# *CHAPTER 5*
# *Data Gaps*

*Landslide/earthflow adjacent the main stem Van Duzen River near Swimmers Delight. Note the height of the ridge line, loss of trees, and amount of direct sediment delivery to the river. Photo by P. Trichilo.*

## *Total Maximum Daily Load (TMDL)*

When discussing degradation of forest and stream ecosystems, questions of why and how these processes occurred inevitably arise. Several reports have addressed the cause and origin of sedimentation within the VDR Basin (Kelsey 1977, Pacific Watershed Associates 1999, Environmental Protection Agency 1999, and Humboldt County Resource Conservation District 2002), most of which rely on the information provided by Kelsey (1977) originally, and more recently the work done on the TMDL (PWA 1999). In their work to develop an estimate for TMDL, PWA combined extensive field surveys with aerial photographic analysis of sediment sources to quantify the amount of past erosion and sediment delivery throughout the entire basin. One of the major goals was to determine how much of the total erosion and sediment delivery was due to management related activities, such as logging, referred to as controllable sediment versus non-management related processes referred to as natural sources.

As stated earlier, the analysis used a stratified random sampling (STRS) method to estimate total erosion and sediment delivery to the streams having occurred within the basin over the preceding 44 years. This method divided (stratified) the basin into five strata based on five major terrain types reported by Kelsey (1977), and described earlier in Chapter 1 (Geology).

Based on a study of Jordon Creek (Eel River main stem tributary), for the VDR TMDL, 80 plots of 42 acres in size were randomly chosen for on the ground analysis throughout the VDR Basin. Ground work and associated analysis was additionally supported by the use of aerial photographs to identify features of erosion greater than 5000 cubic yards in volume. The amount of erosion estimated to have occurred from the CMZ was calculated as a separate source as compared with the other geologic processes identified earlier (e.g., melange, active earthflows, sediment creep, etc.). Of the total sediment calculated to have been delivered from the CMZ between 1941 and 1998 (6,635,000 yds3), 73% (4,836,000 yds3) was estimated to have occurred in the Lower Basin. Of the total amount of sediment estimated to have been delivered to the entire basin, 21% was associated with CMZ (channel changes and bank erosion), two-thirds of which was reported to have occurred in the lower basin.

Of the total sediment estimated to have been delivered within the VDR Basin between 1955 and 1998, PWA (1999) stated that 80%, 84%, and 58% were identified as natural background sources in the upper, middle, and lower sub basins, respectively, and thus not associated with past land use activities such as timber harvest. These data suggest that 42% of erosion within the lower basin was controllable, but in the document only 36% was deemed controllable. In contrast to the TMDL study, natural sources of sediment in the Mattole River Basin were estimated at about 36%, leaving as much as 64% the result of management-related activities (Kramer et al. 2001, Mattole Restoration Council 2005). This discrepancy in the data between the two river basins represents a major data gap with regard to the Van Duzen River Basin.

Additional information needs to be provided on the Van Duzen TMDL as to how sediment yield was quantified and assigned as to being natural or management related. As nearly all the lower basin has been subjected to some level of timber harvest, it is very difficult to differentiate and determine the extent to which erosional processes are affected by timber harvest activities, and how many years these activities continue to influence these processes. The question can then be asked, what criteria were used to eliminate logging practices from consideration? Was a time limit established after which a logging operation was considered to no longer have an effect? If so, what was the limit? Lag time between disturbance on the hillslopes and visual recognition of the resulting sediment in the stream is highly variable (USEPA 1999), and although studies have been conducted on the time between hillslope disturbance and noticeable geomorphic changes in the stream channel (Madej 1999), the mathematical relationships are largely unresolved (Meehan 1991).

In other words, if an area was harvested 10 years prior to the assessment, was the area considered to be management related? How about 20 years or 30 years? The problem is that no information is available as to how long logging operations, especially the severe practices (clear cutting, tractor yarding cut and run operations) used in the mid 1900s, can affect surface stability of the land today. Therefore, the question again is, how were criteria established in both space and time in order to eliminate management related effects from consideration as to the cause of the erosional process? Certainly, more information needs to be provided if a TMDL is to be acceptable for the overseeing state agencies and the local community.

