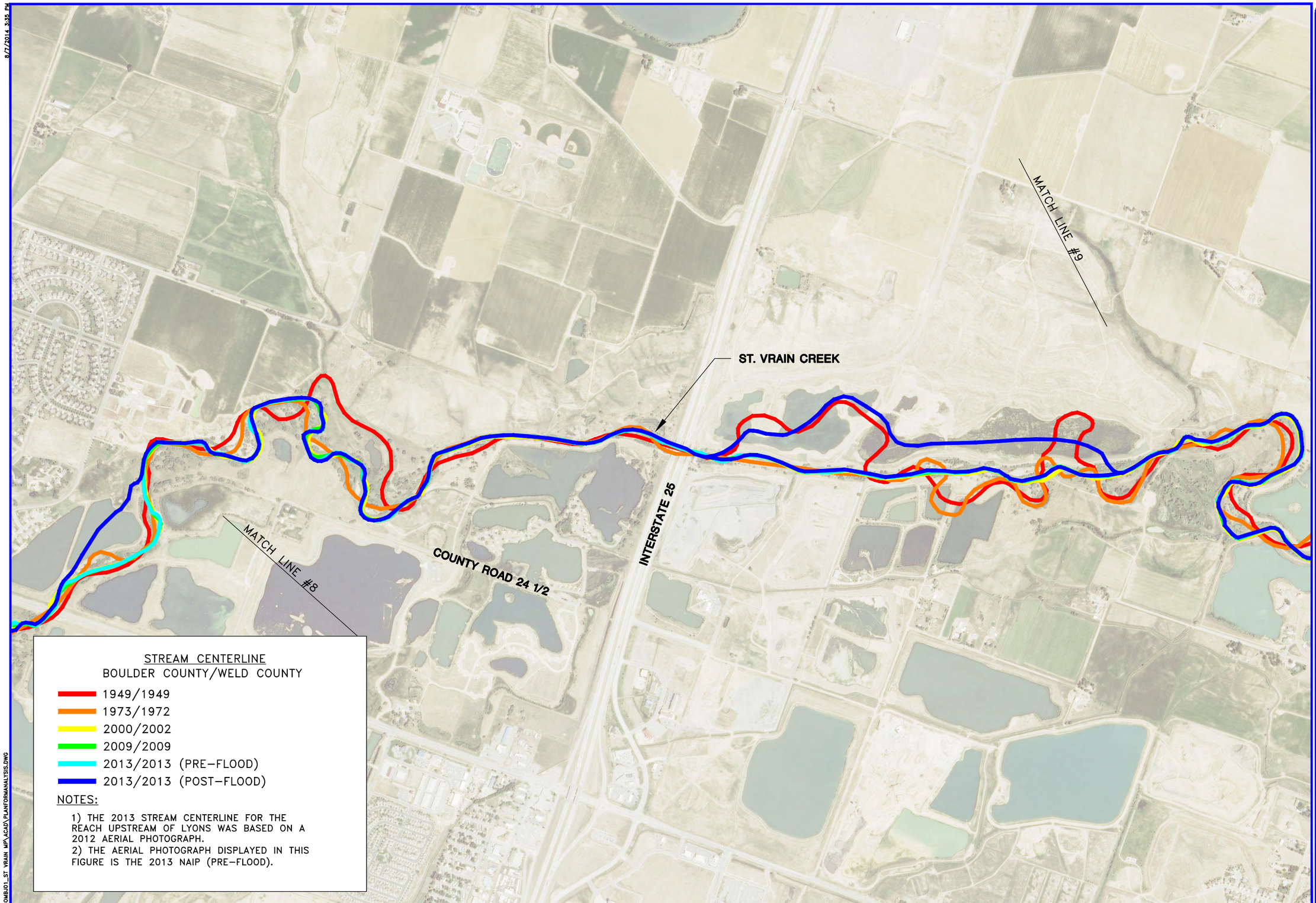

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GEOMORPHIC ASSESSMENT: PLAN FORM ANALYSIS

ST. VRAIN CREEK MASTER PLAN BOULDER COUNTY

GRAPHICAL SCALE IN FT:
0 100 200 400

DRAWN BY:	BDT
DESIGNED BY:	JDD
CHECKED BY:	GJK
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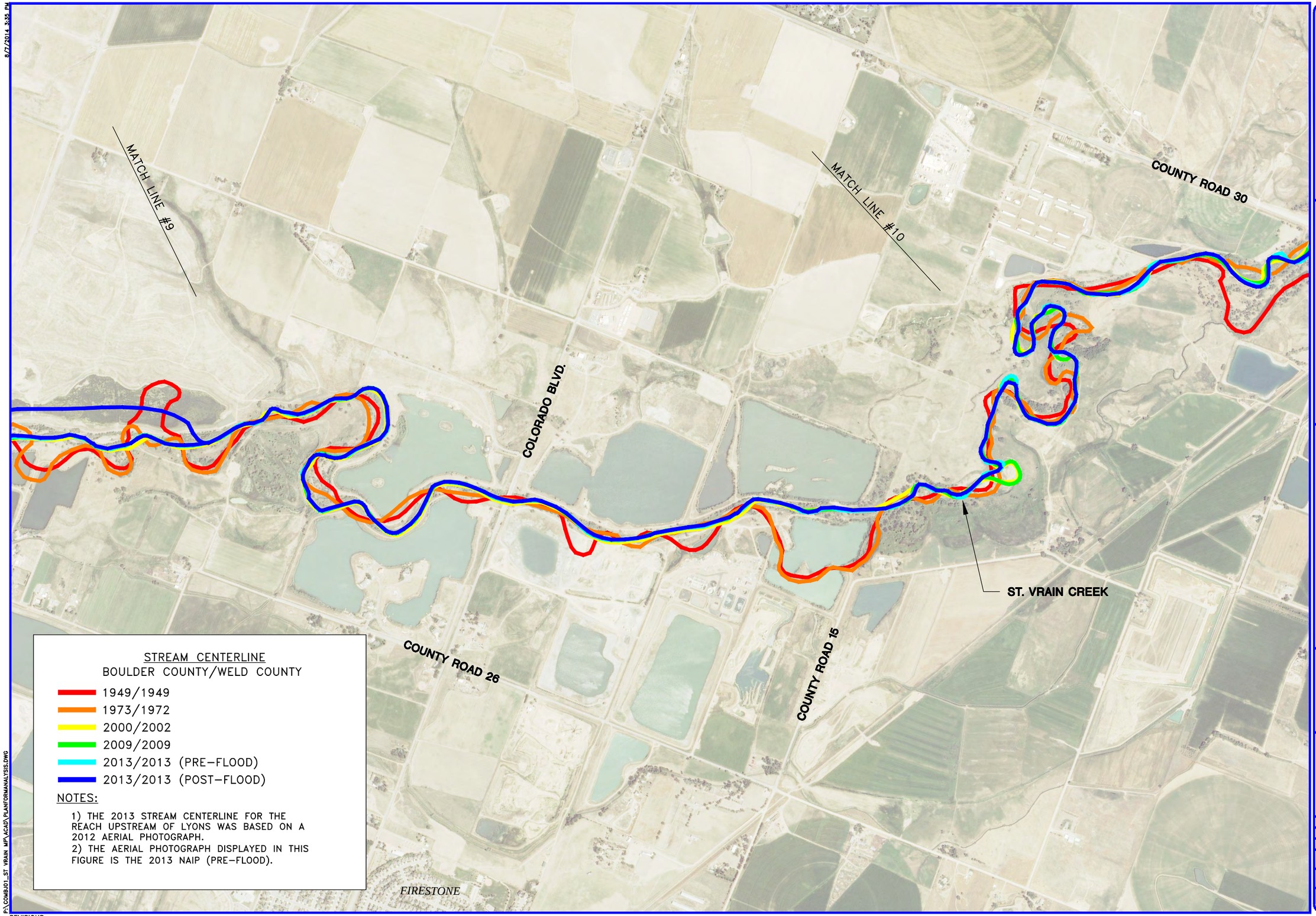

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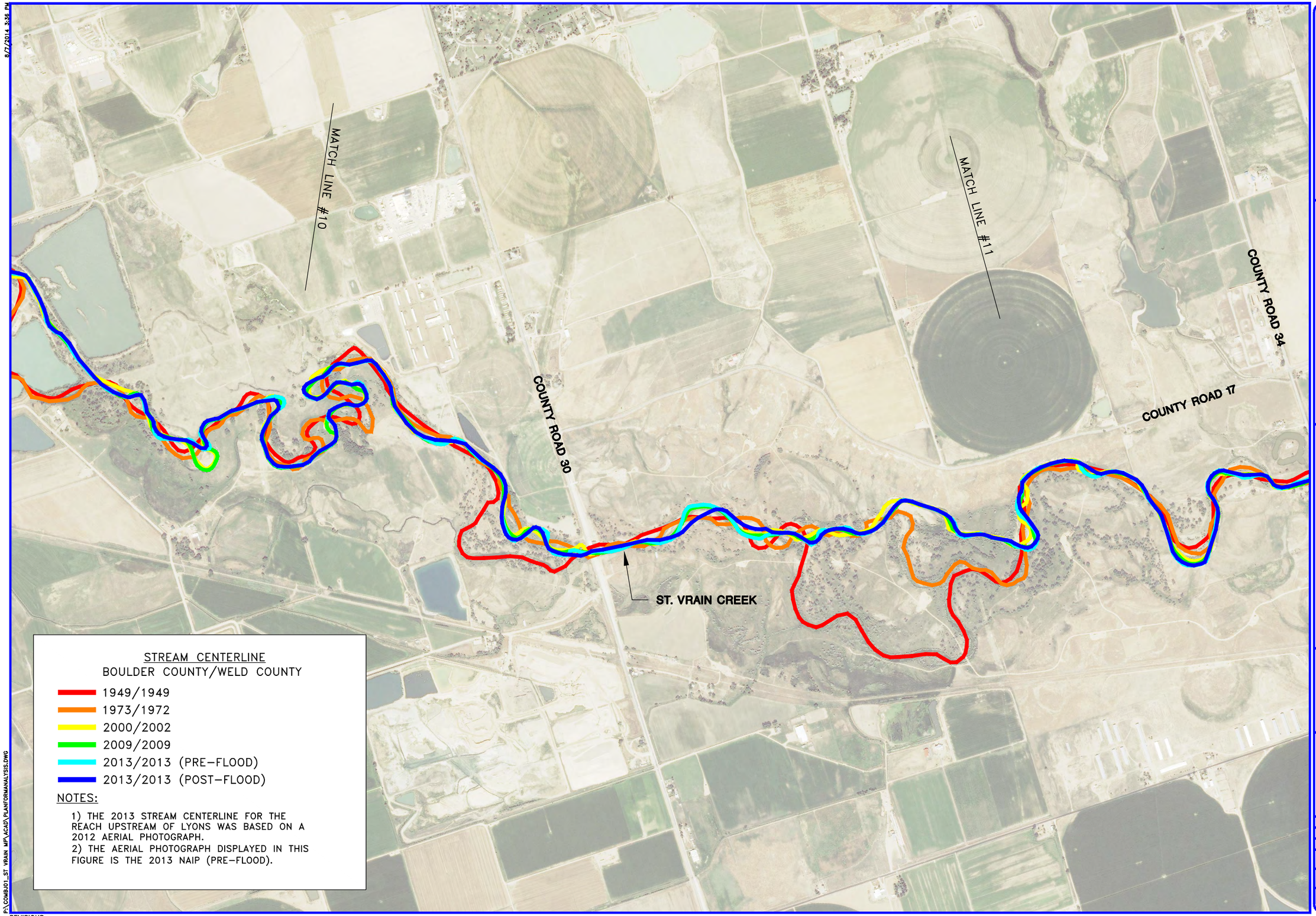

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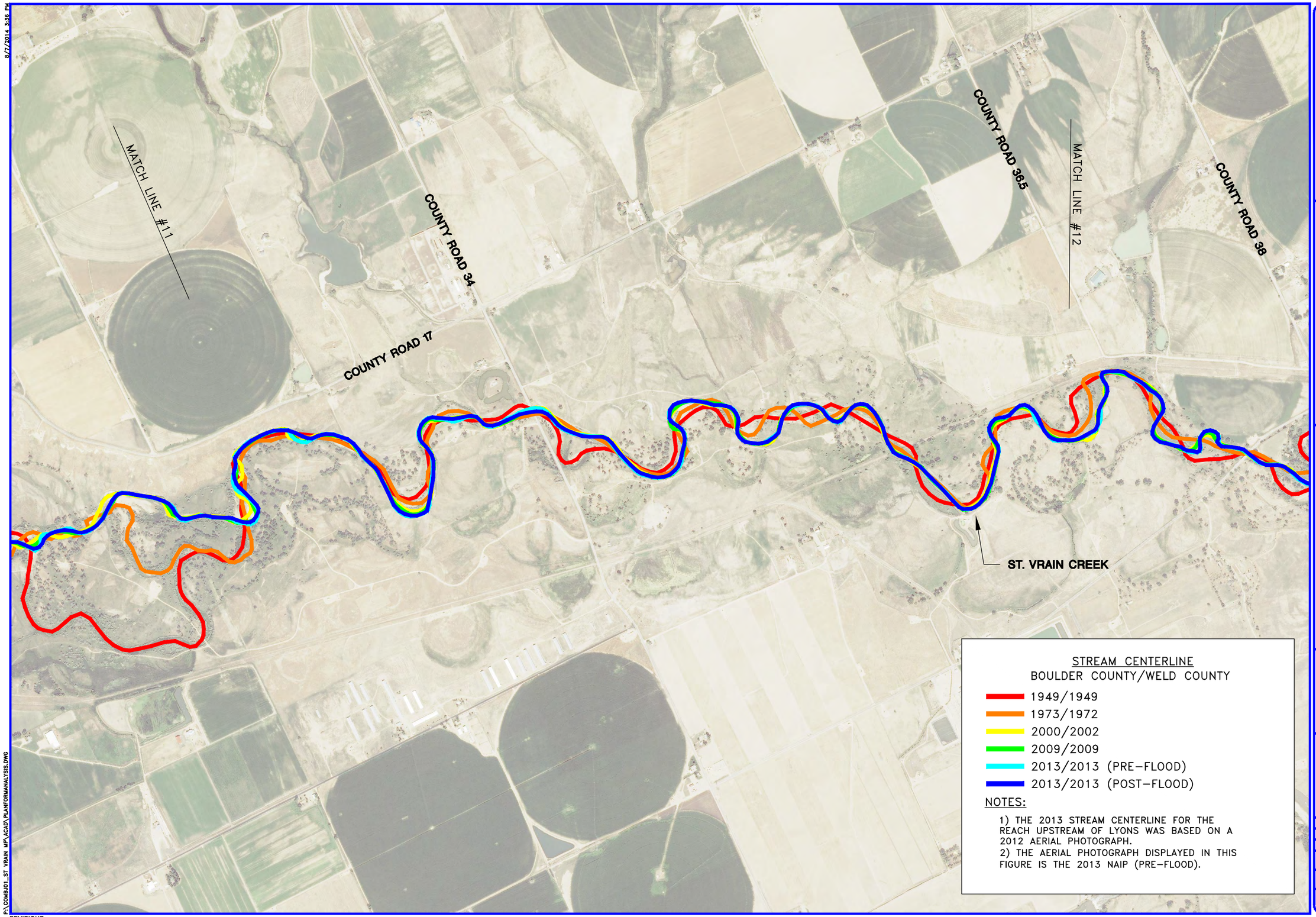

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Phone (970) 226-0120 / Fax (970) 226-0121
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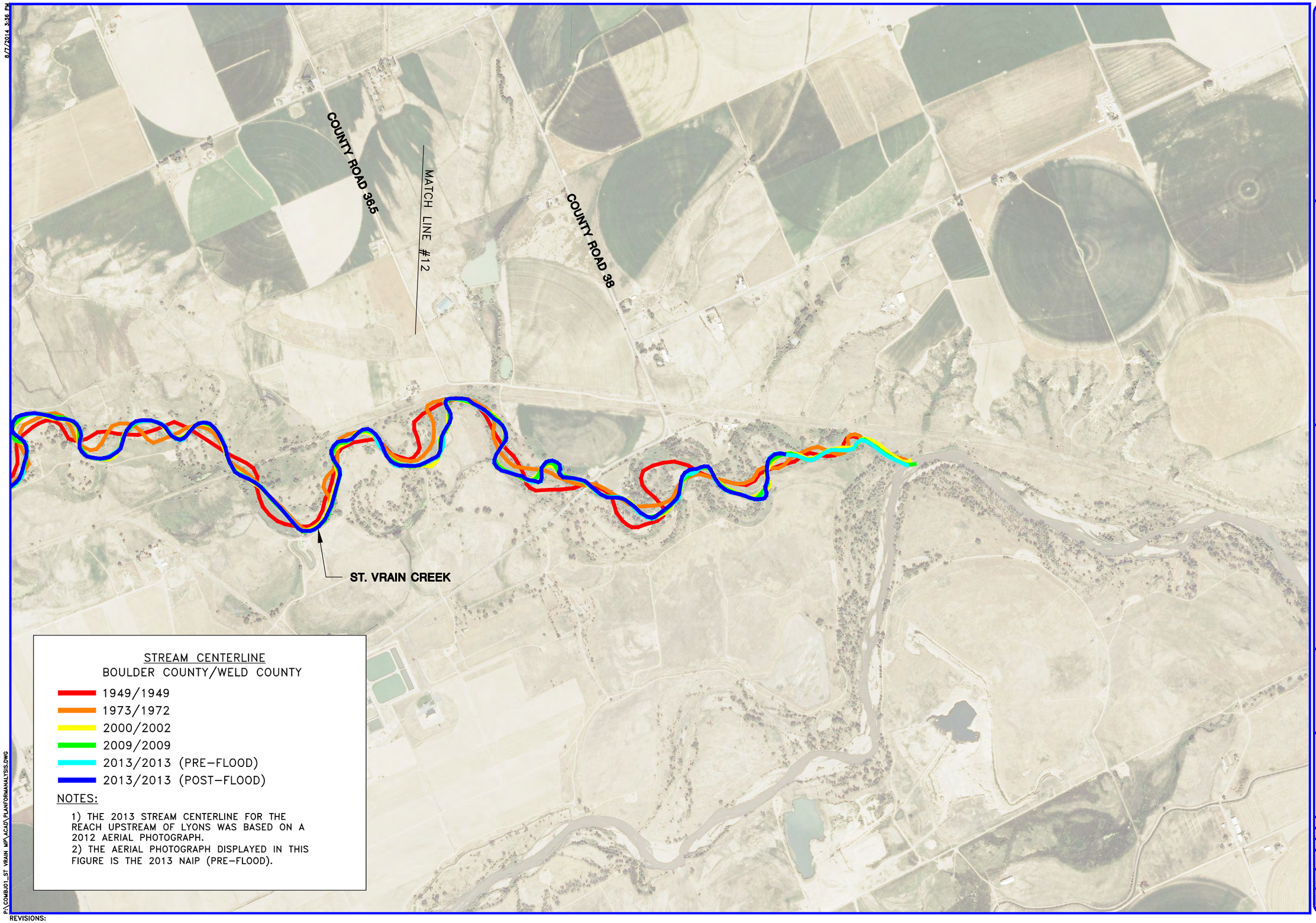

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Civil / Water Resources / Environmental
373 East Elkhorn Avenue, Estes Park, CO 80517
Phone (970) 226-0120 / Fax (970) 226-0121
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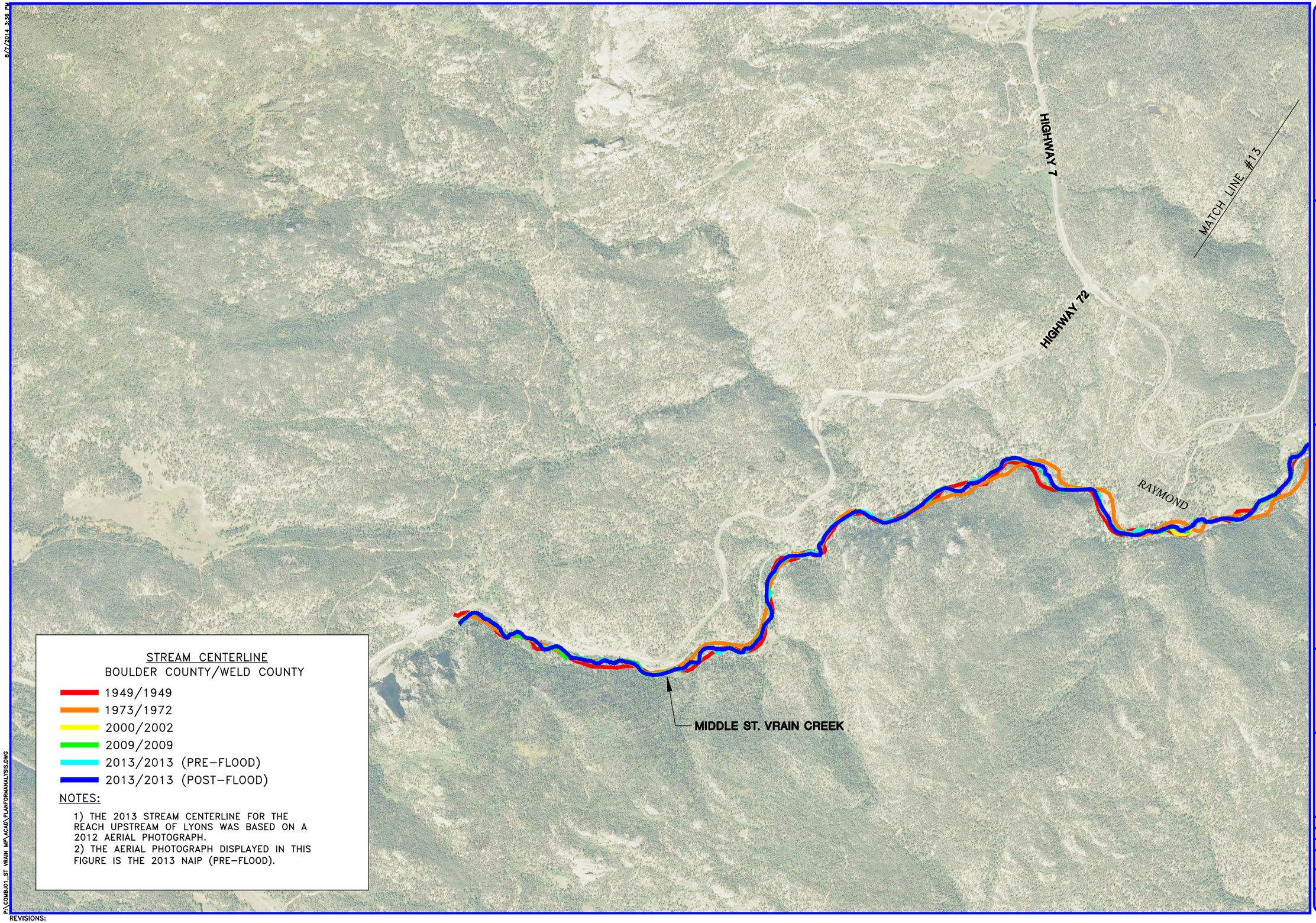

Anderson Consulting Engineers, Inc
Civil / Water Resources / Environmental
373 East Elmer Street, Lyons, Colorado 80540
Phone (970) 236-0120 / Fax (970) 236-0121
www.acewater.com

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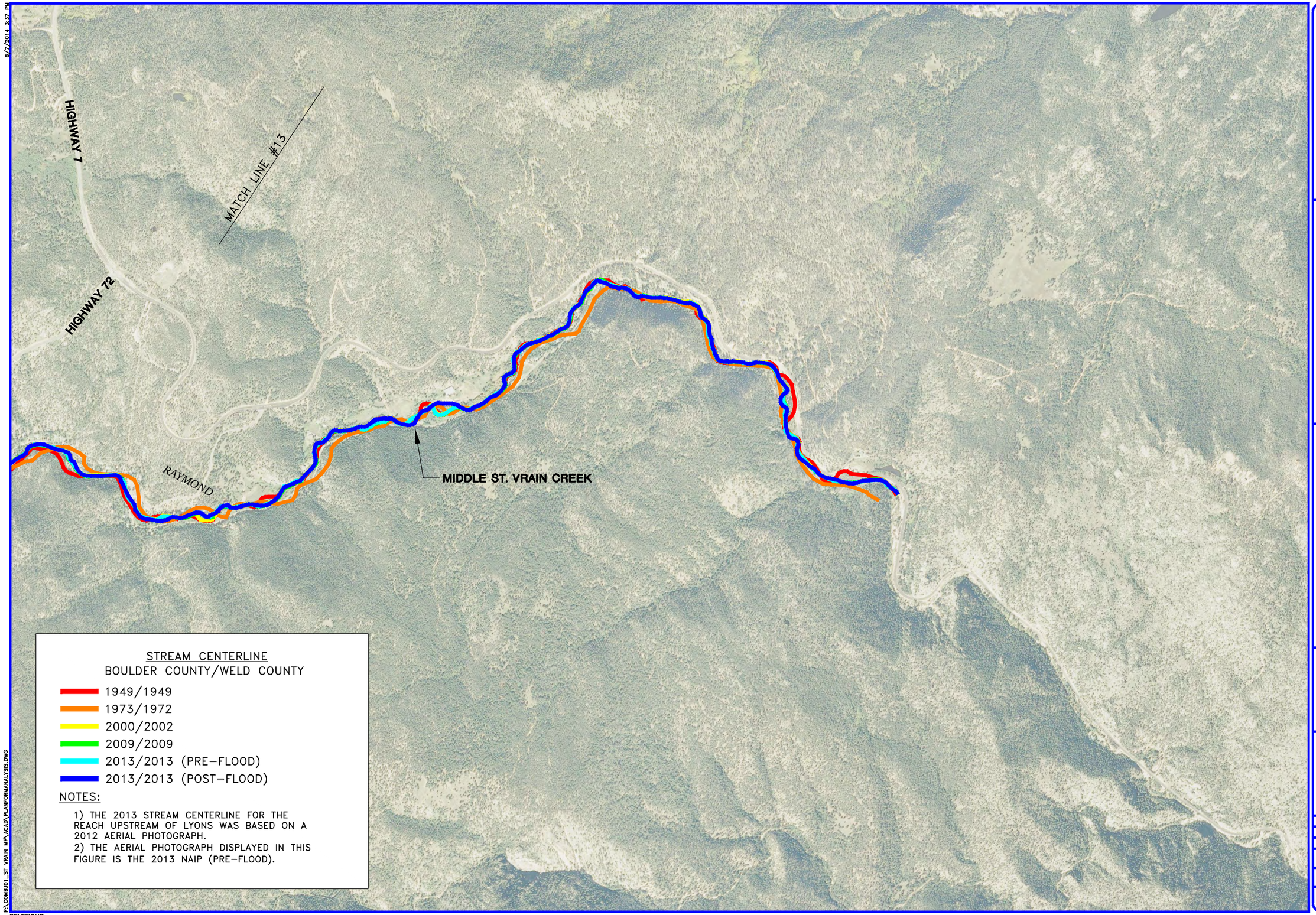

Anderson Consulting Engineers, Inc
Civil / Water Resources / Environmental
373 East Elmer Street, Lafayette, Colorado 80026
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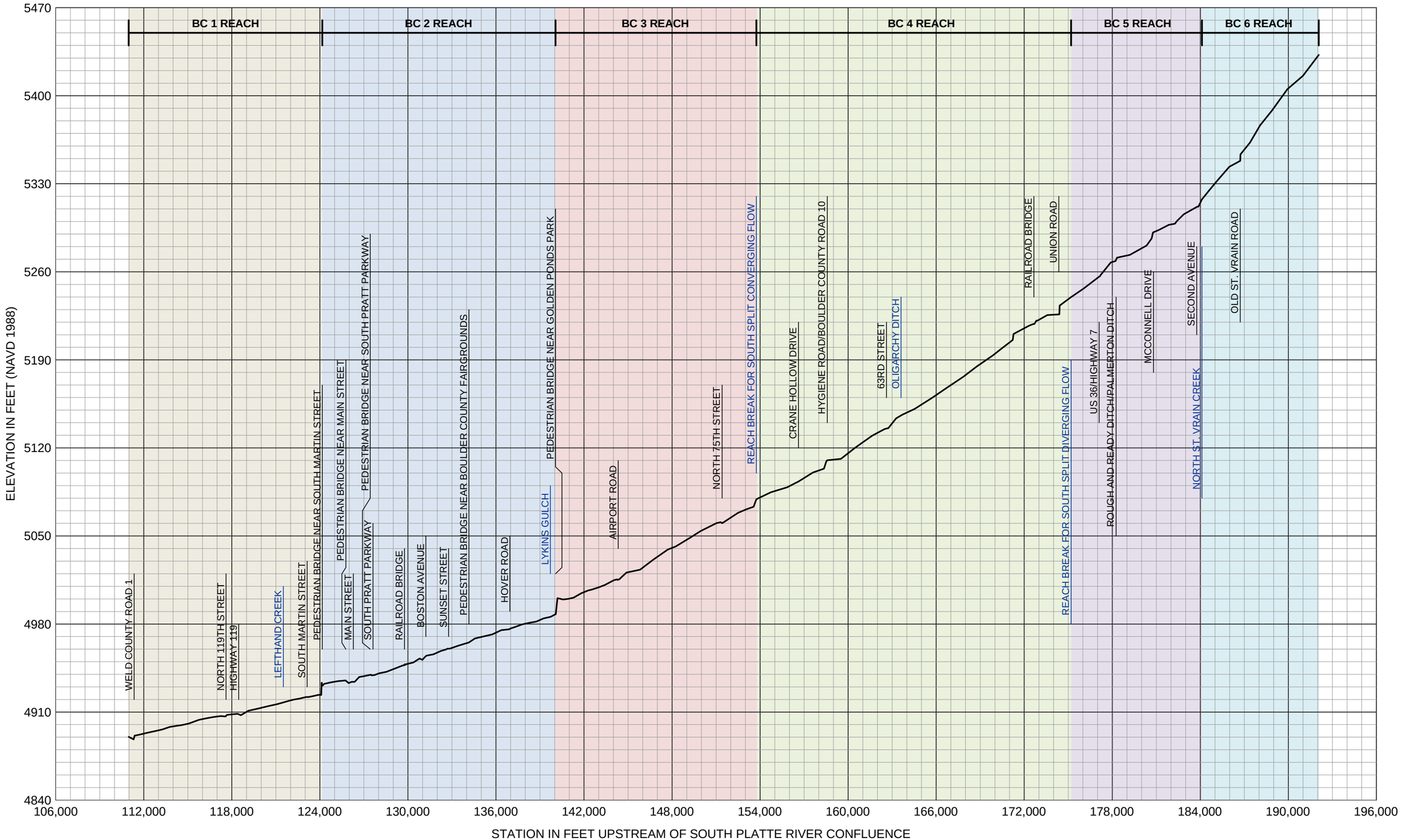


Figure 1. Streambed Profile for St. Vrain Creek and South St. Vrain Creek (Pre-Flood).

