University of Delaware

UAPP 611 – Regional Watershed Management

The F.O.R.C.E

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Mission Statement:

The F.O.R.C.E.'s goal is to reduce turbidity by 10%, increase the dissolved oxygen content to 5 mg/L, restore the function of the floodplain, and increase the Coho salmon population by 20% by the year 2030 in the Redwood Creek, Marin County. We also hope to engage the community in an educational program for the watershed by 2020.

Figure 1: Location of the Redwood Creek Watershed

General Watershed Characterization:

The Redwood Creek Watershed is a very diverse watershed located in Marin County, California. The watershed encompasses an area of approximately 7.3 square miles and is located north of San Francisco. See **Figure 1** above for a map regarding the location of the Redwood Creek Watershed. The Redwood Creek is about 4.7 miles with 6.8 miles of potential habitat in the watershed when considering the following tributaries: Bootjack, Fern, Kent Canyon, Rattlesnake, and Spike Buck Creeks. The source of the Redwood Creek is at Mount Tamalpais and it discharges into the Pacific Ocean at Muir Beach. The Redwood Creek watershed provides habitat for several sensitive species, including northern spotted owl, California red-legged frog, Coho salmon, and steelhead trout. The watershed is located in a recognized global biodiversity "hot-spot" (one of only 5 in the continental United States) and is also within the Golden Gate biosphere Reserve. Lately, some issues that have impacted the watershed are invasive plants, creek water turbidity, and rapidly declining numbers of the Coho salmon population. From USGS Streamstats, the impervious cover of the watershed was 0.9% from the NLCD 2001 Imperviousness dataset. In terms of vegetation within the watershed, it is 31% coniferous, 32% shrubland,18% riparian, and 12% grassland.

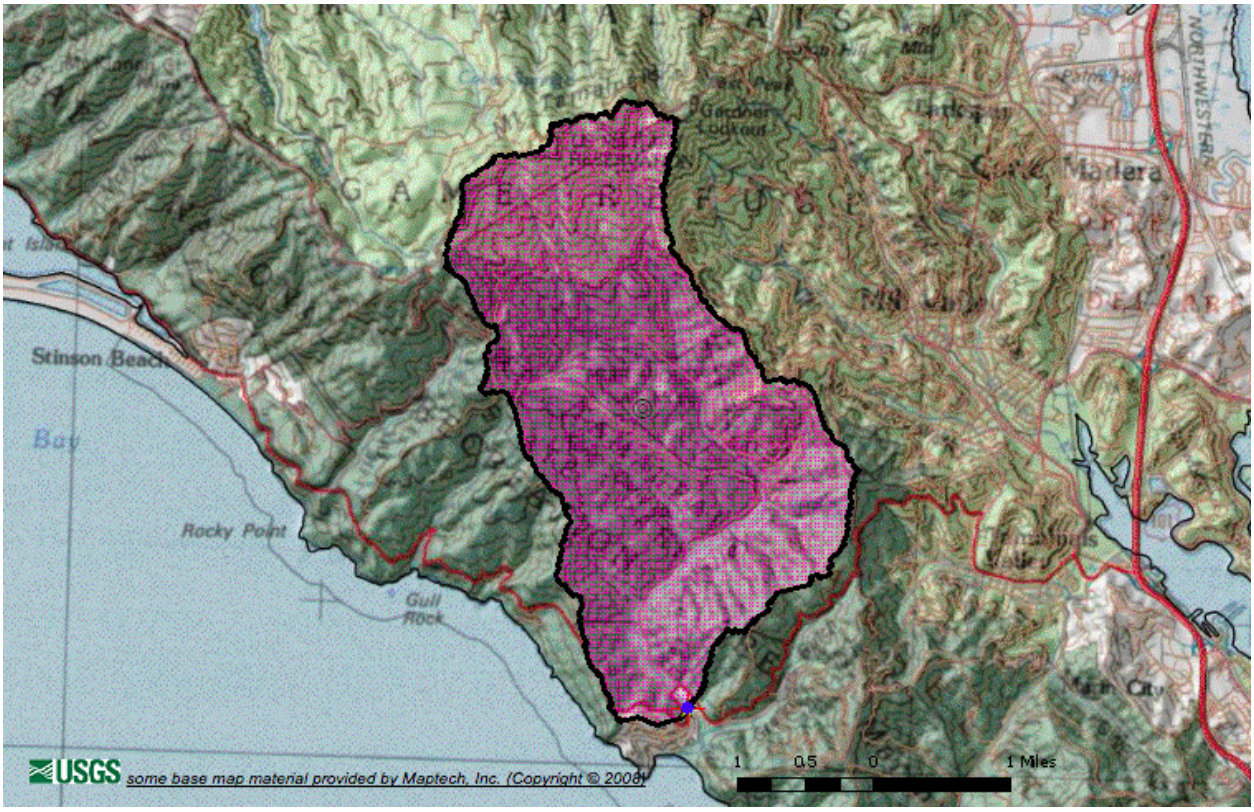

Figure 2. USGS Streamstats Redwood Creek Watershed Delineation

The History of the Redwood Creek Watershed:

