OAK CREEK WATERSHED

STREAM STABILITY ASSESSMENT AND RESTORATION RECOMMENDATIONS REPORT

North Fork Oak Creek riparian vegetation regrowth

INYO NATIONAL FOREST

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EXECUTIVE SUMMARY

Alluvial fan systems on the east flank of the Sierra Nevada do experience large scale floods and debris torrents, a natural occurrence responsible for the very existence of these dynamic landforms. They fan out from every stream coming off the mountain front, so much so that these fans of rock and soil overlap each other. The east flank is also an active fault zone and home to one the largest quakes in California history (USGS, 1991). Streams that travel through, and end in the valley bottom below the fan, are often the conduits for debris torrents. This is especially true when large scale intense fire is followed by a flood that triggers a debris torrent (Wagner, 2012). These events can obliterate a stream form and vegetation due to extensive debris scour and fill; in some cases the stream can be plugged with debris and forced laterally to a new position on the fan. Fortunately these large scale debris events are rare, occurring only about every few hundred years. However, when they happen there can be catastrophic effects to aquatic habitat and wildlife resources, as well as human infrastructure.

A spectacular example of fire-flood-debris torrent response occurred in the Oak Creek watershed located above the settlements of Independence and the Fort Independence Native American Reservation. Early historic accounts indicate that stream was quite stable and no debris torrent events had occurred on Oak Creek for over a century or more. But in 2007 conditions were ripe for a debris torrent when the Inyo complex fire burned over much of the watershed with south, middle, and north fork streams and riparian corridor subjected to high burn intensity. About a year later on July 12th a summer thunderstorm with intense rains triggered a debris torrent on all three forks. On the south fork a boulder rich debris flow forced the channel to shift laterally, abandoning the existing stream course entirely. Sediment laden flows on north and middle fork channels ate away at scorched stream banks causing extensive incision. Channels cut down into the north and middle fork stratigraphy up to 30 feet below the active fan surface. The end result was a gully corridor 30 feet deep and 50 feet wide in some places, with significant damage to residences and infrastructure downstream. Post debris flow studies indicate that most of the 1.5 million cubic yards of material was generated from within the stream channel itself (Wagner, 2012).

Almost immediately, post debris flow water quality issues resulted throughout Oak Creek affecting Tribal Lands, the Owens Valley Aqueduct and the Mt. Whitney hatchery facilities. In 2010 the Inyo National Forest designated Oak Creek as a priority watershed for restoration, establishing a Watershed Restoration Action Plan (WRAP). One of the essential projects in the WRAP was to assess the current trends in stream stability and come up with a list of recommended actions to improve stream stability and to restore water and environmental quality in a watershed with a rare Black Oak riparian over story.

This report presents stream channel stability assessment using pre- and post-flood georeferenced aerial photos and review of ground based photos. Results indicate that the streambed and banks of the south fork are starting to stabilize with a few specific areas requiring intervention to improve recovery. The stream beds of the middle and north forks are also stabilizing and riparian vegetation is starting to colonize channel margins. There is however, a weed infestation (Russian thistle) along portions of the north fork. Gully walls in certain areas are also prone to failure, limiting riparian recovery and creating an unsafe human environment.

The recommended restoration actions for the Oak Creek Watershed are: 1) strategic riparian plantings on the north fork 2) weed removal and riparian plantings on the north fork 3) install structures on north and south forks that encourage distributary flow and strategic riparian plantings of distributary flood channels and 4) develop partnerships that help support and restore aquatic species in the Oak Creek watershed.

TABLE OF CONTENTS

Acknowledgments: The author would like to thank Todd Ellsworth of the Inyo National Forest for graciously giving me the opportunity to become reacquainted with this fascinating landscape; a special place that inspired me as a geology graduate student long ago.

INTRODUCTION

The 22 mi^2 Oak Creek watershed is located in the Inyo National Forest above the settlements of Independence, California, and the Fort Independence Native American Reservation **(FIGURE 1)**. The watershed is located on the steep east sierra escarpment, originating on the high peaks above the timberline (elevation 13000) ending in the high desert of the Owens valley (elevation 4050). The snow pack on these high peaks feed streams and local perennial springs that are especially important for supporting base flow conditions in the area. The consistent water supply combined with long warm growing seasons established stable-robust riparian vegetation upon an alluvial fan system (based on visual review of the 2005 aerial photo). In June of 2007 however, a high intensity fire scorched a large percentage of the Oak Creek watershed and severely burned the stream side vegetation leaving it vulnerable to debris flow. A catastrophic summer rain event followed a year later on July 12 2008. The stream channels avulsed or severely incised and destabilized the three forks. In total, 1.5 million cubic yards of debris moved through the system obliterating the functional channel-fan surface relationship on portions of all three forks of Oak Creek.