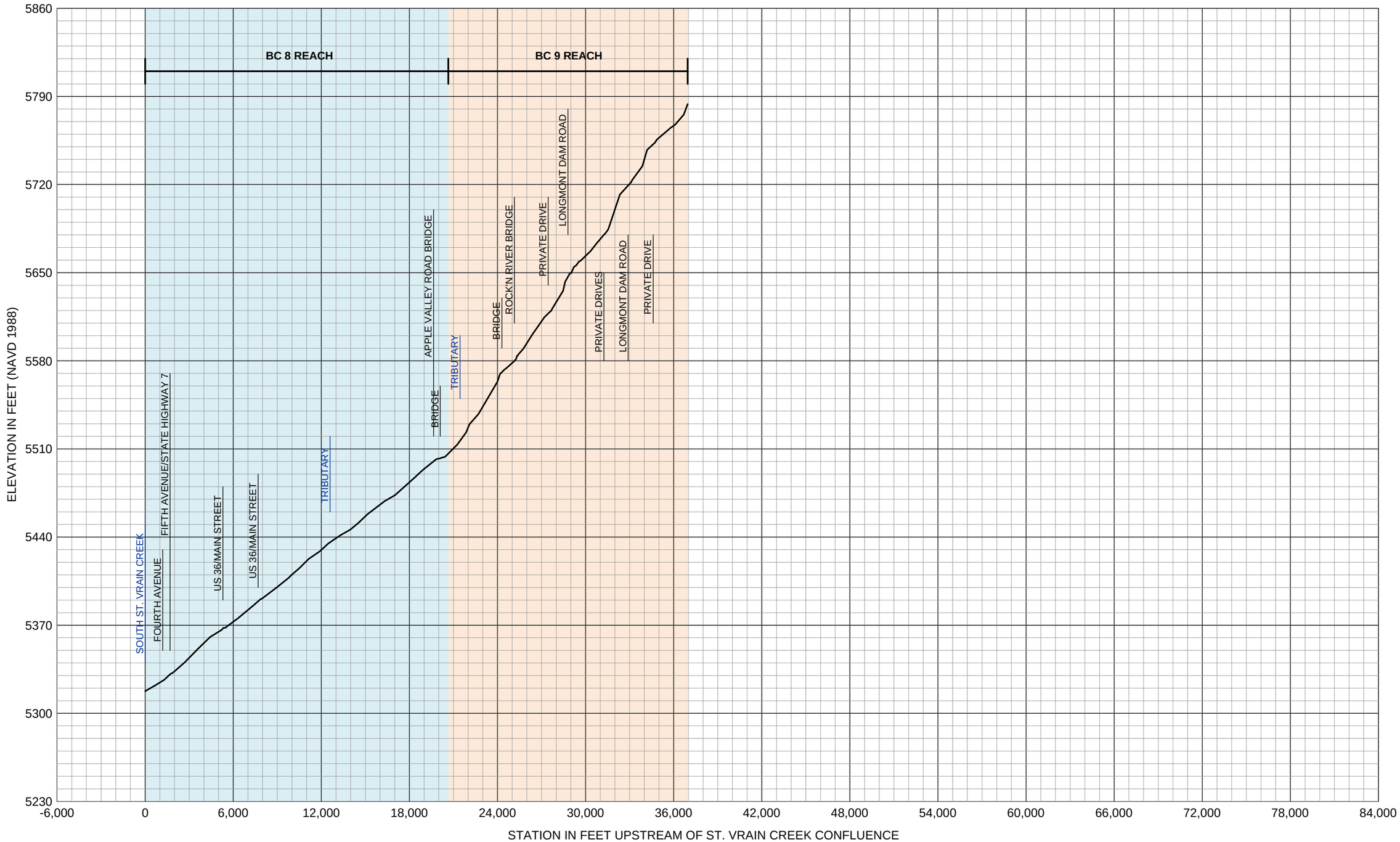


Figure 2. Streambed Profile for North St. Vrain Creek (Pre-Flood).

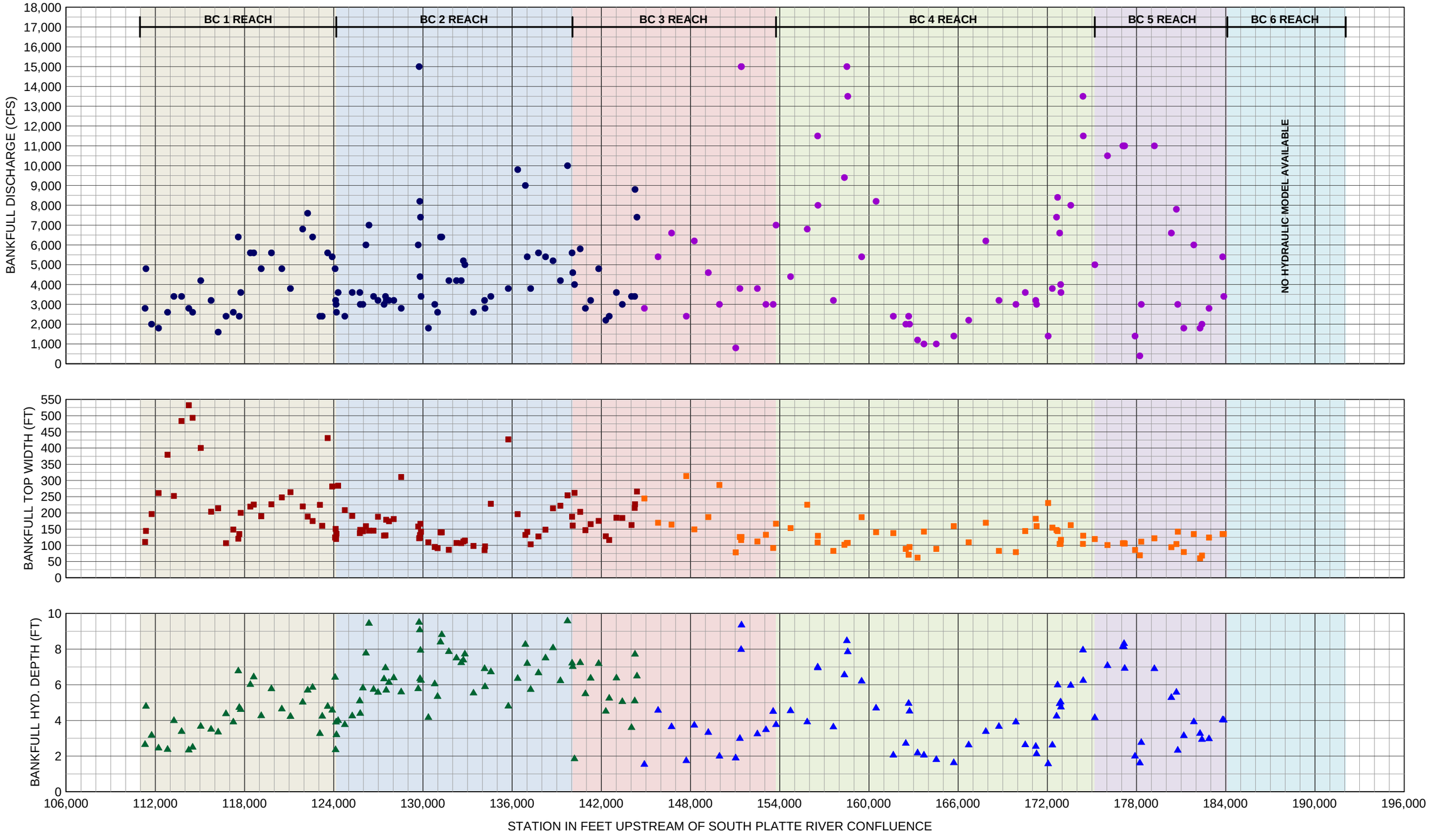


Figure 3. Bankfull Hydraulic Characteristics for St. Vrain Creek (Pre-Flood).

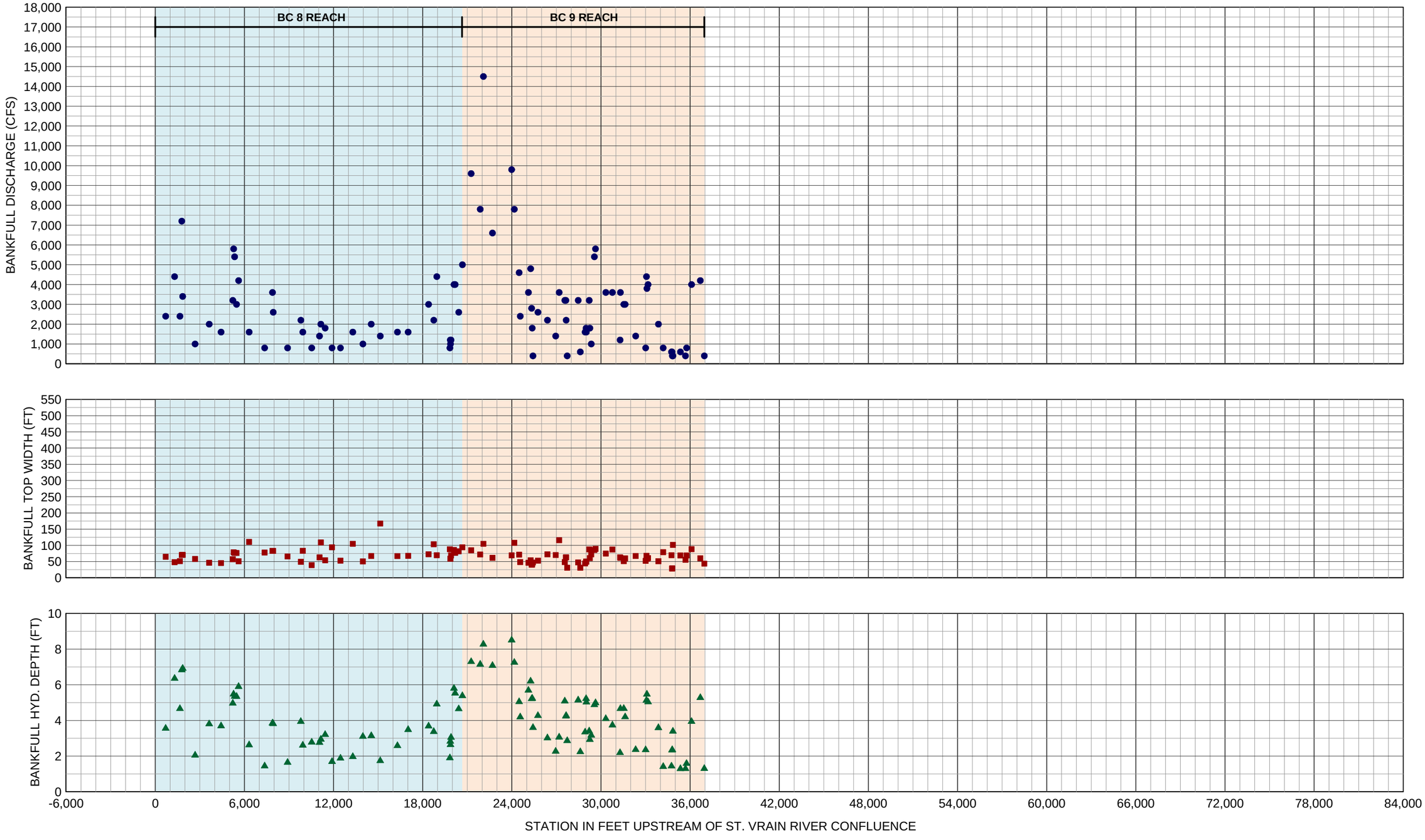


Figure 4. Bankfull Hydraulic Characteristics for North St. Vrain Creek (Pre-Flood).

Walsh
Environmental Scientists and Engineers, LLC
an **ecology and environment** company

Technical Memo

To: David Jula, PE – Michael Baker Jr., Inc.

From: Katie Jagt, PE, Michael Blazewicz, and Julie Ash, PE – Walsh Environmental

Date: July 28, 2014

Re: Geomorphic Assessment of St. Vrain Creek System

Introduction

As part of the St. Vrain Creek Watershed Master Planning project, scientists and engineers from Walsh Environmental completed a geomorphic assessment of the St. Vrain Creek system, consisting of a rapid geomorphic assessment and the mapping of a planning-level channel migration zone (pCMZ). The rapid assessment and pCMZ mapping cover St. Vrain Creek, including its North St. Vrain, South St. Vrain and Middle St. Vrain tributaries. This memo is intended exclusively for planning purposes and only within the context of the St. Vrain Watershed Master Planning project and the Boulder County Comprehensive Creek Planning Initiative.

The rapid geomorphic assessment began with a remote sensing evaluation of geomorphic reaches followed by several field days of visual "windshield surveys" to observe and record field data related to stream channel type, dominant bed material, and dominant channel erosion and sedimentation processes. These surveys were necessarily limited to points along the stream that were easily accessed by car or short walk, as well as by access approvals for private properties and other parcels. This initial field work was followed by supplemental analysis of alluvial landforms using available GIS data and aerial imagery. Final evaluation and quality checks and assurances were obtained during a follow-up field day.

There are two objectives for these data and analysis:

1) <u>System Understanding via Rapid Geomorphic Assessments</u>: Define post-flood geomorphic conditions in the St. Vrain system to supplement an overall understanding of the dynamics of the St Vrain Creek and assist with focusing on geomorphically appropriate flood risk reduction and restoration strategies. As the rapid assessment employed representative reaches, future investigations should include comprehensive evaluations of berms, crossing structures, floodplain fills, and other features that contribute to instability.

2) Mapping of a Planning-Level Channel Migration Zone (pCMZ) : A channel migration zone (CMZ) refers to the area a stream has occupied in recent history and may migrate through again as it moves, stores, and reworks its sediment load on its path down the valley. Identification and management of these channel migration zones is intended to reduce flood damage to community and private infrastructure – all of which may be in jeopardy when and if the channel does re-occupy this area. A CMZ can also be thought of as the "river corridor" where dynamic system processes, under a broad range of flow conditions, can occur providing for long-term geophysical and biological stability. The pCMZ is intended to offer local governments insight into the likely long-term behavior of their streams and to aid their efforts to reduce future flood and erosion damage and improve riparian and aquatic habitat through the management of a river corridor.

Methods

Rapid Geomorphic Assessments

As a first step in the rapid geomorphic assessment, Walsh scientists and engineers identified geomorphic reaches, or sections of the St Vrain Creek, with roughly homogenous physical and dynamic characteristics. For planning purposes it is important to delineate zones with similar migration potential, river planform patterns, or valley characteristics. Possible geomorphic reach-break criteria included:

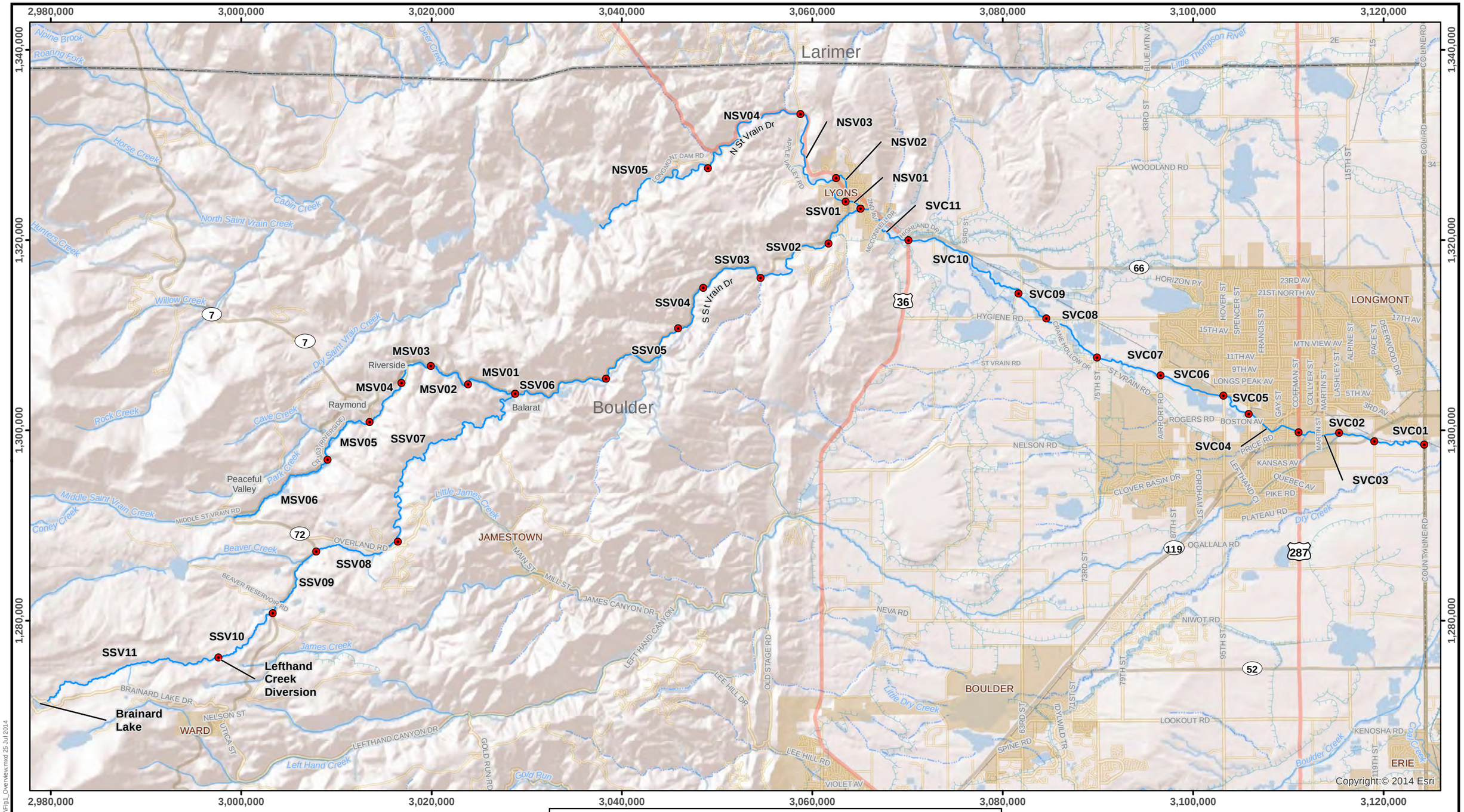
- Changes in gradient (proportional to sediment transport capacity)
- Changes in valley width and channel confinement
- Tributary junctions (changes in the ratio of sediment transport capacity to sediment supply)
- Changes in channel pattern
- Changes in infrastructure that control lateral erosion and migration
- Changes in geology/ erodibility of adjacent valley slopes
- Changes in land use

In total, 33 geomorphic reaches were identified within the study area, see Figure 1.

Walsh scientists and engineers conducted a rapid visual survey of existing geomorphic conditions during a driving tour of the creek corridors, which included short walks to channel access points when possible. Qualitative assessments of the geomorphic conditions for each reach were recorded at representative locations within each reach. While it is our best professional judgment that the qualitative assessments represent general conditions in the reach, they are a generalization of the most dominant characteristics in the corridor and do not exclude the possibility that other conditions are or could be present. This study was scoped to be a rapid visual assessment and as such, no quantitative measures of channel or valley width, width to depth ratios, grain size, or other widely accepted geomorphic characteristics were determined.

Based on visual assessments, estimates of existing and reference stream channel type and form, dominant bed material, channel evolution stage, and dominant sediment transport processes were made for each reach.

- Existing and reference stream channel type and form—Stream channel type, using Rosgen (1994) and Montgomery-Buffington (1997) stream type classifications, were assessed for



NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 5
Miles
1 inch = 9,500 feet

Reach Break	St Vrain Creek	U.S. highway
Town boundary	Perennial stream	State highway
County boundary	Intermittent stream	Major road
Railroad	Canal/ditch	Local road

Figure 1
Reach Locations
St. Vrain Creek
Boulder County, Colorado

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existing conditions as well as reference conditions (i.e., equilibrium conditions). Rosgen classification uses numerous discrete classes represented by a suit of morphologic parameters used to categorize a stream reach (e.g., B2, C3b). Montgomery-Buffington (primarily used in mountain stream systems) uses seven categories represented by channel substrate or bed form (e.g., cascade, step pool, pool riffle, plane bed).

- Dominant bed material—Dominant bed material (D_{50}) was visually and qualitatively identified for each reach as either bedrock, boulder, cobble, gravel, or sand. An assessment was also made as to whether the existing dominant material would be part of the reference conditions.

- Channel evolution stage—The channel evolution model described by Schumm, et. al. (1984) was used to assess the current channel condition and active processes in terms of streambed adjustment. As shown in Figure 2, the model includes five stages that describe the adjustment of a streambed starting with incision, the detachment from the existing floodplain, and eventually the formation of a new floodplain at a lower elevation. Based on evidence of bank stability, floodplain connectivity, and meander migration, each reach was assigned a channel evolution stage. While these stages are provided for instructional purpose and to aid in predicting future adjustments (and indeed strong on-the-ground correlations do frequently exist) it should be noted that the Schumm model does not account for aggrading channels, multi-thread channels, and non-linear processes, all of which exist in the St. Vrain creeks. New models are being developed to describe these conditions, such as the Stream Evolution Model (Cluer & Thorne, 2013), however, for the purposes of this rapid geomorphic assessment, the widely adopted and current industry standard Schumm model was utilized.

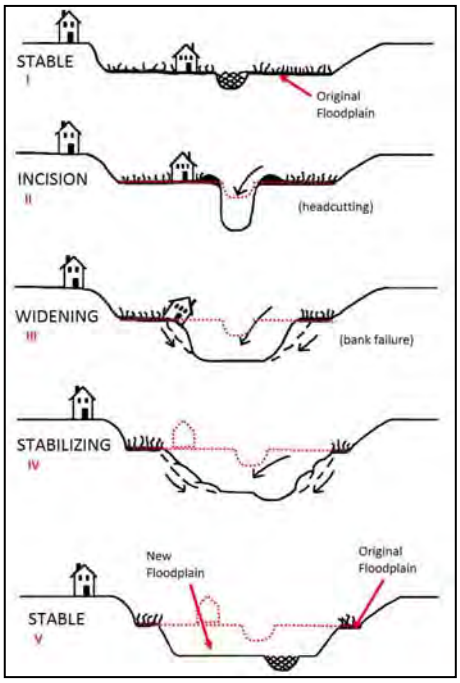

Figure 2: Conceptual representation of channel evolution model based on (Schumm, et al., 1984). Source: (Kline, 2010)

- Dominant sediment regime type—Dominant sediment regimes were evaluated for each reach, using guidelines presented in Kline (2010). Sediment regime mapping attempts to characterize the source and fate of both fine and course sediment loads (i.e., wash and bed loads) which can be a useful exercise in project development and attempting to restore equilibrium conditions to a watershed. Based on existing stream type and condition, channel evolution stage, degree of incision and width, and channel alterations, each reach is categorized singularly or as a combination of a “source”, “transport”, or “deposition” reach.

Planning-Level Channel Migration Zone Mapping

There are several scientifically vetted protocols in states with similar physiographic characteristics that provide guidance on the mapping of channel migration zones. For this assessment, Washington

State's pCMZ method was selected, based on Washington State's *DRAFT Planning-Level Channel Migration Zone Assessment and Delineation Methodology* (Ecology et al., 2014).

The following items were mapped for the St. Vrain Creek system using digital elevation models (DEMs) derived from the 2013 post-flood LiDAR and 2013 post-flood aerial photography:

1) ***Modern Valley Bottom (MVB)***: LiDAR derived DEMs were used to remotely delineate the modern valley bottom (MVB), which encompasses the area where channel migration has occurred in the past few thousand years. Due to the ease of accessibility during a flood event and the nature of the surficial geology (alluvium), the MVB is an area of very high hazard because reoccupation by the river during a flood event is likely.

2) ***Avulsion Hazard Zones (AVZ)***: Within the MVB, there are low areas with abandoned or relict channels connecting to the main active channel, or low portions of the valley connected to the active channel with gradients steeper than the active channel gradient. These are areas where abrupt shifts in channel location have the possibility to occur at moderate to high flows and may have catastrophic consequences for adjacent property and infrastructure. These are extreme hazard areas.

3) ***Erosion Hazard Area (EHA):*** The erosion hazard area accounts for potential valley widening caused by future channel migration. The extent of the EHA is related to the erodibility of the valley walls as well as the likelihood that the stream channel will come into contact with these features. These are areas of high hazard.

4) ***Alluvial fans (AF):*** Alluvial fans are fan-shaped accumulations of alluvium that form along the margins of larger valleys at the mouths of tributary valleys. The natural tendency of the tributary streams to drop their sediment loads and avulse on alluvial fan surfaces makes them potentially hazardous areas for development. These are areas of very high hazard.

5) ***Disconnected Migration Area (DMA):*** Disconnected migration areas (DMA) are low-lying areas that would naturally be mapped within the MVB of a stream channel but are disconnected from channel migration influence by man-made structures such as levees, railroads, and major roads. When observed, these areas were mapped outside of the pCMZ though still have the potential to capture flow if the infrastructure fails. Their mapping may indicate areas where future floodplain reconnection projects could occur. These are areas of high hazard.

The complete methodology for the pCMZ method can be found in Washington State's *DRAFT Planning-Level Channel Migration Zone Assessment and Delineation Methodology* (Ecology et al. (2014).

Results

Rapid Geomorphic Assessment

Reach-scale rapid geomorphic summaries are documented in Appendix A as well as in Table 1. While these reach-scale assessment results are important to document on-the-ground conditions and processes, they may not fully convey the overall patterns and landscape scale trends that best describe how the St. Vrain Creeks are delivering their water and sediment from their headwaters to the plains east of Longmont. The following descriptions are provided as an overview, not comprehensive assessment, of the dominant forces and processes.

Upper South St. Vrain Creek – Brainard Lake to Confluence of South and Middle St. Vrain Creeks

The South St. Vrain Creek spilling out of Brainard Lake holds very little sediment due to sediment capture by the Lake. The creek runs east in a semi-confined valley, reaching the Lefthand Ditch Diversion structure several miles downstream and at which point its flows are significantly diverted. The remaining water tumbles through a steep boulder controlled forested valley, eventually gaining Beaver Creek and some other minor tributaries near the Peak to Peak Highway (Colorado State Highway 72) north of Ward, Colorado. Here it is confined by the highway in what historically was likely a beaver dominated wetland system. Downstream the valley opens up in the vicinity of Overland Road before pinching down and entering a canyon near the Ceran St. Vrain trailhead. This canyon is remote and dominated by U.S. Forest Service land with very little access. It is likely a very stable riffle and step-pool dominated system with large amounts of woody debris recruitment and colluvial inputs from the surrounding hillsides.