Sediment yield associated with “advanced” second growth (Redwood) in the Van Duzen amounted to 6% in the lower basin, and it was suggested that this sediment should be considered natural erosion because the identified land use activities had occurred over 30 years prior to the study. However, thirty years prior to the study would place the harvesting (of old growth redwood) around 1969 and earlier, much of it certainly before 1964. As the 1964 flood was referenced as the major factor contributing to sedimentation in the VDR Basin, it seems unrealistic to arbitrarily remove those activities from the overall estimates of controllable erosion, especially as the study was clearly an estimate of sediment delivery from 1955 to 1999 (well over a 30 year period). Of course, the authors also admitted that determining the extent to which an event is “controllable,” that is management-related, is certainly subjective and what is referred to as a “judgment call.” Very little description was given as to how these determinations were made.

If the second growth erosion category is considered natural, then controllable sediment drops from 42% to 36%. However, second growth trees are, in fact, indicators of past timber harvest. Much of the terrain in the lower basin consists of melange and unstable sandstone, making it very difficult to determine how long an area could continue to exhibit the effects of timber harvest and deliver sediment. This would be especially true for areas logged without regard to environmental side effects (externalities). Moreover, while these areas may appear to have healed, affected soil and geomorphic conditions could have delivered large amounts of sediment during the mid and late sixties (well within the 44 year period under consideration), as a result of the original logging. The sediment delivered then could still be seen today as course sediment in the streams. Without knowing all of the factors that contribute to geologic instability, it would be presumptuous to set a limit on the amount of time a logged area continues to impact a stream.

The TMDL document presented data showing that up to 76% of all sediment delivered to the VDR Basin occurred prior to 1980, and during that period (prior to 1980) within the lower basin, 56% was management related. After 1980, natural and management related sediment delivery were roughly equal in the lower basin (PWA 1999, USEPA 1999). According to the authors, these data indicate that differences in sediment delivery before and after 1980 were primarily due to greater frequency and magnitude of storms that occurred in this region prior to 1980 and secondarily due to improvements in modern management practices and the enactment of the California Forest Practices Rules, which became functional in the late 1970s. However, especially in the lower basin where 56% of sediment delivery was management related prior to 1980, it would seem that improvements in timber management could have been largely responsible for the reductions in sediment delivery from pre 1980 to post 1980. This explanation was evidenced by a reduction in management-related sediment delivery of 87% versus a non-management related drop of 63%.

If we assume that logging practices were at least in part responsible for bank erosion in the channel migration zone, as must be true, then the estimate of controllable erosion in the lower basin becomes even larger than 42%. Using a conservative estimate that 50% of the CMZ erosion was management related, as described earlier in this document, then the amount of controllable sediment in the lower basin rises to 48%. If all of the erosion in the CMZ is attributed to logging activity, then the figure for the same time period increases to 75% controllable erosion. Obviously, as stated in the TMDL, the CMZ represents a significant contribution of sediment to the system, and should not be dismissed lightly. Not only does it degrade the quality of habitat by increased levels of sediment in the water column, but also severely degrades the integrity of the channel and stream habitat, including quantity and quality of pools. Therefore, the cause of this source of sediment (i.e., bank erosion) should not be subjectively disregarded. At the very least, the process of erosion in the CMZ needs more consideration and analysis.

As stated earlier, the TMDL study also did not consider the impact or consequence of surface erosion, although much, if not all of this sediment delivery is the result of past and current management practices. When quantifying sources of sediment to the stream habitat, surface erosion, especially from unpaved roads and exposed earth such as skid trails, clear cuts, and landings (i.e., surface lowering) should be considered. Just how much sediment is delivered from surface erosion is controversial. However, until it can be quantified accurately, it should not be dismissed as a contributing factor. Standard methods for quantifying surface erosion and runoff should be developed and incorporated into a TMDL methodology. Of course, all of the above factors implicated as major contributors to sediment delivery to streams, are magnified and intensified with regard to cumulative effects.

