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February 6, 2015

Mr. John Svahn
Stewardship Director
Truckee Donner Land Trust
10069 West River Street
Truckee, CA

RE: Van Norden Dam 100-Year Flood Attenuation Evaluation

Dear Mr. Svahn:

This letter report summarizes the findings of a hydrologic and hydraulic analysis of Van Norden Dam and its contributing watershed near Soda Springs, California. Our previous hydraulic evaluation of Van Norden Dam (Riedner and others, 2014) surmised that flood control benefit from the dam is small, and is largely a function of antecedent lake level and spillway configuration. Here, we test that hypothesis through hydrologic and hydraulic modeling. In addition to quantifying the flood control benefits of the dam under its current configuration, we evaluate benefits under several future potential configurations: a 2.3-foot deep, narrow notch in the spillway; a lowering of the entire spillway width by 5.0 feet; and a complete removal of the dam (both with and without concurrent meadow restoration). Flood control benefits are discussed in terms of changes to the 100-year flood hydrograph immediately downstream of the dam, and possible implications for inundation extents in Soda Springs and several miles downstream at Cisco Grove. Ultimately this information is intended to be used for environmental documentation purposes, decision-making regarding future dam configurations and management, and evaluation of potential flooding effects associated with various dam configurations.

HYDROLOGIC SETTING

Lake Van Norden is situated just west of the Sierra Crest, and has a mean basin elevation of 7,300 ft. Elevations within the watershed range by more than 2,200 feet, and its highest points along the Sierra

Crest exceed 9,000 feet (see Figure 1). Spring snowmelt typically drives annual peak flow rates; however, the most extreme peaks of the last 60 years have been from early-winter rain-on-snow events. Most of the runoff arriving at Lake Van Norden comes from two locations: Upper Castle Creek drains Castle Valley (3.9 square miles) to the northeast, and the South Yuba River drains Summit Valley (4.6 square miles) to the southeast[1]. A number of intervening hillside areas also contribute runoff directly to the lake; the total drainage area at the Van Norden Dam spillway is 10.1 square miles. According to the map of mean annual precipitation published by Nevada County Public Works (Standard Drawing D-10, revised May 10, 1995), the mean annual precipitation of the watershed ranges from 50 inches near the Sierra Crest to 60 inches near Van Norden Dam[2]. Soils are classified primarily as Hydrologic Soils Group D, with some B soils at lower elevations and within the lake footprint and surrounding meadow (NRCS, 2013). The majority of the basin is lightly developed with the most significant impacts to land cover from ski area infrastructure (Sugar Bowl, Donner Ski Ranch, and Boreal), the Union Pacific Railroad, and roads including Interstate 80, Old Highway 40, and numerous dirt roads. Rock outcrops are abundant along higher elevations, and are significant in terms of total impervious area.

HYDROLOGIC MODEL DEVELOPMENT

The goal of the hydrologic modeling effort was to synthesize hydrographs for the 100-year flow event that could be routed through Van Norden Dam under several future potential configurations. We developed hydrographs according to Hydrologic Design criteria for Storm Drainage associated with Nevada County Road Standards. These guidelines call for streams with watershed areas greater than one square mile to be analyzed utilizing the Soil Conservation Service (SCS) Unit Hydrograph Method in the HEC-1 modeling platform. The model was built using the U.S. Army Corps of Engineers HEC-HMS software; this software is the successor of HEC-1 and uses a nearly identical computational engine.

Subbasins within the Van Norden Dam watershed were delineated using ArcHydro for ArcGIS 9 (Version 1.4, January 5 2011), and the National Elevation Dataset (NED) for topography. Soil abstraction was modeled with the SCS Curve Number method. Curve numbers for individual regions of similar hydrologic soil group and land use[3] were assigned per Nevada County guidelines (Standard Drawing D-16). Composite curve numbers were then computed in GIS for each subbasin by weighted area. Initial abstraction was estimated as 20 percent of soil retention, wherein retention was modeled as a function of the curve number per SCS equations presented in TR-55 (USDA, 1986). The percent of impervious area

[1] Watershed areas are based on the National Elevation Dataset (NED), 1/3 arc-second (10 meter) resolution DEM. We acknowledge these numbers are slightly different than from what was presented in Riedner and others (2014). The differences are due to slightly different points of concentration used for the hydrologic model.

