Appendix B

Hydrologic Analysis, Artesa Fairfax THP and Conversion

Prepared for

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October 2007
Revised February 2011

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Overview

Conversion of timberland to vineyard and vineyard development on existing pasture lands may affect hydrologic processes by two primary mechanisms. First, the removal of forest vegetation reduces interception of rainfall by forest canopy and would be expected to reduce annual consumption of water from the soil by vegetation (reduced evapotranspiration or ET).

Experimental data indicate that forest canopy intercepts and evaporates approximately 20% of storm precipitation in temperate coniferous forests (Dunne and Leopold 1978) pp. 87-88). Removal of the forest canopy therefore is expected to increase the quantity of precipitation reaching the ground surface, potentially causing increases in

- infiltration of water to the soil and percolation to groundwater aquifers
- summer base flow in streams
- total water yield (annual runoff) and
- peak and total storm runoff.

These potential effects are discussed below in the context of regional scientific studies of redwood forest watershed hydrology.

Second, development of vineyards is likely to alter soil conditions. Potential changes in soil conditions that could affect hydrologic function of soils include changes in cover on the soil surface, changes in root abundance and root channels, and changes in soil bulk density and permeability, all or some of which could affect the processes of infiltration and surface runoff.

Comprehensive monitoring or experimental data for vineyard conversion projects are not available to directly assess potential hydrologic effects. Applicable scientific literature from the region provides a basis for qualitative and semi-quantitative assessment of likely hydrologic effects of the project. The most useful of these studies is the watershed experiment conducted at Caspar Creek in coastal Mendocino County by the USDA Forest Service, PSW Research Station, Redwood Sciences Lab (RSL) in cooperation with the California Department of Forestry and Fire Protection, Jackson Demonstration State Forest.

The Caspar Creek experimental study of forest hydrology examined the impacts of forest harvest on runoff, comparing pre-treatment conditions (second growth redwood forest) to post-treatment conditions (clearcut harvest areas comprising various percentages of watershed area from about 50% to 95%). The breadth and depth of that study provides by far the best information available regarding impacts of vegetation management (timber harvest) on hydrologic processes, and therefore warrants a thorough review to provide a starting point for supplemental assessment. Following the review and interpretation of the Caspar Creek study, additional relevant research is reviewed to identify likely effects of the project on critical hydrologic processes. Finally, a water balance is developed to assess likely project effects on hydrology in the project area.

Review of the Caspar Creek Study

Comparison of Project Site Conditions and Caspar Creek Conditions

The proximity and general similarity of the Caspar Creek watershed to the project site near Annapolis indicates that the experimental results at Caspar Creek would be generally applicable at the project site. The Caspar Creek watershed, located in Mendocino County a few miles from the coast about halfway between the communities of Ft. Bragg and Mendocino, has similar climate, soil and geologic conditions compared to the site near Annapolis. Annual rainfall at Caspar Creek is about 45 to 50 inches, compared to about 60 to 70 inches in Annapolis. There are some differences in geology, soils, topography and vegetation. Caspar Creek is underlain entirely by sandstone of the Coastal Belt Franciscan Formation; the project site is also underlain by this formation, but also includes a younger marine sandstone (the Ohlsen Ranch Formation) overlying the Franciscan over most of the project site.

Caspar Creek soils are "well drained clay loams" and are derived from parent materials of the Coastal Belt Franciscan, including sandstone and shale; they are 3 to 6 ft deep (Henry 1998, p2). They have "high hydraulic conductivity and subsurface stormflow is rapid, producing saturated areas only limited extent and duration". The Goldridge soils are "moderately well-drained fine sandy loams that have a sandy clay loam subsoil", and have available water capacity of 8 to 11 inches (Miller 1972). Goldridge soil dominates the project area, and is derived from parent material of the Ohlsen Ranch Formation. The remainder of the project site is mantled by Hugo soils, a common soil type found associated with Coastal Belt Franciscan parent material under redwood forest vegetation. Hugo soils are "well-drained very gravelly loams that have a gravelly sandy clay loam subsoil", generally greater than 3 ft thick, with a 4 to 8 inches available water capacity (Miller 1972).

The Patchett Creek watershed in which potential hydrologic impacts are concentrated, has a drainage area of about 1,130 acres. The sub-basin drainage areas of interest in the project area range in area from about 5 to 75 acres. The North Fork Caspar Creek watershed is about 1,170 acres, and experimental sub-basins range in size from about 25 to 70 acres. These similarities in watershed size allow qualitative extrapolation of experimental results to the project site.

Caspar Creek Changes in Rainfall Interception and Runoff

Watershed experiments regarding the effects of harvesting redwood forests on streamflow and water quality have been conducted in the region for over 30 years at Caspar Creek (Ziemer 1998a). As found in other watershed studies in the Pacific Northwest, increases in storm runoff during the first few rainstorms of the season may be large (Ziemer 1981), however, "[t]hese first rains and consequent streamflow in the fall are usually small and geomorphically inconsequential in the Pacific Northwest" (Ziemer 1998)b. These early winter increases in storm runoff have been attributed to reduced evapotranspiration from forest vegetation during the growing season, resulting in

increased soil moisture. In other words, following harvest, forest vegetation draws less water from the soil via its root system and more of the rain water that enters the soil during the wet season remains in the soil or moves by gravity into surface or sub-surface channels, or percolates to groundwater aquifers.

Interception and evaporation of rainfall by forest canopy is a significant hydrologic process in forest ecosystems. Previous studies found that interception losses in temperate forests average about 20% (Dunne and Leopold, 1978). Reid and Lewis (in press), found that about 25% of annual rainfall was intercepted by forest canopy in experimental plots located in 100 year-old stand of redwood and Douglas-fir at Caspar Creek. About a tenth of the intercepted rainfall reached the forest floor via stemflow, hence about 22% of the annual rainfall is evaporated. In larger storms (about 3 inches rainfall), interception losses were about 21%, somewhat less than the annual average. Interception losses are equivalent to about 8 to 9 inches of additional precipitation that would reach the soil surface annually.

At Caspar Creek, annual runoff increased an average of 15% (ranging from 6 to 29%) for monitoring periods of about 10 years following harvest (Keppeler 1998). These levels of flow increase were observed in the North Fork and South Fork of Caspar Creek in successive watershed experiments on fish-bearing perennial streams with drainage areas > 1000 ac. Minimum mean daily summer flows increased an average of 148% following clearcut harvesting of about 50% of the watershed of North Fork Caspar Creek (Keppeler 1998). The smallest annual increase was 75% and the largest was 287% over the period 1990-1997 (Table 1). Increased minimum flows in the dry season at Caspar Creek resulted in "increased habitat volumes, and…lengthened the flowing channel network along logged reaches" (Keppeler, 1998, p. 43).

The Caspar Creek experiments also found increases in peak storm runoff following clear cut harvest of 50% of the North Fork watershed. Streams draining >95% clearcut harvested watersheds ranging in size from 25 to 67 ac in North Fork Caspar Creek were gauged for streamflow and compared to unlogged control watersheds (Ziemer, 1998b). For storms with a recurrence interval of about 2 years, which generate peak runoff greater than about 0.11 cfs per acre of watershed area, there was a mean peak flow increase of 27% in the five clearcut tributaries. For the entire North Fork watershed (1,170 ac), the instantaneous peak flow increase for a 2-yr recurrence interval was 9% for an area that was 50% harvested. "As the size of the watershed increases and the proportion of the watershed logged decreases, the post-logging and pre-logging observations become more similar"(Ziemer, 1998b, p.18).

Increases in total storm runoff were similar to those for peak runoff. Under the wettest antecedent conditions, total storm runoff volume increased 27% for clearcuts and 16% for partially harvested watersheds. Percentage increases were higher when antecedent wetness was lower. Annual storm runoff volume for all storms increased 60% in clearcut watersheds and 23% in partially harvested watersheds. The depth of excess storm runoff was 0.37 ft in clearcut areas and 0.14 ft in partial harvest areas. The depth of excess

annual runoff for the entire North Fork watershed (~50% clearcut) was 0.20 ft, compared with mean annual runoff of about 1.3 to 1.7 ft.

Statistical analyses of the runoff data that were designed to determine factors that significantly affect runoff rates found that only logged area and antecedent wetness were important. "No variables related to roads, skid trails, landings, firelines, burning, or herbicide application were found to improve the fit of the linear least squares model that includes logged area and its interaction with antecedent wetness" (Ziemer, 1998b, p.19).

Table 1. North Fork Caspar Creek annual water yield 1963-1997 and minimum mean daily flow, ranked from lowest to highest annual yield. Bold face numerals represent post-logging data; water yields for these years were adjusted to the level predicted from pre-logging data after (Keppeler 1998) Table 1. Minimum mean daily flows were not adjusted. Post-harvest flow increases are given in columns 3 and 5. No data were reported for the drought year 1977 in the source reference.

Water Year	Water Yield (m^3/ha/yr)	% Change Post-harvest Water Yield	Minimum Mean Daily Flow (L/s/km^2)	% Change Post-harvest Minimum Mean Daily Flow
1991	**1447**	**21**	**0.46**	**256**
1994	**2190**	**29**	**0.46**	**166**
1992	**2539**	**27**	**0.59**	**287**
1981	2754		0.28	
1976	3337		0.36	
1987	3337		0.23	
1964	3541		0.17	
1988	3560		0.26	
1985	3646		0.23	
1990	**3687**	**6**	**0.41**	**75**
1972	3730		0.34	
1968	3747		0.22	
1979	4111		0.64	
1989	4239		0.46	
1966	4943		0.22	
1963	5283		0.72	
1986	6265		0.49	
1980	6289		0.54	
1984	6782		0.28	
1996	**6800**	**13**	**0.80**	**75**
1997	**6801**	**15**	**1.19**	**129**
1978	6898		0.43	
1967	6929		0.40	
1970	6986		0.16	
1965	7210		0.29	
1971	7447		0.46	
1993	**7833**	**6**	**1.28**	**107**
1975	7932		0.55	
1973	8093		0.37	
1969	8184		0.26	
1995	**9566**	**7**	**0.72**	**89**
1982	9812		n.a.	
1974	13054		0.43	
1983	13919		0.74	

(Lewis 1998) found that suspended sediment yield measured from the small harvested watersheds increased on the order of 200% (Table 2). Although the experiment did not determine the source of this increase in suspended sediment, it was suggested that a substantial portion was caused by accelerated channel or bank erosion associated with observed increases in stream flow. The Caspar Creek study (Lewis 1998) did not demonstrate that increases in suspended sediment yield in intermittent and ephemeral headwater streams (Class II and Class III channels) resulted in increased suspended sediment loads in Class I channels downstream. Three monitoring stations on the mainstem of the North Fork Caspar Creek (LAN, FLY and ARF) located downstream of tributary watersheds where large percentage increases in sediment yield were measured showed an increase in suspended sediment yield of 2% at LAN, and decreases of 2% (FLY) and 17% (ARF), an average decrease of about 6%.

Table 2. Data from Lewis (1998, Table 1, p. 62); the last 4 columns result from converting suspended sediment (SS) yield per unit watershed area to units of t/yr. This allows comparison of the absolute quantities of sediment yield from tributaries relative to mainstem stations. Bold face entries emphasize the comparison of percentage increases in logged tributaries and percentage increases relative to the nearest downstream mainstem station. KJE and JOH are compared to LAN, GIB is compared to FLY, and DOL, CAR and BAN are compared to ARF. Mainstem stations are compared to ARF. Station EAG is not presented; its effect is represented by station (DOL), located downstream of EAG in the same tributary.

Station	Years Post Harvest	Area (ha)	Percent Harvest	Percent Change in SS	Observed SS Yield (kg/ha/yr)	Predicted SS Yield (kg/ha/yr)	Change SS Yield (kg/ha/yr)	Observed Total SS Yield (t/yr)	Pre-dicted Total SS Yield (t/yr)	Change Total SS Yield (t/yr)	Change SS Yield as % of Main-stem SS Yield
Tributary stations (drainage area < 80 ha)											
KJE	5	15	97	-40	821	1371	-550	12.3	20.6	-8.3	-13
JOH	5	55	30	-23	667	865	-198	36.7	47.6	-10.9	-17
GIB	4	20	99	**200**	358	119	239	7.2	2.4	4.8	**4**
DOL	5	77	36	**269**	1130	306	824	87.0	23.6	63.4	**33**
CAR	5	26	96	**123**	240	108	132	6.2	2.8	3.4	**2**
BAN	4	10	95	**203**	85	28	57	0.9	0.3	0.6	**0.3**
Mainstem stations (drainage area > 150 ha)											
LAN	5	156	32	5	420	400	20	65.5	62.4	3.1	2
FLY	5	217	45	-3	536	555	-19	116.3	120.4	-4.1	-2
ARF	4	384	46	-15	505	591	-86	193.9	226.9	-33.0	-17
NFC	6	473	50	89	465	246	219	219.9	116.4	103.6	n.a.

Hence, there was little or no change in suspended sediment yield in fish-bearing Class I channels downstream, despite large (three-fold) increases in tributary watersheds. This can be explained by the fact that erosion rates in the headwater channels are low, and that when those rates are increased by a factor of two or more, the absolute erosion rate

remains small relative to erosion rates in the watershed as a whole. The overall increase in suspended sediment yield for the North Fork Caspar Creek (89%) is attributed to a single landslide that occurred near the end of the study period (Lewis 1998), and not to increased erosion rates in headwater channels (this topic is discussed in greater detail in Appendix A). Hence, the risk to downstream habitat and water quality implied by potential increases in channel erosion or surface erosion associated with anticipated peak flow increases at the project site probably would not be significant. These considerations should temper assessment of the significance of the erosion hazards as well as the efficacy and cost of proposed mitigation measures.

Summary of Hydrologic Effects of Timber Harvest

In summary, watershed experiments at Caspar Creek indicate substantial increases in annual water yield, summer minimum flows, and storm runoff following clearcut harvest in the North Fork Caspar Creek. Increased summer flows are significant, but storm runoff is a larger proportion of the increased annual yield. Peak flow increases for storms with 2 yr recurrence intervals are about 25 to 30% for watershed areas that were >95% clearcut. Reduced evapotranspiration and canopy interception is the likely cause of increases in both total annual runoff and minimum summer stream flow. In addition, suspended sediment yield for small watersheds (about 25 to 70 ac) increased substantially, but this effect diminished downstream such that watersheds > 370 ac showed a mean decrease in suspended sediment yield.

Anticipated Hydrologic Effects of Proposed Vineyard Development

Owing to the fundamental similarity of hydrologic processes in clearcuts and vineyard conversion areas relative to a forest stands, the increasing trends in runoff parameters and the approximate magnitude of change observed at Caspar Creek should be expected for conversion of forest to vineyard at the project site near Annapolis. Observations from Caspar Creek suggest that the project will result in higher soil moisture levels at the project site owing to reduced evapotranspiration and higher annual streamflow and higher summer baseflow in watersheds affected by conversion of forest vegetation to vineyards. Qualitatively, it is very likely that the conversion process is likely to create additional runoff and soil moisture. On a quantitative basis, the likely maximum increase in runoff quantitative

The Caspar Creek data indicate that increases in summer baseflow and annual runoff is likely to persist in dry years. As can be seen in Table 1, the post-logging period included the three years of lowest runoff (excluding 1977 and adjusting for the estimated increase in flow attributed to harvest effects), and a representative range of water yield compared to the pre-logging record. These data demonstrate that even in relatively dry years, it is expected that both minimum summer flows and annual yields will increase relative to existing conditions at the project site.

Water yield data suggest that groundwater quantity would tend to increase, and be unlikely to decrease, as a result of the project. Increased summer baseflow observed at

Caspar Creek can be attributed to increased infiltration of precipitation to the soil and increased percolation of soil water to groundwater. In watersheds with topographic relief and fractured Franciscan bedrock such as Caspar Creek and much of Patchett Creek, it is likely that flow from groundwater aquifers sustain a portion of the summer baseflow in local stream channels. The velocity of groundwater may be sufficiently slow in Franciscan bedrock that increases in percolation rates may not be reflected in streamflow for a period of years. The Caspar Creek data may include minimum flow increases related to increased percolation rates, however, that study was not designed to examine groundwater conditions.

The preceding review and discussion of Caspar Creek experimental results leads to the conclusion that annual and seasonal stream flows are expected to increase as a result of the proposed conversion of timberland to vineyard. Greater quantities of water reaching the soil may be expected to increase groundwater percolation rates. Peak flow rates in stream channels are also expected to increase, and this creates potential for increased channel and bank erosion Inferred project effects based on the Caspar Creek research are evaluated by means of a water balance analysis presented below. Limited further analysis of potential project effects on groundwater quantity is also warranted; the Caspar Creek experimental data do not directly measure percolation rates or effects on groundwater, despite strong implications of increased quantity. Potential effects on groundwater are assessed in the following section.

It should be noted that vineyard development and cultivation could also cause changes in soil infiltration capacity and flow paths that might affect rates of transmission of water from the soil surface into the soil (infiltration) and from the soil into bedrock aquifers (percolation). The conclusions drawn above do not explicitly account for such potential changes in soil hydrologic characteristics. These potential changes and their potential significance are discussed below.

Groundwater Aquifer Characteristics

Published Descriptions

As shown in Figure 1, there are two distinct geologic formations underlying the project site and the surrounding area, each with distinctive hydrogeologic characteristics (DWR 1975). The gently-sloping ridgetops, mantled with Goldridge soils, are underlain by the Ohlson Ranch Formation, which is similar to the more widely-distributed Merced Formation in western Sonoma County. This formation consists of flat-lying beds of marine sandstone, siltstone and conglomerate up to 160 ft thick. These bed lie unconformably atop steeply dipping beds of the Franciscan Formation, which includes a wide variety of fractured rocks.

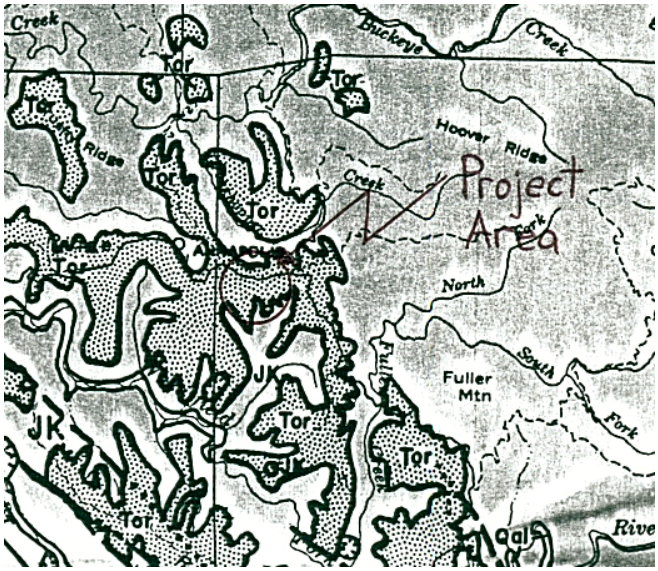


Figure 1. Surficial geology of project area (DWR 1975). "Tor" is the Ohlson Ranch Formation and "JK" is the Franciscan Formation. North is the top of the image. Approximate scale is 1"=2 miles. This map is effectively identical in its rendering of bedrock geology to Figure 1 in Erosion Analysis.

Yields from wells in the Franciscan are typically small, and are generally < 3 gpm (DWR 1975). In contrast, the Ohlson Ranch Formation has yields of 2 to 36 gpm in five wells in the Annapolis area. Yields in the Franciscan are low because water is transmitted and stored primarily in fractures in the rock, whereas in the Ohlson Ranch Formation (assumed similar to the Merced Formation), the well-sorted sand produces numerous pores in the structure of the rock and a high specific yield of 10 to 20%. Specific information regarding depths and yields of wells in the vicinity of the project site are not available, however, based on the characteristics described above, the Ohlson Ranch Formation is the more productive aquifer.

Reports by well owners in the Ohlson Ranch Formation indicated that "water levels decline markedly during the summer months and many wells go dry by early fall (DWR 1975, p. 157)". It was estimated that the Ohlson Ranch Formation has a maximum storage capacity of about 3.1 ac-ft/ac (DWR 1975, p. 157), and that this total capacity is likely to be significantly less when water levels decline in late summer.

Locations of Wells and Surface Water Diversions

North Coast Resources Management (NCRM) received from the County of Sonoma Permit and Resource Management Department a listing of wells and surface water diversions within a 1,000 ft radius of the project site. Additional information on wells and water supplies in the vicinity was solicited from nearby residents by NCRM. These wells and diversions were plotted on a topographic map to help evaluate potential impacts of the project. The wells, diversions, and water supply systems are listed in Table 3. The approximate locations of the parcels and systems are shown in Figure 2.

Most of the wells are located west or northwest of the project area, with one County of Sonoma well (located at the Transfer Station) located to the southeast.

Table 3. Known domestic water supplies and small water systems.

Assessor's Parcel #	Type	Owner	Address
122-100-008	Well	Burbach	35158 Annapolis Rd.
122-110-012	Well	Nichols	35411 Annapolis Rd.
122-110-016	Well	Veregge	35369 Annapolis Rd.
123-010-011	Creek Diversion	Campbell	35180 Annapolis Rd.
123-030-004	Well	County of Sonoma	33551 Annapolis Rd.
123-040-011	Well	Beck	35401 Annapolis Rd.
122-140-006	Small Water System	Horicon School	35555 Annapolis Rd.
123-040-10	2 Wells	Spacek	35405 Annapolis Rd
123-040-017	2 Wells	Taeuffer/Anderson	34175 Annapolis Rd
123-040-037	Well	Breidenthal	33700 Annapolis Rd
123-040-033	3 Wells	Starcross Community	34500 Annapolis Rd
123-040-023	3 Wells and creek diversion[1]	Wellman	PO Box 6 Annapolis
123-040-180	Spring	Hall	34910 Annapolis Rd
123-040-013	Well	Duncan	n.a.
122-110-006	Well and creek diversion	Dew	35337 Annapolis Rd

[1] "Red Fern Creek" may have several wells in its drainage

Site Hydrogeology

Field observations of outcrops of the Franciscan Formation at the site (Figure 2), in combination with hydrogeologic maps and descriptions (DWR 1975), reveal the general hydrogeologic character of the site. The geologic cross-section in Figure 3 defines the approximate boundaries of the aquifer and the likely groundwater gradient underlying the project site. The Ohlson Ranch Formation is probably < 50 ft thick under the project area. The pattern and elevation of outcrops of Franciscan Formation bedrock (Figure 2 and Figure 6) indicate that the geologic contact between the Ohlson Ranch Formation and the underlying Franciscan Formation dips gently but distinctly to the east. Owing to the high specific capacity of the Ohlson Ranch Formation and the low permeability of the underlying Franciscan Formation, a perched water table is formed in the Ohlson Ranch Formation. The groundwater gradient most likely parallels the slope of the geologic contact, which is in turn generally parallel to the surface topography. Most of the project area is underlain by this sloping shallow aquifer. The dominant hydraulic gradient of groundwater under most of the project area is expected to move groundwater from west-northwest to east-southeast, toward Patchett Creek as shown in Figure 3. Some groundwater moves from south to north perpendicular to Annapolis Road, following the topography in the northern portion of the project area.