Middle St. Vrain Creek — Highway 72 to Confluence of South and Middle St. Vrain Creeks

The Middle St. Vrain Creek flows out of the Indian Peaks Wilderness area arriving in Peaceful Valley as a boulder/ cobble dominated step-pool system. As it enters the small developments of Raymond and then Riverside, the valley slope decreases and bedload sediments drop out as channel meanders amplify in the wider valley bottom. From here, development increases in the stream corridor as does the presence of numerous undersized crossing structures and attempts to confine the channel, which further destabilize it. At the eastern edge of Riverside, Colorado State Highway 7 (Highway 7) significantly occupies the Middle St. Vrain corridor downstream to its confluence with the South St. Vrain Creek. The Highway 7 embankment disconnects former floodplain areas and removes meander bends resulting in several mapped DMZs.

Lower South St. Vrain Creek – Confluence of South and Middle St. Vrain Creeks to Confluence of North and South St. Vrain Creeks

The South St. Vrain Creek emerges to join the Middle St. Vrain Creek nearly doubling its size into the main canyon. From this point until the mouth of the South St. Vrain Canyon the river corridor is dominated by Highway 7. Steep tributaries periodically bring sediments into the main channel which, lacking floodplain meandering ability, transports material out to the canyon mouth. At the mouth (near the gravel quarry upstream of Lyons) the valley slope significantly flattens, the channel becomes unconfined and the South St Vrain becomes a highly depositional riffle-pool gravel dominated C-type channel with a propensity for braiding and meandering. Alteration of the corridor and reaction to these depositional features results in channel dredging, straightening, and berming into and through the Town of Lyons where it joins with the North St. Vrain Creek.

North St. Vrain Creek — Button Rock Dam to Confluence of North and South St. Vrain

The Ralph Price Reservoir behind Button Rock Dam stores runoff and bed load sediments carried down from its feeder streams. At the outlet of the Dam, which is the upstream boundary for this study, the North St. Vrain Creek is a sediment-starved channel flowing through a semi-confined valley. The reservoir access road has confined the channel significantly through this valley and was overtaken during the September 2013 flood as the sediment-starved channel had significant erosive capability and a desire to fully meander within the valley bottom. This trend of narrow valley with road encroachment continues downstream through the Highway 36 corridor where erosional energy is transferred to outside meander bends and to the most erodible surfaces. Upon reaching the canyon mouth at Apple Valley, the North St. Vrain Creek may be both erosive and depositional at the same time plugging old channels and cutting new ones through valley bottom alluvial soils as it struggles to capture and then maintain its sediment load. Bedrock escarpments at the mouth of Apple Valley force the channel through a series of tight meanders before sluicing through a straightened and armored channel within the Town of Lyons to meet the South St. Vrain Creek.

St. Vrain Creek — Confluence of North and South St. Vrain Creeks to County Line Road

The St. Vrain Creek downstream of the North and South St. Vrain Creek confluence is a meandering gravel-bed riffle-pool channel in a wide valley bottom. A vegetated riparian corridor is interrupted by floodplain ponds (a result of historical gravel mining operations), road crossings, and development as it makes its way downstream through Longmont to County Line Road. Historical channel and floodplain alteration are pervasive. Stream power declines, as the extent of overbank flooding increases.

Table 1: Geomorphic Summaries of St. Vrain Creek Reaches

Reach	Existing Stream Type[1]	Reference Stream Type[1]	Existing Bed Form[2]	Reference Bed Form[2]	CEM Stage[3]	Existing Sediment Regime[4]	Reference Sediment Regime[4]
MSV01	B3	C3b	Plane bed	Plane bed	V	Transport	Transport
MSV02	C3b	C3b	Plane bed	Riffle-pool	III-IV	Fine Source & Transport and Coarse Deposition	Coarse Equilibrium & Fine Deposition
MSV03	B3	C3b	Plane bed	Riffle-pool	II-III	Unconfined Source & Transport	Coarse Equilibrium & Fine Deposition
MSV04	C3	C3	Riffle-pool	Riffle-pool	IV	Fine Source & Transport and Coarse Deposition	Coarse Equilibrium & Fine Deposition
MSV05	C3b	C3b	Plane bed	Step-pool	II-III	Unconfined Source & Transport	Coarse Equilibrium & Fine Deposition
MSV06	C3b	C3b	Step-pool	Step-pool	V	Coarse Equilibrium and Fine Deposition	Coarse Equilibrium & Fine Deposition
NSV01	C3	C4	Plane bed	Riffle-pool	II-III	Unconfined Source & Transport	Coarse Equilibrium & Fine Deposition
NSV02	C4	C4	Riffle-pool	Riffle-pool	I	Coarse Equilibrium and Fine Deposition	Coarse Equilibrium & Fine Deposition
NSV03	C4	C4	Riffle-pool	Riffle-pool	I	Coarse Equilibrium and Fine Deposition	Coarse Equilibrium & Fine Deposition
NSV04	B3c	C3	Riffle-pool	Riffle-pool	II-III	Unconfined Source & Transport	Coarse Equilibrium & Fine Deposition
NSV05	B3	C3b	Riffle-pool	Riffle-pool	II-III	Unconfined Source & Transport	Coarse Equilibrium & Fine Deposition
SSV01	C4	C4	Plane bed	Riffle-pool	II-III	Unconfined Source & Transport	Coarse Equilibrium & Fine Deposition
SSV02	C4	C4	Riffle-pool	Riffle-pool	N/A	Deposition	Deposition
SSV03	C3	C4	Riffle-pool	Riffle-pool	III-IV	Unconfined Source & Transport	Coarse Equilibrium & Fine Deposition
SSV04	B3	B3	Step-pool	Step-pool	II-III	Confined Source & Transport	Transport
SSV05	G2	B3	Step-pool	Step-pool	II	Confined Source & Transport	Transport
SSV06	B3	B3	Step-pool	Step-pool	III-IV	Confined Source & Transport	Transport
SSV07	B3	B3	Step-pool	Step-pool	I	Transport	Transport
SSV08	C4b	C4b	Riffle-pool	Riffle-pool	I	Coarse Equilibrium and Fine Deposition	Coarse Equilibrium & Fine Deposition
SSV09	C4	C4	Riffle-pool	Riffle-pool	III	Unconfined Source & Transport	Coarse Equilibrium & Fine Deposition
SSV10	B3	B3	Step-pool	Step-pool	I	Transport	Transport
SSV11	B3	B3	Step-pool	Step-pool	I	Transport	Transport
SVC01	C4	C4	Riffle-pool	Riffle-pool	IV	Fine Source & Transport and Coarse Deposition	Coarse Equilibrium & Fine Deposition

Reach	Existing Stream Type[1]	Reference Stream Type[1]	Existing Bed Form[2]	Reference Bed Form[2]	CEM Stage[3]	Existing Sediment Regime[4]	Reference Sediment Regime[4]
SVC02	C4	C4	Riffle-pool	Riffle-pool	III	Fine Source & Transport and Coarse Deposition	Coarse Equilibrium & Fine Deposition
SVC03	C4	C4	Riffle-pool	Riffle-pool	IV	Fine Source & Transport and Coarse Deposition	Coarse Equilibrium & Fine Deposition
SVC04	B4	C4	Plane bed	Riffle-pool	II-III	Unconfined Source & Transport	Coarse Equilibrium & Fine Deposition
SVC05	C4	C4	Riffle-pool	Riffle-pool	IV	Fine Source & Transport and Coarse Deposition	Coarse Equilibrium & Fine Deposition
SVC06	C4	C4	Plane bed	Riffle-pool	III	Unconfined Source & Transport	Coarse Equilibrium & Fine Deposition
SVC07	C4	C4	Riffle-pool	Riffle-pool	III-IV	Fine Source & Transport and Coarse Deposition	Coarse Equilibrium & Fine Deposition
SVC08	C4	C4	Riffle-pool	Riffle-pool	V	Coarse Equilibrium and Fine Deposition	Coarse Equilibrium & Fine Deposition
SVC09	C4	C4	Riffle-pool	Riffle-pool	IV	Fine Source & Transport and Coarse Deposition	Coarse Equilibrium & Fine Deposition
SVC10	C4	C4	Riffle-pool	Riffle-pool	V	Coarse Equilibrium and Fine Deposition	Coarse Equilibrium & Fine Deposition
SVC11	C4	C4	Riffle-pool	Riffle-pool	IV	Fine Source & Transport and Coarse Deposition	Coarse Equilibrium & Fine Deposition

[1] (Rosgen, 1994)
[2] (Montgomery & Buffington, 1997)
[3] (Schumm, Harvey, & Watson, 1984)
[4] (Kline, 2010)

Planning-Level Channel Migration Zone Mapping

Figures 3 through 36 display the pCMZ results and associated draft geomorphic hazard zones. These maps are provided for planning purposes and while much attention was given to accuracy, there may be locations along the boundaries that warrant additional refinement as part of future, detailed investigations.

Upper South St. Vrain Creek – Brainard Lake to Confluence of South and Middle St. Vrain Creeks

LiDAR was unavailable for the upper section of this reach flowing out of Brainard Lake. Where LiDAR becomes available, CMZ mapping follows a narrow valley embedded in a large glacial outwash feature. As the creek enters a broader valley adjacent to Highway 72, DMAs exist where the road bed has bisected the valley bottom. As the creek turns east in the vicinity of Overland Road an AVZ was mapped in an area where numerous former channels have threaded together and where a significant channel shift of several hundred feet is possible. The MVB remains fairly broad through the riparian shrub forest before the creek passes under Overland Road and enters the Upper South St. Vrain Creek Canyon near the Ceran St. Vrain Trailhead. From here the MVB was mapped from valley wall to valley wall.

Middle St. Vrain Creek — Highway 72 to Confluence of South and Middle St. Vrain Creeks

The MVB below Peaceful Valley was mapped to catch recent terraces but intentionally left out higher glacial outwash terraces that are not likely to be part of the active channel. (NOTE: These features are typically captured by the EHA, which accounts for those adjacent lands that are less likely but still susceptible to erosion should a debris or sediment jam occur or should erosion at the toe cause a slope failure). Several alluvial fans were mapped in the Raymond area as was a segment deemed an AVZ where the valley flattens and significant aggradation was observed to have occurred in September 2013. Below Riverside within the Route 7 corridor a large swath of DMA was mapped on the east bank. Just upstream of the confluence with South St. Vrain Creek, a very obvious historical meander bend was mapped as a DMA where the highway cut off the bend and forced the stream into a straight configuration.

Lower South St. Vrain Creek – Confluence of South and Middle St. Vrain Creeks to Confluence of North and South St. Vrain Creeks

Minor DMAs are mapped downstream of the confluence where meander bends were taken out by the Highway 7 road embankment. Following the recommendation in the pCMZ protocol the embankment, although susceptible to erosion, was used as the boundary of the MVB even though the stream historically occupied the entire valley bottom. Although steep gullies running from the canyon walls contributed significant sediments to the Creek during the September 2013 flood, alluvial fans were only mapped where an obvious fan was visible in the imagery and where that fan impacted the location of the MVB. At the mouth of the South St. Vrain Canyon the MVB widens significantly to delineate a large depositional area (also identified as an AVZ) which runs through the Town of Lyons, an area where historical and recent channel braiding are common.

North St. Vrain Creek — Button Rock Dam to Confluence of North and South St. Vrain

Sediment starved water coming out of the Ralph Price Reservoir coupled with a narrow, fairly steep canyon make it prudent to include the dam access road in the MVB. Indeed, the road was recently accessed by the creek channel. Highway 36 provides the edge of the MVB in this corridor

although the road is still predominately in the EHA. At Apple Valley, significant geomorphic conditions warranted a large AVZ.

St. Vrain Creek — Confluence of North and South St. Vrain Creeks to County Line Road

Below the confluence of the North and South St. Vrain creeks, the main channel continues in an AVZ. The town of Lyons' wastewater treatment facility is considered to be within this AVZ. LiDAR data becomes unavailable over an approximately 4.5 mile stretch several miles downstream of Lyons. Considering the stream exhibited some significant movement within this area, this almost 5-mile stretch should be added in the future, likely as an AVZ, when data availability makes this possible. Upstream of Longmont, LiDAR data begins again and the MVB is influenced by the existence of ponds in the floodplain. The ponds are predominately the result of gravel mining operations. Alluvial gravels and sands laid down by the river prior to settlement indicate historical migration areas. Due to the propensity of gravel ponds to be "captured" by the moving river, all of the ponds are mapped as AVZs. Where the stream enters an urbanized section of Longmont, historical migration scars have been obliterated. Here a MVB was delineated by buffering the current stream meander centerline to a measured meander wavelength of 350 feet on each side of the stream centerline. This approach employs a best fit method for a highly altered landscape. Further downstream, the Longmont wastewater treatment center is mapped as a DMA, based on an assumption that the facility was constructed behind a 100-year FEMA certified berm. This assumption should be verified as part of future investigations.

Table 2: Erosion Hazard Area Width by Reach on the St. Vrain Creeks

Reach	Erosion Hazard Area (EHA) Width Determination[1]	EHA Buffer (feet on each side of MVB)
MSV01	One channel width	35
MSV02	One channel width	35
MSV03	One channel width	35
MSV04	One channel width	35
MSV05	One channel width	35
MSV06	One channel width	35
NSV01	Half meander width	150
NSV02	Half meander width	150
NSV03	Half meander width	150
NSV04	One channel width	60
NSV05	One channel width	55
SSV01	Half meander width	125
SSV01	Half meander width	125
SSV02	Half meander width	125
SSV02	Half meander width	125
SSV03	One channel width	55
SSV04	One channel width	55
SSV05	One channel width	55
SSV06	One channel width	55

Reach	Erosion Hazard Area (EHA) Width Determination[1]	EHA Buffer (feet on each side of MVB)
SSV07	One channel width or less	17
SSV08	One channel width	35
SSV09	One channel width	35
SSV10	One channel width	35
SSV11	One channel width	35
SVC01	One meander width	350
SVC02	One meander width	350
SVC03	One meander width	350
SVC04	One meander width	350
SVC05	One meander width	350
SVC06	One meander width	350
SVC07	One meander width	350
SVC08	One meander width	350
SVC11	Half Meander width	200
SVC11	Half Meander width	200

[1] Based on guidance in WA State protocol (Ecology et al., 2014)

Discussion and Recommendations

The results and recommendations of this memo should be used exclusively for planning purposes and only within the context of the St. Vrain Watershed Master Planning project and the Boulder County Comprehensive Creek Planning Initiative. Any follow-up programmatic or engineering design work must be accompanied by a thorough and complete design-level analysis on a site specific or reach specific basis. Results represent conditions found in the St. Vrain Creek system during the months of June and July 2013. Due to the natural, constantly evolving characteristics of streams, as well as the large investment that towns, counties, state and federal agencies, and local property owners are currently making to change the physical condition of the streams, all results, recommendations, and project development require field verification and supplemental investigations before design-level analysis. Verifications and investigations should be completed by qualified fluvial geomorphologist(s) and/or river engineer(s) on the reach in question, as well as the reaches upstream and downstream that could affect sediment sources and storage areas, sediment transport characteristics, and stream power.

While the channel evolution phase is presented for representative reaches in the St. Vrain Creek system as it exists in June of 2013, during future design-level analyses, it will be important to assess the current channel evolution phase for the smaller and more specific design reaches as well as changes in disturbance and function in associated upstream and downstream reaches. A weakness of the Schumm Channel Evolution Model is that it implies a linear process from Stage I to Stage V, whereas if disturbances continue or upstream sediment supply changes the reach may cycle through the middle stages without establishing an interim quasi-equilibrium state. Similarly, for aggrading reaches, such as those found in the lower reaches of the South St. Vrain Creek, the Schumm model cannot be applied. Despite these limitations, the CEM model can still potentially aid in the prediction of

how the channel will adjust in the future as it attempts to reach a quasi-equilibrium condition after the flood.

Road Infrastructure and the St. Vrain Creek System

Man-made structures such as bridges and diversion dams may exacerbate channel migration or lateral erosion if the infrastructure directs flow directly into a bank or embankment or more typically the structure fails to pass sediment and debris being transported by the water. There are many examples of undersized crossings that racked debris of all types and caused the creek to back up and eventually flank the bridge or culvert. It is important to understand that this is most often a structure problem not a sediment/ debris problem and as such, it can often be ameliorated through improved design and/or structure retrofit.

The pCMZ mapping included in this report does not attempt to predict debris jams at man-made structures or the most likely location of new channels should infrastructure jam or fail. It is recommended that the St. Vrain Coalition consider road crossing designs that allow for appropriate sediment transport at low, medium, and high flows (including the overflow areas), as well as the capability to pass debris and/or design crossings that break away if debris racks and upstream pressure becomes too great. Similarly, it is recommended that the St. Vrain Coalition consider reconstructing low-head diversion dams to transport sediments and not re-direct flow into weak embankments. These types of low-head structures have the additional benefits of allowing for boater passage and fish and aquatic organism passage, while reducing the sediment load into ditches.

Highway 7 and Highway 36 in the canyon reaches of the North, Middle, and South St. Vrain Creeks constrict the floodplain and channel. In turn flow depths, shear stresses, and sediment transport capacities are all likely higher than they would be in a more natural condition. This corridor alteration has likely transformed some canyon reaches from sediment storage areas to sediment transport reaches, which potentially impacts downstream communities where the excess sediment then deposits. As Highway 36 and Highway 7 are rebuilt, coordination with qualified fluvial geomorphologist(s) and/or river engineer(s) is highly recommended to limit constrictions, reduce sheer stress against the road embankments, and to consider future changes in stream bed elevation when designing roadways.

Similarly, local roads including Riverside Dr. (alongside portions of Middle St. Vrain), Old Saint Vrain Road (alongside portions of South St. Vrain upstream of Lyons), and neighborhood roads in Lyons and Longmont have encroached on the stream corridor. Local roads are generally not considered robust enough to limit channel migration or lateral channel movement; furthermore, changes in the geomorphic channel conditions in relation to these roads translates up and downstream as sediment and erosive energies are transferred in channel adjustment processes that may extend far beyond the impact site.

Altered Hydrologic Regime

Changes in hydrologic regimes disrupt the water sediment balance in creek systems. Water quantity and flow timing has been dramatically altered in the St. Vrain Creek watershed, mainly because of upstream reservoirs/ lakes and diversion ditches. The Ralph Price Reservoir is located on the North St.

Vrain Creek, and while there is a seasonal high flow release from the Buttonrock Dam, it does not follow the natural hydrograph of this system. Brainard Lake, located in the headwaters of the South St. Vrain Creek, releases a fairly natural hydrograph, but just downstream of Brainard Lake, a portion of flow from South St. Vrain Creek is diverted into James Creek altering both creeks' hydrographs. The hydrologic regime continues to be impacted downstream in St. Vrain Creek due to the increasing number of diversion ditches as the river flows from upstream of Lyons to Longmont. Reduced flows have reduced capacity to regularly move sediment through the system, which leads to aggradation and is often problematic in developed areas.

While ditches pull water out of the channel, floodplain development and increased impervious surfaces in the Town of Lyons and City of Longmont may conversely increase water returns through increased efficiency of stormwater discharge. Stormwater entering the channel may increase the volume of runoff for a given rainfall, exacerbating the developed watershed's already flashier runoff regime with higher flood peaks. Erosion, incision, and channel widening are often associated with increased urbanization and associated increases to stormwater runoff.

Channelization, Armoring, and Floodplain Disconnections

Channelization (straightening) and streambank armoring occurs throughout the St. Vrain Creek system. The response of the stream system to these modifications typically occurs within and beyond the modified reach and frequently begins with a bed incision process. As channels incise or berms are constructed, channels are disconnected from their floodplains, and in turn, the excess energy in the system causes an increase in erosion laterally and/or vertically. The increased erosion leads to an increase in sediment load transferred downstream of the channelized reach, where the channel may not have the capacity to continue to move the sediment through, ultimately leading to bed aggradation.

Furthermore, this increased scour directed at the channel bed reduces bed form features and typically leaves a homogenous plane bed channel morphology. Channelization and armoring not only disrupt the water sediment balance in the stream system, but the modifications also disrupt the ecological character of the stream and riparian corridor. When possible the St. Vrain Coalition should seek to maintain a naturally meandering stream with frequent opportunities for floodplain access.

Floodplains play an important role in dissipating stream energy and provide low-risk locations for natural sediment deposition in addition to providing ecological complexity and good riparian habitat. For decades, the prevailing theory was that river channelization benefited flood control due to resultant perpetually scouring channels. As a result, river systems have been cut off from their floodplains by berms, levees, and other aggressive channelization, yet successful flood control has not resulted from these efforts. Over the last couple decades, this channelization for flood control theory has proven problematic and prevailing philosophies on efficient (for both sediment and water) river systems have trended towards floodplain reconnections with multi-stage channels.

Overflow channels and flood chutes carved though the floodplains during the 2013 flood provide opportunities for seasonal floodplain access. It is recommended that the St. Vrain Coalition prioritize protecting and restoring these locations as well as the wider channel corridor from the impacts of development, in order to reap the multiple benefits of increased flood protection and improved stream health provided by floodplain access and seasonal side channels.

Interpreting the pCMZ maps and pCMZ Applications

The pCMZ methodology tends to be a conservative assessment that uses LiDAR data as a basis for delineating areas of past and potential future channel migration. The planning-level method does not analyze historical channel occupation or migration rates, and therefore does not allow for assignment of a CMZ design life (effective time period), associated probabilities for migration or erosion, or migration or erosion rates. The pCMZ boundary line is a conservative approximation of areas reasonably likely to be influenced by channel migration. While channel migration should be considered unlikely outside of the CMZ boundary, extreme events where channel migration occurs outside of CMZ boundaries are nonetheless possible. Where a perceived threat to critical infrastructure or life is present, a detailed-level assessment should be undertaken to quantify channel migration rates and processes.

The boundaries of the CMZ and FEMA floodplain generally will not coincide, and should be considered independent of one another. FEMA floodplains will commonly exceed the CMZ in underfit streams with low gradients and little migration potential as is seen on the St. Vrain Creek though the City of Longmont. Conversely, CMZs may exceed the FEMA floodplain in actively migrating streams and depositional areas such as in Apple Valley and along Old South St. Vrain Road.

While we present it as a valuable planning tool with hopes of minimizing future flood damage, it is certainly not all-inclusive and should be utilized with other tools such as FEMA-derived inundation maps. In addition, the pCMZ does not capture extreme landscape disturbances such as debris flows, landslides, earthquakes, etc., and this pCMZ analysis did not examine the spatial extents of these geotechnical failures. In addition to endangering life and property within the within these landscape disturbance areas, resulting debris, sediment, or fractures may alter the course of the St. Vrain Creeks into areas not identified in the pCMZ. Likewise, the possibility of diversion ditches capturing the main stem of the river is not considered in the pCMZ mapping.

The pCMZ maps are presented to support coalition efforts to work with local governments and state agencies to develop programs and codes that limit investment and asset development within the mapped pCMZ hazard areas. Erosion hazards and channel avulsions present extreme risks during high flow events in all watersheds along the Front Range and having a robust data set that assesses multiple hazards is critical to long term planning and community resilience. Avulsion hazard areas and mapped alluvial fans are priority locations for buyouts, especially, though not limited to, where they overlap with mapped FEMA floodplains. The modern valley bottom, erosion hazard area, and disconnected migration zones should similarly be examined for opportunities to remove critical infrastructure and homes in favor of greenways or open space corridors, or at the very least, provide education for those citizens, businesses, and government agencies that invest in high risk areas. Additionally, in some locations, mapped disconnected migration zones can be used to identify locations for floodplain reconnection projects.

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

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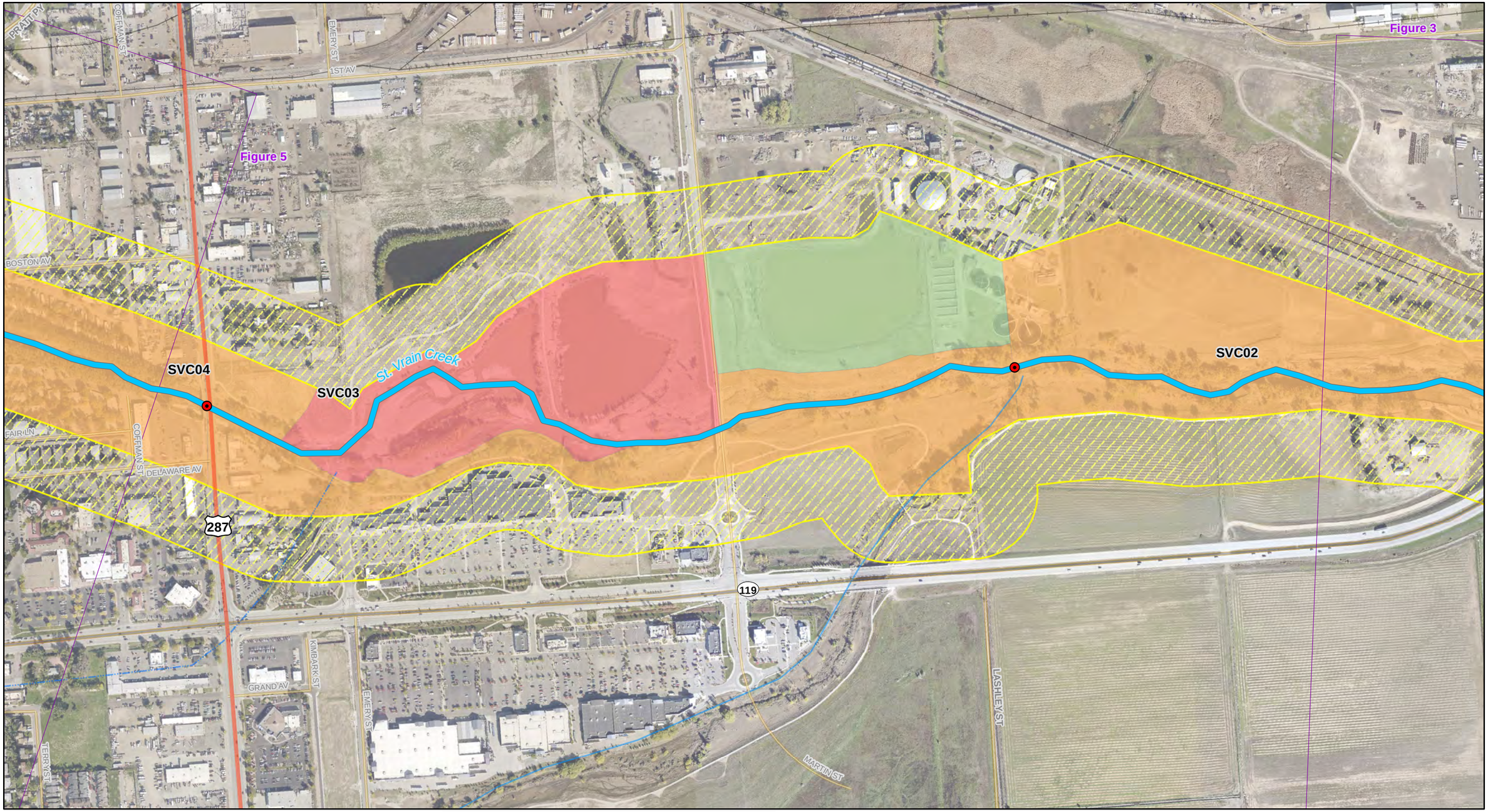
Figure 3
Draft Geomorphic Hazard Zones
St. Vrain Creek System - St. Vrain
Boulder County, Colorado



NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 4
Draft Geomorphic Hazard Zones
St. Vrain Creek System - St. Vrain
Boulder County, Colorado