[2] Mean annual precipitation was estimated as 65.9 inches by Riedner and others (2014) using the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) climatic dataset, 800 meter resolution; includes data from 1971 to 2000. This study uses hydrologic criteria for storm drainage associated with Nevada County Public Works, Department of Transportation, and has adopted their estimates.

[3] The Soil Survey Geographic (SSURGO) database for Tahoe National Forest Area, California was used to define hydrologic soils group. The 2011 National Land Cover Dataset (NLCD) was used to define land use.

in subbasins was calculated in GIS as the percent of the subbasin comprised of rock outcrops, high intensity development, and open water. Lag time was estimated as 0.6 times the time of concentration, and the time of concentration was estimated based on SCS Technical Publication 149. The depth of the 100-year storm was selected from Nevada County depth-duration curves (Standard Drawing D-14, revised 5-11-95). Since mean annual precipitation varies over the watershed, a storm depth on the high side of the range was selected (10.0 inches) to provide a conservative estimate of the 100-year event. A storm duration of 24-hours was selected because it will produce the most volume; this is significant in this application because the 24-hour storm will cause the most response in Lake Van Norden, and uphold our effort to provide conservative results. All final subbasin locations, parameters, and 100-year flows are shown in Figure 1 and Table 1.

Hydrographs for subbasins that do not directly drain to Lake Van Norden were routed using the Muskingham-Cunge approximation. This method was selected for its ability to represent attenuation of flood waves, as would happen in systems with broad, flat overbank areas (i.e. meadows). Storage in Lake Van Norden was simulated with a stage-storage curve developed from a bathymetry survey by Balance in July 2013 (Shaw and others, 2014). A level pool routing scheme was chosen to simulate hydraulic interactions between Lake Van Norden and the dam spillway. Initial model runs overpredicted flow depths at the spillway to a point that did not make physical sense, nor was aligned with field observations. Furthermore, HEC-HMS is not capable of representing complex spillway geometry, as in the notched configurations. For these reasons we developed rating curves to represent flow metering at the spillway with a series of steady-state hydraulic models (described in next section). The curves were input to HEC-HMS as storage-discharge relationships.

The simulated outflow hydrographs from Lake Van Norden adequately represent the flood control benefit from the spillway under the existing and the two proposed notched configurations. Under the dam removal scenario, however, potential flood control benefits are that of a typical subalpine Sierra Meadow, in which attenuation of the flood wave largely depends on the overbank geometry of the meadow. Quantifying flood control benefit becomes a hydraulic problem that is too complex for the relatively simple channel routing schemes within HMS. As such, we developed a novel hydraulic modeling approach to estimate hydrographs for the dam removal scenario.

HYDROLOGIC MODEL VALIDATION

There are no streamflow gages within or immediately downstream of the Van Norden Dam watershed that have robust, long-term records that would facilitate a flood-frequency analysis of the 100-year flood. In the absence of such data we attempted to validate the hydrologic model output through multiple alternate lines of evidence. This is of particular importance for this modeling application because large recurrence interval floods are driven by rain-on-snow events in the central Sierra region. As such, the SCS curve number methodology—originally conceived for lowland, agricultural hydrology—needed to be tested for its ability to simulate this process.

The USGS operated a gage on Castle Creek between Donner Pass Road and Interstate 80 (USGS Gage 11413900) from 1957 to 1963. Coincidentally, the highest peak flow on record occurred in 1963 at many local streamflow gages, including USGS Gage 11414000 located on the South Yuba River 10 miles downstream of Van Norden Dam near Cisco Grove, California. The Castle Creek gage estimated the 1963 peak instantaneous flow as 1,300 cfs on January 31, 1963. The South Yuba River gage at Cisco Grove peaked at 18,400 cfs on the same day in 1963, so it is probable that 1,300 cfs was the largest flow on Castle Creek between 1942 and 1997 (the period of record at Cisco Grove). Estimating the 100-year flood, however, requires extrapolation of the Cisco Grove gage data because the record is only 57 years long. Moreover, though FEMA has mapped portions of the South Yuba River near Cisco Grove, a detailed study has not been completed that would estimate the 100-year flood. We therefore plotted annual peaks against their respective exceedance probabilities (Weibull plotting positions). No single curve fit the data well because there was a clear break in the plot that separated the annual peaks driven by snowmelt from the larger annual peaks driven by rain-on-snow events. By extrapolating the rain-on-snow subpopulation (a conservative approach since the slope of the rain-on-snow events is steeper), we estimate the 100-year flood on the South Yuba River at Cisco Grove to be between 19,500 and 21,000 cfs, or between 106% and 114% of the 1963 peak. Scaling the 1963 peak at Castle Creek up by the same amount approximates the 100-year flood between 1,380 and 1,480 cfs. This estimate is corroborated by from regional regression equations (Gotvald and others, 2006) which approximate the 100-year flood at Castle Creek as 1,406 cfs. The HEC-HMS model simulated the 100-year flood as 1,370 cfs. The model output is within 10 percent of these two estimates which we consider to be a reasonable margin of error for estimating the 100-year flood. Based on this comparison, we conclude that the HMS model adequately represents the 100-year flood for the remainder of the watershed.