The geometry of the aquifer and the location of the contact between the Franciscan and the Ohlson Ranch Formation to the west is uncertain (Figure 3). It is possible that the Ohlson Ranch Formation thickens to the west, depending on the configuration of the underlying Franciscan Formation. The topography of the small

drainage in the northwest corner of the project area that flows to the west suggests a hydraulic gradient that would move groundwater in this area to the west.

Figure 2. Site map showing features pertaining to hydrogeology.

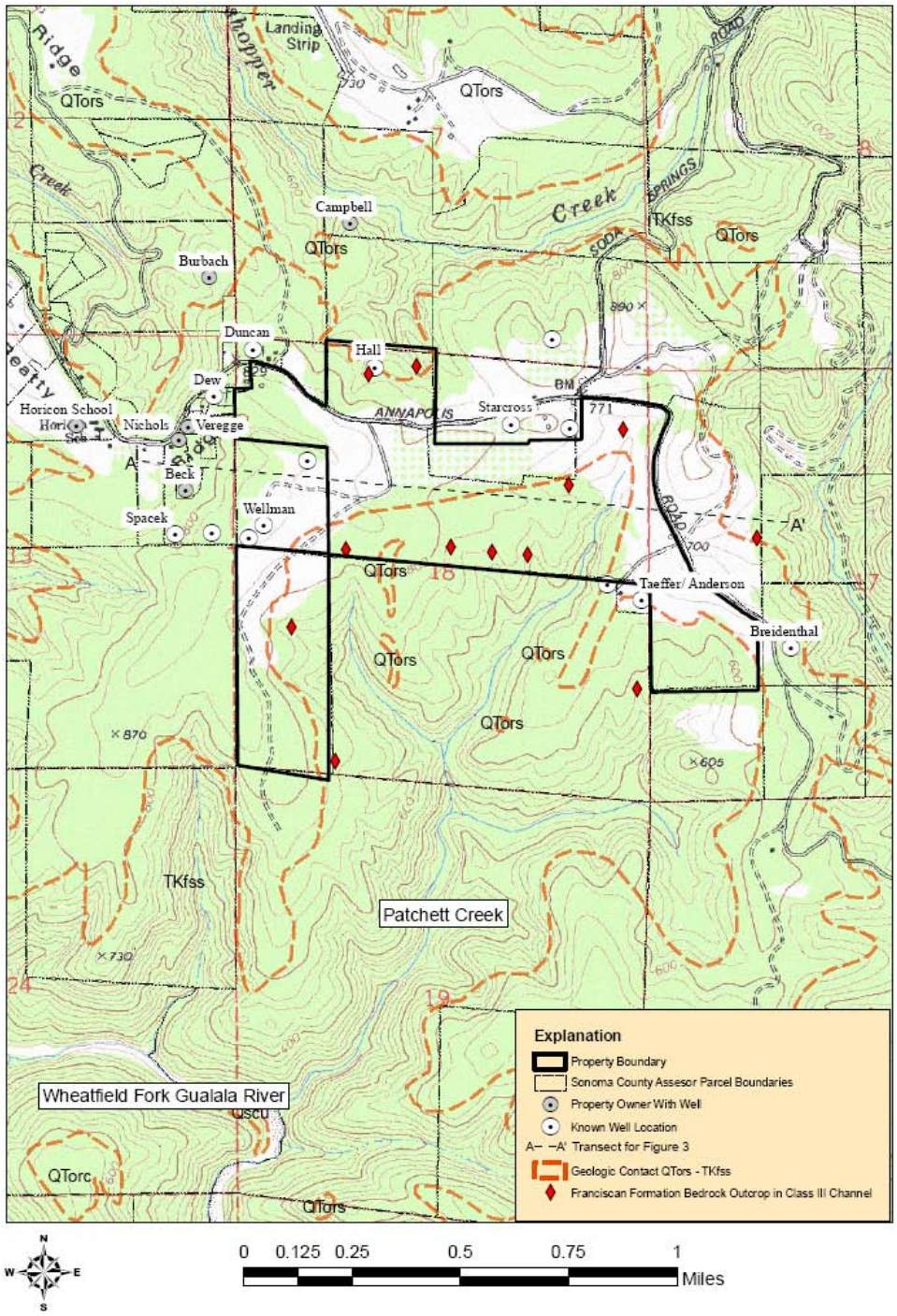
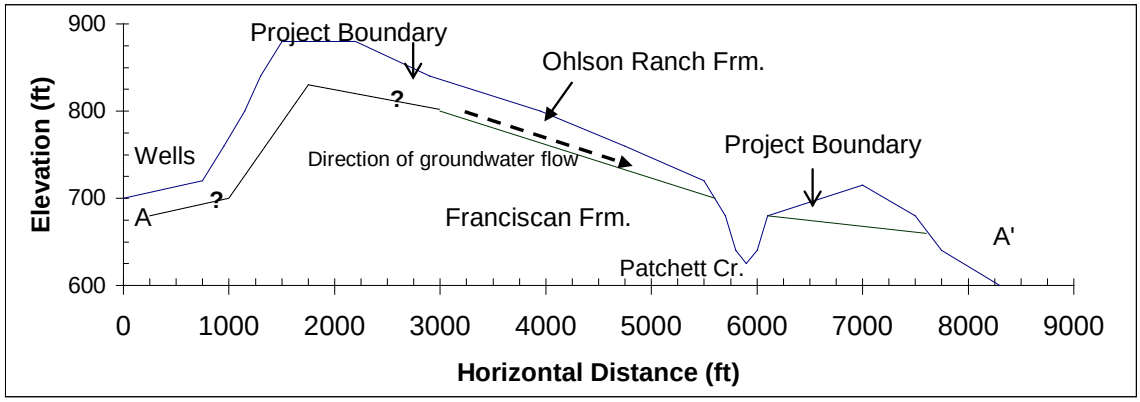


Figure 3. Geologic cross-section A-A' (see Figure 2 for location). Contact between the Franciscan Formation basement rocks and the overlying Ohlson Ranch Formation is dashed with "?" where uncertain, solid where inferred from mapped outcrops. See text for discussion.



Anticipated Effects of Project on Existing Wells

As shown in Figures 2 and 3, most existing wells are located to the west and north of the project area, and most groundwater in the project area flows away from these areas. Project areas on the north side of the project area that drain to Grasshopper Creek and Little Creek are located upgradient from some wells shown in Figure 2 and listed in Table 3. Flow from portions of the project area to the west is also likely to be upgradient from wells west of the project area. The wells of Taueffer-Anderson, located near the southeastern corner of the project area, are also likely to be downgradient from the project area. The County of Sonoma well is located southeast of the project site, but a canyon interrupts the continuity of the Ohlson Ranch formation, and groundwater flow beneath the canyon is unlikely.

The Ohlson Ranch Formation is a relatively thin, perched aquifer that is relatively permeable. The elevation of the water table in this aquifer declines seasonally as water drains to stream channels and is extracted from well. The aquifer is recharged seasonally during the winter. As described in following water balance analysis, the project is not expected to diminish groundwater supplies, and may increase water delivery to the soil through conversion of forest vegetation, creating potential for increased groundwater recharge. Irrigation water will be obtained from surface runoff.

Wells to the west of the project area likely to be down gradient of potential aquifer recharge areas within the project area have the greatest potential to be affected by the project, however, this impact is unlikely to be significant. First, the majority of the likely recharge area for these wells is not within the project area, substantially reducing potential impacts. Second, the dominant recharge zone in the project area that could affect these wells consists of a relatively flat valley bottom extending about 2,000 ft into the project area. Vineyard development is set back from the stream and wetlands in this valley by an average distance of about 100 ft, thereby preserving the hydrologic function of this area. Potential increases in runoff from conversion areas reaching this valley

bottom would have a high potential of recharging the water table in this area. Finally, the water balance analysis indicates increased soil water availability in conversion areas, which has the potential to increase groundwater recharge.

The surface drainage areas of the project that lie within the likely recharge area for the Taueffer-Anderson wells in the southeast portion of the project area include a wetland mitigation area that would tend to increase groundwater recharge. In addition, increased soil water in conversion areas has the potential to increase groundwater recharge.

In summary, it is unlikely that the project would significantly reduce groundwater availability. Increased soil water availability expected to result from forest conversion could potentially increase groundwater recharge. Although some soil compaction could occur, this will be counteracted by site preparation (limited ripping of soils), and overall higher water delivery to the soil owing to reduced canopy interception is likely to further compensate for potential soil compaction. Existing compacted soils in historic pasture areas may actually have higher infiltration rates following vineyard development. Cover crops and elongated flow paths in v-swales will reduce sheet flow velocity and encourage infiltration. Groundwater flow gradients in most of the project area are toward Patchett Creek (east-southeast), away from know domestic wells. Considering and weighing these factors, the project is not expected to reduce groundwater percolation or affect domestic wells and water supplies.

Water Balance Analysis

The fundamental conceptual basis for a water balance is described by Dunne and Leopold (1978) as follows:

> *[t]he water balance of a small drainage basin underlain by impervious rock at depth can be represented by [the] figure [4] below and expressed in the following equation:*
>
> $$P = I + AET + OF + \Delta SM + \Delta GWS + GWR$$
>
> *where the symbols, expressed as equivalent depths of water for some time interval, represent precipitation, interception, evapotranspiration [AET], overland flow, change of soil moisture storage, change of groundwater storage, and groundwater runoff.*

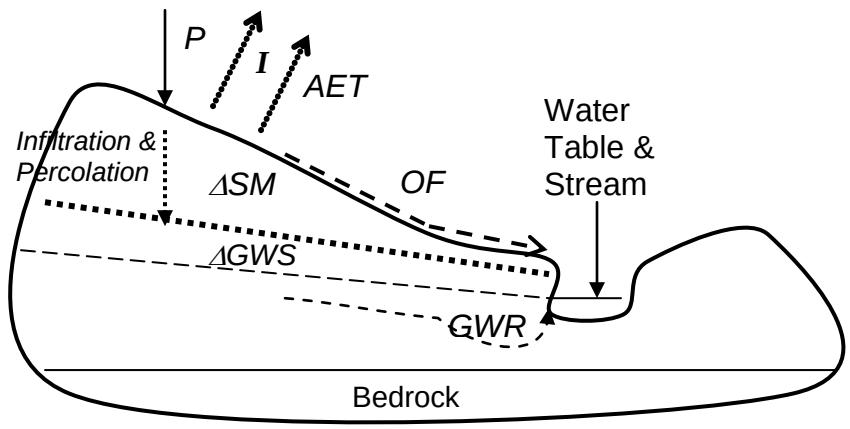


Figure 4. Simplified diagram of water balance components in an upland watershed.

The process of infiltration of water to the soil surface leads to an increase in soil moisture storage; evapotranspiration represents a decrease in soil moisture as plants utilize water from the soil for respiration. The process of percolation leads to an increase in groundwater storage; groundwater runoff occurs as streamflow and removes groundwater from storage. Where streamflow records are available, annual water yield represents the sum of *OF* and *GWR.*

In this section, elements of the water balance for both North Fork Caspar Creek and for the proposed project are quantified in an effort to analytically verify the qualitative expectations of increased runoff and groundwater. Growing season evapotranspiration rates for forests, vineyards and grassland vegetation from a variety of sources are presented to assess likely changes in the local water balance that could occur as a result of the project.

North Fork Caspar Creek Water Balance

The Thornthwaite technique (Dunne and Leopold, 1978, p. 236-250) for estimating evapotranspiration was applied to data from Caspar Creek by Redwood Sciences Lab for the period 1990-1995 (www.fs.fed.us/psw/topics/water/caspar/Thornthwaite.shtml). Figure 5 below graphically portrays mean monthly precipitation and potential evapotranspiration from the RSL analysis. Evapotranspiration implicitly includes interception losses. Potential evaporation is generally distinguished from actual evapotranspiration, however, in the moist coastal climate at Caspar Creek, sufficient soil moisture is likely to be available for plant use and actual and potential evapotranspiration probably have similar values. When P-PET is negative, evapotranspiration exceeds precipitation, and plants utilize stored soil moisture. This condition exists during the period June through September.

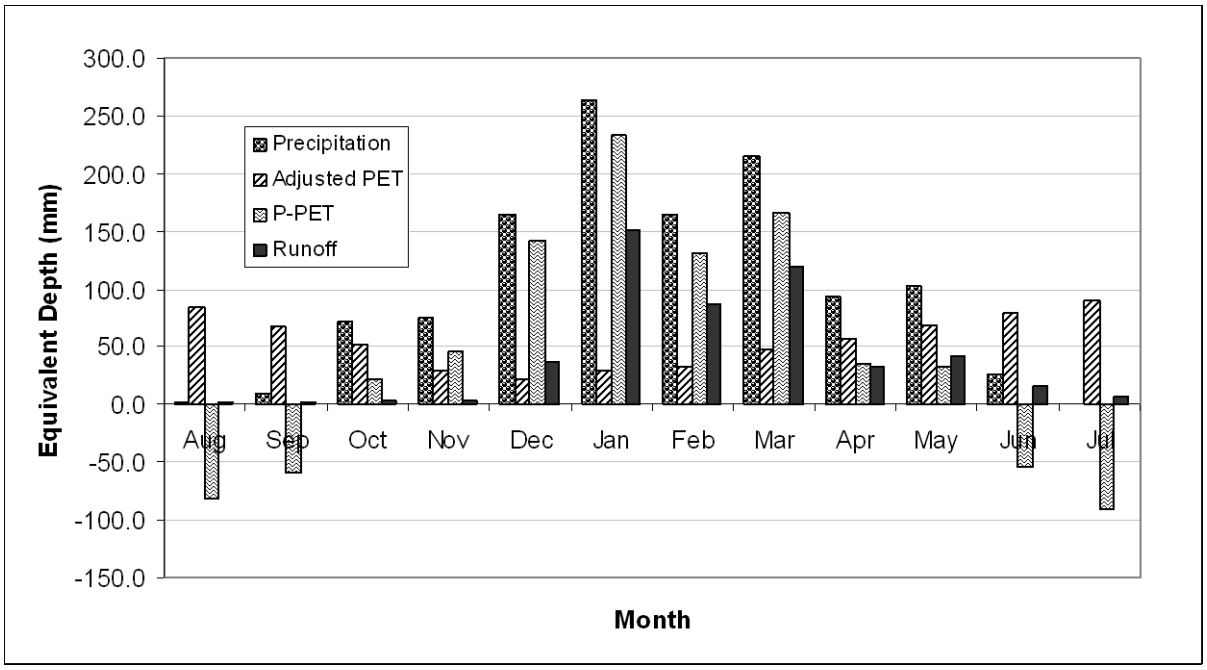


Figure 5. Water balance for North Fork Caspar Creek 1990-95 based on data published by RSL.

The difference between precipitation and evapotranspiration (P-PET) represents water available for runoff and infiltration. The RSL water balance for North Fork Caspar Creek showed that annual P-PET was 528 mm and that measured streamflow was 503 mm. The mean annual water balance for North Fork Caspar Creek above indicates 56% of annual precipitation leaves the watershed by evapotranspiration, and about 42% leaves the watershed as runoff. The annual calculation suggests that the water balance is relatively accurate based on the agreement between P-PET and runoff, however, it does not provide perspective on infiltration and groundwater components of the water budget.

We used daily runoff data from North Fork Caspar Creek to compute mean monthly runoff as shown in Figure 5. The difference between P-PET and runoff provides an estimate of infiltration. During the winter months November through March, P-PET

exceeds runoff by about 50 to 100 mm per month, and indicates the likely magnitude of infiltration and percolation. This demonstrates that during the rainy season in the California Coast Range, when the effects of canopy interception losses would be realized as increased water delivery to the soil surface, infiltration and groundwater recharge occurs. This evidence tends to confirm that project effects are likely to include increased infiltration of rainfall to the soil with likely increases in groundwater recharge.

Growing Season Evapotranspiration

During the growing season, vineyard evapotranspiration is expected to be less than evapotranspiration that would occur from the existing vegetation. Limited data are available for actual evapotranspiration from forests in a Mediterranean climate. (Unsworth, Phillips et al. 2004) measured evapotranspiration from different components of an old-growth Douglas-fir—Western Hemlock stand at Wind River, Washington in the interior Cascade Range near the Columbia River. For the months of June and July 1999, they measured mean daily evapotranspiration of about 2.3 mm with a standard deviation of 0.6 to 0.7 mm. They also found evidence indicating that the forest vegetation is capable of drawing soil moisture into the root zone from greater depth in the soil. For comparison, the North Fork Caspar Creek water balance estimated evapotranspiration for the period June to September of about 2.7 mm/day, a value similar to that measured in the Cascades. Finally, an estimate based on professional opinion was developed in response to our inquiry regarding redwood forest evapotranspiration rates by Oregon State University Professor Emeritus Dick Waring (personal communication, February 2005). He estimated average transpiration during the summer of about 3 mm/day, or about 90 mm/month for a 50-80 year old forest with a leaf area index of between 5 and 10. Maximum mean daily potential evapotranspiration was about 3 mm/day at North Fork Caspar Creek in the month of July.

Actual evapotranspiration for various locations in Sonoma County has been estimated by (Elford 1964), based on an assumed 4 inches of plant available soil moisture. Goldridge soils on gentle slopes have up to 3.9 inches of available water in the upper 28 inches of soil profile given available water capacity of 0.14 inches/inch. Goldridge soils on steeper slopes would have less available water, and would be predicted to have proportionately lower actual evapotranspiration. The project site lies between the Point Arena and Cloverdale climate stations, and Elford (1964) estimated actual growing season evapotranspiration to be 16.9 and 12.3 inches (429 and 312 mm), respectively at these locations. For reference, North Fork Caspar Creek evapotranspiration was estimated to be about 450 mm for the period May through September. Grassland evapotranspiration would be expected to be less than in forests, but no explicit estimate for grassland vegetation is offered.

Growing season evapotranspiration for grapevines and irrigation requirements for vineyards have been measured in California by (Williams 2001). He calculated that in a Paso Robles (Central Coast region) vineyard during a 126 day irrigation season in 2000 growing season that average water use was about 2.3 mm/day, with a maximum of 3.3

mm/day. Total water use was equivalent to 11.2 inches. Williams (2001) also found that the yield of grapes declined relatively little when irrigation rates were reduced below plant evapotranspiration rates. For example, when irrigation was reduced to half of calculated evapotranspiration, harvest yields from four vineyards and two cultivars ranged from 70 to 96% of yield (mean = 84%) compared to vines irrigated at 100% of the evapotranspiration rate. At irrigation rates of one-fourth calculated evapotranspiration, harvest yields ranged from 61 to 92% with a mean of 74% compared to fully-irrigated vines. These findings demonstrate that vines cultivated with modest applications of water produce viable crops; many viticulturists have found that vines that are stressed in their growing environment produce high quality wines.

The proposed vineyard project has been planned with irrigation applications of about 0.3 ft, equivalent to 3.5 inches or about 90 mm (Erickson Engineering, 2002). Given the likely soil moisture available and the findings regarding vineyard irrigation by Williams (2001), the proposed vineyards would likely use substantially less water than the existing vegetation. Consequently, based on likely water use by native vegetation and vineyards, the proposed project would tend to increase soil moisture and ground water percolation.

Summary of Water Balance Analysis

Comparisons between existing forest vegetation and anticipated vineyards with respect to hydrologic effects of vegetation indicates decreased evapotranspiration is likely under project conditions, both in the growing season and the rainy season. During the rainy season, reduced interception losses are expected to be about 10% to 20%, which represents a net gain to water delivered to the soil surface for infiltration and percolation.

Vineyard Development and Potential Changes in Soil Hydrologic Characteristics

Vineyard development may affect soil hydrologic characteristics through several mechanisms. These include potential changes in water infiltration rates and changes in topography and drainage that affect surface runoff paths.

Soil Characteristics

There are two soils on the project site where vineyards are proposed (Miller 1972). These are the Goldridge fine sandy loam, 15-30% slope (map unit GdE) and the Hugo very gravelly loam, 30 to 50% slopes (map unit HkF). Table 4 provides a summary of relevant information about these soils. These characteristics indicate that the Goldridge soil has a shallow subsurface horizon that can impede infiltration and generate surface runoff under rainfall rates of about 0.2 to 0.6 in/hr once the relatively thin surface horizon is saturated. In contrast, Hugo soils are deeper and more porous, and would only be expected to generate surface runoff under rainfall rates > 0.6 in/hr or more, which rarely occur in this area.

Field observations in early 2002 are consistent with these data. The Goldridge soils were observed to have a shallow water table and showed clear evidence of significant surface runoff, including rill and gully formation, particularly on the lower portions of hillslopes.

The Hugo soils did not appear to generate surface runoff except in Class III stream channels mapped on the project site.

Table 4. Selected soil characteristics at the project site. Based on soil descriptions and Estimated Engineering Properties in the Sonoma County Soil Survey (USDA 1972).

Soil Parameter	**Goldridge 15-30% slope**	**Hugo 30-50% slope**
Surface Horizon Texture	Fine sandy loam	Gravelly loam
Surface Horizon Depth (in)	16	48
Surface Horizon Infiltration Rate (in/hr)	0.63-2.0	0.63-2.0
Subsurface Horizon Infiltration Rate (in/hr)	0.2-0.63	n.a.
Typical % Gravel	0	35
Typical % Sand	50	23
Typical % Silt & Clay	50	42

Infiltration Processes and Rates

Changes in infiltration rates associated with vineyard development at the project site could be either positive or negative. Decreased infiltration rates are generally expected when converting forested areas to agricultural fields owing to reduced root mass and soil compaction from agricultural practices. Pasture areas would also be expected to have lower infiltration rates than forest soils, but probably greater than agricultural fields.

