WATERSHED SYSTEMS

NAPA VALLEY HILLSIDE VINEYARDS

CUMULATIVE EFFECTS OF CONVERSION OF UPLAND WOODLANDS AND CHAPARRAL TO VINEYARDS

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EVALUATION OF CURRENT NAPA COUNTY REGULATIONS

CUMULATIVE EFFECTS OF UPLAND VINEYARD CONVERSIONS

PROBLEM STATEMENT

Misapplication of fundamental principles of soil science and hydrology has lead to a dangerous loss of upland infiltration capacity in the upland areas of Napa Valley that were formerly oak woodlands, chaparral and mixed conifer woodlands. Continued approval of conversions of native vegetation and undisturbed natural soil units to vineyards will likely lead to increases in downstream flood hazards and sediment yields. The sediments that accumulate in channels of the Napa River and its primary tributaries are not all derived from vineyards themselves, but also from channel erosion associated with increased runoff associated with hillside development. I have been asked to evaluate Erosion Control Plans for conversion to vineyards that have already been approved by the Napa County Planning Department pursuant to the Napa County Hillside Ordinance. These are also known as Conservation Regulations at Napa County Code Chapter 18, Section 108.

The approach of the Napa County ordinances is fundamentally incorrect and cannot protect either public health and safety or long-term land productivity. The existing ordinances seem to assume that by attempting to capture sediments from upland vineyard conversion areas; downstream cumulative effects are reduced to insignificance. This is not correct. Increased upland sediment yields, while important, are less hazardous to Napa Valley than are the changes in runoff timing, volumes, and rates. Increased runoff does have cumulative downstream effects through changes in rates of runoff and frequency of runoff events of a given magnitude. These changes are likely to be a significant factor in changing sediment loads in the main Napa River through changes in stability of side its tributaries.

The application of erosion control principles as a potential mitigation for all downstream cumulative effects of runoff change is misguided. Effects of vineyard conversion on hillside sediment yield and water runoff are largely independent of each other. It is probable that well-intentioned evaluation of the effects of potential hillside vineyard conversions without testing and monitoring of actual practices will result in incorrect hypotheses about how conversion of natural lands to tilled vineyards will behave. There can be no land management without land monitoring. The underlying principles that seem to guide the current Napa County Ordinance are not applicable and appropriate for evaluating the actual hydrologic effects of upland conversion to vineyards in the Napa area on slopes or hilltops.

Critical to proper cumulative effects evaluation is an understanding of the infiltration capacity of a site before and after vineyard conversion. Use of generalized regional soil characteristics to predict effects of conversion is shown to yield an incorrect model of the actual changes that occur during the preparation and planting of vineyards. Models of soil response that are derived from observations by the US Department of Agriculture for agricultural lands do not accommodate either the actual soil characteristics of Napa area uplands or the deep tilling and local stone removal that accompanies modern vineyard planting or replanting. These models derived from the Modified Universal Soil Loss Equation (MUSLE) are what the consultants for the conversion plans used as the bases of their analyses.

Routine application of the MUSLE without accommodation of the unique Napa Valley soil characteristics that give rise to the inherent extremely valuable substrate for wine grape production, leads to errors that are now being multiplied throughout the Napa appellations. For example, the simple error that assumes, based on agricultural soil loss principles, that the steeper the slope, the greater the risk of soil losses and increased runoff, is fundamentally false for the eastern side of the Napa Valley uplands and for parts of the western side. In fact, slopes less than 30 percent have higher sediment and water yields than do those of greater than 30 percent, simply because the less steep slopes retain the clay-rich volcanic soils that are simultaneously more valuable for premium grape production and are more susceptible to decreased infiltration capacity when disturbed and are therefore more hazardous for conversion.

FIELD INVESTIGATIONS

During 1999 three vineyard conversion sites were visited for close inspection of field hydrologic and erosion control conditions. These sites were those for which erosion control plans had been developed and approved by Napa County. Added erosion control plans submitted and approved in the spring and summer of 2000 were reviewed and those sites were reviewed on aerial photos and overflights. Two overflights of the whole of the Napa Valley new vineyard conversion areas were made specifically to evaluate the magnitude of the conversion efforts and the characteristics of the sites being converted, to establish the representativeness of the sites and conditions of more detailed on-the-ground investigations.