HYDRAULIC MODEL DEVELOPMENT

The US Army Corp of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 4.1, along with its geospatial extension for ArcGIS, HEC-GeoRAS version 4.3.93, was used to model Lake Van Norden and portions of its contributing watershed. A digital terrain model (DTM) in the ArcInfo TIN format was developed from a survey completed for a previous study for the Truckee Donner Land Trust (TDLT) by Andregg Geomatics. The survey included a 2-foot interval photogrammetric contour map supplemented with spot elevations in areas of low relief. The survey data were combined with the bathymetry survey by Balance to create a seamless meadow surface, including the South Yuba River and Castle Creek channels across the meadow and where they are inundated by Lake Van Norden. The data were thoroughly reviewed for quality control in preparation for subsequent steps.

Cross sections were cut from the DTM in GeoRAS at intervals ranging from 50 to 200 feet, depending on the uniformity of the terrain. Since the DTM was largely based on a photogrammetric survey that does not penetrate the South Yuba River upstream of the dam, the cross sections needed to be augmented to account for the channel shape below the water surface. A low flow channel was added to each cross section based on average channel dimensions reported by Shaw and others (2014). The additional area added to cross sections through this step was very small compared to the total flow area during the 100-year event. Manning's *n* values used to represent roughness throughout the channel cross section was 0.080, and is based on the procedure for adjusting for floodplain irregularities proposed by Aldridge and Garrett (1973).

Two hydraulic models were built for this study: one to develop the rating curves to represent flow metering at the spillway, and a second to simulate flood wave attenuation from the meadow in the dam removal scenario. Both models were developed from the same data and were parameterized as described above.

RESULTS

The following sections present the calculated flood control benefits of Van Norden Dam under existing conditions and the three proposed future configurations. For each scenario flood control benefits are discussed in terms of: (1) changes to the hydrograph and peak flow rate immediately downstream of Van Norden Dam; (2) flood risk to the community between Van Norden Dam and Interstate 80; and (3) a very conservative estimate of changes to the flood stage at USGS Gage 11414000 in Cisco Grove, 10 miles downstream. For all scenarios, the same inflow hydrograph to Lake Van Norden/Van Norden meadow is used so differences among the scenarios are due to changes in the dam configuration only. The inflow hydrograph is the simulated 100-year runoff from all subbasins (see Figure 1 for extents), and has a peak magnitude of 3,640 cfs. The amount of storage in Lake Van Norden at the onset of routing the 100-year hydrograph varied among scenarios as the lake stage was set at the spillway elevation associated with each configuration.

Existing Conditions

The existing spillway of Van Norden Dam is 68.2-feet wide, with an invert elevation of 6754.60 feet (NGVD29). The dead storage[4] in Lake Van Norden is 175 acre-feet. The 100-year peak flow immediately downstream of the dam is 2,300 cfs (Figure 2) meaning the lake, existing dam, and meadow provide some degree of flood attenuation.