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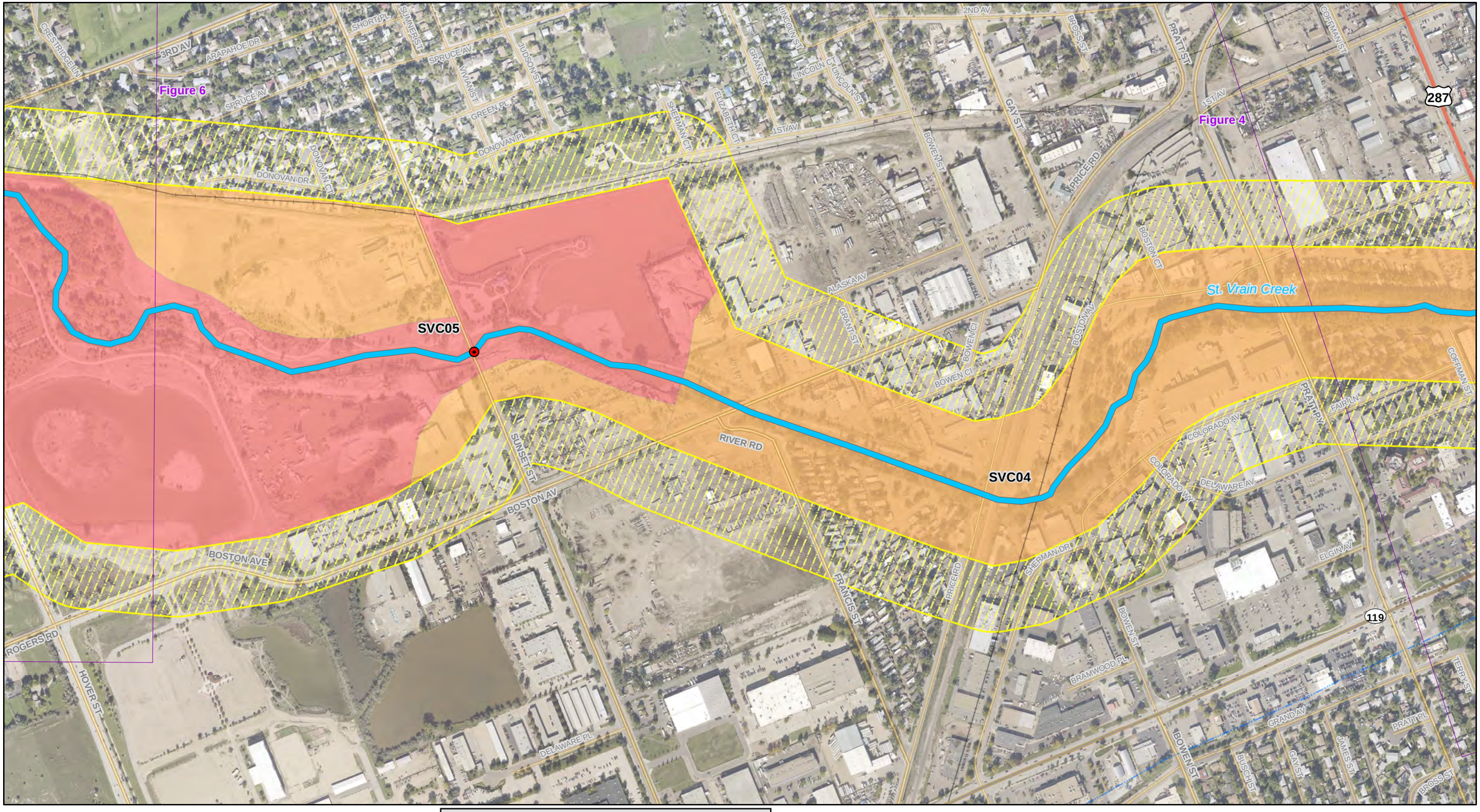

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 5
Draft Geomorphic Hazard Zones
St. Vrain Creek System - St. Vrain
Boulder County, Colorado

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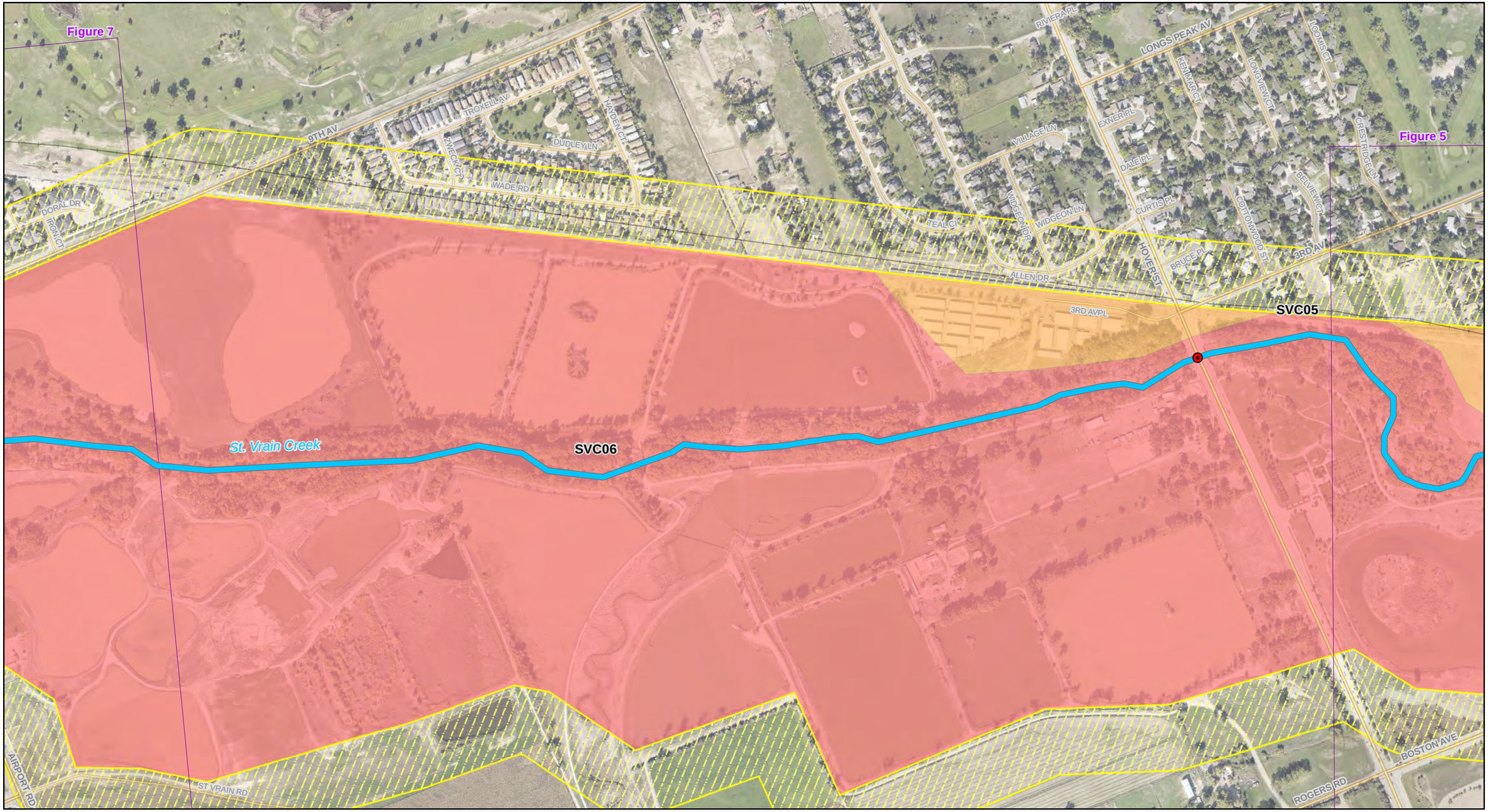

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 6
Draft Geomorphic Hazard Zones
St. Vrain Creek System - St. Vrain
Boulder County, Colorado

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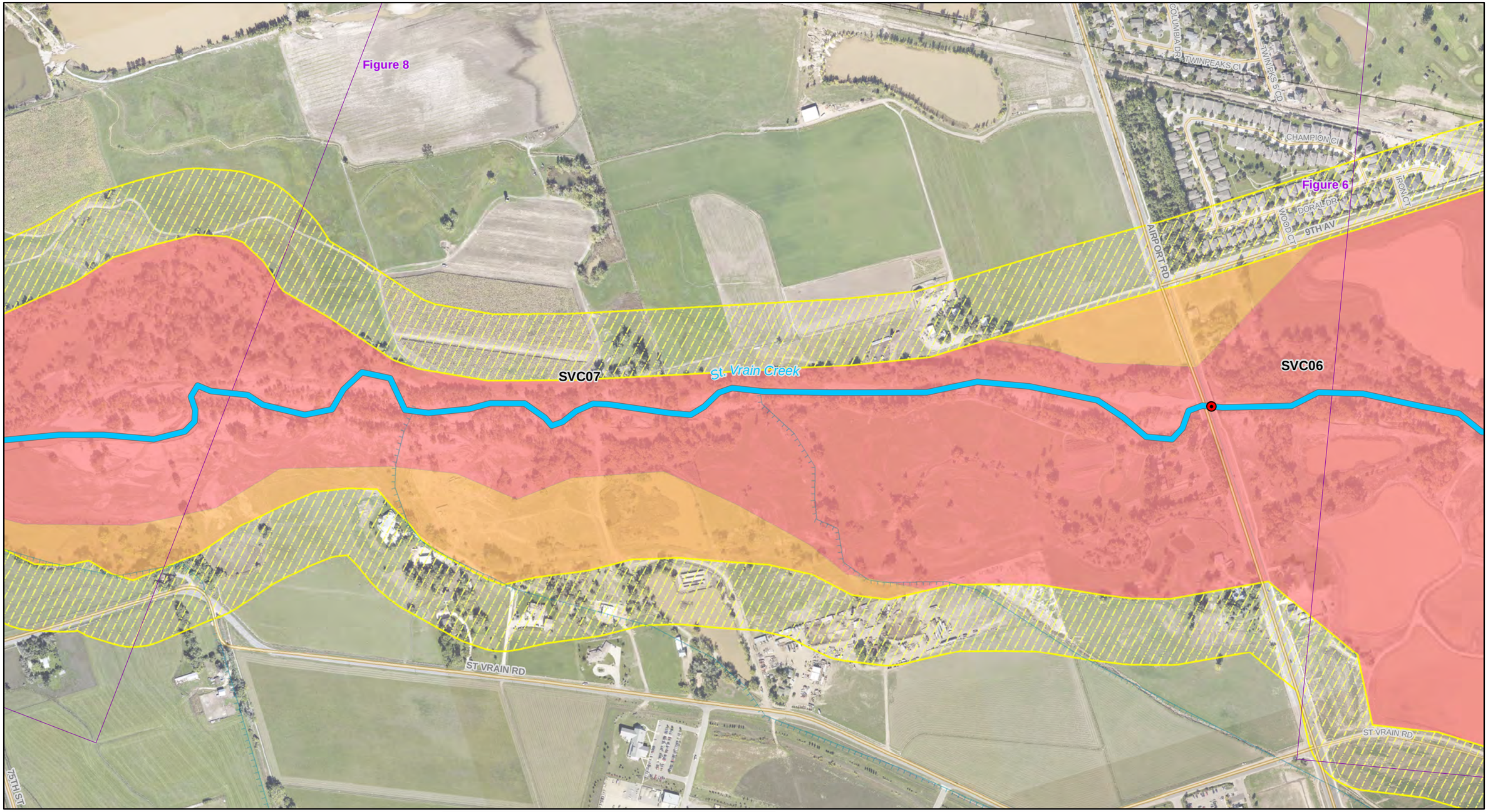

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 7
Draft Geomorphic Hazard Zones
St. Vrain Creek System - St. Vrain
Boulder County, Colorado

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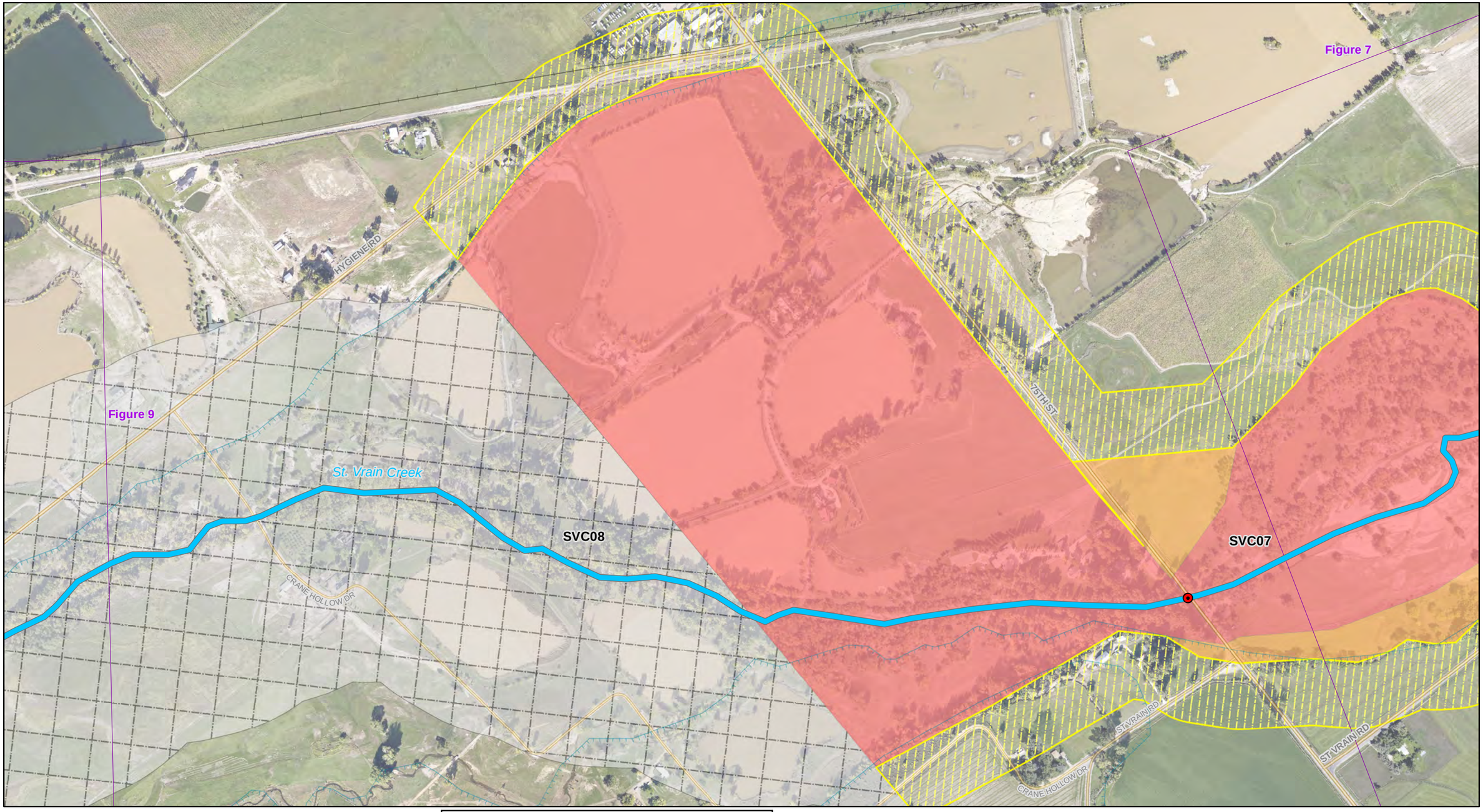

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

Figure 8
Draft Geomorphic Hazard Zones
St. Vrain Creek System - St. Vrain
Boulder County, Colorado

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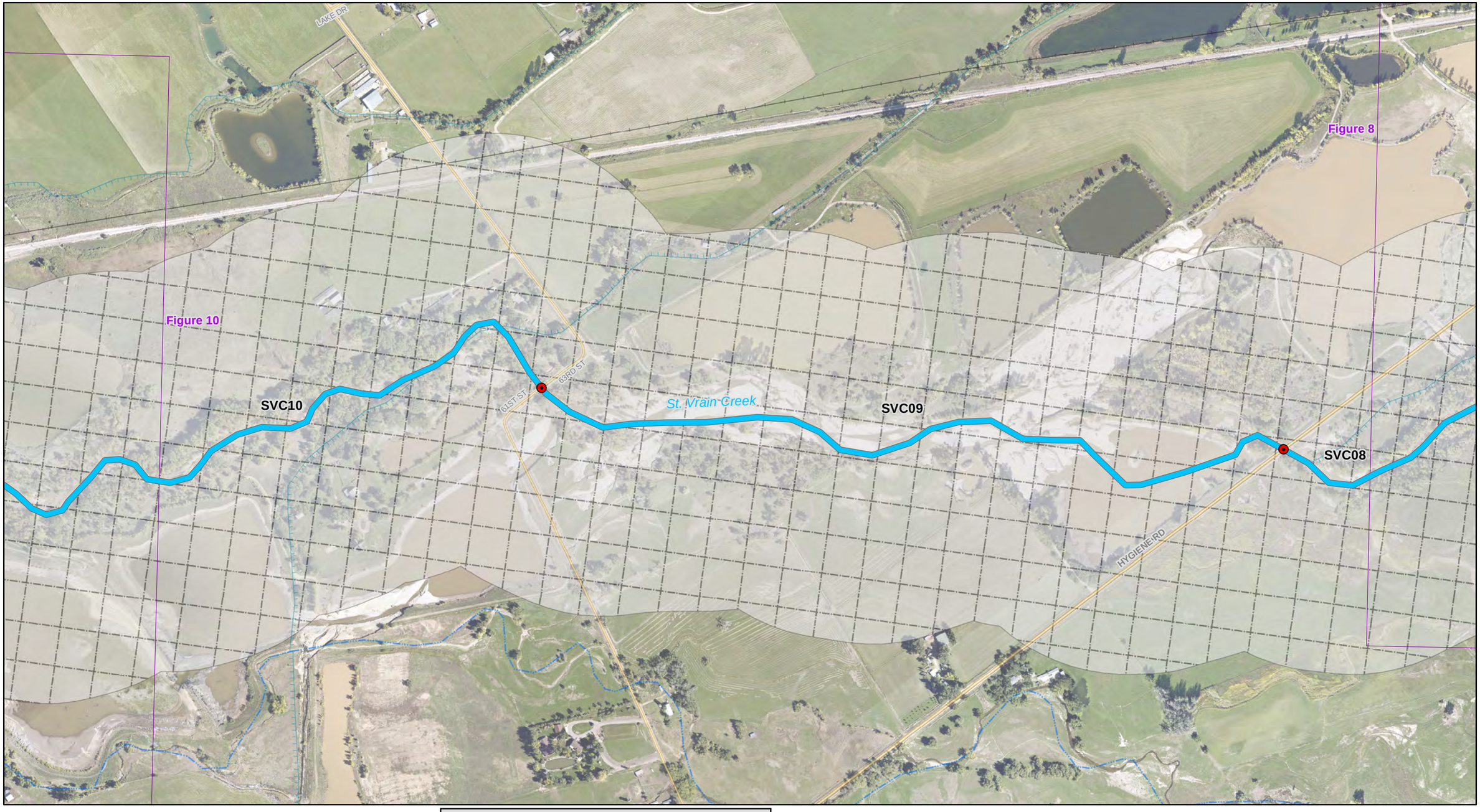

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

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Figure 9
Draft Geomorphic Hazard Zones
St. Vrain Creek System - St. Vrain
Boulder County, Colorado

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

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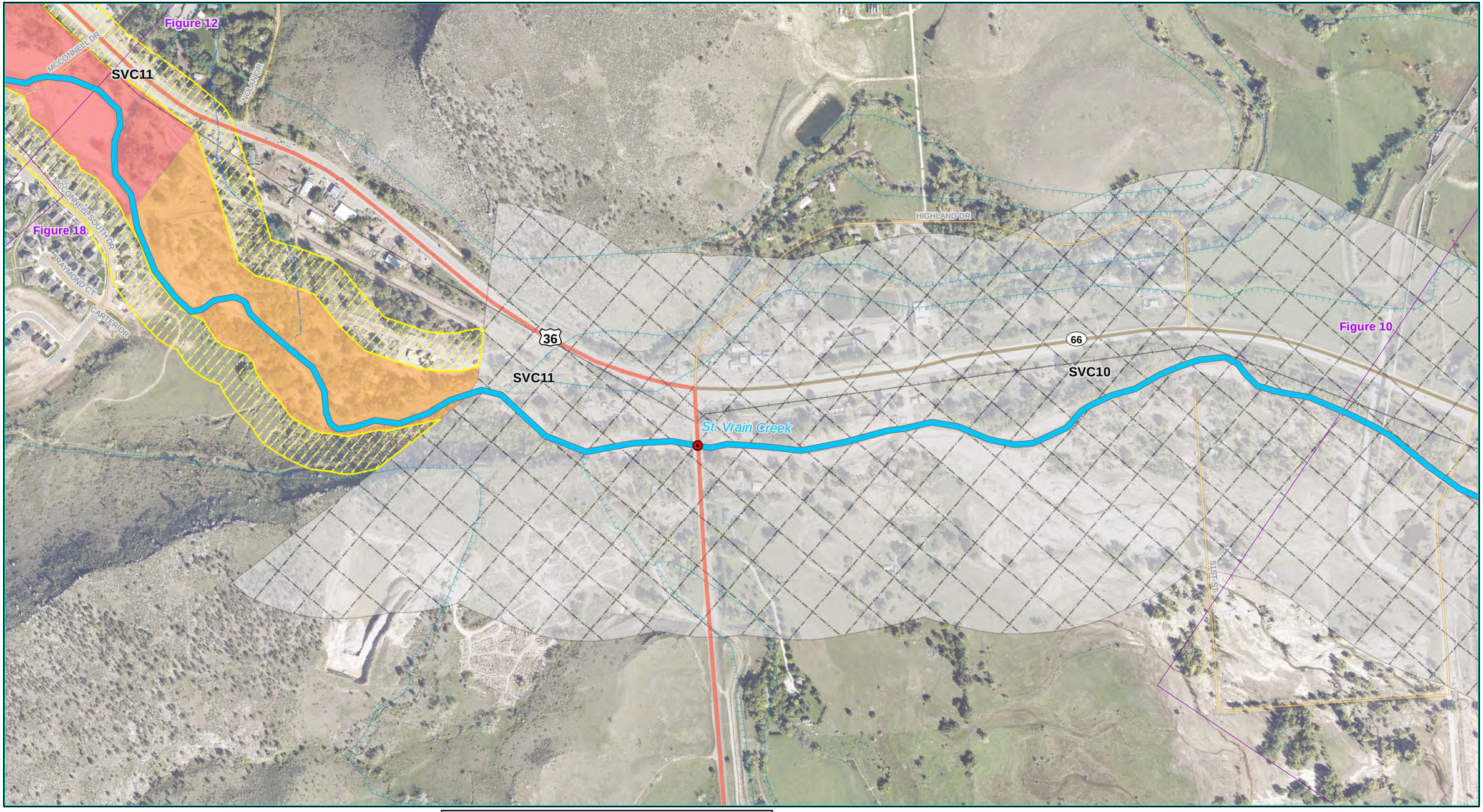
Figure 10
Draft Geomorphic Hazard Zones
St. Vrain Creek System - St. Vrain
Boulder County, Colorado



NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 11
Draft Geomorphic Hazard Zones
St. Vrain Creek System - St. Vrain
Boulder County, Colorado

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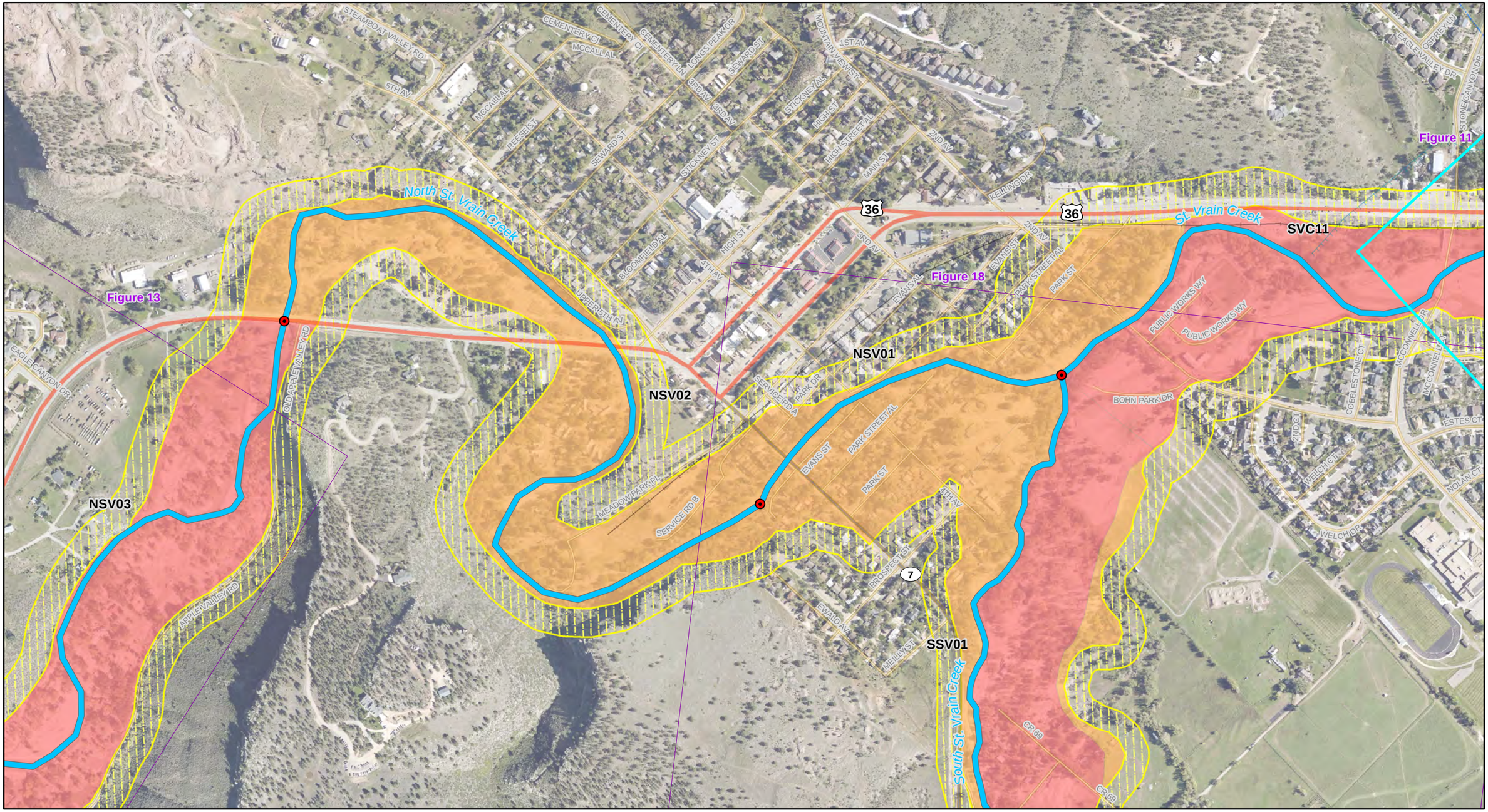

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000

Feet

1 inch = 500 feet

Walsh
an ecology and environment company

Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 12
Draft Geomorphic Hazard Zones
St. Vrain Creek System - North-South St. Vrain Confluence
Boulder County, Colorado

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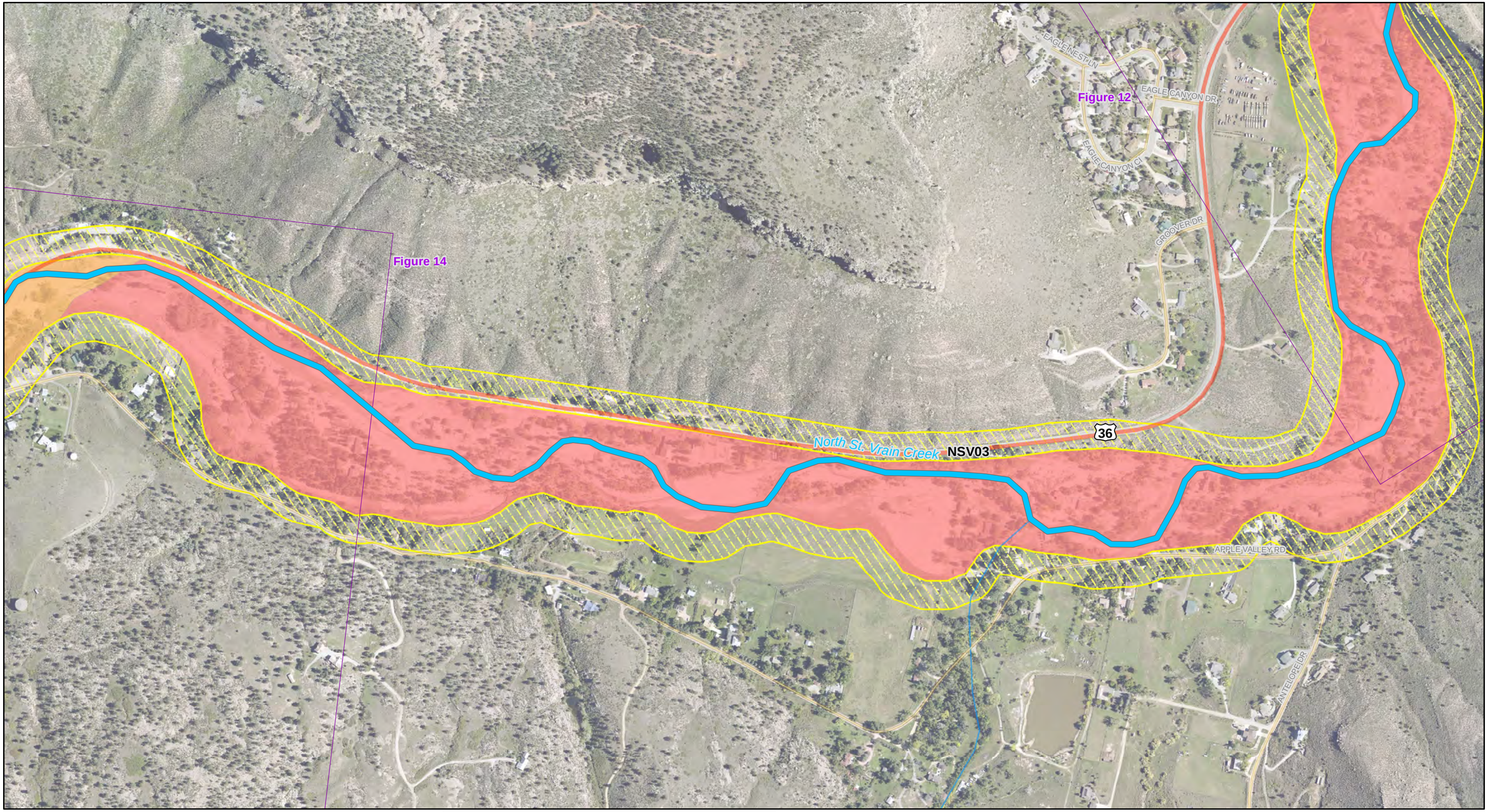