Field investigations of hillside vineyard conversions were made on December 29, 1999 at Pahlmeyer Vineyards west-sloping and ridgetop development sites that were cleared and prepared for planting in 1999. This site is tributary to Milliken Reservoir and upper Milliken Creek, and was considered as representative of east-side headwater vineyard conversion conditions in oak woodland and mixed chaparral on Sonoma Volcanic series soils. Based on subsequent overflights (of early 2000 and 8/10/00), this site is believed to be representative of soil-hydrologic conditions on over 50% of the new Napa Valley upland vineyard sites. Chateau Potelle in the Mt. Veeder area on the west side was also inspected at sites already converted, at sites to be converted, and at sites of prior vineyards in the process of redevelopment. The Ch. Potelle conditions of mixed oak-madrone and conifer woodlands on rhyolite tuff parent materials may represent about 30 percent of the conversion sites of the last 5 years. Vineyard Properties West on and near the Hopper Creek headwaters were field inspected as a site that represents a mixed Franciscan metamorphic and volcanic parent material site in the west central fault zone portion of Napa Valley that had gone undeveloped for vineyards because of long-recognized poor quality grape production conditions but is now being developed in small parcels on steeper lands by persons for whom grape quality may be less important than appellation. This substrate characteristic includes landslides, erodable soils, and mixed hardwood and conifer native vegetation, and probably represents less than 15% of new vineyard development sites. Other new vineyard development in the southern part of Napa Valley and the Carneros area in oak grassland lower-gradient sites represent 10 percent or less of new hillside vineyards. These southern sites were reviewed from the air and through their erosion control plans and published soil maps but not with on-site soil investigations. The general findings and conclusions of this present report do not include opinions about low-gradient southern Napa County oak-grassland sites.

Additional field investigations were conducted in 1999 along the Napa River and its tributaries to inspect channel conditions, status of erosion and deposition, bank stability, present and past gauging sites, and stream substrate conditions. These investigations extended from the Napa/Lake County Line (Montesol Ranch) to the City of Napa and included observation of soil characteristics, evidence of gullying or rilling that would indicate need for erosion control on uplands, and evidences for increases in runoff in minor ephemeral channels. Soil drainage characteristics in Napa Valley floor alluvial soils were not inspected for this study effort but this author is familiar with them based on past work for established vineyards.

FINDINGS OF FIELD INVESTIGATIONS

Basic findings of field work were clear and rather straightforward. Vineyard development on uplands where natural vegetation is removed and where Napa County Erosion Control ordinance conditions are followed and approved by the County markedly decrease the capacity of the soil and the watersheds to absorb and retain rainfall. This is precisely the opposite of the predictions of the Napa NRCS/RCD upon which the Erosion Control Ordinance was justified[1].

Field investigations in December, 1999, showed that undisturbed soils under native vegetation, even where fire-maintained, had very much greater porosity and infiltration capacity than did the same sites after conversion to vineyards. Vineyard conversion does not emulate agricultural field conditions for which soil management models are developed. In all sites inspected in the Napa region, it was found that the deep raking and tilling of modern mechanized vineyard preparation brought high-clay-content subsoils to the surface, stripped off the protective and beneficial near-surface stone layers, and destroyed the one-to-three foot porous and permeable surface soil structure.

Napa County soil mapping was conducted from 1965 through 1973 and represents conditions as they existed in 1974[2]. The upland areas were at that time classed as rangelands and used for range, wildlife and recreation. The mapping scale and accuracy was appropriate for that land use, but not for later conversion to vineyards or other uses. In general, stone content was not originally delimited in the upland mapping units. For the Pahlmeyer site, the old maps show the Forward gravelly-loam as the primary soil unit which is defined as loamy soils developed on volcanic rocks (see Appendix A - Soil Descriptions).

Stone content is critical to soil hydrology. The loam and especially the clay-loam sites have soils that contract in the summer as they dry out. The stones in the soil profile do not contract, so a void space is left around each rock. Grass roots and percolating water need those spaces to move into when it starts to rain in the fall. As the soils become saturated they expand but the previous season's grass and shrub roots continue to provide avenues for infiltration of rainfall. Thus, the infiltration capacity of rocky expansive clay-rich soils is much greater than that of a simple clay-rich soil. Where stones remain throughout the soil profile, rainfall is carried down through the soil into cracks in the bedrock and it recharges the groundwater.. Where stones are absent on sloping clay-rich soils, rainfall runs off over the soil surface and removes the soil over geologic time. Where stones are removed, slopes will rill and gullies will form to remove that soil and expose bedrock to direct infiltration. It is a very simply balance and all natural slopes in Napa County are adjusted to the steepness and infiltration capacity necessary to accommodate the natural rainfall that has occurred historically. You cannot change the slope hydrologic characteristics without simultaneously changing the rainfall. Such change is not possible.