These potential decreases in infiltration rates for the project area might be counteracted by the deep tillage of soil prior to vineyard planting. Tillage would be expected to have the greatest effect on the Goldridge soils, which were observed in the field to have a high winter water table, and are to be tilled to a depth of about 2 ft. In addition, vineyard cover crops (annual grasses) will provide significant root mass and surface roughness to slow the flow of surface water, promoting infiltration. Consequently, infiltration and percolation rates for vineyard conditions are not expected to decrease significantly relative to pre-project conditions.

The foregoing assessment was echoed by A.T. O'Green, PhD, a soil scientist in the Cooperative Extension program at University of California, Davis, in an e-mail response in February 2005 to an inquiry regarding impacts of vineyard development on deep percolation of water in the Goldridge soil. The text of the e-mail is reproduced below.

> *Deep tillage of this soil is probably unnecessary. It is moderately well drained soil and any evidence of poor drainage appears to be a result of a seasonally high ground water table rather than a hydraulically restrictive soil horizon. Thus there will always be a direct but seasonal connection between the soil and groundwater no matter how the land is used*
>
> *If a clay layer is perching or slowing water infiltration the type of tillage has important implications on the persistence of a clay pan. Ripping a clay-rich soil is not an effective strategy to improve infiltration. Over the course of one or two seasons the clay layer will restore itself. Complete mixing with upper horizons to the base of the clay layer is needed to improve water penetration.*

> *The natural state of this soil is capable of handling a huge amount of infiltrating water and deep percolation. In my opinion, any form of soil disturbance would probably temporarily reduce infiltration rates by destroying the natural aggregates that have developed over time, particularly at or near the soil surface. Once the vineyard is established and cover crops planted I would expect that the natural aggregation would restore itself.*

Experiments on runoff and erosion processes on vineyard soils in Napa County provide evidence regarding infiltration capacity of vineyard soils. (Battany and Grismer 2000) used an artificial rainfall generator to measure runoff, infiltration, and soil moisture changes in response to simulated rainstorms in February and March 1997 on six year old vineyards with relatively low vegetative cover and tilled soils. Artificial rainstorms had an intensity of 1.6 in/hr and 40 minute duration. These simulated rainstorms provided 8.5% greater energy and 55% greater depth than natural 100 yr recurrence interval 40 minute rainstorm ((Battany and Grismer 2000) p. 1292). Thirty study plots with mean slope of about 10% (range 2 to 17%) and mean cover of about 35% (range 2 to 67%) on clay loam soils of the Fagan soil series were studied. These soils have an infiltration rate of 0.2-0.6 in/hr in the upper 16 in and 0.06-0.2 in/hr at 16-28 in depth, substantially lower than those at the project site (Table 4).

Runoff and infiltration rates observed in the experiment were consistent, with mean runoff of 18% of rainfall and mean infiltration of 82%. Infiltration ranged from 75 to 89% of delivered rainfall, equivalent to about 1.3 inches of rainfall in a 40 minute period. This infiltration rate was about three times the maximum typical infiltration rate for this soil type (0.6 in/hr or 0.4 in per 40 minute period). Soil moisture in the upper 4 inches of soil increased 14%, equivalent to about 0.6 inches of water, nearly half of infiltrated volume. The remaining balance of infiltrated water was probably distributed to depths > 4 inches; the experiment did not measure soil moisture below 4 inches in the soil column.

Extrapolating the hydrologic behavior of the Fagan soils in Napa vineyards to the proposed vineyards at the project site should be cautious, however, given the observations in Napa, qualitative conclusions can be made with considerable confidence. Under unusually intense simulated precipitation, water infiltration to the soil occurred at very high rates on soils that are less permeable and generate more rapid runoff than the Goldridge and Hugo soils on the project site near Annapolis. The Fagan soils at the experimental site in Napa are classified by USDA soil survey criteria in hydrologic group C (slow infiltration rate when thoroughly wet). Soils near the project site in Annapolis are classified in hydrologic group B (moderate infiltration rate when thoroughly wet). Overall, it appears that vineyard soils should be expected to be capable of relatively high infiltration of rainfall.

Changes in topography and runoff management in the vineyard are expected to change surface flow paths relative to existing site conditions. Erickson Engineering, Inc., has performed a detailed runoff analysis to calculating 100 yr recurrence interval flows from proposed vineyard areas on the site to verify the design capacity of the proposed reservoir and associated facilities as per requirements of Sonoma County. One component of this runoff analysis was calculation of the time of concentration (the time required for all

points of a watershed to contribute flow to the mouth of the watershed). The analysis found that the time of concentration for two representative sub-drainages of about 5 ac each was about 18 minutes under existing conditions and under proposed vineyard conditions. Time of concentration is maintained at pre-project levels because "[t]he post-construction combination of short run of sheet flow, low-slope vee ditching at one-half to one-third existing runoff slopes, and longer more serpentine drainage pathways tend to balance presence of higher velocities in drainage pipes" (Erickson 2001).

Although the time of concentration is unchanged, increased length of flow paths in the vineyards would tend to enhance infiltration processes. As noted above, the shorter flow lengths and more gentle slopes in the system of v-swales compensate for relatively high velocity in drainage pipes. Surface runoff velocity prior to entering drainage pipes is actually slower than under existing conditions, thereby promoting infiltration relative to existing conditions. This effect would be accentuated by the presence of cover crops on the vineyard soil surface.

Summary of Likely Effects on Hydrologic Character of Soils

In summary, significant decreases in infiltration rates and percolation rates are not expected under post-project conditions. Potential changes in soil hydrologic characteristics are unlikely to reduce the quantity of groundwater recharge from the project, however, it is possible that there could be an increase in groundwater recharge.

Slope Stability

Potential increases in soil moisture in the vicinity of the project area are not expected to significantly increase potential slope instability in the vicinity of the project. Slope stability hazards are generally low or very low in the project conversion area, with some areas of moderate hazard, and no landslides have been observed in the project conversion area in our field studies or in previous landslide surveys of the area[1]. In addition, local slopes along the perimeter of conversion areas are not sufficiently steep (e.g. approximately 60% gradient or greater) to be generally susceptible to debris slide processes, and the extent and density of woody vegetation (trees and shrubs) that will remain in these areas provide significant additional reinforcement to the soil (Schmidt, Roering et al. 2001), reducing the potential for slope failure in the future.

Potential increases in pore water pressure or short term increases in the elevation of a perched water table lying above the geologic contact between the overlying Ohlson Ranch Formation and the underlying Franciscan Formation is a mechanism that could hypothetically translate increased soil moisture from hydrologic change into increased risk of debris slides or debris torrents. There is no evidence of such landslides in the historic aerial photo record analyzed by the California Geological Survey in the NCWAP Gualala report;there is one area of "high" potential for landslides within the watershed described by Drainage Node 33[2].

[1] See Erosion Analysis, Figure 2.
[2] See Erosion Analysis, Figure 2.

This area of high potential was observed in the field to have evidence of one debris slide originating on steep slopes in past decades. Vineyard drainage for Node 33 will be largely controlled by sedimentation basins (Figure 8), mitigating the potential for increased soil moisture on down-gradient slopes. Existing woody vegetation is to be retained in this area, and as noted above, the maintenance of root strength in this area is expected to provide significant reinforcement of slopes. Project hydrologic impacts are not expected to significantly increase landslide hazards in the project area, either within or adjacent to project conversion areas.

Expected Hydrologic Effects

Increases in winter peak flows could occur, and this issue is analyzed further. The magnitude of peak flow change is estimated and its potential effect on channel erosion processes is assessed in the following section. The rational runoff method is used to estimate peak flow changes. The resulting maximum magnitude of changes using the rational method is consistent with the results of the Caspar Creek study, providing supporting evidence that this relatively simple empirical approach can be expected to provide reasonably accurate estimates of the likely magnitude of peak flow change. Locations where potential runoff increases were predicted were evaluated for their sensitivity to peak flow increase (i.e. potential for accelerated bed and bank erosion), based on field survey data characterizing existing conditions of channel development and channel substrate.

Potential peak flow increases would only have potentially significant effects on small intermittent and ephemeral drainage channels on and near the project site. Channels further downstream are not sensitive to potential peak flow changes because of the small potential magnitude of peak flow increase at a larger watershed scale[3] and the degree of erosion resistance in the steep channels draining the project area. Downstream channels have historically experience peak flows that are very large in relation to potential peak flow changes, and channel substrates typically include bedrock, boulders, cobbles and other fluvial materials. The degree of natural channel armoring that inherently exists in Patchett Creek is sufficient to prevent significant channel response to project effects on peak flow. Moreover, the Caspar Creek experiment found no increases in sediment load in fish-bearing (CDF Class I) portions of North Fork Caspar Creek, despite observed increases in sediment yield from small tributaries of North Fork Caspar Creek that were hypothesized to have been affected by erosion associated with observed increases in peak flow. Peak flow increases are therefore not expected to cause significant changes in downstream fish habitat.

Potential increases in annual water yield and summer base flow could occur as a result of timber harvest and conversion. Increased minimum flows in the dry season at Caspar Creek resulted in "increased habitat volumes, and…lengthened the flowing channel network along logged reaches" (Keppeler, 1998, p. 43). This could benefit aquatic habitat by increasing the extent and duration of flow and the habitat area available to aquatic organisms.

[3] See hydrologic analysis by West Yost & Associates.

Collection of runoff from a portion of the proposed vineyard area for storage in an onsite, off-stream reservoir for irrigation is not expected to have a significant adverse effect on annual yield or peak runoff. Surface runoff from approximately 47 acres of the project area, including 9 acres comprising the reservoir and sump footprint, will be routed to the reservoir. Subsurface flow, including groundwater discharge to surface flow that comprises the baseflow, is not expected to be significantly reduced by the project; it is likely to increase as previously described.

Reductions in peak runoff are not expected to have deleterious effects. The magnitude of decrease in peak flow owing to the reservoir as it affects Patchett Creek has been estimated as described in the following section. Briefly, the drainage area of Patchett Creek at the project boundary (Drainage Node 50)[4] is about 152 acres. Peak surface runoff for the 15 minute, 2-yr design storm at this point is expected to decrease about 10% under proposed project conditions where about one-third of the drainage area is affected by reservoir collection. At the point in the Patchett Creek watershed where all portions of the project area are contributing runoff (about one-half mile downstream from Drainage Node 50), the total drainage area is about 1.27 mi^2 (813 acres). At that point in the watershed, about 3.6% of the drainage area drains to the proposed reservoir, and expected peak flow changes are negligible.

Given the expected increases in soil moisture and annual runoff, particularly summer baseflow, and soil moisture associated with forest conversion in the remaining portions of the project area, and the small percentage of drainage area contributing to the reservoir, there is no reason to expect that runoff or streamflow in Patchett Creek will be adversely affected by the reservoir. The reservoir collection system mitigates potential peak runoff increases from portions of the project area by intercepting runoff and attenuating peak runoff rates. Given the expectation that the conversion project will increase soil moisture and runoff, the development and use of the reservoir tends to offset those increases. Nevertheless, only a portion of the project area is designed to drain to the reservoir, and the project as a whole is expected to increase peak runoff and yield.

The following analysis assesses potential peak flow increases and potential channel sensitivity to peak flow increases. As described above and in Appendix A, research at Caspar Creek showed that despite significant local increases in erosion and runoff in tributaries, mainstem habitat water quality (as expressed by annual suspended sediment yield) did not decline. The lack of detectable impact in fish-bearing reaches of North Fork Caspar Creek is probably attributable to the relatively small magnitude of additional erosion relative to total watershed sediment supply. Hence, large percentage increases in small erosion volumes spread out over the watershed proved to be undetectable against the background of other erosion processes that are spatially concentrated along the banks of larger streams. This subject is discussed in detail in Appendix A.

[4] See Figure 6.

Magnitude and Location of Potential Peak Flow Increases

As discussed above, removal of forest vegetation is expected to increase runoff rates. Watershed experiments at Caspar Creek found that the rate of stream flow associated with a 2-year recurrence interval storm (probability of occurrence in any year = 50%) after clearcut harvest was about 27% greater than expected pre-harvest for small watersheds (about 25 to 70 ac). This portion of the analysis describes the method used to quantify the magnitude and location of expected peak flow increases at the project site.

Application of the Rational Runoff Method

There are a variety of techniques that could be employed to quantify expected runoff rates. Owing to the small size of the drainage areas involved, modest data requirements, and relative simplicity of the technique, the "rational runoff method" was selected (Leopold and Dunne, 1978, pp. 2989-305, (PWA, Weaver et al. 1994)). This technique is often used in developing flow estimates for culvert sizing and other hydraulic design problems. The rational method utilizes a simple formula, Q = C I A, where instantaneous stream discharge, Q (cfs) is the product of a coefficient pertaining to the character of the watershed C, the precipitation rate I (in/hr), and the drainage area A (ac).

The limitations of estimating peak flows using any method, including the rational runoff method, are substantial. Hydrologic systems are complex, many of the variables are difficult to quantify, and models rarely produce precise results. The method employed for this analysis is expected to give peak flow estimates that are of the proper order of magnitude, but of undetermined accuracy. Of greater importance is generating an estimate of relative change for pre- and post-project conditions, and the technique used provides repeatable estimates of relative change using accepted methods and data inputs of a level of detail consistent with available data.

The coefficient C is determined from tables relating to land use characteristics of the watershed area (e.g. Dunne and Leopold, 1978, p.300). Relevant values of C for loam soils under cultivation or pasture may range from 0.35 to 0.45, depending on conditions. Woodlands may have C ranging from 0.25 to 0.35, depending on conditions. To estimate the effects of vineyard conversion on peak runoff, the rational method is evaluated under existing conditions and proposed project conditions. Grassland and cultivated areas are represented by C = 0.4, while woodland is represented by C = 0.3. Areas converted from woodland to vineyard therefore are represented by a one-third increase in the runoff coefficient.

As previously discussed, the Caspar Creek experiment found peak flow increases after logging of about 27% for 2-year recurrence flows. Using the rational runoff method, and holding all other factors equal, the conversion of woodland (C = 0.3) to vineyard (C = 0.4) would yield peak flow increases of 33% ([0.4-0.3]/0.3). Hence, using a 2-year design flow for the analysis would yield runoff predictions that are in general agreement with the Caspar Creek experimental data pertaining to changes in peak flow following vegetation removal.

The precipitation rate (I) used is determined by the time of concentration of flow in the watershed and the magnitude and/or frequency of the design storm. The frequency (return period or recurrence interval) selected for evaluation is 2 years. Runoff increases for larger, less frequent rain storms are expected to diminish. For smaller, more frequent rain storms, percentage changes in runoff rates are expected to be larger, but of little geomorphic significance. The 1.5 year to 2 year recurrence interval flows are believed to be the most influential in determining channel form, and represent the magnitude of flows that do the most geomorphic work (Richards 1982) p.141-2). Considering the geomorphic significance of the 2-year flow, and considering that the most significant effect of peak flow increases are hypothesized to be channel and bank erosion, the 2-year recurrence interval flow is particularly appropriate for this analysis.

As noted earlier, EEI determined the time of concentration for representative watersheds in the project area to be about 18 minutes under both vineyard and existing conditions. Hence, the duration of the storm to be evaluated is about 15 minutes. Since higher rainfall amounts would be produced for a shorter storm duration, the use of 15 minutes instead of 18 minutes for time of concentration is conservative in that it would tend to overestimate runoff. Estimates of precipitation for 15 minute storm duration can also be calculated using existing data (Miller, Frederick et al. 1973). For Annapolis, the estimated 2-year recurrence, 15-minute duration rainfall intensity was 0.44 in/hr. The equivalent rate for a one hour period used in the rational runoff equation is 1.76 in/hr.

GIS Methods for Rational Runoff Analysis

Hydrologic change analysis utilized GIS data and tools to compute pre- and post-project conditions. Much of the GIS analysis also contributed directly to an application of the USDA Revised Universal Soil Loss Equation 2 (RUSLE2) to analyze potential changes in rates of surface erosion associated with vineyard development. The results of the surface erosion analysis are incorporated in a sediment budget for the Patchett Creek watershed (also know as Annapolis Falls Creek) presented in the following section.

Geographic Information System (GIS) tools were used for both of these analyses to calculate watershed drainage areas for different portions of the project area and adjacent portions of the landscape. This required creating a series of attributes for areas within the analysis including existing vegetation type (grassland, woodland, or existing cultivated crops), future cover and land use type (new proposed vineyard areas), local slope gradient of the land surface, and existing and future drainage characteristics (natural sub-watersheds and future drainage routed through proposed sedimentation basins). The GIS was also used to produce maps illustrating critical components of the hydrologic and erosion analyses.

We used ESRI's ArcGIS 9.2 and data from a variety of sources. All data sources that were created were generated as “feature classes” in a “personal geodatabase”. The benefit of creating a feature class is that perimeter and area values are automatically generated in the attribute table for each polygon. The project area, including adjacent upstream drainage areas, was sub-divided into 18 sub-watersheds terminating in small stream channels at drainage nodes at or near the project boundary. The drainage areas

contributing to drainage nodes formed polygons that were digitized in an onscreen editing session utilizing topographic data from Erickson Engineering. The average contributing drainage area to these 18 drainage nodes is 23.8 acres. The average node drainage area is 18.7 acres when the largest node, (N50-111 acres), is excluded.

Two adjacent drainage nodes on the northern edge of the project area contribute flow to Grasshopper Creek. Another two other nodes on the western edge of the project area contribute flow to two unnamed tributaries of the Wheatfield Fork west of Patchett Creek. The remaining 14 drainage nodes contribute flow to Patchett Creek.

The area covered by grassland was digitized onscreen from NAIP 2006 aerial photography available online from the USDA. The remaining area was assumed to be in a forested condition for this analysis. Grassland area was digitized conservatively in that small areas of grassland vegetation and areas of mixed vegetation types were classified as forest. Two other GIS layers were created from CAD files that Erickson Engineering created: proposed vineyard areas to be drained by a system of surface collectors and drop inlet pipes to sedimentation basins, and the proposed vineyard boundaries. In order to transform the CAD data to line up with other data, the technique described in this online article (http://support.esri.com/index.cfm?fa=knowledgebase.techArticles.articleShow&d=29039) was used. The proposed vineyard boundaries were broken into two subsets, one layer represented the interior vineyard boundary and the other incorporated the unplanted area of vineyard perimeter avenues.

Table 5. Summary of layers used for hydrologic analysis.

Layer	Method
Sub-watershed drainage boundaries (drainage nodes)	Onscreen digitizing using topography from Erickson Engineering
Grassland	Onscreen digitizing using 2006 airphoto; areas not in grassland were assigned forest for existing vegetation
Drainage area to sedimentation basins	Imported CAD coverage from Erickson Engineering
Proposed vineyards	Imported CAD coverage from Erickson Engineering

The above layers were merged into one feature class. The attribute table was exported into Microsoft Excel where pivot tables were used to generated summed acreages.

Results: Predicted Pre- and Post-Project Peak Flow

The runoff analysis estimates the magnitude of peak flows pre- and post-project at several points around the project site where concentrated and/or dispersed runoff would be routed by the vineyard drainage system. The Drainage Nodes are shown in Figure 6. Soils data, vegetative cover and drainage type data used in the analysis are presented in Figures 7, 8, 9 and 10. Calculated drainage areas and vegetation types for existing and proposed conditions and estimated design storm peak discharge for existing and proposed conditions and percentage change in discharge are summarized in Table 6.

Table 6. Summary of results of the runoff analysis for individual runoff nodes (see Figure 6) for a 2-year, 15-minute duration rainstorm of 0.44 inches. The runoff coefficient (C) for existing pasture, existing cultivated areas and proposed vineyard areas is 0.4; for woodland areas, 0.3. The first column identifies the vineyard drainage nodes analyzed. Drainage area is rounded to the nearest acre.

		Existing Conditions		Proposed Project Conditions		Peak Discharge		
Drainage Node	Total Area (ac)	Woodland (ac)	Grassland & Cultivated (ac)	Woodland (ac)	Grassland & Cultivated (ac)	Existing (cfs)	Proposed Project (cfs)	% change
N01	23.0	22.1	0.8	13.0	9.9	12.3	13.9	13%
N07	41.9	41.9	0	22.5	19.4	22.1	25.5	15%
N17	12.6	12.6	0	4.3	8.2	6.6	8.1	22%
N20	40.8	19.6	21.2	9.4	39.1 [a]	25.2	25.8 [b]	2% [b]
N26	5.8	5.8	0	1.2	4.6	3.1	3.9	26%
N30	22.3	10.7	11.6	4.1	18.2	13.8	15.0	9%
N31	38.8	36.1	2.7	27.9	10.9	21.0	22.4	7%
N33	10.5	10.5	0	6.0	4.5	5.5	6.3	15%
N35	3.5	3.5	0	3.4	0.1	1.8	1.9	5%
N37	8.0	8.0	0	8.0	0	4.2	4.2	0%
N40	6.9	6.9	0	3.1	3.8	3.6	4.3	18%
N45	27.8	27.8	0	6.5	13.5 [a]	14.7	12.9 [a]	-12% [a]
N50	111.2	58.4	52.8	48.3	62.9	68.0	69.9	3%
N20+N50	151.9	77.9	74.0	56.9	102.8	93.2	95.7 [b]	3% [b]
N56	27.2	22.7	4.5	18.7	8.5	15.2	15.9	5%
N60	12.1	11.9	0.3	3.9	13.2 [c]	6.5	11.4 [c]	76% [c]
N61	20.8	6.1	14.7	6.1	14.7	13.6	13.6	0%
N62	9.5	9.5	0	7.0	2.4	5.0	5.4	9%
N63	6.6	2.5	4.1	0.1	1.5 [c]	4.2	1.1 [c]	-73% [c]
Total	429.2	316.5	112.7	179.4	249.8			
				Total-Reservoir Filling		246.5	261.4 [b]	6% [b]
				Total-Reservoir Full, No Spill		246.5	268.1	9%

Notes

a. 7.8 acres of contributing area in Drainage Node 45 is diverted to Drainage Node 20 for reservoir supply.

b. Assumes 6.7 cfs of peak flow (pump capacity of 3000 gpm) diverted to reservoir at Node 20 with no spill from reservoir.

c. 5.0 acres in Drainage Node 63 diverted to Drainage Node 60 for treatment in sedimentation basin.

The largest flow increase is about 76% at Drainage Node 60 and results from diversion of about 5 acres of runoff from its natural drainage to a proposed sedimentation basin to minimize potential delivery of sediment from vineyard fields to stream courses. The next largest peak flow increase is 26% at Drainage Node 26, and several other drainages are predicted to experience peak flow increases, generally less than 20%. Relatively large predicted increases result from a relatively high proportion of conversion area in the watersheds contributing runoff to those drainage nodes.