The hydraulic evaluation of Van Norden Dam (Riedner and others, 2014) focused on the risk associated with a hypothetical failure of the dam under a similar set of potential future dam configurations, and identified one structure located just upstream of the Donner Pass Road crossing to be the first structure inundated to the point of endangering the inhabitants. The critical flood stage at this location was estimated at 6,680.7 feet. With the dam and lake in the current configuration, the hydraulic model predicts that the 100-year flow achieves a flood stage at the same structure of 6,677.6 feet, with freeboard of 3.1 feet and a zero loss of life risk.[5] The 100-year flood under existing conditions is not expected to cause property damage upstream of Interstate 80, however it is large enough to overtop the Soda Springs Road bridge and causes a temporary economic disruption for the Serene Lakes community.

[4] Per U.S. Forest Service Manual 7500 definitions, dead storage is the storage that lies below the invert of the lowest outlet and cannot readily be withdrawn from the reservoir. We acknowledge that there is a pipe with a gate valve below the spillway invert, however, it is no longer used to manage the lake and may not be functional. For these reasons, we consider dead storage to be the storage below the spillway invert.

[5] Per the Bureau of Reclamation DSO-99-06 procedure, described in detail in Reidner and others (2014).

Flood depths for the 100-year flood at USGS Gage 11414000 in Cisco Grove were estimated from a rating curve developed from instantaneous flow and depth measurements taken by the USGS at this location over the 57-year gaging period. At 21,000 cfs, the flood stage is estimated to be approximately 20.7 feet (arbitrary datum) at the Cisco Grove gage.

2.3-foot Notch

Lowering the spillway elevation to a level at which the dead storage in Lake Van Norden is less than 50 acre-feet has been identified by the Truckee Donner Land Trust and stakeholders as a viable alternative because (1) it would result in a non-jurisdictional designation for the dam, and (2) it is a compromise between having a lake and removing the dam entirely. Based on the bathymetric survey, the invert elevation of the spillway would need to be lowered by 2.3 feet to an elevation of 6,752.3 feet. A trapezoidal notched configuration for the spillway has been proposed where the spillway would function as a two-stage weir. The lower stage would have an invert of 6,752.3 feet thereby bringing the storage below 50 ac-ft, and the upper stage would have the same invert elevation of the existing spillway. The bottom width of the trapezoidal notch would be optimized for flood control benefit to be 10 feet. A narrower notch could provide a modest amount of additional flood control, however, a very narrow notch would be prone to debris racking, thereby reducing the flood control benefit and potentiating a sudden flood pulse should the debris become dislodged.

The 100-year peak flow immediately downstream of the dam for the 2.3-foot notch scenario is calculated to be 2,330 cfs, a 1.3 percent increase from existing conditions (Figure 2). The change is minor because during extreme floods, the storage between the notch invert and the existing spillway invert is small compared to the total storm volume. As such, the lake fills up quickly, and the existing spillway width becomes the primary hydraulic control for the 100-year flood. The 2.3-foot notch may reduce flood peaks for smaller return period floods, however, this topic is beyond the scope of this report.

The flood stage at the critical structure upstream from the Donner Pass Road crossing is 6,677.7 feet at 2,330 cfs, a 0.1-foot rise from existing conditions. This increase is insignificant with respect to loss of life, property damage, or economic disruption to the community upstream of Interstate 80.

To evaluate changes in flood depths at the Cisco Grove gage for the 2.3-foot notch and all other future potential configurations, two very conservative assumptions were made. First, we assumed that the peak of the hydrograph from the dam was perfectly timed with the peaks from other hydrographs in the system so that the incremental increase in peak flow would simply be added to the peak at Cisco Grove. Second, we assumed no attenuation of the flood wave from the dam along the 10-mile course to Cisco Grove. Realistically, there would be considerable attenuation over such a distance as additional floodplain storage becomes available. Quantifying this effect would require expanding the hydrologic and hydraulic model to include all of the South Yuba River and its watershed down to Cisco Grove. Based on these assumptions, a 30 cfs increase immediately downstream of Van Norden Dam translates to a 30 cfs increase at Cisco Grove. A flow of 21,030 cfs at Cisco Grove corresponds to a flood depth of 20.7 feet, indicating that no change in 100-year water surface elevations would result from a 2.3-foot notch.

5.0-foot Notch

A 5.0-foot notch was the dam configuration identified by Riedner and others (2014) to have a low hazard potential classification per USFS definitions. Under this configuration the entire spillway width would be lowered by 4.5 feet, and a small, narrow notch would be graded within the lowered spillway having an invert elevation of 6749.6 feet. The configuration modeled for this scenario is identical to what appears on the spillway modification engineering plans by Holdrege & Kull, dated August 2014.