Methods used to develop the TMDL for the VDR Basin were based on stratified random sampling of upslope conditions, combined with use of historic aerial photographs to estimate large quantities of earth flow sediments (PWA 1999). The advantages of using this method were described earlier. However, this project represents a major undertaking in time, expense, material, and personnel, and is not easily repeated. Moreover, the authors recommend that if the study were to be repeated in order to identify changes that might have occurred in the system, and in order to separate natural versus controllable erosion, at least two conditions should apply: 1) Five to 10 years must pass beyond the first study, presumably to allow for preventative measures to be implemented and significant changes to take place within the basin, and 2) there must be at least one 15- to 25-year storm event in the preceding year or two, prior to reimplementation of the study.

The first requirement would supposedly have been addressed (at least in the lower basin) by the PALCO HCP and the implementation agreement, which (for example) stated that 75 miles of road would be storm proofed annually. The second requirement is fundamental to further scientific understanding of the relationship between land use practices and processes of erosion at the watershed level. These interactions and resulting large-scale erosion are strongly influenced by the occurrence of severe storms, which are generally high in impact, long in duration, but infrequent in occurrence. These types of storms are probably even more infrequent today than they were 50 or 100 years ago. However, it is only these large storms that adequately test the efficacy of road and management designs, and the ability of the regulatory process to insure protection of those areas most susceptible to severe processes of erosion, such as steep slopes, riparian habitats adjacent the CMZ, and unstable geologic and soil types (e.g., unstable sandstone terrain).

The TMDL study was informative and for the most part, thorough, and as described earlier, had a number of advantages. However, it is unquestionably incomplete. Surface erosion, all of which should be considered deliverable and predominantly if not all controllable, has been assessed to account for 8-10% of all the sediment delivered within the basin (EPA 1999b, Stillwater Sciences 1999). This component of sediment delivery should be quantified in a study such as the TMDL in order to maximally determine the level of controllable sediment in the basin.

Secondly, the data collected with respect to controllable sediment, would have had more applicability had the study been able to quantify in-stream sediment loads (i.e., suspended sediment and turbidity) and relate them to erosion delivery rates on the hill slopes. Granted, there may not be a direct relationship time wise between mass wasting on the hillslopes and sediment in the streams (i.e., response in the streams may not be an immediately response to erosion on the slopes). However, supplementing the landslide assessments with in-stream data on turbidity and suspended sediment several years prior to and after the actual TMDL study, and if continued through several additional studies of similar types, eventually a pattern might emerge that would allow us to understand the timeline between upslope delivery rates and in-stream sediment loads. The potential value of this type of data is enormous and could offer insights into stream behavior beyond anything else studied so far. Unfortunately, our study was not designed to address mass wasting conditions on the ground, but such a study coupled with appropriately placed turbidity threshold sampling (TTS) stations could result in much more data and more meaningful data than has so far been collected.

There are a variety of ways in which data could be collected with regard to sediment delivery and water quality (Table 5-1). With the exception of on-the-ground reconnaissance, all of the measures listed in Table 5-1 can be deployed and used to collect data on an annual basis. From a practical perspective, addition of in-stream monitoring devices to the geological studies would eventually largely eliminate the need for upslope sampling of earth flows, etc., and allow TMDL assessments to be conducted through use of in-stream sampling devices, such as the TTS stations placed logistically throughout the basin. Obviously, projects that assess mass wasting are able to include all sizes and types of sediment delivery, including the fine particles that make up suspended sediment, but also all other forms of course sediment (e.g., sand, gravel, rocks, boulders, etc.) that make up to entire component of sediment bed load that inevitably fill the stream. Larger sized material cannot be assessed by in-stream samplers, but correlations with total sediment yield may allow in-stream samplers to suffice for most years.