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[1] A theoretical modeling study was conducted by the USDS-NRCS Napa Field Office and the County RCD in 1998-99, comparing east and west side development based on agricultural soil management concepts and models: Haas, Julie, January 2000, *Napa River Watershed Hillside Development Runoff and Erosion Study*, Napa RCD.

[2] Lambert, G, J. Kashiwagi, B. Hansen, P. Gale and A, Endo, 1978, Soil Survey of Napa County: USDA Soil Conservation Service and UC Ag. Experiment Station. Published on-line at http://www.ca.nrcs.usda.gov/mira/NapaSS/main.html.

By comparing the development of rills on newly exposed vineyards, the yield of sediment to the small catchments required under the Ordinance, and the runoff volumes associated with fall, 1999, small storms as evidenced by overflow of the sediment catchment basins, we were able to estimate the downstream offsite effects of conversion of hillside sites to vineyards. Although some allowance must be made for the "maturing" of new vineyards through time and the reestablishment of vertical permeability through no-till management of cover erosion-control crops, the real long-term damage is done through the deep tilling. The hourly precipitation record from Atlas Peak was used for this field analysis.

Hundreds of thousands of years of slow downward movement of clay particles derived from volcanic ash inputs to all the Napa Valley hillside soils, as well as from the varied parent soil materials, is undone in a few days of modern site preparation for vineyards. Those segregated clays are brought again to the surface and mixed in the soil column, creating a substrate for planting that is only able to absorb 10 to 50 percent of the normal and usual seasonal rainfall peak events. To add insult to injury, the larger stones and small boulders that have, over hundreds of millennia, accumulated as a lag deposit near the surface through several geologic processes, including ground freezing during 10's of thousands of years of much colder weather in past geologic time, and that now serve to create seasonal voids and surface protection, are often deliberately removed from the soil in the mistaken belief that they may impair fertility or management options for vineyards. In clay-rich parts of southern France these stones are deliberately worked into the soil to prepare new sustainable vineyards, while here we deliberately reduce tilth and soil moisture holding capacity and increase soil erodibility by removing them.

By comparing the observed reductions in soil moisture holding capacity and capacity to allow water infiltration with the actual historical record of precipitation in and around the Napa Valley, it is a straightforward and simple exercise to determine how hillside vineyard conversion will affect runoff. Determining how that increased runoff will erode and transport soil is somewhat more complicated and is the focus of erosion control plans, but by observing and monitoring the existing Napa County upland conversion sites, theoretical erosion models can be calibrated and the volumes of sediment to be derived from the vineyards themselves can be determined. Monitoring is not difficult. Maintaining and removing sediment from the small sediment basins required under the County Ordinance is a necessary part of vineyard management. It is but one more step to calculate the volume of that sediment and not too much more difficult to determine the overflow of runoff from those basins to calculate increased water yield. Again, one cannot manage without monitoring.

The increased runoff volumes themselves can be expected to erode banks and beds of tributary channels and to entrain in-channel sediment that will then be deposited in the lower-gradient reaches of those tributaries or in the main-stem of the Napa River. This we see happening in some sites, such as lower Hopper Creek below and within Vineyard Properties West. Construction of reservoirs may have counteracted or slowed this cumulative downstream offsite effect, but if and when those sediment traps fill, we will again see a reversal of channel stability. Below new on-channel tributary reservoirs today, we see channel erosion and net downstream cumulative hydrologic effects. Reservoirs trap coarse sediment that is needed by the tributaries to maintain their erosional energy balance. By trapping course sediment, we increase bank and bed erosion downstream. Fine sediments carried from tributaries below vineyard conversion sites may be ultimately sluiced through the Napa River to be deposited in the tidal marsh. But those sediments reduce spawning gravel function and rearing habitat as they pass to San Francisco Bay. And once they get into the tidal marshlands, they decrease the ability of those sites to transport water and sediment and thus increase backwater effects in the lower River, possibly increasing flooding in Napa. While we cannot pick up a handful of sand and silt from the Napa River bed today and establish where it came from, we can note that today's steelhead populations are but 20% of those of the 1950's and 1960's and that such declines can be explained by observed reduction in spawning and rearing habitats.