The 100-year peak flow immediately downstream of the dam for the 5.0-foot notch scenario is calculated to be 2,780 cfs, a 21 percent increase from existing conditions (Figure 2). The peak of the 100-year hydrograph occurs roughly one hour sooner than under existing conditions due to limited storage in the reservoir. The falling limb of the hydrograph 5.0-foot notch hydrograph is also steeper than the existing conditions hydrograph.

The flood stage at the critical structure upstream from the Donner Pass Road crossing is 6,679.2 feet at 2,780 cfs, a 1.6-foot rise from existing conditions which may cause property damage to uninhabited portions of the structure. At this stage there is still 1.5 feet of freeboard to the living space, and this configuration therefore is not considered to increase risk to loss of life or economic disruption to the community upstream of Interstate 80.

A flow of 21,480 cfs (21,000 cfs plus 480 cfs increase from 5.0-foot notch) at Cisco Grove equates to a flood depth of 20.9 feet, an increase of 0.2 feet over existing conditions. Again, this estimate assumes concurrent timing and no attenuation of the flood waves. It is also worth noting that the 0.2 foot increase is for one point along the South Yuba River, and is presented only to give context to how flood stages could change as a result of altering Van Norden Dam. Over the 10-mile reach between Interstate 80 and Cisco Grove, the amount of increase will depend on the cross section geometry, channel roughness, slope, and backwater effects. For example, the South Yuba River at the USGS Cisco Grove station is confined by steep hillsides so changes in stage are more sensitive to changes in flow than a channel reach adjacent to a broad, flat floodplain. This underscores the importance of evaluating flood hydraulics longitudinally along the South Yuba River, especially where there is risk for loss of life or infrastructure.

Dam Removal

The dam removal scenario involves completely removing the concrete spillway and the earthen embankment that spans the valley floor. Potential flood control benefits for this scenario are that of a typical subalpine Sierra Meadow, so attenuation of the flood wave largely depends on the overbank geometry of the meadow. Broad overbank areas in meadow environments have the ability to temporarily store considerable volumes of flood water which has the net effect of reducing the severity of the flood pulse downstream. Hummocky microtopography within overbank areas provide even more storage opportunities. Infiltration also has the potential to reduce the magnitude of the flood wave, however, for the purpose of modeling the 100-year event, we assumed the amount of attenuation from infiltration to be small compared to that from surface storage in the meadow.

In the dam removal scenario, the channel within the dam footprint will need to be rehabilitated concurrent with dam removal. Sediment deposits just upstream of the dam and the deep scour hole just downstream of the dam make for a steep and unstable slope. Two different treatments were modeled to see if flood hydraulics are sensitive to how the slope is managed: (1) minimal grading with stabilization of the steep slope, and (2) grading pool-riffle sequences to lessen the slope. We envisioned grading to be focused across the dam removal footprint and immediately upstream. Though it seemed that the former treatment had the potential to provide some attenuation because the crest of the stabilized slope would act similarly to the spillway crest in the 5.0-foot notch scenario, differences in output between the two types of channel treatment were not discernible

In addition to the slope treatments, we also attempted to quantify the effects of a restored meadow, in which the incised channel is filled in order to force flow out onto the meadow to provide maximum flood attenuation benefit. While it is unclear exactly what physical changes would be implemented at Van Norden Meadow to drive this process (restoration designs have not been developed), we modeled a series of channel obstructions coupled with ineffective flow areas[6] on the upstream side of obstructions. The model showed a modest amount of attenuation of the flood pulse from the South Yuba River with or without concurrent meadow restoration. Castle Creek traverses a very short portion of the meadow so opportunities for attenuation are limited, and the peak of the flood pulse from Castle Creek is minimally affected by the meadow.

The model—in terms of flood attenuation during an extreme event—was not sensitive to the slope treatments nor the restored meadow configuration. As such, only one set of numbers is presented in the foregoing discussion of the dam removal scenario. These results suggest that the proposed 5.0-foot notch configuration does not constrain flows at the spillway, and that it is storage within the meadow that provides attenuation.