**Table 5-1. Types of sampling data and how they relate to data gaps - information that could be collected as indices of water quality in the Lower Van Duzen River Basin.**

| Category | Data Gaps | Technology Necessary to Gather Required Data |
|---|---|---|
| Suspended Sediment | Naturally Occurring Background Levels of Sediment | In-Stream TTS Stations |
| Suspended Sediment | Annual Sediment Load (tons/sq. mi) | In-Stream TTS Stations |
| Course and Suspended Sediment | Ratio of On-the-Ground Sediment Yield to Instream Suspended Sediment | On-the-ground reconnaissance, aerial photography, & In-Stream TTS Stations |
| Turbidity | Naturally Occurring Background Levels of Turbidity | In-Stream TTS Stations |
| Turbidity | Number Hours of Turbidity > 25 NTU (Chronic Turbidity) | In-Stream TTS Stations |
| Temperature | Annual Summer Temperatures in the Van Duzen River and all Major Tributaries | HOBO Temperature Data Loggers |
| Temperature | Number of Hours/Days above Stress and Lethal Levels for Salmonid Species | HOBO Temperature Data Loggers |
| Habitat | Ratio of In-Stream Turbidity to Stream Habitats | Habitat Typing Equipment and TTS Stations |
| Fish | Current & Future Distribution of Adult Coho & Chinook Salmon, Steelhead [1] | Carcass Counts of Spawned Adults, Appropriately placed Weirs, & Visual Surveys of Spawners |
| Fish | Current & Future Distribution of juvenile Coho & Chinook Salmon, Steelhead [1] | In-Stream Dive Counts of Juveniles by Age Class |

[1] Adequate habitat for Salmon & Steelhead will also foster healthy populations of Cutthroat Trout

However, estimates of total sedimentation could be accomplished once the relationship between mass wasting and suspended sediment in the streams is quantified. Of course occasional validation of the model would be required. Then, the assessment of conditions within the basin becomes a much more practical application, and one which can be quantified on an annual basis. Thus, there would exist a way to continually monitor the health of the watersheds within the basin, submit annual reports, and weigh the efficacy of measures taken to ameliorate water quality and habitat conditions within the river and its tributaries. In other words, we could ask on a regular basis: Is water quality and the sediment problem in the basin improving or getting worse? Are the goals of 10% or 15% improvement being met? If not, why not, and how can we best readdress the problem? Of course, with annual in-stream monitoring, the response time to answer that question would be much faster than waiting for a 10-15 year cycle geologic study.

Another potential advantage to sampling in streams for sediment is that compared to on the ground estimates of mass wasting, estimates of suspended sediment are probably more accurate and precise than estimates of hill slope delivery. Variability in upslope estimates of erosion was admittedly associated with a high degree of error. While the TTS is not error free, the variability associated with the sampling process is within reason. Another advantage to using in-stream sampling devices is that compared with the magnitude of the effort required for geologic estimates of mass wasting, TTS stations are relatively inexpensive to operate and offer years of consistent data collection for estimations of daily and annual load.

Moreover, they represent a direct measurement of conditions that adversely and severely impact cold water fisheries like salmon and steelhead. While fine sediment is only one component of the bed loads that fill streams, as was discussed in Chapter 1, it is the primary component that adversely affects salmon reproduction (i.e., silt is known to smother salmon eggs and the resulting young), and the ability of young salmon to effectively find food in the stream. Fine sediment is also correlated with, and a predictor of total sediment load. With moderate study and adequate modeling, estimates of fine sediment loads could be used to predict total maximum daily load in each stream being monitored in the basin.

## *In-Stream Water Quality Data*

Very little in-stream water quality data have been collected and quantified for the Lower VDR Basin. This lack of data represents an absence of information and thus an obstacle for more fully understanding the behavior of these streams. Our project was an effort to engage California agencies and the general public in a program to increase our knowledge and understanding of the relationships among these streams and quantify the relative health of these watersheds in a comparative manner. While the majority of data collected was obtained from grab (hand) sampling for turbidity and sediment, the project has increased our understanding of the behavior of sediment in streams in the lower basin. Some of this information was a greater awareness of current conditions and how streams respond to storm events.