NAPA SOIL CHARACTERISTCS - EAST VS WEST SIDE

Eastside upland soils derived from both volcanic parent materials and from more recent additions of volcanic ash were found to be those with the greatest changes accompanying conversion to vineyards. Our field investigations showed that soils under chaparral or mixed oak and chaparral were able to absorb on the order of 12 inches of intense short-period precipitation without generating overland flow. Stony subsoils can allow percolation of that accumulated 12 inches of precipitation in a week or less so that natural upland areas can accommodate even the extreme precipitation events recorded in the Napa area, including several 12-inch rainy periods in a single season. This determination is based on surface and subsurface soil characteristics in the sites of native vegetation, and on the evidences or lack thereof for rill, gully, and sheetwash erosion. Soil types were mapped on the old maps as Forward gravelly loam and Bressa-Dibble complex.

This means that surface runoff is minimized under natural soil and vegetation conditions and that the geomorphic development of a drainage network does not need to accommodate frequent surface runoff by developing a denser headwater tributary network. Because broad areas are able to absorb all the precipitation that falls in almost all years, groundwater is recharged readily into fractured permeable volcanic rocks, water tables are not perched, and springs and seeps will flow in lower canyons through dry periods as well as wet. The primary upland drainage network is probably developed after major fire followed by El Niño type winters when temporarily hydrophobic soils reduce infiltration and increase the ratio of runoff to rainfall.

A particular characteristic of many eastside soils is that the *less* steep the slope, the higher the clay content, and the greater the post-conversion erosion hazard under contemporary conversion techniques. Slopes over 30 to 40 percent have largely been stripped of their residual clay-rich soils, or they may never have developed there. Such sites are characterized by exposed surface bedrock and residual stones with moderately high infiltration capacity and little soil moisture holding capacity. The Napa County Erosion Control Ordinance requires assessment and mitigation on sites that are less erodable while ignoring those that are more erodable. This reversal of standard theory is not seen on the west-side watersheds.

Eastside soils with higher silt-clay subsoils were observed to loose 60 to 70 percent of their capacity to absorb regularly occurring intense rainfall after initial conversion to vineyard. What this means practically is that an east-side site that could absorb the maximum-intensity cumulative 1-week rainfall that might occur only once every hundred years or longer, will now become saturated and generate runoff every average year. This means, roughly, that surface erosion may occur 100 times more frequently.

As the following figure (1) illustrates, there is a 10 percent chance that a rainfall of 1-inch will fall in any given day in late January of any year along the east side of Napa Valley. There is almost a 5% chance that a 2-inch daily rainfall will fall in any given winter day, but there is virtually no chance (less than 1 percent) that an 8-inch daily rainfall will occur. The natural shape of hillsides in Napa Valley and the drainage networks that develop naturally to drain them, are delicately adjusted to the natural characteristics of rainfall and runoff that occur under native vegetation on native soils. When these are changed, the slope equilibrium, or fluvial geomorphology of the hillsides must change to respond to the new conditions. We found that natural slopes of less than 30 percent gradient could accommodate an initial 6 to 8 inches of daily rainfall without surface saturation and runoff while those converted to vineyard immediately adjacent on the Pahlmeyer site generated runoff, silting, and completely filled and overflowed the County-required detention ponds with the first 1 to 2 inches of fall rainfall in 1999[3].

Looked at another way, Figure 2 shows the extreme values recorded historically through the year and the average daily values for two Napa Valley long-term climate stations. Daily precipitation that exceeds 6 inches (the minimal capacity of natural ridge-top soils) is very rare, but those that exceed One and one-half to 2 inches (the capacity of the converted lands) are very common. At both Calistoga and Angwin there have been an average of 13 days per year with precipitation greater than 1 inch in the 52-years of records since 1948. At Calistoga there was one day only (2/17/86) with precipitation greater than 6 inches (8.10 inches) for 52 years of record. Thus we can expect that the converted lands will yield runoff that exceeds the preconversion values by a substantial amount about 13 times a year, and that this excess will exceed runoff from unconverted natural lands at least 1200 days per century [one event in 52 years on natural lands versus 13 events per year on converted lands]. This is even more than a hundred-fold increase. All statistics are taken from Western Regional Climate Center sources at http://www.wrcc.dri.edu/cgi-bin/