The large decrease (-73%) at Drainage Node 63 results from the diversion of 5 acres of contributing area to Drainage Node 60. The 5 acre of drainage area is a large proportion of the total drainage area for Drainage Node 63. The decrease in peak flow at Drainage Node 45 (-12%) reflects the diversion of 7.8 acres of watershed to the reservoir collection system located in Drainage 20; 7.8 acres represents a modest proportion of the drainage area for Drainage Node 45.

The project reservoir is located in the watershed of Drainage Node 20. During the period of reservoir filling, runoff collected in the reservoir sump (located very near to Drainage Node 20) would be pumped to the reservoir at a maximum rate of 6.7 cfs (3000 gpm). A small increase (2%) in design storm peak flow is predicted at Drainage Node 20 during periods of reservoir filling. At Drainage Node 50, including runoff from Drainage Node 20 (N20 + N50 in Table 6), peak flow increase is estimated to be about 3% when the reservoir is filling. When the reservoir is full, drainage to the reservoir sump is routed through from the sump to the bedrock channel at the bottom of Drainage 20. In this scenario, peak flow would increase about 29% at Drainage Node 20. At Drainage Node 50, with the increased runoff at Drainage 20 included, peak runoff is predicted to be about 10%.

The runoff collection system in the watershed above Drainage Node 20 will substantially reduce surface flows in the channel draining this area. Under existing conditions, the 2-yr recurrence interval design flow is about 25 cfs; under project conditions, the design flow would decrease to about 5 cfs. This flow reduction is expected to substantially reduce channel and bank erosion in this drainage and is discussed in greater detail in the Erosion Analysis.

Overall peak flow for the analysis area in aggregate increases about 9% if the reservoir is full and runoff is routed through the sump to Drainage Node 20. If the reservoir is being filled, then the aggregate change in peak runoff is an increase of about 6%.

A wide range of additional combinations of realistic runoff scenarios could be hypothesized and subjected to analysis. The foregoing scenario describes the most likely conditions with a design storm (2-yr recurrence interval) believed to represent the largest percentage increases in peak flows and that do the most geomorphic work. The perspective provided through this approach is sufficient, if not exhaustive, with regard to evaluating the potential significance of peak flow change associated with the proposed project.

Assessment of Drainage and Channel Sensitivity to Potential Peak Flow Increases

The predicted flow changes shown in Table 6 indicate a measure of the relative potential for accelerated channel and bank erosion at different locations on the project site. Channel conditions were observed in the field in January 2002 and January 2007 following periods of high rainfall and runoff in the preceding months. Flow levels recorded at stream gauging stations in the region were near the 1.5- to 2-year recurrence interval for some of these rainstorms, indicating that field conditions reflected the effects of the design storm.

Channel Survey Overview

Field geologists surveyed all potentially significant surface drainage features intersecting the proposed project area boundaries in January 2007. Site maps at a scale of 1 inch to 250 ft developed by Erickson Engineering Incorporated (EEI) were used to guide the survey and record geographic observations.. Drainage features were initially identified through interpretation of EEI's 10-ft contour intervals topographic map, supplemental maps of jurisdictional and non-jurisdictional waters and channels developed by Monk & Associates, and prior surveys of the site conducted by OEI in 2001 and 2005. Drainage features within the scope of this field investigation included any topographic feature that could potentially concentrate surface runoff, including convergent topography, swales and existing channels. Drainage features thus identified were enumerated on maps used in the field to guide surveys and to aid in the development of a system for uniquely-identifying drainage features for future reference.

All drainage features intersecting the perimeter of the project area were surveyed in the field. Surveys recorded a broad range of systematic observations of the drainage feature from the approximate location of proposed sedimentation basins identified on EEI maps, or the channel head identified on EEI maps (whichever was farthest upslope), to a point at least 300 feet downslope.

Channel Survey Protocol

Field geologists used the EEI map to navigate the study area. Each surveyed drainage feature was flagged in the field with a unique identifying alphanumeric code and mapped at the location of the proposed sediment basin or the intersection of the drainage feature and the study area boundary. Field maps were annotated to document survey points.

One of the chief objectives of the survey was to identify existing swales and channels and assess their condition at or near the proposed sediment basins and boundaries of proposed vineyard blocks to help assess the sensitivity of drainage features to potential increases in peak runoff. The survey teams used criteria similar to, but somewhat distinct from, those established by the California Department of Forestry and Fire Protection (CDF) to define a Class III channel, and by the US Army Corps of Engineers to define jurisdictional waters. The field geologists from OEI located channel heads according to definitions commonly in use by scientists: the presence of morphology indicating the development of

stream banks, which is inferred to indicate the capability of the feature to erode some of the hillslope material comprising the channel bed.

First, the point where the axis of the drainage feature crossed the proposed sediment basin, or a channel head, was located. Digital photographs were taken to document conditions. From this point on, continuing down the axis of drainage, the presence or absence of a channel was documented; if a channel was present, the substrate, slope and dimensions of the channel were observed or measured as per the protocol for point observations described below. Channel head locations were noted on the continuous observation form; for a majority of the surveys this point coincided with the beginning of the survey.

A series of systematic observations were collected and recorded from the beginning (uppermost) point of the survey. Following is a description of these observations, which were recorded on a one-page form (Appendix B). The survey form had four main parts:

1. Continuous observations,
2. Point observations,
3. Geomorphic observations, and
4. General comments.

The continuous and point observations are referenced to the top point of the survey. Point observations were initiated at the top point as described above, and then repeated at 100 ft intervals to a point 300 ft downhill from the top point. Distance measurements were accomplished using either a string-dispensing hip chain or a 300 ft reel-mounted flexible tape measure. In some cases, the survey continued past 300 ft to develop a more complete set of observations for lengthier channels on the project site, and to locate a transition point at which the channel substrate was either bedrock or cobbles and boulders. The mean survey length was approximately 500ft.

Continuous Observations

Continuous observations were recorded from 0 to 300 ft using a hip chain or tape to determine locations along the axis of the drainage feature. Observations were categorical data classifying the drainage feature according to its local morphology as summarized in Table 7. The point of transition from one class to another was recorded on the data form. In addition, at each transition point an observation was made regarding whether or not local evidence of sediment transport was present.

Table 7. Summary of continuous observations.

Class #	Drainage Feature Class	Description
1	Swale-weak convergence	Weakly – moderately convergent topography. No channel.
2	V-swale-strong convergence	Strongly convergent topography. No channel
3	Dry surface channel	Banks evident > 50% of length
4	Wetted surface channel/seep	Wetted surface of flowing water with or without banks
5	Subsurface-under wood	Drainage feature covered by thick piles of slash or large logs
6	Subsurface-soil pipes	Water travels through natural soil pipes in the ground.
7	Knick point	Near vertical drop (step) in channel bed greater than 0.5 ft. Substrate noted.
8	Road	Drainage feature crosses road
9	Skid trail	Drainage feature crosses logging skid trail
10	Flat Area	Drainage feature crosses flat area. Flow dispersed, channel becomes braided or dissipates
11	Landslide	Drainage feature passes through/ crosses landslide deposit.
12	Channel head	Channel head location per definition stated earlier in report.

Point Observations

Point observations were collected to characterize critical parameters of channel geometry, including the active channel width, depth, slope and substrate. The active channel is typically defined by the absence of vegetation and organic litter, and displays evidence of frequent surface flow and sediment transport. Channel bank height and top width were also measured as illustrated in Figure 7.

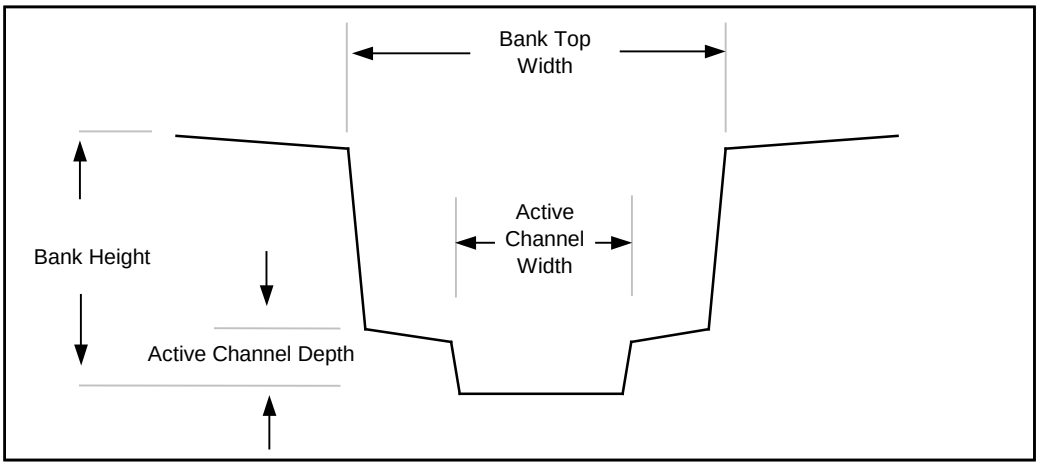


Figure 7. Channel geometry definition sketch.

Point observations were recorded at 0, 100, 200, and 300 ft from the top survey point as shown on the field form (Appendix B). In cases where the survey continued past 300 ft, additional measurements were recorded when conditions changed from those found at the

end of the 300 ft survey. A photo was taken at each observation point to document local conditions. Point observations included active channel width and depth (when a channel was present) and bank height and bank top width. The slope of the axis of the drainage feature looking downhill was measured in units of percent with a clinometer.

Channel swale substrate was observed and classified as (1) soil, (2) organic litter, (3) fluvial sediment, or (4) bedrock/boulders. Soil was defined as mineral soil or colluvium. Organic litter was defined as a layer of organics, leaves, branches or logs, with an average thickness greater than 0.2 ft. Deposits of silt, sand, gravel and cobbles define fluvial sediments. Multiple substrates could be recorded for one point indicating the presence of a primary and/or secondary substrate. Substrate data were ordinal and were subsequently interpreted with respect to the expected degree of resistance to erosion by concentrated surface runoff, where soil provided the least resistance and bedrock/boulders the greatest resistance to erosion.

Geomorphic Observations

Geomorphic observations were made throughout the survey and reviewed in the field at the conclusion of the survey to ensure that a consistent set of observations were completed. Geomorphic observations focused on functional characteristics of headwater channels relating to

1) Active erosion processes,
2) Resistance to erosion, including
    a) Valley-scale effects of plant roots and stems along the drainage axis and
    b) Discrete elements channel morphology (e.g. logs), and
3) Effects of roads and skid trails on hydrologic processes

The specific field observation pertaining to these functional characteristics are summarized below.

Evidence of <u>active erosion</u> was typically observed in the form of discrete features characterized by relatively fresh, unvegetated soil surfaces lying in or adjacent to a channel as described in Table 8. Erosion scarps indicating past erosion with substantial potential for renewed erosion were also noted. The survey team would record the presence of an individual erosion feature the first time it was encountered. The relative abundance of these features was noted and at the end of the survey a ranking of the top 3 features present was given. In some cases only one or two features were present and only the top two or one feature was ranked. Hence these data identify the range and relative intensity of active erosion processes present. These features would not typically be found in swales where no channel was present.

Table 8. Summary of observations pertaining to active erosion features.

Erosion feature	Description
Stream banks	Stream banks actively eroded as indicated by fresh, unstable soil surfaces, undercut banks and/or bank collapse..
Stream bed	Stream bed actively eroded as indicated by exposed fine roots and/or fresh exposures of underlying substrate.
Rill or gully	Erosion scars, typically located on planar or divergent topography and frequently associated with roads or landslides.
Knick point	Actively eroding or relatively stable, near-vertical drop in the channel greater than 0.5 ft. Face of step in channel bed composed of soil or colluvium.
Erosion of road cut or fill slope	Actively eroding cut or fill slope of a road or skid trail
Landslide	Channel appears to be cutting through landslide deposits or scarp, or other evidence of landslide.

Observations pertaining to factors that contribute to resistance to erosion by concentrated flow in drainage features included characterization of vegetation type in the axis of the drainage feature and individual elements of flow resistance found in channels. Vegetation observed along the axis of each drainage feature was classified into three groups: grass, shrubs and trees. At the end of each survey the survey team estimated the percentage of the length along the drainage feature axis occupied by vegetation in each class.

In channels, resistance elements are expected to provide local checks on stream flow, reducing stream velocity and promoting local deposition of sediment. The survey team recorded the presence of an individual erosion feature the first time it was encountered. Features were noted only once, even if there were multiple occurrences of a particular feature. Hence these data identify the range of types of resistance elements present.

Individual elements of flow resistance found in the axis of drainage features that were observed in surveys are summarized in Table 9. Elements of flow resistance are expected to armor the drainage feature and make it less prone to erosion by surface flow in swales. In channels, resistance elements are expected to provide local checks on stream flow, reducing stream velocity and promoting local deposition of sediment. The survey team recorded the presence of an individual erosion feature the first time it was encountered. Features were noted only once, even if there were multiple occurrences of a particular feature. Hence these data identify the range of types of resistance elements present.

Table 9. Summary of observations pertaining to elements of flow resistance.

Resistance element	Description
Stumps	Tree stump located within the drainage feature axis.
Bedrock	Bedrock identified within channel axis.
Boulders/cobbles	Boulders or cobbles identified as channel substrate.
LWD	Large woody debris located along the drainage feature axis.

The effect of roads and skid trails on hydrologic processes pertains to existing features in the project area developed primarily for past timber management. This set of observations (Table 10) characterizes the degree to which past road construction affected drainage features and runoff or stream flow processes. The survey team recorded the presence of a road feature the first time it was encountered. Features were noted only once, even if there were multiple occurrences of a particular feature. These data identify the range of types of road features present.

Table 10. Summary of observations pertaining to effects of roads and skid trails on hydrology.

Effects of Roads and Skid Trail on Hydrology	Description
Minor-only at crossing, local effect	Road crosses drainage feature. No diversion of flow along road. Local erosion of road prism may be present.
Substantial-flow diversion of natural flow path	Water from drainage feature is diverted onto road and away from natural drainage path.
Additional flow-road/skid runoff increases flow	Road concentrates additional flow into drainage feature.
Interception of water table in cut slopes	Seep or spring observed in cut slope. Very moist soil or flowing water present.

Interpreting and Summarizing Field Data

Field data were initially analyzed to determine mean values and variability around the mean value (See Appendix C for complete data set). Observations of geomorphic processes were summarized in a manner that allows comparison of frequency. These summary data were evaluated to determine whether any systematic variations in channel characteristics were attributable to controlling geologic or geomorphic factors such as distinct differences in bedrock or slope-forming processes.

Distinct, systematic differences among groups of channel were not apparent. Consequently, channels were described and assessed individually with respect to sensitivity to potential peak flow increases associated with conversion of forest to vineyard. To facilitate the assessment, overall mean values for all point measurement (slope, channel width and depth, bank height and top width and slope) for all drainages surveyed (Table 11) were compared to values for individual drainages. Field data are summarized in Appendix C. Mean values presented in Table 11 were calculated from taking the mean of the mean values for each point measurement.

Table 11. Mean and distribution of observed channel geometry.

Channel characteristic	**Mean***
Slope (percent)	18
Active Channel Width (ft)	1.8
Active Channel Depth (ft)	0.4
Active Channel Cross Sectional Area (ft^2)	0.8
Bank Height (ft)	2.8
Channel Top Width (ft)	5.2
Bank-top Cross Sectional Area (ft^2)	14.4

* Calculated as the mean of means for point observations at 0,100, 200 and 300 ft.

To assess sensitivity of each drainage to peak flow increase, the field data were evaluated with respect to evidence of fluvial erosion processes at present and likely response to peak flow increase. The magnitude of expected peak flow increase (described in the previous section) was also considered.

Indicators of erosion potential are considered as a means to assess relative erosion potential and sensitivity to potential peak flow increase. The primary water quality concern in the Gualala River watershed is sediment, in particular fine sediment that can be carried in suspension over long distances to streams reaches supporting fish habitat. Peak flow increase and associated fluvial erosion that could potentially result from timberland conversion is the mechanism considered here. The extent and degree of channel development can be used as indicators of erosion potential in headwater drainages.

Headwater drainages characterized as a swale, and lacking a defined channel, are considered to have higher sensitivity to concentrated peak flow increases (e.g. vineyard runoff collected in a drainage system and discharged at a point into a headwater drainage). Drainages containing higher proportions of existing channel are considered less sensitive to such flow increases; an existing channel would already have been subject to fluvial erosion and would have developed some degree of stability compared to what my be expected in a swale exposed to concentrated flow.

Furthermore, the degree of stability and erosion potential of a channel or swale would be indicated by the channel substrate. Channels with boulders or bedrock forming the channel bed are stable with low potential for increased erosion in response to increased flow. Channels with beds comprised of fluvial sediment have been previously eroded to some degree such that finer sediment (e.g. clay and silt) has been winnowed out of the bed material and coarser sediment (e.g. sand and gravel) remains on the bed. The coarser bed material left on the bed resists erosion up to a peak flow, threshold, hence the bed is relatively resistant to erosion for a range of lower magnitude flows. Channels or swales with organic litter, such as debris from trees, leaves and duff, have a substantial layer of material protecting underlying soil from erosion. Finally, bare soil is vulnerable to erosion, and could be expected to have a higher erosion rate in response to peak flow increase.

Another indicator of a channel's relative sensitivity to peak flow increase in terms of potential increased fluvial erosion is channel cross sectional area. Channel cross sectional area is proportional to flow magnitude. Wider and deeper channels would be expected to be less susceptible to erosion caused by an increase in flow than a narrower channel; the proportion of flow increase would be less in the larger channel than in the smaller channel.

Erosion potential could be expected to be proportional to slope, but this is frequently not the case in the project area. Swales and channels with steeper slopes are potentially more susceptible to erosion; however, few swales and channels observed in the field have relatively steep slopes. This is largely because areas proposed for vineyard development are located on gentle to moderate slopes lying upslope from steeper terrain. Where the steeper terrain develops, there is typically sufficient drainage area and slope to support an energetic stream channel that has cut down to relatively stable substrate, frequently the underlying Franciscan bedrock.

Field Observations in Channels Draining the Project Site

In this section, each of the surveyed drainages is described and evaluated. The location and extent of surveys are shown in Figure 6. Drainages were identified by reference to project maps developed by EEI pertaining to the erosion control and drainage plan. Each surveyed channel is identified by reference to the sub-watershed it drains; the outlet of each watershed is referred to as a "drainage node". Potential peak flow changes for a 15-minute, 2 yr recurrence interval rainfall event were estimated for each of these drainages in the preceding section. The drainages are described beginning with those that drain

to an unnamed tributary to the Wheatfield Fork and then those draining to Grasshopper creek. The remaining drainages drain to Patchett creek. These are described beginning in the southwest corner of the project and proceeding in a clockwise direction.

Drainage 40 is located in the southwestern portion of the property draining portions of Vineyard Units 8b and 8c through **Drainage Node 40** on the southwestern property boundary to an unnamed tributary to the Wheatfield Fork. The survey began at the channel head and approximate location of proposed Sediment Basin 40 and continued 550 ft downstream just beyond the southwestern property boundary. The drainage has a relatively broad valley bottom comprised primarily of soil substrate with a mean slope of 21%. The active channel is continuous and its mean dimensions are 1.2 ft wide by 0.5 ft deep which is a cross section 25% smaller than the overall average of all drainages surveyed. The mean bank depth is 1.9 ft; the mean channel top width is 3.5 ft . This is a cross section which is smaller than the overall average bank cross section of all drainages surveyed. Evidence of active erosion observed includes minor stream bed erosion and soil steps. Stabilizing elements observed in the drainage were stumps and multiple pieces of large woody debris. Shrubs are the dominant vegetation present in the axis of the drainage taking up 40% of the length of the surveyed channel axis. Potential peak flow increase is 18%. About half of the proposed vineyard runoff is dispersed around field perimeters and would reach natural channels via forested flow paths that would tend to attenuate and disperse runoff increases. Vegetation and woody debris is widely distributed in the channel tend to resist significant erosion, and moderate slope and relatively wide valley floor reduce the potential for erosion. Given the existing soil substrate, Drainage 40 has moderate sensitivity to potential peak flow increases.

Drainage 4 is located in the northwestern portion of the property draining Vineyard Units 1a and 1b through **Drainage Node 1** on the western property boundary, ultimately flowing to the Wheatfield Fork via an unnamed tributary west of Patchett Creek. The survey began at the approximate location of proposed Sediment Basin 4 and continued to the western property boundary 1400 ft below. The drainage is a relatively broad valley comprised of an entirely soil substrate with a gentle mean slope of 6% and no channel for the first 834 ft. The mean active channel dimensions are 1.5 ft wide by 0.6 ft deep which is 21% larger cross section than the overall average of all drainages surveyed. Evidence of active erosion present during the field survey includes minor stream bed erosion. Additional flow is received from rills along a skid/ATV road parallel to the drainage along the right (northern) bank. Stabilizing elements observed in the drainage were stumps and multiple pieces of large woody debris. Grass and shrubs are the dominant vegetation present in the axis of Drainage 4. The grass is concentrated in the upper 300 ft and makes up 20% of the survey and shrubs cover 15% of the axis. Potential peak flow increase is 13% for Drainage Node 1. Considering the drainage's gentle slope, wide valley bottom, existing vegetation and stabilizing elements, and the modest potential for peak flow increase, Drainage 4 has low sensitivity to peak flow increase. Proposed vineyard runoff is largely dispersed around field perimeters and would reach natural channels via forested flow paths that would tend to attenuate runoff increases.

Drainage 70 is located in the northwest portion of the property and drains portions of Vineyard Units 1a and 1d passing through **Drainage Node 7** on the northernmost property boundary toward Grasshopper Creek. The drainage was surveyed starting at the channel head about 50 ft downstream of the outlet of a culvert that passes under Annapolis Road and extended 458 ft downstream to the confluence with a tributary on the left bank. The channel begins flowing down a broad swale with soil substrate that develops into a steep walled V-shaped swale with a slope of 20%. The soil substrate continues until the end of the survey. Road runoff from approximately 700 ft of Annapolis Road, along with some runoff from Vineyard Unit 1a, is directed into the culvert. The mean slope of the drainage is 24%, which is steeper than the overall mean slope of all surveyed drainages. The mean active channel dimensions of the survey are 1.8 ft wide by 0.3 ft deep and the cross section is about one-third smaller than the overall average cross section of all drainages surveyed. The mean bank height is 1 ft; the mean channel top width is 3 ft forming a cross section which is approximately one-fifth the size of the overall mean bank cross section of all drainages surveyed. Evidence of active erosion present during the field survey includes stream bed and bank erosion, and multiple soil steps in the channel bed. Stabilizing elements observed in the drainage were stumps, bedrock and multiple pieces of large woody debris. The lower portion of the surveyed channel is stable and well developed with a continuous bedrock substrate. Predicted peak flow increase is about 15%. Given existing channel conditions including a moderate amount of County road runoff directed into the drainage with a continuous, developed channel with soil substrate over the first 400+ ft, containing numerous active erosion elements, Drainage 70 has moderate sensitivity to peak flow increase. A stable bedrock channel is present at the bottom of the surveyed channel.