### *Turbidity*

Turbidity can be described as a measure of water clarity (USEPA 1999). Excessive turbidity can have sublethal effects on salmon and steelhead that can result in reduced feeding and growth, avoidance, respiratory impairment, and physiological stress (Newcombe and MacDonald 1991).

The proposed numerical target for turbidity (no greater than 20% increase above naturally occurring background levels) is a part of the water quality objective for turbidity, as described in the Basin Plan of 1994. However, nowhere in the EPA document are the natural background levels specified, and the authors comment that it is extremely difficult to set target levels for Total Maximum Daily Load because 1) watershed conditions, particularly sedimentation levels, naturally fluctuate widely over time and space; 2) minimal data exist on reference conditions, 3) many in-stream indicators cannot distinguish between human-induced disturbance versus natural disturbance, and 4) indicators can be difficult and expensive to measure (adapted from Bauer and Ralph 1999).

According to the EPA, turbidity measurements may be useful in assessing the effectiveness of management practices within the context of a well-designed monitoring program. The EPA described turbidity sampling as an emerging approach for constructing turbidity rating curves, using a citizen-based monitoring program in Humboldt County, in conjunction with discharge records, to determine whether turbidity levels in disturbed watersheds are a problem for salmonids (USEPA 1999). Such an approach is said to hold promise as an effective monitoring tool for the Van Duzen River basin.

Some of the information gained from our project was acquired from activities that we later deemed insufficient, as well as from those that were considered adequate. For example, weaknesses in the grab sample method became more apparent as the project progressed. During major storm events, in some cases grab samples were taken several times within a single day, but more commonly were obtained at the most, once a day, or even once every several days. Thus, timing of the grab samples made it virtually impossible to calculate chronic turbidity (hours of turbidity above a given threshold). While deemed insufficient for calculation of certain metrics, grab samples provided the only way turbidity and sediment samples could be collected at many of the sites throughout the project area. Accurate calculation of chronic turbidity necessitates using instrumentation comparable to a Turbidity Threshold Sampling (TTS) station that can collect each new sample within minutes of the previous sample. The usefulness of such a TTS station was demonstrated by our project station on Cummings Creek (Figure 5-1).

In our study, the original plan to install a TTS station on private property adjacent the main stem was modified based on the opinion that the volume and velocity of the river would be too severe, and carry such large material, including fallen trees (moving at great speeds) that a complete TTS station and its sampling devices would not survive the season. Instead, an ISCO 24-bottle sampler was installed and set to automatically collect sediment samples at regular intervals (i.e., 2 or 4-hour intervals) throughout each storm event. These samples would be associated with date and time, and allow for the collection of corresponding discharge data from the USGS discharge recording station upstream, thus allowing for the development of a sediment rating curve based on known discharge levels throughout the season, and corresponding estimates of suspended sediment as a function of discharge.

**Figure 5-1.** Turbidity threshold sampling station located on Cummings Creek, which was sampled for chronic turbidity and sediment during HY07 and HY08 (Photo by P. Trichilo).

Using the ISCO by itself, although less prone to damage, was an unsatisfactory method to collect suspended sediment data compared to a full TTS station. Without the in-stream turbidimeter that provides virtually continuous data (once every ten minutes), it is impossible to later calculate or estimate the total amount of continuous turbidity above a given threshold (e.g., 25 NTU), otherwise known as chronic turbidity. Without the complete station it is much more difficult to calculate annual sediment load, and any estimate using that described above becomes more subject to analytical and experimental error. Without a doubt, the most dependable and experimentally satisfactory method to estimate stream turbidity and sediment loading is with a complete TTS station setup.