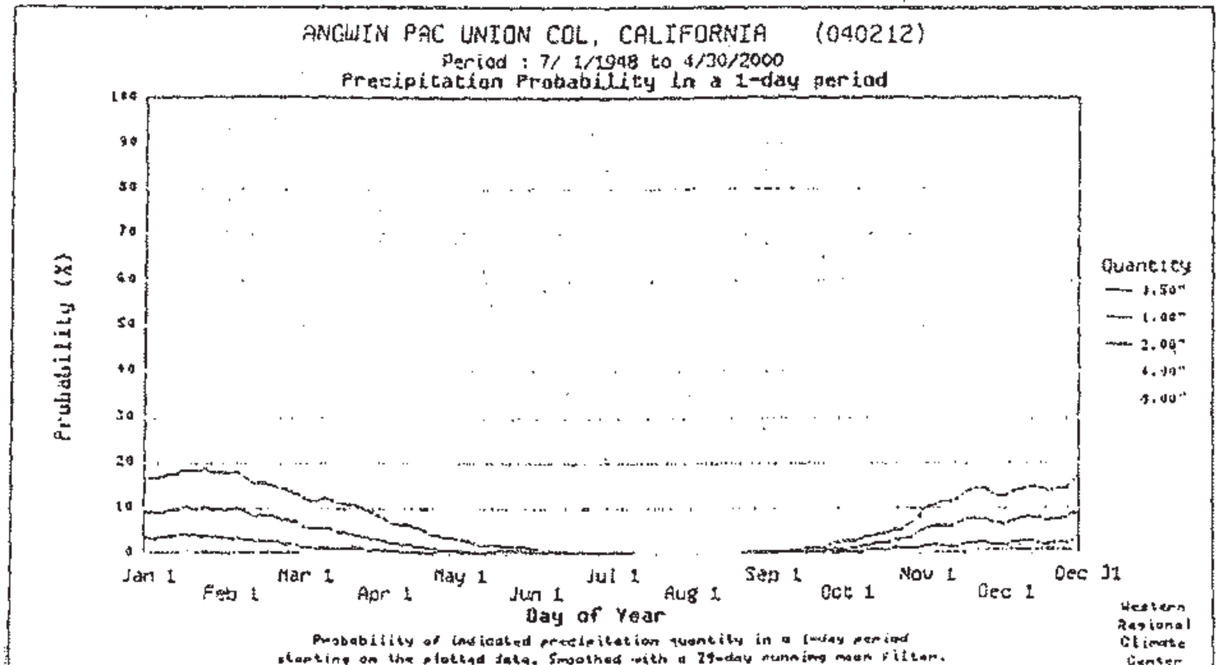

Figure 1 - East-side Napa Valley 24-hour precipitation probability

[3] Based on Atlas Peak hourly precipitation record. Pahlmeyer's on-site record was not available to us.

