EXHIBIT 6

HABITAT INVENTORY AND INITIAL ASSESSMENT OF ANTHROPOGENIC SEDIMENTATION OF UPPER MARK WEST CREEK, SONOMA COUNTY, CALIFORNIA

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EXECUTIVE SUMMARY

- In October of 2008, Dr. Stacy Li and Douglas B. Parkinson ("We"), under contract with New Old Ways Wholistically Emerging (NOWWE), performed a Level IV Habitat Inventory of a section of upper Mark West Creek in Sonoma County California. The stream section inventoried begins at Tar Water Bridge and proceeds upstream to just past the confluence with the North Fork (NF) of Mark West Creek. The steelhead trout (*Oncorhynchus mykiss*) that inhabit this waterway are listed as *Threatened* under the Endangered Species Act of 1973 (ESA), and Mark West Creek has been designated as "critical habitat" for them. (A Level IV Assessment uses the most detailed classification of habitat types; It is used to describe stream habitat for baseline or assessment purposes).

- Coho salmon (*Oncorhynchus kisutch*) also inhabit Mark West Creek further downstream. They are listed as *Endangered* under the ESA. Mark West Creek has also been designated as Critical Habitat for coho salmon.

- California Department of Fish and Game (CDFG), made at least three salmonid abundance estimates between 1965 and 1970 in Mark West Creek. Those estimates included 60 steelhead and coho salmon per100 feet, 60 yearling steelhead per 100 feet and 175 steelhead per 100 feet. (California Department of Fish and Game, 2000). Bill Cox, CDFG district fisheries biologist for Sonoma and Marin counties, rated these salmonid abundances as very high.

- We found that Upper Mark West Creek (hereinafter "Creek") has been adversely affected by severe sedimentation. Although the creek is narrow, entrenched and steep-banked, it has the capacity to store a significant amount of sediment. This is particularly true when stream flows decline; almost 40% of the Creek habitat consists of flat-water (pools and runs) and another 40% consists of step-habitat with mostly flat-water. Because of the Creek's sediment storage capacity, it will typically take longer to transport and disperse this sediment load.

- The Creek banks consist mostly of boulders and bedrock walls. This means they are typically stable and, consequently, not a significant source of sediment. We also checked for tributary sediment contribution; we saw no significant sediment augmentation, except from NF Mark West Creek.

- There have been two anthropogenic (caused by humans) sediment spills from NF Mark West Creek into Upper Mark West Creek. A spill from the Minton property in 2004 created a debris dam and stored approximately 500 cubic yards of cobbles. This means the spill was at least that large.

A second, dramatically larger spill, originating from the Cornell Property, occurred during the rainy season of 2005-2006. One estimate of the spill size is 10,000 cubic yards of finer sediment. The sediment damage caused by this spill was compounded by the fact that the debris dam from the earlier Minton spill broke during the same season.

- The downstream edge of the Cornell sediment slug was identified at Station 1618; sedimentation ratings were much lower downstream from that station than upstream. All ratings of sedimentation within the sedimentation zone were heavy and severe, especially in the pool and step-pool habitats. Riffles that were inventoried had interstitial spaces clogged with sediment, but were relatively free of fines (tiny particles/fine particles). The downstream edge of the Cornell sediment within the Creek has traveled 4,020 feet in the past two rainy seasons; both these seasons have been drier than normal. However, adverse effects of the spill are still evident upstream at the confluence of NF Mark West Creek and Mark West Creek.

- The depth and area of embeddedness and percent surface fines in flat-water and step-habitats has resulted in higher adverse ratings than in riffles or cascades. Since fines were smaller than 2 mm, they were transported quickly. Most of the remaining sediment is composed of larger particles.

- SEDIMENTATION AND LOW STREAM DISCHARGE ARE MAJOR CONTRIBUTORS TO HABITAT DEGRADATION IN THE CREEK.

- At one point, the sediment supply was so large that deposits isolated the stream into five segments. This segmentation fractured the habitat; this in turn stopped fish movement, interrupted the stream's energy flow and undoubtedly reduced the supply of food for the fish. The passage of time and/or significant streamflows will be required before the sediment is dispersed; only then will the stream be restored to its pre-spill condition.

- Sedimentation is known to be a serious problem, and the mechanisms of its adverse effects have been studied for decades. "....After a half-century of the most rigorous research, it is now apparent that fine sediment, originating from a broad array of human activities (including mining), overwhelmingly constitutes one of the major environmental factors – perhaps the principal factor – in the degradation of stream fisheries." (Waters, 1995)

- Dr. Li examined the photographs of the Cornell sediment spill. There was high turbidity (having sediment suspended in solution) for at least 24 hours, which means that steelhead were likely killed (Newcombe and Jensen, 1996; Cluer and Li, 2005).

- The previously mentioned spill sediments have reduced fish living space by filling the habitat "units" in Upper Mark West Creek. Other known effects of this type of sedimentation include, but are not necessarily limited to:
  - Decrease in substrate roughness;
  - Reduced steelhead growth due to increased metabolic costs of maintain stream position;
  - Reduction in aquatic invertebrates that are fish food;
  - Decreased feeding efficiency;
  - Increased competition for food and space;
  - Increased rates of predation;
  - Increased susceptibility to parasites and disease;
  - Reduced stream access due to sediment blockage;
  - Increased incidence of stranding; and
  - Reduced production of steelhead.

- Steelhead spawning gravels in Upper Mark West Creek were extremely rare. We believe the anthropogenic sediment buried steelhead spawning gravels, which has resulted in less suitable spawning material and less suitable spawning locations. Entombing of alevins (newly hatched fry still living within gravels) trying to leave the gravels is also a common effect of sedimentation.

- Upper Mark West Creek is part of designated critical habitat for steelhead trout. More than 10,000 cubic yards of anthropogenic sediment have been washed into this narrow stream; <u>this level of impact should qualify as adverse modification of critical habitat.</u>

- **The threat of severe sedimentation to Mark West Creek and Upper Mark West Creek is not over.** The Cornell property has more stored sediments, with no adequate provision to isolate those sediments from the waterway. This means that there is an ongoing threat that a spill will happen again and cause further delay to the restoration of the waterway as a healthy, functioning steelhead habitat.

- The adverse impacts of sedimentation will not end once they disperse from Upper Mark West Creek. These sediments will continue to degrade Mark West Creek as they migrate downstream to where the endangered coho salmon are living and will continue to degrade habitat until they are dispersed in the Pacific Ocean.

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INTRODUCTION

Stacy K. Li, Ph.D. is experienced in habitat inventory methods and has delineated approximately 150 miles of streams in California, Oregon, and Nevada. New-Old Ways Wholistically Emerging (**NOWWE**), a community-based non-profit, retained Dr. Li to perform a stream habitat inventory assessment of upper Mark West Creek between Tar Water Road and the confluence with the North Fork (NF) Mark West Creek, a distance of about 1.1 miles. Upper Mark West Creek itself is a permanent third order stream within the Russian River Watershed in Sonoma County, California.

Dr. Li became familiar with upper Mark West Creek during his tenure at the National Marine Fisheries Service (NMFS), from which he retired on September 30, 2008. While an employee of the NMFS, Dr. Li visited upper Mark West Creek on two occasions. However, these visits were prior to a development caused landslide that resulted in 10,000 cubic yards of sediment entering upper Mark West Creek.

Douglas Parkinson, of Douglas Parkinson and Associates, Arcata, California, assisted Dr. Li in conducting the habitat inventory. Mr. Parkinson has delineated approximately 300 miles of streams in California, Oregon, Nevada, Washington, and Alaska.

BACKGROUND

Sonoma County's landscape is replete with steep ridges and canyons. Extensive land areas are landslide prone (Huffman and Armstrong 1980), and landslides are the most common type of ground failure in the County. As a result, all land development, especially in known landslide areas, must avoid actions that will cause the downslope movement of soil and/or rock materials (a landslide).

Increased land development within the Mark West Creek watershed has become of growing concern to those who value the natural assets of the creek. Already, due to heavy sediment loading, the Russian River watershed, of which Mark West Creek is a part, is listed as an impaired water body under Section 303(d) of the Clean Water Act (CWA). Upper Mark West Creek produces 17% of the sediment in the Laguna-Mark West watershed; it is the steepest creek with the highest level of natural erosion. This fact means that all development proposals (especially upslope activities) within proximity of upper Mark West Creek must be carefully evaluated to assure that there are no negative environmental impacts. It also means that regulatory agencies must be committed to assure that all laws, regulations, or ordinances protecting the waterway are followed and enforced.

Unfortunately, recent unauthorized and/or likely unauthorized land disturbing and property development activities on two different properties resulted in a large landslide and a series of sediment spills. These occurrences have increased sediment input into Mark West Creek far beyond natural sedimentation rates. They have seriously degraded

the steelhead habitat quality in upper Mark West Creek and will seriously degrade coho salmon habitat downstream, when the sediment reaches this habitat.
In 2004, spoils resulting from widespread and unauthorized grading activity on the Minton property, St. Helena Road, Santa Rosa, caused disturbed sediment to enter NF Mark West Creek, then move on to upper Mark West Creek. The sediment was subsequently stored as a debris dam in the vicinity of Station 4375 (this Inventory), until the following year. The amount of sediment stored within the debris dam was on the order of 500 cubic yards; it was mostly cobble-sized material and larger. During the winter of 2005-2006, this debris jam failed.

Compounding this, there was a landslide from the Cornell property on 245 Wappo Road, Santa Rosa. This landslide, most likely caused by an unauthorized fire break just upslope of the slide, washed thousands of cubic yards of slide material into NF Mark West Creek then into upper Mark West Creek. This began on 31 December 2005 and continued with each succeeding storm through spring of 2006. In addition, RGH Consultants (20 October 2006) reported that a landslide that occurred in April 2006 also transported sediments downhill to an intermittent flow ravine (NF Mark West Creek) and partially blocked the drainage. This landslide occurred in an area that had been disturbed by older, larger landslides. The estimated amount of slide material sent to the creek from the Cornell landslide was 10,000 cubic yards of silts, sands, and gravels (Keiran 2007). Instead of removing the landslide sediment from the ravine to prevent further sedimentation of Mark West Creek, a culvert was placed through the slide material within the drainage way and then material was mounded over the culvert. This inadequate provision will not keep these sediments from entering Mark West Creek.

THE FISH COMMUNITY

The fish community of Upper Mark West Creek consists of California roach (*Hesperoleucus symmetricus*), three spined stickleback (*Gasterosteus aculeatus*), steelhead trout (*Oncorhynchus mykiss*), and coastrange sculpin (*Cottus aleuticus*). This is a typical steelhead trout headwater fish community (Moyle 2001). Coho salmon (Oncorhynchus kisuch), has also inhabited Mark West Creek, but in the lower parts of the stream.

At least three fish abundance surveys were conducted by California Department of Fish and Game (CDFG). These occurred in July 1965, September 1969, and August 1970 (CDFG 2000). They estimated steelhead abundance at 175/100 feet of stream in 1965, 60 yearling steelhead/100 feet in 1969 and 60 steelhead and coho salmon/100 in 1970. Bill Cox, CDFG District Biologist for Marin and Sonoma counties, considered these abundances as very high (personal communication 2009).

Steelhead trout have been listed as threatened under the U.S. Endangered Species Act (ESA). The Central California Coast Steelhead distinct population segment (DPS) was listed as a threatened species under the Endangered Species Act (ESA) on August 18, 1997; the threatened status was reaffirmed on January 5, 2006 (71FR834).

This Steelhead DPS includes:

- All naturally spawned anadromous *Oncorhynchus. mykiss* (steelhead) populations below natural and manmade impassable barriers in California streams from the Russian River (inclusive) to Aptos Creek (inclusive), and the drainages of San Francisco, San Pablo, and Suisun Bays eastward to Chipps Island at the confluence of the Sacramento and San Joaquin Rivers;

- Tributary streams to Suisun Marsh including Suisun Creek, Green Valley Creek, and an unnamed tributary to Cordelia Slough (commonly referred to as Red Top Creek); and

- Excludes the Sacramento-San Joaquin River Basin, as well as two artificial propagation programs: the Don Clausen Fish Hatchery, and Kingfisher Flat Hatchery/Scott Creek (Monterey Bay Salmon and Trout Project) steelhead hatchery programs.

A final Critical Habitat designation was published on September 2, 2005 with an effective date of January 2, 2006 (70FR52488) and final revised protective regulations were issued for this DPS on June 28, 2005.

Coho salmon within the Central California Coast Evolutionarily Significant Unit (ESU) has been listed under the U.S. Endangered Species Act as endangered on 28 June 2005 (70FR37160). The Central California Coast ESU includes all naturally spawned populations of coho salmon from Punta Gorda in northern California south to include San Lorenzo River in central California, tributaries to San Francisco Bay excluding the Sacramento-San Joaquin system. Also included are four artificial propagation programs: the Don Clausen Fish Hatchery Captive Broodstock Program, Scott Creek/King Fisher Flats Conservation Program, Scott Creek Captive Broodstock Program, and the Noyo River Fish Station egg-take Program. A final designation of Critical Habitat was published on May 5, 1999 (64FR24049). The take prohibitions of section 9 of the ESA that may apply to this ESA were published on June 28, 2005 (70FR37160).

Streams vary in space and time. There are three climatological factors we considered that could affect the variability of physical conditions and recent steelhead/coho salmon abundance, or lack thereof. First, there have been two consecutive years below normal rainfall; therefore, there was less opportunity to transport the sediments we have mentioned previously. Second, the frost protection season of 2008 made unusually severe demands on the regional water supply. By its nature, frost protection represents a regional demand on water. When one vineyard, pear orchard, or almond orchard is diverting water to their irrigation system to protect their crops, all the neighboring farmers are doing the same. The consequent water demand is sudden and enormous. Steams such as Mark West Creek are very sensitive to frost protection activities because of their small discharges. During this past frost protection season, there are recorded instances where a small stream was dehydrated due to frost protection pumping. Federally endangered coho salmon were living in that small stream.

Even main stem rivers, such as the Russian River, were not immune to the adverse effects of frost protection diversions. Almost 40% of the flow on the Russian River, as recorded at the USGS gauge at Hopland, California, was diverted in April of 2008. This diversion dropped the water surface elevation over a foot and exposed a gravel bar to air, killing recently emerged steelhead fry. Third, the spring of 2008 was dry. Very little rain fell during the spring months, so flow recession to base-flow conditions occurred earlier.

METHODS

A) Two observers (Li and Parkinson) were used as a safety precaution. The observers walked upstream to minimize water clarity disturbance and methodically recorded observations in field books. The field data were entered into an Excel spreadsheet and reviewed for accuracy by both Li and Parkinson. These data are appended to this report on a compact disk.

By convention, a habitat inventory begins at the starting point with habitat unit one, with each succeeding habitat unit increasing by a single positive integer. The starting point for this survey was the Tar Water Bridge.

"Station" is the cumulative distance from the starting point. Station is measured using a hip chain (with precision to the nearest foot) and following the thalweg – the line of maximum depth of the stream. Hip chain string was tied frequently to local stream features to avoid shortening the measured station. Hip chain string was removed after measurement to prevent wildlife entanglement. We report Station as the number of feet upstream of Tar Water Bridge.

We followed three other habitat delineation conventions: 1) Since habitat units rarely transition from one to another with borders perpendicular to flow, the observer (Doug Parkinson) with the hip chain determined the most representative location for that border, typically the mean distance between the downstream edge of one and the upstream edge of the other. 2) In addition, U. S. Forest Service uses a minimum habitat unit length criterion. A habitat unit that is shorter than its stream width is lumped with the next upstream unit. This issue is particularly common in small streams such as Mark West Creek. 3) Orientation for left and right is looking downstream.

B) Habitat types were identified using published definitions (Overton *et al.* 1997) [Table 1]. We delineated habitat types at a Type IV, with the exception of identifying the source of scour for pools. Since habitat identification is based upon water surface appearance and water appearance varies with stream flow level, the habitat type proportions in this habitat inventory reflect low base-flow conditions.

Table 1. Habitat Type Definitions (Overton *et al.* 1991).

There are three general types of aquatic habitat:

1) **Flat-water habitats** are typically zones of scour during stream-flow increases and zones of sediment deposition when stream-flow decreases.

A **Pool** is a portion of the stream with reduced current velocity, often with water deeper than surrounding areas. Deeper areas are the result of scour. During periods of flow recession, pools are zones of sediment deposition.

A **Run** is deep and fast with a defined thalweg and little surface agitation; runs also become zones of deposition when stream velocity in the run becomes slow. Sediment deposition occurs later than sediment deposition in pools.

2) **Falling-water habitats** are zones of deposition during periods of increasing stream-flow and zones of substrate erosion during stream-flow recession.

A **Riffle** has shallow rapids where the water flows swiftly over completely or partially submerged obstructions, producing surface agitation, but standing waves are absent. Riffles typically have a consistent slope. Two types of riffles are identified – **Low Gradient Riffles (LGR)** are less than 4% slope and **High Gradient Riffles (HGR)** are steeper than 4% slope.

A **Cascade (CAS)** has swift current, exposed rocks and boulders, high gradient, and considerable turbulence, surface agitation, and consists of a series of drops. A synonym for cascade is cataract.

3) **Flat-water within falling-water habitats**. These habitat types do not have a consistent slope within the units. Habitat consists of flat-water with vertical gradient loss at steps. The relationship between rising and falling hydrology and sediment transport is very complex, with some parts of the habitat behaving as flat-water and other parts behaving as falling-water.

A **Pocket pool (POC)** is small (between 10 and 30 percent of wetted width); bed depressions form around channel obstructions within fast water habitats only. A synonym for pocket pool is pocket-water.

A **Step-run (SRUN)** is a series of runs with gradient breaks in between.

A **Step-Pool (SPOOL)** is a complex and has a series of three or more mid-scour pools separated by short turbulent water. The length of the turbulent water cannot exceed the average wetted width. Step pool complexes are found in headwater channel types and typically consist of pools that are formed by boulders and bedrock.

Step pocket pool (SPOP) is a series of pocket pools with gradient breaks in between.

C) We used a wading staff graduated in feet and tenths of feet to measure:

- Stream width from wetted edge to wetted edge; Parkinson viewed both banks and measured the typical width.
- Mean depth, based upon multiple measurements in each habitat unit.
- Maximum depth of pools and step-pools.
- The hydraulic control of each pool or step-pool, i.e., the elevation that determines the standing pool when flow ceases.
- Parkinson estimated the steelhead spawning gravel area within each habitat unit. We used the >8 mm to 64 mm size criterion as steelhead spawning gravel (Kondolf and Wolman 1993).

D) Global Positioning System (GPS)

- Parkinson used a Garmin™ GPSmap 60CSx to take GPS periodic readings.

E) Visual estimates:

- Parkinson used a Pentax™ Optio W30 to photograph stream features of interest.
- We measured local gradient periodically using a clinometer and also estimated grade, based on experience.
- Parkinson visually estimated **depth of embeddedness** (how deeply the rocks are buried at the tails of the units)[Table 2]. The depth of embeddedness is related to the degree of sedimentation and its effect on steelhead spawning conditions and aquatic invertebrate production. The more the rocks are buried by sediment, the less suitable it is for steelhead spawning and aquatic invertebrate production. The most apparent visual indication of sedimentation is the degree to which space between substrate rocks is filled by smaller sediment particles.

Table 2. Depth of Embeddedness Codes

Code	Criterion	Condition
0	None	Sediment absent, interstitial space open
1	1-25%	Light – sediment present, but interstitial space open
2	26-50 %	Moderate – significant clogging of interstitial space
3	51-75%	Heavy – interstitial space filled
4	76-100%	Severe – substrate rocks almost buried

- Parkinson visually estimated the percent surface fines within each habitat unit (Table 3). Fines are smaller (<2 mm) substrate particles that typically clog the space between the dominant substrate and reduce hydraulic roughness to the substrate's profile. Others have used particles as large as 8 mm as fines. Percent surface fines estimates the area within a habitat unit affected by fine sedimentation.

Table 3. Percent Surface Fines

Percent	Condition
None	Clean
1-25%	Light
26-50%	Moderate
51-75%	Heavy
76-100%	Severe

- Parkinson used the Wentworth substrate size classes to describe substrate (Table 4). Dominant substrate was the most abundant area in the habitat unit and subdominant rocks are the second most abundant area in the habitat unit.

TABLE 4. WENTWORTH SUBSTRATE SIZE CLASSIFICATION

Substrate Size Code	Description	Size in inches	Rough Equivalent Metric sizes
01	Organic		
02	Silt/Clay	<0.1	<1
03	Coarse Sand	0.1 to 0.2	2-4
04	Small Gravel	0.2 to 1	4-32
05	Medium Gravel	1 to 2	32-64
06	Large Gravel	2 to 3	64-90
07	Small Cobble	3 to 6	90-128
08	Medium Cobble	6 to 9	128-256
09	Large Cobble	9 to 12	256-300
10	Small Boulder	12 to 24	300-600
11	Large Boulder	>24	>600
12	Bedrock		

- Li made **Habitat Quality** assessments. These are visual evaluations of the physical interaction between streamflow, depth, velocity, cover, and substrate conditions (Kelley and Dettman 1980). David Dettman and/or Li used this technique to great success on the Carmel River, Lagunitas Creek, Soquel Creek, Zayante Creek in California, and the Tucannon River in Washington. Substrate roughness is the primary consideration of habitat quality in habitats with stream current. A rough substrate means a tall boundary layer near the substrate surface that provides a low stream velocity when water flows over it (Gordon *et al.* 1992).

This reduces a fish's energy expenditure while holding the feeding location (station) (Fausch 1984). The best substrate size for bed roughness for young-of-the-year steelhead is cobble; gravel is too small to create adequate roughness, and boulder is too large and becomes smooth to streamflow.

The best substrate size for benthic aquatic invertebrates is also cobble because sand or gravel are unstable and too small to provide optimal space, and boulder is too large and becomes smooth to streamflow. (Only specialized organisms adapted to laminar flow, such as black flies (Simuliidae), can live on boulders [Hydrozoology1981 The adverse effect of sediment deposition is a reduction of the roughness of substrate surface, which reduces boundary layer height, increases steelhead energy expenditure to maintain station, and/or reduces living space. A rough substrate will not have sediment clogging the space between rocks. Open interstitial space is required for high aquatic invertebrate production (Waters 1995). In addition, there should be sufficient current to deliver drift for fish to eat. Good in–stream cover also increases fish abundance. Habitat Quality is ranked in five grades, No habitat, poor, fair, good, and excellent. No habitat is given the value of zero and poor habitat is given the value of one. With each subsequent increase in habitat quality, the habitat grade doubles in value, thus, fair habitat is graded with a two and good habitat is graded with a four. The highest rated habitat, excellent habitat, is given the value of eight.

- Li described **primary bank components** in each habitat unit for both banks (left and right).

- Li described **bank slope** for both banks using a 30/60 right triangle as a reference. This is a rapid estimate intended to indicate relative steepness; it is not accurate to the nearest degree.

- Li rated **bank stability** for each bank within each habitat unit using criteria adapted from Platts *et al.* (1983) [Table 5].

Table 5. Bank Stability Code (Adapted from Platts et al. 1983).

Code	Criterion	Condition
1	0-25%	Streambank is stable; less than 25% is receiving any kind of stress; stress is light.
2	26-50%	At least 50% of the streambank is in a natural stable condition.
3	51-75%	Less than 50% of the streambank is in a natural stable condition.
4	76-100%	Less than 25% of the stream bank is in a stable condition.

- Li ranked Area Embeddedness within each habitat unit (Table 6). Area embeddedness is the degree to which dominant substrate is affected by finer substrate. This assessment is similar to percent surface fines, but is not limited to the fine size (<2 mm) category.

Table 6. Area Embeddedness Code

Code	Criterion	General Condition
0	None	Clean substrate – No sediment in habitat unit.
1	1-25%	Light – Sediment deposited only at edges of boundary.
2	26-50%	Moderate – Sedimentation apparent.
3	51-75%	Heavy – Habitat and food production greatly reduced.
4	76-100%	Severe - Habitat filled in and marginal.

- Observations of biological or fluvial geomorphological significance were noted.

RESULTS

Reach Comparisons

The habitat inventory survey occurred under late season low flow conditions on October 20, 21 and 30, 2008. Flow conditions remained essentially the same with streamflow estimated at 0.1 cubic feet per second (cfs).

Li and Parkinson assessed 6163 lineal feet of Mark West Creek from the Tar Water Bridge upstream just past NF Mark West Creek; this represented 154 habitat units between October 20 and October 30, 2008 (Table 7). The 10,000 cubic yard sediment release from the Cornell landslide has a significant effect on habitat conditions in the surveyed reach of upper Mark West Creek. There were four units that were dry; this was caused by excessive sediment deposition. Because they are dry, they cannot be identified as aquatic habitat.

Flat-water habitat types represented almost 39% of the portion of Mark West Creek we surveyed. Less than 20% was represented by falling-water habitat types and over 40% of the reach was represented by some form of flat-water within a falling gradient habitat type (Table 8). Therefore, over 79% of the reach is subject to sediment deposition during the recessional limb of the annual hydrograph.

Table 7. Summary of the habitat units and their frequency of occurrence during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008

Habitat Type	Frequency (number)	Cumulative Length (feet)	Mean Length (feet)	Mean Width (feet)	Mean Depth (feet)
Pool	045	2287	52.87	9.67	0.95
Run	003	0096	32.00	5.00	0.45
LGR	024	0727	30.79	3.41	0.27
HGR	017	0385	22.65	2.44	0.26
Cascade	011	0107	09.73	2.45	0.16
Pop	003	0130	43.33	3.83	0.50
Step-pop	009	0442	49.11	4.89	0.58
Step-run	011	0602	54.74	5.45	0.44
Step-pool	026	1330	51.15	6.48	0.99
DRY	004	0057	14.25	NA	0.00
Totals	154	6163	40.02	5.74	0.61

Table 8. Summary of habitat type proportions during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Flat-water habitats	= 38.67%
Pool	= 37.11%
Run	= 01.56%
Falling water habitats	= 19.78%
Low Gradient Riffle	= 11.80%
High Gradient Riffle	= 06.25%
Cascade	= 01.74%
Flat-water within falling gradient habitats	= 40.63%
Pocket Pool	= 02.11%
Step-pocket pool	= 07.17%
Step-run	= 09.77%
Step-pool	= 21.58%

We developed a preliminary relative elevation profile based upon periodic gradient measurements and estimates of gradient (Figure 1). The stream has a consistent gradient between 3% and 4%.

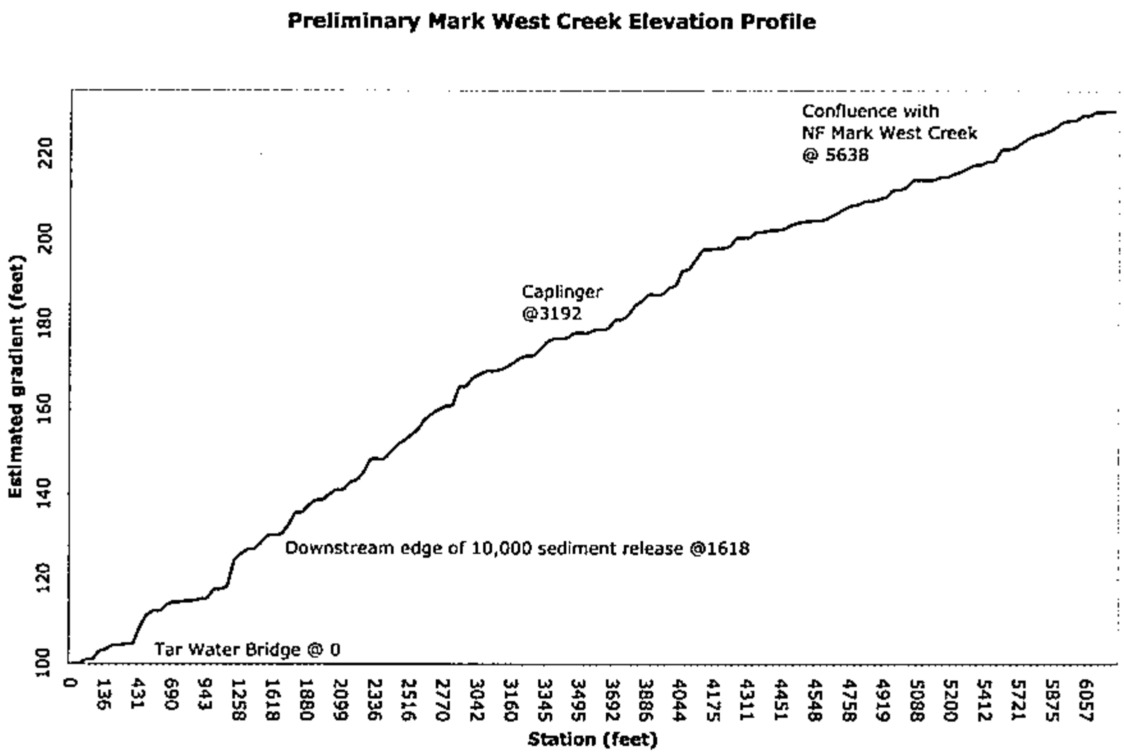

Figure 1. Initial elevation profile of upper Mark West Creek from Tar Water Bridge to upstream of NF Mark West Creek, October 2008.

We found evidence of the 10,000 cubic yard sediment release from its origin (Station 5638) into Mark West Creek 4020 feet downstream from confluence with NF Mark West Creek downstream to Station 1618 of this habitat survey. There were differences in the color of the released sediment and the stream substrate. There was a noticeable increase of boulder wakes. Boulder wakes are depositions of sediment caused by lack of stream velocity. Boulder wakes are indicative of high sediment loading. Stoss occurred. Stoss is an accumulation of a few coarse particles on the upstream side of a large particle (e.g. boulder); it is formed when a large obstacle comes to rest and one or more particles lean against the upstream side of it. Stoss occurs more commonly when sediment supply is high. We also made the unusual observation that substrate was higher in sediments upstream of the slide than downstream

Due to the size of the sediments Depth of Embeddedness was highest in DRY habitats. Step-habitats had higher me an embedded depths than runs, riffles, cascades, or pools. Cascades were low in embeddedness due to their higher gradients (Table 9).

Table 9. Depth of Embeddedness in the different habitat types during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Habitat Type	Mean Embedded Depth
Cascade	0.62
High gradient riffle	0.99
Low gradient riffle	1.00
Run	1.00
Pocket pool	1.00
Step-pool	1.13
Step-run	1.31
Step-pocket pool	1.43
Pool	1.49
Dry	4.00

Percent Surface Fines in each habitat unit were multiplied by its length so that their presence would be weighted by representation. Length was used as the affected parameter, rather than area, because it is more accurate; it is measured only once while width and depth require multiple measurements. Dry, Pool, and Step-pool habitats were the most adversely affected by fine sediment (Table 10).

Table 10. Effect of percent surface fines on habitat during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Habitat Type	Cumulative length fines weighted by length	Mean Percent affected by sediment
Cascade	002.79	002.61%
Pocket-pool	003.90	003.00%
High gradient riffle	012.65	003.29%
Low gradient riffle	025.30	003.48%
Step-pocket pool	036.32	008.22%
Run	009.92	010.33%
Step-run	074.09	012.31%
Step-pool	270.30	020.32%
Pool	927.40	040.55%
Dry	0	100.00%

We measured maximum depth and hydraulic control of each pool and step-pool to develop a preliminary residual pool depth analysis (Lisle and Hilton 1992) [Table 11]. Normally, such an index is used to monitor some activity that generates sediment and baseline conditions are pre-project. In this case, the residual pool depth index can be used to monitor the progress of returning upper Mark West Creek to an undisturbed state.