A Post-fire flood study on Oak Creek alluvial fan processes was performed by Wagner in 2012. Results indicate a debris charged flood interval of every few hundred years; suggesting these systems evolved with large scale debris torrents, and in fact have been shaped by them throughout the millennia. Another important finding is that in channel erosion generated the bulk of the debris. This study supports the idea that Oak Creek channels are remarkably stable for long periods of time, but are punctuated by abrupt periods of mayhem – referred to in geomorphology as *Punctuated Equilibrium*.

Because of the significant threats to downstream water users and the desire to restore environmental function, the Inyo NF designated Oak Creek a priority watershed for restoration. The first stage of the planning involved the development of a Watershed Restoration Action Plan (USFS, 2011) which identified the need for a stream channel stability assessment with conceptual level restoration strategies.

This document provides analysis of sequential aerial photographs and ground photos to judge the present day trend in channel stability along portions of south, middle and north forks of Oak Creek **(FIGURE 1)**. Data indicates stream banks and beds are stabilizing and are slowly re-vegetating. The evidence indicates the need for actions that can benefit and possibly expedite the recovery process on the north and south forks. The sections below provide a methodology and management approach to implement actions required to achieve restoration objectives; specifically, improve Oak Creek water quality and enhance the fan stream recovery processes on the north and south fork of Oak Creek.

The four proposed restoration strategies are: 1) broadcast riparian plantings on the north forks to increase stream corridor riparian cover, 2) removal of invasive weeds on the north fork - specifically Russian Thistle, 3) partner with LADWP to modify the diversion flow scheme; install stream structures that promote flow spreading that encourage recovery of fan form and function on north and south forks; conduct riparian plantings along reactivated fan channels 4) engage partners in developing a plan to utilize Oak Creek as a native fish nursery and educational experience.