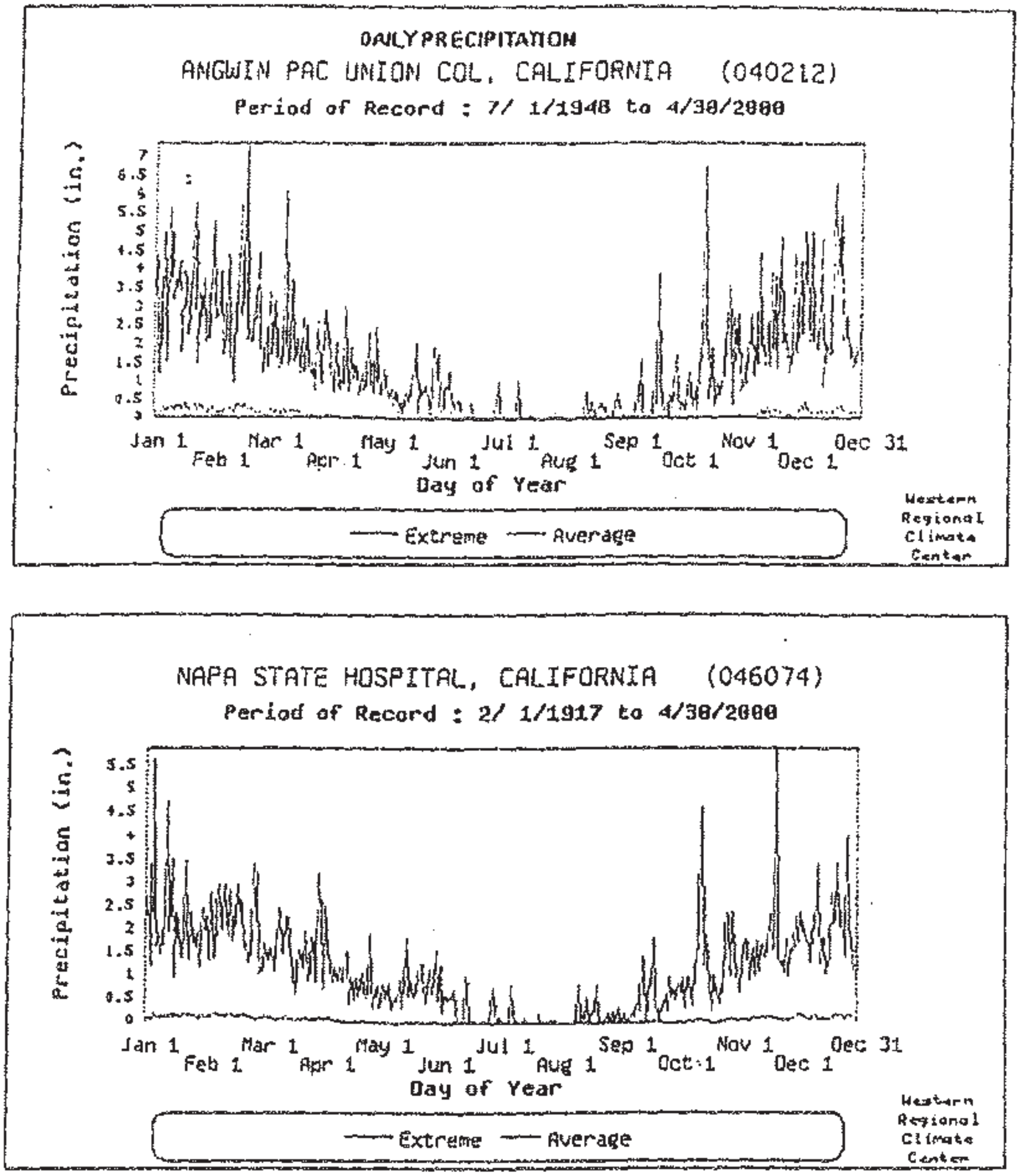

Figure 2: Means and Extremes for period of record at Angwin and Napa

Westside conditions are much more varied because both substrates and vegetation are more varied than are seen on the east side. Soil mapping on the hillside vineyard areas of Napa Valley is not adequate for detailed evaluation of runoff-generating characteristics. Napa County soil survey mapping is generally not suitable for evaluating vineyard conversion risks for non-alluvial soils above the valley floor. Soil mapping by the Soil Conservation Service and, later, by the Natural Resources Conservation Service has concentrated on the soil characteristics in the top two feet of agriculturally significant soil materials[4]. Soil mapping is not generally done to

[4] See "Napa County Soil Hydrologic Groups" map from the Soil Survey Geographic Database (SSURGO), Napa County RCD.

the degree or refinement necessary for hillside land conversions. Ongoing conversions for vineyards thoroughly change the mapped soil characteristics (see next Section on need for EIR analyses).

The Napa Valley floor vineyard lands are generally mapped to what is called an Order 2 mapping level. Because the conversions on these lands took place a century or more ago and these alluvial-substrate soils are relatively flat lying and are either well drained or have long had augmented drainage facilities, erosion is not generally a problem. The Order 2 maps are quite accurate and detailed, as is appropriate for very valuable crops. The hillsides around the Napa Valley, however, are only mapped at 4th Order reconnaissance level in forests or, at best, 3rd Order levels (see Appendix B for discussion of this mapping standard). Those lesser standards were appropriate for the open range and recreational uses of the hillsides in the 1960's. New syntheses of those older survey maps (see http://www.ca.nrcs.usda.gov/mlra/NapaSSA) come with a caveat on each map that states:

> *Due to complex features of the landscape and map scale limitation accuracy, on-site field inspections should be conducted with staff from the Natural Resources Conservation Service or professional soil scientists to verify soil mapping unit characteristics..*

Thus, hillside soil maps in Napa County include lumped complexes or associations of undifferentiated soil types that cannot be mapped separately at a scale of 1:24,000. Under westside woodlands, these soils are largely interpreted from aerial photographs and often cannot be resolved to land units under about 40 acres. Further, soils on hillsides are generally defined as slope phases of an upland or better-developed soil that may be found at one site. This mapping convention means that soils mapped on hillslopes of greater than 15 percent are generalized and imprecise. This is particularly troublesome in Napa County where hilltop soils may be derived from volcanic ash with much clay content while hillside soils below those sites are developed on unrelated bedrock. This is one fundamental reason that slope steepness is a poor predictor of erodibility in parts of Napa County.