Under the dam removal scenario, the 100-year peak flow immediately downstream of the dam is calculated to be 2,800 cfs, a 22 percent increase from existing conditions (Figure 2). The hydrograph for this scenario is very similar to that of the 5.0-foot notch with an earlier peak and a steep falling limb.

The 100-year flood stage at the critical structure upstream from the Donner Pass Road crossing is calculated to be 6,679.3 feet at 2,800 cfs, a 1.7-foot rise from existing conditions which may cause property damage to uninhabited portions of the structure. At this stage there is still 1.4 feet of freeboard to the living space, and therefore the dam removal scenario is not anticipated to increase risk to loss of life or economic disruption to the community upstream of Interstate 80.

A flow of 21,500 cfs (21,000 cfs plus 500 cfs increase from dam removal) at Cisco Grove corresponds to a flood depth of 20.9 feet, or a potential increase of 0.2 feet over existing conditions.

Our results are consistent with Hammersmark and others (2008) who found that flood peak reduction in restored meadows is capped by the floodplain accommodation space during very large storm events. The

[6] Ineffective flow areas are regions within cross sections where water is allowed to pool, but has zero velocity and does not get included in computing total flow at the cross section.

modest amount of attenuation of the flood pulse from the South Yuba River within the meadow suggests that the meadow would provide attenuation from smaller return period events. Hammersmark and others (2008) showed restored meadows could reduce flows between the 2 and 5-year event by up to 25 percent; we anticipate similar results are plausible for Van Norden Meadow.

CLOSING

The analysis described herein quantifies the flood control benefit during the 100-year flood from Van Norden Dam under its current and several future potential configurations. Key output from the modeling effort is summarized in Table 2, and the hydrographs for the four scenarios in Figure 2. The results for the 5.0-foot notch and dam removal scenarios are very similar, and would cause the greatest changes in terms of peak flow immediately downstream of the dam and flood depth at Cisco Grove. The model suggests that the dam removal with or without concurrent meadow restoration would provide flood control benefit for small return period floods. The advantage of concurrent meadow restoration is improved geomorphic stability of the system. In the case of Van Norden Meadow, however, inflow from Castle Creek largely bypasses the meadow which limits the flood control benefit from a restored meadow during the 100-year flood. None of the scenarios would increase the risk of loss of life, property damage, or economic disruption in the community upstream of Interstate 80.

We appreciate the opportunity to contribute to the formulation of this complex project. Do not hesitate to contact Balance Hydrologics staff if you have questions or comments.

Sincerely,

BALANCE HYDROLOGICS, Inc.

Peter Kulchawik, P.E.
Civil Engineer / Hydrologist

David Shaw, P.G.
Principal Hydrologist / Geologist

Enclosures: Figures 1-2
Tables 1-2

References:

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Table 1. Subbasin Parameters for the Lake Van Norden Watershed HEC-HMS Model Placer and Nevada Counties, California

Subbasin	Area	Initial Abstraction	Curve Number	Percent Impervious	Lag Time	100-yr Modeled Peak Discharge[1]
	(square miles)	*(inches)*			*(minutes)*	*(cfs)*
SuBo	1.5	1.2	63.3	5.1%	60.2	711
UpSY	1.2	1.1	64.4	11.5%	94.5	502
LoSY	1.0	2.6	43.7	0.6%	118.7	129
Lytt	0.9	1.0	66.9	2.7%	72.6	413
LoCC	2.3	1.0	65.7	5.9%	158.9	765
UpCC	1.6	1.0	67.0	8.5%	59.7	853
LoVN	1.6	0.9	69.5	36.1%	143.7	710

Note:

1. Peak discharge are for individual subbasins, and do not include flows from upstream subbasins.

Table 2. Summary of Flood Control Benefits from Van Norden Dam Configurations Placer and Nevada Counties, California

Dam Configuration	Peak discharge upstream of Soda Springs Road	Maximum flood stage at first home upstream from Donner Pass Road[1]	Maximum possible rise in 100-year flood stage at Cisco Grove[2]
	(cfs)	*(elevation, feet NGVD29)*	*(feet)*
Existing	2,300	6,677.6	---
2.3-foot Notch	2,330	6,677.7	0.0
5.0-foot Notch	2,780	6,679.2	0.2
Dam Removal	2,800	6,679.3	0.2

Notes:

1. The living floor elevation is 6,680.7
2. At USGS 11414000 South Yuba River near Cisco, CA. Estimates are derived from a rating curve developed from gage data, and assume the peak of flood wave from Lake Van Norden is concurrent with the flood wave from the rest of the watershed. Estimates also assume no attenuation of the flood wave along the South Yuba River between Lake Van Norden and Cisco Grove (roughly 10 miles).