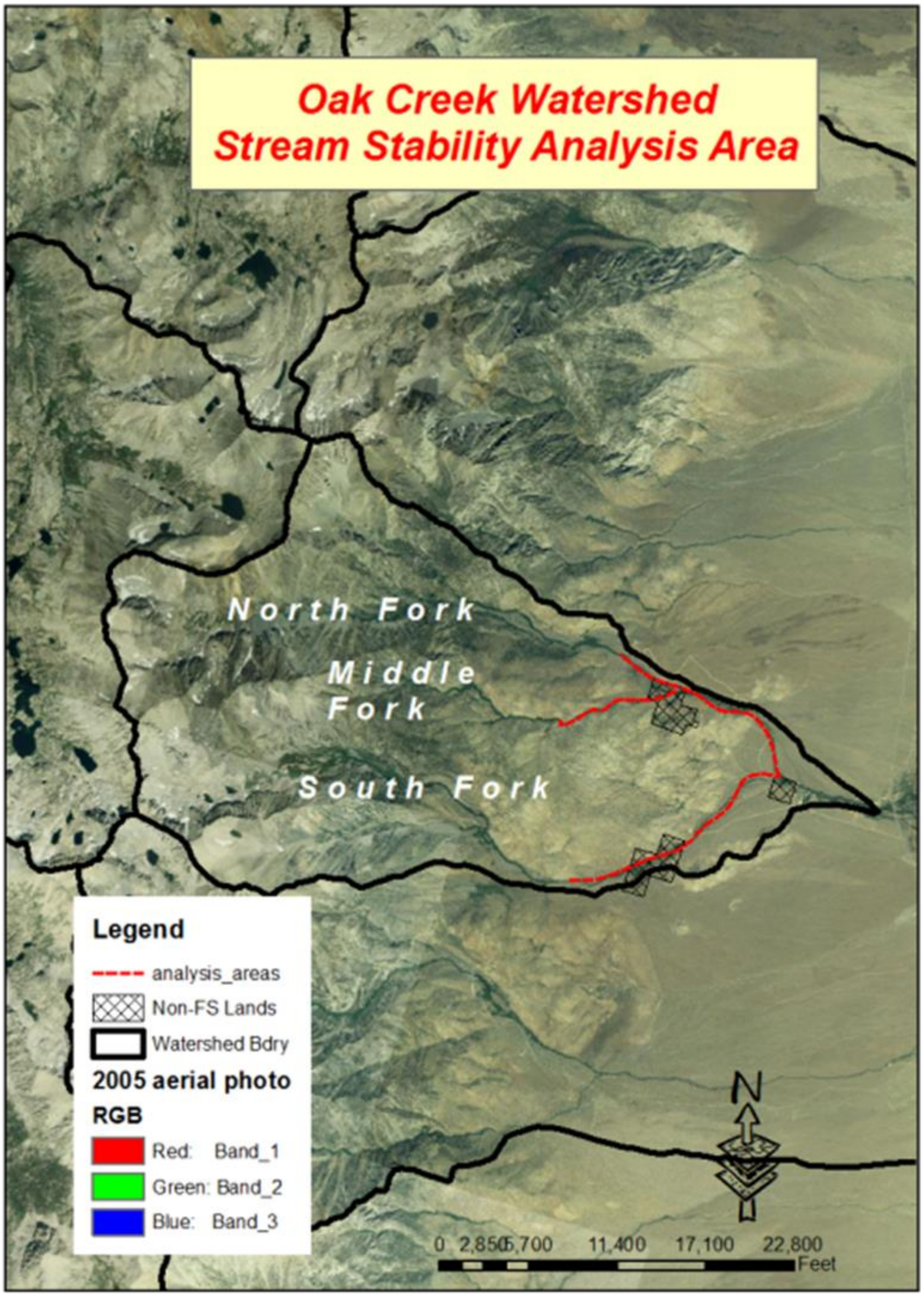


FIGURE 1 – Oak Creek watershed and stream stability analysis areas. These areas were chosen because they have depositional zones that are as "a canary in a coal mine" so-to-speak. These areas are the best examples of stream instability in response to a disturbance, then can turn around and exhibit forms indicative of stream recovery.

METHODOLOGY

The primary tool used in determining stream channel stability involved sequential aerial photo review in a GIS platform. Sequential aerial photo review is one of the most effective techniques for evaluating system wide channel adjustments after disturbance (Reid 1996). Providing a strong vantage point with a repetitive view of the project area, this approach can be used to show the trajectory of recovery in channel bed forms and stream banks over time. This technique lends itself especially well to the Oak Creek site because the pre- versus post-fire flood conditions are so dramatically different.

The Oak Creek Watershed analysis began with an overview of basic watershed hydrology and review of a 2005 aerial photo. This photo represents pre-disturbance conditions and provides a look at the watershed with a robust riparian system. The 2009-2011 aerial photos were then reviewed which appear to be the climax of disturbance in terms of loss to bed and bank stability. Followed by a review of the 2014 aerial photo to evaluate how the stream has evolved since the climax of flood disturbance. This was also followed by review of higher resolution aerial photos to verify the photo review.

Because aerial photography is a large scale planning tool, aerial photos were supported with on-the-ground knowledge and research such that a quick analysis of watershed condition related to landscape and channel form, as well as vegetation cover and community type could be determined. Ambient water quality, and geomorphic observations made by the Inyo National Forest, the Paiute Tribe, LADWP, and Wagner were used to support the assessment process.

Aerial photo review utilized the following parameters for comparison of relative channel stability:

- Trends in channel incision
- Trends of riparian colonization adjacent to stream banks
- Trends in riparian colonization on streambeds with no vegetation and braided flow pattern

The vegetative cover trend comparison was conducted using higher resolution geo-referenced Google Earth images of 2010 and 2013. Stream banks of the north and middle analysis areas were rated based on three cover levels (contiguous, patchy, and bare) and mapped in GIS. The percentages of each level were summed to show the changes in stream cover from 2010 to 2013 numerically.

RESULTS

The information presented below will help the Inyo National Forest and its partners form reasonable expectations for recovery, while setting the stage for feasible restoration actions that can be implemented within a five to ten year time frame.

HYDROLOGY AND PRE FIRE-FLOOD STREAM STABILITY

Oak Creek has a very interesting hydrology and stream system; for over 150-years it had supported a well-established and robust Black Oak and Cottonwood riparian forest (Wagner, 2012). This watershed in fact, was recognized as an excellent water resource by Fish and Game which established a golden trout hatchery in 1917. Conditions of long term channel stability are also supported by stratigraphic and cross section data by Wagner (2012) as well as Fish and Game accounts that no large floods occurred during most the 20th century. Riparian conditions representative of this are presented on the 2005 pre fire -flood aerial photo on all three forks **(FIGURE 2)**.

Overall, flows seem to be relatively mild based on 72 years of LADWP records of mean daily flow (Skaggs 2015). LADWP diversions were also known to draw high flows away from the north and south forks, muting higher flows. Skaggs reported that mean daily streamflow throughout the year on the north and south forks ranged from 6 to 20 CFS with a maximum of 70 CFS, and average base flows of 6 to 8 CFS. It should be noted however, that these are records of mean daily flow rather than peak flow which does introduce some uncertainty. Regional regression flood estimates (Gotvald et.al, 2012) indicate instantaneous peak flows that ranged between 50 and 400 CFS on the north and south forks; it seems likely that larger flows may have produced some small scale stream instability; but with no disturbance signals in the photos or anecdotal accounts , any interpretation of past channel instability during modern times is speculative.

Stability parameters in the 2005 baseline aerial photo revealed:

- **No evidence of incision on any of three forks**
- **Nearly contiguous robust riparian vegetative cover along stream banks and adjacent, hydrologically connected, fan surfaces**
- **No evidence of stream bed instability indicators (braiding or large bar deposits)**

With long periods of stable stream function and a controlled flow regime there is a good chance that prudent restorative actions can have a lasting effect, so long as another catastrophic fire and flood sequence is not repeated in the near future.