Table 11. Preliminary Residual Pool Depth Index (Lisle and Hilton 1992) based pools and step-pools in upper Mark West Creek, Sonoma County, California, October 2008.

Habitat Type (definition)	Frequency (n)	Mean Maximum Depth (feet)	Mean Hydraulic Control Control (feet)	Mean Residual Pool Depth (feet)
Pool	45	2.04	0.13	1.91
Step-pool	26	1.31	0.13	1.13

We developed mean area embeddedness for each habitat type that was weighted by length (Table 12).

Table 12. Mean area embeddedness for each habitat type during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Habitat Type	Mean Area Embeddedness
Run	1.63
Cascade	1.51
High gradient riffle	2.11
Low gradient riffle	2.35
Step-pocket-pool	2.80
Pool	2.91
Spool	3.17
Step-run	3.20
Pocket-pool	3.52
Dry	4.00

The amount of steelhead spawning gravel area was low (Table 13).

Table 13. Surface area of steelhead spawning gravels by habitat type during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Habitat Type	Spawning Gravel Area (square feet)	Cumulative Area Area (square feet)	Percent of Habitat Type (percent)
Pool	327	23353	1.40
Run	007	00510	1.37
Low gradient riffle	066	2649.2	2.49
High gradient riffle	000	0932.5	0
Cascade	000	0214	0
Pocket-pool	000	0519	0
Step-pocket-pool	000	2229.5	0
Step-run	005	3265.5	0.15
Step-pool	045	8869.5	0.51
Dry	000	No water	0.0

Habitat quality was mostly poor to fair. Step-pocket pool and Step-pools were fair. Pools were fair to good (Table 14).

Table 14. Summary of habitat quality weighted by representation during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Habitat Type	Cumulative Quality x length	Mean Quality	Habitat Grade
Pool	7774	3.40	fair to good
Step-pocket-pool	0955	2.16	fair
Step-pool	2793	2.10	fair
Run	0172	1.79	poor to fair
Pocket-pool	0228	1.75	poor to fair
Low gradient riffle	1225	1.69	poor to fair
Step-run	0972	1.61	poor to fair
High gradient riffle	0615	1.59	poor to fair
Cascade	0069	0.64	poor
Dry	0000	0.00	none

1. POOL SUMMARY

Pools are typically deep habitats with slow stream velocity (current). They collect sediments after the rain season and are deepened by scour from seasonal storms. Because their stream velocities are typically slow, the effect of sediment on substrate roughness is not as meaningful. However, sedimentation does adversely affect pools since deposition causes a reduction in their living space.

Pools were the dominant flat-water habitat in upper Mark West Creek. They were the most abundant habitat type in frequency or cumulative length. Pools were one of the longer (mean 52.87 feet), and deeper (mean 0.95 feet) habitat types. They were wider than any of the other habitats (mean 9.67 feet), and were also the deepest (2.2 feet), based on maximum depth measurements in pools and step-pools. Pools occurred throughout the surveyed reach from Tar Water Bridge upstream beyond the confluence with NF Mark West Creek (Figure 2). Pools had 19 different substrate combinations that ranged in size from sand to bedrock, reflecting the depositional character of pools during low streamflow conditions. Pools provide living space for steelhead, but do not produce much fish food. This lack of food production occurs because the invertebrates that live in pools are within the substrate and generally unavailable. In addition, the majority of aquatic invertebrates normally used as fish food require current to exist.

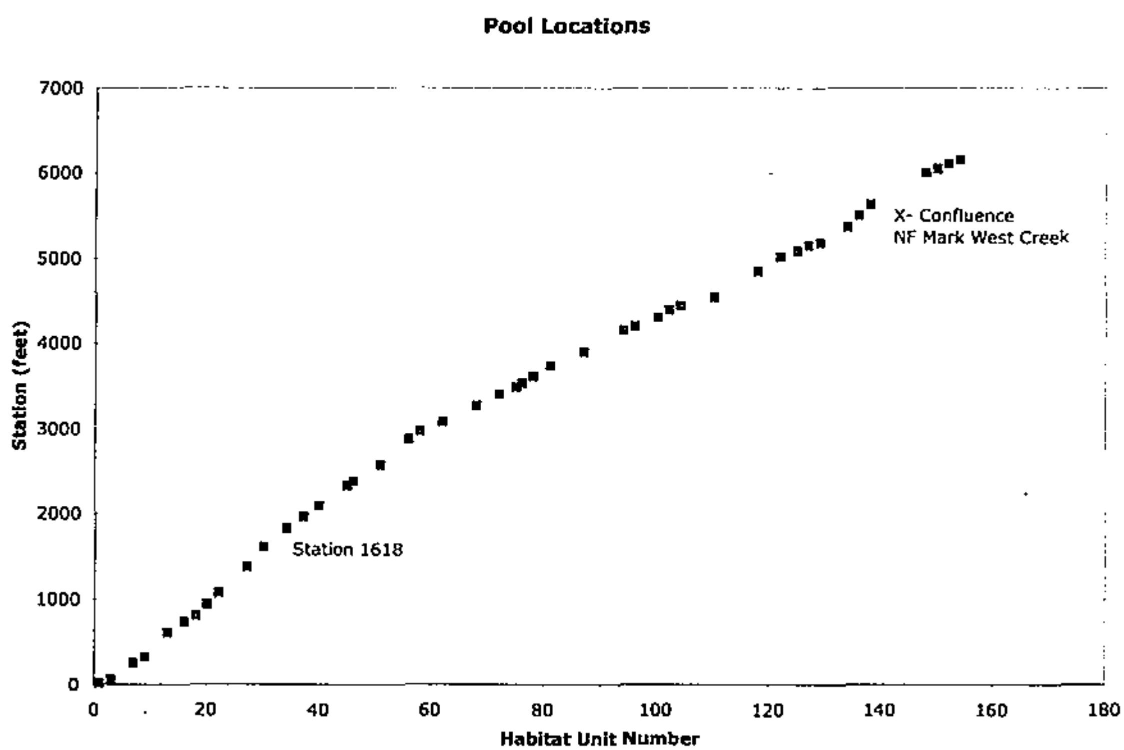

Figure 2. Occurrence of pools between Tar Water Bridge to just upstream of North Fork Mark West Creek in Mark West Creek, Sonoma County, California, October, 2008.

There were 19 different dominant/subdominant substrate combinations observed, ranging from bedrock to coarse sand for the dominant substrate. The most frequent was coarse sand and small gravel, which also covered the most pool length (Wentworth 3/4).The same size classes were in the 10,000 cubic yard sediment release (Table 15).

Table 15. Pool substrate composition during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Substrate Distribution Type Dominant/subdominant (Wentworth Scale)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)	Percent Larger Than
12/10	03	0088	003.58	03.58
12/7	01	0018	000.79	04.37
12/4	02	0053	002.32	06.69
11/3	01	0044	001.92	08.61
10/9	02	0105	004.59	013.20
10/7	01	0039	001.71	014.91
10/6	01	0040	001.75	016.66
9/10	01	0032	001.40	018.06
9/7	01	0056	002.45	020.51
9/4	01	0033	001.44	021.95
8/10	01	0098	004.29	026.24
7/9	01	0035	001.53	027.77
5/3	01	0071	003.10	030.87
4/10	02	0063	002.75	033.62
3/12	03	0196	008.57	042.19
3/10	03	0208	009.09	051.28
3/5	01	0040	001.75	053.03
3/4	18	0989	043.24	096.27
3/1	01	0079	003.45	100.00
Totals 19 = n	45	2287	100.00	

Pool banks were stable (Table 16); only 5.12% of the length and 6.67% by frequency had unstable ratings.

Table 16. Pool bank stability during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Left Bank/Right Bank Rank (Code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
1/1	37	082.22	1831	080.06
1/2	06	013.34	0307	013.42
2/2	01	002.22	0032	001.40
4/2	01	006.67	0117	005.12
Totals 4 = n	45	100.00	2287	100.00

The largest component of the banks (combined at 47.77% frequency and 59.33% length), was bedrock, followed by boulder (combined at 45.54% frequency and 36.75% length) (Table 17). There was one observation with bedrock, boulder, and rootwads. Half of that observation was assigned to bedrock/boulder and the other half to bedrock/rootwads.

Table 17. Pool bank components, during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Bank Components	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
Bedrock/Bedrock	08	017.78	0439	019.20
Bedrock/Boulder	06.5	014.44	0275.5	012.05
Bedrock/Redwood	01	002.22	0056	002.45
Bedrock/Rootwads	03.5	007.78	0159.5	006.97
Bedrock/Cobble	04	008.89	0173	007.56
Bedrock/Gravel Bar	02	004.44	0191	008.35
Bedrock/Vegetation	01	002.22	0063	002.75
Boulder,trees/Boulders,trees	03	006.67	0124	005.42
Boulders/Boulders	05	011.11	0134	005.86
Boulders, trees/Rootwads	01	002.22	0043	001.88
Boulder, roots/Cobble, roots	01	002.22	0098	004.29
Boulder, trees/Vegetation	01	002.22	0071	003.10
Boulder/Log	01	002.22	0024	001.05
Boulder/Gravel Bar	02	004.44	0071	003.10
Hardpan/Hardpan	01	002.22	0081	003.54
Cobble/Rootwads	01	002.22	0059	002.59
Vegetation/Vegetation	02	004.44	0107	004.68
Trees/ Slide Toe	01	002.22	0117	005.12
Totals 18 = n	45	100.00	2287	100.00

Depth of embeddedness was light to moderate in pools (Table 18). There was one observation where we could not discern whether the code was a 2 or a 3, so we assigned a value of 2.5.

Table 18. Pool depth of embeddedness during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Depth of Embeddedness (code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)	Weighted Length	Mean
1	28	062.22	1236	054.04	1236	
2	15	033.33	0919	040.18	1838	
2.5	1	002.22	0112	004.90	0280	
3	1	002.22	0020	000.87	0060	
Totals 4 = n	45	100.00	2287	100.00	3414	1.49

There were 26 different combinations of bank slope associated with pools. Two out of three bank pairs (left and right) had a slope of at least 45°. Slopes of the pool banks were steep (Table 19).

Table 19. Pool bank slopes during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Left Bank/Right Bank Slope Angle (degrees)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
	90/90	04	0175	007.65
	90/80	03	0191	008.35
	90/70	01	0073	003.19
	90/45	02	0088	003.85
	90/30	01	0079	003.45
	90/15	01	0045	001.97
	90/10	01	0012	000.52
	90/5	05	0258	011.29
	90/2	01	0040	001.75
	90/1	02	0152	006.65
	85/80	01	0015	000.66
	80/5	01	0067	002.93
	80/2	01	0061	002.67
	60/45	02	0092	004.02
	45/45	01	0081	003.54
	45/30	02	0035	001.53
	45/2	01	0063	002.75
	45/1	01	0037	001.62
	30/20	01	0056	002.45
	20/10	01	0117	005.12
	15/10	01	0050	002.19
	15/5	01	0019	000.83
	10/5	02	0137	005.99
	5/5	01	0032	001.40
	5/1	02	0157	006.86
	1/1	05	0155	006.78
Totals	28=n	45	2287	100.00

The area of most pools was heavily embedded (Table 20).

Table 20. Proportion of pool area covered by sediment during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008. Where 1 = 25% or less, 2 = 26% to 50%, 3 = 51%-75% and 4 = 76% to 100%.

Rank (code)	Frequency (Number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)	Mean
1	09	020.00	0500	21.86	
2	05	011.11	0288	12.59	
3	08	017.77	0422	18.45	
4	23	051.11	1077	47.09	
Totals	45	100	2287	100	2.91

One third of the pools and over 70% of the weighted length of pools had at least 70% of their surface area covered with fines. The value 0.03 was used for the <5% rating (Table 21).

Table 21. Distribution of percent surface fines in pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent Fines (%)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Cumulative Length (feet)	Weighed Length (feet)	Percent Weighted Length (%)
0.03	09	020.00	0402	017.58	012.06	001.30
0.05	01	002.22	0086	003.76	004.30	000.46
0.10	07	015.56	0267	011.67	026.70	002.88
0.15	04	008.89	0125	005.47	018.75	002.02
0.20	01	002.22	0059	002.58	011.80	001.27
0.30	03	006.67	0248	010.84	074.40	008.02
0.40	02	004.44	0118	005.16	047.20	005.09
0.50	01	002.22	0044	001.92	022.00	002.37
0.60	02	004.44	0086	003.76	051.60	005.56
0.70	04	008.89	0239	010.45	167.30	018.04
0.75	03	006.67	0149	006.52	111.80	012.05
0.80	05	011.11	0318	013.90	254.40	027.43
0.85	02	004.44	0126	005.51	107.10	011.55
0.90	01	002.22	0020	000.87	018.00	001.94
n = 14	45	100.00	2287	100.00	927.40	100.00
Mean Percent Weighted Length = 40.55%						

Pool areas were relatively free of sediment downstream of Station 1618 and were more highly embedded thereafter in the upstream direction (Figure 3).

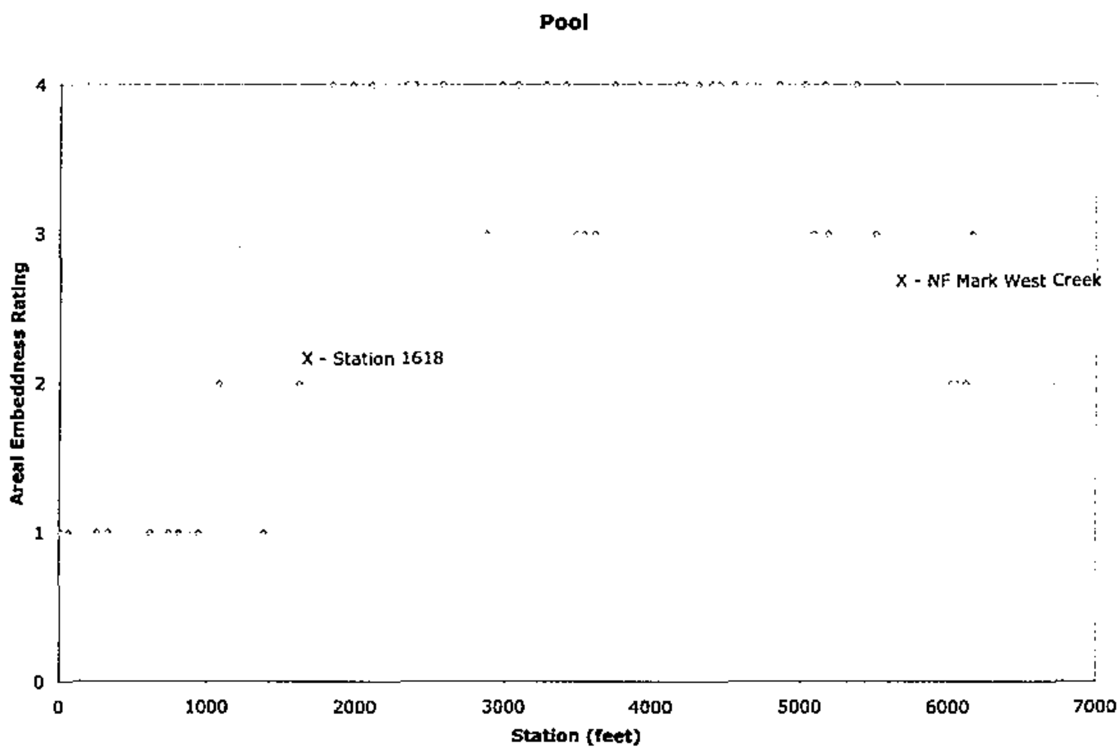

Figure 3. Longitudinal profile of area embeddedness in pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

The percent of surface fines in pools was lower prior to Station 1618 and was higher thereafter in the upstream direction (Figure 4).

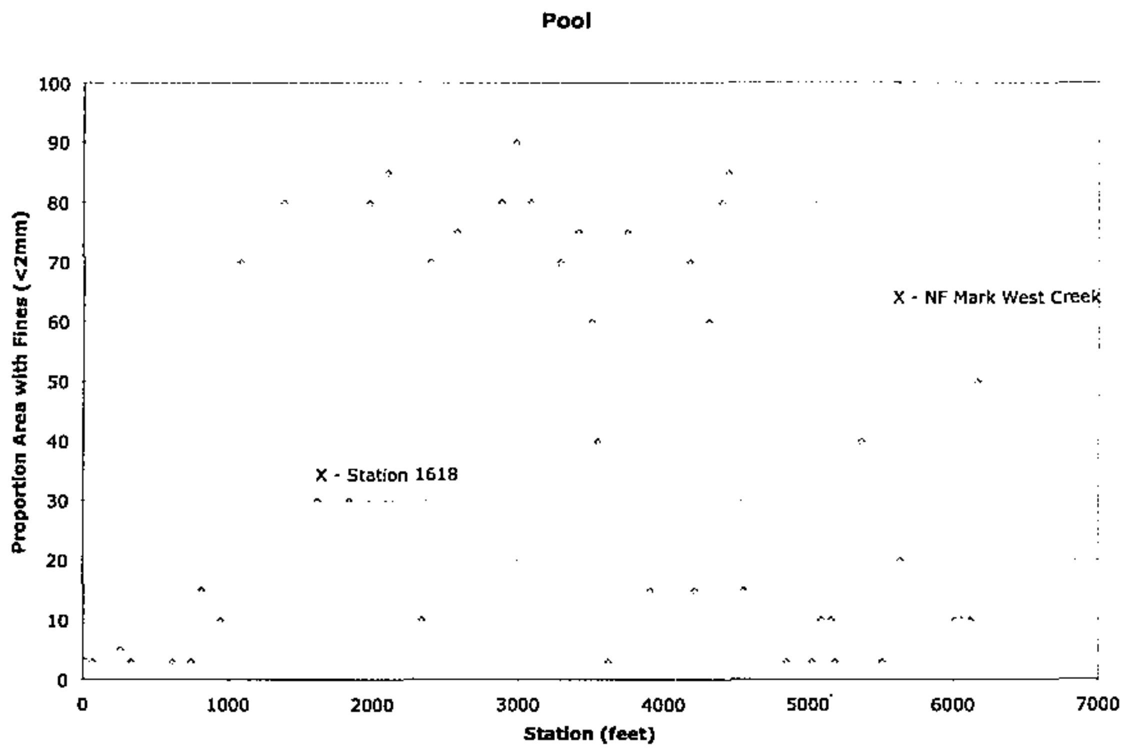

Figure 4. Longitudinal profile of percent surface fines in pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008

There was an increase in embeddedness depth in pools from station 1000 to station 5000 (Figure 5).

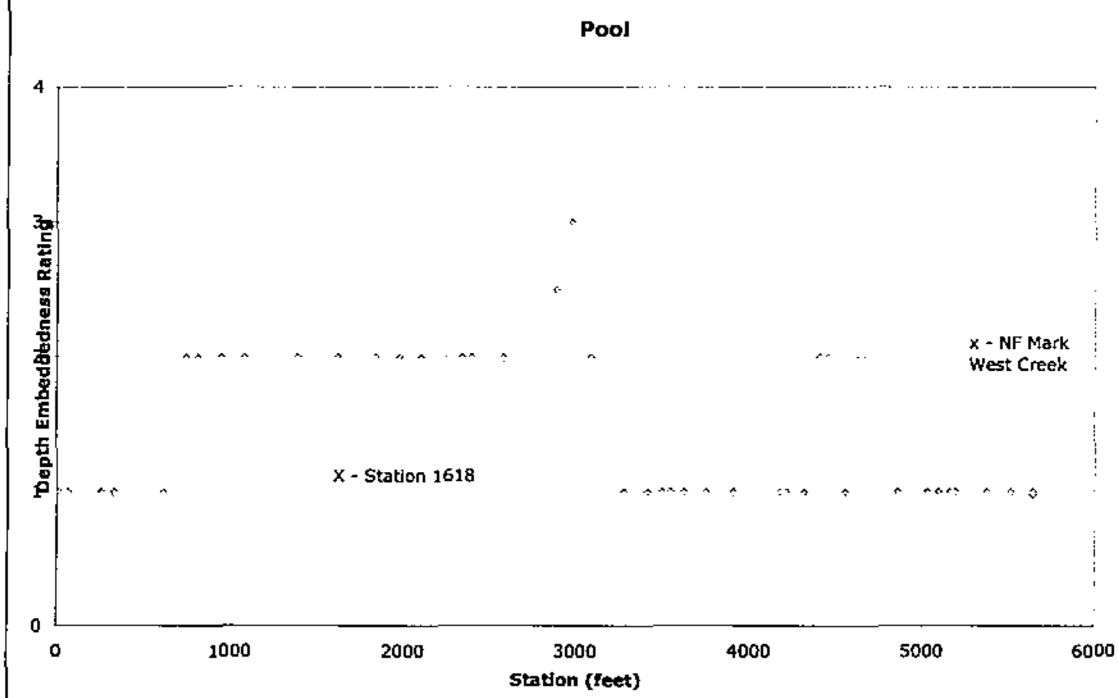

Figure 5. Longitudinal profile of depth embeddedness ratings in pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Habitat quality for pools was fair to good (Figure 6). There were some excellent habitat ratings within the sediment slug (upstream of station 1618). The adverse effects of sediment in pools are delayed until the living space is filled up.

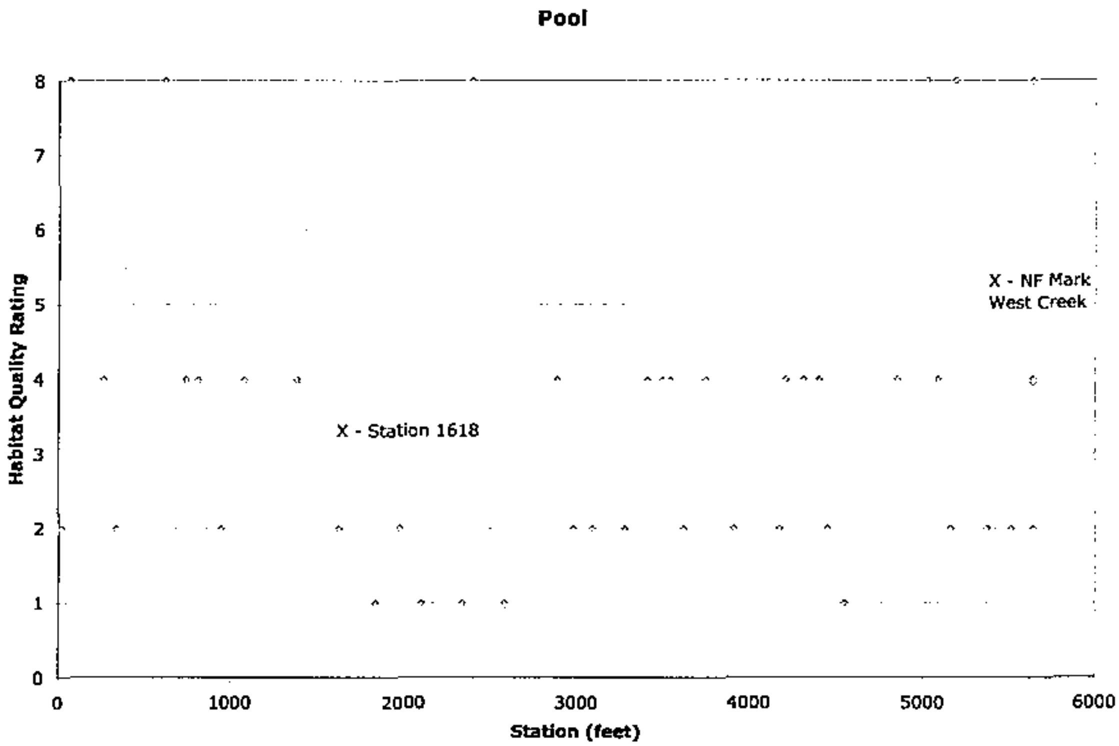

Figure 6. Longitudinal profile of habitat quality ratings for pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

2. STEP-POOL SUMMARY

A step-pool is a series of pools with vertical gradient breaks between the pools. The pools must be longer than the gradient breaks. It is the immediate vertical loss of elevation at the gradient breaks that allows flat-water habitat to occur within an area of sloping gradient. The flat-water portions of this habitat type are sensitive to sediment deposition during the recessional limb of the hydrograph, *i.e.,* the period of declining streamflow level. The most significant adverse effect of sedimentation is loss of living space, although there is can be loss of food production. A Step-pool is the most frequently occurring flat-water habitat within a sloping gradient in upper Mark West Creek. Step-pools are similar to pools. Like pools, they are relatively longer (Mean 51.15 feet) and relatively deeper (mean 0.99 feet) than other habitat types. Except for pools, step-pools are the widest habitat type (Mean 6.48). As habitat types, step-pools were second in depth (1.31 feet). Step-pools are less scoured in profile than pools; their mean depths were greater than pools, but their maximum depths were less. Typically, they have faster stream velocities than pools. Step-Pools occurred throughout the surveyed reach from Tar Water Bridge upstream beyond the confluence with NF Mark West Creek (Figure 7). There were 18 different substrate combinations; they ranged in size between sand and bedrock. Fish food may be produced in step-pools, provided there is some current moving through them.

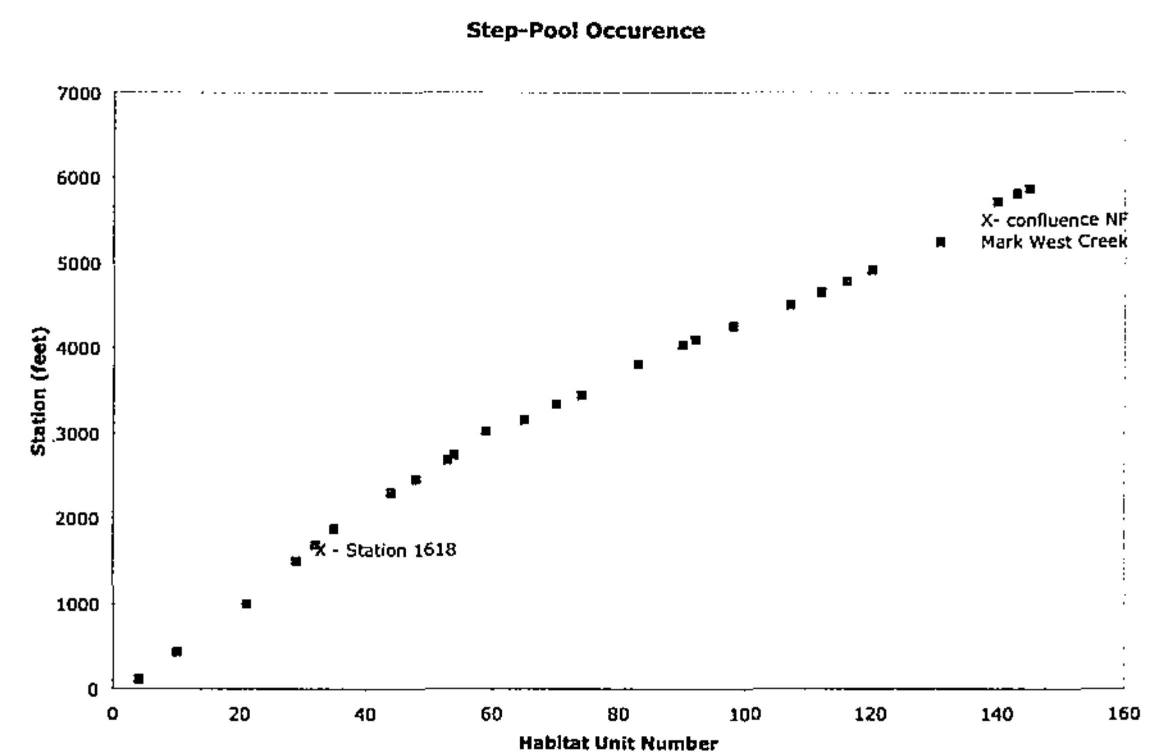

Figure 7. Step-pool occurrence from Tar Water Bridge to just upstream of NF Mark West Creek in upper Mark West Creek, Sonoma County, California, October 2008.

There were 18 different combinations of substrate for step-pools (Table 22).

Table 22. Step-Pool substrate composition during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Substrate Distribution Type Dominant/subdominant (Wentworth Scale)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)	Percent Larger Than
	12/12	01	0052	003.91	003.91
	12/10	01	0030	002.26	006.17
	12/4	01	0101	007.59	013.76
	11/10	01	0057	004,29	018.05
	10/12	01	0024	001.80	019.85
	10/9	02	0114	008.57	028.42
	10/8	02	0087	006.54	034.96
	10/7	01	0037	002.78	037.74
	10/3	02	0116	008.72	046.46
	9/10	02	0099	007.44	053.90
	8/10	01	0040	003.01	056.91
	8/9	01	0023	001.73	058.64
	7/3	02	0071	005.34	063.98
	4/9	01	0050	003.76	067.74
	4/3	01	0086	006.47	074.21
	3/10	03	0129	009.70	083.91
	3/4	02	0118	008.87	092.78
	3/2	01	0096	007.22	100.00
Totals	18 = n	26	1330	100.00	

The banks of step-pools were stable (Table 23).

Table 23. Step-Pool bank stability during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Left Bank/Right Bank Rank (Code)	Frequency (number)	Percent Occurrence (%)	Cumulative Length (feet)	Percent length (%)
1/1	15	057.69	0821	061.73
1/2	08	030.77	0351	026.39
1/4	02	007.70	0099	007.45
3/2	01	003.85	0059	004.44
4 = n	26	100.00	1330	100.00

Bedrock and boulder were the major bank components in step-pools (Table 24). There was one observation with boulder, bedrock and rootwad; half of its contribution was assigned to bedrock/boulder and the other half to bedrock/rootwad.

Table 24. Step-pool bank components during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Bank Components	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
Bedrock/Bedrock	6	023.80	0425	031.95
Bedrock/BR duff	1	003.85	0050	003.76
Boulders/Bedrock	5.5	021.15	0231	017.37
Bedrock/Root wad	2.5	009.62	0137	010.50
Bedrock/Bar	3	011.54	0137	010.50
Bedrock/Cobble	1	003.85	0034	002.56
Boulder/Boulder	1	003.85	0052	003.91
Boulder-RW/Bar	1	003.85	0059	004.44
Boulder/LWD	1	003.85	0024	001.80
Boulder/Bar	1	003.85	0057	004.29
Cobble/Redwood	1	003.85	0040	003.01
Vegetation/Boulders	1	00 3.85	0042	003.16
Slide/B-BR-RW	1	00 3.85	0042	003.16
Totals 13= n	26	100.00	1330	100.00

Embeddedness depth in step-pools was low to moderate (Table 25).

Table 25. Depth of embeddedness in Step-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Embeddedness Depth (code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)	Mean
1	20	076.92	1028	077.29 1028	
2	03	011.54	0134	010.08 0268	
3	03	011.54	0168	012.63 0204	
Totals 3 = n	26	100.00	1330	100.00	1.13

There were 15 different combinations of bank slope in step-pools (Table 26). Most of the banks were steep (73% were steeper than 45°).

Table 26. Step-pool bank slopes during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Left Bank/Right Bank slope angle (degrees)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
	90/90	04	0250	018.80
	90/80	01	0045	003.38
	90/60	01	0079	005.94
	90/10	06	0073	005.49
	90/5	01	0264	019.85
	90/1	04	0154	011.59
	70/10	01	0037	002.78
	60/45	01	0045	003.38
	25/15	01	0052	003.91
	25/5	01	0042	003.16
	15/10	01	0101	007.59
	10/1	01	0042	003.16
	5/2	01	0030	002.26
	2/0	01	0057	004.29
	1/1	01	0059	004.44
Totals	15 = n	26	1330	100.00

Most step-pool areas were adversely affected by sediment (Table 27).