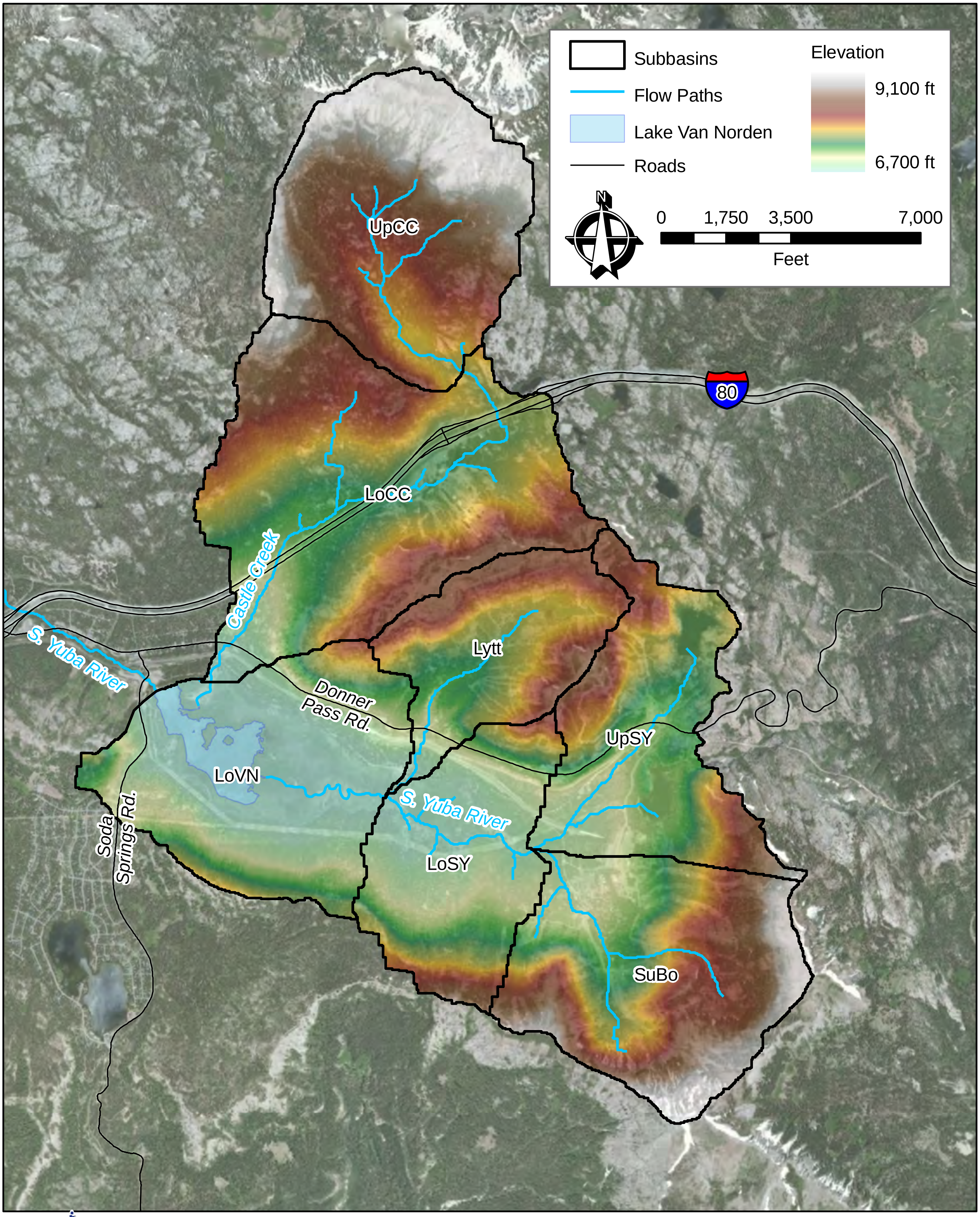

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Figure 1. Van Norden Dam subbasins and flow paths, Nevada and Placer Counties, California