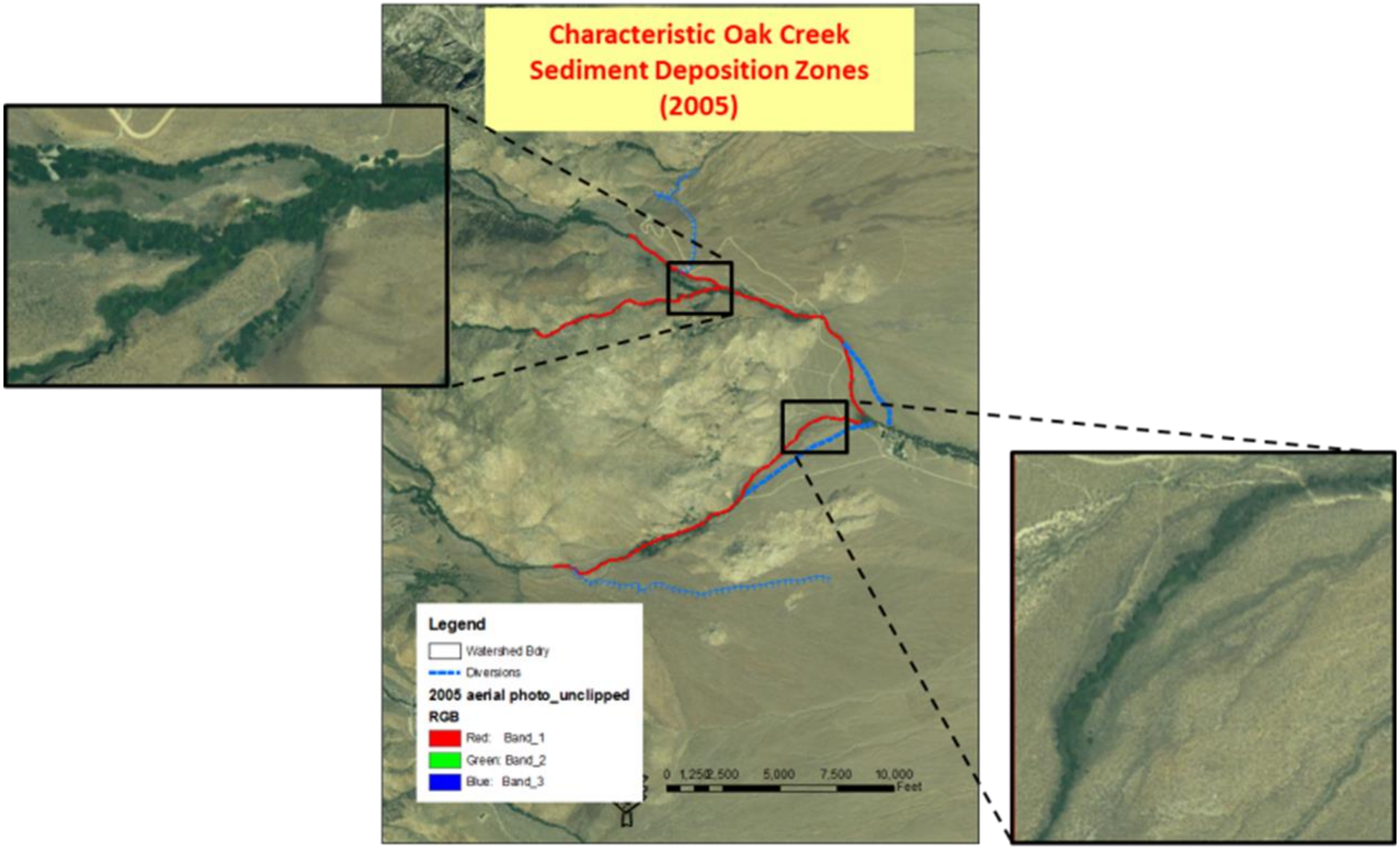


FIGURE 2 – Photo of the pre fire-flood Oak Creek analysis areas with zoomed in photos of depositional zones on the south fork and north/middle fork confluence areas. These depositional zones are wider than other sections of stream and would tend to show a response (heavy bar formation or braiding indicative of an excessive sediment input) if instability was occurring upstream.

POST FIRE-FLOOD STREAM INSTABILITY

In 2007, the Inyo Complex fire set the stage for debris torrents the following summer in the Oak Creek watershed. The fire and debris flow caused catastrophic damage to several stream channels, the LA Aqueduct, the Mt Whitney Fish Hatchery, and Tribal stormwater infrastructure. The burn severity map in the Wagner (2012) report indicates a high intensity burn occurred on stream banks and adjacent riparian zones along all three forks of Oak Creek. Degraded riparian vegetation resulted in a loss of root strength and the ability to store sediment on the fan surface. The flood took place on July 12, 2008. The rain intensity mapping presented in the Wagner report showed the most intense rain zone (rainfall intensity up to 2.5 inches /hour) in the storm cell centered over the burn area near the starting points of the debris flows.