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000

Feet

1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 13
Draft Geomorphic Hazard Zones
St. Vrain Creek System - North St. Vrain
Boulder County, Colorado

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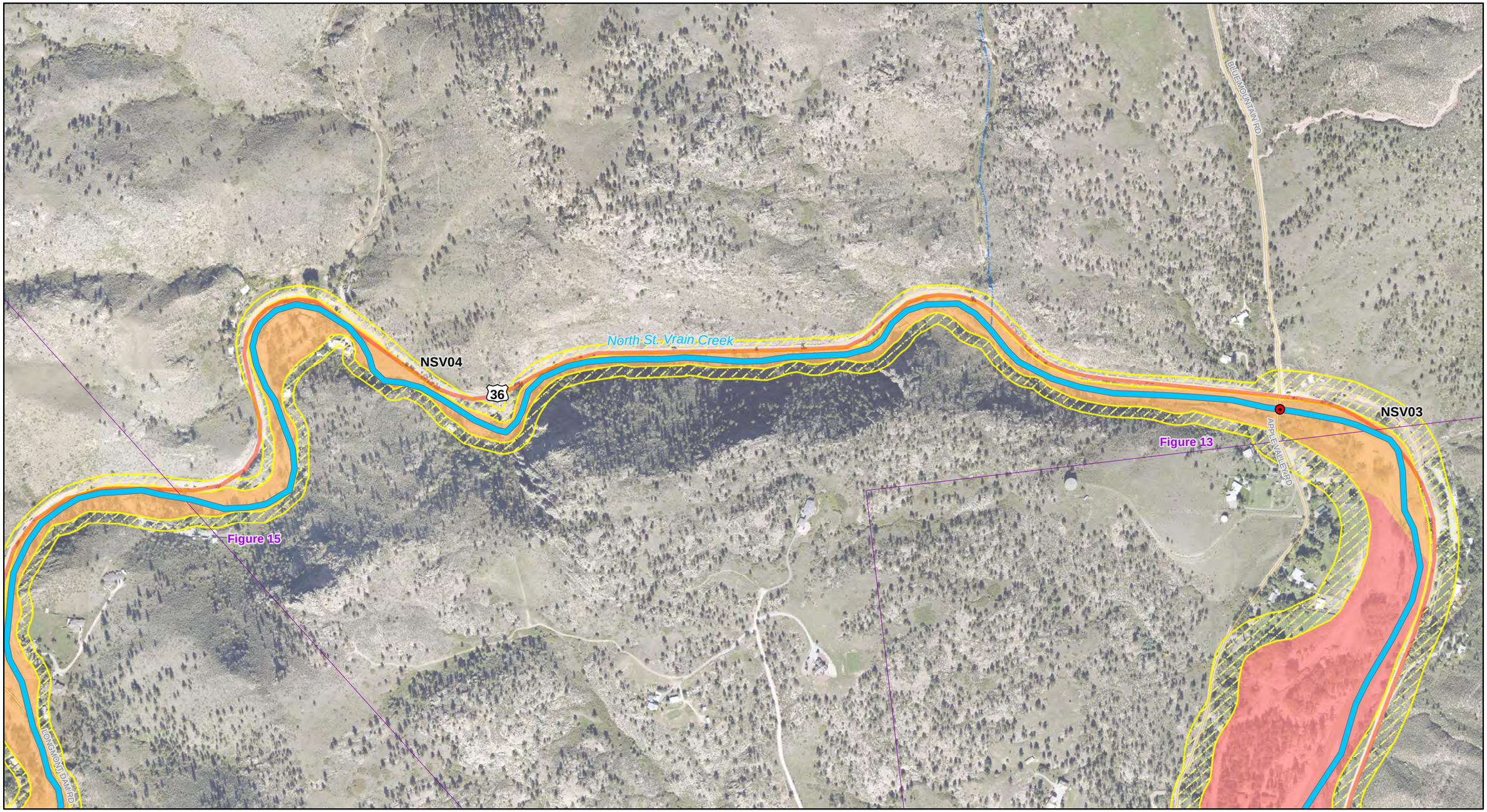

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

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Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 14
Draft Geomorphic Hazard Zones
St. Vrain Creek System - North St. Vrain
Boulder County, Colorado

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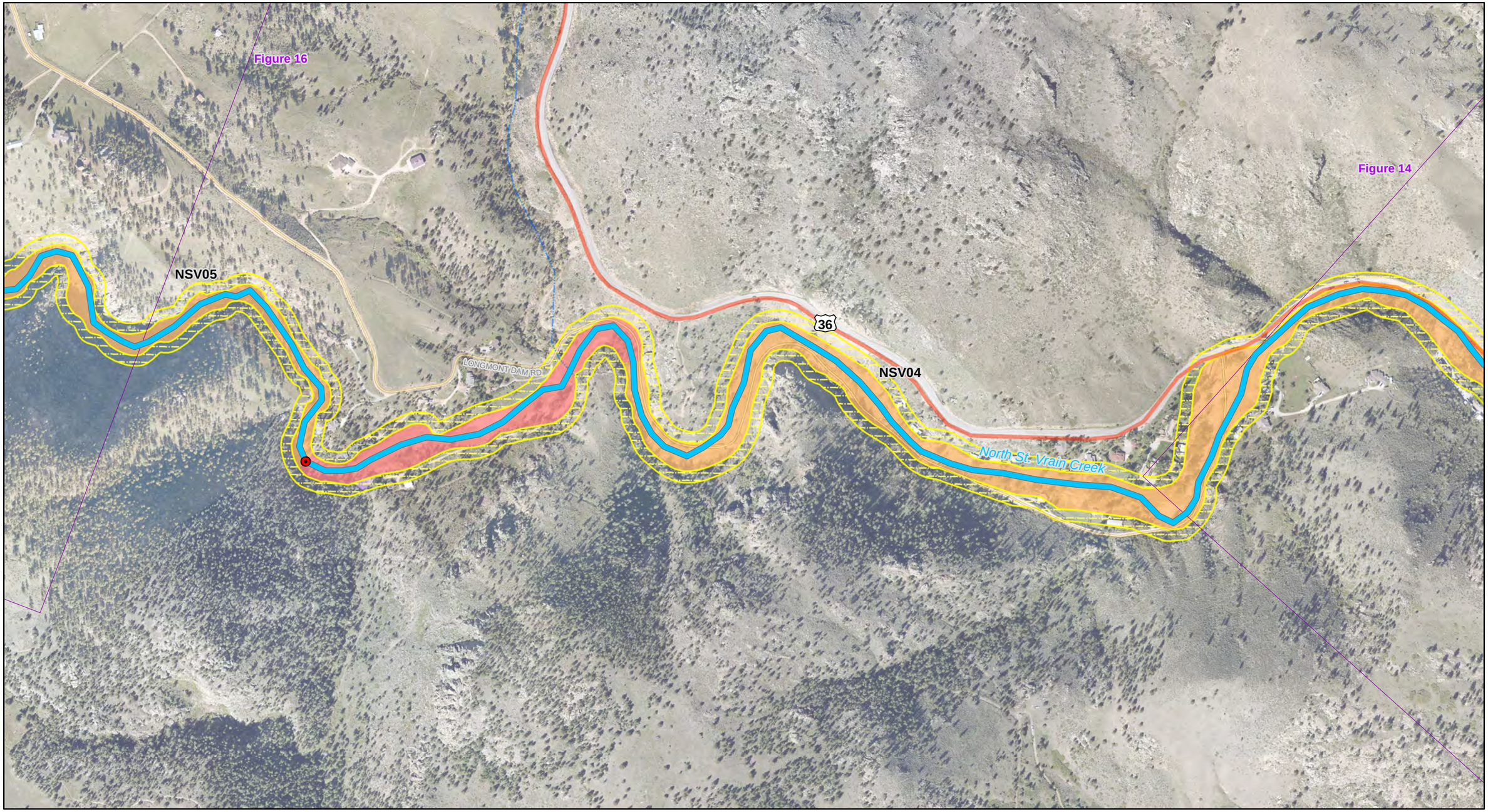

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Walsh
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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 15
Draft Geomorphic Hazard Zones
St. Vrain Creek System - North St. Vrain
Boulder County, Colorado

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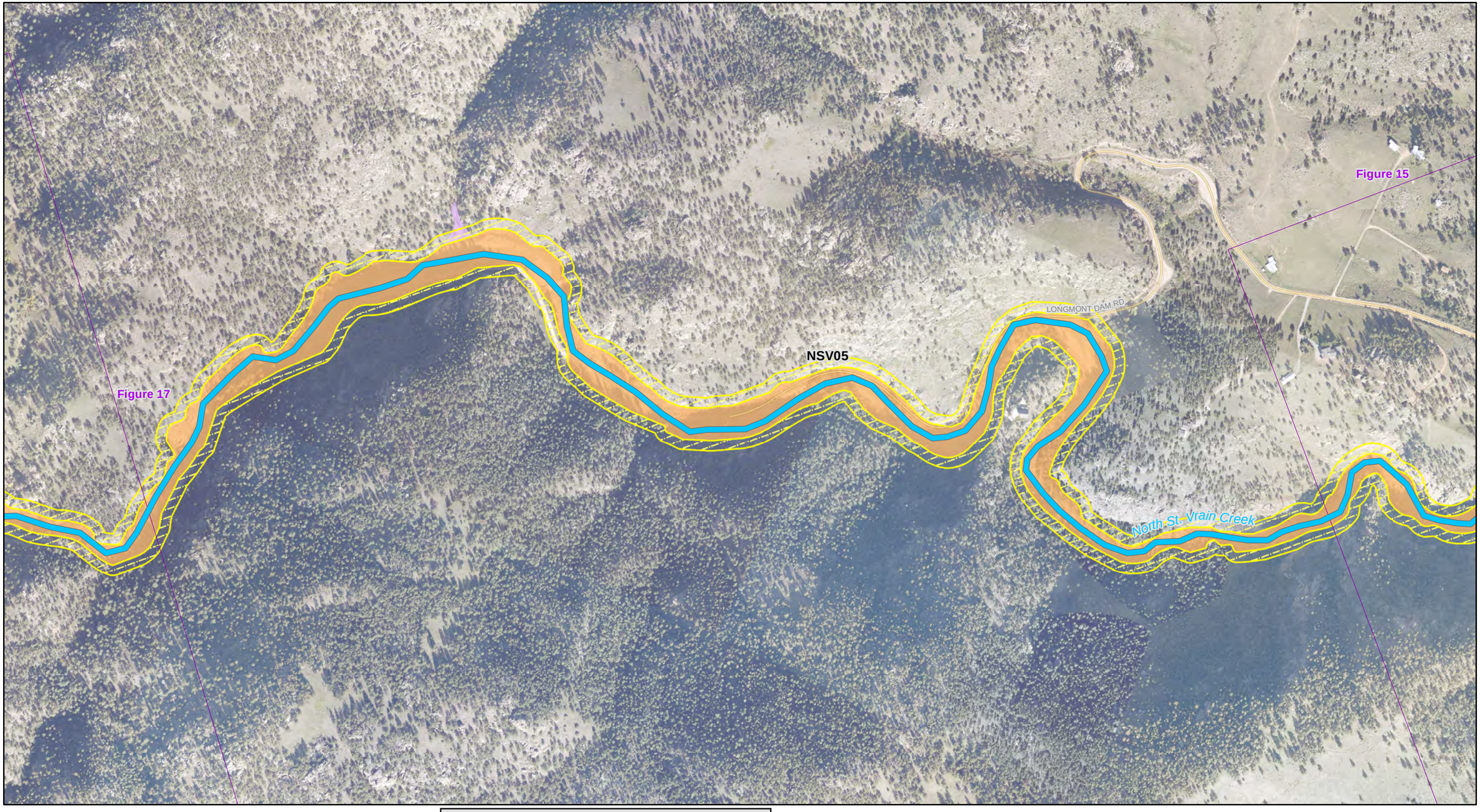

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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an ecology and environment company

Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 16
Draft Geomorphic Hazard Zones
St. Vrain Creek System - North St. Vrain
Boulder County, Colorado

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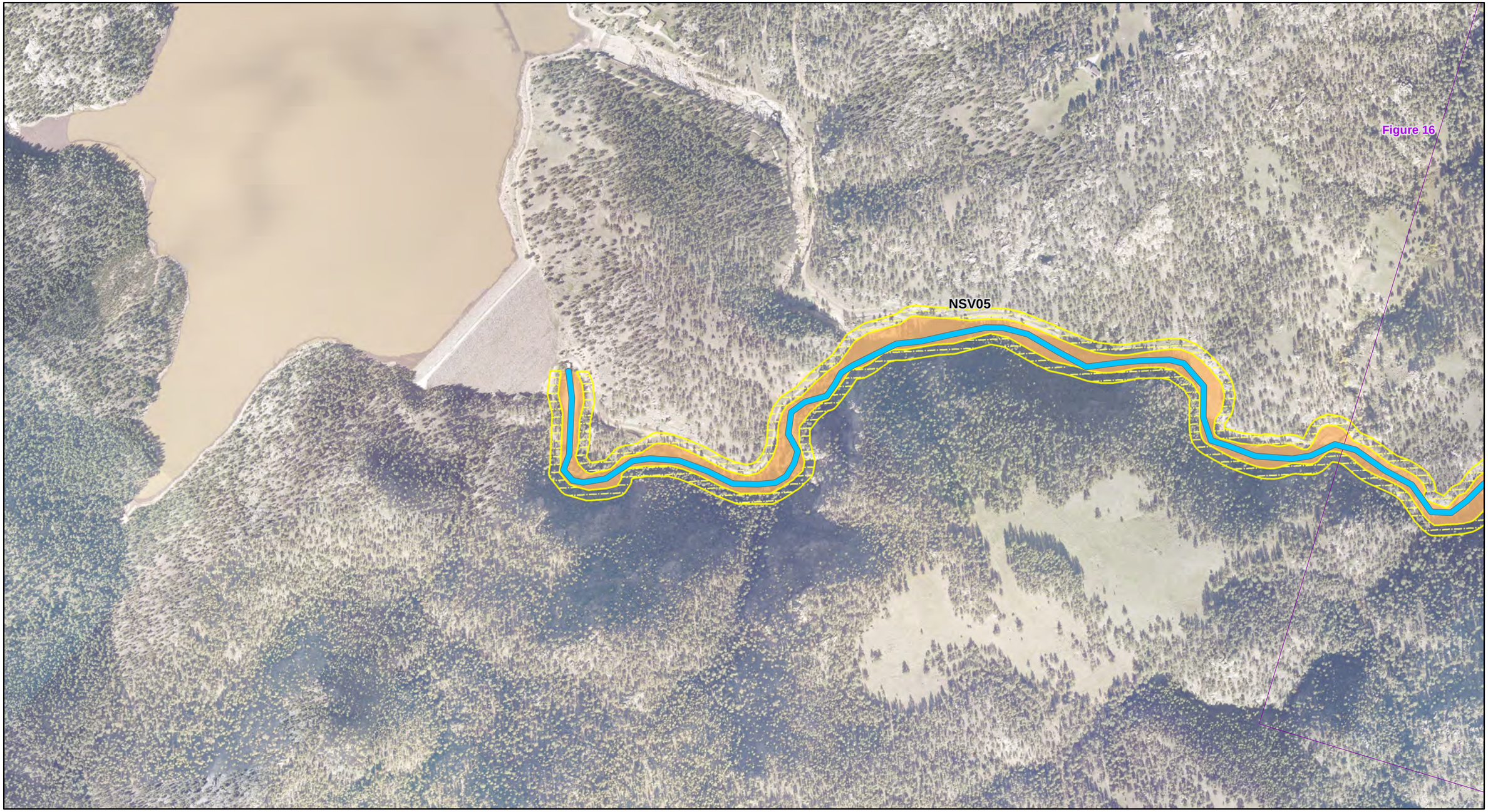

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Walsh
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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 17
Draft Geomorphic Hazard Zones
St. Vrain Creek System - North St. Vrain
Boulder County, Colorado

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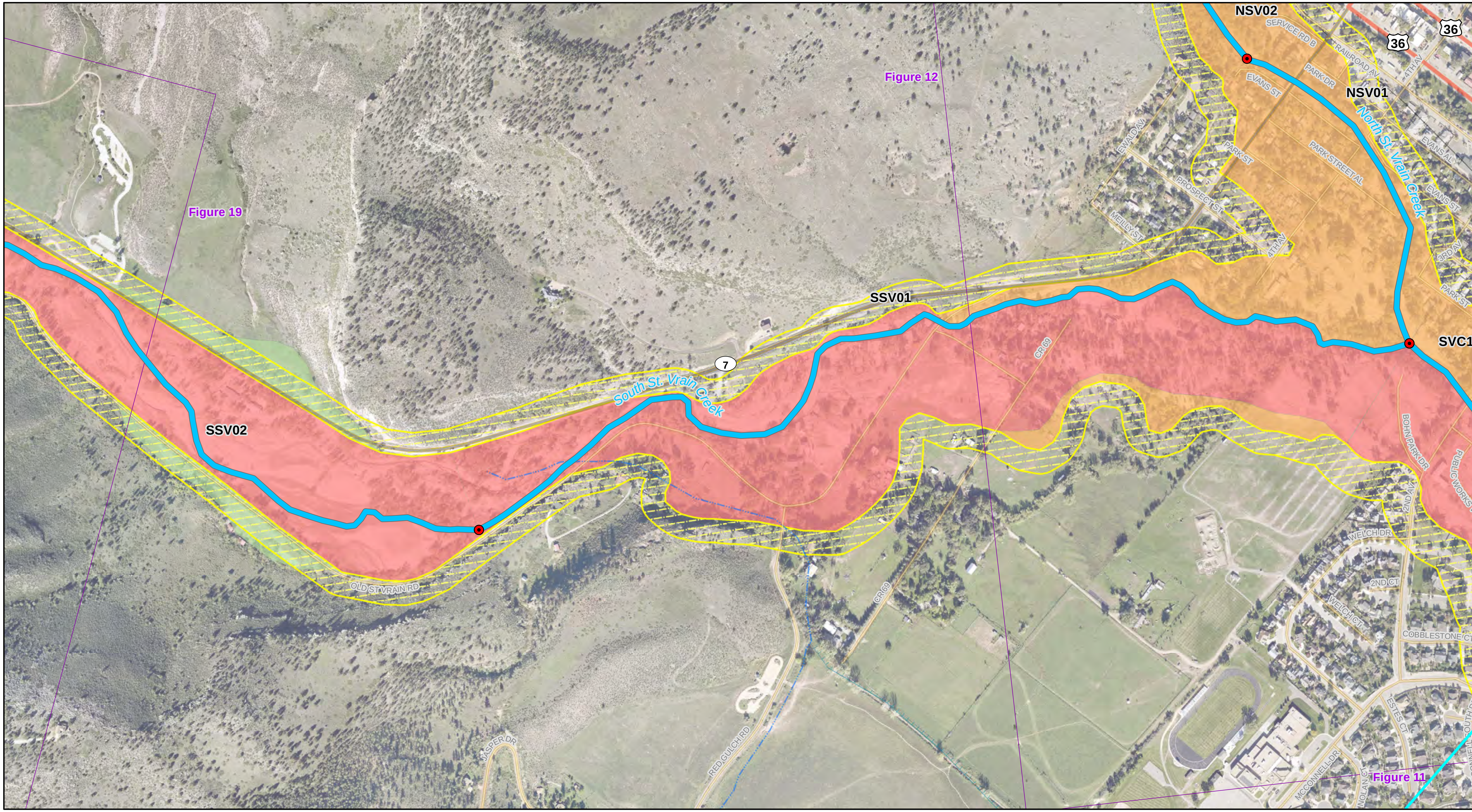

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000

Feet

1 inch = 500 feet

Walsh
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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 18
Draft Geomorphic Hazard Zones
St. Vrain Creek System - North-South St. Vrain Confluence
Boulder County, Colorado

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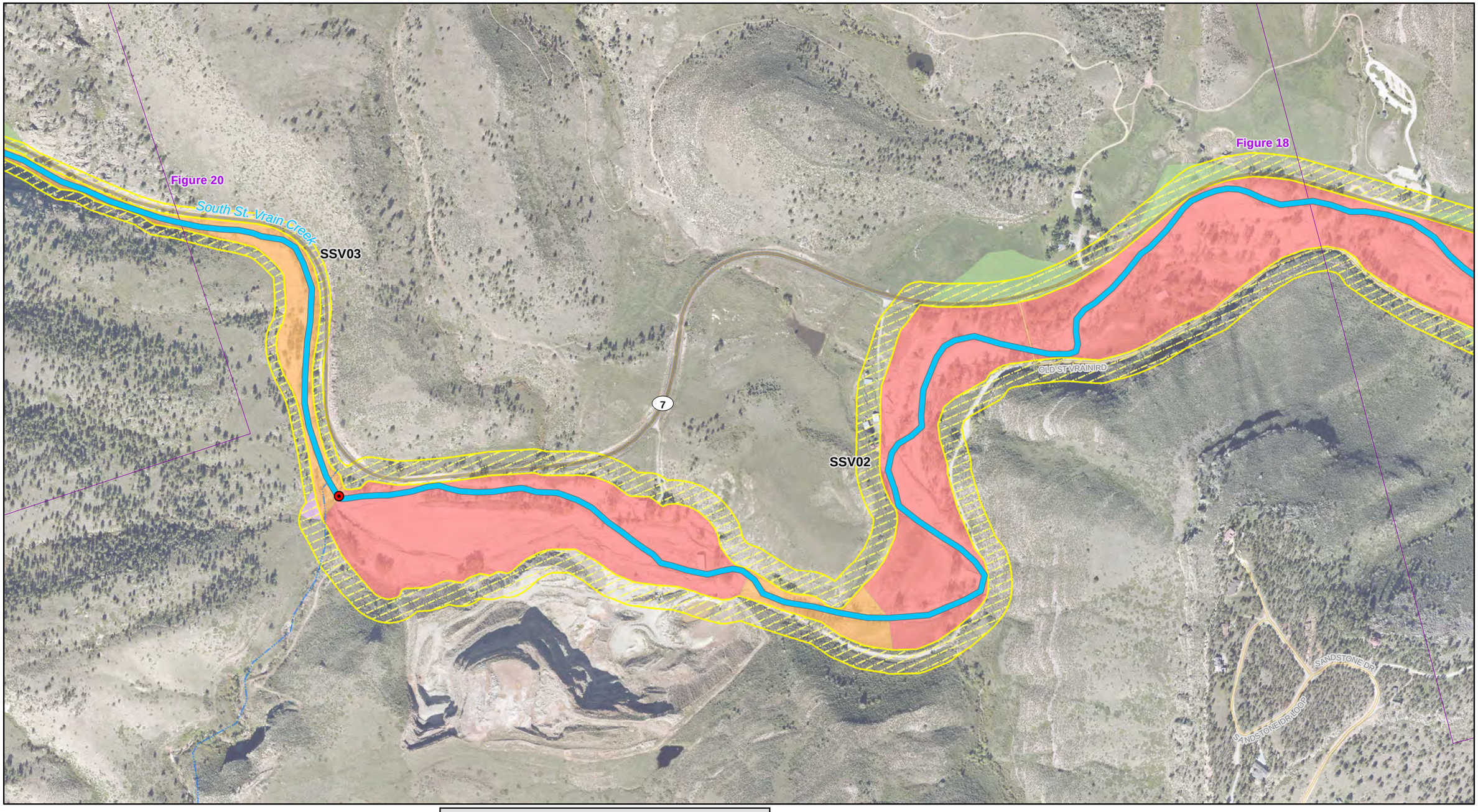

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

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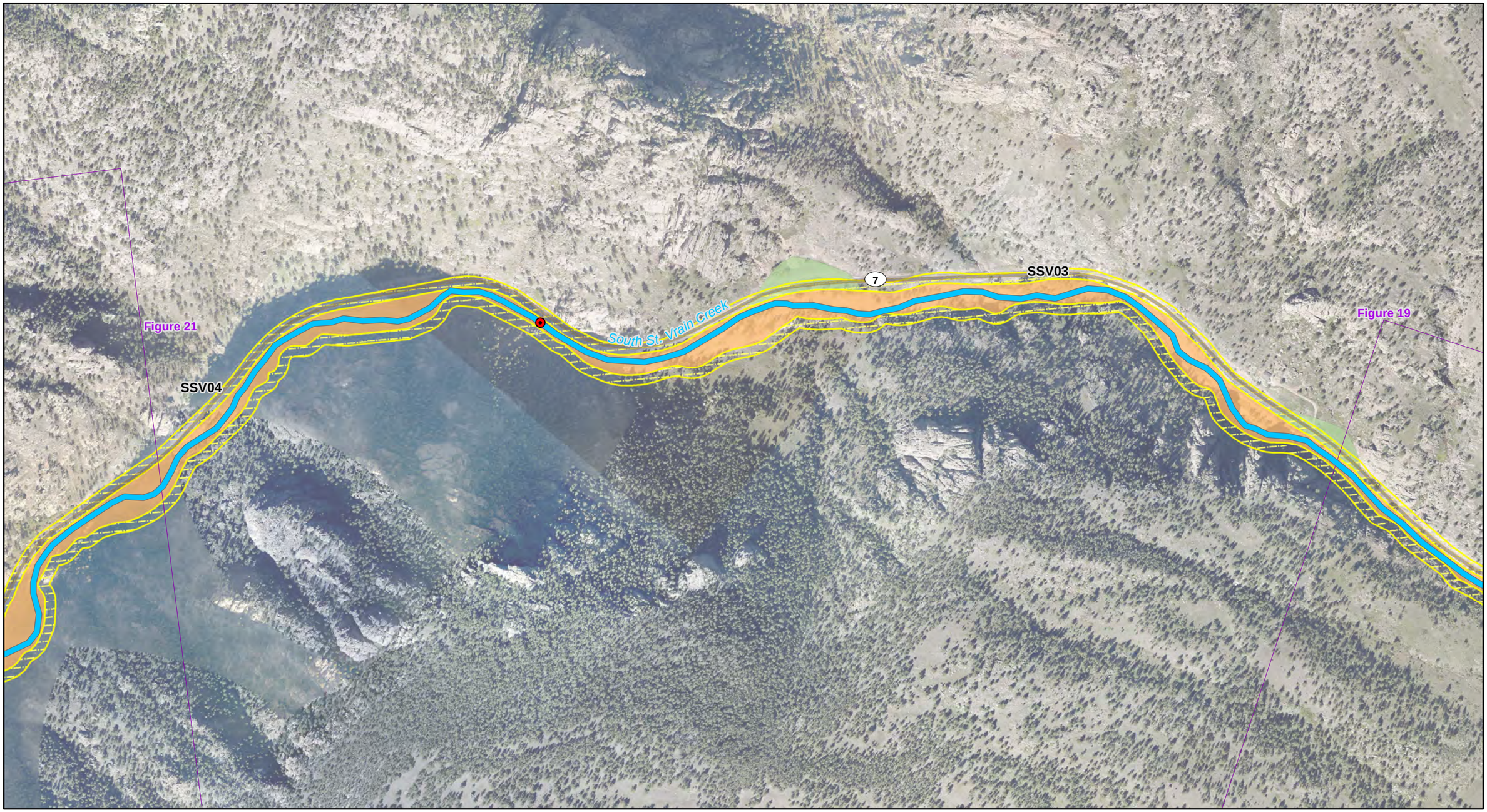
Figure 19
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado



NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

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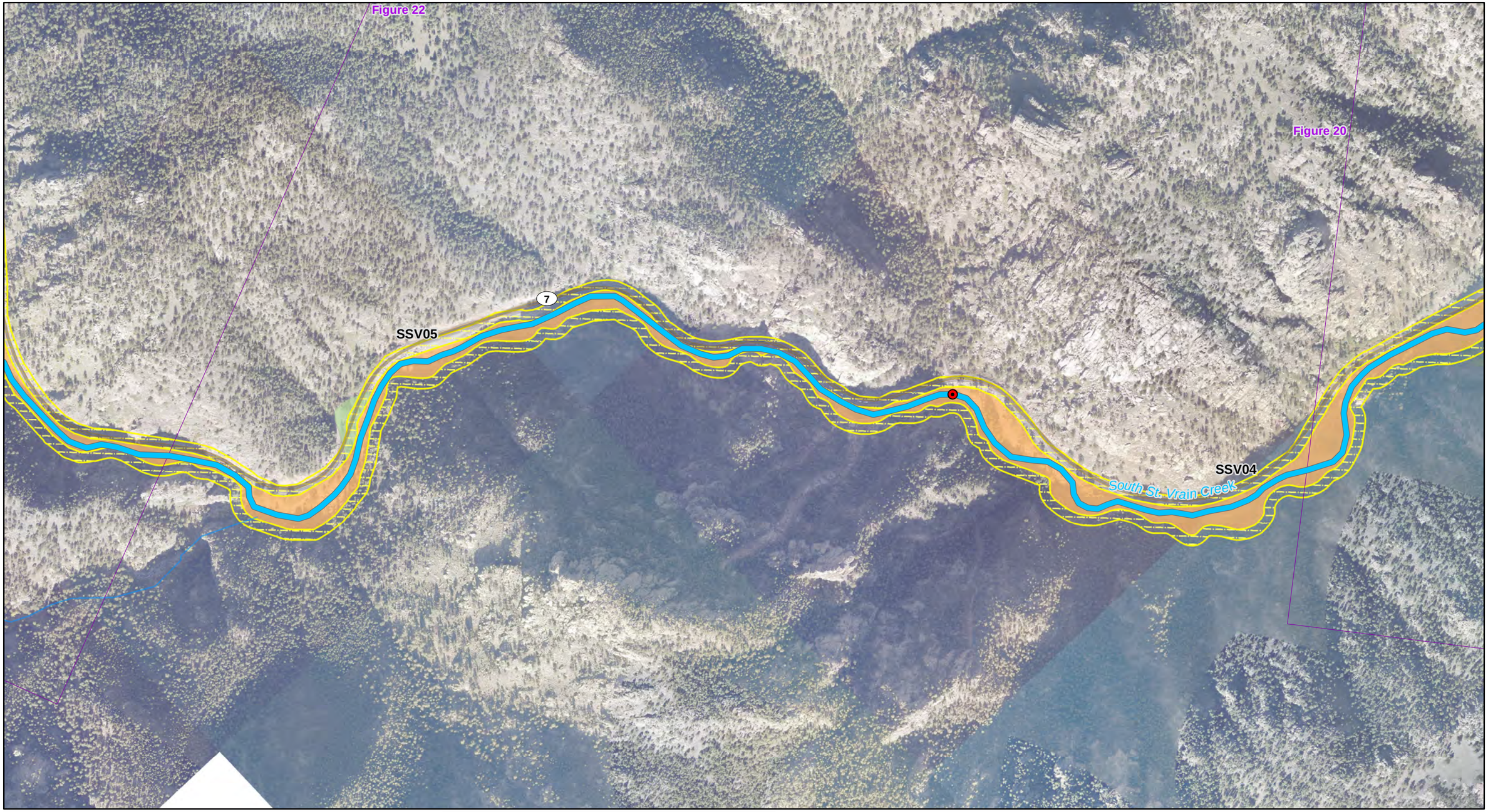
Figure 20
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado



NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 21
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado

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NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 22
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado

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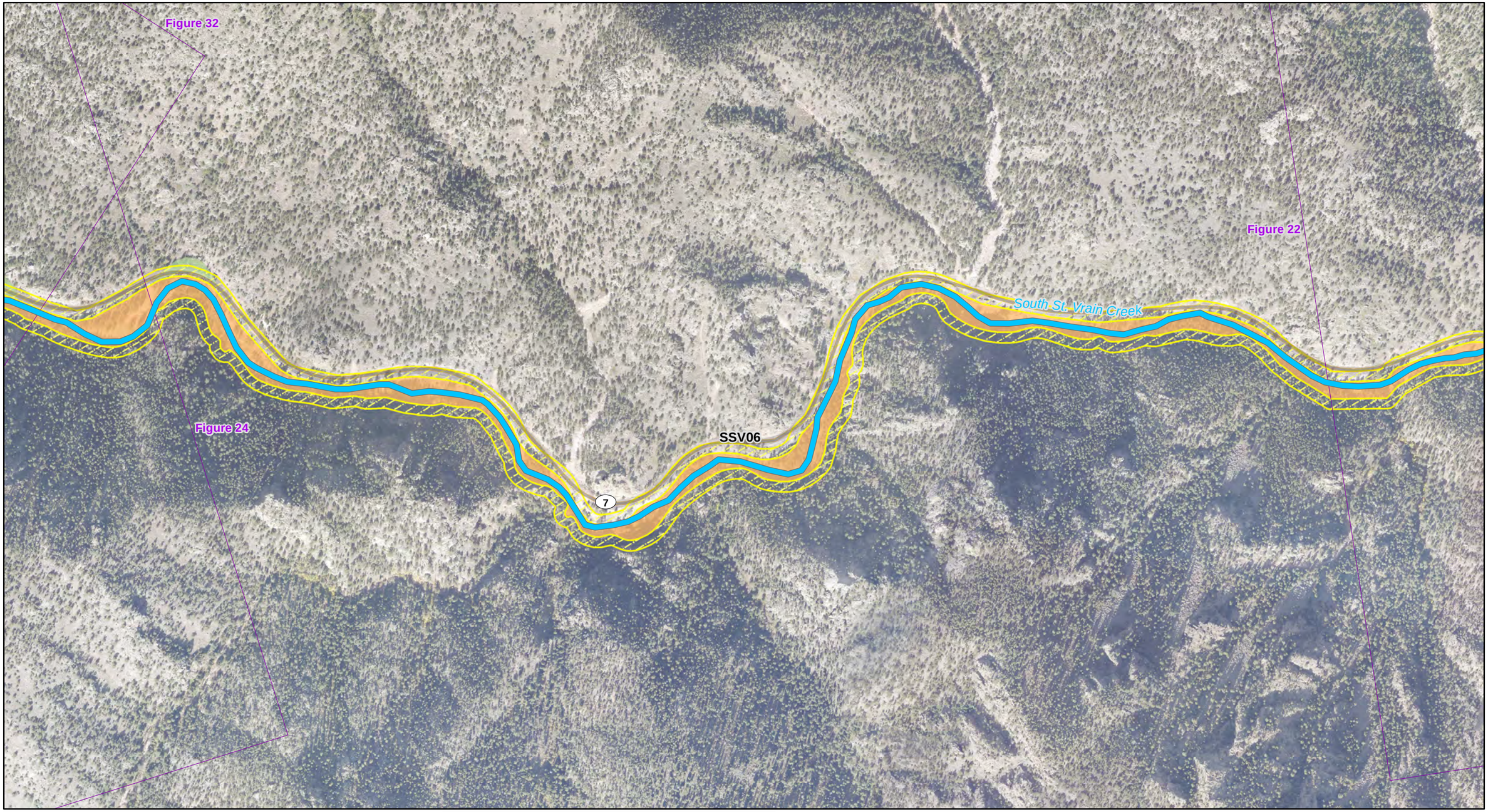

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

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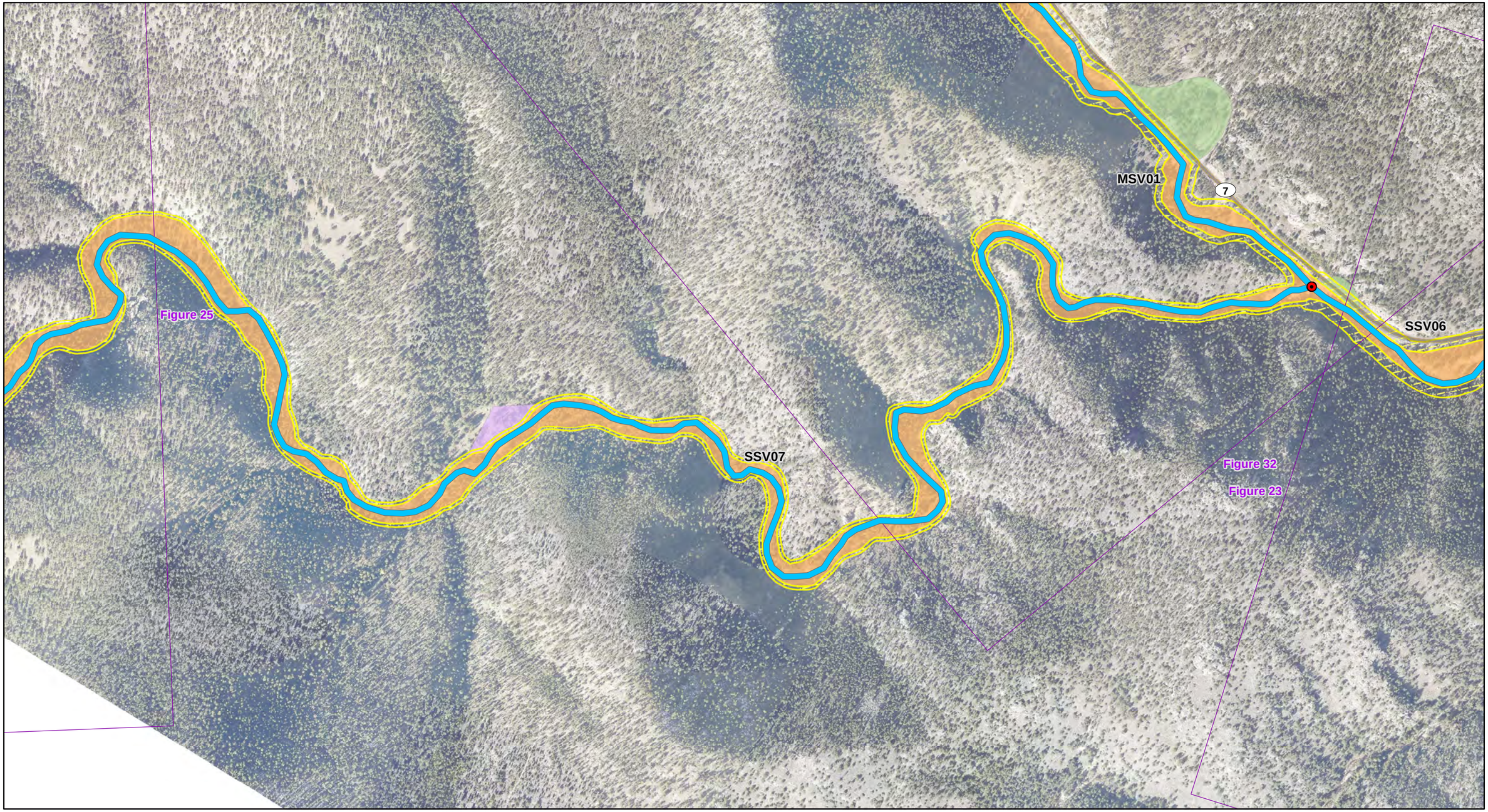
Figure 23
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado



NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

Figure 24
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado

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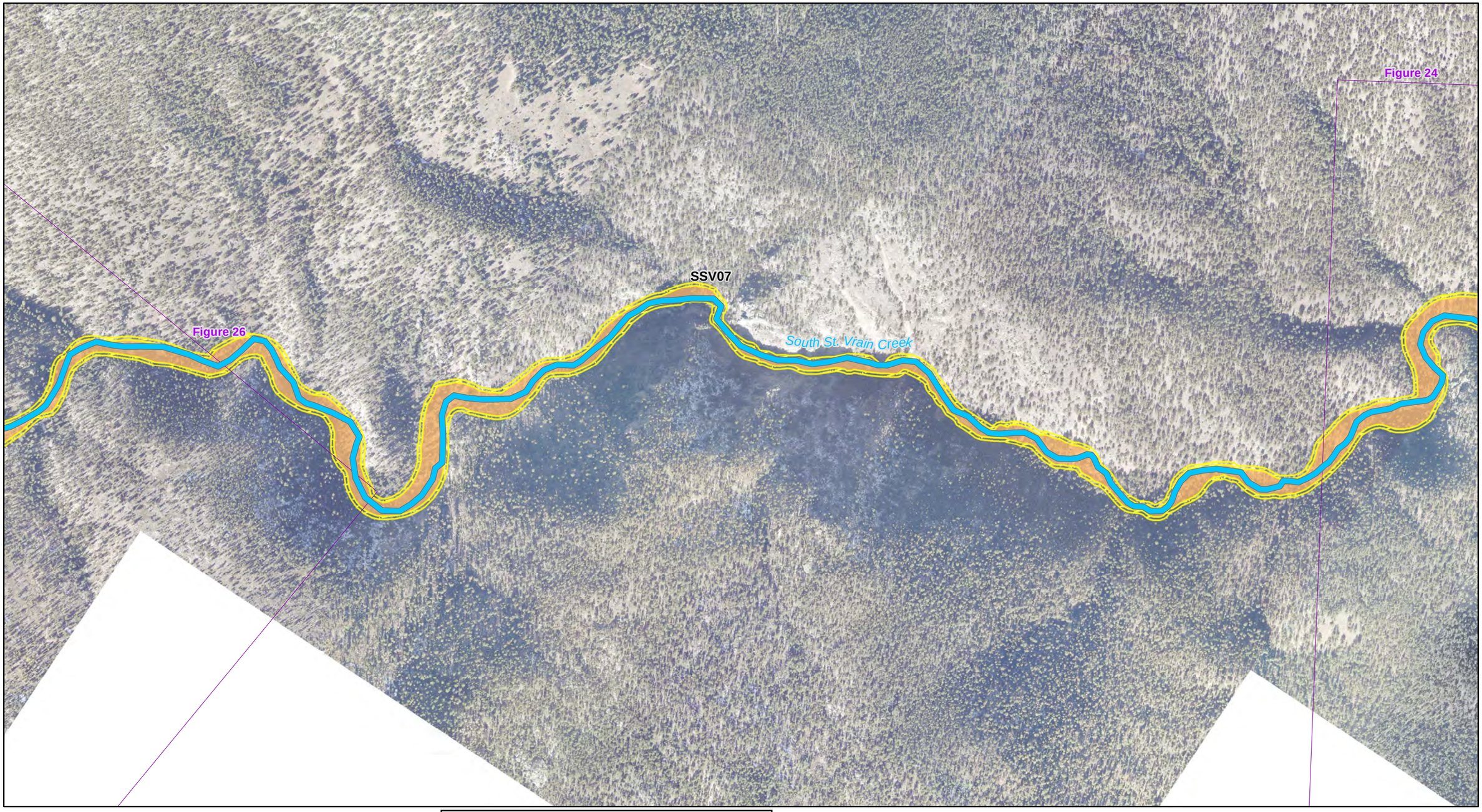

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 25
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado

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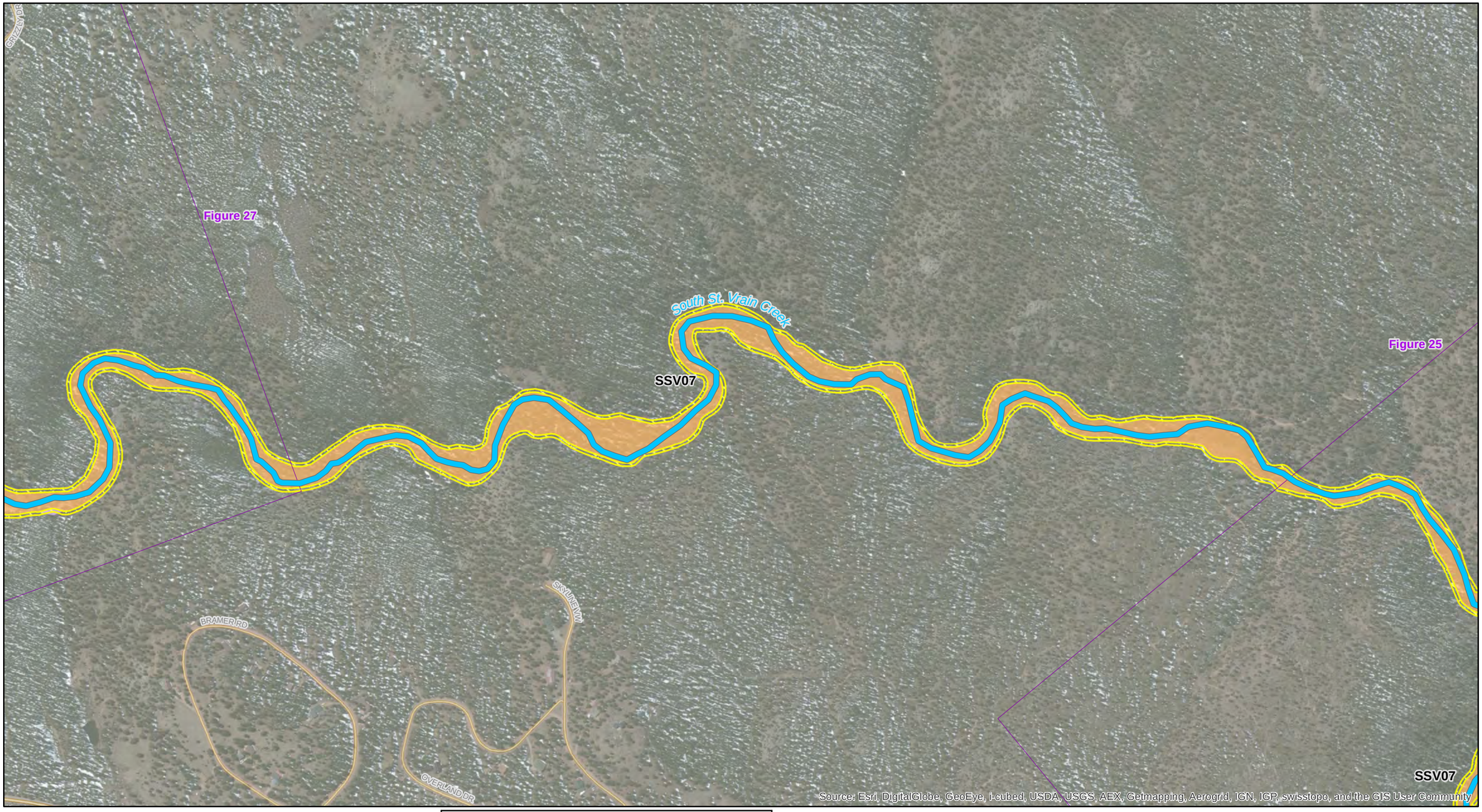

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 26
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado

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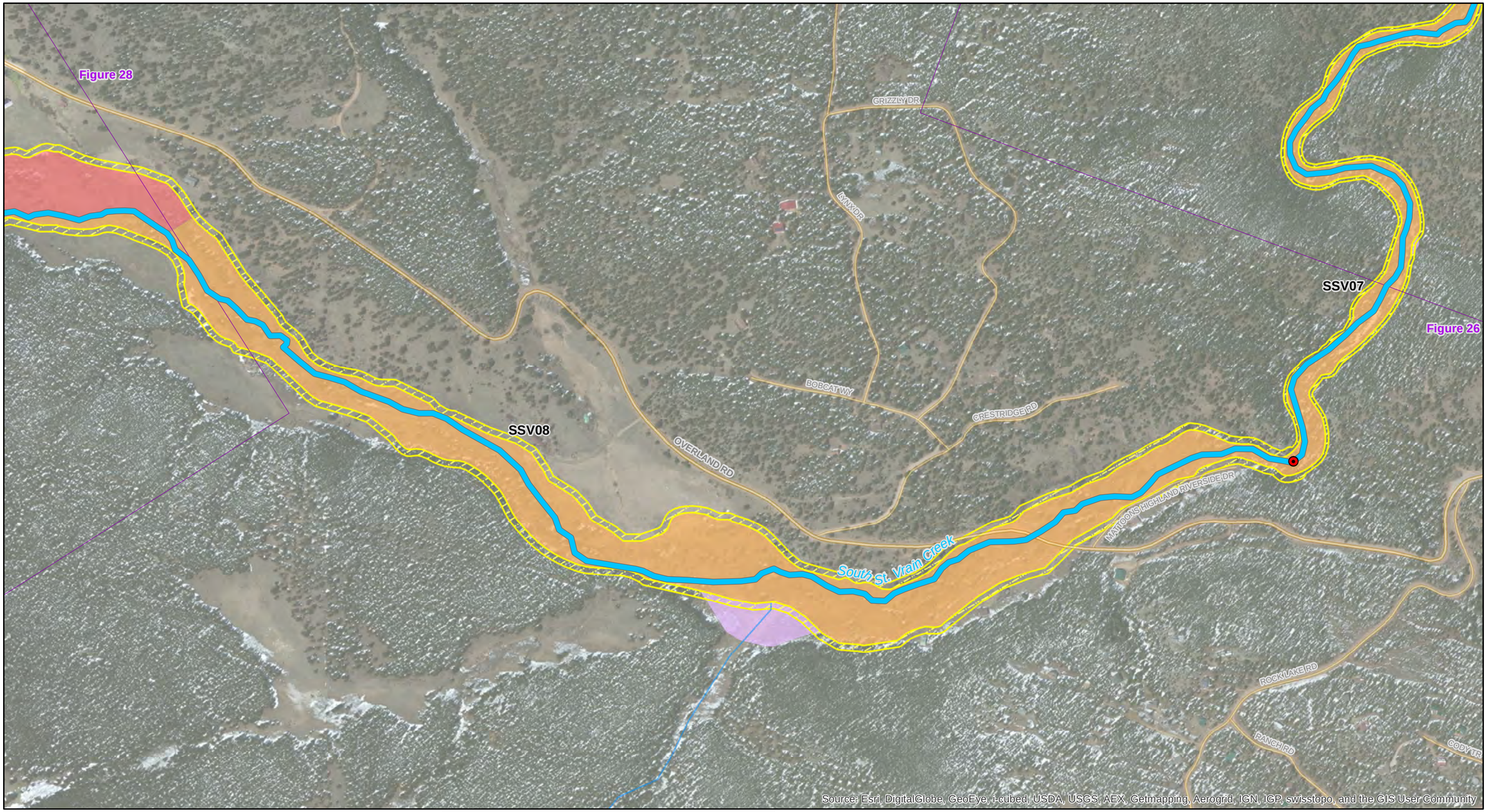

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

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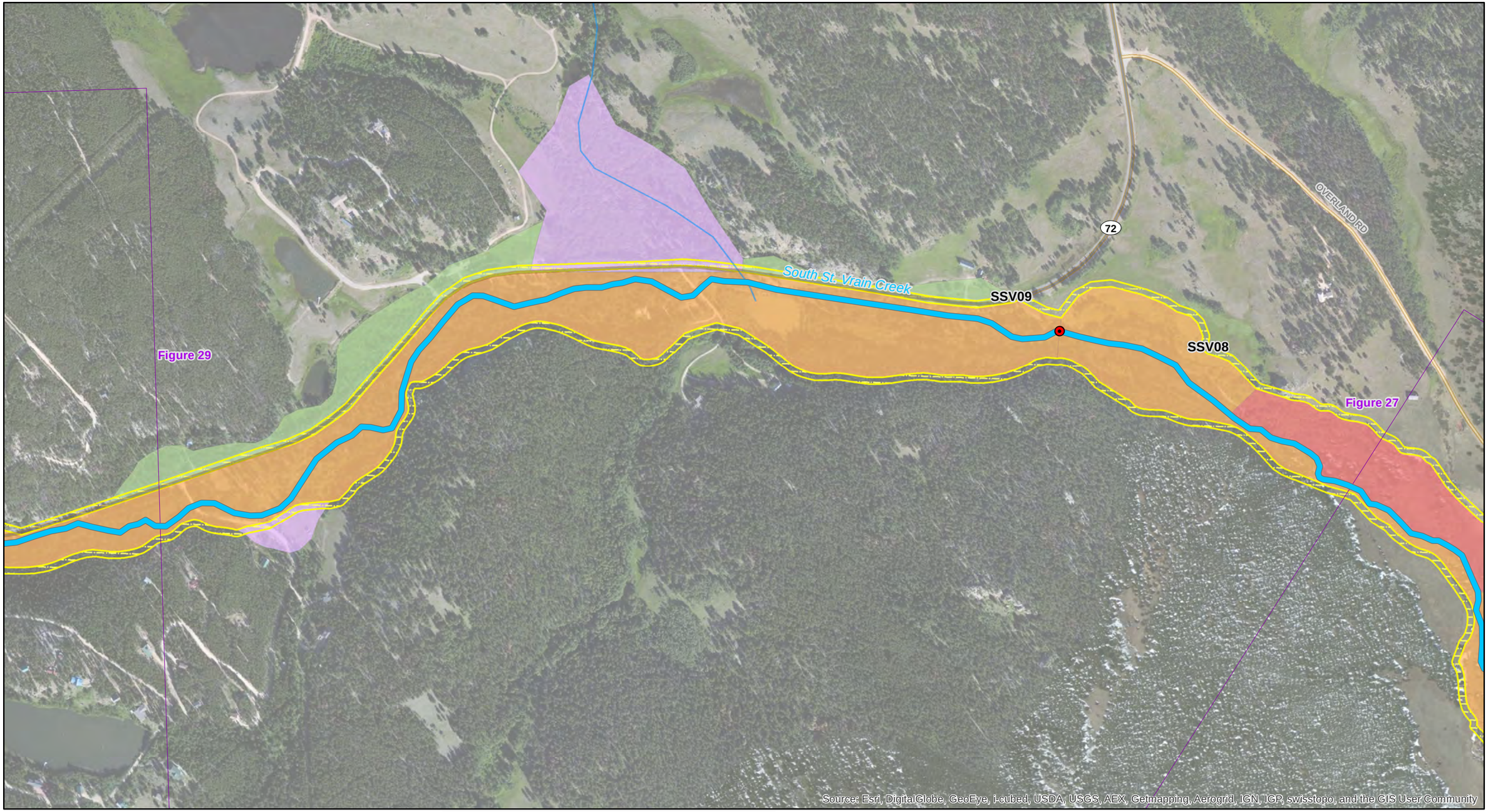
Figure 27
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado



NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 28
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado

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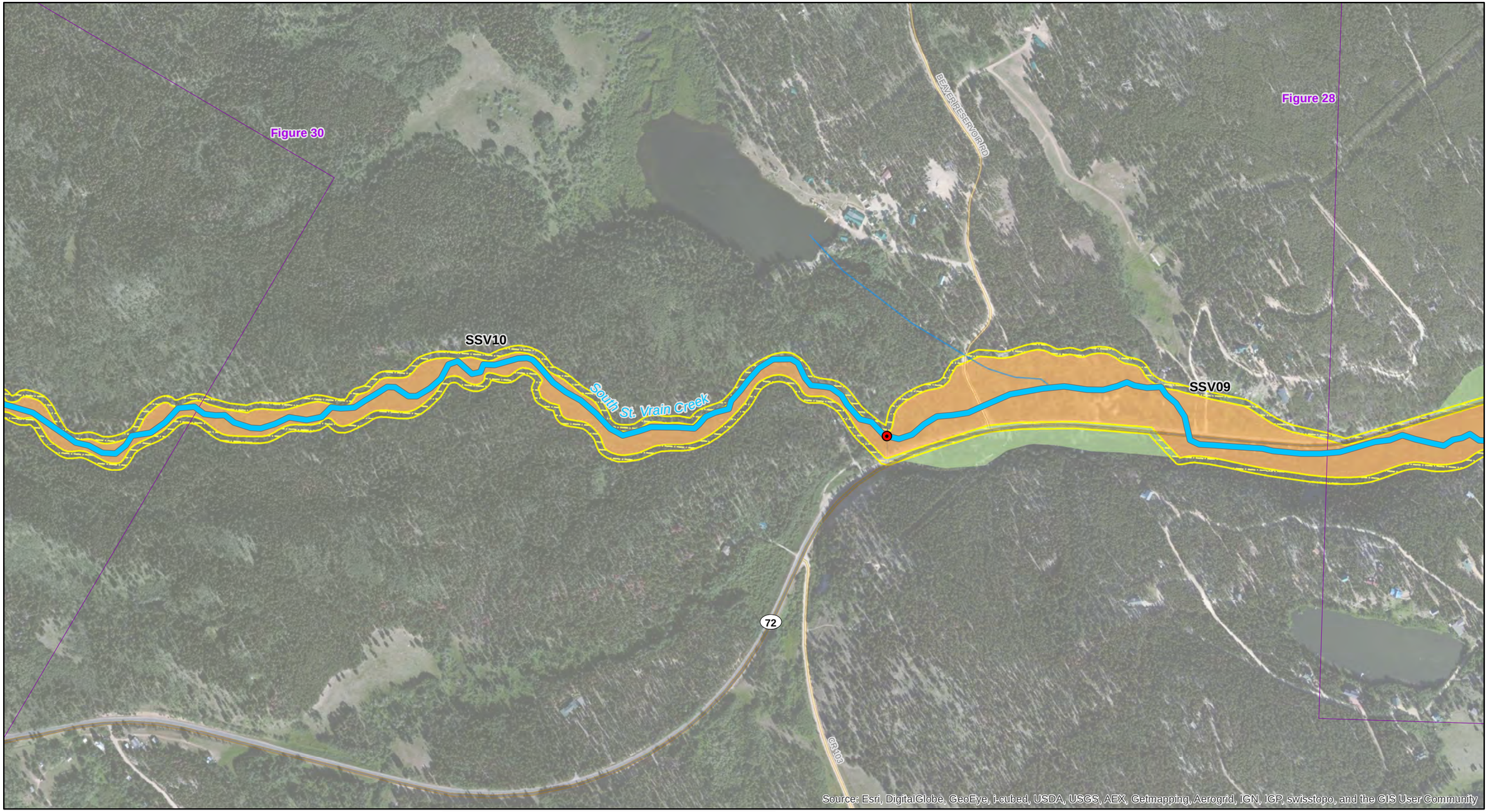