Table 27. Proportion of step-pool area covered by sediment during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008. Where 1 = 25% or less, 2 = 26% to 50%, 3 = 51%-75% and 4 = 76% to 100%.

	Rank (code)	Frequency (Number)	Percent Occurrence	Cumulative Length (feet)	Percent Length	Mean
	1	04	15.38	252	18.95	
	2	01	3.85	50	3.76	
	3	06	23.07	246	18.50	
	4	15	57.69	782	58.80	
Totals		26	100	1330	100	3.17

Over 60% of the percent surface fines covered at least 30% of step-pools (Table 28).

Table 28. Distribution of percent surface fines in step-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent Fines (%)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Cumulative Length (feet)	Weighed Length (feet)	Percent Weighted Length (%)
0.03	09	034.62	0424	031.88	012.72	004.71
0.10	02	007.69	0099	007.44	009.90	003.66
0.15	04	015.38	0212	015.94	031.50	011.65
0.20	04	015.38	0191	014.36	038.20	014.13
0.25	01	003.85	0059	004.44	014.75	005.46
0.30	03	011.54	0141	010.60	042.30	015.65
0.40	01	003.85	0086	006.47	034.40	012.73
0.70	01	003.85	0039	002.93	027.30	010.10
0.75	01	003.85	0079	005.94	059.25	021.92
n = 9	26	100.00	1330	100.00	270.30	100.00

Mean percent weighted length = 20.32%

Area embeddedness was low downstream of Station 1618, but increased upstream of that location (Figure 8).

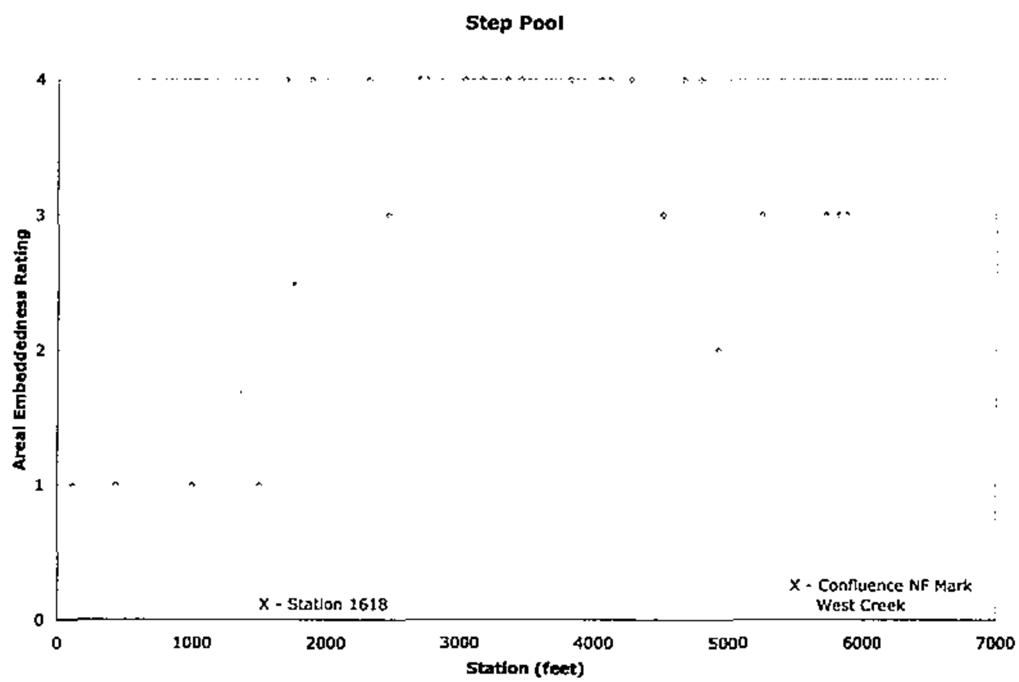

Figure 8. Longitudinal profile of area embeddedness in step-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent surface fines in step-pools was initially low, but increased noticeably upstream of Station 1618 (Figure 9).

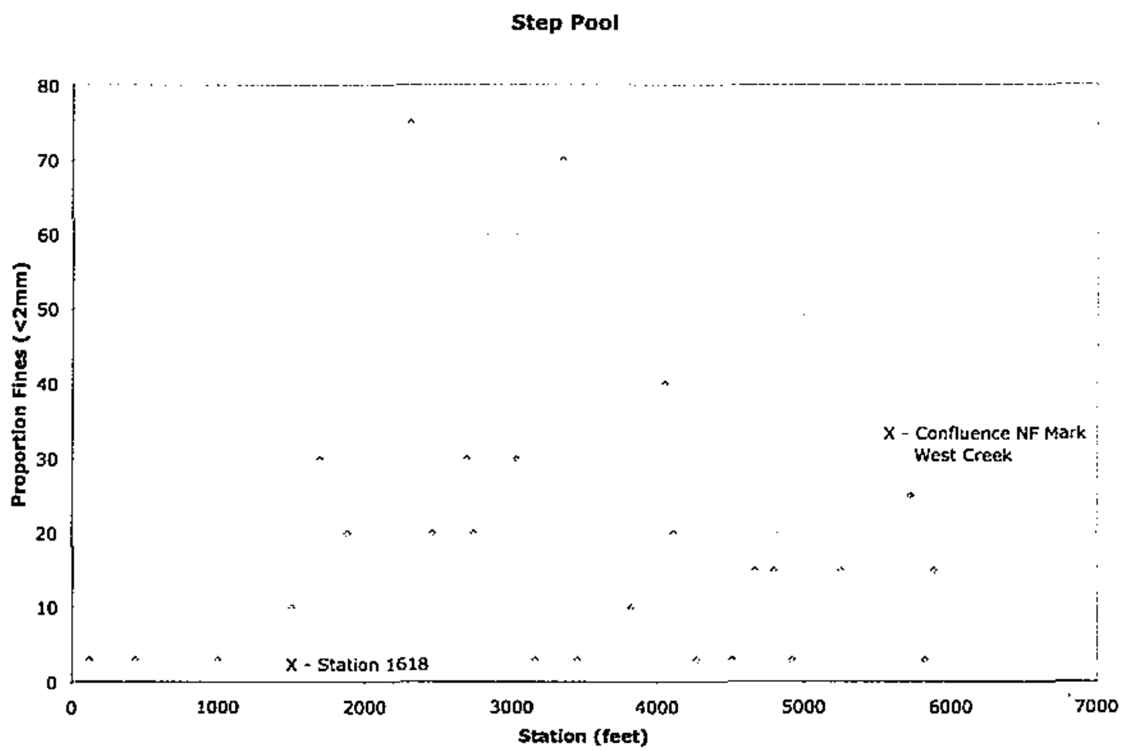

Figure 9. Longitudinal profile of step-pool percent surface fines during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

There was an increase in depth embeddedness upstream of station 1618 (Figure 10).

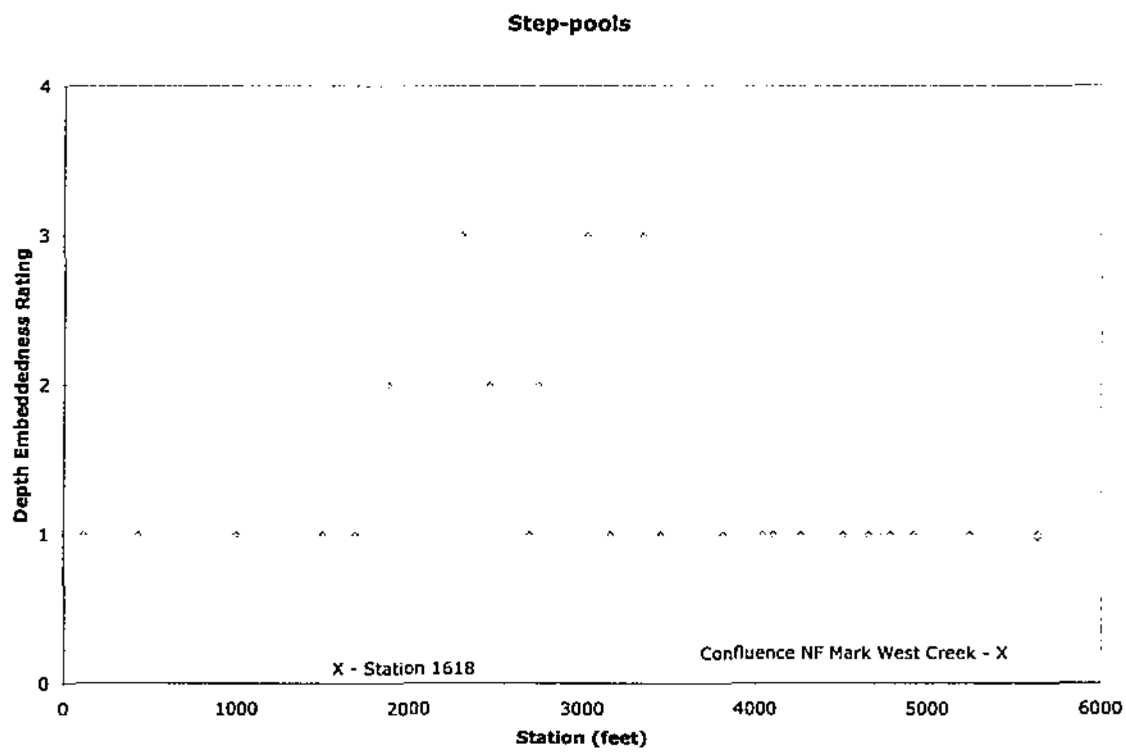

Figure 10. Longitudinal profile of depth embeddedness ratings in step-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Step-pool habitat quality was lower between Station 1000 and Station 5500 (Figure 11).

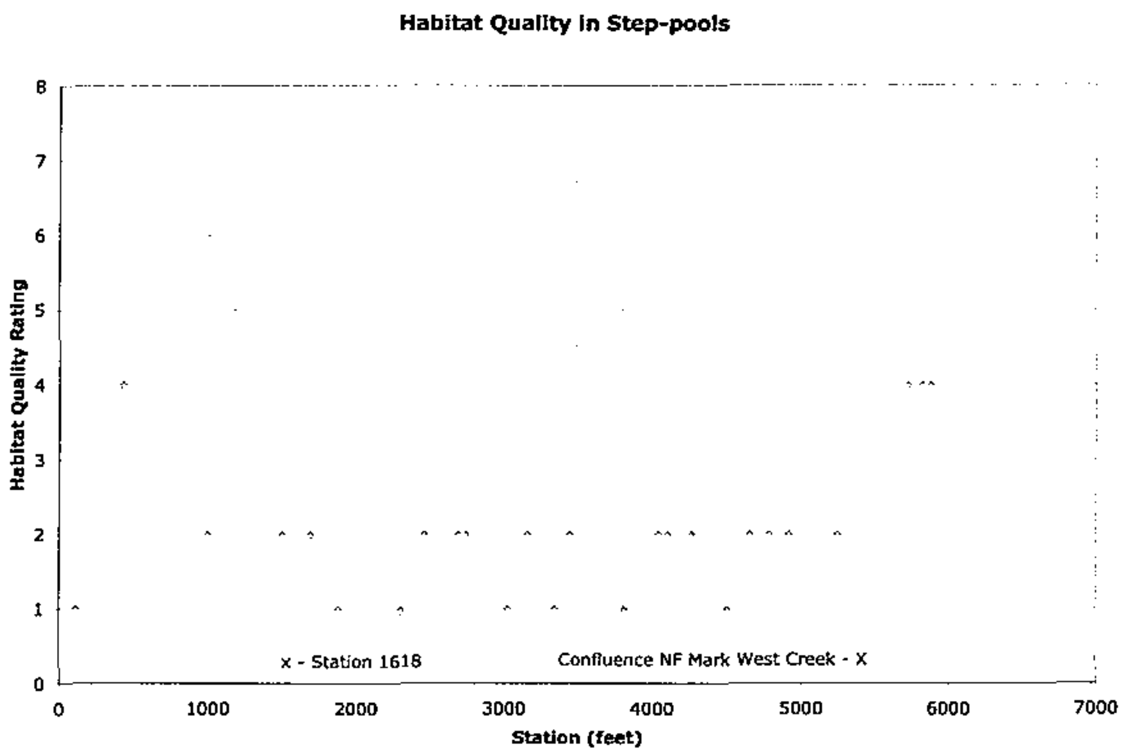

Figure 11. Longitudinal profile of habitat quality ratings in step-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

3. RUN SUMMARY

A run is a relatively deep habitat with flow. It is the intermediate between pool and riffle. A run does not scour during storms the way pools do and does not collect much sediment after the rains end. It does not have the gradient of a riffle and does not collect much bedload during the rain season. The greatest adverse effect of sediment on runs is the reduced roughness of the substrate. Another adverse effect is the filling of interstitial spaces used as habitat by aquatic invertebrates. In upper Mark West Creek, runs were shorter than the step-habitats and similar to riffle and cascade lengths (mean 32 feet), with a widths (mean 5.00 feet) and depths (mean 0.45 feet) similar to the step-habitats. There were only three runs in upper Mark West Creek; two of them occurred downstream of 10,000 cubic yard sediment release (Figure 12). Sediment related assessments are under-estimated in relation to this habitat type, compared with the other, more numerous habitat types in the sediment affected reach. Aquatic invertebrates can be supported in runs if the substrate is gravel to cobble sized, and there is current through the run.

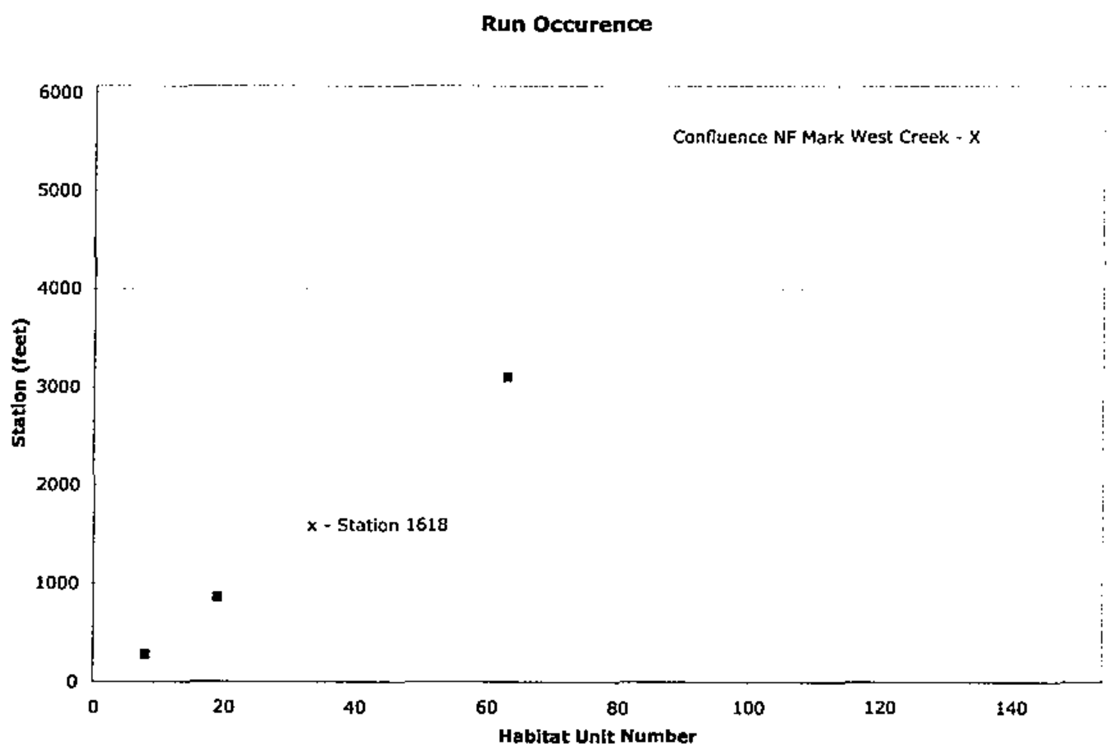

Figure 12. Occurrence of run habitats from Tar Water Bridge to upstream of NF Mark West Creek during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Run substrates were typically large without sediment influence, but were small (Wentworth 3/5) within the sediment release zone (Table 29).

Table 29. Run substrate composition during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Substrate Distribution Type Dominant/subdominant (Wentworth Scale)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
12/5	1	24	025.00
10/9	1	52	054.17
3/5	1	20	020.83
Totals 3=n	3	96	100.00

Run banks were stable (Table 30).

Table 30. Run bank stability during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Left Bank/Right Bank Rank (Code)	Frequency (number)	Percent Occurrence (%)	Cumulative Length (feet)	Percent length (%)
1/1	3	100	96	100

Bedrock was a major component of run banks (Table 31).

Table 31. Run bank components during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Bank Components	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
Bedrock/Bedrock	1	33.33	20	020.83
Bedrock/Trees	1	33.33	24	025.00
Vegetation Boulders	1	33.33	52	054.17
Totals 3 = n	3	99.99	96	100.00

Depth of embeddedness in runs was light (Table 32).

Table 32. Depth of embeddedness in runs during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Embeddedness Components (code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
1	3	100.00	96	100.00

Run bank slopes were steep (Table 33).

Table 33. Run bank slopes under low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Left Bank/Right Bank slope angle (degrees)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
	90/45	1	20	20.83
	45/25	1	52	54.17
	15/5	1	24	25
Totals 3 = n		3	96	100

Two of the three runs were downstream of the 10,000 cubic yard sediment spill, so sedimentation relative to the other habitat types is under-represented (Table 34).

Table 34. Proportion of run area covered by sediment during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008. Where 1 = 25% or less, 2 = 26% to 50%, 3 = 51%-75% and 4 = 76% to 100%.

	Rank (code)	Frequency (Number)	Cumulative Length (feet)	Mean
	1	2	76	
	4	1	20	
Totals		3	96	1.63

Table 35. Distribution of percent surface fines in runs during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.						
Percent Fines (%)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Cumulative Length (feet)	Weighed Length (feet)	Percent Weighted Length (%)
0.03	1	033.33	24	025.00	0.72	007.26
0.10	1	033.33	52	054.17	5.20	052.42
0.20	1	033.33	20	020.83	4.00	040.32
n = 3	3	100.00	96	100.00	9.92	100.00
Mean [percent surface fines of weighted length] = 10.33%						

The two downstream runs are not under the influence of the 10,000 cubic yard sediment spill, consequently their area embeddedness is low (Figure 13).

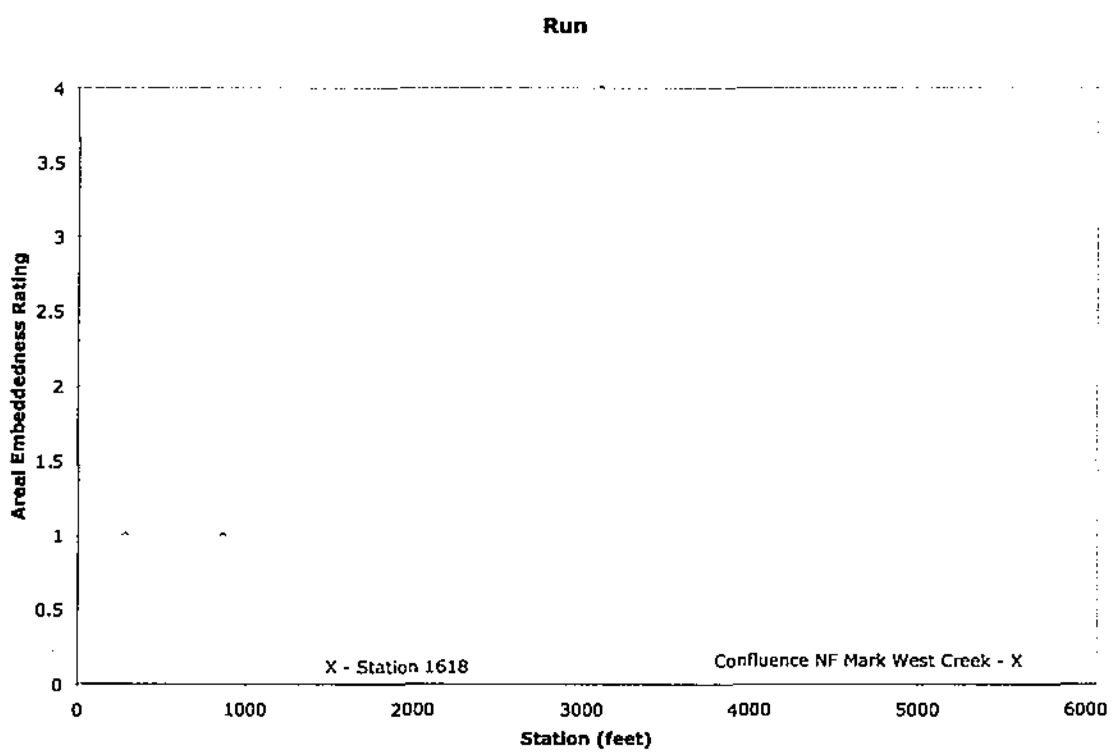

Figure 13 Longitudinal profile of area embeddedness in runs in upper Mark West Creek, Sonoma County, California, October 2008.

The two downstream runs are not under the influence of the 10,000 cubic yard sediment spill; as a result, their percent surface fines are low (Figure 14).

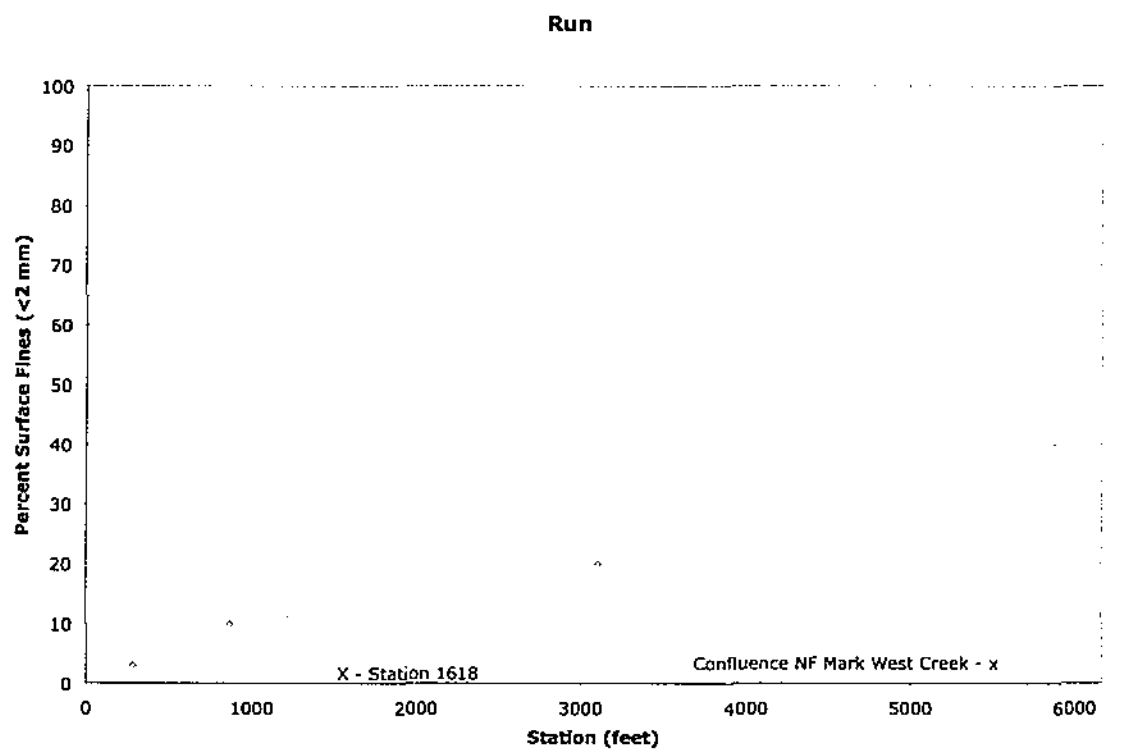

Figure 14. Longitudinal profile of percent surface fines in runs during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Depth embeddedness was low in runs (Figure 15).

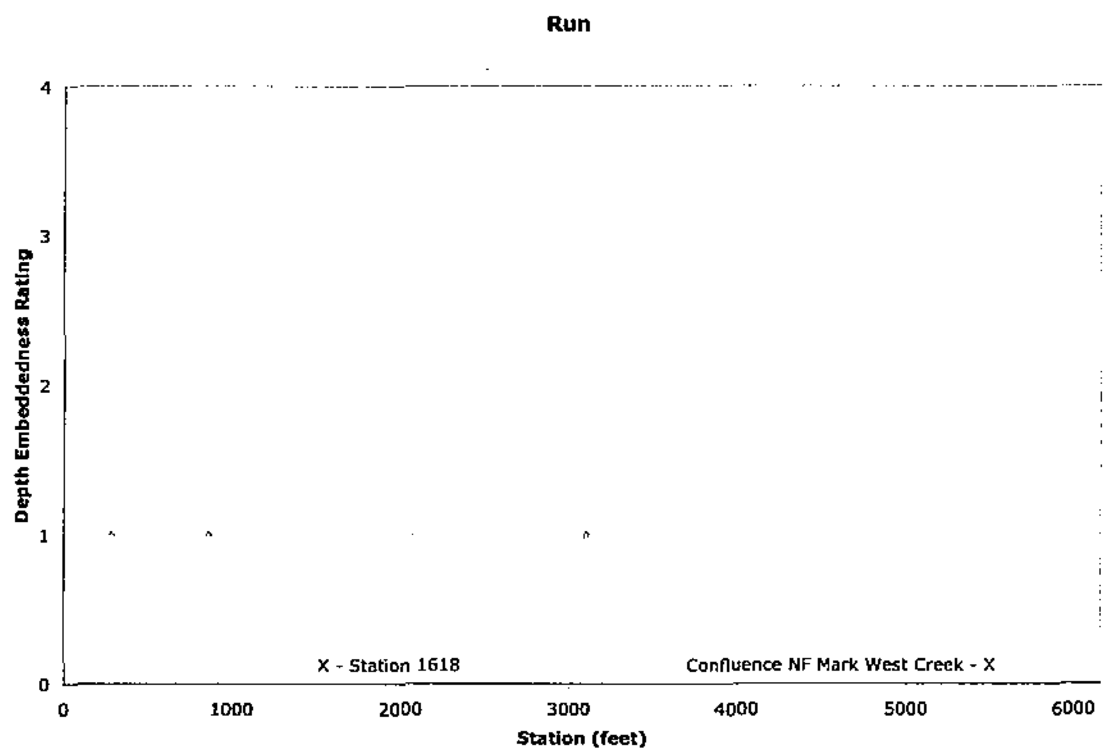

Figure 15. Longitudinal profile of depth embeddedness ratings in runs during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Runs had poor to fair habitat quality (Figure 16).

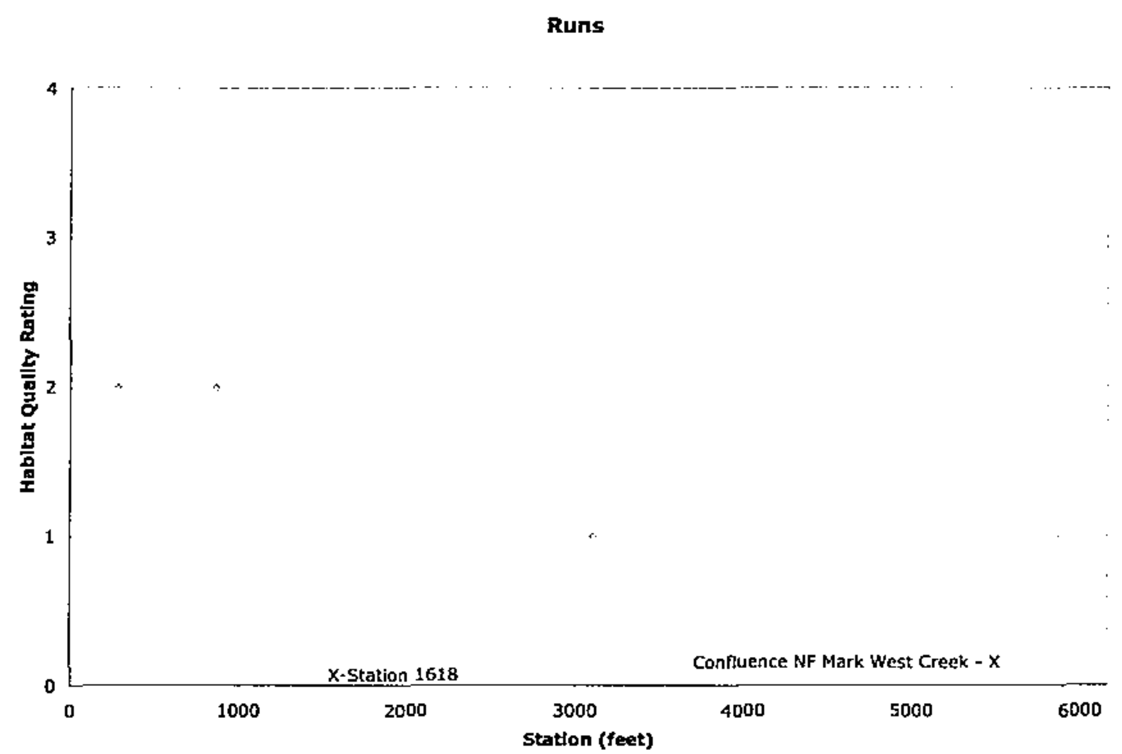

Figure 16. Longitudinal profile of habitat quality ratings in runs during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

4. STEP-RUN SUMMARY

A step-run is a flat-water habitat within a sloping gradient. It is a series of runs with a vertical gradient break between each run. A gradient break provides an immediate vertical loss in elevation. The run portion of the habitat must be longer than the gradient breaks. Sedimentation reduces roughness in the run portion. This affects station holding, juvenile steelhead abundance, and aquatic invertebrate production. In upper Mark West Creek, step-runs were longer (mean 54.74 feet *v.* mean 32.00 feet), wider (mean 5.45 feet *v.* mean 5.00 feet) and almost as deep as runs (mean 0.44 feet *v.* mean 0.45 feet). Step-runs were the shallowest of the step-habitats; they occurred mostly in the lower half of the surveyed reach (Figure 17). There were eight different substrate combinations, ranging from large gravel to bedrock. Some step-runs may produce aquatic invertebrates, if the substrate is sized between gravel and cobble, and there is current through the habitat.