Debris flow mapping in the DeGraff (2008) report identified the origin of debris flow to be within the streams themselves, likely triggered when rain intensity exceeded hillslope infiltration capacity. Once exceeded, overland flow produced extensive rilling on the steep barren hillslopes; conditions indicative of a rapid muddy water input into the main stem. As erosion intensified, flow becomes hyper-concentrated with sediment and gouged away at the stream bed and banks. The end result was 1.5 million cubic yards of debris. That fall after the debris flow, ongoing rainstorms continued to generate water quality impacts downstream; high turbidity levels of 2 to 400 NTU were measured on Fort Independence Tribal Land between 2008 and 2011.

Inspection of the 2009 and 2011 aerial photo revealed some form of instability along the all three forks in the analysis areas. Stability parameters in the 2009 and 2011 aerial photos revealed:

- **Visible head cutting of the channel bed on all three forks**
- **Wide spread cut bank erosion and almost no stream bank vegetation present 2009 with just a small increase in stream bank vegetation by 2011**
- **Channel sections with a braided flow pattern on portions all three forks**

FIGURE 3 presents typical examples of stream instability on the north and south forks.

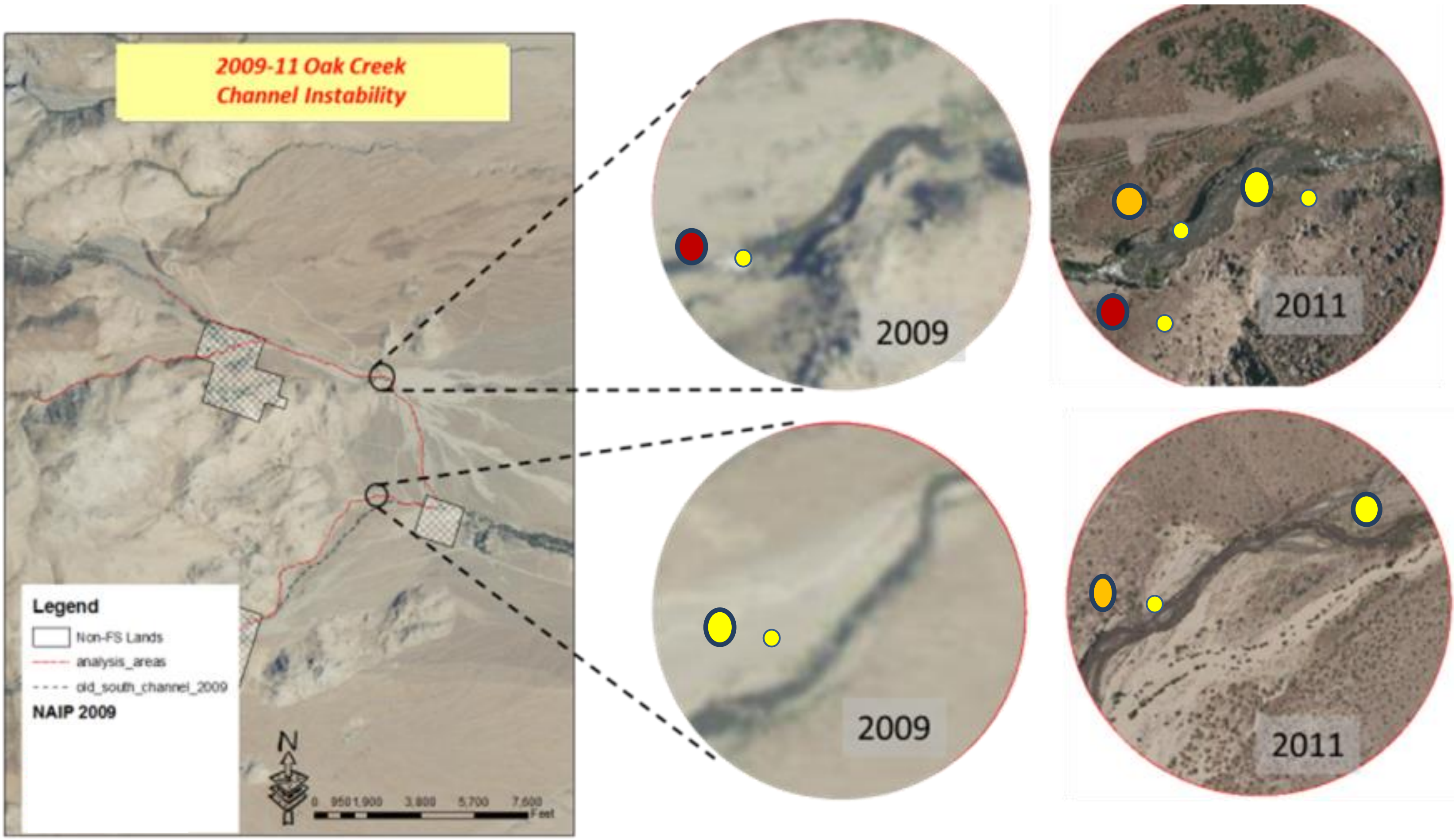


FIGURE 3 – Location and images of characteristic channel instability on the North and South Fork Oak Creek. Close up Images downloaded and clipped from ArcGIS Online World Imagery at a 1:3000 scale. Photos display braiding , bank erosion , and streambed head cutting indicative of an unstable stream conditions typical of that identified on all three forks of Oak Creek.