## *Sediment*

It was suggested that there is less natural and management related sediment being produced in the VDR basin in the post-1980 period (USEPA 1999a). This may reflect differences in the frequency and magnitude of storms which trigger widespread watershed response, but it is also suggested that this effect could be partially attributed to improvements in land management practices brought on by the FPR or voluntarily by individual landowners. However, history of the Van Duzen River shows that the Maxaam-Hurwitz era of the Pacific Lumber Company had begun well before the TMDL publication and that logging frequency and severity (e.g., amount and intensity of clear cutting and tractor yarding) of this basin, as well as in much of the Eel River Basin at large, increased dramatically during this time period (1985-2008) (Figure 5-2).

**Figure 5-2.** Clear cutting in the Lawrence Creek sub basin during the Maxaam era from 1985 through 2008. Photo by D. Thron.

It is highly probable that land management practices conducted by the Pacific Lumber Company from 1985 through the point that marked its change of ownership in 2008, were more likely highly detrimental to forest and watershed health due to the intense clear cutting and tractor yarding activity that characterized the priorities of the company at that time (P. J. Trichilo, S. Steinberg, W. Thorington, personal observations). Another very large data gap relating to this issue is that there is little information as to the time frames that exist between management-related activities on the hillsides, and when the effects of those activities become manifest as increased sedimentation and turbidity in the streams.

Admittedly, this information is difficult to quantify 1) because it may require projects that extend over very long periods of time (e.g., 20-30 years of study), and it is difficult to fund projects of that length and magnitude, 2) because activities like timber harvest (especially clear cutting, tractor yarding, and the scraping of dirt roads and skid trails) that impact the land so severely can have short term and long term effects, and long term effects especially, are difficult to link back to the causes, and 3) the negative impact of logging practices have far-reaching effects that become nested within other effects, further complicating the picture and our ability to assign cause. According to the EPA, aggradation can cause filling of formerly incised channels, channel widening, loss of riparian vegetation, increased bank erosion, loss of deep pools, and consequently increased water temperatures (USEPA 1999). All of these characteristics negatively impact fish habitat.

With regard to the nesting of effects, sedimentation fills in stream channels, thereby reducing the capacity of the stream to carry water effectively. Where water once flowed moderately within the channel, it now flows at much greater volumes after a storm event causing flash floods over the channel banks carrying wood and other debris with it. Flash floods can wipe out riparian vegetation and in so doing, destroy the integrity of the channel, erode the banks, widen the channel migration zone, and cause the stream channel to become even shallower. While the logging operation may not directly destroy the stream bank, secondary and tertiary effects of logging on the hillslopes can severely impair stream bank integrity. With the riparian zone gone further erosion of the stream banks can occur at even faster rates, and the shading and cooling effects on the stream are also lost.

Data gaps still exist with regard to how much actual sediment is contributed specifically by surface erosion. These metrics are difficult to separate from other effects and individually quantify. With regard to roads, information is greatly needed on where logging roads and skid trails are no longer of sufficient use to be maintained, or are so degraded as to be considered hazardous (Figure 5-3). These roads located on timberland should be scheduled for decommissioning as soon as possible, and a time frame should be established as to when these roads can likely be removed. Therefore, information is necessary as to 1) which roads can and should likely be decommissioned, and 2) when and what time frame can be used to accomplish this goal. In the case of skid trails, all of these types of transport infrastructure should be scheduled for removal. It is our contention that tractor logging is far too damaging to these ecosystems to be allowed to continue.

**Figure 5-3.** Example of a road constructed directly into the stream – a severe by-product of unregulated logging that should be banned (Photo by P. Higgins).

The efficacy of road removal and/or decommissioning can be effectively monitored and quantified by establishing in-stream TTS water quality monitoring stations at critical sites that receive runoff from these roads. Therefore, one of the most glaring data gaps within the lower basin relates to the inadequacy of available information on road-related in-stream sedimentation rates. Our project was the first in the lower basin to attempt to quantify continuous turbidity and annual sediment load. The stream used for this effort was Cummings Creek, which was chosen because it is readily accessible and offers a large enough flat area to house the station, it is on private property and therefore relatively safe from vandalism, and the creek was at one time a salmon-bearing stream, and exhibits habitat appropriate for steelhead, and is therefore an ecologically important tributary to the Van Duzen River. Cummings Creek was also one of the coldest streams measured throughout the study period.