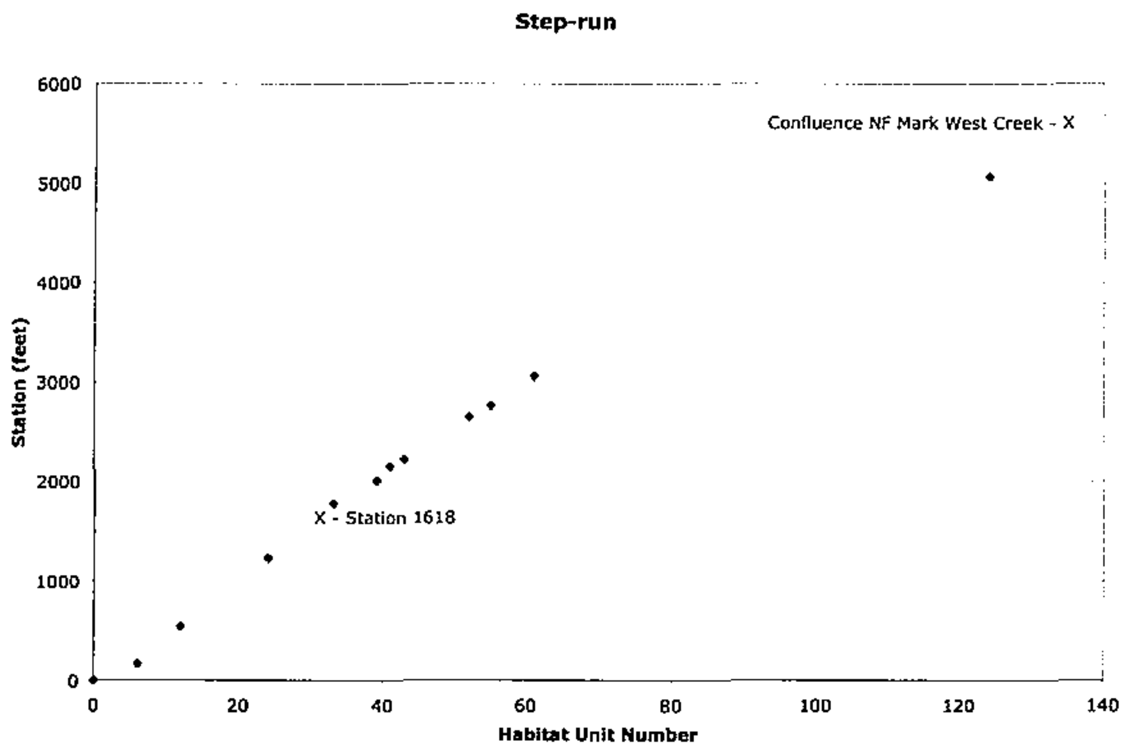

Figure 17. Occurrence of step-run from Tar Water Bridge to just upstream of NF Mark West Creek in upper Mark West Creek, Sonoma County, California, October 2008.

Step-runs were composed of larger substrate (Table 36).

Table 36. Step-Run substrate composition during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Substrate Distribution Type Dominant/subdominant (Wentworth Scale)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)	Percent Larger Than
	12/10	02	185	030.73	030.73
	12/7	01	029	004.82	035.55
	10/9	01	034	005.65	041.20
	10/7	02	065	010.80	052.00
	10/3	01	093	015.45	067.45
	9/3	01	027	004.49	071.94
	7/9	02	139	023.09	095.03
	6/10	01	030	004.98	100.00
Totals	8 = n	11	602	100.00	

Step-run banks were stable (Table 37).

Table 37. Step-run bank stability during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Left Bank/Right Bank Rank (Code)	Frequency (number)	Percent Occurrence (%)	Cumulative Length (feet)	Percent Length (%)
	1/1	10	090.91	573	095.18
	1/2	01	009.09	029	004.82
Totals	2 = n	11	100.00	602	100.00

Bedrock was the dominant bank component of step-runs (Table 38).

Table 38. Step-run bank components during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Bank Components	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
Bedrock/Bedrock	05	045.45	275	045.68
Bedrock/Bedrock-rootwad	01	009.09	030	004.98
Boulder/Bedrock-rootwad	01	009.09	125	020.76
Bedrock/cobble	01	009.09	029	004.82
Boulder-Vegetation/Bedrock	01	009.09	078	012.96
Boulder-trees/boulder-trees	02	018.18	065	010.80
Totals 6 = n	11	100.00	602	100.00

Embeddedness depth in step-runs was light to moderate (Table 39).

Table 39. Depth of embeddedness in step-runs during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Embeddedness Depth (code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)	Weighted Length	Mean
1	08	072.73	417	069.27	417	
2	03	027.27	185	030.73	370	
Totals 2 = n	11	100.00	602	100.00	787	1.31

Bank slopes were generally steep (Table 40).

Table 40. Step-run bank slopes during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Left Bank/Right Bank slope angle (degrees)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
	90/90	1	60	9.97
	90//85	1	93	15.45
	90/80	1	27	4.49
	90/60	1	61	10.13
	90/15	1	78	12.96
	75/5	1	30	4.98
	60/30	1	125	20.76
	45/45	1	34	5.65
	45/5	1	29	4.82
	5/5	2	65	10.8
Totals	10=n	11	602	100

Step-run areas were generally covered by sediment (Table 41).

Table 41. Proportion of step-run area covered by sediment during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008. Where 1 = 25% or less, 2 = 26% to 50%, 3 = 51%-75% and 4 = 76% to 100%.

	Rank (code)	Frequency (Number)	Cumulative Length (feet)	Percent Length (%)	Mean
	1	02	068	011.30	
	2	01	125	020.76	
	3	01	029	004.82	
	4	07	380	063.12	
Totals		11	602	100.00	3.20

Over 55% of step-runs had percent surface fines greater than 15% (Table 42).

Table 42. Distribution of percent surface fines in step-runs during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent Fines (%)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Cumulative Length (feet)	Weighed Length (feet)	Percent Weighted Length (%)
0.03	02	018.18	063	010.47	01.89	002.55
0.05	01	009.09	034	005.65	01.70	002.29
0.10	05	045.45	291	048.34	29.10	039.28
0.15	02	018.18	121	020.10	18.15	024.50
0.25	01	009.09	093	015.45	23.25	031.38
5 = n	11	100.00	602	100.00	74.09	100.00

Mean Percent Surface Fines in weighted length = 12.31%

Step-runs areas were typically filled with sediment upstream of Station 1618 and only lightly sedimented downstream (Figure 18).

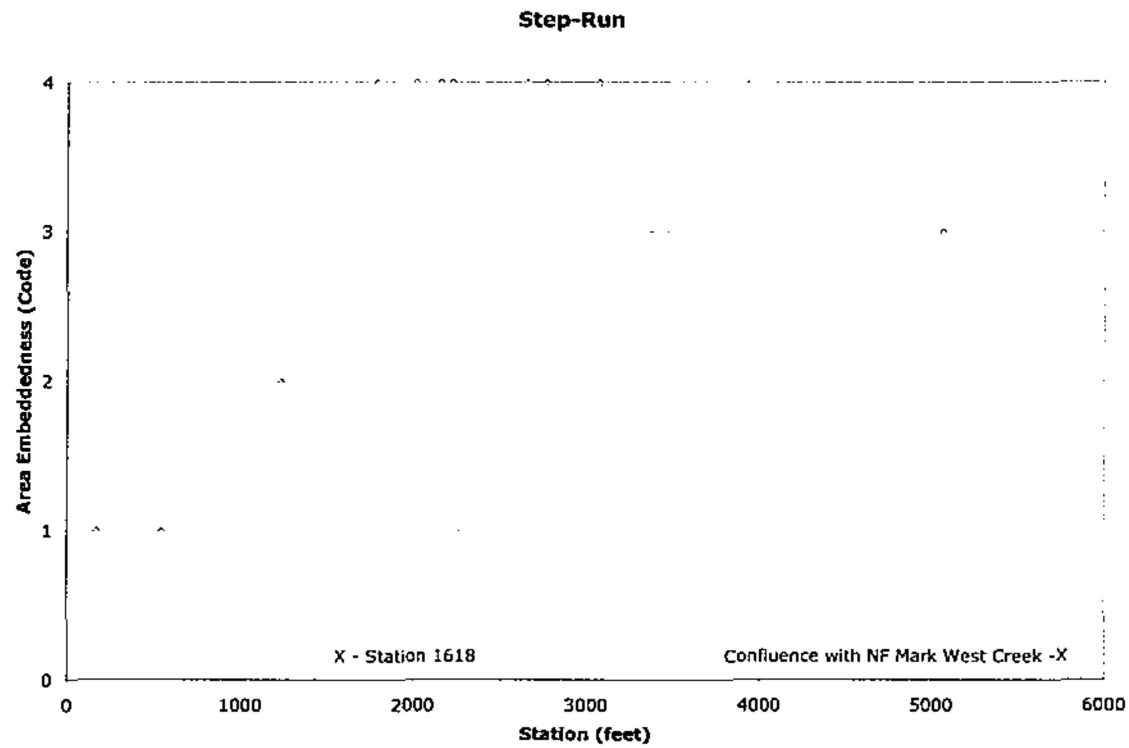

Figure 18. Longitudinal profile of area embeddedness in step-runs during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent surface fines (<2mm) was typically higher upstream of Station 1618 (Figure 19).

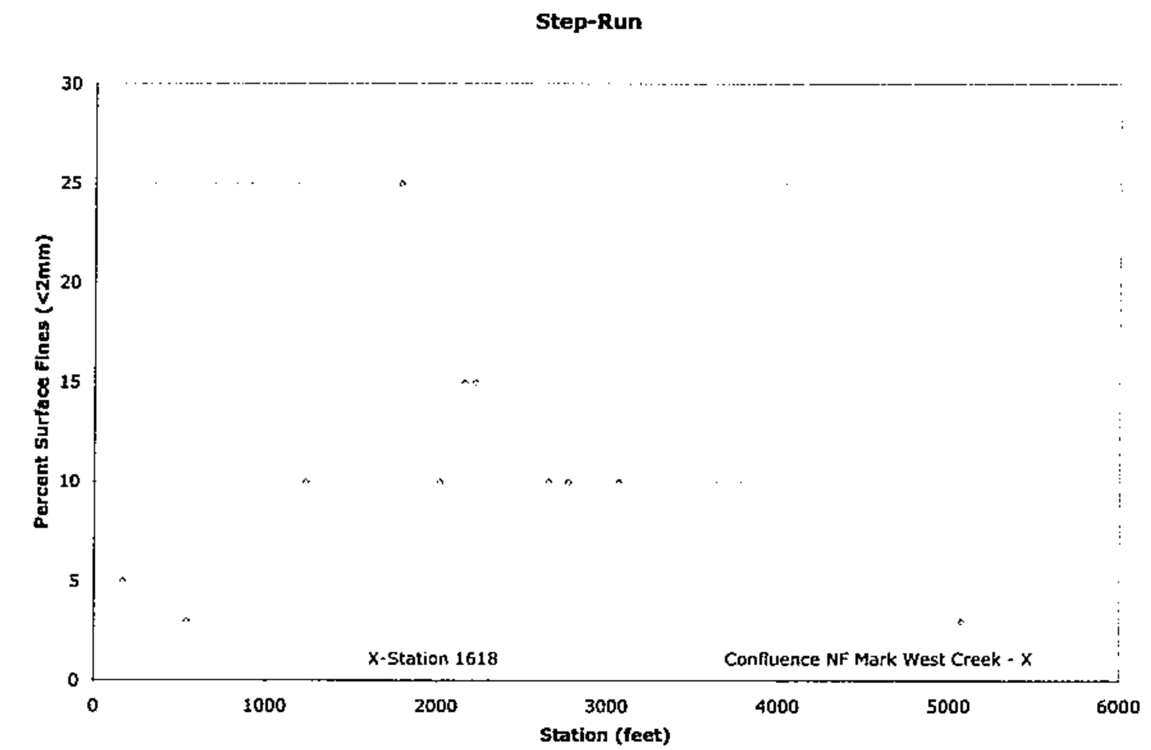

Figure 19. Longitudinal profile of percent surface fines in step-runs during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

There was an increase in depth embeddedness upstream of Station 1618 (Figure 20).

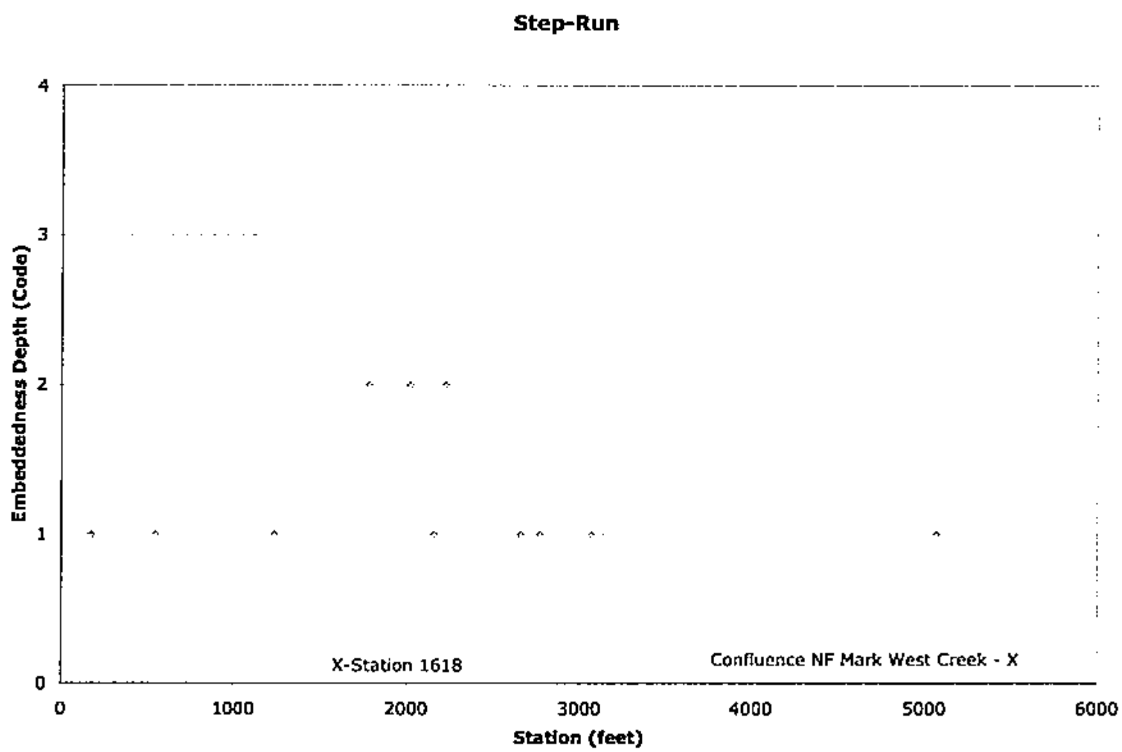

Figure 20. Longitudinal profile of depth embeddedness ratings during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Step-run habitat quality was fair (Figure 21).

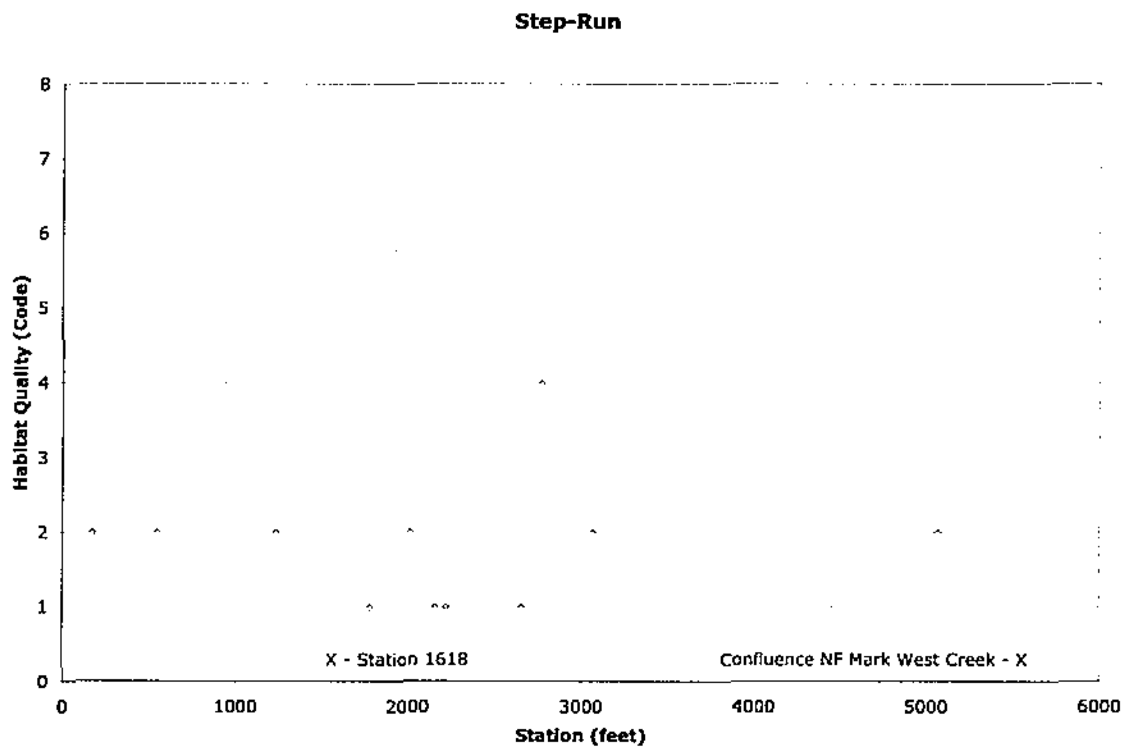

Figure 21. Longitudinal profile of habitat quality ratings during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

5. POCKET-POOL SUMMARY

In order for pocket-pools to form, there must be stream current and large obstructions. These conditions result in pockets of quiet water behind the obstructions, hence, the synonym pocketwater for pocket-pool. The quiet water does not occupy the entire width of the stream channel; there must also be flow between the obstructions. Pocket-pools in upper Mark West Creek are less than 50 feet long (Mean 43.33 feet), which makes them shorter than any of the step-habitats. They are less than 4 feet wide. This makes them narrower than any of the step-habitats, but wider than the riffles or cascades. Although they are shallower than any other pool (about half a foot), they are deeper than riffles or cascades. However, we only surveyed three pocket pools, so these generalities may also be the result of low representation (Figure 22). All pocket-pools occurred within the 10,000 cubic yard sediment plume. Pocket-pools generally provide habitat for both aquatic invertebrates and steelhead.

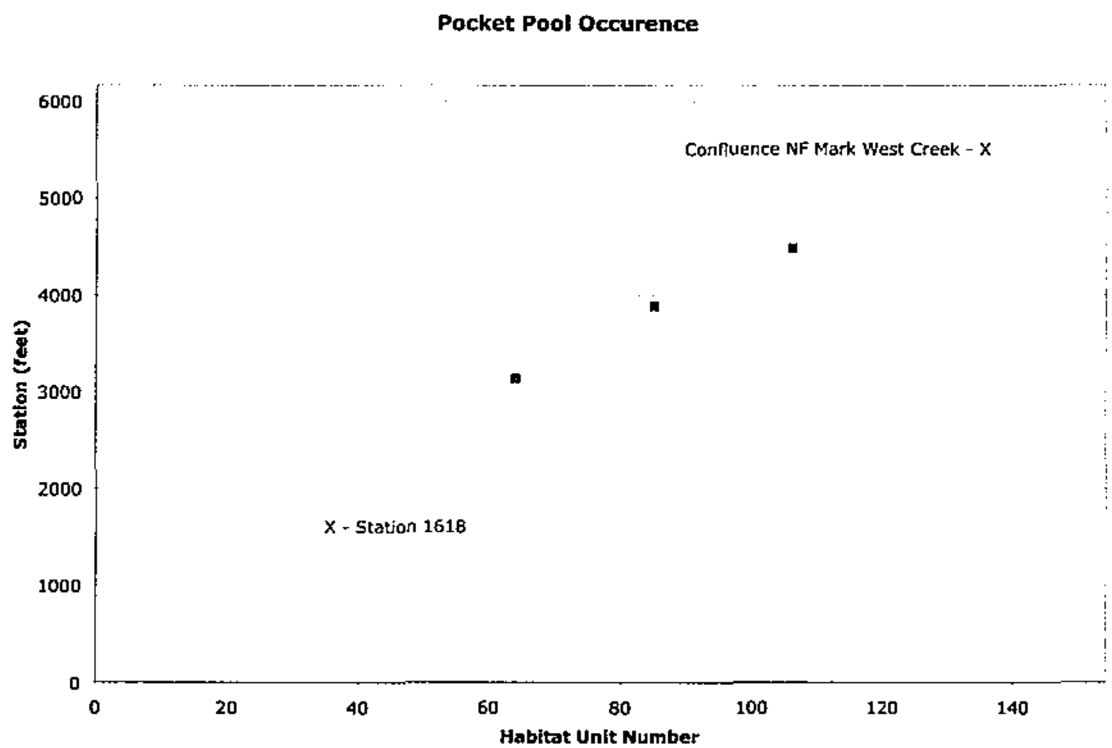

Figure 22. Occurrence of pocket-pools from Tar Water Bridge to just upstream of NF Mark West Creek during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Pocket-pool substrate tends toward the larger sizes (Table 43).

Table 43. Pocket-pool substrate composition during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Substrate Distribution Type Dominant/subdominant (Wentworth Scale)	Frequency (number)	Cumulative Length (feet)	Percent (%)
12/10	1	032	024.62
10/9	1	062	047.69
5/3	1	036	027.69
Totals 3 = n	3	130	100.00

Pocket-pool banks were stable (Table 44).

Table 44. Pocket-pool bank stability during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Left Bank/Right Bank Rank (Code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
1/1	2	066.67	094	072.31
2/1	1	033.33	036	027.69
Totals 2 =n	3	100.00	130	100

Bedrock was a major component of pocket-pool banks (Table 45).

Table 45. Pocket-pool bank components during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Bank Components (description)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
Bedrock/Bedrock	1	33.33	032	024.62
Bedrock/boulder	1	33.33	062	047.69
Bedrock/Bar	1	33.33	036	027.69
Totals 3 = n	3	99.99	130	100.00

Embeddedness depth in pocket-pools was light (Table 46).

Table 46. Depth of embeddedness in pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Embeddedness Depth (code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
1	3	100.00	130	100.00

Pocket-pool bank slopes were typically steep (Table 47).

Table 47. Pocket-pool bank slopes during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Left Bank/Right Bank slope angle (degrees)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
	90/40	1	062	047.69
	90/1	2	068	052.31
Totals	2=n	3	130	100

All pocket-pools occurred within the 10,000 cubic yard sediment plume, upstream of Station 1618, so all the areas were heavily embedded (Table 48).

Table 48. Proportion of pocket-pool area covered by sediment during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008. Where 1 = 25% or less, 2 = 26% to 50%, 3 = 51%-75% and 4 = 76% to 100%.

	Rank (code)	Frequency (Number)	Cumulative Length (feet)	Mean
	1	0	0	
	2	0	0	
	3	1	62	
	4	2	68	
Totals		3	130	3.52

Percent surface fines in pocket-pools was 3% (Table 49).

Table 49. Distribution of percent surface fines in pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent Fines (%)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Cumulative Length (feet)	Weighed Length (feet)	Percent Weighted Length (%)
0.03	3	100.00	130	100.00	3.9	100.00
n = 1	3	100.00	130	100.00	3.9	100.00

Mean percent surface fines weighted length = 3%

All pocket pools were within the 10,000-yard sediment plume; consequently, their area embeddedness was high (Figure 23).

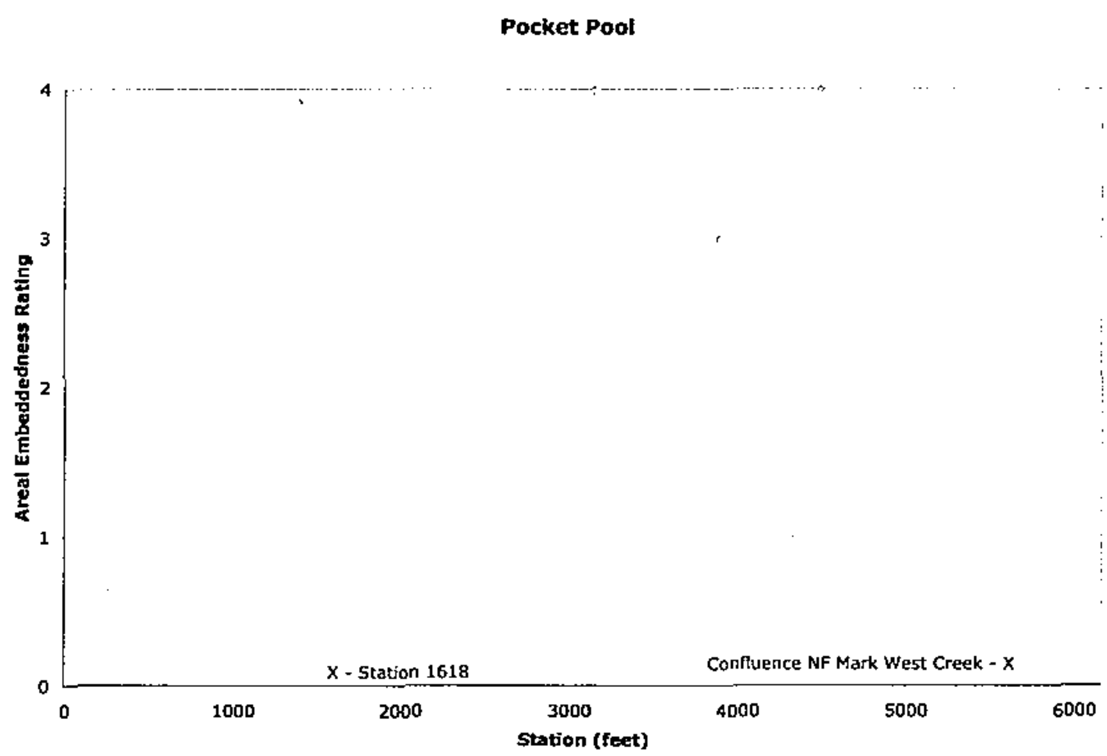

Figure 23. Longitudinal profile of area embeddedness in pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent surface fines in pocket-pools were small (Figure 24).

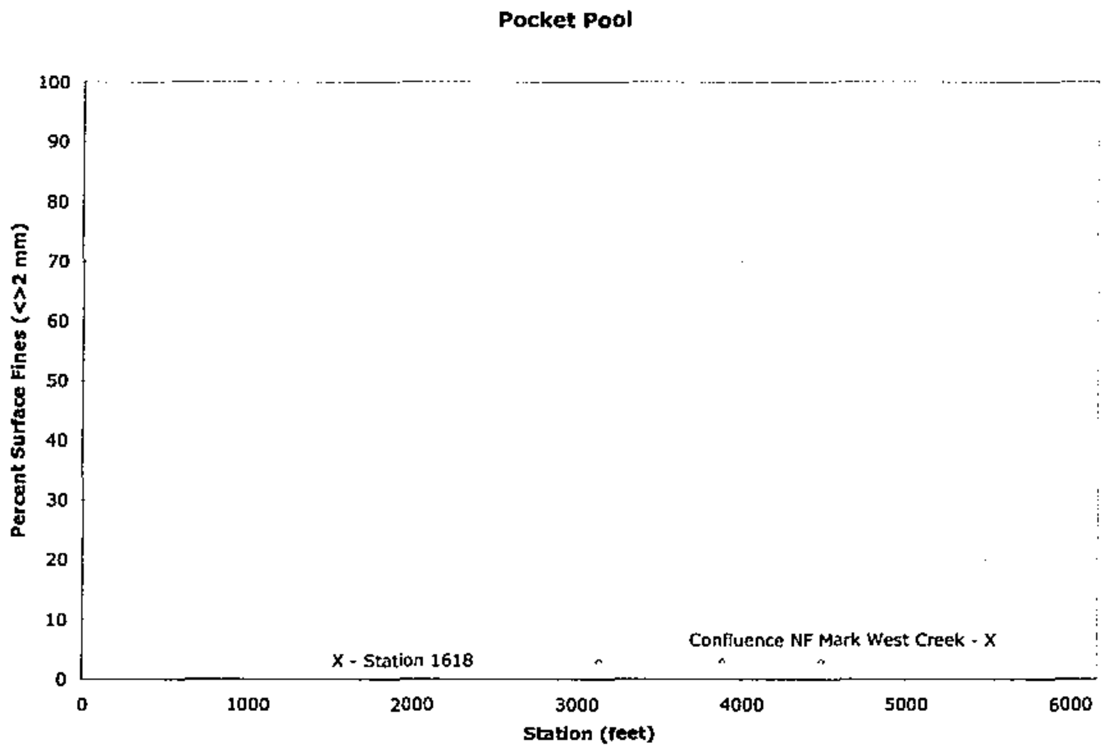

Figure 24. Longitudinal profile of percent surface fines in pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California October, 2008.

Pocket-pool depth embeddedness was light (Figure 25).

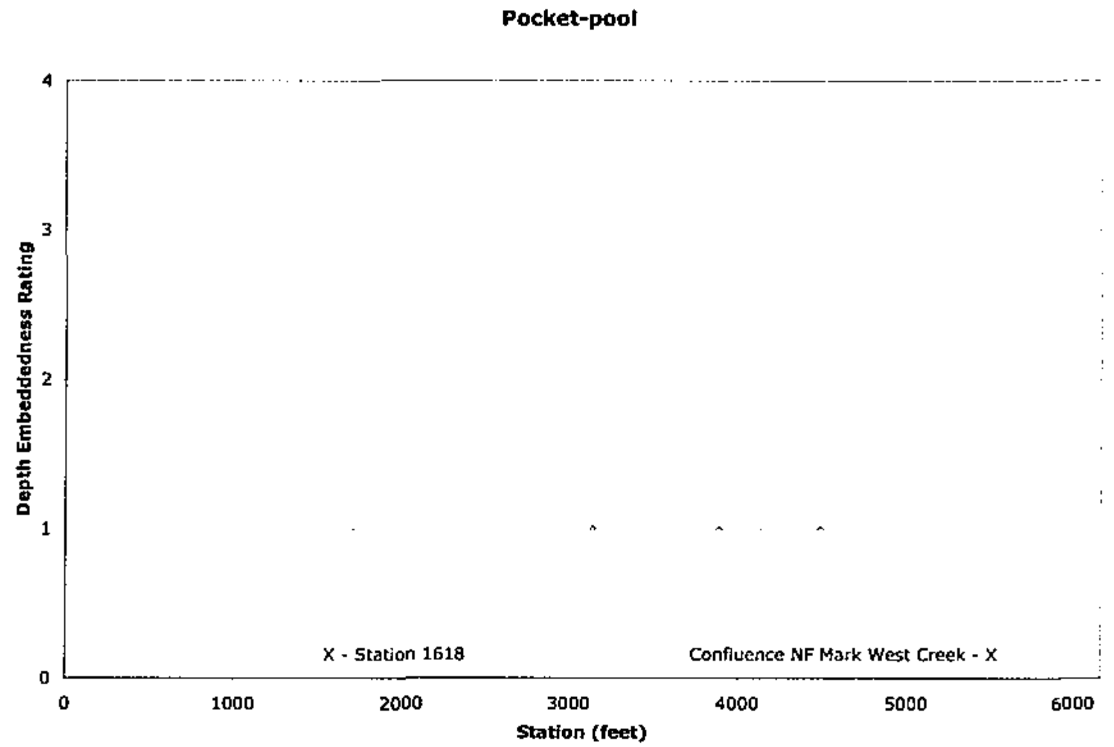

Figure 25. Longitudinal profile of depth embeddedness in pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Habitat quality in pocket-pools was poor to fair (Figure 26).