POST FIRE-FLOOD FLUVIAL ADJUSTMENTS

By 2014, the steam corridor began showing signs of stabilization, which is not surprising given three consecutive years of mild winters and light snow pack. Conditions of reduced steam flow ultimately benefited the re-establishment of riparian vegetation along all three forks.

Stability parameters in the 2013 and 2014 aerial images revealed:

- **Little or no head cut advancement (channel incision) on all three forks**
- **An upward trend in riparian plant colonization on stream banks**
- **An upward trend in stream bed stability with increasing vegetation in areas with braided flow**

FIGURE 4 shows examples of where the stream bed and banks have become more stable.

On the south fork, stream bank riparian vegetation has come back quickly along the narrow and steep boulder bed sections. This is likely the result of good riparian seed stock and a mild consistent water supply. There are however, two deposition zones downstream of the Bright Ranch that appear to be recovering at a slower pace.

On the middle fork, stream bank and bed vegetation has also come back quickly; so much so that restoration treatments are not recommended at this time.

On the north fork, riparian vegetation has comeback in many areas; however there are conditions, specifically weed infestation and gully wall instability, that need to be addressed in order for the north fork to continue the positive trend in stream stability. Sometime before 2010, there was a high wind event that blew Russian thistle off the fan surface and into portions of the north fork (Casey Shannon Inyo National Forest, 2015-Personal Communication). By 2014 many stream bank and bed surfaces were covered with the weed, which inhibits riparian plant colonization. **FIGURE 5** is a photo of a characteristic example of weed infestation on the north fork.

Even though the data on the north fork shows an upward trend in stream channel stability, there are still areas where the channel is deeply incised and the adjacent gully walls are tall, bare, vertical, and unstable presenting a public safety hazard. **FIGURE 6** is a characteristic example of gully wall condition on the north fork upstream of the north fork road crossing.