For thousands of years before European colonization of the Bay Area, the watershed was inhabited by the native people of the Coast Miwok. At this point in time, the watershed was primarily agricultural land. After European colonization, the area attracted many visitors and from 1948-1949 levees were constructed along the right bank to prevent flooding. These actions created an unnaturally straight stream resulting in the loss of channel complexity and riparian vegetation. Over the years, farming and development along the watershed continued and drastically affected the hydrological system causing poor flow, flooding, fish stranding, and weak habitats for salmon and trout. The watershed currently is dominant in recreational land use. It is also 95% publicly owned and managed as parkland by the Marin Municipal Water District, California Department of Parks and Recreation, and National Park Service. There are also three communities within the watershed; Muir Beach, Muir Woods Park, and Green Gulch Farm. These communities rely heavily on the watershed for clean water, and, in turn, help contribute to its well-being. Each year more than one million tourists visit the watershed to experience its true natural beauty. Because of the watersheds high attraction arises issues of overcrowding, roadway interruptions, diversions of water, invasive plants and animals, and increased flooding.

Current Land Use:

The Redwood Creek Watershed is ninety-five percent publicly owned with three private communities occupying a small portion of the watershed. Refer to **Figure 3** to understand the land use. Over a million people visit the watershed during the year for it's recreational opportunities including Muir Woods National Monument. Other attractions within the watershed boundaries include Mt. Tamalpais State Park and portions of the Golden Gate Recreational Area. The Redwood Creek watershed has a diverse mix of habitat types due to it's close proximity to the Pacific Ocean and the forest. In the area, coastal chaparral, grasslands, old-growth redwood forest, mixed hardwood forest, seasonal wetlands, and riparian wetlands can all be found. The majority of the watershed area is undeveloped so the impervious cover is low, but the developed communities are the areas where the watershed issues are occurring. This distribution can be observed in **Figure 4**.

Figure 3: Land Use in the Redwood Creek Watershed

Figure 4: Impervious Cover in the Redwood Creek Watershed

Problems:

Table 1: Redwood Creek Problems and Descriptions

Problem	Description
1. Aquatic and Riparian Habitat Quality	Coho salmon are state and federally listed as endangered. Steelhead trout and California red-legged frogs threatened. Abundant invasive species present.
2. Sediment Impairment and Flood Control	Construction features in recent years have confined the creek flow and influenced sediment transport. A visitor parking lot and footbridge are currently located in the center of the floodplain, which eliminates the function of the floodplain.

P1. Aquatic and Riparian Habitat Quality

The Redwood creek watershed is considered a biodiversity hotspot, however there are many animal populations living within the watershed that are on the endangered species list or threatened. The coho salmon population is state and federally listed as an endangered species. Coho salmon are semelparous, meaning they produce offspring only once, and then die after reproduction. These fish migrate from the ocean environment into freshwater streams in order to mate. The entire Pacific coast of the United States is experiencing in drastic decline in salmon populations. One of the many causes for this decline is caused by the modification of the natural flow of the freshwater streams. For example, the creation of dams and land use activities like logging and development have severely altered the streams and destroyed habitats. Because of these issues, the water quality of the stream is also an issue. The ongoing drought in the area has also contributed to the decline in the reproduction of coho salmon. **Figure 5** depicts the population trend from 1994-2013 for coho salmon and steelhead trout in the Redwood Creek Watershed. The primary predators of the spawning salmon are river otters and raccoons. Other potential impacts including low flow, physical barriers, and warm water temperatures may also impede the ability of adult salmon to reach spawning habitat.

Steelhead trout are federally listed as threatened in the watershed. This species also migrates from a marine ocean environment to freshwater streams in order to mate. The females will nest in the stream and deposit their eggs in nesting pockets. Unlike the coho salmon, steelhead trout can spawn more than once and their maximum age is about 11 years. However, they are also greatly affected by many human-induced and natural factors with the stream.

Invasive species of plants, such as cape ivy and pampas grass, have been an issue along the Redwood Creek as well. Because the Redwood Creek is in a recognized global biodiversity “hot spot”, it is important that these invasive species are reduced, and ideally eliminated.

Figure 5: Population Graph of Coho Salmon and Steelhead Trout

P2. Sediment Impairment and Flood Control

The Redwood Creek Watershed's problems root from the construction features in recent years. Currently, a visitor parking lot and footbridge are located in the center of the floodplain on either side of the mouth of the creek. These two obstructions in the floodplain eliminate the natural function of the floodplain. The water elevation in the surrounding areas has increased and the natural shape of the creek has been altered. The loose sediment from the banks is eroded and carried down the creek. The displacement of the sediment has caused the flow of the water to decrease and as a result has decreased the quality of the water and destroyed the various habitats found in the watershed. The Redwood Creek Watershed is a biodiversity hotspot and a popular tourist attraction, by implementing flood and erosion control solutions the watershed will experience restoration in multiple areas.