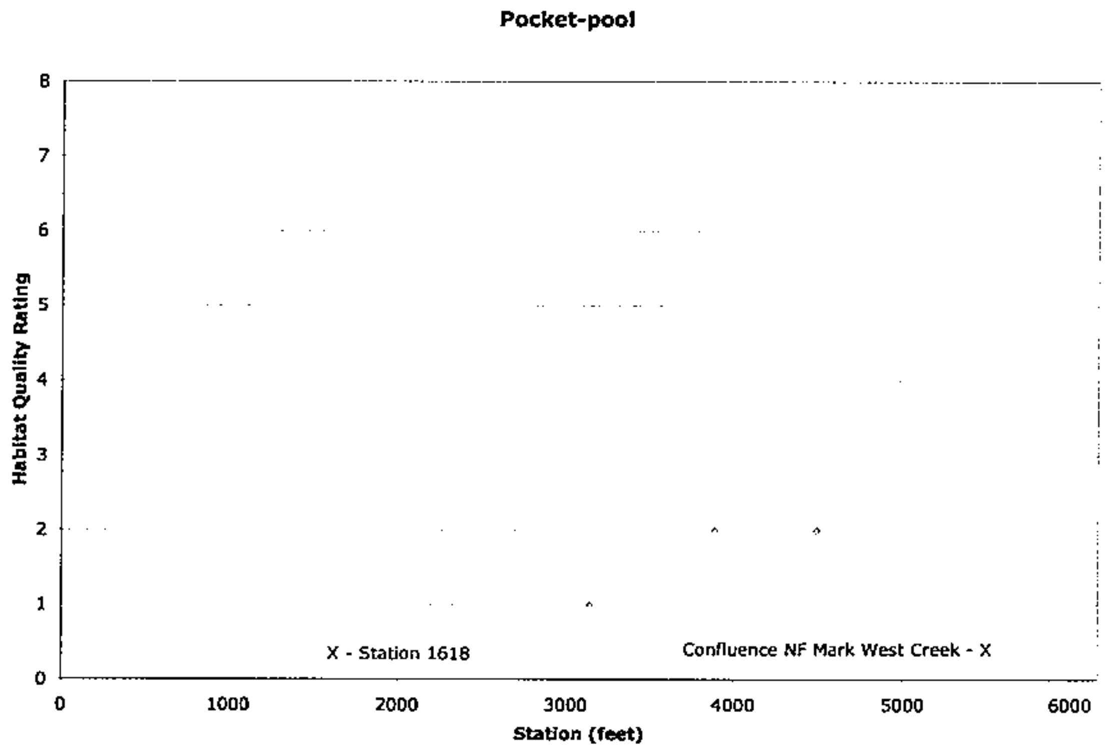

Figure 26. Longitudinal profile of habitat quality ratings in pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

6. STEP-POCKET-POOL SUMMARY

Step-pocket-pools are a series of pocket-pools with vertical gradient breaks in between them. Pocket-pools must be longer than the steps, and they should not occupy the entire channel width. Step-pocket-pools are among the longer habitat units (mean 49.11 feet). They are generally narrower (mean 4.89 feet) and deeper (mean 0.58 feet) than the other step-habitats. Step-pocket-pools occurred throughout the area assessed; however, there were spatial gaps early and late in the assessment. We surmise that those areas were lacking the sediment plugs that facilitate the development of step-pocket-pools (Figure 27). Step-pocket-pools can support both aquatic invertebrates and steelhead.

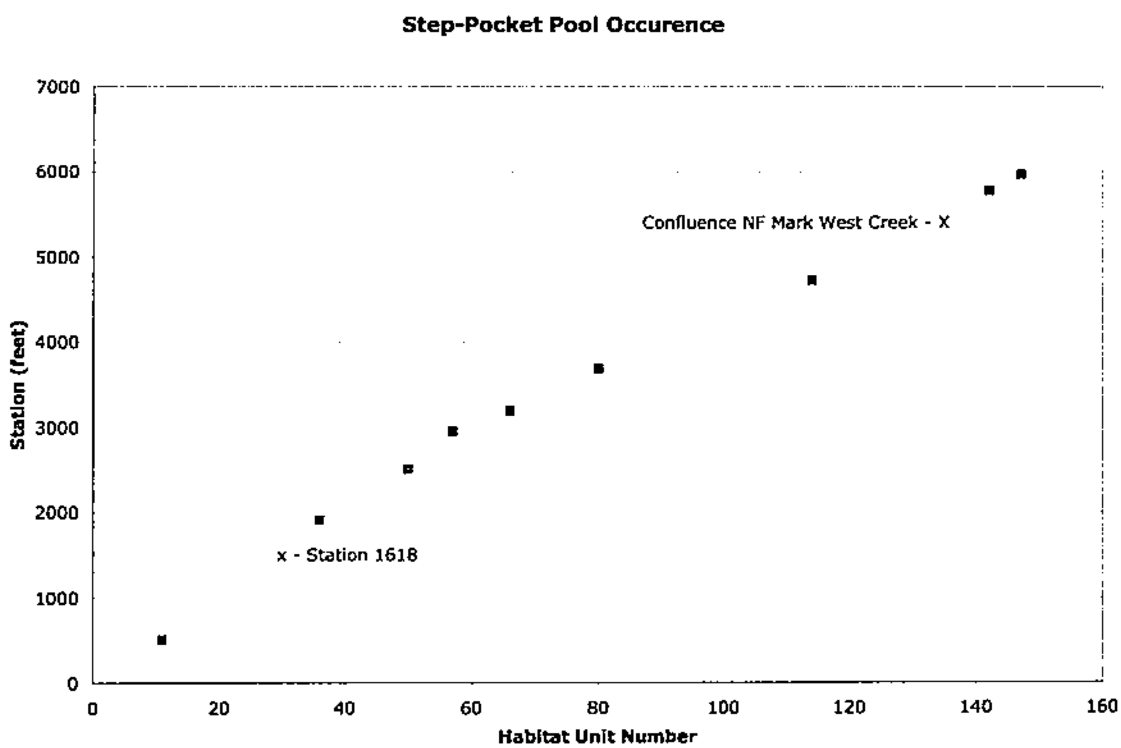

Figure 27. Occurrence of step-pocket-pools from Tar Water Bridge to just upstream of NF Mark West Creek during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Step-pocket-pool substrate tends to be large, but potentially mobile (Table 50).

Table 50, Step-pocket-pool substrate composition under low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Substrate Distribution Type Dominant/subdominant (Wentworth Scale)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
	10/9	3	142	032.13
	10/8	1	056	012.67
	10/7	3	148	033.48
	10/3	1	058	013.12
	8/10	1	038	008.60
Totals	5 = n	9	442	100.00

Step-pocket-pool banks were stable (Table 51).

Table 51. Step-pocket-pool bank stability during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Left Bank/Right Bank Rank (Code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
	1/1	5	055.56	283	064.03
	1/2	3	033.33	127	028.73
	2/2	1	011.11	032	007.24
Totals	3=n	9	100	442	100

Boulder is the major bank component associated with step-pocket-pools (Table 52).

Table 52. Step-Pocket Pool bank components during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008

Bank Components (description)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
Bedrock/Bedrock	1	011.11	035	007.92
Bedrock/Boulder	3	033.33	189	042.76
Boulder/Boulder	2	022.22	114	025.79
Boulder/Bar	1	011.11	032	007.24
Vegetation/Hardpan-tree	1	011.11	038	008.60
Rootwad/Vegetation	1	011.11	034	007.69
Totals 6 = n	9	100.00	442	100.00

Depth of embeddedness in step-pocket-pools was light to moderate (Table 53).

Table 53. Depth of embeddedness in step-pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Embeddedness Depth (code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)	Weighted Length	Mean
	1	6	066.67	253	057.24	253	
	2	3	033.33	189	042.76	378	
Totals	2 = n	9	100.00	442	100.00	631	1.43

Step-pocket-pool bank slopes were steep (Table 54).

Table 54. Step-pocket-pool bank slopes, during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Left Bank/Right Bank slope angle (degrees)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
	90/80	1	035	007.92
	90/45	1	075	016.97
	90/5	2	114	025.79
	60/10	1	035	007.92
	45/2	1	032	007.24
	15/5	1	079	017.87
	10/2	1	038	008.60
	1/1	1	034	007.69
Totals	8=n	9	442	100.00

Step-pocket-pool area was heavily embedded with sediment (Table 55).

Table 55. Proportion of step-pocket-pool area covered by sediment during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008. Where 1 = 25% or less, 2 = 26% to 50%, 3 = 51%-75% and 4 = 76% to 100%.

	Rank (code)	Frequency (Number)	Cumulative Length (feet)	Percent Length (%)	Mean
	1	1	079	017.87	
	2	1	034	007.69	
	3	4	224	050.68	
	4	3	105	023.76	
Totals		9	442	100.00	2.80

Almost 32% of step-pocket-pool surface had 20% or more percent surface fines (Table 56).

Table 56. Distribution of percent surface fines in step-pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent Fines (%)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Cumulative Length (feet)	Weighed Length (feet)	Percent Weighted Length (%)
0.03	6	066.67	274	061.99	08.22	022.63
0.15	2	022.22	110	024.89	16.5	045.43
0.20	1	011.11	058	013.12	11.6	031.94
n = 3	9	100.00	442	100.00	36.32	100.00
Mean percent surface fines weighted length = 8.22%						

Step-pocket-pools show the effects of the 10,000 cubic yard sediment plume; there is elevated area embeddedness upstream of station 1618 (Figure 28).

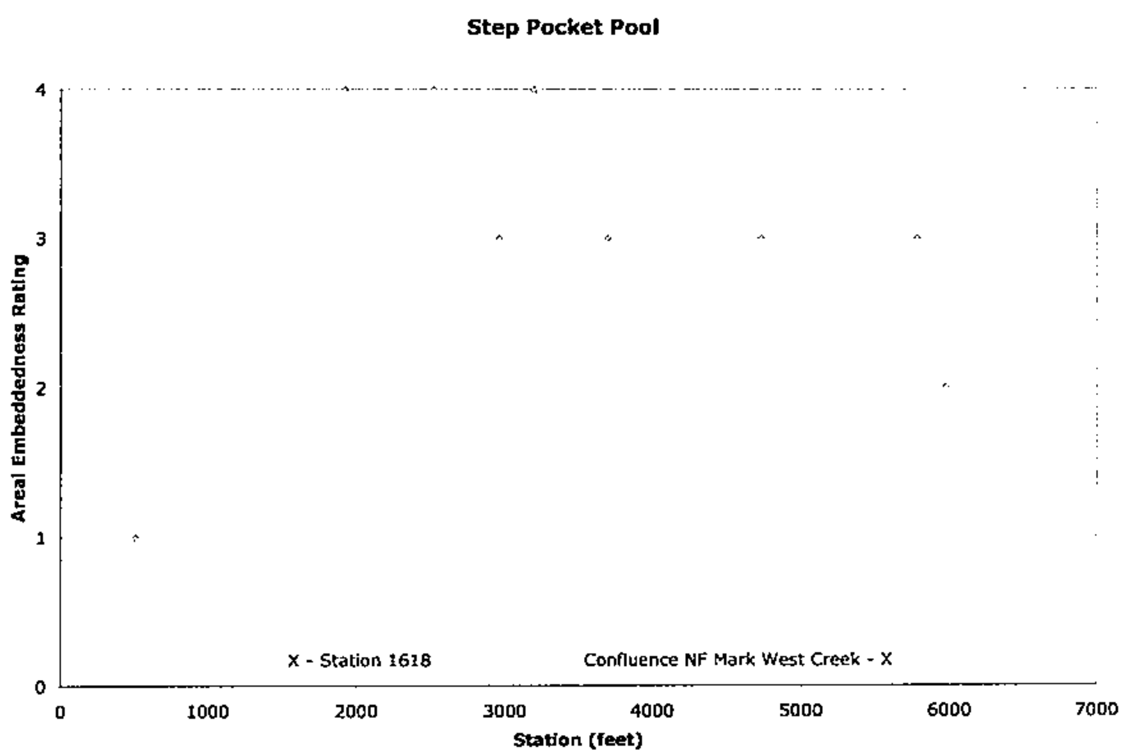

Figure 28. Longitudinal profile of area embeddedness of step-pocket-pools in upper Mark West Creek, Sonoma County, California, October, 2008.

Percent surface fines were relatively light in step-pocket-pools (Figure 29).

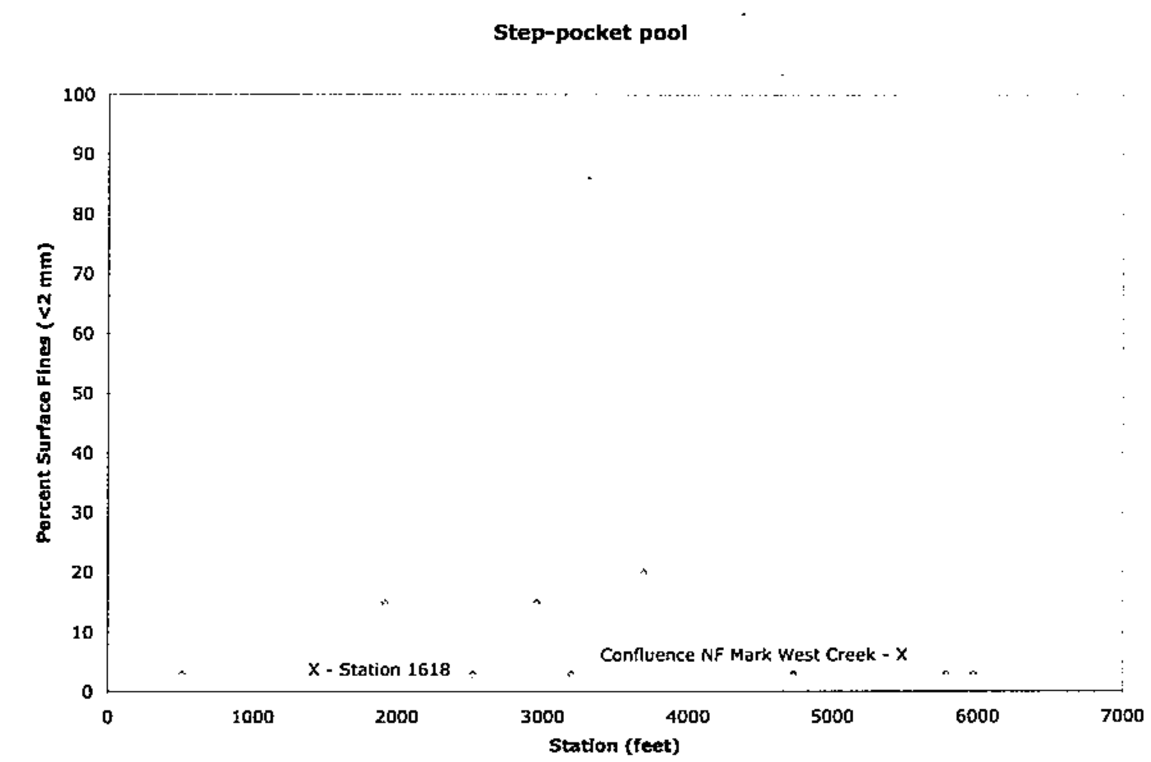

Figure 29. Longitudinal profile of percent surface fines in step-pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Step-pocket-pool depth embeddedness ratings were light to moderate (Figure 30).

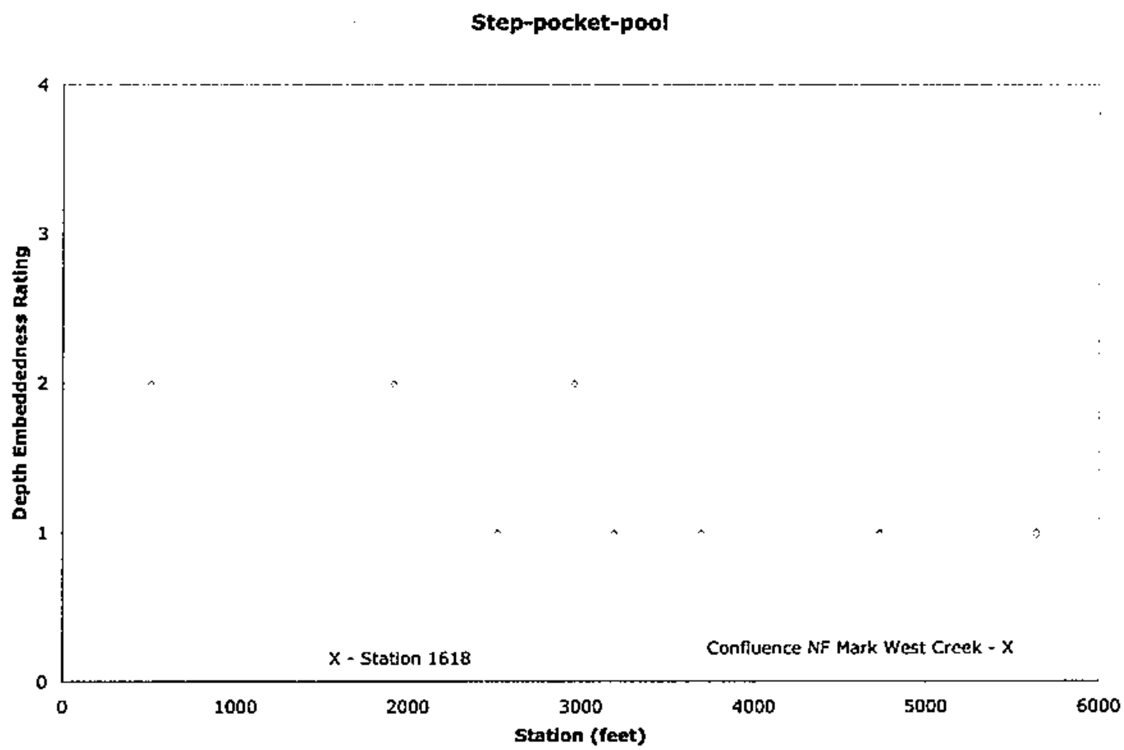

Figure 30. Longitudinal profile of depth embeddedness ratings in step-pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Step-pocket-pool habitat quality ratings were generally fair, but increased around station 5500 (Figure 31).

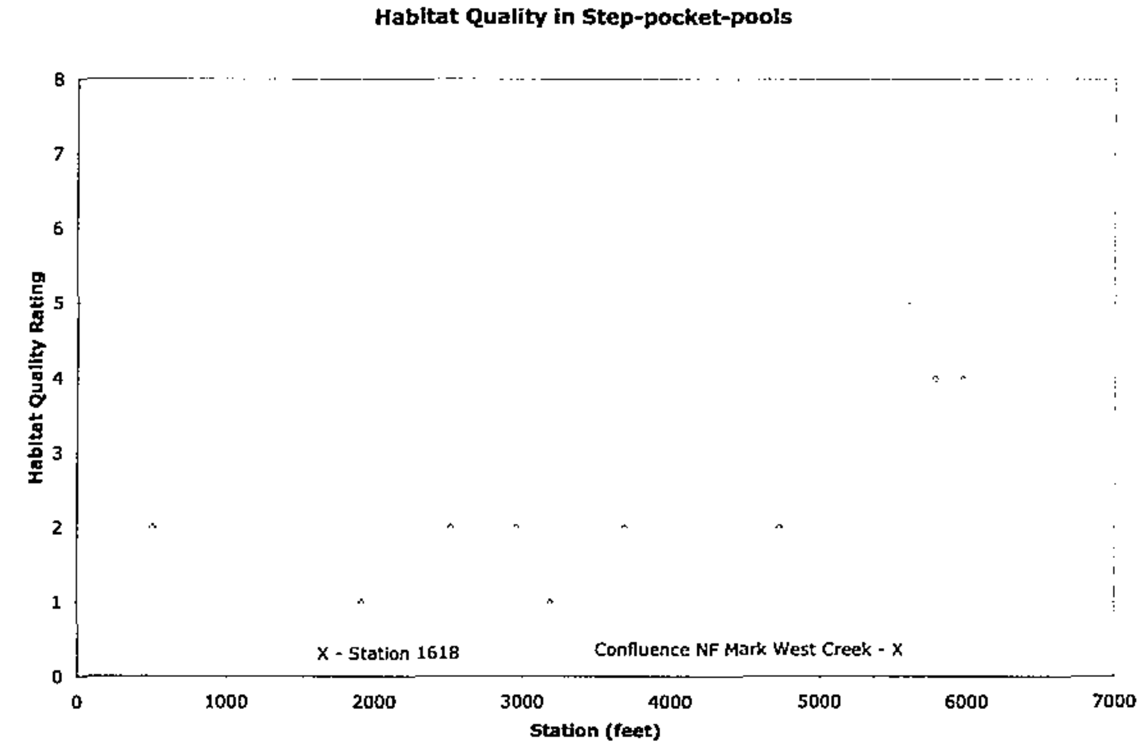

Figure 31. Longitudinal profile of habitat quality ratings in step-pocket-pools during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

7. LOW GRADIENT RIFFLE SUMMARY

Riffles are habitats with a sloping gradient. Low gradient riffles have a gradient of 4% or less. During the time of this assessment, low gradient riffles were short (mean 30.79 feet), narrow (mean 3.41 feet), and shallow (mean 0.27 feet). Riffles are habitats where fish food is produced (Needham 1938). They are the habitats where aquatic invertebrate abundance is highest. This means that they can also be habitats for steelhead, if there is sufficient depth. Low gradient riffles occurred throughout the surveyed reach, but there is an absence of low gradient riffles between Stations 1800 to 3100 (Figure 32).

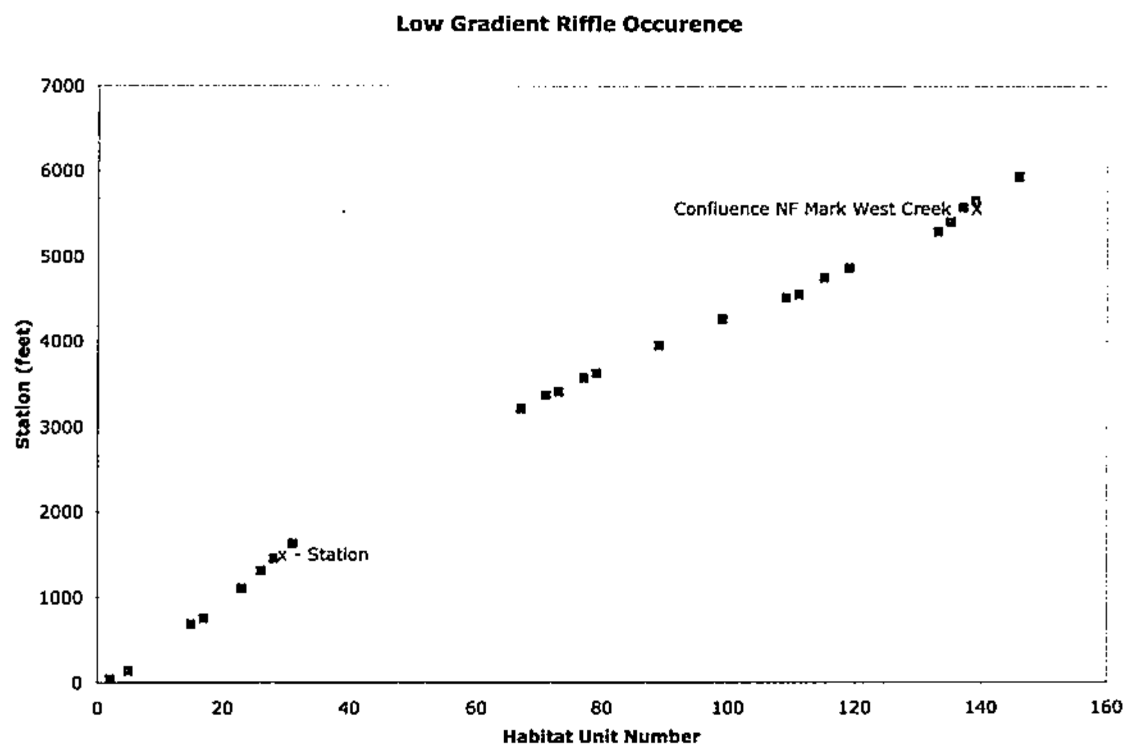

Figure 32. Occurrence of low gradient riffles from Tar Water Bridge to just upstream of NF Mark west Creek during low streamflow conditions in upper Mark West Creek, Sonoma County, California October, 2008

Low gradient riffles had a wide range in substrate size composition (Table 57).

Table 57. Low Gradient Riffle substrate composition during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Substrate Distribution Type Dominant/subdominant (Wentworth Scale)	Frequency (Number)	Cumulative Length (feet)	Percent Length (%)
	12/10	01	026	003.58
	11/10	01	030	004.13
	10/9	02	024	003.30
	10/8	04	119	016.37
	10/7	02	095	013.07
	9/10	01	037	005.09
	9/7	02	070	009.63
	9/5	01	006	000.83
	7/10	01	016	002.20
	7/9	03	144	019.81
	7/6	02	090	012.38
	6/5	01	017	002.34
	6/3	01	014	001.93
	4/12	01	028	003.85
	4/8	01	011	001.51
Totals	15=n	24	727	100.00

Low gradient riffle banks were stable (Table 58).

Table 58. Low gradient riffle bank stability during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Bank Rank (Code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
1/1	13	054.17	470	064.65
1/2	09	037.50	219	030.12
1/4	01	004.17	015	002.06
2/2	01	004.17	023	003.16
Totals 4 = n	24	100.00	727	100.00

Bedrock and Boulder were major bank components adjacent to low gradient riffles (Table 59).

Table 59. Low gradient riffle bank components during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Bank Components (description)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
Bedrock/Bedrock	01	004.17	015	002.06
Bedrock/Trees	02	008.33	089	012.24
Bedrock/Boulder	06	025.00	209	022.56
Bedrock/Bar	04	016.67	067	009.22
Boulder/Boulder	04	016.67	119	016.37
Boulder-Rootwad/Bar	01	004.17	011	001.51
Boulder/Hardpan	01	004.17	033	004.54
Boulder/Rootwad	01	004.17	023	003.16
Cobble/Cobble	02	008.33	106	014.58
Cobble/Bar	01	004.17	023	003.16
Vegetation/Vegetation	01	004.17	013	001.79
Totals 11 = n	24	100.00	727	100.00

Depth embeddedness in low gradient riffles was light (Table 60).

Table 60. Depth of embeddedness in low gradient riffles during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Embeddedness Depth (code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
1	24	100	727	100

Low gradient riffles are generally associated with steep banks in upper Mark West Creek (Table 61).

Table 61. Low gradient riffle bank slopes during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Left Bank/Right Bank slope angle (degrees)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
90/90	01	015	002.27
90/45	01	030	004.53
90/15	01	033	004.98
90/5	03	056	08.46
90/2	01	037	005.59
90/1	03	051	007.70
75/10	01	075	011.33
60/15	02	044	006.65
60/5	01	059	008.91
45/45	01	026	003.93
30/30	01	013	001.96
15/10	02	070	010.57
5/5	01	009	001.36
1/1	03	144	021.75
Totals 14 = n	22	662	100

Low gradient riffle areas were either low or high in area embeddedness (Table 62).

Table 62. Proportion of low gradient riffle area covered by sediment during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008. Where 1 = 25% or less, 2 = 26% to 50%, 3 = 51%-75% and 4 = 76% to 100%.

Rank (code)	Frequency (Number)	Cumulative Length (feet)	Percent Length (%)	Mean
1	08	270	037.14	
2	05	147	020.22	
3	04	096	013.20	
4	07	214	029.44	
Totals	24	727	100.00	2.35

Only 17% of low gradient riffles had weighted lengths in percent surface fines as great as ten percent (Table 63).

Table 63. Distribution of percent surface fines in low gradient riffles during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent Fines (%)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Cumulative Length (feet)	Weighed Length (feet)	Percent Weighted Length (%)
0.00	01	004.17	011	001.51	00.0	000.00
0.03	20	083.33	643	088.45	19.5	077.08
0.05	01	004.17	030	004.13	01.5	005.93
0.10	02	008.33	043	005.91	04.3	017.00
n = 4	24	100.00	727	100.00	25.3	100.00

Mean percent surface fines for weighted length = 3.48%

Low gradient riffles downstream of Station 1618 had low area embeddedness, while those upstream of Station 1618 had high area embeddedness (Figure 33).

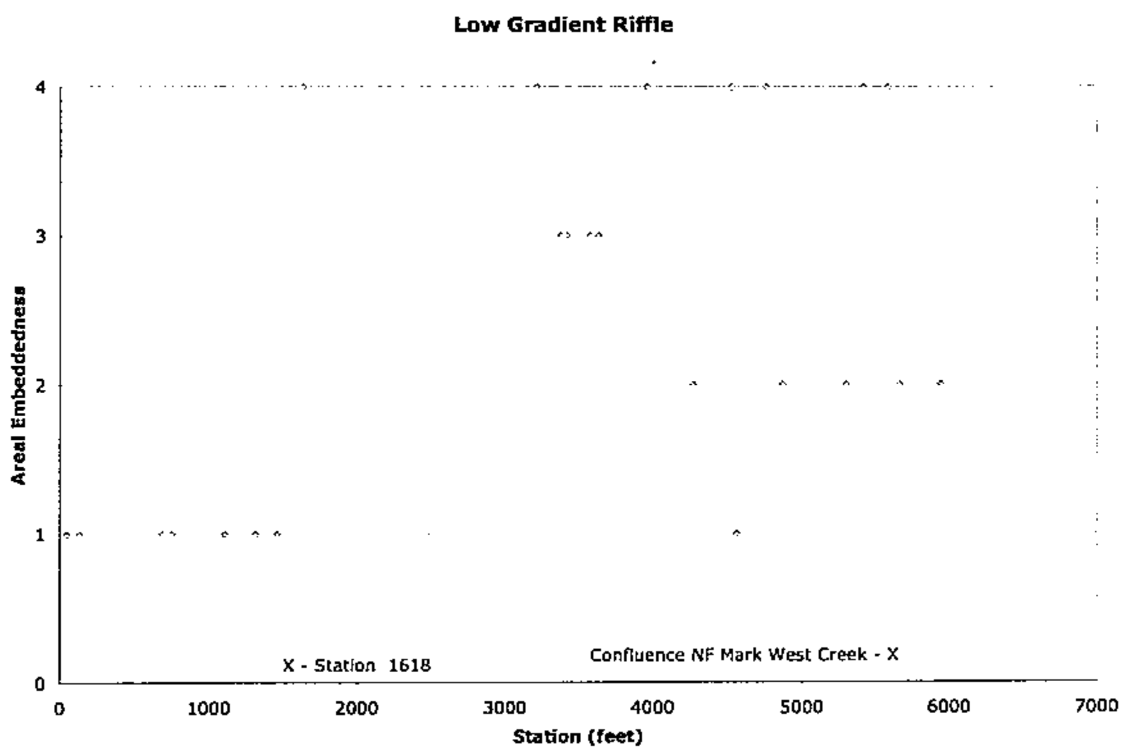

Figure 33. Longitudinal profile of area embeddedness in low gradient riffles during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Low gradient riffles generally had low percent surface fines (Figure 34).