Over the course of the two-year winter sampling period, annual sediment loads were estimated for each year, although due to the time that authorization of our project was received from WQCB, the first year's sampling program (Hydrologic Year 2007) started too late to provide a realistic estimate of annual load. Therefore, our only true estimate of annual sediment load was obtained in Hydrologic Year 2008. Data from the second year were also used to estimate the severity of chronic turbidity throughout the season as well as turbidity exceedence levels. Although the first year was hampered severely, our project did successfully demonstrate the usefulness of TTS stations in quantifying turbidity and sedimentation rates, and serves as a model for what can be accomplished in future endeavors at other sites in other streams throughout the lower basin. Chronic turbidity and exceedence levels need to be calculated for all of the major tributaries to the Van Duzen, especially in the Lawrence Creek, Yager Creek, Cummings Creek, Hely Creek, and Grizzly Creek sub basins. Ultimately, being able to quantify sediment and turbidity levels for all of the major tributaries will provide a complete database and greatly enhance our understanding of water quality conditions throughout the lower basin.

Water quality data combined with improved and more concerted efforts to quantify numbers of salmonid adults and juveniles, and additional assessments of habitat quality throughout the fish-bearing streams will provide excellent information of those streams that are in the greatest need of attention and rehabilitation. When these kinds of data (Table 5-1) have been available for at least 10 years, we will be able to begin making sound decisions as to where management is adequate and where it needs to be improved, where policies are adequate and where they need to be improved, where stream conditions (including the riparian zone) and where restoration would be of value. Monitoring activities listed in Table 1 would also be mandatory to annually document the benefit derived from restoration activities in these streams.

## *Hydrology*

Channel damage from floods is partly caused by elevated peak flows. In addition, baseflow conditions appear to be lower than historic, but it is difficult to discern whether this condition is due to bed aggradation or other causal mechanisms like more water use in the early seral forest. New flow data need to be collected where historic flows were measured and high flow and rainfall compared for historic periods and the present. If flow information were collected on paired small tributaries with different seral stage conditions, effects of forest age on flows could be determined and changes over time recorded as part of adaptive management.

The mainstem Van Duzen River in recent years has been experiencing stagnation to the point where toxic algae are proliferating (Figure 5-4). There have not been any studies to determine why this appears to be a recent anomaly and has not occurred historically. Such a study would include installing flow gauges that work in low flow conditions and subsequently measuring parameters such as total nitrogen, ammonium, ammonia, phosphorous and pH, which are excellent indicators of the eutrophic conditions that typically give rise to algal blooms.

**Figure 5-4.** Slow moving and stagnant water observed in the main stem Van Duzen River, typically observed during summer months (Photo by P. Trichilo).

While there are acute temperature problems in lower Yager Creek and the mainstem Van Duzen River, alluvial reaches such as these likely had substantial influence from the hyporheic zone. A reaches such as the Lower Main Stem Van Duzen River or Lower Yager Creek should be targeted for restoration and floodplain reconnection. Studies using numerous automated temperature sensing probes could then be designed to determine whether hyporheic reconnection could establish and sustain refugia.

## *Meadows and Gullies*

More information is needed before restoration of meadows and their hydrology can be undertaken. Studies should focus on changes in water storage potential in meadows affected by gullies (Figures 5-5 & 5-6) versus those that are more intact.

**Figure 5-5.** Grazing land and hillslopes typical of the upper (northeastern) part of the Yager Creek sub basin, showing soil creep and movement of land mass over time (Photo by P. Higgins).

**Figure 5-6.** Gullying as a result of exposure to rainfall and runoff, causing loss of topsoil and excessive sediment delivery to streams (Photo by P. Higgins).

In cases where gullies are extensive, pilot projects should be implemented using fill materials and willow mattresses to stop head-cutting and to restore hillslopes and hydrology.  However, more baseline information needs to be collected, including photo documentation and efficacy monitoring of project implementation.