Drainage 2 is located in the northwest portion of the property and drains a portion of Vineyard Unit 1d passing through **Drainage Node 7** on the northernmost property boundary toward Grasshopper Creek. The drainage was surveyed starting at the channel head and approximate location of proposed Sediment Basin 2 and extended 469 ft downstream to the confluence with Drainage 7. The channel head is located approximately 50 ft downstream of the proposed Sediment Basin in a moderately convergent swale. The mean slope of the drainage is 31%, moderately steeper than the mean slope of all surveyed drainages. The mean channel dimensions of the active channel are 1.2 ft wide by 0.3 ft deep, comprising a cross section about half the size of the overall average cross section of all drainages surveyed. The mean bank height is 2 ft ;the mean channel top width is 1.8 ft. This cross section is about one-fourth the size of the mean bank cross section of all drainages surveyed. The channel substrate is soil for the first 300 ft of the survey where bedrock first appears. At 440 ft the channel is well developed with a continuous bedrock substrate. Evidence of active erosion observed includes stream bank erosion, fill slope erosion of an old skid road along with multiple soil steps in the channel bed. Stabilizing elements observed in the drainage were stumps, boulders, cobbles, and multiple pieces of large woody debris. Shrubs and tree are the vegetation types present in the axis of the surveyed drainage. Shrubs take up 15% while trees occupy 3% of the axis. Estimated peak flow increase is about 15%. Given existing conditions, including a continuous, developed channel with moderate erosion elements and relatively abundant resistance elements and a stable bedrock channel downstream,

Drainage 2 has moderate sensitivity to increased peak flows resulting from the vineyard conversion.

Drainage 3 is located in the northwest portion of the property and drains a portion of Vineyard Unit 1d. Runoff ultimately exits the project area passing through **Drainage Node 7** on the northernmost property boundary toward Grasshopper Creek. The survey began at the approximate location of proposed Sediment Basin 3 and extended 279 ft downstream to the confluence with Drainage 7. The channel head is located 102 ft downstream of the top of the survey forming in the fill slope of an old road. The channel is neither well defined nor continuous through its length and has soil substrate only near the top. The mean slope of the drainage is 40%, much steeper than the overall mean slope of all surveyed drainages. The mean active channel dimensions of the sections present along the survey are 0.9 ft wide by 0.3 ft deep, the cross section is about one-third the size of the overall average cross section of all drainages surveyed. Evidence of active erosion observed is limited to fill slope erosion of an old skid road and rills along a skid road crossed by the drainage. Stabilizing elements observed in the drainage were bedrock, boulders, cobbles, and pieces of large woody debris. Shrubs occupy 5% of the surveyed drainage axis. Potential peak flow increase is about 15%. Given channel conditions (an intermittent, poorly developed channel on a relatively steep slope and both fluvial and bedrock substrate in the lower portions of the drainage), and moderate predicted peak flow increase, Drainage 3 has moderate sensitivity to peak flow increase.

Drainage 7 is located in the northwest portion of the property and drains portions of Vineyard Units 1c and 1d passing through **Drainage Node 7** on the northernmost property boundary toward Grasshopper Creek. The drainage was surveyed starting at the channel head (the approximate location of proposed Sediment Basin 7) and extended 550 ft downstream to the property boundary. The channel head is located just above a wetland area and as the channel flows into this area it disperses and becomes braided and intermittent through the wetland vegetation. At 185 ft downstream the flow passes through a culvert running north under Annapolis Road. No road runoff is directed into the culvert. The mean slope of the drainage is 10%. Below the culvert the channel flows through a flat and weakly convergent area that gradually develops over the next 300 ft into a stable channel at 550ft from the top of the survey. The dimensions of the active channel are 1.8 ft wide by 0.5 ft deep. The cross section is about 10% larger than the overall average of all drainages surveyed. The mean bank height is 2 ft; the mean channel top width is 3.5 ft, approximately half the size of the overall mean bank cross section of all drainages surveyed. Evidence of active erosion observed includes stream bed and bank erosion, rills along the hill slope and multiple soil steps in the channel bed. Stabilizing elements observed in the drainage were stumps, boulders and multiple pieces of large woody debris. Grass makes up 15% of the vegetation in the drainage axis in the upper section of the survey. The upper half of the survey has a soil substrate which develops into fluvial and cobble substrate at 250 ft, but reverts to cohesive soil through the end of the survey. Approximately 700ft below the bottom of the survey the drainage is well developed with a continuous bedrock substrate. Potential peak flow increase for Drainage Node 7 is about 15%. Given the existing conditions observed (relatively gently slope, the stable wetland area near the vineyard boundary that would tend to

attenuate peak flow increases, and a continuous, developed channel including relatively abundant flow resistance elements), Drainage 7 has moderate sensitivity to peak flow increases.

Drainage 38 is located in the southeastern corner of the southwest portion of the property draining Vineyard Unit 8c through **Drainage Node 37**. The survey began at the approximate location of proposed Sediment Basin 39 in a drainage ditch adjacent to a Mendocino Redwood Company road and continued to the confluence with Drainage 36, 264 ft below. Drainage 38 is a drainage ditch with a soil substrate which runs adjacent to an existing logging road. The mean active channel dimensions are 1.5 ft wide by 0.6 ft deep which is about one-fifth larger than the average of all drainages surveyed. The mean bank height is 1.5 ft; the mean top width is 2.5 ft wide, a cross section which is smaller than the overall average bank cross section of all drainages surveyed. Evidence of active erosion observed includes rills along the road, some of which drop off the road into the adjacent channel near Drainage Node 37. Potential peak flow increase is 0%. Given the existing conditions, Drainage 38 has low sensitivity to potential increased runoff. The existing road and its influence on drainage flow paths is the chief erosion hazard. The extent of sensitive channel is relatively small; bedrock channel is located about 300 ft downstream.

Drainage 36 is located in the southeastern corner of the southwest portion of the property draining Vineyard Units 8b and 8c through **Drainage Node 37**; it is immediately adjacent to and north of Drainage 38. The survey began just downstream from the proposed Sediment Basin 36, at a culvert crossing under a Mendocino Redwood Company, and continued 300 ft downstream. The culvert outlet appears to be the head of the natural channel in this drainage. The natural drainage has a mean slope of 23% and a mainly soil substrate with some fluvial deposits and bedrock outcrops near the end of the survey at 280 ft. The mean active channel dimensions are 1.7 ft wide by 0.7 ft deep, a cross sections that is about 50% larger than the mean of all drainages surveyed. The mean bank height is 2.8 ft; the mean channel top width is 4.7 ft wide. This is smaller than the overall average bank cross section of all drainages surveyed. Evidence of active erosion present during the field survey includes rills along the road, some of which have their flows diverted by a water bar which lies directly over the culvert and drop off the road into the main drainage. Minor stream bed erosion, soil steps and woody debris steps were also observed. Additional flow is received from the road diverting flow from its natural path along Drainage 38 as well as the section of road which parallels the lower section of Drainage 36. Potential peak flow increase is 0%. The existing conditions of Drainage 36 (the active erosion along the road and soil substrate near the proposed vineyard boundary) have low sensitivity to potential peak flow increase. The extent of sensitive channel is relatively small; bedrock channel is located about 280 ft downstream.

Drainage 35 is located in the southwestern portion of the property draining portions of Vineyard Units 8a and 8b through **Drainage Node 35** to Patchett Creek. The survey began at the approximate location of proposed Sediment Basin 35 and continued 500 ft downstream to a confluence with another drainage draining mostly Mendocino Redwood Company land on the right bank at 289 ft. The drainage begins as a broad swale with no

channel and no channel forms before the confluence where an already developed channel exists. The mean slope of the drainage is 39%, moderately steeper than the mean overall slope of all drainages surveyed. The channel observed after the confluence runs atop an old logging skid road built down the axis of the drainage. The active channel has a soil substrate and its mean dimensions are 2 ft wide by 1.25 ft deep, about three times the size of the overall average cross sectional area of all drainages surveyed. Stabilizing elements observed during the survey were stumps and multiple pieces of large woody debris. Trees are the dominant vegetation present in the axis of the surveyed drainage taking up 10% of the axis. Predicted peak flow increase is 24%. Given the existing conditions observed (lack of a channel near the vineyard boundary and a soil substrate and relatively steep slopes), in relation to expected peak flow change, Drainage 35 has moderate sensitivity to increased flows.

Drainage 34 is located in the southwestern portion of the property draining Vineyard Units 8b and 8c through **Drainage Node 33** to Patchett Creek. The survey began at the approximate location of proposed Sediment Basin 34 and continued 375 ft downstream to a section of very steep channel. The drainage begins as a broad swale with no channel. The channel head is located 173 ft downstream of the top of the survey. The mean slope is 26%, moderately steeper than the overall mean slope value for all surveyed channels. The active channel has a mostly soil substrate until the steep drop off at 375 ft where an intermittent bedrock substrate was observed. Mean channel dimensions are 2.2 ft wide by 0.2 ft deep, about half of the overall average cross sectional area of all drainages surveyed. Evidence of active erosion observed is limited to landslide terrain and soil steps associated with the same deposit found on Drainage 33. Stabilizing elements observed during the survey were bedrock, cobbles, stumps and multiple pieces of large woody debris. Although bedrock is present it does not become a continuous channel substrate. Dense shrubs are the dominant vegetation present in the axis of the surveyed drainage taking up 40% of the axis. Trees are less abundant, they are only present in 5% of the axis. Peak flow increase in this drainage is predicted to be 15%. Given the existing conditions observed (lack of a channel near the vineyard boundary, a soil substrate for the majority of the survey, landslide deposits and a relatively steep slope, with relatively abundant stabilizing elements), Drainage 34 has moderate sensitivity to increased peak flows.

Drainage 33 is located in the southwestern portion of the property draining a portion of Vineyard Unit 8b through **Drainage Node 33** to Patchett Creek. The survey began at the channel head and approximate location of proposed Sediment Basin 33 and continued 500 ft downstream to the confluence with Drainage 34 on the right bank. The drainage begins as a strongly convergent V-shaped swale with a dry surface channel. The mean slope is 37%, substantially steeper than the overall mean slope value of all surveyed channels. The active channel has a soil substrate and its mean dimensions are 1.2 ft wide by 0.4 ft deep which is 40% smaller than the overall average cross sectional area of all drainages surveyed. The mean bank height is 3.7 ft; the mean channel top width is 5.7 ft. This cross section is larger than the overall mean bank cross section of all drainages surveyed. Evidence of active erosion observed includes stream bed and bank erosion, and soil steps. Historic debris slide deposits are likely present near the bottom of the

drainage. Stabilizing elements observed during the survey were a bedrock cascade at 200 ft, stumps and multiple pieces of large woody debris. Although bedrock is present, it does not become the continuous substrate in the surveyed channel. Predicted peak flow increase is 15%. Given the existing conditions observed (a predominantly soil-bedded channel, numerous active erosion sites, including debris slide deposits, and a relatively steep slope), Drainage 33 has moderate sensitivity to increased peak flow.

Drainage 32 is located in the southwestern portion of the property draining portions of Vineyard Units 8a and 8b through **Drainage Node 31** to Patchett Creek. The survey began at the channel head and approximate location of proposed Sediment Basin 32 and continued 950 ft downstream to the confluence with Drainage 31 on the left bank. The drainage begins as a broad hillside with a dry surface channel and a mean slope 11% and gradually develops into a narrow V-shaped valley bottom around 700 ft. The active channel has a soil substrate and its mean dimensions are 2.1 ft wide by 0.4 ft deep, about the same as the overall average for all drainages surveyed. The mean bank height is 4 ft; the mean top width is 10 ft. This cross section is more than two and a half times the size of the overall average bank cross section of all drainages surveyed. Evidence of active erosion present during the field survey includes stream bed and bank erosion, along with soil steps. Stabilizing elements observed during the survey were continuous bedrock beginning at 900 ft, stumps and multiple pieces of large woody debris. Shrubs are the dominant vegetation present in the axis of the drainage taking up 20% of the axis. Potential peak flow increase is 7%. Proposed vineyard runoff is largely dispersed around field perimeters and would reach natural channels via forested flow paths that would tend to attenuate runoff increases. Given the existing conditions (a continuous, gently sloping soil-bedded channel with substantial woody debris and vegetation resisting erosion, leading to bedrock channel, with a relatively gently slope), in relation to the small predicted increase in peak flow and the relatively broad dispersion of vineyard runoff, Drainage 32 has low sensitivity to peak flow increase.

Drainage 31 is located in the southwest portion of the property and drains Vineyard Unit 8a passing through **Drainage Node 31** into the Patchett Creek watershed. The drainage was surveyed starting at the channel head located approximately 25 ft downstream of proposed Sediment Basin 31 and extended 666 ft downstream. Approximately 150 ft below the end of the survey lies the confluence with Drainage 32. The mean slope of the drainage is 13%. The channel begins with a soil substrate, gently sloping 10% near the channel head and, following some steeper sections. At 666 ft the channel drops off steeply over a bedrock cascade (slope 45%)). The mean active channel dimensions for the top 300 ft of the survey are 3.4 ft wide by 0.3 ft deep; the cross section is about 40% larger than the overall average of all drainages surveyed. Evidence of active erosion present during the field survey includes minor stream bed erosion and multiple steps in the channel bed. Stabilizing elements observed in the drainage were stumps, bedrock and multiple pieces of large woody debris. The vegetation creating channel and valley erosion resistance are trees and shrubs. Trees were observed in 15% of the total surveyed channel axis while shrubs were observed in only 5%. At 435 ft, the channel substrate becomes continuous bedrock. The peak flow increase in this drainage is 7%. Considering the small potential peak flow increase, this drainage has low sensitivity to

erosion because the channel is well developed starting near the edge of the proposed vineyard boundary, the slope is relatively shallow, natural flow resistance elements are relatively common, and the substrate becomes continuous bedrock. In addition, proposed vineyard runoff is largely dispersed around field perimeters and would reach natural channels via forested flow paths that would tend to attenuate runoff increases. Proposed wetland mitigation areas adjacent to the north would also be expected to increase runoff detention storage, tending to diminish the magnitude of peak flow increase.

Drainage 30 is located in the central portion of the property draining Vineyard Units 7a and 7c through **Drainage Node 30** on the southern property boundary toward Patchett Creek. The survey began at the channel head at the approximate location of proposed Sediment Basin 30 and continued 520 ft downstream. The mean slope of survey is gentle (about 8%), moderately shallower than the overall mean slope value for all surveyed channels. The active channel is well developed with moss growing on much of the soil substrate. The mean dimensions are 2.7 ft wide by 0.4 ft deep, about one-third larger than the mean cross sectional area of all drainages surveyed. The mean bank height is 2 ft; the mean channel top width is 6.5 ft wide. This is cross section is slightly smaller than the mean bank cross section of all drainages surveyed. Evidence of active erosion observed includes soil steps and stream bed and bank erosion. Stabilizing elements observed during the survey were bedrock, boulders and cobbles and pieces of large woody debris. Trees are the dominant vegetation present in the axis of the surveyed drainage but occupy only 5% of the length of the surveyed axis. Predicted peak flow increase at Drainage Node 30 is 9%. Given channel conditions, including a continuous, well developed channel starting near the vineyard boundary with a gentle slope and cohesive soil substrate, along with the relatively low predicted peak flow increase, Drainage 30 has low sensitivity to increased peak flows.

Drainage 28 is located in the central portion of the property draining a portion of Vineyard Unit 7a through **Drainage Node 30** on the southern property boundary toward Patchett Creek. The survey began at the approximate location of proposed Sediment Basin 28 and continued 175 ft downstream to the confluence with Drainage 30 on the right bank, and then on to 300 ft from the top of the survey. The survey began in a broad swale, with no channel until 160 ft just above the confluence with Drainage 30. The mean slope of survey is 19%, about the same as the overall mean slope value for all surveyed channels. The active channel after the confluence with Drainage 30 has a soil substrate and its mean dimensions are 3 ft wide by 0.4 ft deep, about 50% larger than the overall average cross sectional area of all drainages surveyed. The mean bank height is 0.4 ft; the mean channel top width is 5 ft wide. This cross section is about 15% of the size of the overall mean bank cross section of all drainages surveyed. Evidence of active erosion is limited to soil knickpoints and stream bank erosion. Stabilizing elements observed during the survey were bedrock, boulders and cobbles which are intermittent starting at the confluence with Drainage 30 and become increasingly abundant after the 300 ft point in the survey. As is the case in the majority of the channels surveyed, multiple pieces of large woody debris were also observed. Shrubs and trees are the dominant vegetation present in the axis of the surveyed drainage. Shrubs occupy 5% of the length of the axis; trees occupy 10%. Predicted peak flow increase for Drainage

Node 30 is 9%, but it is probably higher for Drainage 28 above Drainage 30. Given the existing conditions observed (lack of a channel near the vineyard boundary, a broad swale with a soil substrate, draining into a developed channel), Drainage 28 has moderate sensitivity to increased peak flows above its confluence with Drainage 30.

Drainages 26 and 27 are located on the western edge of the central portion of the property draining Vineyard Unit 7a and flow off the property and through **Drainage Node 26** to the south and into the Patchett Creek watershed. Both surveys began at the approximate location of proposed Sediment Basins numbers 26 and 27, extending 300 ft downstream. The two drainages are similar and characterized by gentle, weakly convergent slopes. The mean slope of Drainage 26 is 10%; it is 13% for Drainage 27, both shallower than the overall mean slope of channels in the project area. No channel is present throughout the entire length of either drainage. The swale substrates are entirely soil. No evidence of active erosion was observed, with the exception of minor local effects of runoff concentration in the form of small rills where the drainage crosses logging roads of the Mendocino Redwood Company. Stumps, large woody debris, and slash piles in the drainages constitute the main stabilizing elements present. Potential peak flow increase for the entire drainage, comprised of sub-drainages 26 and 27, is 26%. The absence of a channel and presence of road crossings present potential for erosion to occur during peak runoff events. However, the shallow slope, weakly convergent topography and extensive organic stabilizing elements serve to reduce the energy of runoff and disperse the flows, reducing sensitivity. Drainages 26 and 27 have moderate sensitivity to peak flow increase. Mitigation should be developed for conveyance of flow across temporary logging roads to minimize erosion potential.

Drainage 45B is located in the central portion of the project site draining portions of Vineyard Units 6a, 7a and 7b through **Drainage Node 45** on the southern property boundary to Patchett Creek. The survey began at the channel head and continued 800 ft downstream. The drainage begins as a weakly convergent swale with a slope of about 13% and a poorly developed channel with no banks. The mean slope for the drainage is 11%, smaller than the overall mean slope of all drainages surveyed. The mean active channel dimensions are 1.6 ft wide by 0.3 ft deep, 40% smaller than the overall average size for all drainages surveyed. The channel substrate alternates between soil and fluvial for the top 670 ft, beyond which bedrock substrate becomes continuous. Evidence of active erosion present during the field survey includes stream bed erosion, soil knick points and erosion of fill slope material from an old skid road. Stabilizing elements observed in the drainage were bedrock, boulders, cobbles and multiple pieces of large woody debris. Trees and shrubs are the dominant vegetation present in the axis shrubs covering 15% of the surveyed axis while the trees cover 5%. Given the existing conditions of the upper 600 ft of the survey (mostly soil substrate near the conversion boundary, abundant active erosion elements) along with the fact that there is no proposed sediment basin , Drainage 45B would have moderate sensitivity to increased flows. Runoff from about 7.8 acres of proposed vineyard that formerly would have entered Drainage 45B is to be directed to reservoir storage, therefore reducing expected peak flows. Consequently, Drainage 45B will have low sensitivity to increased peak flow. In

addition, bedrock substrate is continuous in the lower portion of Drainage 45B, and the channel is not sensitive to concentrated runoff from proposed Sediment Basin 25.

Drainage 45A is located in the central portion of the property draining portions of Vineyard Units 6a and 6b through **Drainage Node 45** on the southern property boundary toward Patchett Creek. The survey began at the approximate location of proposed Sediment Basin 45 and continued 605 ft downstream to the confluence with Drainage 18 on the left bank. The survey begins on a flat area, possibly an old skid road, with no channel. The channel head is located 128 ft downstream of the top of the survey at a soil knick point at the base of a coniferous tree. The channel is not well developed for the upper 300ft of the survey and is intermittent in sections. The mean slope of the drainage 9%, half the mean slope value for all surveyed channels. The active channel substrate varies between soil and organic litter . The mean active channel dimensions are 1.5 ft wide by 0.5 ft deep, about 10% smaller than the average cross sectional area of all drainages surveyed. Evidence of active erosion is limited to erosion of the fill slope of a road the drainage crosses. Stabilizing elements observed during the survey were bedrock and multiple pieces of large woody debris. At 500 ft the substrate becomes continuous bedrock. Shrubs are the dominant vegetation present and occupy about 10% of the axis of the drainage. Peak flow increases are not expected at Drainage Node 45, however, peak flow increases in Drainage 45A might be 25 to 30%. Given the existing conditions observed (gently sloping, unchanneled swale near the vineyard boundary, a poorly developed channel when present, with soil and organic litter substrate for the top 500 ft), Drainage 45A has moderate sensitivity to peak flow increase.