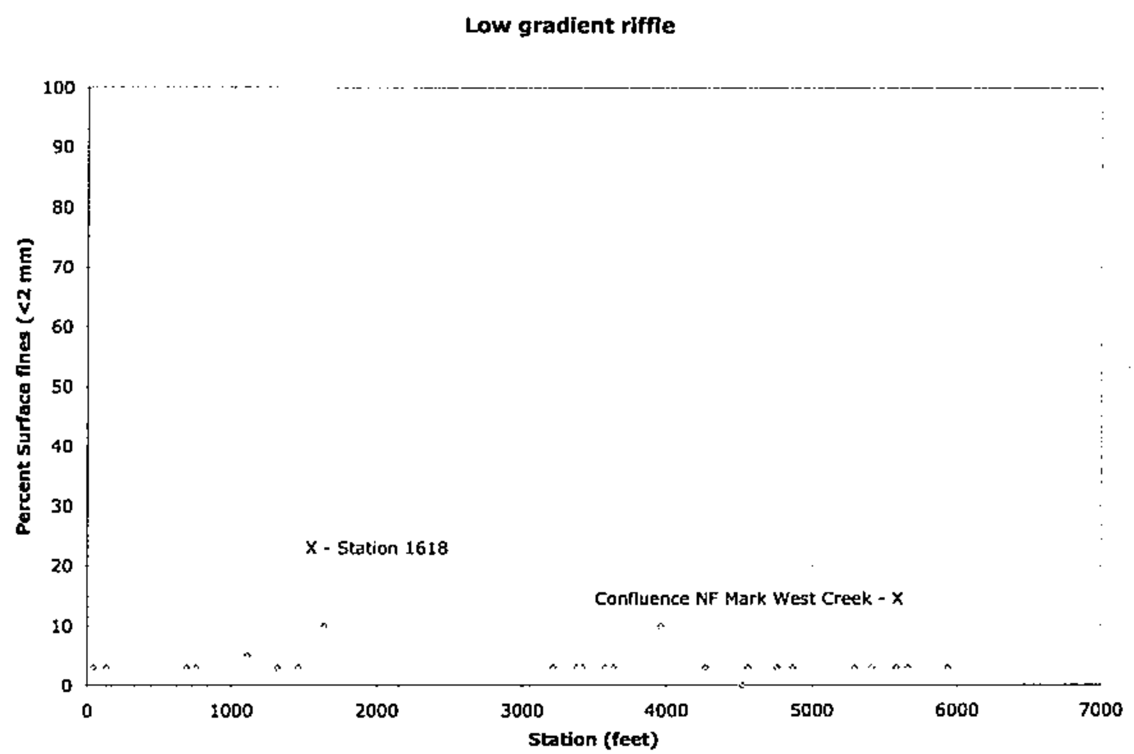

Figure 34. Longitudinal profile of percent surface fines in low gradient riffles during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Depth embeddedness was light (Figure 35).

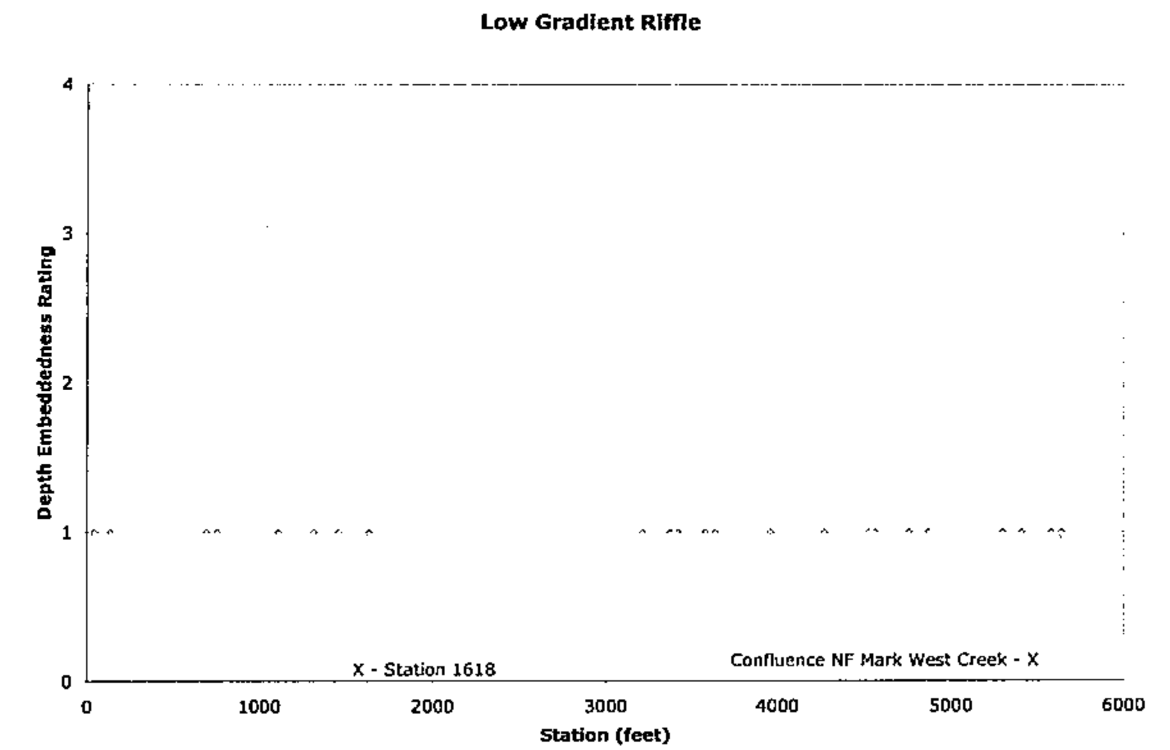

Figure 35. Longitudinal profile of depth embeddedness ratings during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Low gradient riffle habitat quality was poor to fair (Figure 36).

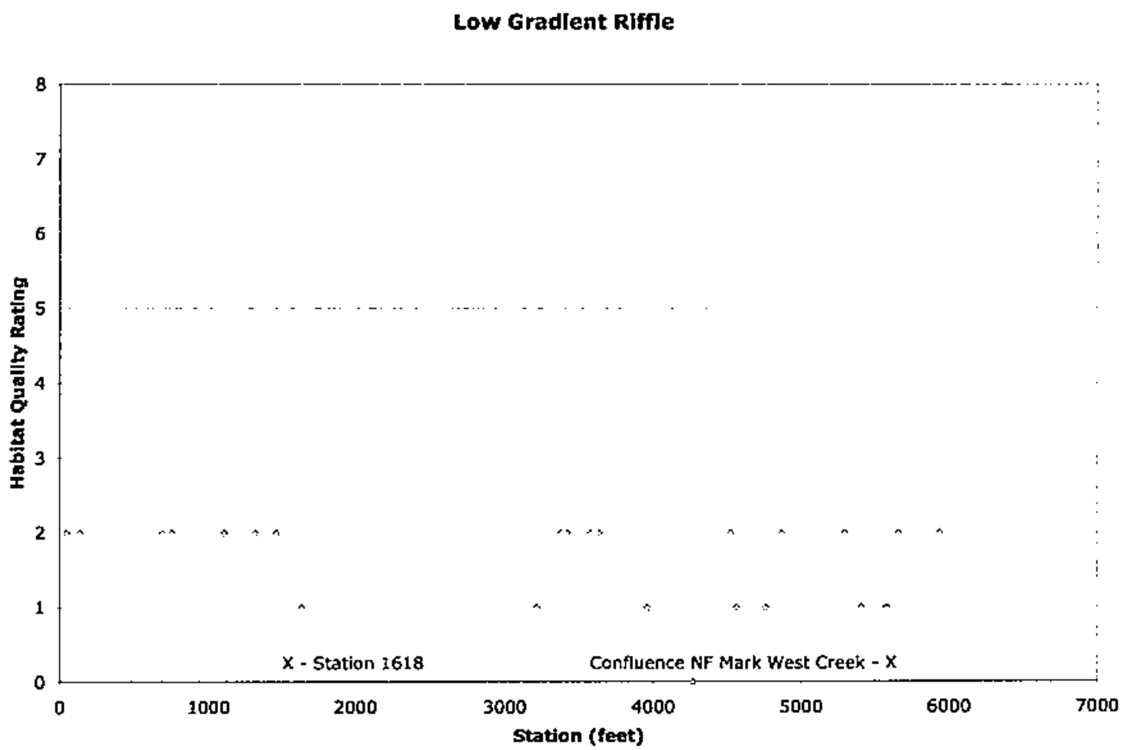

Figure 36. Longitudinal profile of habitat quality ratings in low gradient riffles during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

8. HIGH GRADIENT RIFFLE SUMMARY

Riffles are habitats with gradient. High gradient riffles have a gradient of more than 4%. During this habitat assessment, high gradient riffles were shorter (mean 22.65 v. mean 30.79 feet), narrower (mean 2.44 feet v. mean 3.41 feet), and shallower (mean 0.26 v. mean 0.27 feet) than low gradient riffles. High gradient riffles have higher energy water. Riffles are habitats where fish food is produced (Needham 1938). They are the habitats where aquatic invertebrate abundance is highest, and aquatic invertebrates that thrive there have adaptations that allow them to survive. High gradient riffles occurred throughout the surveyed reach (Figure 37) and although they support aquatic invertebrates, they are typically too shallow to function as steelhead rearing habitat.

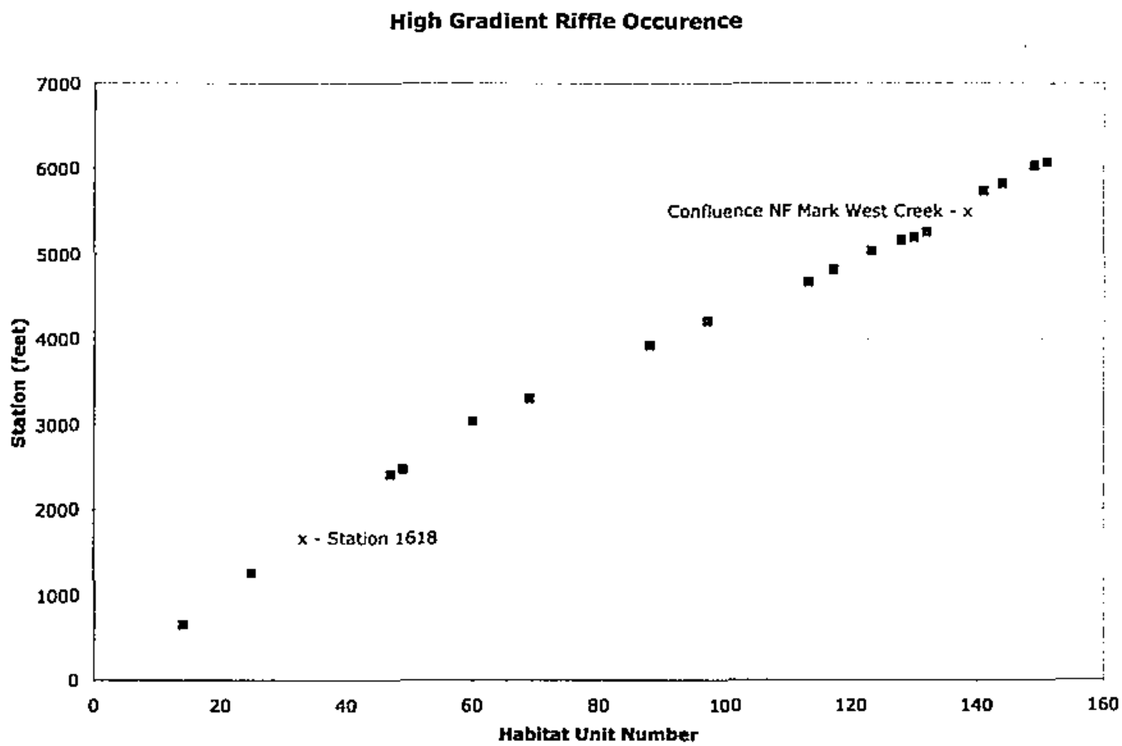

Figure 37. Occurrence of high gradient riffles from Tar Water Bridge to just upstream of NF Mark West Creek during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

High gradient riffles generally had large substrates (Table 64).

Table 64. High gradient riffle substrate composition during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Substrate Distribution Type Dominant/subdominant (Wentworth Scale)	Frequency (Number)	Cumulative Length (feet)	Percent Length (%)
12/10	02	042	010.91
12/7	01	018	004.68
10/11	01	029	007.53
10/9	07	173	044.94
10/8	01	015	003.90
10/7	02	045	011.69
9/10	02	020	005.19
9/7	01	015	003.90
8/9	01	028	007.27
Totals 9=n	18	385	100.00

High gradient riffle banks were stable (Table 65).

Table 65. High gradient riffle bank stability during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Bank Rank (Code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
	1/1	14	077.78	308	080.00
	1/2	03	016.67	063	016.36
	2/2	01	005.56	014	003.64
Totals	3 = n	18	100.00	385	100.00

Bedrock and Boulder were major components of high gradient riffle banks (Table 66).

Table 66. High gradient riffle bank components during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Bank Components	Frequency (number)	Percent Frequency (feet)	Cumulative Length (%)	Percent Length (feet)
Bedrock/Bedrock	02	011.11	033	008.57
Bedrock/Boulder	06	033.33	122	031.69
Bedrock/Tree	01	005.56	018	004.68
Bedrock/Bar	01	005.56	016	004.16
Boulder/Boulder	04	022.22	071	018.44
Boulder/Hardpan	01	005.56	042	010.91
Boulder/Cobble	01	005.56	029	007.53
Cobble/Trees	01	005.56	028	007.27
Cobble/Vegetation	01	005.56	026	006.75
Totals 9 = n	18	100.00	385	100.00

Depth of embeddedness in high gradient riffles was light (Table 67).

Table 67. Depth of embeddedness in high gradient riffles during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Embeddedness Depth (code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)	Weighted Length	Mean
0	01	005.88	018	004.68	0	
1	15	088.24	352	091.43	352	
2	01	005.88	015	003.90	030	
Totals 3 = n	17	100.00	385	100.00	382	0.99

High gradient riffles were associated with steep sloping banks (Table 68).

Table 68. High gradient riffle bank slopes during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Left Bank/Right Bank slope angle (degrees)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
90/90	1	015	3.90
90/5	5	105	27,28
90/1	3	059	15.32
85/5	1	028	7.27
60/60	1	018	4.68
60/30	1	024	6.23
45/5	2	029	7.53
15/10	1	042	10.91
1/1	3	065	16.88
Totals 9 =n	18	385	100

High gradient riffles responded widely to area embeddedness (Table 69).

Table 69. Proportion of high gradient riffle area covered by sediment during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008. Where 1 = 25% or less, 2 = 26% to 50%, 3 = 51%-75% and 4 = 76% to 100%.

Rank (code)	Frequency (Number)	Cumulative Length (feet)	Percent Length (feet)	Mean
1	04	099	025.71	
2	07	161	041.82	
3	06	110	028.57	
4	01	060	015.58	
Totals	18	385	100.00	2.11

A little over 20% of high gradient riffles had weighted lengths greater than ten percent (Table 70).

Table 70. Distribution of percent surface fines in high gradient riffles during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent Fines (%)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Cumulative Length (feet)	Weighed Length (feet)	Percent Weighted Length (%)
0.00	01	005.56	24	006.23	00.00	000.00
0.03	16	088.89	335	087.01	10.05	079.45
0.10	01	005.56	26	006.75	02.60	020.55
n = 3	18	100.00	385	100.00	12.65	100.00

Mean percent surface fines weighted length = 3.29%

There was low area embeddedness downstream of Station 1618 and higher embeddedness upstream, but there was also low embeddedness upstream (Figure 38).

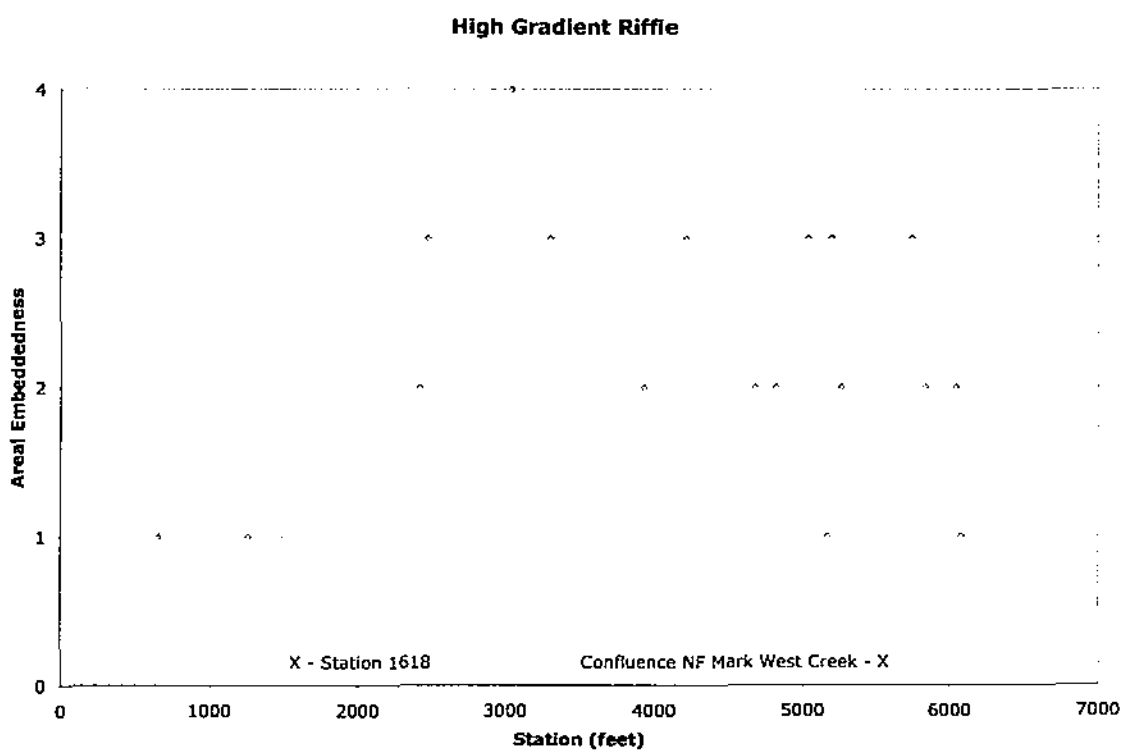

Figure 38. Longitudinal Profile of area embeddedness in high gradient riffles during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October, 2008.

Percent surface fines for high gradient riffles was generally low (Figure 39).

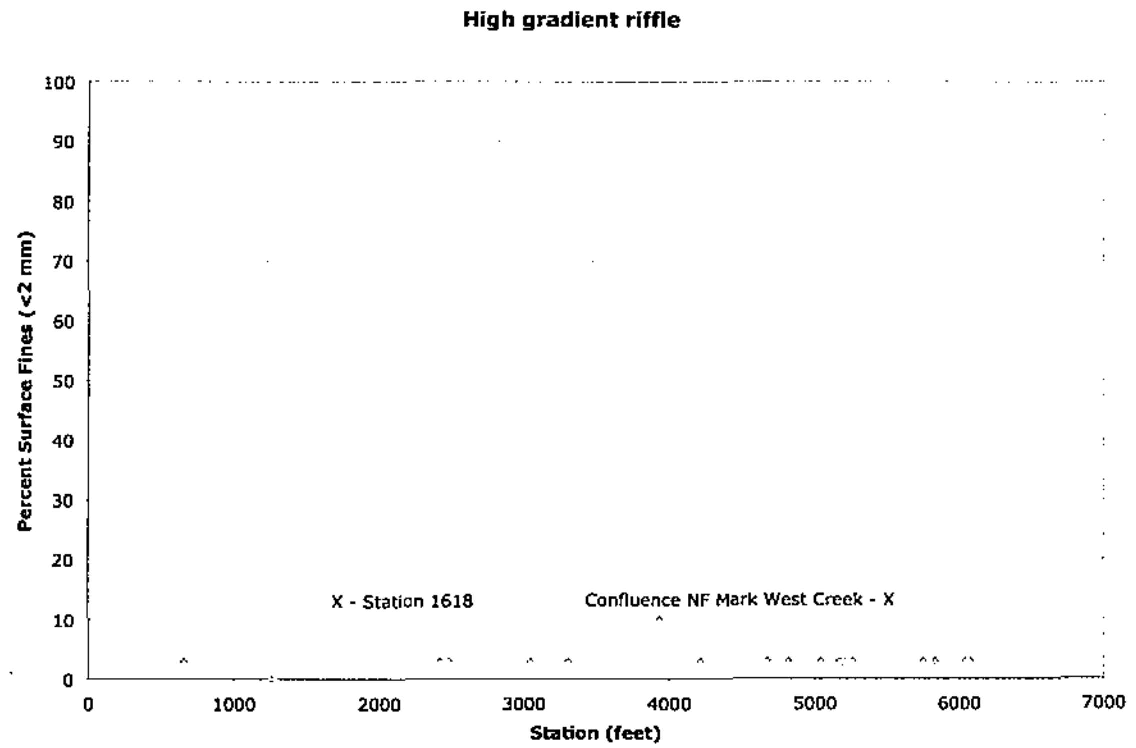

Figure 39. Longitudinal profile of percent surface fines in high gradient riffle during low streamflow conditions in upper Mark West Creek, Sonoma County, California October, 2008.

Depth embeddedness was generally light (Figure 40.

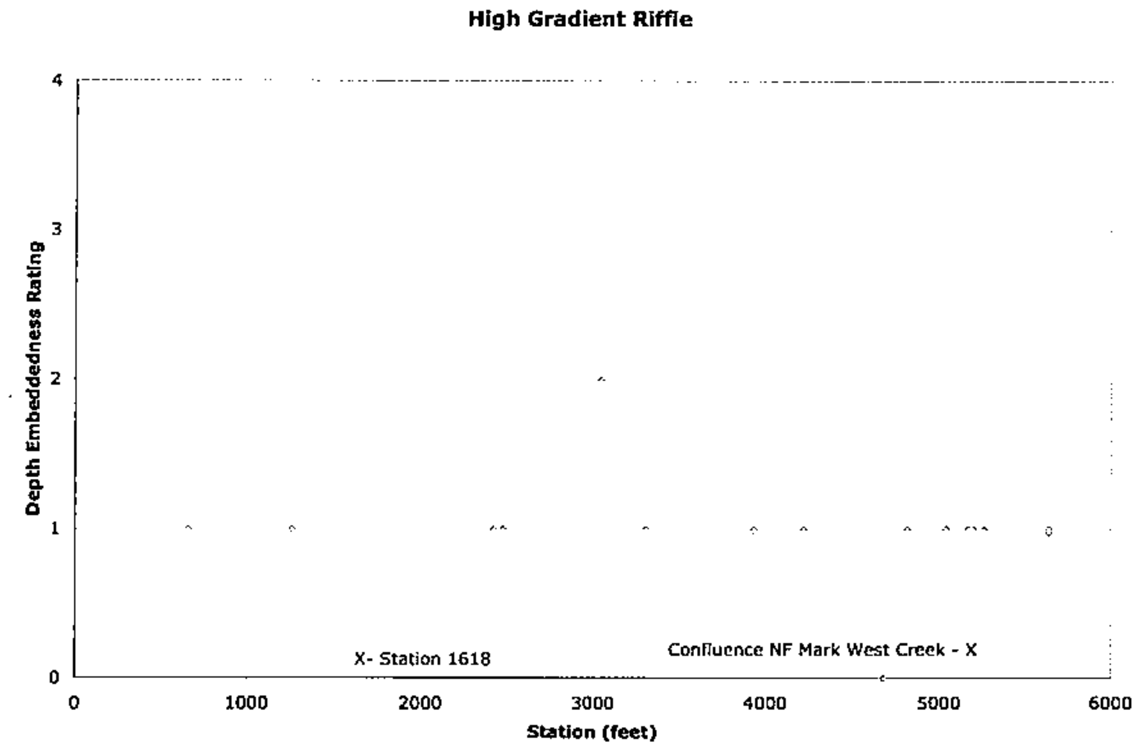

Figure 40. Longitudinal profile of depth embeddedness ratings in high gradient riffles during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

High gradient habitat quality was poor to fair (Figure 41).

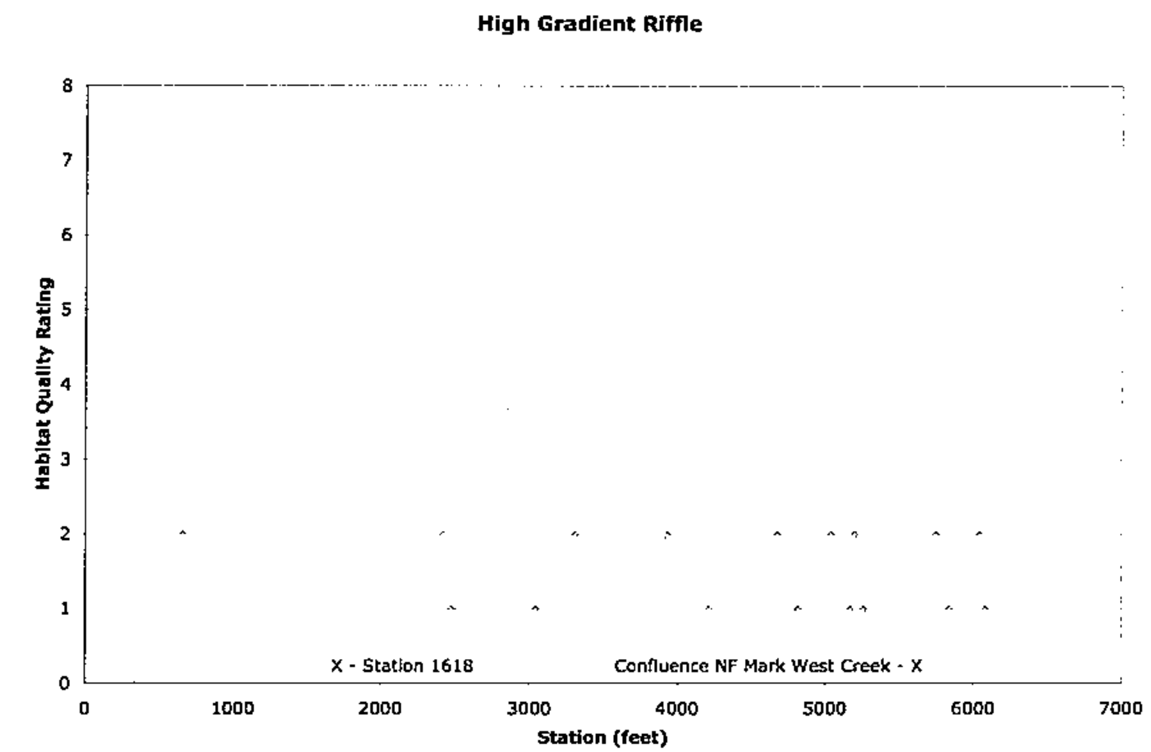

Figure 41. Longitudinal profile of habitat quality ratings in high gradient riffles during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

9. CASCADE SUMMARY

Cascade is the steepest gradient habitat possible, without being a falls. In upper Mark West Creek it was the shortest (mean 9.73 feet), narrowest (mean 2.45 feet), and shallowest (mean 0.16 feet) habitat. Water is concentrated in this habitat, and it has the highest velocity and energy of the habitats we assessed. Cascades were observed after the first third of the survey (Figure 42). Cascades may provide steelhead-rearing habitat, if the cascades have small pools. Only specially adapted aquatic invertebrates live here.

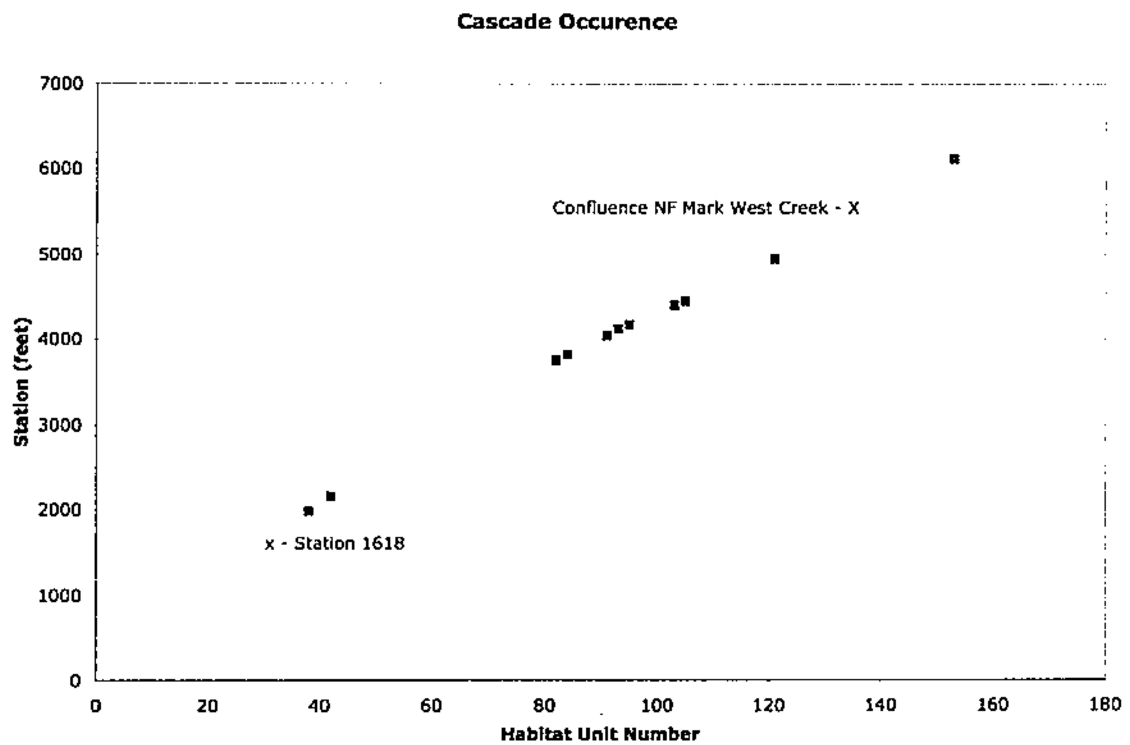

Figure 42. Occurrence of cascades from Tar Water Bridge to just upstream of NF Mark West Creek during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Substrate composition in cascades was large (Table 71).

Table 71. Cascade substrate composition during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Substrate Distribution Type Dominant/subdominant (Wentworth Scale)	Frequency (Number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
12/10	01	009.09	005	004.67
11/10	02	018.18	024	022.43
11/9	01	009.09	027	025.23
10/11	02	018.18	014	013.08
10/10	03	027.27	009	008.41
10/9	02	018.18	028	026.17
Totals 6 = n	11	100.00	107	100.00

Cascade banks were stable (Table 72).

Table 72. Cascade bank stability during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Bank Rank (Code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
1/1	10	090.91	097	090.65
1/2	01	009.09	010	009.35
Totals 2 = n	11	100.00	107	100.00

Bedrock and boulder were major components of banks adjacent to cascades (Table 73).

Table 73. Cascade bank components during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Bank Components	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
Bedrock/Bedrock	03	027.27	022	020.56
Bedrock/boulder	04	036.36	044	041.12
Bedrock/Rootwad	02	018.18	015	014.02
Boulder/Boulder	02	018.18	026	024.30
Totals 4 = n	11	100.00	107	100.00

Embeddedness depth in cascades was light (Table 74).

Table 74. Depth of embeddedness in cascades during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Embeddedness Depth (code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
0	07	063.64	041	038.32
1	04	036.36	066	061.68
Totals 2 = n	11	100.00	107	100.00

Cascade bank slopes were steep (Table 75).

Table 75. Cascade bank slopes during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Left Bank/Right Bank slope angle (degrees)	Frequency (number)	Cumulative Length (feet)	Percent Length (%)
90/90	02	008	007.48
90/80	01	014	013.08
90/15	01	005	004.67
90/5	02	038	035.51
90/1	03	016	014.95
1/1	02	026	024.30
Totals 6=n	11	107	100.00

Cascade area was generally light in embeddedness (Table 76).

Table 76. Proportion of cascade area covered by sediment during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008. Where 1 = 25% or less, 2 = 26% to 50%, 3 = 51%-75% and 4 = 76% to 100%.

Rank (code)	Frequency (Number)	Cumulative Length (feet)	Percent Length (%)	Mean
1	04	055	051.40	
2	06	049	045.80	
3	01	003	002.80	
4	00	000	000.00	
Totals 3 = n	11	107	100.00	1.51

All but one cascade had a 3% percent surface fines rating (Table 77).