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 29
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado

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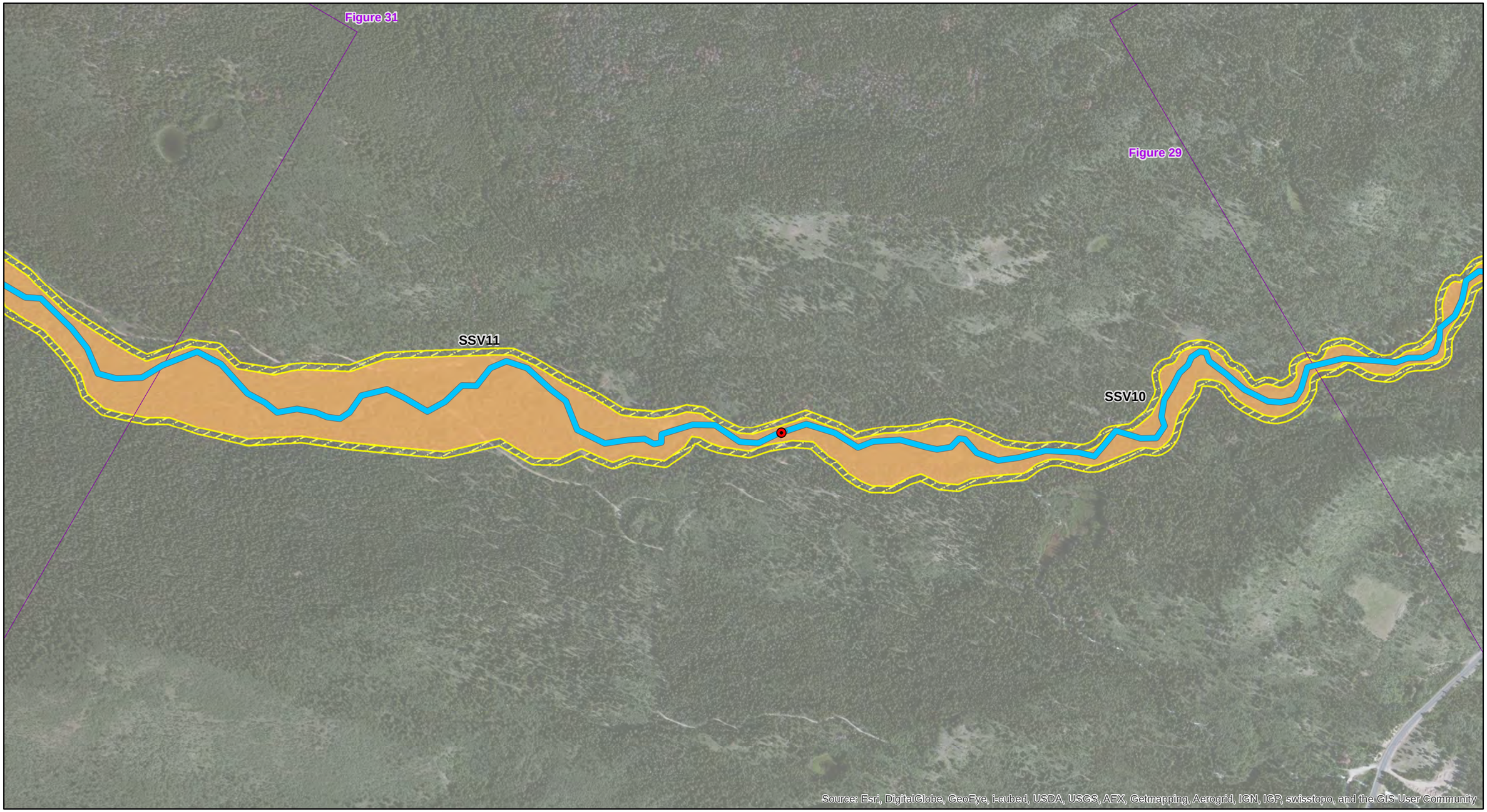

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 30
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado

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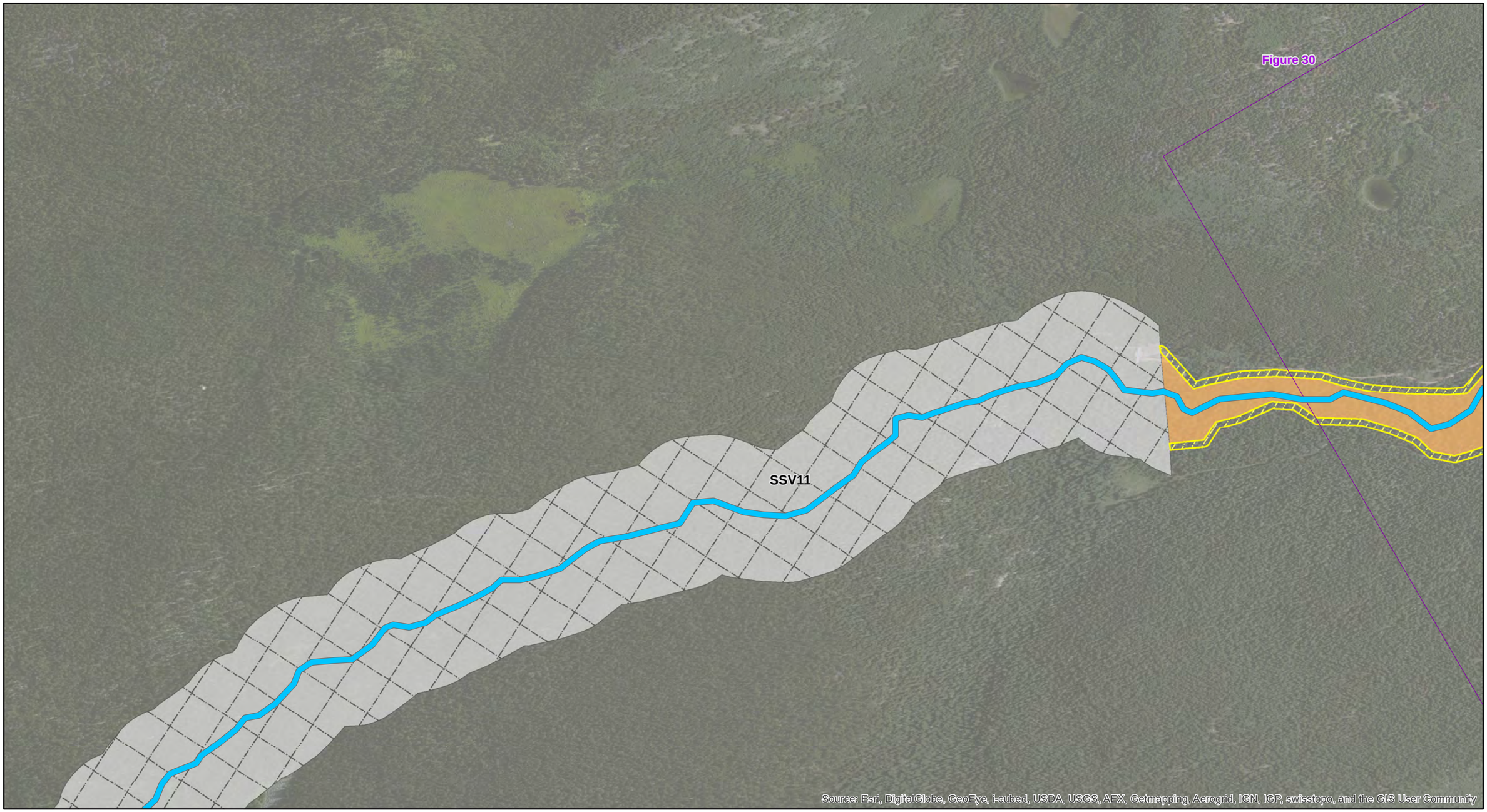

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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- Reach Break
- Active Channel
- Adjacent Map

pCMZ Delineations

- Modern Valley Bottom
- Avulsion Hazard Zone
- Erosion Hazard Area
- Alluvial Fan
- Disconnected Migration Area
- No Data

Figure 31
Draft Geomorphic Hazard Zones
St. Vrain Creek System - South St. Vrain
Boulder County, Colorado

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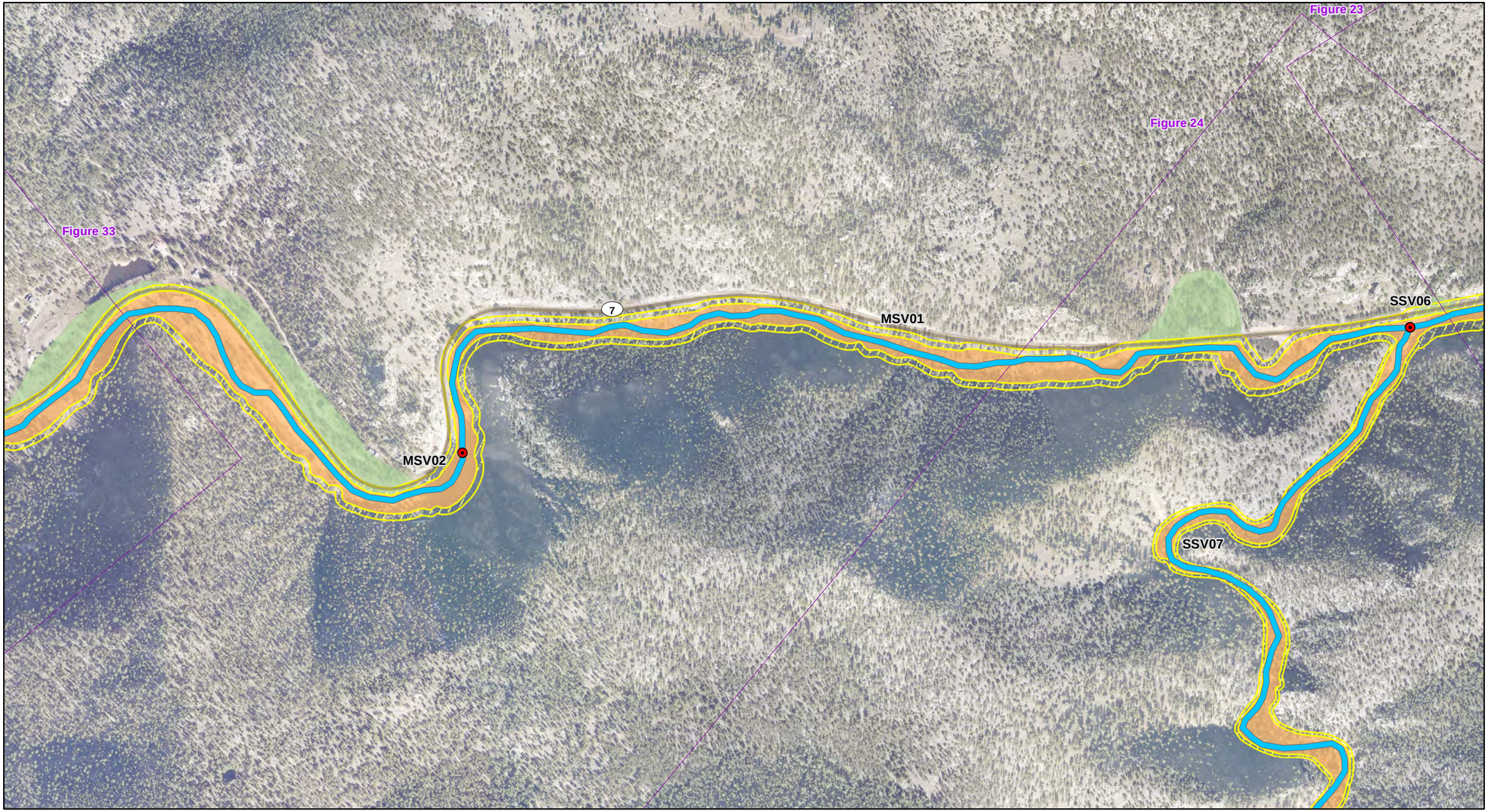

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

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Figure 32
Draft Geomorphic Hazard Zones
St. Vrain Creek System - Middle St. Vrain
Boulder County, Colorado

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Reach Break
Active Channel
Adjacent Map

pCMZ Delineations
Modern Valley Bottom
Avulsion Hazard Zone
Erosion Hazard Area
Alluvial Fan
Disconnected Migration Area
No Data

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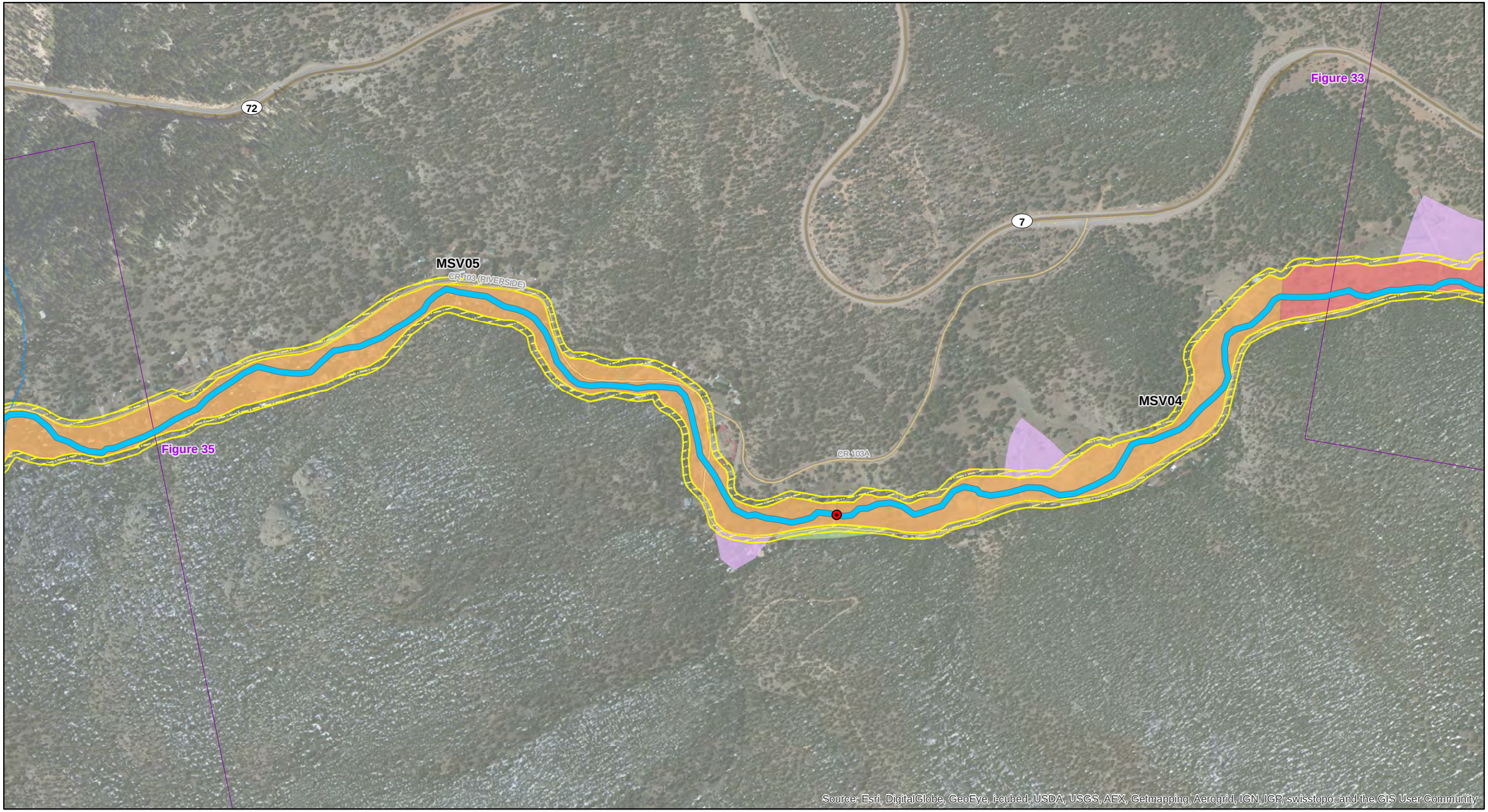
Figure 33
Draft Geomorphic Hazard Zones
St. Vrain Creek System - Middle St. Vrain
Boulder County, Colorado



NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 34
Draft Geomorphic Hazard Zones
St. Vrain Creek System - Middle St. Vrain
Boulder County, Colorado

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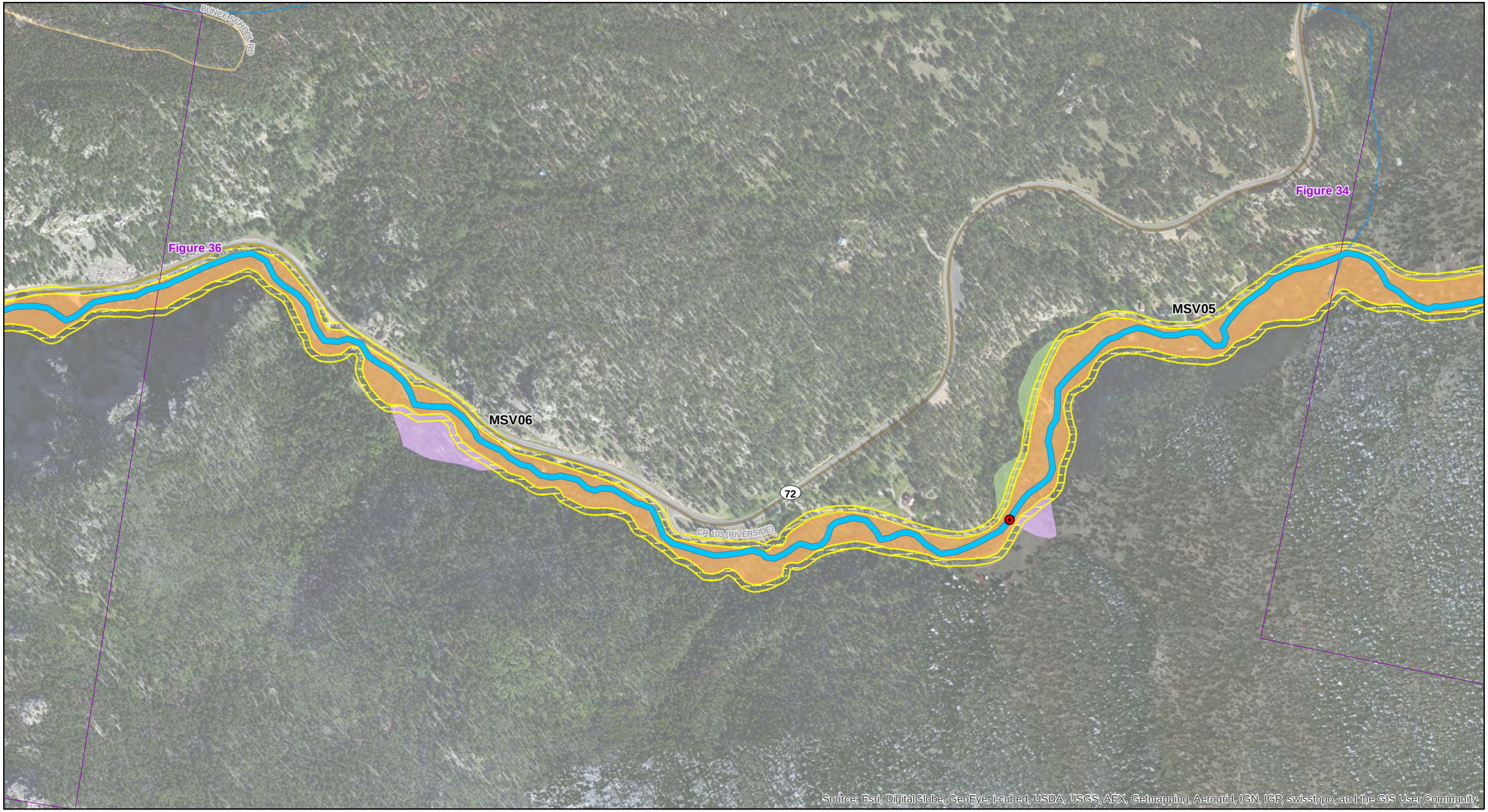

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 35
Draft Geomorphic Hazard Zones
St. Vrain Creek System - Middle St. Vrain
Boulder County, Colorado

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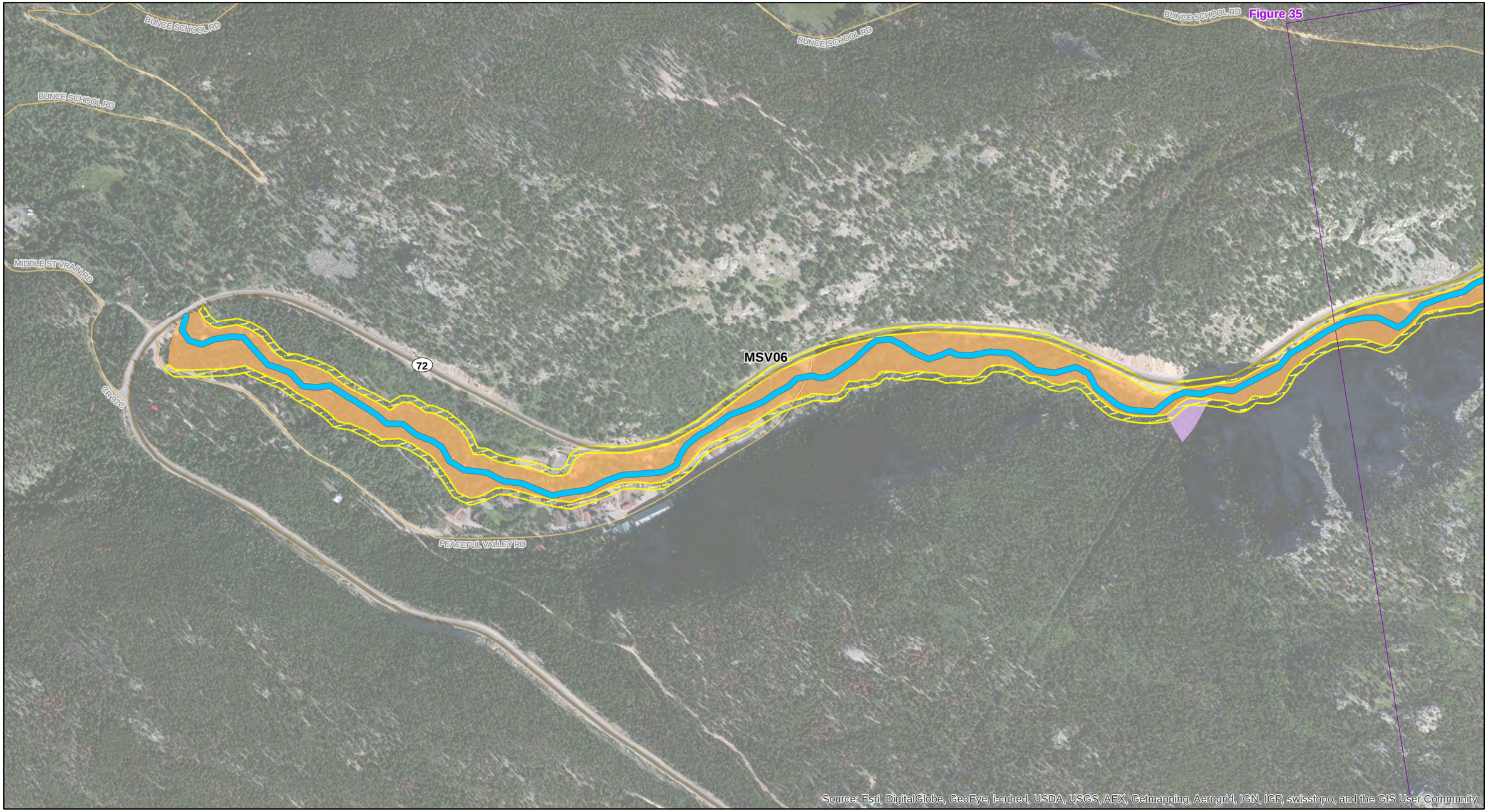

NAD 1983 HARN StatePlane Colorado North FIPS 0501 Feet

0 500 1,000
Feet
1 inch = 500 feet

Walsh
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Reach Break	**pCMZ Delineations**
Active Channel	Modern Valley Bottom
Adjacent Map	Avulsion Hazard Zone
	Erosion Hazard Area
	Alluvial Fan
	Disconnected Migration Area
	No Data

Figure 36
Draft Geomorphic Hazard Zones
St. Vrain Creek System - Middle St. Vrain
Boulder County, Colorado

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Appendix A

St. Vrain Creek Watershed Master Plan

Rapid Geomorphic Assessment

Reach-scale Geomorphic Summaries

July 28 2014

Reach SVC01 – St. Vrain Creek

Upstream of County Line Rd. – looking river right at outlet of pour-over gully (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool (weak)
Departure Type	None
Channel Evolution Stage	IV
Channel Processes	Minor planform adjustment during flood except in the vicinity of County Line Rd. bridge where major adjustment occurred. Significant overbank flooding and existing riparian vegetation may have helped maintained the existing channel. Continued planform adjustment may erode banks contributing fine and course material to the system.
Sediment Regime	Fine Source & Transport and Coarse Deposition

Reach SVC02 – St. Vrain Creek

Upstream of Hwy 119 – looking upstream (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool (weak)
Departure Type	None
Channel Evolution Stage	III
Channel Processes	Minor widening and historical incision relative to wider floodplain. Some bar development and bank erosion indicating planform adjustment may be expected in the future.
Sediment Regime	Fine Source & Transport and Coarse Deposition

Reach SVC03 – St. Vrain Creek

Upstream of Martin St., downstream of channel avulsion into pond – looking downstream (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	None
Channel Evolution Stage	IV
Channel Processes	Significant planform adjustment (breaching and accessing gravel mining ponds) during flood. Continued planform adjustment may erode banks contributing fine material to the system while providing opportunities to store coarse materials in bars and side channels.
Sediment Regime	Fine Source & Transport and Coarse Deposition

Reach SVC04 – St. Vrain Creek

Boston Ave. – looking upstream (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	B4
Reference Bed Form	Riffle-pool
Existing Bedform	Plane bed
Departure Type	Bedform change due to straightening. Incision and development may have changed entrenchment – might be a "B" type channel now
Channel Evolution Stage	II-III
Channel Processes	Reach has been historically straightened and is likely underfit during most runoff events. Channel was able to access floodplain in September 2013 and returned to low flow channel on the tail end of the hydrograph. Scouring is directed at the bed which because of this lacks well-defined riffle-pool features and is predominately a transport reach.
Sediment Regime	Unconfined Source & Transport

Reach SVC05 – St. Vrain Creek

Upstream of Sunset Ave. and pedestrian bridge – looking upstream (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	None
Channel Evolution Stage	IV
Channel Processes	Planform adjustment (new point bars and steep eroding outside banks) during flood. Continued planform adjustment may erode banks contributing fine material to the system while providing opportunities to store coarse materials in bars and side channels.
Sediment Regime	Fine Source & Transport and Coarse Deposition

Reach SVC06 – St. Vrain Creek

Golden Ponds – looking upstream (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Plane bed
Departure Type	Bedform change due to straightening.
Channel Evolution Stage	III
Channel Processes	Reach has been historically straightened and is likely underfit during most runoff events. Channel was able to access low floodplain bench during flood and returned to low flow channel on the tail end of the hydrograph. Scouring is directed at the bed which because of this lacks well-defined riffle-pool features and is predominately a transport reach.
Sediment Regime	Unconfined Source & Transport