Drainage 18 is located in the central portion of the property draining a portion of Vineyard Unit 6b through **Drainage Node 45** on the southern property boundary toward Patchett Creek. The survey began at the approximate location of proposed Sediment Basin 18, continued 135 ft downstream to the confluence with Drainage 45A on the right bank and then on to 300 ft from the top of the survey. The survey begins on a broad swale, with no channel until the confluence with Drainage 45A. The mean slope of the section above the confluence is 27%, steeper than the mean slope for all surveyed channels. Post confluence the mean slope value drops to 13%, slightly shallower than the overall mean slope for all surveyed channels. The active channel at the confluence has is initially organic litter, becoming fluvial/bedrock substrate. Its mean dimensions are 1.75 ft wide by 0.66 ft deep, about 40% larger than the average cross sectional area of all drainages surveyed. Evidence of active erosion observed is limited to erosion of the fill slope of a skid road crossed by the drainage and soil steps. The skid road diverts flow from its natural flow path between 200ft and 230 ft along in the survey. Stabilizing elements observed during the survey were stumps and multiple pieces of large woody debris. Trees are the dominant vegetation present in the axis of the surveyed drainage occupying 5% of the surveyed length. Peak flow increases are not expected at Drainage Node 45, however, peak flow increases in Drainage 45A might be 25 to 30%. Given existing channel conditions (lack of a channel in a swale near the vineyard boundary, draining into a moderately developed channel), Drainage 18 has moderate sensitivity to increased peak flows.

Drainage 17 is located in the central portion of the property draining Vineyard Units 6b and 6c through **Drainage Node 17** on the southern property boundary to Patchett Creek. The survey began at the approximate location of proposed Sediment Basin 17 and continued 480 ft downstream. The drainage begins as a weakly convergent swale with a slope of 10% with no channel for the first 57 ft. An intermittent dry surface channel with an organic litter substrate begins at that point, but never develops into a continuous channel over the course of the 480 ft survey. The mean slope for the channel is relatively gentle 14%, this is slightly less than the overall mean slope of all drainages surveyed. The mean channel dimensions are 1.8 ft wide by 0.3 ft deep which is about one-third smaller than the average size for all drainages surveyed. The mean bank height is 3 ft; the mean channel top width is 9ft wide. This cross section is approximately 50% greater than the overall mean bank cross section of all drainages surveyed. Evidence of active erosion observed includes stream bank erosion, soil knick points and erosion of fill slope material from an old skid road. Stabilizing elements observed in the drainage were fractured bedrock, boulders, cobbles and multiple pieces of large woody debris. Trees and shrubs are the dominant vegetation present in the axis, each occupying 5% of the surveyed drainage axis. Predicted peak flow increase is 22%. Owing to the organic substrate, intermittent channel and skid road, in relation to predicted peak flow change, Drainage 17 has moderate sensitivity to increased peak flows. Just beyond the end of the survey for this drainage lies the confluence with Drainage 16.

Drainage 16 is located in the central portion of the property draining Vineyard Unit 6c through **Drainage Node 17** on the southern property boundary into Patchett Creek. The survey began at the approximate location of proposed Sediment Basin 16 and continued 300 ft downstream meeting Drainage 17 at 195 ft from the top in a confluence on the right bank. The drainage begins as a weakly convergent swale with a slope of 11%. No channel was observed above the confluence with Drainage 17, where a well-developed bedrock channel is located. The mean slope of the survey is 22%, steeper than the mean slope of all drainages surveyed. The mean channel dimensions are 2.3 ft wide by 0.6 ft deep, which is 70% larger than the overall average cross section for all drainages surveyed. The mean bank height is 2.3 ft; the mean channel top width is 3.3 ft wide. This cross section is approximately half the size of the mean bank cross section of all drainages surveyed. Stabilizing elements observed in the drainage included fractured bedrock, cobbles and multiple pieces of large woody debris. Predicted peak flow increase is 22%. Given existing channel condition (organic substrate, lack of a channel near the vineyard boundary, lack of substantial existing erosion and its eventual confluence with a developed channel), in relation to predicted peak flow increases, Drainage 16 has moderate sensitivity to increased peak flows.

Drainage 50C is located in the northeast corner of the property draining portions of Vineyard Units 2 and 3. The runoff ultimately exits the property through **Drainage Node 50** on the southern property boundary into Patchett Creek. The survey began at the channel head at the approximate location of the property boundary and continued 1100 ft downstream. The drainage begins on a broad grassy swale including a wetted surface channel with a slope of 10%. The channel flows through dense brush and by 200 ft becomes well developed and continues until the confluence with Drainage 50D at

approximately 1100 ft. The mean slope of Drainage 50C is 12%, moderately less than the mean slope value for all surveyed channels. The active channel has a soil substrate and its mean dimensions are 1.7 ft wide by 0.8 ft deep, about two-thirds larger than the overall average cross sectional area of all drainages surveyed. A typical bank height taken at 800 ft is 3 ft; the corresponding channel top width is 15 ft . This is more than 3 times larger than the overall mean bank cross section of all drainages surveyed. Shrubs and grass are the dominant vegetation types present in the axis of the surveyed drainage. Shrubs occupy 15% of the length of surveyed channel axis while grass occupies 10%. Peak flow changes affecting Drainage 50C are expected to be minimal owing to the absence of conversion area in this location. Given channel conditions observed (a continuous, well developed channel near the vineyard boundary with few observed erosion features), Drainage 50C has low sensitivity to peak flow increase.

Drainage 50D is located in the northeast corner of the property draining a portion of Vineyard Unit 3. It also conveys runoff from the property north of Annapolis Road outside the project area, which passes through a culvert Annapolis Road. Runoff ultimately exits the project area through **Drainage Node 50** in Patchett Creek on the southern property boundary. The field survey began at the outlet of the Annapolis Road culvert and continued 500 ft downstream to the confluence with Drainage 50C. A plunge pool is located at the culvert outlet, leading to unchannelized V-shaped swale with a slope of 12%. The channel becomes well defined at 50 ft but disperses at flat sections reforming as the valley walls narrow and the drainage meets a tributary on its left bank. The mean slope of Drainage 50D is 9%, much shallower than the mean slope value for all surveyed channels. The active channel has a soil substrate and its mean dimensions are 2.3 ft wide by 0.8 ft deep, more than twice that of the average cross section of all drainages surveyed. Shrubs and grasses are the dominant vegetation types present in the axis of the surveyed drainage; shrubs occupy 10% of the drainage axis and grass occupies 20%. The remaining 70% of the axis is soil substrate. Peak flow changes affecting Drainage 50D are expected to be minimal owing to the absence of conversion area in this location. Given channel conditions including gentle slope, abundant wetland grass and shrubs with no observed erosion features and large cross section), Drainage 50D has low sensitivity to increased peak flows.

Drainage 50F is located in the eastern portion of the project area and drains a small portion of Vineyard Unit 4 into Patchett Creek and through **Drainage Node 50**. The drainage receives runoff from Annapolis Road and a neighboring vineyard on a hillside east of via a culvert under Annapolis Road. Observations of this drainage were made to evaluate this site for potential mitigation; this channel is not substantially affected by the project. Active erosion of the channel bed and banks was observed. Flattened grasses on the channel banks were also observed, indicating the flows overtopped the natural banks of the channel peak flow events. Concentrated flows emerging from this culvert are the likely cause of observed erosion. Gully control techniques would likely reduce long-term erosion at this site from concentrated runoff originating outside the project area.

Drainage 50E is located on the eastern edge of the property draining Vineyard Unit 4 and the Manzanita & Wetland Reserve through **Drainage Node 50** to Patchett Creek. The survey began in mixed forest and grassland above the steep slope leading to Patchett Creek and continued 130 ft downstream to the confluence with Patchett Creek. The survey begins at a large soil knick point appearing to be a stabilized gully dropping off a flat area (possibly a road and abandoned mill site) and then drops off steeply. The mean slope of survey above the confluence with Patchett Creek is 24%, moderately steeper than the mean slope value for all surveyed channels. No channel is present at the top of the survey although steep banks are present. The bank height is 5 ft; the width is 20 ft near the upper portion of the drainage. This cross section is over seven times the size of the overall mean bank cross section of all drainages surveyed. The drainage has a bedrock/boulder and organic litter substrate. Evidence of active erosion present during the field survey was minimal. Stabilizing elements observed during the survey were bedrock and multiple pieces of large woody debris. Peak flow increases are expected to be minimal because little conversion is proposed in this area, and no concentrated vineyard drainage will be delivered to this drainage. Given channel conditions observed, including underlying bedrock and boulder substrate, and the lack of expected peak flow increase, Drainage 50E has low sensitivity to peak flow increase.

Drainages 50A and 50B are located in the central east portion of the property draining Vineyard Unit 4 through **Drainage Node 50** at Patchett Creek. Both surveys began at the approximate location of proposed Sediment Basin 50, however, a major diversion of flow along an old road forms a gully that was surveyed (as Drainage 50A), in addition to the naturally occurring drainage (Drainage 50B). **Drainage 50A** follows the road bed for 275 ft, then drops off the road into a steep section of gully back to the natural drainage. The active channel of Drainage 50A (the gully on the road) has primarily bedrock substrate and its mean dimensions are 2 ft wide by 0.7 ft deep, about three-fourths larger than the average cross sectional area of all drainages surveyed. The mean bank height is 4.3 ft; the mean channel top width is 4.3 ft wide. This is about one-third larger than the mean bank cross section of all drainages surveyed. Evidence of active erosion observed includes stream bed and bank erosion, the large gully along the road, multiple soil steps and erosion of fill slope material of the road. Stabilizing elements observed during the survey were bedrock, boulders and cobbles. Shrubs and trees are the dominant vegetation present in the axis of the surveyed drainage, both occupy 5% of the length of the surveyed channel axis.

Drainage 50B begins on a broad swale, with no channel for the first 200 ft. The mean slope is about 31%, punctuated by steeper segments. The active channel after 200 ft has a substrate of bedrock and fluvial deposits which becomes continuous after 400 ft from the top of the survey. The mean active channel dimensions are 3 ft wide by 0.5 ft deep, about 50% larger than the average cross section for all drainages surveyed. Evidence of active erosion observed includes soil steps, stream bank erosion, and and gully/fill slope erosion of the road (Drainage 50A). Stabilizing elements observed during the survey were bedrock and multiple pieces of large woody debris. Shrubs and trees are the dominant vegetation present in the axis of the surveyed drainage; both occupy 5% of the length of the surveyed channel axis. Peak flow increases are expected to be minimal

because little conversion is proposed in this area. Given the existing conditions observed (historic flow diversion and numerous active and potentially active erosion elements and locally steep slopes), Drainages 50A and 50B have moderate sensitivity to peak flow changes. Peak flows are not expected to change much owing to forest conversion, however, concentrated runoff from proposed Sediment Basin 50 could increase erosion potential in both Drainages 50A and 50B.

Drainage 56 is located in the southeast portion of the property draining Vineyard Units 5a and 5b through **Drainage Node 56** to the Patchett Creek watershed. The survey began at the channel head at the approximate location of proposed Sediment Basin 56 and continued 700 ft downstream. The drainage begins on a broad grassy area with a wetted surface channel that traverses a flat area at 100 ft where the flow is dispersed. The channel reforms at 220 at a knickpoint where the slope increases. The mean slope of the drainage is 16%, slightly less than the mean slope for all surveyed channels. The active channel has a soil substrate and its mean dimensions are 0.9 ft wide by 0.4 ft deep, about half the size of the overall average cross sectional area of all drainages surveyed. Banks are not observed until after 650 ft from the top of the survey. The bank height at 700 ft is 10 ft and the channel top width is 5 ft. This is more than three times larger than the mean bank cross section of all drainages surveyed. Evidence of active erosion observed includes soil steps, stream bed and bank erosion along with rills formed along a road near the top of the survey. Stabilizing elements observed during the survey were cobbles and multiple pieces of large woody debris. By the end of the survey the channel runs down a relatively large, steep-walled valley with a broad, flat valley bottom. Trees and shrubs are the dominant vegetation present in the axis of the surveyed drainage, each occupying about 5% of the length of the surveyed axis. Predicted peak flow increase for node 56 is about 5%; most of the drainage area for the surveyed channel is not under forest canopy and the project would not likely have a substantial impact on peak flow for this surveyed channel. Given channel conditions, including an intermittent soil channel with numerous active erosion features), Drainage 56 has moderate sensitivity to peak flow increases, primarily owing to introduction of concentrated runoff from Sediment Basin 56.

Drainage 60B is located in the southeast portion of the property draining Vineyard Unit 5a through **Drainage Node 60** to the Patchett Creek watershed. The survey began just above the channel head and continued 300 ft downstream to the confluence with the outlet of Sediment Basin 60 (Drainage 60A) on the left bank. The survey begins on a flat area, possibly an old skid road, with no channel. The channel head is located 80ft downstream. The mean slope of the drainage is about 11%, substantially less than the mean slope for all surveyed channels. The active channel has soil substrate. The mean active channel dimensions are 1.8 ft wide by 0.2 ft deep, about half the size of the average cross section for all drainages surveyed. The mean bank height is 2.3 ft; the mean channel top width is 9.5 ft. This is more than 50% larger than the mean bank cross section of all drainages surveyed. Stabilizing elements observed during the survey were bedrock and multiple pieces of large woody debris. Trees are the dominant vegetation present in the axis of the surveyed drainage occupying 10% of the length of the surveyed channel axis. Predicted peak flow for Drainage Node 60 is 22%, however, most of the vineyard runoff to this channel is routed through Sediment Basin 60 and would not flow

through this channel. Given expected flow changes and channel conditions (gentle slope, broad valley bottom, and a high degree of channel development with abundant bedrock), Drainage 60B has low sensitivity to peak flow.

Drainage 60A is located in the southeast portion of the property draining portions of Vineyard Units 5a, 5b and 5c through **Drainage Node 60** to the Patchett Creek watershed. The survey began at the approximate location of proposed Sediment Basin 60 and continued 100 ft downstream to the confluence with Drainage 60B on the right bank. The survey begins on a flat area, possibly an old skid road with no channel. The mean slope of the drainage is about 15%, slightly less than the mean slope for all surveyed channels. The active channel has a soil substrate and its mean dimensions are 3 ft wide by 0.3 ft deep, a cross section about one-tenth larger than the mean cross section for all drainages surveyed. The mean bank height is 2 ft; the mean channel top width is 3.5 ft. This is about half the size of the overall mean bank cross section of all drainages surveyed. Evidence of active erosion present during the field survey includes soil steps and bank erosion. Stabilizing elements observed during the survey were bedrock, cobbles and multiple pieces of large woody debris. By 450 ft from the top the channel is relatively well developed with frequent bedrock outcrops. Trees are the dominant vegetation present in the axis of the surveyed drainage, occupying 10% of the length of the surveyed channel axis. Expected peak flow increases are high, about 75%, due to conversion in the natural drainage area and diversion of most of the flow from the watershed for Drainage Node 63 to Sediment Basin 60. Given channel conditions, including gentle slope, and a well developed channel with bedrock), Drainage 60A has moderate sensitivity to increased peak flow. As designed, the outlet from Sediment Basin 60 will bypass the unchanneled portion of Drainage 60A, preventing erosion in the existing swale.

Summary of Drainage Sensitivity to Peak Flow Increase

The foregoing narrative descriptions of drainage and channel conditions consider both predicted peak flow increases and likely potential for channel response to determine the relative sensitivity to peak flow. Sensitivity was generally considered low if peak flow increases were less than 10% and drainage and conditions were moderately stable. Sensitivity was considered to be moderate in a wider range of situations. These include the following general examples:

- if peak flow was greater than 10% and drainage and channel conditions were somewhat unstable;
- peak flow increases greater than 20% combined with unusually stable drainage conditions or unstable conditions are of limited extent.

High sensitivity would be applied to channels with moderately unstable conditions and predicted peak flow increases in excess of 50%, which are considered to be likely to induce a substantial channel response manifested by extensive bed and/or bank erosion over a substantial length of drainage or channel. Peak flow sensitivity is summarized by Drainage in Table 12 below.

Table12: Summary of surveyed drainages and overall assessment of sensitivity to predicted peak flow increases; see Figure 6 for locations.

Watershed	Drainage Channel	Drainage Node	Sensitivity to Peak Flow
Unnamed Tributary to Wheatfield Fork	40	40	Moderate
Unnamed Tributary to Wheatfield Fork	4	1	Low
Grasshopper Creek	70	7	Moderate
Grasshopper Creek	2	7	Moderate
Grasshopper Creek	3	7	Moderate
Grasshopper Creek	7	7	Moderate
Patchett Creek	38	37	Low
Patchett Creek	36	37	Low
Patchett Creek	35	35	Low
Patchett Creek	34	33	Moderate
Patchett Creek	33	33	Moderate
Patchett Creek	32	31	Low
Patchett Creek	31	31	Low
Patchett Creek	30	30	Low
Patchett Creek	28	30	Moderate
Patchett Creek	27	26	Moderate
Patchett Creek	26	26	Moderate
Patchett Creek	45B	45	Low
Patchett Creek	45A	45	Moderate
Patchett Creek	18	45	Moderate
Patchett Creek	17	17	Moderate
Patchett Creek	16	17	Moderate
Patchett Creek	20	20	Low
Patchett Creek	50C	50	Low
Patchett Creek	50D	50	Low
Patchett Creek	50E	50	Low
Patchett Creek	50A	50	Moderate
Patchett Creek	50B	50	Moderate
Patchett Creek	56	56	Moderate
Patchett Creek	60B	60	Low
Patchett Creek	60A	60	Moderate

The extent and degree of channel sensitivity does not represent a likely significant effect, defined as accelerated erosion processes inducing a significant increase in sediment delivery rates to Patchett Creek, particularly relating to degradation of habitat for coldwater fish. If all moderately sensitive drainages were substantially eroded throughout their individual zones of sensitivity, the resulting erosion could approach sediment yield of on the order of 100 tons over several years of winter runoff. The order of magnitude estimate is obtained as follows: 20 drainages, each eroding over a length of 500 ft over an average width of 1 ft (~60% of mean active channel width) by a depth of 0.1 ft (25% of mean active channel depth); 20 x 500 ft x 1 ft x 0.1 ft x 0.05 ton/ft^3 = 100 t. If this were to occur over a 5 year interval, this quantity of sediment (~ 20 t/yr) could

represent as much as a few percent of current erosion rates in the watershed[5]. Erosion of this magnitude could conceivably have some sedimentation impacts in reaches of Patchett Creek accessible to coldwater fish.

Given the threshold of significance as defined above, the recommended course of action would be to implement a monitoring program capable of detecting channel response to peak flow prior to potentially significant effects becoming manifest. Should monitoring reveal substantial acceleration of erosion in channels draining the project area, appropriate documentation, reporting and implementation of erosion control measures would follow.

Potential Peak Flow Change in Wheatfield Fork Gualala River

Hydrologic analyses of potential project effects have been conducted at different spatial scales, including the site (project area) scale and the watershed (impact area) scale. The foregoing analysis evaluated potential project effects on peak flows in very small drainages on the project site. It was estimated that peak flow increases in typical conversion areas could range up to about 30% for a 2-yr recurrence interval event for drainages of about 0.02 square miles. For the project area, comprising a drainage area of about two-thirds of a square mile, overall peak flow increase was estimated to be about 10% for a 2-yr recurrence interval event.

Hydrologic analyses conducted by West Yost Associates (WYA) for the Patchett Creek watershed evaluated potential project effects on off-site peak flows for the small watershed (1.76 square miles) draining the majority of the project area. WYA estimated peak flow increases resulting from the project would be as high as 5% for a 2-yr recurrence interval event and about 3% and 2% for 10-yr and 100-yr events, respectively.

Patchett Creek is a tributary of the Wheatfield Fork Gualala River, which has a drainage area of about 111 square miles. The project area occupies about 0.6% of the Wheatfield Fork watershed, and the Patchett Creek watershed contributes about 1.6% of the Wheatfield Fork watershed. Although no direct estimates of project impacts on peak flow in the Wheatfield Fork have been made, the small extent of the project area in relation to the Wheatfield Fork drainage area indicates that the likely magnitude of impact is negligible. Assuming a 5% peak flow increase in Patchett Creek, comprising 1.6% of the Wheatfield Fork watershed, and assuming that flow is proportional to drainage area, the corresponding peak flow increase in the Wheatfield Fork would be 0.08% (0.05 x 0.016 = 0.0008 or 0.08%). This potential magnitude of peak flow increase is insignificant.

Potential Downstream Impacts of Channel Erosion Hazards

In the preceding assessment of erosion potential, erosion hazards were judged to exist for channels with significant existing or potentially significant future erosion where peak

[5] See Patchett Creek estimated sediment budget in Erosion Analysis.

flows increase at least 10%. The potential magnitude of potential channel and/or bank erosion is estimated to be on the order of as much as a few percent of the estimated sediment input to the Patchett Creek watershed. A means to assess the potential significance of hypothesized channel erosion derives in large part from the Caspar Creek study (Lewis 1998), which suggested that channel erosion could be a significant component of observed increases (200% or more) in suspended sediment yield from small watersheds. Although increased sediment yield from channel erosion in the project area could potentially affect downstream aquatic habitat in Patchett Creek, the Caspar Creek study (Lewis 1998) did not demonstrate that increases in suspended sediment yield in headwater streams (CDF Class II and Class III channels) attributed to channel erosion resulted in increased suspended sediment loads in Class I channels downstream. Three monitoring stations on the mainstem of the North Fork Caspar Creek showed an increase of 2% at one station, and decreases of 2% and 17% at two other stations.

These data document that there was little or no change in suspended sediment yield in fish-bearing CDF Class I channels downstream, despite large increases in tributary channels. This can be explained by the fact that erosion rates in the headwater channels are very low, and that when those rates are increased by a factor of two or more, the absolute erosion rate remains small relative to erosion rates in the watershed and mainstem channel as a whole. The overall increase in suspended sediment yield for the North Fork Caspar Creek is attributed to a single landslide that occurred near the end of the study period (Lewis 1998), and not to increased erosion rates in headwater channels. Hence, the risk to downstream habitat and water quality implied by potential increases in channel erosion associated with anticipated peak flow increases at the project site are uncertain, but probably would not be significant. These considerations should temper assessment of the potential impacts of the project-induced erosion as well as the efficacy and cost of proposed mitigation measures.

Another consideration regarding mitigation of potential erosion from the site is that the proposed vineyard drainage collection system and reservoir will significantly reduce existing rill, gully and channel erosion. Vineyard drainage controls, particularly on the sloping pasture between the proposed reservoir and sump (Figure 4), and diversion of peak flows from existing eroding channels in the east-west flowing Class III channels south of the reservoir and sump, will substantially reduce existing erosion from the project area. Estimated peak flows in the Class III channel above the sump outfall will be reduced from about 25 cfs under pre-project conditions to about 5 cfs under post-project conditions (Table 6) because of the diversion of surface runoff to the sump and reservoir. This Class III tributary had by far the greatest incidence of existing channel and bank erosion under current, pre-project conditions. Although the diversion of runoff to the irrigation reservoir will reduce stream flow during some periods of storm runoff, this will occur only during peak flow periods where the reduced flow will be negligible downstream. The diversion of this runoff will tend to offset predicted increases in runoff from the project area.