Table 77. Distribution of percent surface fines in cascades during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent Fines (%)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Cumulative Length (feet)	Weighed Length (feet)	Percent Weighted Length (%)
0.00	01	9.090	014	013.08	0.00	0.00
0.03	10	90.91	093	086.92	2.79	100.00
n = 2	11	100.00	107	100.00	2.79	100.00

Cascade mean percent surface fines weighted length = 2.61%

Cascades had low to moderate area embeddedness (Figure 43).

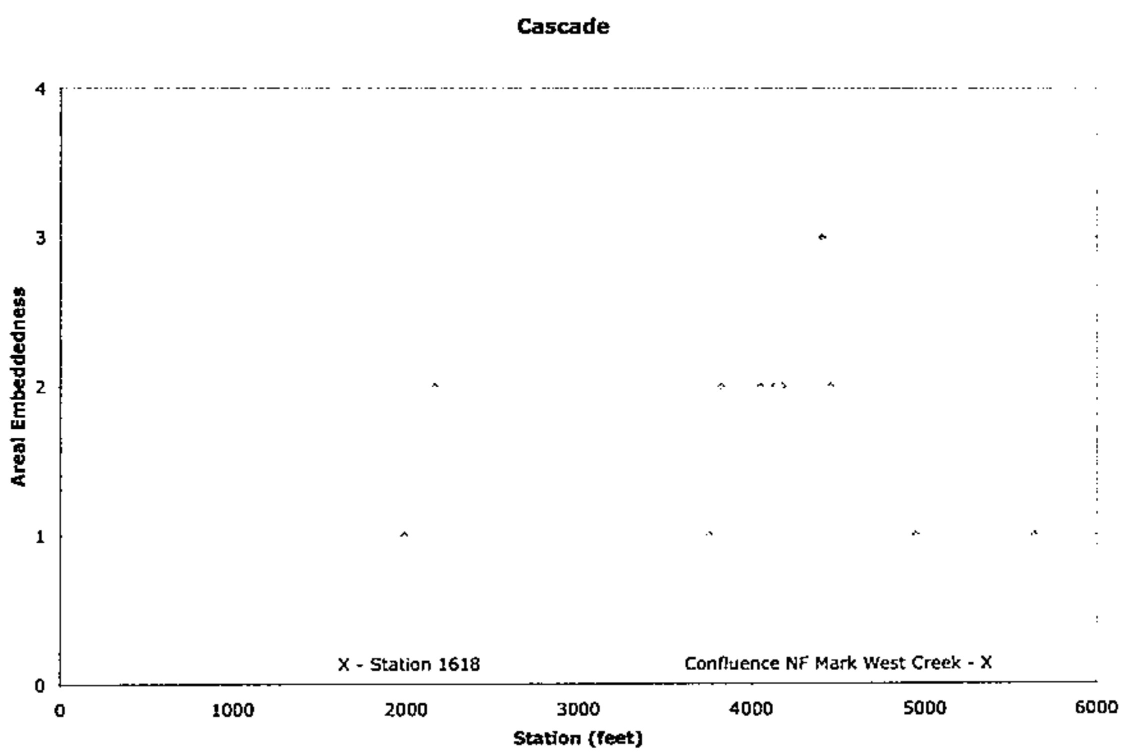

Figure 43. Longitudinal profile of area embeddedness in cascades during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent surface fines in cascades was low (Figure 44).

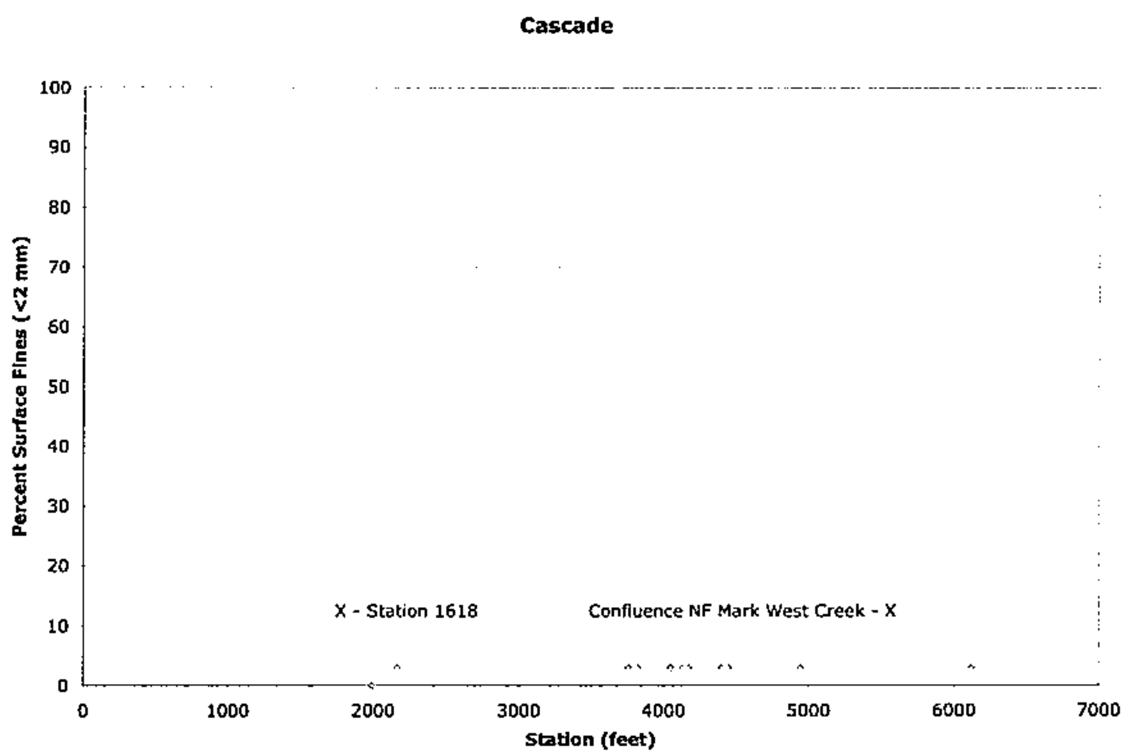

Figure 44 Longitudinal profile of percent surface fines in cascades during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Depth embeddedness ratings were between none and light in cascades (Figure 45).

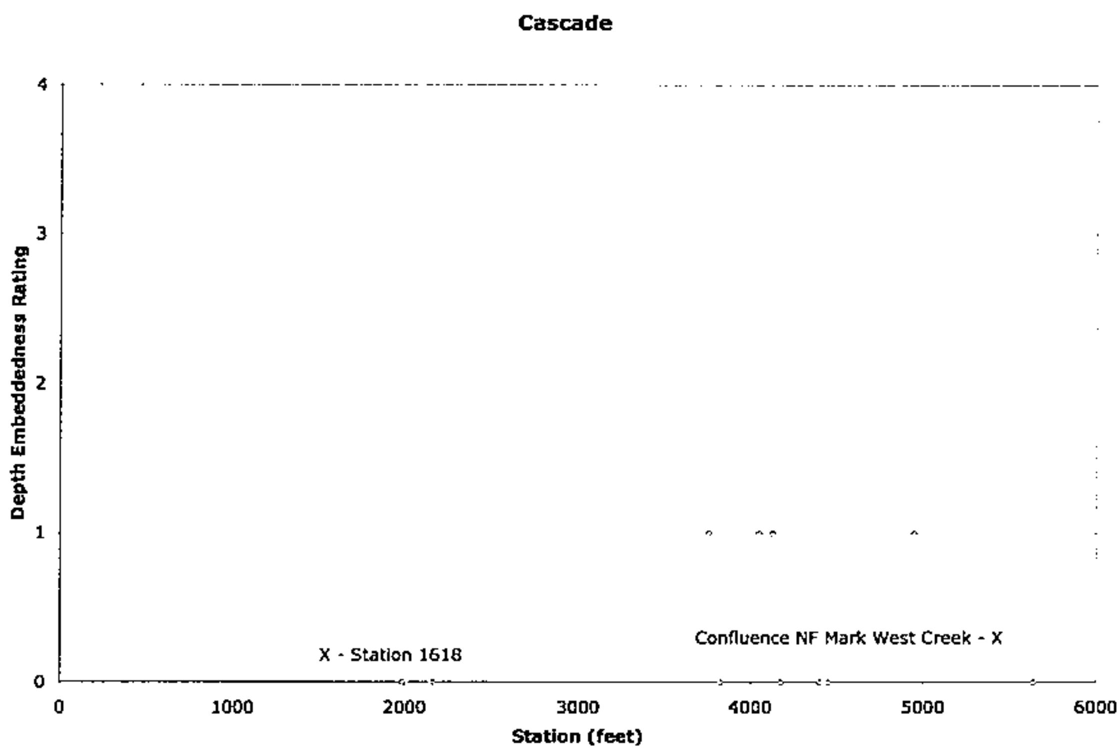

Figure 45. Longitudinal profile of depth embeddedness ratings in cascades during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Cascade habitat quality was poor to none (Figure 46).

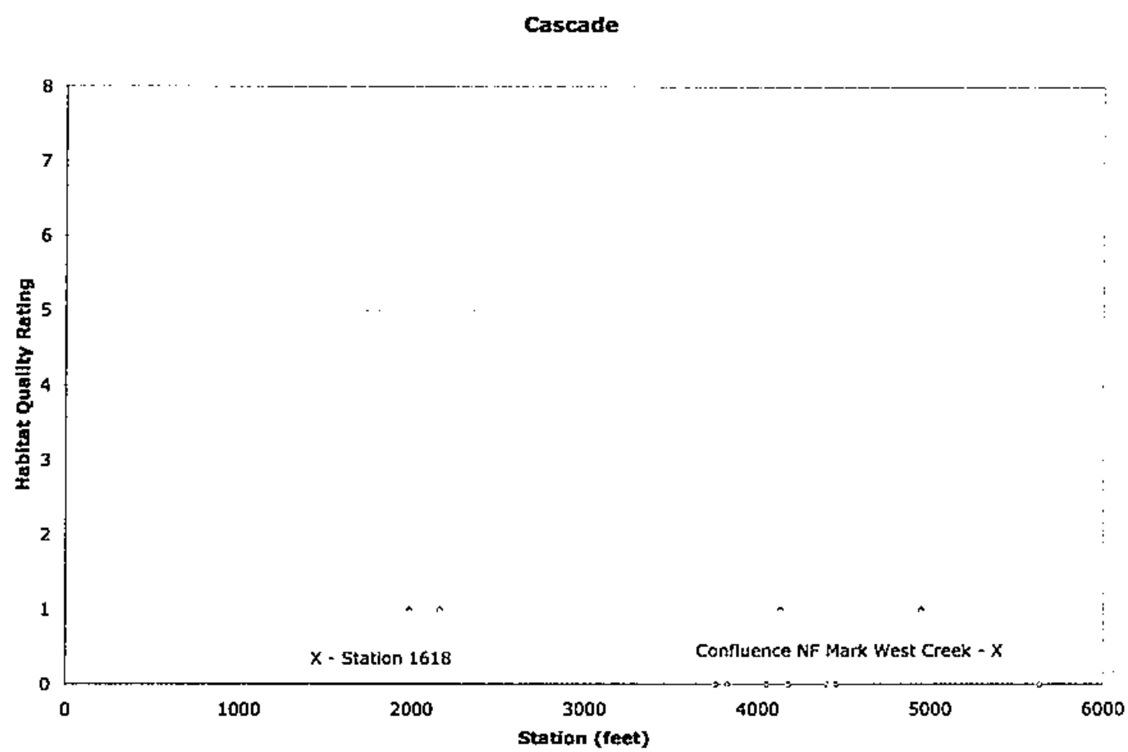

Figure 46. Longitudinal profile of habitat quality ratings in cascades during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

10. DRY SUMMARY

In October 2008, under low streamflow conditions, Li and Parkinson observed that there were four habitat units where sediment deposition caused the interruption of continuous surface streamflow. They called these units DRY. In three instances, the sediment deposition was associated with the tail of a pool, which is where sediment deposition occurs during flow recession. Flow discontinuity occurs when the elevation of the sediment deposition exceeds the water surface elevation of the declining streamflow. The fourth DRY unit occurred between a low gradient riffle upstream and a pool downstream. The base of the riffle consisted of large boulders that created boulder shadows for sediment deposition. All DRY habitat units were in the upper reach of the surveyed creek (Figure 47). DRY units cannot support aquatic invertebrates or fish. DRY units also interrupt the energy flow and fish movement. In all cases, the DRY habitat units were complete migration barriers.

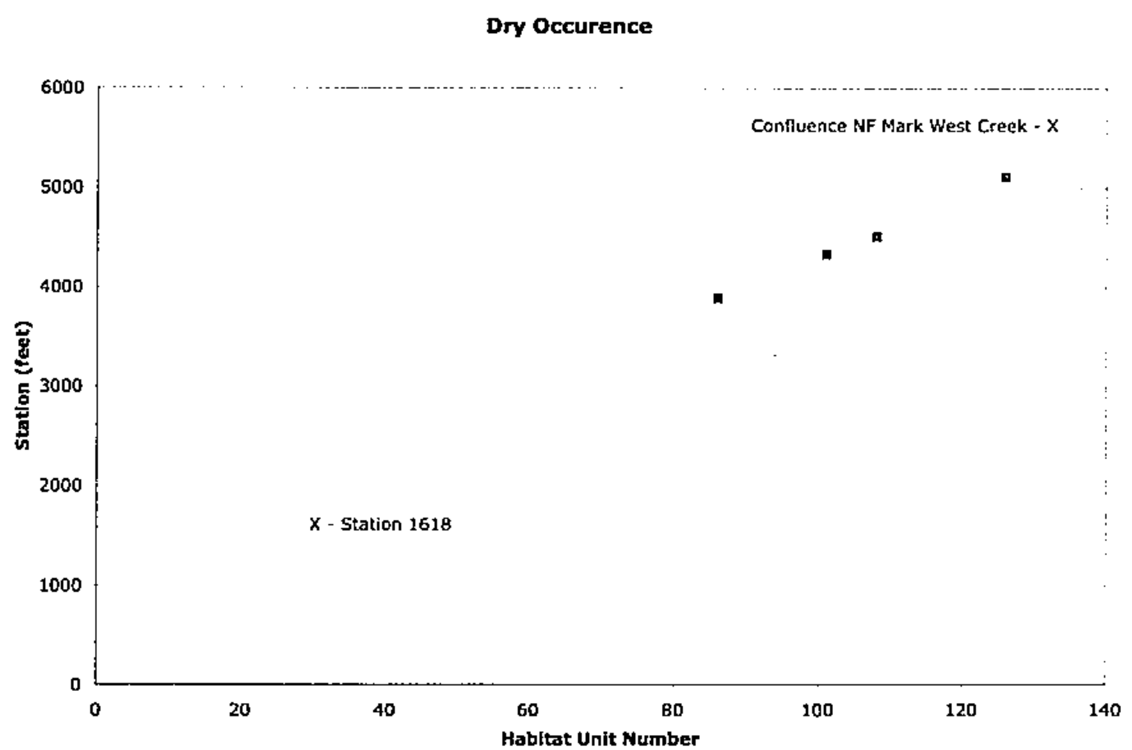

Figure 47. Occurrence of DRY habitat units between Tar Water Bridge to just upstream of NF Mark West Creek during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

DRY substrate sizes were small gravel and sand (Table 78).

Table 78. DRY habitat unit substrate composition during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Substrate Distribution Type Dominant/subdominant (Wentworth Scale)	Frequency (Number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
4/3	4	100	57	100.00

Banks of the DRY habitat units were stable (Table 79).

Table 79. DRY bank stability during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Bank Rank (Code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
	1/1	3	075.00	54	094.74
	1/2	1	025.00	03	005.26
Totals	2 = n	4	100.00	57	100.00

DRY bank components were largely bedrock (Table 80).

Table 80. DRY bank components under low streamflow conditions in upper Mark West Creek, Sonoma County, California, and October 2008.

Bank Components	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
Bedrock/Bedrock	1	025	23	040.35
Bedrock/Boulder	2	050	31	054.39
Boulder-RW/Bar	1	025	03	005.26
N = 3	4	100	57	100.00

Depth embeddedness in DRY habitat units was heavy (Table 81).

Table 81. Depth of embeddedness in DRY habitat units during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Embeddedness Depth (code)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Length (%)
4	4	100	157	100

Bank slopes adjacent to the DRY habitat units were steep (Table 82).

Table 82. DRY bank slopes, during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

	Left Bank/Right Bank slope angle (degrees)	Frequency (number)	Cumulative Length (feet)	Percent (%)
	90/90	1	23	040.35
	90/5	1	25	043.86
	40/90	1	06	010.53
	1/2	1	03	005.26
Totals	4=n	4	57	100.00

By definition, area embeddedness in DRY units was extremely high (Table 83).

Table 83. Proportion of DRY area covered by sediment during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008. Where 1 = 25% or less, 2 = 26% to 50%, 3 = 51%-75% and 4 = 76% to 100%

	Rank (code)	Frequency (Number)	Cumulative Length (feet)	Percent Length	Mean
	1	0	0	000	
	2	0	0	000	
	3	0	0	000	
	4	4	57	100	
Totals	1 = n	4	57	100	4.00

Percent fines in DRY units was 100% (Figure 84)

Table 84. Distribution of percent surface fines in DRY units during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent Fines (%)	Frequency (number)	Percent Frequency (%)	Cumulative Length (feet)	Percent Cumulative Length (feet)	Weighed Length (feet)	Percent Weighted Length (%)
100	4	100.00	57	100.00	57	100.00
n = 1	4	100.00	57	100.00	57	100.00

Mean percent surface fines weighted length = 100%

Area embeddedness in DRY habitat units was high (Figure 48).

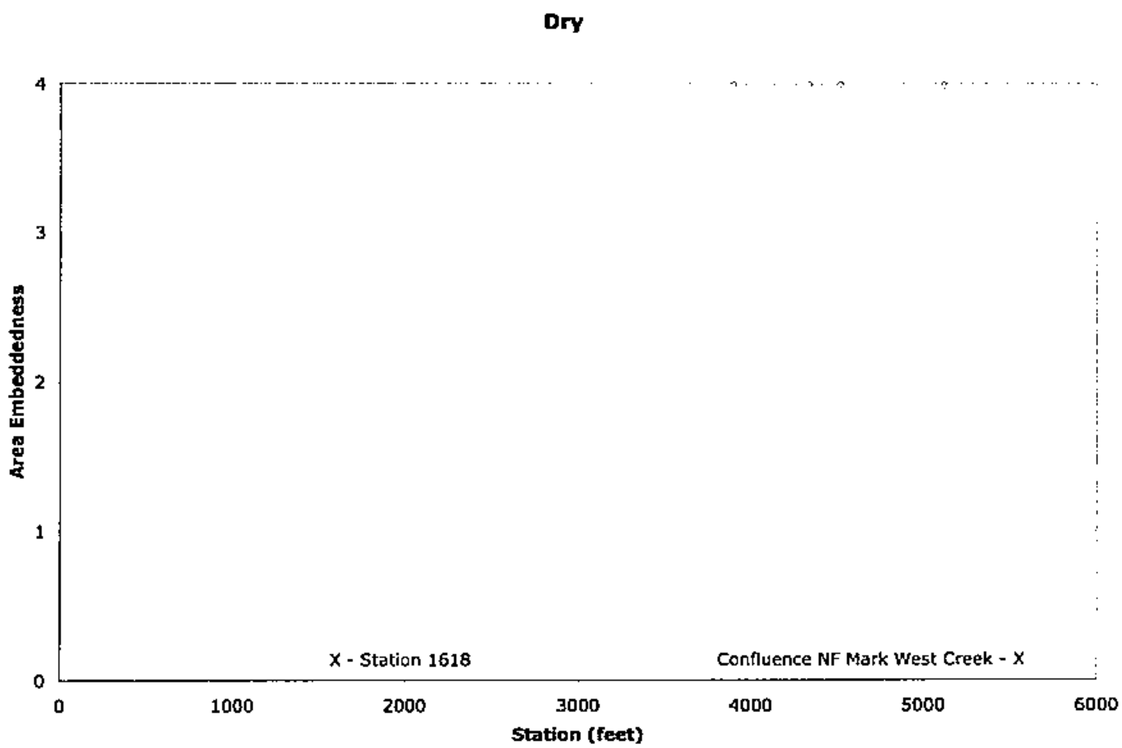

Figure 48. Longitudinal profile of area embeddedness in DRY habitat units during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Percent surface fines were maximized in the upper reaches of Mark West Creek (Figure 49).

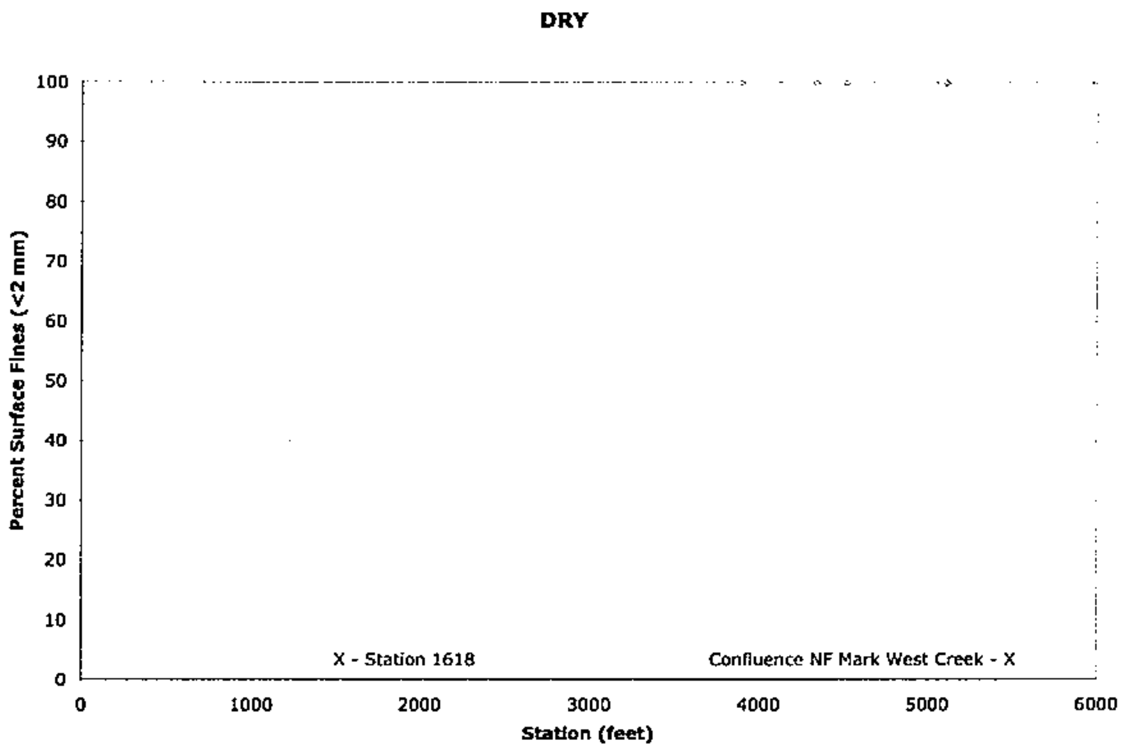

Figure 49. Longitudinal profile of percent surface fines in DRY habitats during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Depth embeddedness was high in DRY habitats (Figure 50).

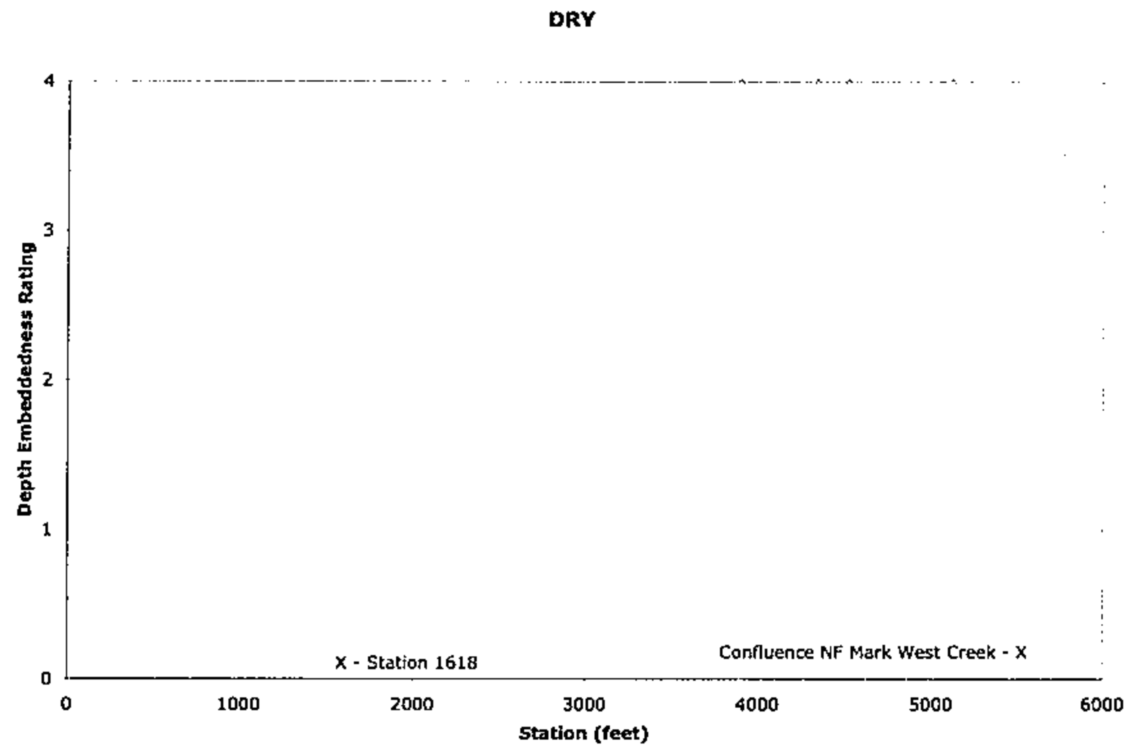

Figure 50. Longitudinal profile of depth embeddedness ratings in DRY habitats during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

There is no fish habitat in DRY habitat (Figure 51).

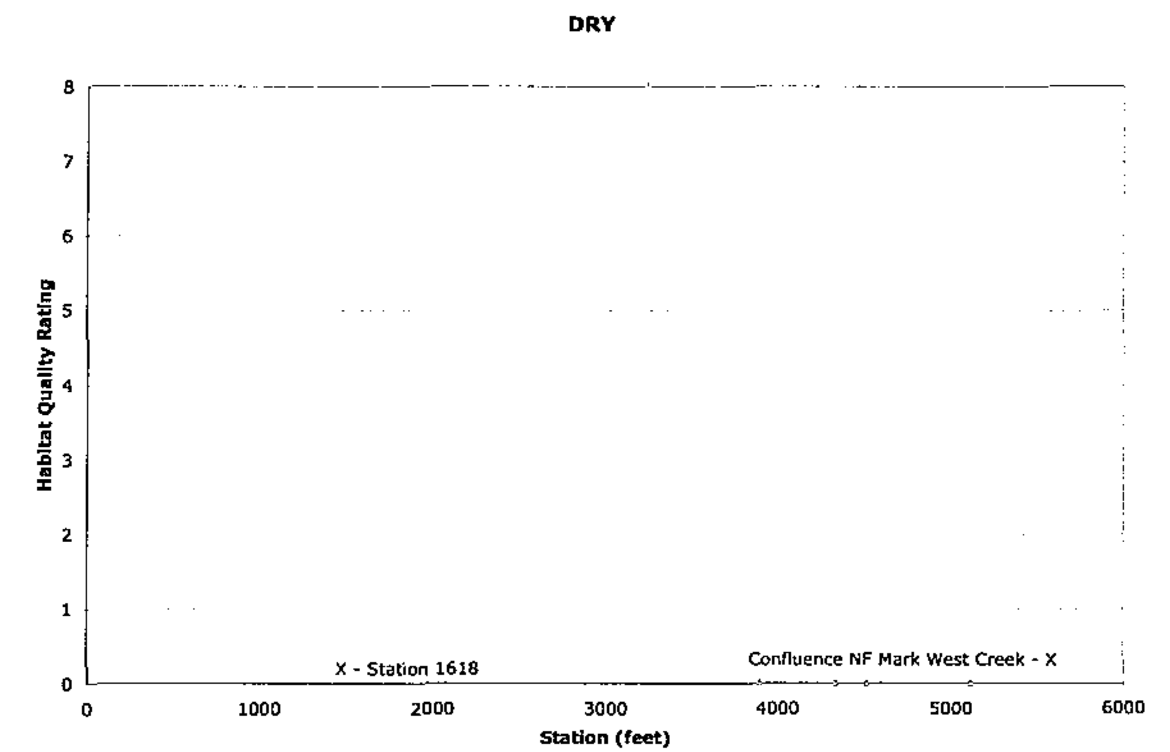

Figure 51. Longitudinal profile of habitat ratings in DRY habitat during low streamflow conditions in upper Mark West Creek, Sonoma County, California, October 2008.

Juvenile migration impediments

We found five juvenile steelhead migration impediments in upper Mark West Creek during the habitat inventory. One impediment was located at a cascade at station 3757; it consisted of a vertical jump of about two feet with insufficient stream depth for a jumping pool. There are potentially more of these types of impediments at places where boulder-field plugs occur. The other four were the DRY habitat units. These are impassable barriers because neither the length nor depth of water is sufficient and there are dry areas. (Figure 52).

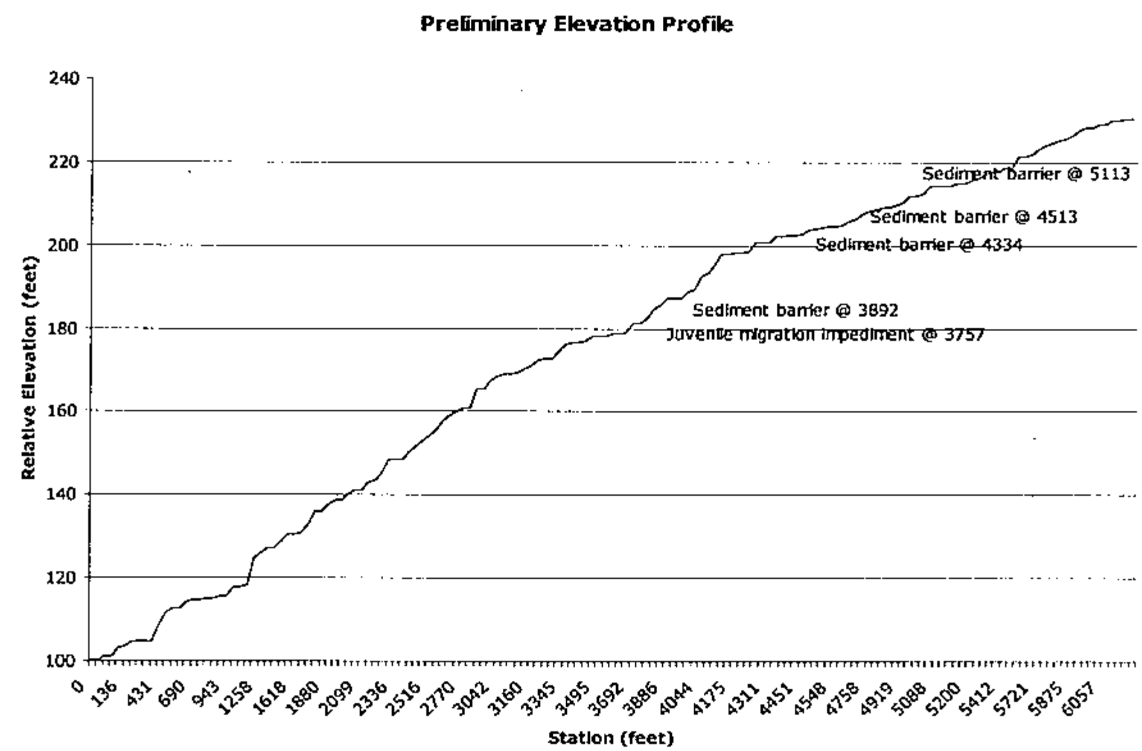

Figure 52. Juvenile steelhead migration impediments during low streamflow conditions in upper Mark West Creek, Sonoma Count, California, October, 2008.