Soil characteristics including content of stones are very important attributes to predict erosion potential. Stone content is a primary characteristic of the erodibility estimate developed in the Modified Universal Soil Loss Equation as part of its K factor. This equation is the basis for both the runoff models that were developed by the Napa County RCD and for the calculations of sediment basin sizes produced by the agricultural engineering consultants who prepare some of the Erosion Control Plans for the County. But stones also have significant effects on the overall function of soil; particularly where high shrink-swell characteristics are inherited from volcanic-ash derived clay minerals (see previous discussion). Long millennia of trial and error in southern Europe have taught the great import of maintaining a surface lag or coating of stones to protect underlying soils from rainsplash and rill erosion. Soil moisture levels are maintained under stone cover, planting is easily effected through stone cover, tilling is unnecessary, and weed control need is minimized. Stones within the soil column do not contract during the dry summer months when clay-rich soils are shrinking, and thus passageways are established along the boundaries of the stones that can readily accommodate infiltration and root growth with the first intense fall or early winter rains. Various stone mulching methods are effective.

The Napa County erosion control ordinances emphasize cover crop plantings of perennial grasses to effect the same kind erosion control. But grasses compete with vines for late summer soil water, are much less effective with initial infiltration capacity for the first winter rains, and do less to increase deep permeability in clay-rich soils. Where native stones are not present in a natural soil profile, as in parts of the west side, perennial grass cover-cropping may be a sound alternative.

To evaluate the ability of a site to develop a stone cover, the stone content of the soil mantle must be assessed. This usually requires a series of representative deep soil pits that are carefully logged. This information is not generally part of a routine agricultural soil survey because larger stones do not contribute to the conventional productivity of the site. But they are very important for soil erosion resistance and enhanced infiltration capacity.

West side soils, as evaluated on Mt. Veeder on the Chateau Potelle site, have less clay-rich subsoils than do east-side sites. Bedrock is closer to the surface, more fractured, and soils are not as subject to summer shrinkage. Less antecedent rainfall is necessary to saturate observed west-side soils so headwater stream and gully density is greater than on the east-side. Management of vineyard conversion sites on Mt. Veeder and similar sites around Mt. Veeder requires drainage infrastructure and larger sediment detention basins for a given vineyard area. At Ch. Potelle, we observed that old vineyards that had been regraded and replanted were able to absorb about two-thirds less rainfall than the undisturbed forest-floor sites immediately adjacent could absorb[5]. Newly converted lands, with slightly higher clay contents than those of the old vineyard lands, could absorb about one-fourth of the precipitation of "undisturbed" naturally vegetated lands. While this reduction in infiltration capacity and resulting increase in runoff is substantially less than we observed on the east-side, it is still significant. It still demonstrates that the modeling that was a basis for the Napa County Erosion Control Ordinance is incorrect.

Most significantly, it is not simply the size of the sediment retention basins that should be at issue, but it is the shape and volume of runoff basins that should be the focus of the ordinance. A sediment basin can also be designed to capture runoff. At all observed sites in Napa County we noted that sediment basins had filled rapidly with runoff and had overflowed with only about 3 inches of rainfall in the fall of 1999. Bathtub rings of fine sediment at the elevation of overflow indicated that suspended sediment-bearing water had overflowed the detention basins.

The capacities of those basins were designed, in the observed east (Pahlmeyer) and west (Ch Potelle) Napa Valley sites, to accommodate 50-year return period sediment yield. That is, they were supposed to be designed to capture most sediment that could be generated in a major storm that would be expected once every 50 years. We found that the calculated sediment yields may have been accurate for the published soil information for the pre-conversion conditions, but were inadequate for the post-conversion conditions with drainage infrastructure. But most alarming was the fact that no accommodation was made to capture the increased runoff of water and suspended sediment. The ponds were sized assuming that all waterborne sediment somehow had time to settle out in a small circular basin, and that the "excess" water could be discharged downslope without further concerns.

[5] Two-inch, 24-hour rainfall event, which can be expected several times in an average year. These estimates are based on field-derived estimates of soil pore volumes and soil density assessed in late December.