Solutions:

P1: Aquatic and Riparian Habitat Quality Solutions

S1: Habitat-based solution:

One way to increase the livelihood of the coho salmon and steelhead trout is to enhance the stream habitat specific to the species in need. For example, we would need to increase the water quality throughout the stream, create good nesting areas for the fish, and alter the stream so the fish can travel deep into the stream. According to The Nature Conservancy, the watershed received poor ratings in the following stream habitat characteristics: shelter, large woody debris, embeddedness, riffles and primary pools throughout the stream. Also, their upstream spawning migration takes a heavy toll on their body due to both physical exertion and the severe change from saltwater to freshwater conditions so we need to make this process as easy as possible for the coho salmon. We need to enhance the complexity of the stream, as it once was before development. In order to fix this problem, possible restoration designs include implementing side channels, backwater and large woody debris. These designs would provide food and shelter for young coho, and threatened steelhead trout.

S2: Population-based solution:

Another way to increase the livelihood of Coho salmon is through a technique called captive rearing. This technique is usually used as a "last effort to prevent local extirpation of a species. The population of Coho salmon is nearly extirpated, and therefore we are proposing the use of captive rearing to prevent extirpation. This project would include temporary removal of juvenile coho from Redwood Creek, rearing them to maturity, and releasing them as adults back into their stream of origin. No hatchery spawning will occur. This project is a temporary measure that will help promote natural reproduction so that the population may persist in the future. The salmon will typically spend about three years in the facility, until they are big enough to survive on their own. The National Park Service would be a great agency to implement this solution.

P2: Sediment Impairment and Floodplain Controls

S1: Improve Floodplain Functionality:

In order to restore the functionality of the floodplain, we are proposing to remove the visitor parking lot and the footbridge from their current locations within the floodplain. We are also proposing the implementation of a new footbridge that will span the creek and floodplain, which would not affect the functionality of the floodplain. Also, since the area is still a park, a parking lot can be added outside of the floodplain closer to the emergency access road so that the area is still accessible to the park's visitors.

S2: Reduce Erosion by Manipulating Stormwater Flow:

We are proposing to reduce erosion by the implementation of an elevated emergency access road and hiking trail lined with rocks and boulders that will manipulate water flow during heavy winter rains to fall into the catchment zones and flow towards the creek. This solution will decrease erosion because the path that the water takes is deliberate. It will also increase flow, reduce turbidity, and increase dissolved oxygen in the creek. An example of what this looks like is in **Figure 6**.

Figure 6: Emergency Access Road and Hiking Trail

S3: Reduce Erosion by Manipulating Stormwater Flow 2:

Another way to reduce erosion is by installing different erosion control techniques that will also manipulate the flow of water towards the creek. An example of a productive management practice is using rice straw wattles to create contours on banks that direct water flow into creek and reduce downslope sediment delivery. This method is demonstrated in **Figure 7**. Vegetation should also be added to the sloped drainage areas in an effort to produce roots and add integrity to the soil to prevent future erosion.

Figure 7: Erosion Control Techniques

Community Outreach Solution:

The FORCE will engage the community in an educational outreach program by 2020 to highlight the importance of the watershed and the restoration efforts taking place. We are proposing to implement educational hiking trail posts throughout the park. Some of the interactive hiking posts include information about the Coho salmon and their extinction, the invasive plant species along the creek, areas that are prone to erosion, and current restoration efforts. We are hoping to add these posts along the trails within the Muir Woods National Monument Park as well as an existing coastal trail near Muir Beach.

Collaboration Efforts:

The F.O.R.C.E will be a collaborative effort National Park Service
and the California Fish and Wildlife foundation. These are the two most established groups working in the area, and their collective resources will help us improve the Redwood Creek environment to the greatest extent. This collaboration represents an effort to use scientific principles when creating policy.

Conclusion:

The objective of this proposal was to devise a plan to improve the aquatic and riparian habitat quality and improve the sediment impairment and flood control conditions of the Redwood Creek Watershed in Marin County, California. Reducing the turbidity and increasing the dissolved oxygen content in the Redwood Creek will improve the overall creek water quality. Restoring the function of the floodplain as well as enacting some erosion reduction techniques will restore streambank erosion of the Redwood Creek to normal levels. Additionally, the population-based solution of captive rearing and the habitat-based solution of repairing natural habitats should increase the Coho salmon population by 20% in the next 15 years. Overall, if our solutions are enacted, the Redwood Creek Watershed will be a healthier, more beautiful watershed that will continue to attract park visitors for decades to come.

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