Steelhead Spawning Activity

We recorded two types of steelhead spawning activity. First, "Spawning Observed" was noted at locations where spawning behavior was seen, but there was no physical evidence of a redd (spawning nest). "Redd" was noted when evidence of a redd, such as a nest mound, imbricated substrate, nest pit, *etc.*, was identified. Parkinson noted that the redds were not in typical locations, such as the tails of pools, but were in locations of lowest scour or in locations where the gravels were shallow (Figure 53).

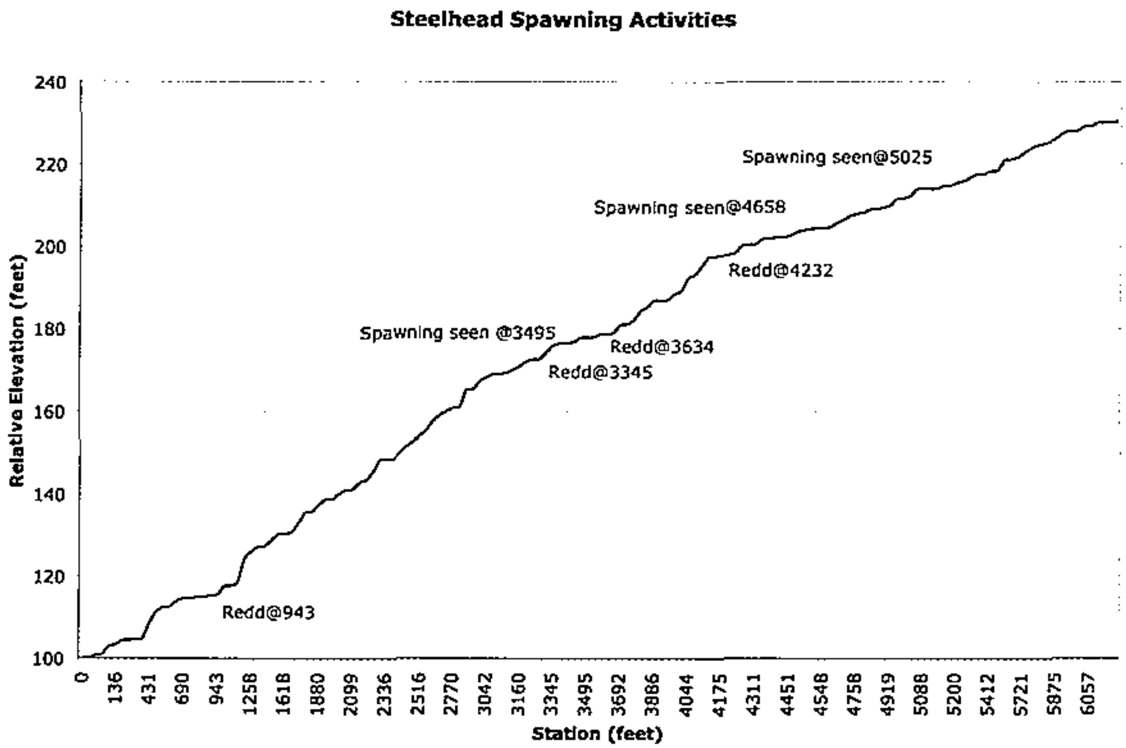

Figure 53. Evidence of steelhead spawning behavior in upper Mark West Creek for the 2007 water year.

TRIBUTARY SEDIMENT CONTRIBUTION

We looked for accumulations of sediment at each of the confluences of tributaries to upper Mark West Creek and found no indication of significant sediment augmentation other than that from NF Mark West Creek.

JUVENILE STEELHEAD ABUNDANCE

While walking upstream during the course of the habitat inventory survey, we periodically spooked juvenile steelhead. Their occurrence was noticeably less than Li's previous two visits.

STRANDED ADULT STEELHEAD

We found five stranded steelhead adults and one steelhead skeleton during the habitat survey (Figure 54). They ranged in size from 24 inches Fork length to 30 inches Fork length.

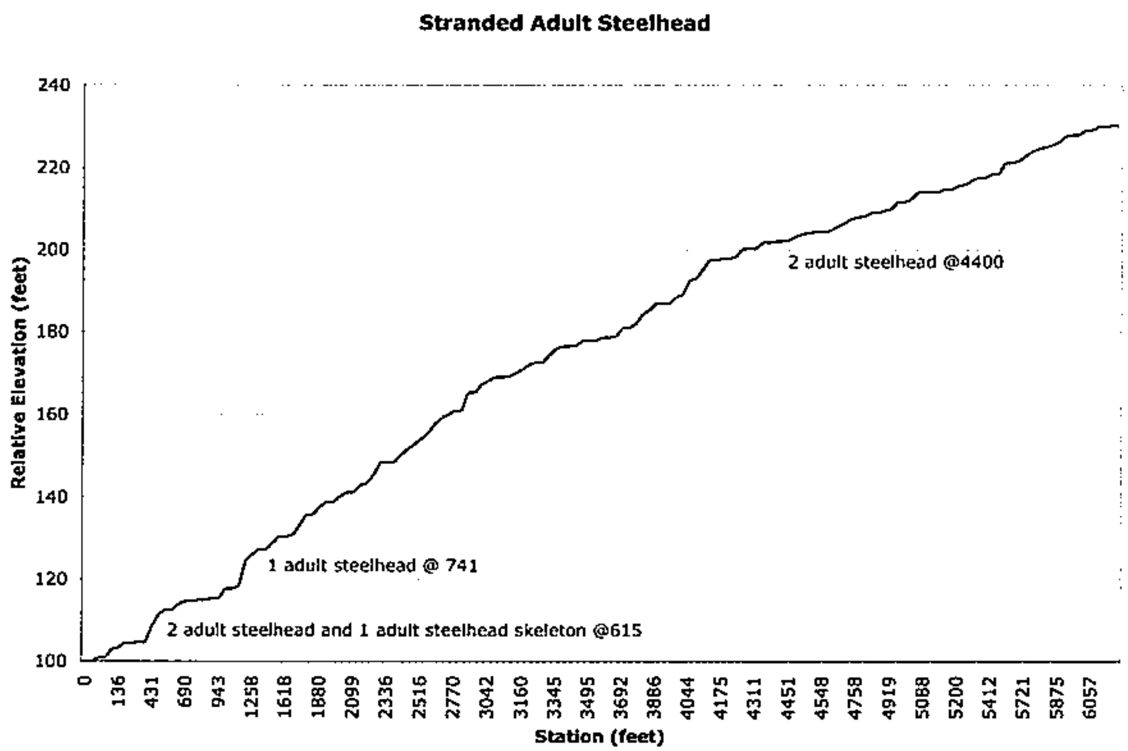

Figure 54. Location of stranded adult steelhead in upper Mark West Creek, Sonoma County, California, October, 2008.

CONCLUSIONS

A habitat inventory is the appropriate first step in watershed studies. It describes the spatial variability of the study area and facilitates subsequent studies. When reviewing our findings, please note:

1. Our findings are generally limited to the reach we surveyed. However, since bedload is carried downstream by streamflow, areas downstream of the surveyed reach will be adversely affected as moving sediment reaches them.

2. This habitat type classification depends upon the appearance of the water surface within the habitat unit. Depending upon slope, some habitat types will transform into others, as streamflow levels change. This survey was performed under very low streamflow conditions, around 0.01 cfs. We noted that the behavior of the sediment was very similar within the step-pool habitats. At this very low flow, they may function very similarly.

3. Upper Mark West Creek is a bedrock stream since it is lined with bedrock for much of its channel. The boulders and smaller substrate rocks lying on top of the bedrock provide alluvial elements that form some of the habitat types. Consequently, it also has characteristics of an alluvial stream. Depending on local conditions, Mark West Creek will transport sediment differently.

4. A habitat inventory must be interpreted through the conditions that shaped it. This habitat inventory describes conditions during low streamflow, with artificially high (anthropogenic) sediment loading, and two drier than normal water years. This low streamflow period creates the worst case conditions for the effects of sedimentation.

5. These data were based on rapid assessments during the course of walking through the stream corridor. As such, they are more qualitative and large scale, than quantitative and finer scale. More detailed information is required for quantitative analyses. However, the degree of habitat disturbance was so high that additional quantitative studies are not necessary to conclude that great damage has occurred.

We use three concepts to help interpret data and understand sediment transport in the different habitat types. First, the different habitats behave differently, depending upon whether streamflow level is increasing or decreasing. Pools are formed by hydraulic scour that lifts substrate and carries it downstream. Scour occurs only with increasing streamflow levels. As streamflow level recedes during the spring, pools become increasingly depositional and become sediment traps.

In contrast, riffles are known for their erosional nature, yet that characteristic typically only occurs when streamflow levels are decreasing. Riffles are actually depositional during periods of increasing streamflow levels; they collect substrate from the bedload.

Second, under most circumstances, the same amount of water flows through adjacent habitat units, i.e., a pool and an adjacent riffle have the same flow, but express it differently. This is known as flow continuity. The reason habitat types look different is due to differences in channel width, channel depth, stream velocity, size of substrate and local gradient. In particular, sediment will travel through different habitats differently depending on its size and streamflow magnitude, frequency, and duration. Third, streamflow is the agent that transports sediment downstream. There is a direct relationship between streamflow energy and the particle size that can be transported.

Although Mark West Creek is a major contributor of sediment in the Laguna-Mark West Drainage because it is steep with a high level of natural erosion (Blatt 2001), the most significant factor in this habitat inventory survey was the extraordinary amount of anthropogenic sediment.

This sediment was released to NF Mark West Creek thence upper Mark West Creek as a consequence of land development activities. We know of two properties that have recently spilled sediments into NF Mark West Creek, These properties were a short distance from its confluence with upper Mark West Creek. The Minton property spilled sediment into NF Mark West Creek in 2004. Sediment from this spill created a debris dam at station 4365 of this habitat inventory. We estimated this debris dam contained about 500 cubic yards of sediment. Additional sediments from this property also slid onto St. Helena Road and closed it several times during 2003-2004. As a result, Sonoma County posted multiple notices of violation. A storm in December 2005 broke the debris dam.

The second sediment source was the Cornell property. There was a 10,000 cubic yard landslide which washed into NF Mark West Creek during the 2005-2006 winter season. Landslide deposits were observed being washed from the Cornell property on 245 Wappo Road, Santa Rosa into NF Mark West Creek then into upper Mark West Creek on 31 December 2005. In addition, RGH Consultants (20 October 2006) reported that a landslide that occurred in April 2006 also transported sediments downhill to an intermittent flow ravine (NF Mark West Creek) and partially blocked the drainage. This landslide occurred in an area that had been disturbed by older, larger landslides. Keiran (2008) estimated the sediment amount that entered NF Mark West Creek from the Cornell property was 10,000 cubic yards. This 10,000 cubic yards of sediment was the overriding causative factor in the adverse effects we observed in the quality of steelhead habitat in upper Mark West Creek. The amount of this sediment material makes it unnecessary to conduct quantitative studies to establish adverse effect. The location of the point source near the Mark West Creek headwaters means that all of Mark West Creek will be adversely affected – because sediment is transported downstream.

Upper Mark West Creek is narrow (mean 5.74 feet wide), entrenched, and steep (between 3% and 4% slope) headwater stream. These parameters typically facilitate high bedload transport rates. Most of the upper Mark West Creek banks are composed of bedrock walls; where bedrock is absent, there is boulder or fully developed vegetation. These factors lead to high bank stability and reduce streambank sediment contribution to the waterway.

Upper Mark West Creek substrate composition is dominated by bedrock and boulder (Tables 15, 22, 29, 36, 43, 50, 57, 64, 71, 78). The habitat types within this reach are defined by the arrangement of large bed elements resting on the bedrock under the influence of streamflow, channel form, and gradient

In upper Mark West Creek, even with rare habitat types that make comparisons with the other habitat types tenuous, the relationships between stream velocity and the various physical dimensions in the different habitat types were generally consistent with flow continuity.

- Mean length - There is a general relationship between stream velocity and habitat unit length in upper Mark West Creek. The faster the stream velocity, the shorter the habitat length. In this habitat inventory, cascade was the shortest habitat type (9.73 feet), followed by high gradient riffle (22.65 feet), then low gradient riffle (30.79 feet), then run (32 feet), pocket pool (43.33 feet), step-pocket-pool (49.11 feet), step-pool (51.15 feet), pool (52.87 feet) and finally step-run (54.47 feet) [Table 7]. The habitat not in its expected position is step-run. Step-run should have placed between step-pocket pool and step-pool because it is generally faster than step-pool and pool but slower than step-pocket pool.

- Mean width – There was a relationship between stream velocity and habitat unit width. The slower the stream velocity, the wider the habitat unit should be. In this habitat inventory, high gradient riffle was the narrowest habitat type (2.44 feet), followed by cascade (2.45 feet), then low gradient riffle (3.41 feet), pocket-pool (3.83 feet), step-pocket-pool (4.89 feet), run (5.00 feet), step-run (5.45 feet), then step-pool (6.48 feet) and finally pool (9.67 feet)[Table 7]. While the difference is very slight, the habitat out of position in this inventory is cascade. It should be narrower than high gradient riffle. (This habitat inventory measurement is not as precise as 0.01 feet.)

- Mean depth – There was a relationship between habitat depth and stream velocity. The faster the stream velocity, the shallower the habitat should be. Cascade was the shallowest (0.16 feet), followed by high gradient riffle (0.26 feet), then low gradient riffle (0.27 feet), then step-run (0.44 feet), then run (0.45 feet), pocket-pool (0.50 feet), step-pocket pool (0.58 feet), pool (0.95 feet), then step-pool (0.99 feet)[Table 7].

  However, pool and step-pool should trade positions. Mean maximum depths in pools (2.04 feet) were greater than mean maximum depth in step-pools (1.31 feet). This suggests that step-pools have a less scoured shape, *i.e.*, step-pools are more flat in cross-section than pools, allowing step-pool mean depth to be greater than mean pool depth.

Habitat type proportions have a bearing on sediment storage in upper Mark West Creek. There were 19.78% of habitats with falling water characteristics. We expect these habitats to quickly transport fine sediment because of the hydraulic energy of water and slope. Flat-water habitat represented 38.67% of the habitat length. Flat-water consisted of pools (37.11%) and runs (1.56%) that store sediment after the rain season; 40.63% of the habitat was represented by step-habitats (step-pocket-poosl, step-runs, and step-pools) that are mostly flat-water. These habitats act as sediment storage areas when streamflow levels are declining (Table 8). While upper Mark West Creek is nominally steep, most of the reach stores sediment after the storms leave, so the sediment will travel through this reach slower than would be expected.

After two rain seasons, the downstream edge of the 10,000 cubic yard sediment plume from the Cornell landslide was 4020 feet downstream of NF Mark West Creek at station 1618. It is important to define the boundary of the sediment spill so that parameters can be compared inside or outside the landslide sediment zone. We were also fortunate to locate the approximate downstream edge of the Cornell sediment slug.

Based on examination of photographs taken as the sediment release was occurring, we noted that the sediment from the Cornell property had a reddish brown color. The sediment we initially observed at the beginning of the habitat inventory had a grayish cast. When we reached Station 1618, we noted a sudden increase in stored sediment with a reddish brown color. What made detection more apparent to us was that we had just passed a slide area with lower levels of stored sediments. We expected higher levels of deposition downstream from a slide rather than upstream from it, so the presence of more sediment upstream was readily noticeable. We now understand that the sediment slug from the Minton property has its own diagnostic characters. We did not fully appreciate this sediment release until after the habitat inventory was completed, so we were not prepared to look for it. We were not as successful identifying the upstream sediment boundary of the Cornell sediment. We were using the confluence with NF Mark West Creek as the upstream boundary of the sediment spills. Upper Mark West Creek is not pristine and produces amounts of bedload without the sediment slug, thus making the appearance of the upstream edge of the sediment slug less apparent. However, the portion of upper Mark West Creek upstream of NF Mark West Creek was less affected by sediment than the reach of stream affected by the Cornell and Minton sediment contributions.

We used longitudinal profiles to show the effect of sedimentation by location. *i. e.*, downstream of station 1618 – the downstream edge of the anthropogenic sediment, between station 1618 and the confluence with NF Mark West Creek at station 5638 where most of the sediment has been stored – and upstream of NF Mark West Creek, which was unaffected by the Minton and Cornell sediment spills.

These comparisons were limited by habitat unit occurrence. There were only three each of run and pocket -pool habitat units. Two of the runs were downstream of station 1618 and one was upstream. All of the pocket-pools and all four of the DRY units were in the

10,000 cubic yard sediment affected reach. Cascades and high gradient riffles were not present downstream of station 1618.

Generally, Area Embeddedness showed low ratings in all habitats downstream of Station 1618, which indicates less adverse effects. There were heavy and severe ratings between Station 1618 and the confluence with NF Mark West Creek, and less severe ratings upstream of NF Mark West Creek. (Figures 3, 8, 13,18, 23, 28, 33, 38, 43, 48). In particular, pools, step-pools, and step-runs not only had large areas covered with sediment, but also had interstitial spaces between the rocks clogged with sediment.

The results from the percent surface fines assessment generally followed Area Embeddedness in the habitats that stored sediment, but showed little response in those habitat units with current. Only in pools and step-pools was there still an increase in Percent Surface Fines upstream of Station 1618 (Figures 4, 9, 14, 19, 24, 29, 34, 39, 44, 49). The comparisons between Area Embeddedness and Percent Surface Fines data were illuminating because both assess surface coverage of the habitat unit with sediment. Percent Surface Fines focuses specifically on substrate particles sized less than 2 mm, while Area Embeddedness does not consider the size of the sediment. We infer from the results of these two assessments that fine sediment has been transported through the surveyed reach except in the most depositional habitat types (pools and step-pools), but sediments larger than 2 mm were still found in all the habitat types within the reach upstream of Station 1618.

Depth of embeddedness or the depth at which dominant substrate is buried could be classified into three groups. Cascades had the lowest embeddedness rating (0.62). Low gradient riffles, high gradient riffles, and pocket-pools had mean ratings around 1.0, and step-pocket-pools, step-runs, and pools had ratings around 1.3 or more (Table 9). This suggests that cascades pass sediment more quickly, and step-habitats and pools have higher embeddedness depths than other non-stepped habitats (Table 9). Depth of embeddedness ratings in pools and step-pools showed a pattern of lower embeddedness depth downstream of station 1618, higher embeddedness between station 1618 and the confluence with NF Mark West Creek, and lower embeddedness depth upstream of that tributary. The other habitat types were either insensitive, were too few in number, and/or not represented in one or more of the zones (Figures 5, 10, 15, 20, 25, 30, 35, 40, 45, 50).

Sediment transport through the creek depends upon the physical nature of the habitat type. The sand and smaller sediment travels quickly through low and high gradient riffles and cascades. These habitat types were relatively free of sediment, even when habitats upstream and downstream of them were clogged with fine sediment. Step-pools and step-pocket-pools were severely affected by sediment deposition. These habitat types are located within steep sections of the stream. However, elevation is lost vertically at the steps of the habitats; there are slow velocity flat-water areas between the steps. The low stream velocity and the normal shallows depths of these small pools allow for sediment disposition. We suspect that all of these habitats within the influence of the 10,000 cubic yard sediment plume are scoured out as flows increase with each storm. Their volumes are small and fill back in immediately when flow recedes after each storm, since there is such a large amount of sediment available. Some very deep pools in Mark West Creek have been almost completely filled with sediment. Several pools that are now 2 ½ feet deep were about eight feet deep prior to the effects of the 10,000 cubic yard spill. Given sediment of the same size, we think these pools will require higher flows to scour the accumulated sediment. They are both deeper and longer than step- pools or step-pocket-pools. This means that they will take longer to recover from the sediment spill because higher flows occur less frequently. The relationship of rate of scour to rate of re-deposition, the pool's storage capacity, the current level of sediment storage, and the sediment sizes stored and future hydraulic conditions will determine when the lasting effects of sedimentation are finally removed.

There was also a debris dam failure during the rain season of 2005-2006. This sediment release was different than the 10,000 cubic yard sediment plume. The materials that were released had been stored in a debris dam which was the result of unauthorized land disturbing activities on the Minton property in 2004. Sediment consisted of larger cobble and boulder clasts instead of gravel and sand. Perhaps there were smaller sediments, but they had already been transported downstream. Sand causes much of the habitat degrading effects. The volume of material released from the debris dam failure was only about 500 cubic yards; it is insufficient to account for the volume of sediment-related habitat degradation that was observed during this habitat assessment.

The habitat quality assessment is influenced by level of sedimentation, but also relies upon other factors such as stream depth, stream velocity, and instream cover. Pool, step-pool, step-run, and step-pocket-pool habitats showed a pattern of higher quality downstream of station 1618, depressed habitat quality within the sediment zone, and slightly higher habitat quality upstream of NF Mark West Creek (Figure 6, 11, 21, 27). Low gradient riffle, high gradient riffle, and cascade habitats did not show this pattern (Figures 36, 41, 46). Runs, pocket-pools, and DRY habitat units were under-represented or missing in at least one zone (Figures 16, 26, and 51).

Different habitat types are affected by sediment differently. In habitat types that are normally deep, with slow stream velocity, the degradation of habitat comes from reduced living space. Pools and step-pools in upper Mark West Creek were filled in with sediment. The deeper pools are more resistant to sediment deposition because they still have space to provide habitat. However, even the large pools lost most of their space.

The reduction of substrate roughness adversely affects habitat units with current, such as runs, step-runs, pocket-pools, and step-pocket-pools. Low energy expenditure zones become smaller as sedimentation occurs. "Costs" of holding a feeding station become higher and food availability becomes less. Consequently, steelhead that inhabit heavily sedimented streams such as upper Mark West Creak, can be expected to experience reduced growth and higher stress. The results of higher stress would be greater susceptibility to disease and parasites (Waters 1995).

The DRY habitat units are the ultimate expression of sediment overload in the stream. The highest elevation of one of them was approximately twelve inches above the water.

All four DRY units were complete migration barriers because the substrate was gradually sloped so that even the shortest DRY unit (3 feet) represented at least a nine foot long barrier. This precluded not only fish movement, but also interrupted energy flow in the stream. Detritus drives stream energetics and the DRY units stop detritus. This reduces food sources for aquatic invertebrates downstream.

Could there be another source of sediment other than the massive sediment spill from the Cornell property?

- The Minton property released large gravel and cobbles into the stream in 2004 during the process of repairing their driveway. These materials settled as a debris jam that failed the following year. We estimated the amount stored to be about 500 cubic yards. This amount was too small relative to the affected area, and the stored material was too large to cause much biological damage, except as a fish passage impediment.

- Bank components data for the surveyed reach showed that bedrock (Tables 17, 24, 31, 38, 45, 52, 59, 66, 73, 80) was the major bank feature. The dominance of bedrock and boulder meant that the banks were stable and sediment contribution from the banks was low.

- The stream has very steep banks (Tables 19, 26, 33, 40, 47, 54, 61, 68, 75, 82), which is typically associated with bank instability and high sediment loading. In this case, however, the banks are armored with bedrock so they are very stable (Tables 16, 23, 30, 37, 44, 51, 58, 65, 72, 79) and contribute little sediment to the stream.

- We found no evidence of significant inputs of sediment from unstable banks of Mark West Creek or from other tributaries other than that from NF Mark West Creek, the tributary that delivered both the 500 cubic yards of cobble from the Pride Mountain Vineyard and Winery property and the 10,000 cubic yard sediment release from the Cornell property.

- For a portion of the inventory, Tar Water Road and St. Helena Road parallel both sides of the surveyed reach, as well as residences. Roads are notorious sediment sources and these may contribute to sedimentation of the stream, but we found no road source that would account for the volume of sediment that filled in the habitats we saw on this survey.

- Because we could not identify another source of fine sediment with sufficient volume to account the volume of sediment in the stream, we believe that the majority of the observed sediment was from the Cornell property; this material caused virtually all the adverse sedimentation effects noted in this survey.

The adverse biological effects of sedimentation are better understood. There are two phases of adverse biological effects from a sediment spill. The first phase is adverse effects from suspended sediment. This phase is typically short. All streams clear up after storms. Based on work on NF Mud Springs Creek and Mud Springs Creek in Mendocino County (Cluer and Li 2005) and after examining the photographs of the Cornell sediment spill, Li believes that the initial turbidity concentration caused by the 10,000 cubic yard sediment release was sufficiently high to cause direct mortality to steelhead trout, even with relatively short exposures (Newcombe and Jensen 1996). Lesser concentrations of sediment can interfere with respiration through gill abrasion. Increased turbidity reduces feeding success.

The second phase considers the adverse effects after the sediment has become bedload, which can increase susceptibility to parasites, disease and predation through increased stress (Waters 1995). Until the 10,000 cubic yard sediment plume is transported out of Mark West Creek, the creek will produce and support fewer fish. Additional sediment into Mark West Creek would further delay recovery.

Needham (1938) in his classic book, *Trout Streams*, partitioned streams into two functional parts. Riffles provide habitat where aquatic invertebrate diversity and abundance is greatest and serve as fish food production areas. Pools downstream of riffles receive drifting aquatic invertebrates and the lower stream velocity reduces energetic costs to steelhead. Juvenile steelhead "rear" in pools.

Riffles and cascades were cleared of surface fines, but were clogged sufficiently to close interstitial space with larger sediment. As long as riffles are clogged, aquatic invertebrate abundance will be low. How much more sediment is still upstream to reoccupy these aquatic invertebrate production areas, and when will there be sufficiently high streamflow levels to transport it away?

The step-habitats may provide habitat for aquatic invertebrates, provided the substrate is gravel or cobble and there is sufficient stream current (Wayne C. Fields, Jr., Hydrozoology, personal communication).

All flat-water habitats should be able to support juvenile steelhead. Unfortunately, we observed that those that had current had reduced substrate roughness, and those that had slow velocity had been filled with sediment.

Dr. Li noted a striking decrease in juvenile steelhead. Prior to the 10,000 cubic yard sediment spill, Li had visited areas now occupied by the massive sediment slug. On his previous visits, there was such an abundance of juveniles that tossing food items into the creek created the same results as feeding time at a hatchery. Regrettably, during this habitat survey, there were only occasional encounters with juvenile steelheads.

Steelhead-spawning gravels were extremely rare. Parkinson identified only 450 square feet of steelhead-spawning gravels in approximately 42542 square feet of habitat. Parkinson noticed that the few steelhead redds he observed were located in areas that would minimize scour; he also observed that the placement of redds seemed unusual. He theorized that this placement was probably related to the lack of steelhead spawning gravels in more usual places. Those places/gravels were buried by the 10,000 cubic yard sediment spill. We suspect that steelhead spawning potential has been reduced because the sediment has buried steelhead spawning gravel, forcing redds to be built with substandard materials. These materials scour more easily; those materials can also smother the developing embryos or entomb the alevins because the interstitial space was so clogged with sediment. This clogging can stop embryonic respiration or prevent emergence out of the gravel.

During the course of the habitat inventory, we located five adult steelhead holding in the larger pools. Three were downstream of station 1618 and two were upstream from two of the DRY habitat units. In addition, we found the skeleton of an adult steelhead that had been eaten by some predator. Both Li and Parkinson believed the number of stranded adults to be unusually high.

The culvert under St. Helena Road on NF Mark West Creek backwatered during the storms of December 2005. This was probably due to sediment reducing the culvert's capacity. If backwatering occurs regularly and the area is inundated for prolonged periods, there is a real threat of saturating the soils and undermining St. Helena Road. In addition, the culvert is not at grade with the stream, so steelhead have to jump into the culvert to gain access upstream.

There are Endangered Species Act issues resulting from the severe sedimentation of upper Mark West Creek. Steelhead trout of the Central California Coast Distinct Population Segment live in Mark West Creek and are listed as *threatened* under the Endangered Species Act (71FR834). Mark West Creek (part of the Russian river watershed), has been designated as critical habitat (70FR52488).

Local residents of the upper Mark West Creek have not seen any coho salmon, an endangered species that once inhabited the creek. Therefore, we conclude that if coho salmon still inhabit Mark West Creek, it is in the lower portions of the stream. They have not yet been directly affected by this sediment spill, since the bulk of the sediment has not yet reached them.

We have concluded that steelhead were killed by the effects of the sediment spills. The habitat upon which they depend has been seriously degraded, which will result in fewer steelhead. This reduced production of steelhead will continue until the excess sediment has been transported out of Mark West Creek.

One of the purposes of the Endangered Species Act is the preservation of ecosystems. The National Marine Fisheries Service must use its authorities not only to conserve species, but also the ecosystems upon which they depend. In this case, the Section 7 process is inappropriate because there are no federal agencies related to these spills; there is no federal nexus. Likewise Section 10 is inappropriate because there was no scientific purpose for releasing these anthropogenic sediments. We are left with Section 9 actions against prohibited acts. (Section 9 makes it unlawful to "take" a listed animal and includes prohibitions against significantly adversely modifying its habitat.)

The endangered species act prohibits the destruction or adverse modification of critical habitat. What qualifies as adverse modification?

We have documented the extent of habitat degradation in upper Mark West Creek due to anthropogenic sedimentation. Sedimentation is a serious problem in streams, and the mechanisms of adverse affects are now known. Waters (1995), in his monograph *Sediment in Streams* wrote, "After a half-century of the most rigorous research, it is now apparent that fine sediment, originating from a broad array of human activities (including mining), overwhelmingly constitutes one of the major environmental factors – perhaps the principal factor – in the degradation of stream fisheries." While our data are qualitative, they are sufficient to predict the adverse effects related of sediment on steelhead and steelhead critical habitat. The degradation of upper Mark West Creek is a clear and excellent example of adverse modification of critical habitat.

The threat of severe sedimentation to Mark West Creek is not over. The Cornell property has more stored sediments; there are inadequate provisions to isolate them from the stream. There remains the imminent threat of another sediment spill, which will further delay the creek from returning to normal functioning as steelhead habitat.

Recommendations:

1) Identify any sediment deposits upstream that threaten Mark West Creek.
   - Halt sediment inputs
   - Identify potential sources of sediment
   - Establish monitoring areas for an ESA Section 9 investigation

2) Find the upstream boundary of sediment slug.
   - Estimate how long the sediment will remain in this reach

3) Describe sediment size composition in the important habitats.
   - Class/size of substrate and amount

4) Continue to measure maximum depth of the pools and the pool's hydraulic control to monitor rate of change in sediment supply. Monitoring of fine sediment will require more intensive sampling than what was performed for this assessment. Bunte and Apt (2001) describe protocols for a quantitative sedimentation (V*) investigation.

5) Develop site specific hydrology by establishing a "gaging" station to monitor streamflow.

6) Longitudinal and seasonal hydrographs should be performed to establish when the stream is gaining or losing streamflow and by how much.

7) Conduct spawning surveys.
   - Locations
   - Substrate composition

8) Determine gravel permeability
   - Redd Piezometers
   - Standpipes
   - Sieve analysis

9) Terrestrial drift analysis to determine amount of fish food from terrestrial sources.

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