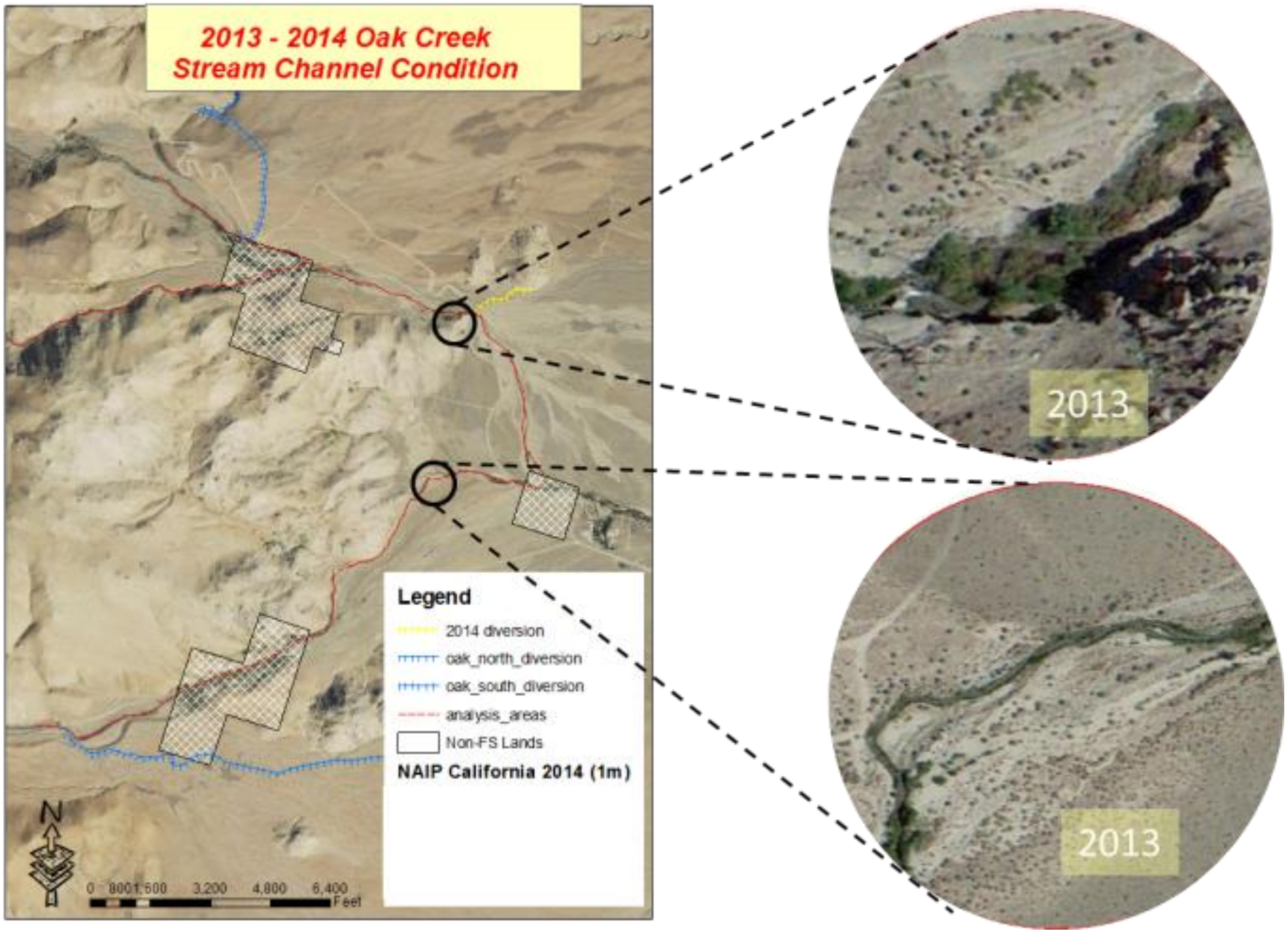


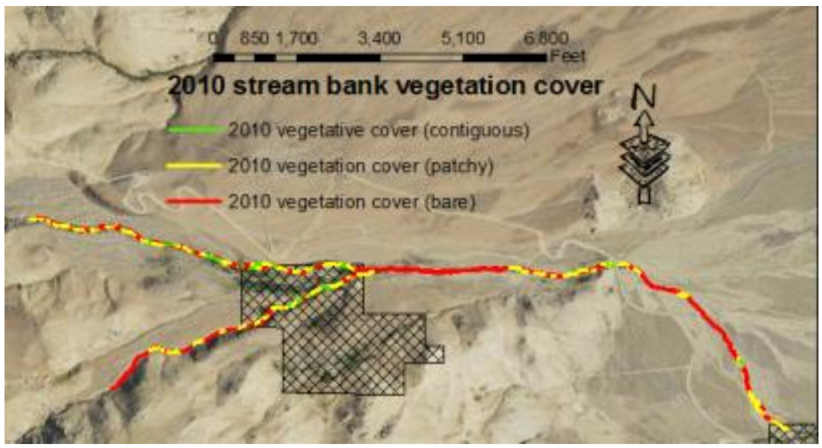
FIGURE 4 - Location and images of characteristic channel changes on the north and south fork of Oak Creek. Close up images were downloaded from Google Earth Pro and Georeferenced in ArcMap 10.2.2. Images display the level of riparian colonization and show streambeds beginning to stabilize.

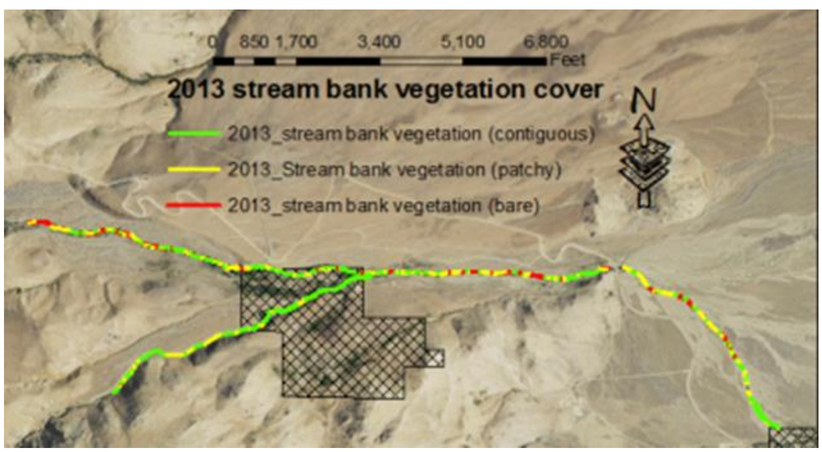
FIGURE 5 - Russian thistle infestation on the north fork

FIGURE 6 – Gully wall condition on the north fork

STREAM BANK VEGETATIVE COVER ASSESSEMENT

Because it is sometimes difficult to visualize what constitutes a trend in stream channel stability, a second level of analysis to estimate stream bank cover was performed using both the north and middle fork areas. This was accomplished by mapping north and middle fork stream bank cover class (contiguous, patchy, or absent) in GIS on the 2010 and 2013 Google Earth with high resolution aerial images. A total of 40,000 feet of stream bank were rated based on aerial photo visual inspection; a reasonable method for showing trend given that drastic differences in stream bank cover change between 2010 and 2013. The percentage of cover class was accomplished by summing up the different class lengths in GIS. The results were:





Year	Vegetation cover class		
-	% Contiguous (green)	% Patchy (yellow)	% Absent (red)
2010	5	25	70
2013	45	36	19

The percentages show the strong upward trend in contiguous stream bank vegetative cover. It also demonstrates that vegetation is still patchy or bare in some areas and is in need of restorative action in order to maintain the upward trend.