Aerial Photo Source: TerraServer (date of photo: 2010)

Data sources: NED, NHD

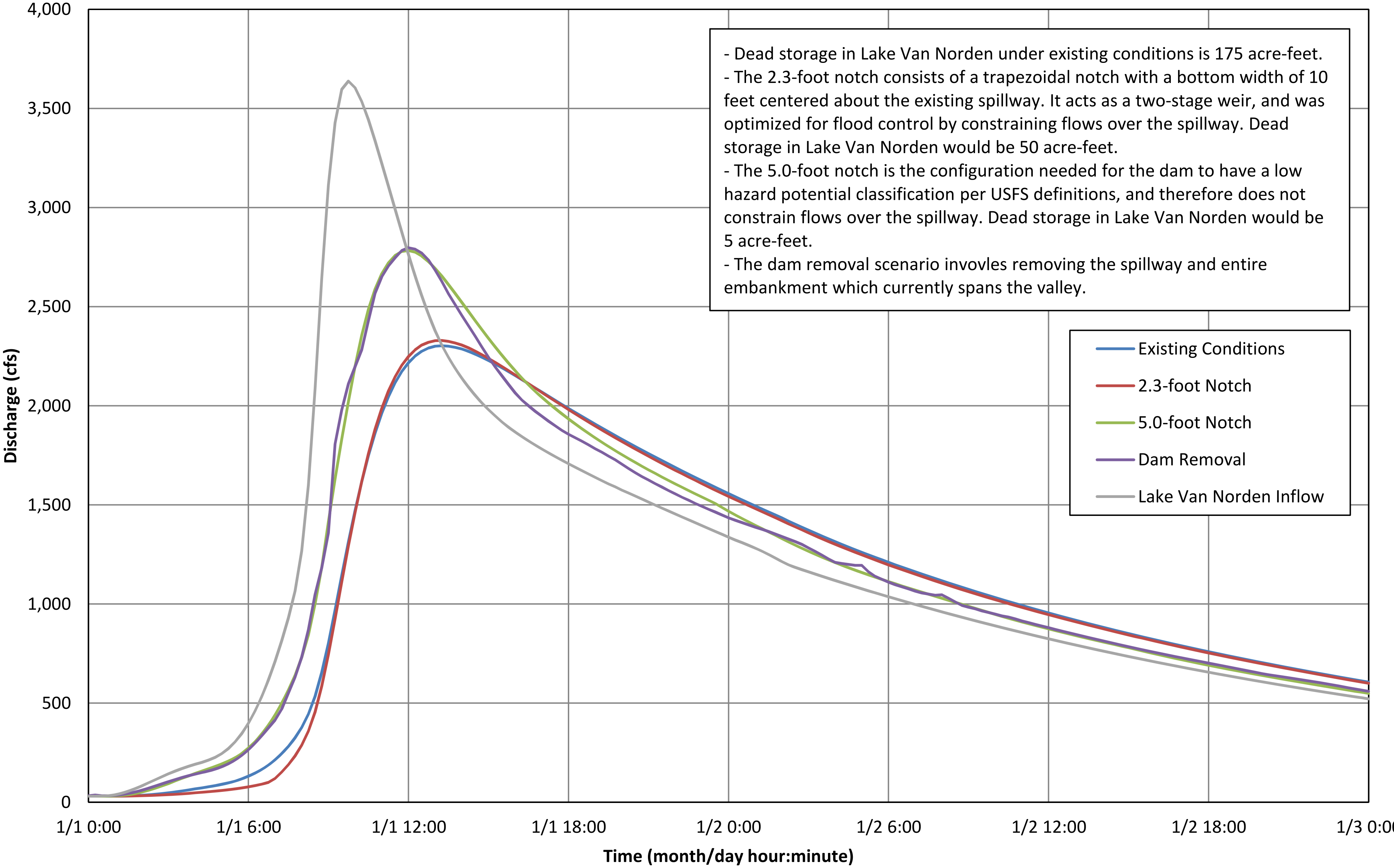

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Figure 2. **Existing and potential future hydrographs under alternative Van Norden Dam spillway configurations.** Flows are calcluated immediately downstream of Van Norden Dam.