Erosion blankets, jute netting, straw-bales, filter fabric, and geotextiles were placed in many instances on the outflow channels below the sediment basins, but these did not extend far downslope or carry to the natural watercourses. They protected the integrity of the sediment basins themselves but not the watersheds below them, where the increased runoff was concentrated. Thus, the sediment basins served to control some of the coarse sediment coming from the conversion sites but, by so doing, increased the erosion offsite below the new vineyards. For a hilltop site like Pahlmeyer, this left a long exposed series of rills and channels to erode into Millikin reservoir. For a hillside site like Ch. Porelle, the tributary creeks were immediately below and adjacent to the vineyard plantings and were protected with riparian buffers, thus relying on root cohesion in those buffers to minimize in-channel erosion and subsequent reentrainment of sediment due to "hungry water" that now flows in volumes in excess of those before conversion. Reduction in offsite cumulative damage is therefore completely dependent on a continuous healthy riparian corridor between the vineyard sites and the Napa River tributaries. Where highways are adjacent to the creeks and the corridor is compromised, as for example Redwood Road and along Dry Creek, that rapid excess runoff simply satisfies its sediment needs by eroding downstream. The offsite effect of increase runoff volumes is independent of east or west side locations except where tributary streams pass through erodable materials, landslides, and oversteepened stream bank areas downstream. The Dry Creek and Redwood Creek canyons in their lower reaches are examples of tributaries that are susceptible to increased downstream erosion associated with increased upstream water yield.

The foothills east of Mt. Veeder west of Yountville contain a Franciscan greywacke (sandstone) that is easily eroded and that appears to be highly fractured by local faulting. This is the site of the Vineyard Properties West developments inspected near the headwaters of Hopper Creek. These are also sites where downstream impacts of upstream changes in runoff were most readily apparent. Tributary stream channels are incised, often deeply, and banks are unstable (for example, Hopper Creek from its very headwater to Yountville). As streams incise, landslides and small slumps occur, further increasing the rate of sediment discharge to those streams. Vineyard development increases water yield faster than it increases sediment yield, so the runoff is "hungry" or sediment-deprived. That sediment carrying capacity is almost immediately met by local bed and bank erosion in the stream channels, as is seen in Redwood, Dry, and Hopper Creeks. While vineyards are not the only sources of that increased runoff, they contribute to the downstream cumulative hydrologic effects, and should be evaluated in that context.

At Vineyard Properties West we noted clear evidence of recent streambed and bank erosion and marked (2 meter) stream incision of middle and upper Hopper Creek that could only be attributed to land clearing and vineyard conversion. Coarse gravel and sand fractions of that eroded stream bed were apparently captured in a local reservoir that was seen to have reduced storage capacity, while fine-grained sediments passed through that residual reservoir and entered the lower creek and passed down into the Napa River.

ONGOING AND NEEDED FUTURE WORK

Further work is in progress that evaluates the existing streamflow record for the tributaries and the main stem of the Napa River. This work is specifically focused on detection of the signatures of cumulative hydrologic effects and the separation of those stream flow change signals from many sources of background noise caused by channel clearing, alteration, precipitation-intensity changes, etc.

APPENDIX B - SOIL MAPPING STANDARDS APPLICABLE TO NAPA VALLEY AND ENVIRONS

As stated in the Soil Survey Manual [6]:

> Third-order surveys are made for land uses that do not require precise knowledge of small areas or detailed soils information. Such survey areas are usually dominated by a single land use and have few subordinate uses. The information can be used in planning for range, forest, recreational areas, and in community planning.
>
> Field procedures permit plotting of most soil boundaries by observation and interpretation of remotely sensed data. Boundaries are verified by some field observations. The soils are identified by traversing representative areas and applying the information to like areas. Some additional observations and transects are made for verification. Map units include associations, complexes, consociations, and undifferentiated groups. Components of map units are phases of soil series, taxa above the series, or they are miscellaneous areas. Delineations have a minimum size of about 1.6 to 16 hectares (4 to 40 acres), depending on the survey objectives and complexity of the landscapes. Contrasting inclusions vary in size and amount within the limits permitted by the kind of map unit used. Base map scale is generally 1:20,000 to 1:63,360, depending on the complexity of the soil pattern and intended use of the maps.

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[6] (USDA, 1993, http://www.statlab.iastate.edu/soils/ssm/gen_cont.html)