Reach SVC07 – St. Vrain Creek

75th St. bridge – looking downstream (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	None
Channel Evolution Stage	III-IV
Channel Processes	Major planform adjustment during flood with development of large flood chutes and avulsions. Numerous side bars and point bars formed. Continued planform adjustment may erode banks and contribute fine material to the system.
Sediment Regime	Fine Source & Transport and Coarse Deposition

Reach SVC08 – St. Vrain Creek

Crane Creek Hollow Rd. – looking upstream (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	None
Channel Evolution Stage	V
Channel Processes	Reach has been historically straightened but floodplain benches have been created and vegetated. Channel was able to access floodplain in September 2013 and returned to low flow channel on the tail end of the hydrograph.
Sediment Regime	Coarse Equilibrium and Fine Deposition

Reach SVC09 – St. Vrain Creek

Downstream of 63rd St. – looking downstream (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	None
Channel Evolution Stage	IV
Channel Processes	Major planform adjustment during flood with development of large flood chutes and avulsions. Numerous side bars and point bars formed. Avulsions into floodplain gravel ponds. Continued planform adjustment may erode banks and contribute fine material to the system.
Sediment Regime	Fine Source & Transport and Coarse Deposition

Reach SVC10 – St. Vrain Creek

CEMEX railroad bridge – looking upstream (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	None
Channel Evolution Stage	V
Channel Processes	Reach has been historically straightened but floodplain benches have been created and vegetated. Channel was able to access floodplain in September 2013 and returned to low flow channel on the tail end of the hydrograph.
Sediment Regime	Coarse Equilibrium and Fine Deposition

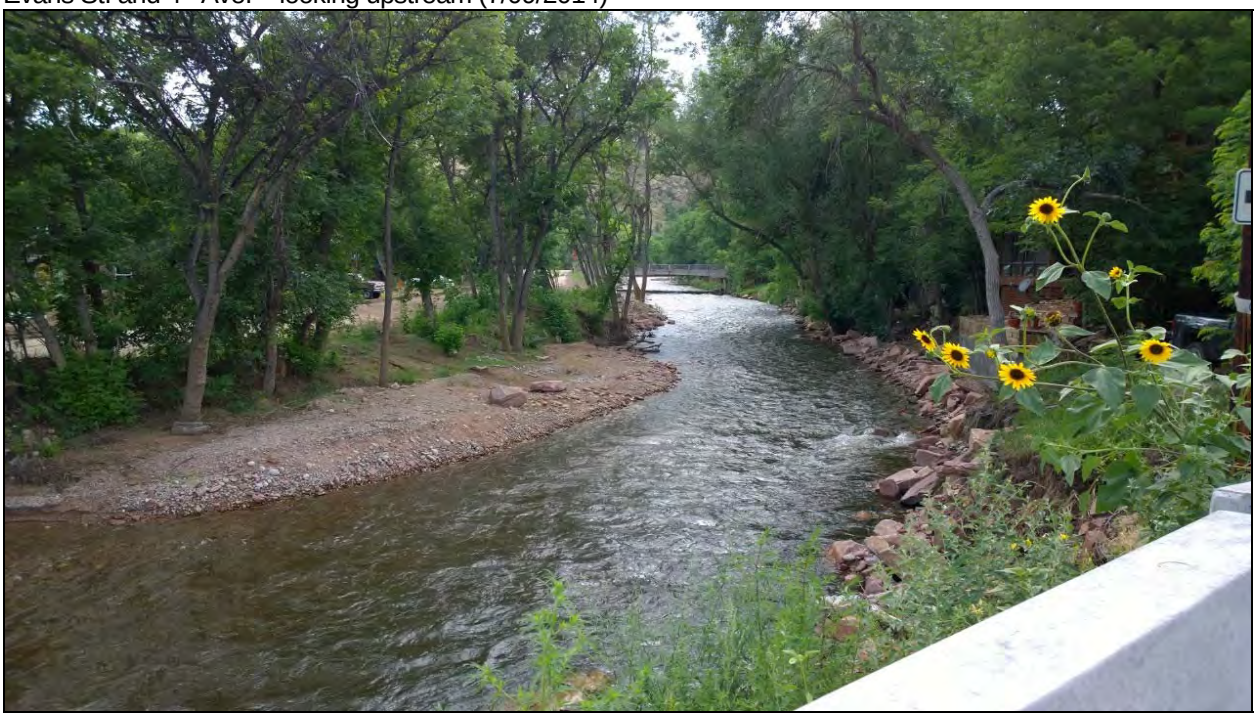
Reach SVC11 – St. Vrain Creek

Downstream of McConnell Dr. – looking upstream (6/20/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	None
Channel Evolution Stage	IV
Channel Processes	Major planform adjustment during flood with development of large flood chutes and avulsions. Numerous side bars and point bars formed. Continued planform adjustment may erode banks and contribute fine material to the system.
Sediment Regime	Fine Source & Transport and Coarse Deposition

Reach NSV01 – North St. Vrain Creek

Evans St. and 4th Ave. – looking upstream (7/09/2014)



Reference Stream Type	C4
Existing Stream Type	C3
Reference Bed Form	Riffle-pool
Existing Bedform	Plane bed
Departure Type	Bedform (and possibly bed material) change due to straightening.
Channel Evolution Stage	II-III
Channel Processes	Reach has been historically straightened and channel adjustments are limited due to armoring. Channel was able to access floodplain in September 2013 and returned to low flow channel on the tail end of the hydrograph. Scouring is directed at the bed which because of this lacks well-defined riffle-pool features and is predominately a transport reach.
Sediment Regime	Unconfined Source & Transport

Reach NSV02 – North St. Vrain Creek

Main St. bridge – looking upstream (7/09/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	None
Channel Evolution Stage	I
Channel Processes	Reach planform largely controlled by bedrock outcroppings. Minor aggradation in the inside bends. Flood chutes developed across the floodplain during the September event but the low flow channel remained largely intact.
Sediment Regime	Coarse Equilibrium and Fine Deposition

Reach NSV03 – North St. Vrain Creek

Looking upstream (6/21/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	None
Channel Evolution Stage	I
Channel Processes	Alluvial valley bottom with only localized sign of incision. Major planform adjustments during flood as channel worked to transport and store sediments across the valley bottom.
Sediment Regime	Coarse Equilibrium and Fine Deposition

Reach NSV04 – North St. Vrain Creek

Looking downstream (6/21/14)

Reference Stream Type	C3
Existing Stream Type	B3c
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	Floodplain encroachment by Highway 36 and Longmont Dam Road largely have changed the channel confinement and therefore the Rosgen stream type classification.
Channel Evolution Stage	II-III
Channel Processes	Reach has been historically straightened within the narrow valley for road building. Typical annual channel adjustments are limited due to heavy armoring and reduced flows as a result of Buttonrock Reservoir. Large alluvial and colluvium materials deposited from the canyon walls have formed some significant step pool sequences. The channel has very little sediment storage capacity however is susceptible to significant channel adjustment during a large flood event.
Sediment Regime	Unconfined Source & Transport

Reach NSV05 – North St. Vrain Creek

Upstream of Longmont Reservoir – looking upstream (6/24/2014)

Reference Stream Type	C3b
Existing Stream Type	B3
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	Floodplain encroachments by Longmont Dam Road largely have changed the channel confinement and therefore the Rosgen stream type classification.
Channel Evolution Stage	II-III
Channel Processes	Reach has been historically straightened within the narrow valley for road building. Typical annual channel adjustments are limited due to heavy armoring and reduced flows as a result of Buttonrock Reservoir. Scouring is directed at the bed which lacks well-defined riffle-pool features in some areas. Large alluvial and colluvium materials deposited from the canyon walls have formed some significant step pool sequences. The channel has very little sediment storage capacity however is susceptible to significant channel adjustment during a large flood event.
Sediment Regime	Unconfined Source & Transport

Reach SSV01 – South St. Vrain Creek

Looking downstream (6/21/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Plane bed
Departure Type	Bedform change due to straightening.
Channel Evolution Stage	II-III
Channel Processes	Reach has been historically straightened and channel adjustments are limited due to armoring. Significant overbank flow and aggradation occurred during the September 2013 flood but post flood dredging and berming largely returned the channel to its pre-flood location. The bed lacks well-defined riffle-pool features and is predominately a transport reach during most events.
Sediment Regime	Unconfined Source & Transport

Reach SSV02 – South St. Vrain Creek

Looking downstream (6/21/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool (weak)
Departure Type	None
Channel Evolution Stage	Depositional stage - braiding
Channel Processes	Significant sediment deposition and braiding. Excellent floodplain access and sediment storage. Riffle-pool bedform features tend to be short and frequent due to multiple braided channels.
Sediment Regime	Deposition

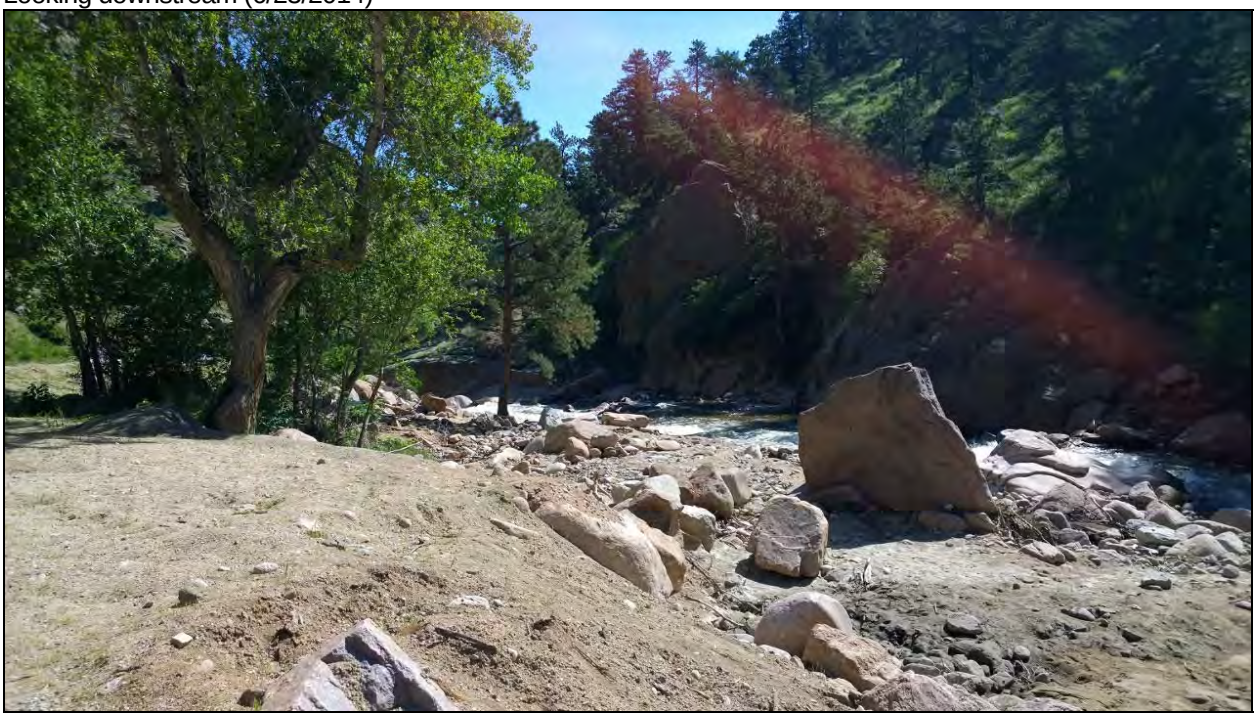
Reach SSV03 – South St. Vrain Creek

Looking upstream (6/23/2014)

Reference Stream Type	C4
Existing Stream Type	C3
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	Reduction in meander wavelength (i.e. straightening) by the construction of Highway 7 has increased the slope of the stream channel coarsening the bed material and degrading the riffle pool bedform features.
Channel Evolution Stage	III-IV
Channel Processes	Reach exhibited significant planform adjustment and aggradation during the September flood. Numerous bars and flood chutes were established. Channel incision remains with only minor floodplain benches accessible (planform adjustment is limited due to a canyon wall on the right bank). Expect continued erosion and deposition sequences to occur as channel wrestles with the road for floodplain access.
Sediment Regime	Unconfined Source & Transport

Reach SSV04 – South St. Vrain Creek

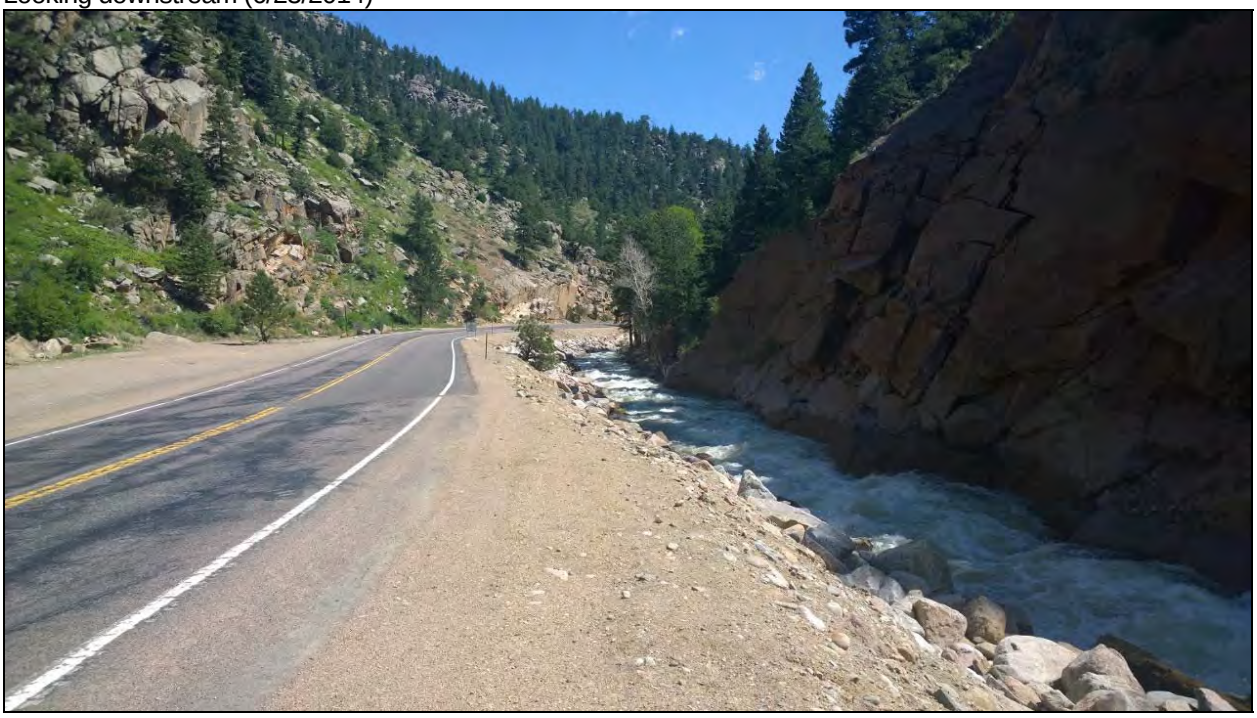
Looking downstream (6/23/2014)



Reference Stream Type	B3
Existing Stream Type	B3
Reference Bed Form	Step-pool
Existing Bedform	Step-pool
Departure Type	Reduction in meander wavelength (i.e. straightening) by the construction of Highway 7 has increased the slope of the stream however the coarser cobble and boulder bed materials make the stream more resistive to change.
Channel Evolution Stage	II-III
Channel Processes	Reach exhibited some planform adjustment into the road during the September flood. Channel entrenchment is moderate with only minor floodplain benches accessible (planform adjustment is limited due to a canyon wall on the right bank).
Sediment Regime	Confined Source & Transport

Reach SSV05 – South St. Vrain Creek

Looking downstream (6/23/2014)



Reference Stream Type	B3
Existing Stream Type	G2
Reference Bed Form	Step-pool
Existing Bedform	Step-pool
Departure Type	Reduction in meander wavelength (i.e. straightening) by the construction of Highway 7 has increased the slope of the stream. The bed now appears to be dominated by boulders as the bed material. Very entrenched and incised.
Channel Evolution Stage	II
Channel Processes	Reach exhibited some widening into the road during the September flood (stage III) but was re-narrowed by armoring (stage II). Channel entrenchment and incision are very high due to the road embankment and canyon wall.
Sediment Regime	Confined Source & Transport

Reach SSV06 – South St. Vrain Creek

Looking upstream (6/23/2014)

Reference Stream Type	B3
Existing Stream Type	B3
Reference Bed Form	Step-pool
Existing Bedform	Step-pool
Departure Type	A more confined valley due to the road embankment but likely no change in stream type as there are still small floodplain benches accessible and the road is further away and higher up from the stream than lower in the canyon.
Channel Evolution Stage	III-IV
Channel Processes	Reach exhibited some widening during the September flood (stage III) as well as some planform adjustment (stage IV). Channel entrenchment and incision are very high due to the road embankment and canyon wall.
Sediment Regime	Confined Source & Transport

Reach SSV07 – South St. Vrain Creek

Ceran St. Vrain trail – looking upstream (6/24/2014)

Reference Stream Type	B3
Existing Stream Type	B3
Reference Bed Form	Step-pool
Existing Bedform	Step-pool
Departure Type	No departures. Stream classification may vary over this long canyon reach as the valley walls entrench or allow more room for channel adjustment. Overall stream type and sediment source in reference condition.
Channel Evolution Stage	I
Channel Processes	Undeveloped canyon. Natural channel processes at work with large wood being a significant driver in sediment storage and release and channel planform alteration contributing stability and habitat.
Sediment Regime	Transport

Reach SSV08 – South St. Vrain Creek

Overland Rd culvert crossing – looking downstream (6/24/2014)

Reference Stream Type	C4b
Existing Stream Type	C4b
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	No departures identified.
Channel Evolution Stage	I
Channel Processes	Channel runs through moderately steep valley and may begin as a C3b and end as a C4. Abundant riparian vegetation and excellent floodplain access aid channel stability through the moderately steep valley. No major adjustments observed during September flood.
Sediment Regime	Coarse Equilibrium and Fine Deposition

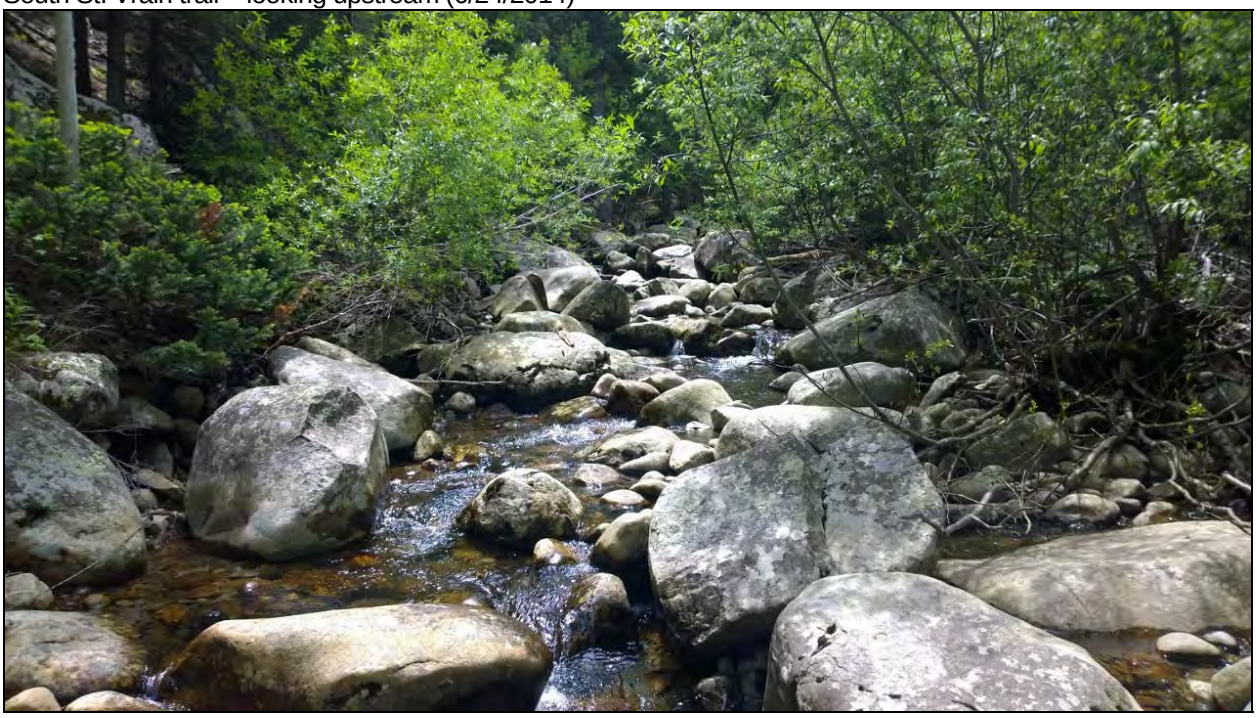
Reach SSV09 – South St. Vrain Creek

Driveway crossing – looking upstream (6/24/2014)

Reference Stream Type	C4
Existing Stream Type	C4
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool (weak)
Departure Type	No significant. Some sections of the reach may type out as a "B" or even "F" channel due to roadway encroachments and/or berming which has also reduced the strength of riffle-pool features.
Channel Evolution Stage	III
Channel Processes	Channel valley bottom has seen significant encroachment and straightening which have deteriorated bedform. Channel widening (post incision) has been the main response. Bank vegetation for the most part is robust and aiding channel stability.
Sediment Regime	Unconfined Source & Transport

Reach SSV10 – South St. Vrain Creek

South St. Vrain trail – looking upstream (6/24/2014)



Reference Stream Type	B3
Existing Stream Type	B3
Reference Bed Form	Step-pool
Existing Bedform	Step-pool
Departure Type	No departures identified.
Channel Evolution Stage	I
Channel Processes	Channel runs through moderately steep valley with a coarse boulder and cobble step-pool bedform. Riparian vegetation is abundant and excellent floodplain access aids channel stability. No major active adjustments observed.
Sediment Regime	Transport

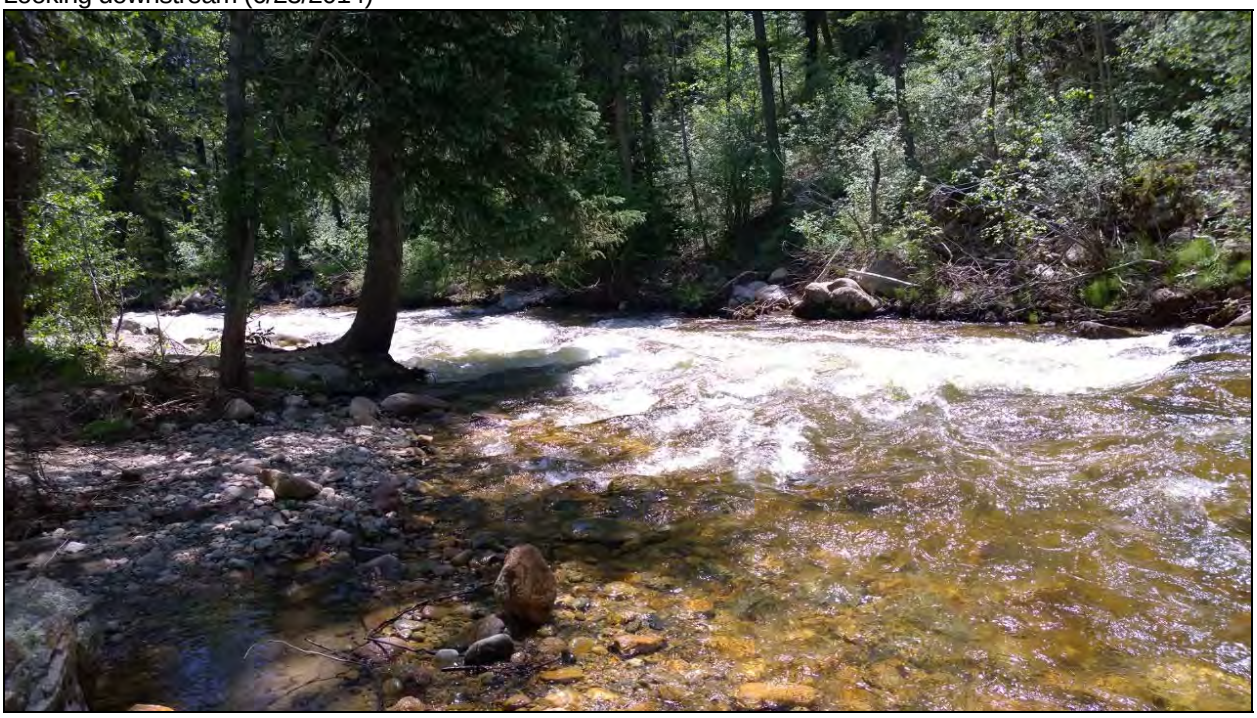
Reach SSV11 – South St. Vrain Creek

Brainard Lake outlet – looking downstream (6/24/2014)

Reference Stream Type	B3
Existing Stream Type	B3
Reference Bed Form	Step-pool
Existing Bedform	Step-pool
Departure Type	No departures identified.
Channel Evolution Stage	I
Channel Processes	Channel runs through moderately steep valley with a coarse boulder and cobble step-pool bedform. Riparian vegetation is abundant and excellent floodplain access aids channel stability. No major active adjustments observed.
Sediment Regime	Transport

Reach MSV01 – Middle St. Vrain Creek

Looking downstream (6/23/2014)



Reference Stream Type	C3b
Existing Stream Type	B3
Reference Bed Form	Plane bed
Existing Bedform	Plane bed
Departure Type	Channel has become more entrenched and steeper due to road embankment but this has likely not had much effect on the dominant bedform (some pool sequences may have been lost) or the size of the material in the channel.
Channel Evolution Stage	V
Channel Processes	Channel banks are vegetated with small floodplain benches. Some channel planform adjustments but limited by bank materials as well as the confinement of the road embankment.
Sediment Regime	Transport

Reach MSV02 – Middle St. Vrain Creek

Looking upstream (6/23/2014)

Reference Stream Type	C3b
Existing Stream Type	C3b
Reference Bed Form	Riffle-pool
Existing Bedform	Plane bed
Departure Type	Highway 7 has cut off numerous meander bends steepening the channel and likely eroding riffle steps and filling pools.
Channel Evolution Stage	III-IV
Channel Processes	Stream exhibited widening and major planform adjustments during the September 2013 flood. The highway embankment has disconnected channel bottom and has limited the streams ability to fully adjust its planform.
Sediment Regime	Fine Source & Transport and Coarse Deposition

Reach MSV03 – Middle St. Vrain Creek

Riverside Dr. bridge – looking downstream (6/23/2014)

Reference Stream Type	C3b
Existing Stream Type	B3
Reference Bed Form	Riffle-pool
Existing Bedform	Plane bed
Departure Type	Significant channel straightening through Riverside has entrenched the channel and eliminated the likely reference riffle-pool bedform.
Channel Evolution Stage	II-III
Channel Processes	Stream exhibited widening and major planform adjustments during the September 2013 flood. Dredging, straightening and armoring post-flood have locked it back into a stage II-III channel.
Sediment Regime	Unconfined Source and Transport

Reach MSV04 – Middle St. Vrain Creek

Raymond Store bridge – looking downstream (6/23/2014)

Reference Stream Type	C3
Existing Stream Type	C3
Reference Bed Form	Riffle-pool
Existing Bedform	Riffle-pool
Departure Type	None observed.
Channel Evolution Stage	IV
Channel Processes	Stream exhibited widening and major planform adjustments during the September 2013 flood. Dredging, straightening and armoring post-flood have locked it back into a stage II-III channel.
Sediment Regime	Fine Source & Transport and Coarse Deposition

Reach MSV05 – Middle St. Vrain Creek

Looking upstream (6/23/2014)

Reference Stream Type	C3b
Existing Stream Type	C3b
Reference Bed Form	Step-pool
Existing Bedform	Plane-bed
Departure Type	Channel straightening and dredging along with removal of large wood in the system have eliminated step-pool development.
Channel Evolution Stage	II-III
Channel Processes	Historical incision. Widened during flood washing out embankments and structures. Dredging, straightening and armoring post-flood have locked it back into a stage II-III channel.
Sediment Regime	Unconfined Source & Transport

Reach MSV06

Hwy 72 – looking downstream (6/23/2014)

Reference Stream Type	C3b
Existing Stream Type	C3b
Reference Bed Form	Step-pool
Existing Bedform	Step-pool (weak)
Departure Type	None observed.
Channel Evolution Stage	V
Channel Processes	Historical incision. Presently stable with minor planform adjustments. The highway has limited floodplain development and sinuosity that would aid in pool development.
Sediment Regime	Coarse Equilibrium & Fine Deposition