Summary

The proposed timberland conversion project is not expected to diminish annual water yield, summer stream flows, or groundwater supplies. The most applicable research available strongly suggests that annual water yield and summer stream flows can be expected to increase owing to decreases in evapotranspiration processes associated with removal of forest vegetation. Soil and geologic conditions are such that infiltration to the water table is not expected to decrease, and is more likely to increase. Off-site groundwater supplies are unlikely to be affected because of the prevailing groundwater flow gradient toward Patchett Creek and away from existing wells. Peak flow increases are expected to occur in some ephemeral and intermittent channels draining the project area, creating limited potential for accelerated erosion; no significant increases in erosion are expected to occur. A monitoring plan should be developed to detect significant channel erosion, should it occur, and ensure that appropriate erosion control and/or mitigation is implemented to address such occurrences. The degree of potential erosion is localized, and it is unlikely that significant changes in water quality or sedimentation would occur in fish-bearing reaches of Patchett Creek located downstream. Furthermore, the project is expected to reduce existing levels of rill, gully and bank erosion in the watershed of Drainage Node 20 owing to expected reductions in peak flow runoff resulting from collection of surface runoff for storage in the proposed irrigation reservoir.

References Cited

Battany, M. C. and M. E. Grismer (2000). "Rainfall runoff and erosion in Napa Valley vineyards: effects of slope, cover and surface roughness." Hydrological Processes 14: 1289-1304.

Cafferata, P. and T. Spittler (1998). Logging impacts of the 1970's vs. the 1990's in the Caspar Creek Watershed. Proceedings of the conference on coastal watersheds: The Caspar Creek Story, Ukiah, California, USDA Forest Service.

Department of Water Resources (1975) Evaluation of ground water resources: Sonoma County. State of California, The Resources Agency, Department of Water Resources in cooperation with County of Sonoma, Bulletin No. 118-4. December, 1975.

Dietrich, W. E. (1982). "Settling velocity of natural particles." Water Resources Research 18(6): 1615-1626.

Dunne, T. and L. B. Leopold (1978). Water in Environmental Planning. New York, W.H. Freeman and Company.

Elford, R. (1964). Climate of Sonoma County.

Henry, N. (1998). Overview of the Caspar Creek Watershed Study. Proceedings of the conference on coastal watersheds: The Caspar Creek Story, Ukiah, California, USDA Forest Service.

Keppeler, E. T. (1998). The summer flow and water yield response to timber harvest, Pacific Southwest Research Station: 35-44.

Lewis, J. (1998). Evaluating the impacts of logging activities on erosion and suspended sediment transport in the Caspar Creek watershed. Proceedings of the conference on coastal watersheds: The Caspar Creek Story, Ukiah, California, USDA Forest Service.

Lisle, T. and M. Napolitano (1998). Effects of recent logging on the main channel of North Fork Caspar Creek. Proceedings of the conference on coastal watersheds: The Caspar Creek Story, Ukiah, California, USDA Forest Service.

Miller, J. F., R. H. Frederick, et al. (1973). Precipitation-frequency atlas of the western United States. Silver Spring, MD, National Weather Service, National Oceanic and Atmospheric Administration, USDC.

Miller, V. C. (1972). Soil survey, Sonoma County, California. Washington DC, USDA Forest Service and Soil Conservation Service, In cooperation with Agricultural Experiment Station, University of California: 188, 123 p. illus.

Napolitano, M. B. (1996). Sediment transport and storage in North Fork Caspar Creek, Mendocino County, California: Water years 1980-1988. Geology. Arcata, Humboldt State University: 148.

NCASI (1999). Scale considerations and the detectability of sedimentary cumulative watershed effects. Research Triangle Park, NC, National Council of the Paper Industry for Air and Stream Improvement: 327.

Pacific Watershed Associates (1994) Handbook for forest and ranch roads. Prepared for Mendocino County Resource Conservation District. 161 p.

Reid, L. M. and T. Dunne (1996). "Rapid evaluation of sediment budgets." Catena Verlag GMBH: 24.

Richards, K. (1982). Rivers: Form and Processes in Alluvial Channels. New York, Metheun.

Schmidt, K., J. Roering, et al. (2001). "Root cohesion variability and susceptibility to shallow landsliding in the Oregon Coast Range." unpublished manuscript.

Unsworth, M. H., N. Phillips, et al. (2004). "Components and controls of water flux in an old-growth Douglas-fir-Western Hemlock ecosystem." Ecosystems 7: 1-14.

Williams, L. E. (2001). Irrigation of winegrapes in California. Practical Winery & Vineyard Magazine.

Ziemer, R.R., 1981. Storm flow response to road building and partial cutting in small streams of northern California. Water Resources Research, 17: 907-917.

Ziemer, R.R. (1998a) (Technical Coordinator) Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story, USDA Forest Service Pacific Southwest Research Station, General Technical Report, PSW-GTR-168, 149 p.

Ziemer, R., J. Lewis, et al. (1998). Streamflow and sediment response to logging, California, USA. Environmental Forest Science, Kyoto, Japan.

Ziemer, R.R. (1998b) Flooding and stormflows. IN Proceedings of the Conference on Coastal Watersheds: The Caspar Creek Story, USDA Forest Service Pacific Southwest Research Station, General Technical Report, PSW-GTR-168, pp. 15-24.

Appendix A:

Re-interpretation of Effects of Timber Harvest on Erosion and Sedimentation, North Fork Caspar Creek

Pages A1-A7 following

Overview

Assessment of runoff and sediment yield changes resulting from timber harvest on small watersheds in the Coast Ranges of northern California can by guided by experimental studies at Caspar Creek [Lewis, 1998 #469]. That study measured changes in runoff and suspended sediment load in the North Fork of Caspar Creek, located in the Jackson Demonstration State Forest in coastal Mendocino County. The study documented increases in suspended sediment yields in small catchments (25 to 70 ac) of about 200%. It was hypothesized [Lewis, 1998 #469] that the source of observed increases of suspended sediment load in some tributary streams (primarily California Department of Forestry Class II channels) was channel beds and banks, and that the agent of erosion was documented increases in peak runoff rates of about 25% for small clear-cut catchments during 2-year recurrence interval rain storms (Ziemer, Lewis et al. 1998). Surface erosion was not considered a likely source of increased sediment yield. Although there are no data presented to document this hypothesized source of erosion, it appears to be the most likely erosion mechanism given the timber harvest practices in the watershed and analyses of experimental data.

The large percentage increases observed in the small tributary catchments were not observed at monitoring stations in the mainstem of North Fork Caspar Creek over the seven-year post-treatment monitoring period. It has been suggested that "…much of the sediment measured in the tributaries has been trapped behind woody debris or otherwise stored in the channels, so that much of it has not yet been measured downstream" (Lewis 1998, p.65). This hypothesis may explain the absence of a measurable downstream increase in suspended sediment yield, however, there are other plausible explanations. As discussed below, an analysis of hydraulic conditions and sediment transport mechanics reveals that suspended sediment transported through the tributary streams in North Fork Caspar Creek would not tend to be deposited in the mainstem of the North Fork. The absence of observed increases in suspended sediment yield at monitoring stations in mainstem North Fork Caspar Creek, despite large increases in tributary watersheds, may also result from the low sediment yield of the tributary watersheds relative to the larger watershed as measured at mainstem monitoring stations. The large percentage increase in tributary yield actually represents a small absolute increase in sediment yield in the watershed, and hence is not detected at the larger watershed scale.

Suspended Sediment Transport Mechanics

In gravel-bed streams such as Caspar Creek, stream energy as measured by bed shear stress is sufficiently high that the finer fraction (silt and clay; < 0.075 mm diameter) of sediment inputs are carried in suspension through the system with minimal deposition in stream channels. This fraction of sediment is sometimes referred to as the wash load (Reid and Dunne, 1996); it typically travels at a velocity equal to the water velocity.

Using grain size data for channel deposits in the mainstem of North Fork Caspar Creek (Napolitano 1996), I calculated the approximate grain diameter thresholds that separate three regimes of sediment transport: wash load (constant suspension), intermittent suspended load, and bed load (Table 1). Sediment finer than about 0.1 mm is expected to

be transported in suspension during periods of flow capable of mobilizing bed load material (these typically occur about twice or more each year). Sediment in the sand size range (about 0.1 to 1+ mm) would be transported in intermittent suspension. Coarser material would be transported as bed load. During periods of more intense flow, these grain diameter thresholds would be larger, and coarser material would be transported in suspension in the water column. Perspective on typical rates of transport for sediment of varying sizes in mountain streams based on a recent extensive literature review (NCASI 1999) is provided in Table 2.

Median surface grain diameter (d50 mm)	Threshold Bed Shear Stress (dy/)	Shear Velocity (cm/s)	Settling Velocity for Maximum Diameter Wash Load (cm/s)	Settling Velocity for Maximum Diameter Intermittent Suspended Load (cm/s)	Maximum Grain Diameter for Wash Load (mm)	Maximum Grain Diameter for Intermittent Suspended Load (mm)
11 (debris jam deposits)	84	9.1	0.91	9.1	~ 0.1	~ 1
36 (streambed deposits)	374	16.5	1.65	16.5	~ 0.1	~ 1.5

Table 1. *Summary of calculated grain size thresholds for wash load and intermittent suspended load. Threshold bed shear stress is calculated using Shield's relationship and a critical Shields stress of 0.047 and represents the shear stress necessary to entrain the bed material represented by the median surface grain diameter. Shear velocity is proportional to the square root of bed shear stress. The settling velocity is calculated using standard shape and roughness parameters (Dietrich 1982). Grain size thresholds for wash load and suspended load are a function of the ratio of settling velocity to shear velocity; the ratio is taken as 0.1 for wash load and 1.0 for intermittent suspended load, consistent with Reid and Dunne (1996). Corresponding grain diameters can be read from a curve or calculated given the shear velocity and the appropriate ratio.*

Particle Size and Stream Type	Range (km/yr)	Mean (km/yr)
Suspended sediment in mountain streams	2-20	10
Sand as the predominant bedload	0.5-5	2
Pebbles and cobbles in mountain streams	0.02-0.5	0.1

Table 2. *Typical annual velocity of sediment in streams after NCASI (1999), p. 299. The suspended sediment case is a reasonable representation of wash load the slowest washload and the fastest intermittent suspended load. The sand case is representative of slower intermittent suspended load. Pebbles and cobbles represent bedload.*

Based on the data in Tables 1 and 2, it is apparent that silt and clay inputs to Caspar Creek will be routed through the mainstem of North Fork Caspar Creek as wash load. Very little of this sediment would be deposited. This is confirmed by sediment analyses

by (Napolitano 1996), which showed that sediment finer than sand (i.e. silt and clay) was never more than 0.25% by weight of the bed material. In other words, silt and clay is selectively removed from the mainstem of North Fork Caspar Creek by normal fluvial processes.

Given the general textural description of soils in the Caspar Creek watershed (clay loam, (Henry 1998)), at minimum, 55% of the soil column would be silt and clay; it is more likely that about two-thirds of the soil column is silt and clay. Hence, at least half and probably two-thrids of the sediment inputs measured at the mouths of logged tributary sub-basins are routed through the mainstem of North Fork Caspar Creek with minimal deposition. The remaining portion of suspended sediment inputs, primarily sand, may travel more slowly. Nevertheless, even sand is easily capable of being transported through the 3 km mainstem reach of North Fork Caspar Creek during the 6-year period of experimental observations (Table 2). Moreover, there were 2 peak flows with recurrence intervals of 5 years or greater in the post-treatment period (January 20, 1993 and March 14, 1995), with recurrence intervals of 8 and 5 years respectively (Cafferata and Spittler 1998). Finally, Lisle and Napolitano (1998) assessed the effects of logging on the mainstem of North Fork Caspar Creek and reported no remarkable evidence of channel aggradation by fine sediment. Therefore, the explanation that the increased suspended sediment load from tributaries was not observed in the mainstem stations because it was deposited is very unlikely. In fact, most of the suspended sediment delivered by tributaries is easily capable of being transported through mainstem North Fork Caspar Creek in the course of the 6-year monitoring period.

Alternate Interpretation of North Fork Caspar Creek Data

There is another plausible explanation as to why the increased suspended sediment is not detected in the mainstem. Presentation of data in terms of percentage change after logging masks the actual magnitude of the increases. Considering percentage changes in tributary sediment yield alone greatly inflates the expectation of corresponding downstream increases in sediment yield because a large percentage increase in a small quantity of sediment amounts to a small quantity of sediment. This conclusion is substantiated in the discussion below.

Table 3 summarizes the North Fork Caspar Creek sediment yield data (Lewis 1998). The data require some spatial interpretation; a map of the North Fork Caspar Creek watershed is shown in Figure 1 below.

Station	Years Post Harvest	Area (ha)	Percent Harvest	Percent Change in SS	Observed SS Yield (kg/ha/yr)	Predicted SS Yield (kg/ha/yr)	Change SS Yield (kg/ha/yr)	Observed Total SS Yield (t/yr)	Pre-dicted Total SS Yield (t/yr)	Change Total SS Yield (t/yr)	Change SS Yield as % of Main-stem SS Yield
Tributary stations (drainage area < 80 ha)											
KJE	5	15	97	-40	821	1371	-550	12.3	20.6	-8.3	-13
JOH	5	55	30	-23	667	865	-198	36.7	47.6	-10.9	-17
GIB	4	20	99	**200**	358	119	239	7.2	2.4	4.8	**4**
DOL	5	77	36	**269**	1130	306	824	87.0	23.6	63.4	**33**
CAR	5	26	96	**123**	240	108	132	6.2	2.8	3.4	**2**
BAN	4	10	95	**203**	85	28	57	0.9	0.3	0.6	**0.3**
Mainstem stations (drainage area > 150 ha)											
LAN	5	156	32	5	420	400	20	65.5	62.4	3.1	2
FLY	5	217	45	-3	536	555	-19	116.3	120.4	-4.1	-2
ARF	4	384	46	-15	505	591	-86	193.9	226.9	-33.0	-17
NFC	6	473	50	89	465	246	219	219.9	116.4	103.6	n.a.

Table 3. *Data from Lewis (1998, Table 1, p. 62); the last 4 columns reflect conversion of suspended sediment (SS) yield to units of t/yr. This units conversion allows comparison of the absolute quantities of sediment yield from tributaries relative to mainstem stations. Bold face emphasizes the comparison of percentage increases in logged tributaries and percentage increases relative to the nearest downstream mainstem station. KJE and JOH are compared to LAN, GIB is compared to FLY, and DOL, CAR and BAN are compared to ARF. Mainstem stations are compared to ARF. Station EAG is not presented; its effect is represented by the downstream station (DOL) in the same tributary.*

Table 3 above shows that for three mainstem stations with greater than 150 ha drainage area (LAN, FLY and ARF), suspended sediment load *decreased* 11% on average. For station NFC at the mouth of the North Fork Caspar Creek watershed, the increase of 89% is attributed to a single landslide in 1995 immediately above the NFC station in the last year of the study (see Lewis 1998, pp. 55 & 60). Hence, the data show that there is *no increase* in suspended sediment in Class I fish-bearing channels in North Fork Caspar Creek, despite large percentage increases in tributary streams. I have previously discussed the physical aspects of sediment transport that strongly suggest that this suspended sediment, particularly the wash load, would be transported to the measurement stations and would therefore be detectable.

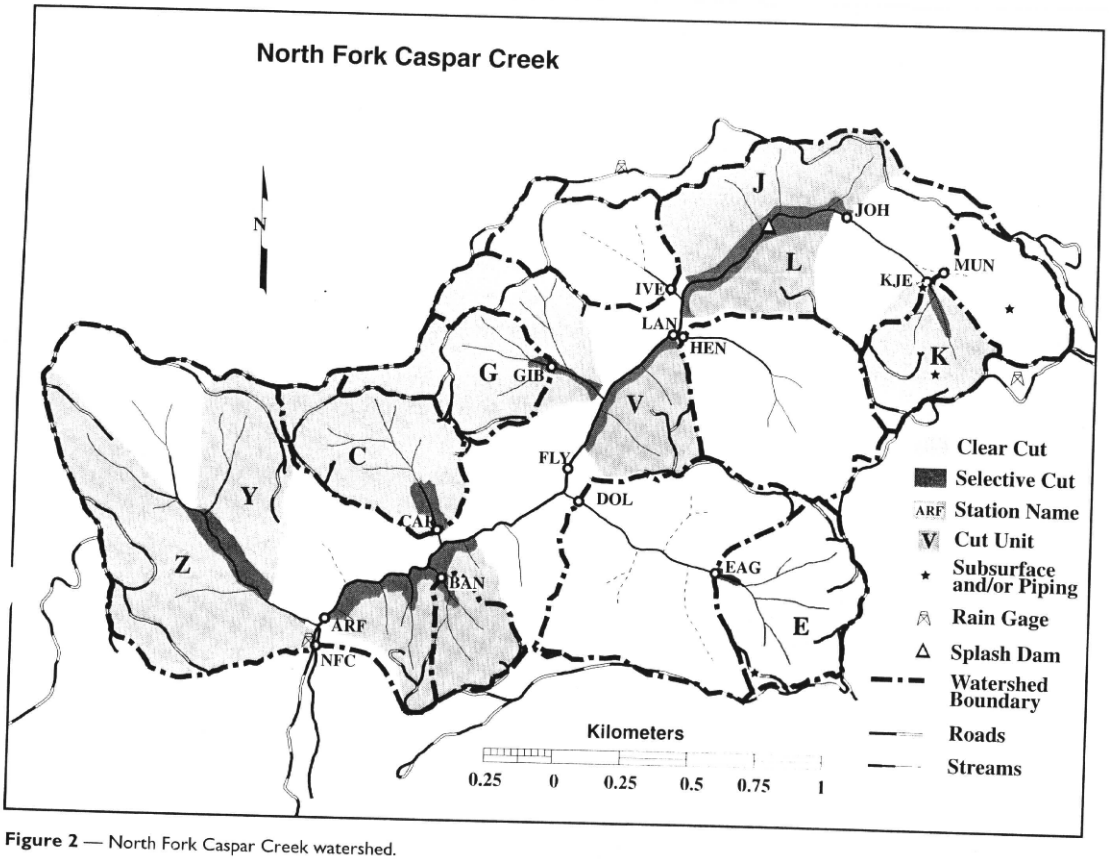


Figure 2 — North Fork Caspar Creek watershed.

iv

USDA Forest Service Gen. Tech. Rep. PSW-GTR-168. 1998.

Figure 1. *North Fork Caspar Creek watershed.*

Considerable effort was taken (Lewis 1998) to explain why station KJE showed a 40% decline in suspended sediment load (e.g. high pre-treatment sediment load due to previous logging, increased sediment deposition owing to dense regrowth of vegetation near channels and excessive blow down of trees in riparian buffer zones). However, there was little effort to explain why station DOL, which was only 1/3 clearcut, showed anomalously high increases in suspended sediment. As can be seen in Table 3 (last column), the increases in observed sediment yield in logged tributaries compared to observed sediment yield in the nearest downstream mainstem station is on average less than 2 percent. Only in the anomalous case of DOL (33% increase) do the data suggest that enough erosion was observed in a tributary watershed to potentially cause a significant increase in suspended sediment. The mainstem monitoring station downstream of DOL is ARF, where suspended sediment yield decreased 17%, suggesting no detectable effect in the mainstem reach affected by DOL. This interpretation of the data also finds no consistent evidence of significant increases in mainstem suspended sediment yields following logging.

The magnitude of downstream effects is graphically demonstrated in Figure 2 below. These data highlight the magnitude of the increase in sediment yield at DOL and at station NFC. In the latter case, the 89% increase in suspended yield is attributed to a single debris flow that entered via a tributary below station ARF, and that increase is attributed to a single year of record (1995). DOL is the only other station with an apparently significant increase. Given the relatively low proportion of harvest, it is plausible that such a large increase might *not* be attributable to hydrologically-induced channel erosion, but rather to a discrete, large scale sediment source (i.e. as for station NFC).

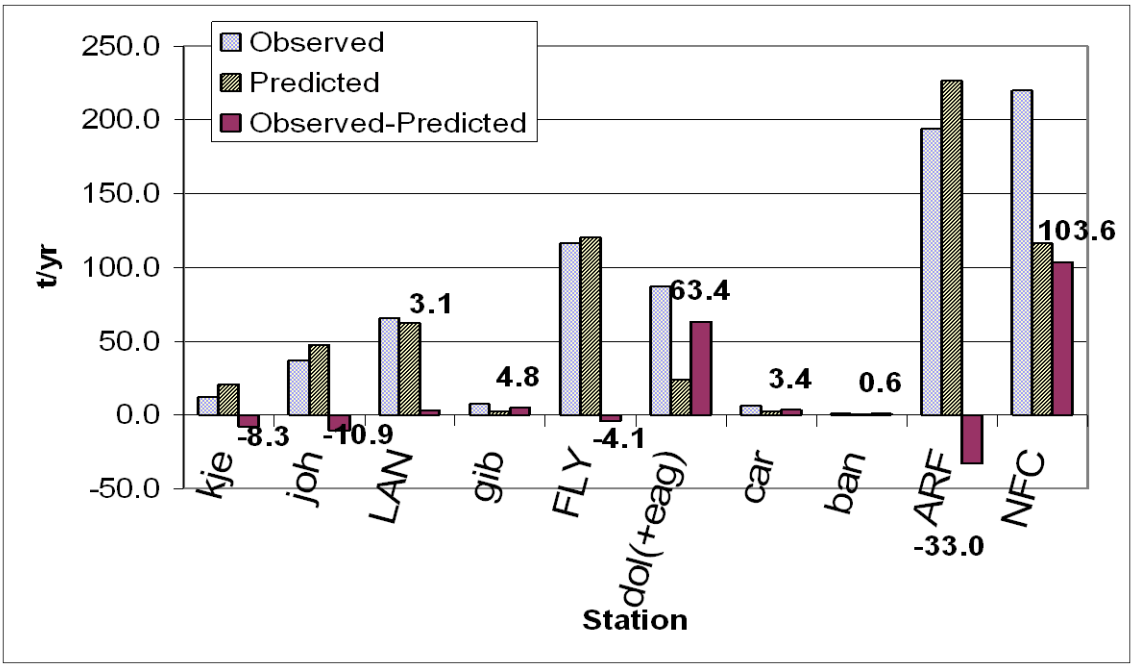


Figure 2. *Caspar Creek experimental results expressed as average annual sediment yield at each station. The values shown in the figure are the change in suspended sediment yield (observed – predicted) in units of metric tons per year following the experiment. Mainstem stations as per the classification in Table 3 are emphasized in CAPITAL letters*

Summary – Sediment Input Associated With Hydrologic Change

Based on the foregoing discussion, the experimental data from North Fork Caspar Creek demonstrating that hydrologic change attributable to timber harvest (e.g. peak flow increase of about 25% for 2-year recurrence interval storms for small drainages with nearly 100% clearcut area), do not reveal commensurate increases in suspended sediment yield in the mainstem of North Fork Caspar Creek where anadromous fish habitat is located. The large percentage increases in sediment yield from small tributaries that were clearcut may have resulted from increased channel erosion. These large percentage, small magnitude increases in sediment yield were not detected in the fish-bearing mainstem reaches either because the sediment entered into storage in the channel

network, and/or the quantity of excess sediment generated in the tributaries was small compared to the sediment yield in the mainstem, preventing its detection at monitoring stations. In either case, there is no evidence that surface erosion or fluvial erosion associated with clearcutting of about 50% of the watershed caused detectable increases in sediment yield in mainstem monitoring stations.

References Cited

(see previous References Cited)

Appendix B-Field Survey Form for Drainage and Channel Sensitivity to Peak Flow

1 page following

Site _____ Date _____

Observers_____

Start time: _____End time:_____

Distance (ft)	1) Swale-weak convergence, no channel 2) V-swale-strong convergence, no channel 3) Dry surface channel-banks evident >50% of length 4) Wetted surface channel/seep 5) Subsurface-under wood 6) Subsurface-soil pipes 7) Knickpoint 8) Road 9) Skid trail 10) Flat area 11) Landslide 12) Channel head	Sediment Transport (y or n)

Loc.	Channel				
	Width (feet)	Depth (feet)	Slope (deg.)	Sub-strate	Photo #
Ch. H.					
0					
100 ft					
200 ft					
300 ft					

Substrate: Organic litter >0.2 ft (O), Soil (S), Fluvial sediment (F), Bedrock/Boulders (B)

General Observations

Evidence of Active Erosion (Rank Top 3 if present)
Stream banks
Stream bed
Rill or Gully
Knickpoint
Erosion of fill or cut bank
Landslide Terrain with Scarp and/or Slump

Channel or Valley Erosion Resistance
Vegetation (% of total length)
Swale Axis
Grass
Shrubs
Trees

Significant elements
Stumps
Bedrock (if present)
Boulders/Cobbles
LWD (on the ground)

Effect of Roads and Skid Trails on Hydrology
Minor-only at crossing, local effect
Substantial-flow diversion of natural flow path
Additional flow-road/skid runoff increases flow
Interception of water table in cut slope

Ch Head Characteristics

Location	
Erosion of Fill or Cut	
Landslide	

Comments:

BankHT	Top width	Bank Material(Vegetated)

Appendix C-Drainage and Channel Field Data Summary

2 pages following

Explanation Of Data

All width, depth and height measurements in feet.

Substrate and Bank Materials

S	Soil
O	Organic Matter
F	Fluvial Sediment
B	Bedrock/Boulders

Presence of a particular Erosion or Stabilizing element signified with a 1; 0 means not present.

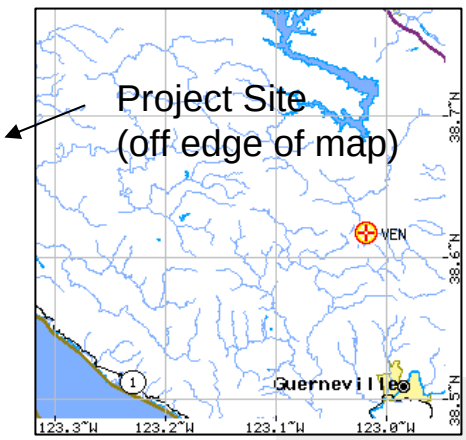
Rank of a Particular Erosion or Stabilizing element is 1, 2, or 3. 1 being most abundant, 3 the least.
Rank only given if more than one element is present and a significant difference in abundance is clear.

Axis % is the percentage of the entire surveyed drainage in which the specified vegetation is present.

UID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Site	30	50E	16	17	18	45A	45B	26	27	28	50D	7	56	50C	60B	60A	50A	50B	3	2	70	4	36	38	40	35	34	33	32	31
Group	A	B	B	B	A	A	B	C	C	A	B	A	B	A	A	A	C	B	B	A	A	A	C	C	A	A	A	A	A	A
Basin #	30		16	17	18	45		26	27	28		7	56			60	50	50	3	2		4	36	39	40	35	34	33	32	31
Node	30	50	17	17	45	45	45	26	26	30	50	7	56	50	60	60	50	50	7	7	7	1	37	37	40	35	33	33	31	31
Date	1/12/2007	1/11/2007	1/12/2007	1/12/2007	1/12/2007	1/12/2007	1/12/2007	1/11/2007	1/11/2007	1/11/2007	1/24/2007	1/23/2007	1/24/2007	1/24/2007	1/24/2007	1/24/2007	1/24/2007	1/24/2007	1/23/2007	1/23/2007	1/23/2007	1/23/2007	1/23/2007	1/23/2007	1/23/2007	1/22/2007	1/22/2007	1/22/2007	1/22/2007	1/22/2007
Ch. H W	1.5			1		1.5	1.25			2		1.5	0.25	1	0.5		1		1	0.75	1.5	1			1		1.5	0.5		1
CH. H D	0.25			0.25		0.5	0.25			0.25		0.33	0.5	0.5	0.2		0.25		0.25	0.25	0.33	0.5			0.5		0.1	0.2		0.2
CH. H S	5			10		5	13			20		10	20	10	13		6		40	35	20	10	10		20		25	30		10
CH. H Sub	S			O		O	S			S/F		s	s	s	s		s		s	s	s	s	s		s		s	s		s
CH Head Location	TOP	TRIB	TRIB	57	TRIB	128	TOP			160	Culvert	top	top	40	80		top		102	top	top	834	Culvert		top		173	top		top
W0	1.5										2	1.5	0.25				1			0.75	1.5				1			0.5	0.75	1
D0	0.25										0.33	0.33	0.2				0.25			0.25	0.33				0.5			0.2	0.33	0.2
S0	5	26	11	9	26	9		9	14	15	12	10	20	12	13	22	6	25	35	35	20	5	10	8	20	26	25	30	13	10
Sub0	S	B/S	O	O	O	S		S	S	S	S	s	s	s	s	s	s	s	o	s	s	s	s	s	s	s	s	s	s	s
BkHt0		5																							1.75					
TW0		20																							2					
BkMtl0		S/B																							S/B					
W100	2.5						1.25				2			0.75	2	4	2			0.75	2.5		1.5	1.5	1.5			1.5	4	3
D100	0.33						0.3				2			0.5	0.2	0.2	1			0.5	0.33		0.5	0.5	0.5			0.33	0.2	0.33
S100	3	33	20	18	28	5	10	16	13	22	14	8	11	12	10	16	15	35	40	32	23	5	22	20	25	38	28	35	10	14
Sub100	S	O	O	O	O	S	S/F	S	S	S	S	S	s	s	s/f	s	b	s	s	s	s	s	s	s	s	s	s	s	s	s
BkHt100																	3			2	1		1	1.5	3			3		
TW100																	3			1.75	3		3	2.5	6			5		
BkMtl100																	s			s	s		s	s	s			s		
W200	4	8	2			1.5	2.25			5	2	2.5	1	2	1.5	3	3		1	2	2		1.5	1.5	1.5		2	2	2	8
D200	0.6	3	0.75			0.5	0.3			0.5	0.2	1	0.25	1	0.33	0.5	0.5		0.33	0.2	0.25		0.5	0.75	0.5		0.2	1	0.4	0.33
S200	8	12	13	18	10	10	6	7	10	20	5	8	25	10	11	8	25	45	45	25	25	3	26	16	25	55	25	60	10	16
Sub200	S/F	B	B	O	O	S/O	F/S	S	S	S	S	F/B	s	s	s	s	b/f	f	b	s	s	s	s	s	s	s	s	b	s	s/f
BkHt200	3	12	2			2				0.5		2			2.5		4						5	1.5	2			5	4	
TW200	6	25	2.5			2.5				7		3.5			9		5						8	2.5	4			8	10	
BkMtl200	S	B	S			S				S		S			s		s/b						s	s	s			s	s	
W300	4		2.5	2.5	1.75		1.5			2	3	1.5	2	3	3	2	3	3	0.75	1.5	1.25		2		1	2	3	1.5	1.5	4
D300	0.33		0.5	0.25	0.66		0.2			0.33	0.5	0.5	0.5	1	0.25	0.2	1.5	0.5	0.25	0.2	0.2		1		0.5	1.25	0.2	0.5	0.66	0.25
S300	2		6	15	16	15	13	7	15	18	5	15	5	15	10	15	22	20	40	30	30	5	33		15	38	28	22	15	15
Sub300	S/F		B	O/F	F/B	S	S	S	S	S	S	F/B	s	s	s	s	f	b/f	b/f	s/b	s	s	s		s	s	s	s	s	s
BkHt300	1		2.5	3	2					0.25		2			2	2	6						2.5		1			3		
TW300	7		4	9	4					3		3.5			10	3.5	5						3		2			4		
BkMtl300	S		S	S	S					S		s			s	s	s						s		s			s		
Total length surveyed	520	200	300	480	300	605	800	300	300	500	300	550	700	1100	300	500	400	415	279	469	458	1400	305	264	550	500	375	500	950	666
length channel	520	70	105	383	165	445	800	0	0	340	300	550	580	1100	220	400	400	215	177	469	458	566	305	149	550	200	202	500	950	666
% channelized	100%	35%	35%	80%	55%	74%	100%	0%	0%	68%	100%	100%	83%	100%	73%	80%	100%	52%	63%	100%	100%	40%	100%	56%	100%	40%	54%	100%	100%	100%
Spring/ Seep	1	0	0	1	1	0	1	0	0	1	1	1	1	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	1	1
Banks	1	0	0	1	0	0	0	0	0	1	0	1	1	0	0	1	1	1	0	1	1	0	0	0	0	0	0	1	1	0
Rank Banks	2									2		2	2			1	1			1	1							1	2	
Bed	1	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	1	0	1	0	1	0	0	1	1	1
Rank Bed	3						3					3									3		3		1			3	3	2
Rill/Gully	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	0	0
Rank Rill/Gully																							1	1						
Knickpoint	1	0	0	1	1	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	1	0	1	0	1	0	0	1	1	1
Rank Knickpt.	1				1		1			1		1	1			2	3	3	1	2	2				2			2	1	1
Erosion of Fill or cut bank	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0
Rank Erosion F/CB					2		2										2	2		3			1							
Landslide Terrain W/ scarp and or slump	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Rank Landslide terrain																														
Stumps	1	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	0	1	1	1	1	1	1
Bedrock	1	1	1	1	0	1	1	0	0	1	0	0	0	0	1	1	1	1	1	0	1	0	1	0	0	0	1	1	1	1
Boulders	0	1	0	1	0	0	1	0	0	1	0	1	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0
Cobbles	0	1	1	1	0	0	1	0	0	1	0	1	1	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0
LWD	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1
Minor/local effect	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0	1	1	0	0	0	0	0	1	1	0	0	0
Flow diversion	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	0	0	0	0
Additional flow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	1	0	0	0	0	0	0
Water table intercepted	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Axis grass %											10	15		10								20								
Axis shrubs %				5		10				5	5		5	15			5	5	5	15		15	10		40		20		20	5
Axis trees %	5			5	5					10			5		10	10	5	5		3	10					10	5		10	15

Channel Sensitivity to Peak Flow Increases

Drainage 30, 1/22/2002

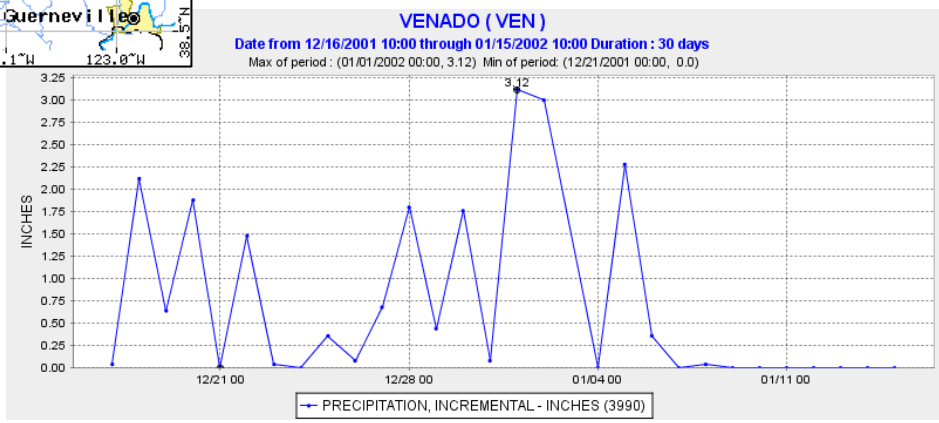


Channel Assessment (from p.46 of Hydrologic Assessment)

- The active channel is well developed with moss growing on much of the soil substrate.
- Evidence of active erosion observed includes soil steps and stream bed and bank erosion.
- Continuous, well developed channel starting near the vineyard boundary with a gentle slope and cohesive soil substrate, along with the relatively low predicted peak flow increase, Drainage 30 has low sensitivity to increased peak flows.

Post Storm Channel Observations

- Prior field observations of channel conditions after storm event (photo); note moss cover on channel bed which demonstrates bed stability; active erosion limited to soil step in foreground.
- Rainfall records from State gage at Venado (graph and map below) document approximately 20 inches of rainfall in month before photo, and over 6 inches in 48 hours January 2 & 3, 2002.
- Observed conditions after approximate 2 yr recurrence interval flood event in Russian River.



Low Sensitivity to Peak Flow
Drainage 4

100 ft from top

300 ft from top

- The drainage is a relatively broad valley comprised of an entirely soil substrate with a gentle mean slope of 6% and no continuous channel for the first 834 ft.
- Evidence of active erosion present during the field survey includes minor stream bed erosion. Additional flow is received from rills along a skid/ATV road parallel to the drainage along the right (northern) bank.
- Stabilizing elements observed in the drainage were stumps and multiple pieces of large woody debris. Grass and shrubs are the dominant vegetation present in the axis of Drainage 4.
- The grass is concentrated in the upper 300 ft and makes up 20% of the survey and shrubs cover 15% of the axis.
- Potential peak flow increase is 13% for Drainage Node 1. Proposed vineyard runoff is largely dispersed around field perimeters and would reach natural channels via forested flow paths that would tend to attenuate runoff increases.
- Considering the drainage's gentle slope, wide valley bottom, existing vegetation and stabilizing elements, and the modest potential for peak flow increase, <u>Drainage 4 has low sensitivity to peak flow increase</u>.

Low Sensitivity to Peak Flow
Drainage 31

100 ft from top-woody debris influence

666 ft from top-transition to bedrock channel

- The channel begins with a soil substrate, gently sloping 10% near the channel head and, following some steeper sections. At 666 ft the channel drops off steeply over a bedrock cascade (slope 45%)).
- The mean active channel dimensions for the top 300 ft of the survey are 3.4 ft wide by 0.3 ft deep; the cross section is about 40% larger than the overall average of all drainages surveyed.
- Evidence of active erosion present during the field survey includes minor stream bed erosion and multiple steps in the channel bed.
- Stabilizing elements observed in the drainage were stumps, bedrock and multiple pieces of large woody debris.
- At 435 ft, the channel substrate becomes continuous bedrock.
- The peak flow increase in this drainage is 8%.
- Considering the small potential peak flow increase, this <u>drainage has low sensitivity</u> to erosion because the channel is well developed starting near the edge of the proposed vineyard boundary, the slope is relatively shallow, natural flow resistance elements are relatively common, and the substrate becomes continuous bedrock. In addition, proposed vineyard runoff is largely dispersed around field perimeters and would reach natural channels via forested flow paths that would tend to attenuate runoff increases. Proposed wetland mitigation areas adjacent to the north would also be expected to increase runoff detention storage, tending to diminish the magnitude of peak flow increase.

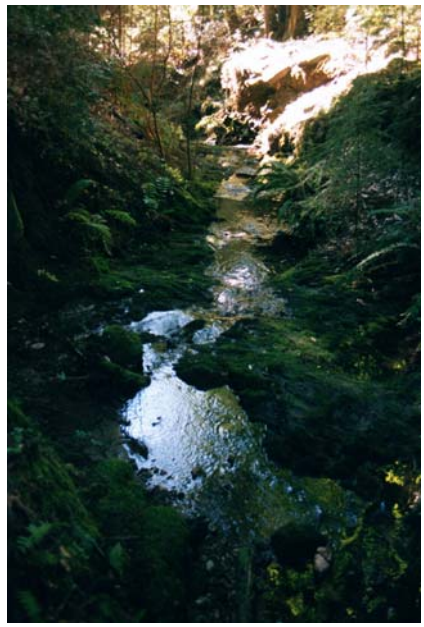
Drainage 20-
Channel Conditions
at Proposed Reservoir Sump
Overflow Discharge Point

- Boulder and weathered bedrock valley floor near Drainage Node 20
- Materials resistant to erosion
- Minimal channel stored sediment available for transport

- Valley width will accommodate flow increase with relatively little increase in flow depth
- Photos from January 2002

Patchett Creek on Project Site
Between Watershed Nodes N20 and N50

Boulder and bedrock
channel substrate



Bedrock substrate

Bedrock substrate

Bedrock substrate

Moderate Sensitivity to Peak Flow
Drainage 3

100 ft below top

200 ft below top

- The channel head is located 102 ft downstream of the top of the survey forming in the fill slope of an old road. The channel is neither well defined nor continuous through its length and has soil substrate only near the top.
- The mean slope of the drainage is 40%, much steeper than the overall mean slope of all surveyed drainages. The mean active channel dimensions of the sections present along the survey are 0.9 ft wide by 0.3 ft deep, the cross section is about one-third the size of the overall average cross section of all drainages surveyed.
- Evidence of active erosion observed is limited to fill slope erosion of an old skid road and rills along a skid road crossed by the drainage.
- Stabilizing elements observed in the drainage were bedrock, boulders, cobbles, and pieces of large woody debris. Shrubs occupy 5% of the surveyed drainage axis.
- Potential peak flow increase is about 16%. Given channel conditions (an intermittent, poorly developed channel on a relatively steep slope and both fluvial and bedrock substrate in the lower portions of the drainage), and moderate predicted peak flow increase, <u>Drainage 3 has moderate sensitivity to peak flow increase</u>.

Moderate Sensitivity to Peak Flow Drainage 33

200 ft from top

400 ft from top

- The drainage begins as a strongly convergent V-shaped swale with a dry surface channel.
- The active channel has a soil substrate and its mean dimensions are 1.2 ft wide by 0.4 ft deep which is 40% smaller than the overall average cross sectional area of all drainages surveyed.
- Evidence of active erosion observed includes stream bed and bank erosion, and soil steps.
- Stabilizing elements observed during the survey were a bedrock cascade at 200 ft, stumps and multiple pieces of large woody debris. Although bedrock is present, it does not become the continuous substrate in the surveyed channel.
- Predicted peak flow increase is 16%.
- Given the existing conditions observed (a predominantly soil-bedded channel, numerous active erosion sites, including debris slide deposits, and a relatively steep slope), Drainage 33 has moderate sensitivity to increased peak flow.

Moderate Sensitivity to Peak Flow
Drainage 40

200 ft from top

550 ft from top

- The drainage has a relatively broad valley bottom comprised primarily of soil substrate with a mean slope of 21%. The active channel is continuous and its mean dimensions are 1.2 ft wide by 0.5 ft deep which is a cross section 25% smaller than the overall average of all drainages surveyed.
- Evidence of active erosion observed includes minor stream bed erosion and soil steps.
- Stabilizing elements observed in the drainage were stumps and multiple pieces of large woody debris.
- Shrubs are the dominant vegetation present in the axis of the drainage taking up 40% of the length of the surveyed channel axis.
- Potential peak flow increase is 22%. About half of the proposed vineyard runoff is dispersed around field perimeters and would reach natural channels via forested flow paths that would tend to attenuate and disperse runoff increases.
- Vegetation and woody debris is widely distributed in the channel tend to resist significant erosion, and moderate slope and relatively wide valley floor reduce the potential for erosion. Given the existing soil substrate, <u>Drainage 40 has moderate sensitivity to potential peak flow increases</u>.

Moderate Sensitivity to Peak Flow
Drainage 45A

200 ft from top

300 ft from top

- The channel is not well developed for the upper 300ft of the survey and is intermittent in sections.
- The active channel substrate varies between soil and organic litter.
- Evidence of active erosion is limited to erosion of the fill slope of a road the drainage crosses.
- Stabilizing elements observed during the survey were bedrock and multiple pieces of large woody debris.
- At 500 ft the substrate becomes continuous bedrock.
- Peak flow increases are not expected at Drainage Node 45, however, peak flow increases in Drainage 45A might be 25 to 30%.
- Given the existing conditions observed (gently sloping, unchanneled swale near the vineyard boundary, a poorly developed channel when present, with soil and organic litter substrate for the top 500 ft), <u>Drainage 45A has moderate sensitivity to peak flow increase</u>.

Mitigation by Control of Gully Erosion Processes

Examples of Active Erosion Processes Expected to be Reduced

Actively eroding gully, mitigation site in Drainage 50

Conifer (~25 years old) growing from tipped stump at upper end of gully provides minimum date estimate for gully origin in Drainage 50

Mitigation by Control of Gully Erosion Processes

Examples of Active Erosion Processes Expected to be Reduced

Actively eroding gully wall,
THP Mitigation site C2

Actively eroding rill,
THP Mitigation site C1

Actively eroding rill,
THP Mitigation site C1

Mitigation Site Drainage 1-
Rill in trail leading to channel

Mitigation by Reduction in Peak Flow

Examples of active erosion processes observed in Drainage 20 after January 2002 peak flow event. Peak runoff to this portion of Drainage 20 is expected to be reduced by runoff collection for irrigation storage.

Incision and bank erosion

Scour and channel erosion

Incipient rill erosion

Channel and bank erosion

Mitigation expected to reduce estimated erosion rate by 75%; equivalent to 1.7 t/yr