RESTORATION RECOMMENDATIONS

Restoration actions will be important for recovery of aquatic habitat attributes such as stream stability, sediment storage, and stream temperature. These attributes are controlled by the amount of riparian vegetation present. Treatment selection must take into account that this is still a recovering fluvial environment and there will still be some stream bank failures with sediment inputs and water quality impacts for some time to come; the very nature of stream channel adjustments following a severe disturbance.

Because it is a stream in transition, simple treatments such as riparian plantings along the stream margin of the north fork are a cost effective method that can increase riparian cover and become seed sources for cover recovery to perpetuate itself. Noxious weed removal is another simple treatment which should be followed up with some plantings to allow riparian plants to colonize and get established.

On the north fork, channel incision disconnected the stream from the fan surface. This hydrologic connection is an important link between the main stream and fan surface where energy can be dissipated and sediment stored t (Rosgen, 2012). In the north fork of Oak Creek, distributary fan flow restoration may be especially important for Black Oak riparian over story recovery, providing some water for Oak and cottonwood reestablishment. To correct this would require instream structural treatments in areas where distributary flood flow could be reestablished without having to raise the channel bed too much. Raw material for such a treatment could be generated by sloping back unstable gully walls, which at the same time would reduce the threat to public safety.

To accomplish distributary flow restoration, the Inyo NF will have to work with LADWP to allow some additional water into the stream below the diversions to re-invigorate fan surfaces on the north fork. This can be achieved by designing of flood structures that raise the channel bed elevation and allow flow to split off the main channel. All of the natural materials (boulders and logs) for this treatment are on site.

On the south fork, lateral channel shifting placed flow in an old channel with little or no riparian vegetation. Since this shift, riparian vegetation is rapidly colonizing stream banks, probably due to the seed bank present in the soil. However, there are two deposition zones where there is potential for continued stream bank erosion. The south fork should be treated by using a few instream structures (similar to that described for the north fork) to encourage flood waters to fan out into flood channels. These overflow channels should be planted with riparian species to increase surface stability. To reinvigorate these flood channels, the Inyo will have to work with LADWP on modified flow regime below the south fork diversion.

CONCEPT LEVEL RESTORATION TREATMENTS AND LOCATION

NORTH FORK (FIGURES 7 AND 8)

Broadcast riparian plantings

The lower and upper north fork areas still have patches of bare soils next to the channel as well as at the toe of gully wall slopes. Opportunistic planting of willow and cottonwood poles or stakes as well as installation of willow fascines installed perpendicular to the flow line, would further support riparian recovery by adding surface stability and trap sediment trapping potential during higher flows once they are established. Plantings should take place when plant stock and water conditions are appropriate.

Total linear feet where planting could occur = 8500

Noxious weed removal

The lower and upper north forks have areas where Russian thistle invaded floodplain and channel bank surfaces which is inhibiting riparian plant establishment. This infestation should be treated based on recommendations by the forest botanist.

Total linear feet of infestation treatment = 8500

Instream flood spreading structures and flood channel riparian plantings

The lower and upper north forks have some distributary channels disconnected by channel incision. A total of Instream/ floodplain structures would raise the stream bed locally to hydrologically reconnect these distributaries. Partner with LADWP to adjust flow regime below diversions to support controlled distributary flow introduction and soil moisture maintenance.

Total structure area in ft^2 on upper north fork = 74000

Total structure area in ft^2 on lower north fork = 18000

Once the structures are established, the old flood channels should be planted with species appropriate for the new hydrologic regime.

Total linear feet of flood channel plantings on upper north fork = 2700

Total linear feet of flood channel plantings on lower north fork = 2000

Material for flood spreading structures

Material for instream structures should be harvested on site by sloping back (2:1) the gully wall on the north side of upper north fork (to reduce the public safety hazard) and use that as fill material.

Total area in ft^2 of gully wall shaping = 86000

SOUTH FORK (FIGURE9)

Instream flood spreading structures and flood channel riparian plantings

The lower and upper south forks have some flood channels disconnected by minor channel incision. A total of Instream/ floodplain structures would raise the stream bed locally to hydrologically reconnect these flood channels. Partner with LADWP to adjust flow regime below diversions to support controlled distributary flow introduction and soil moisture maintenance.

Total structure area in ft^2 on upper south fork = 12000

Total structure area in ft^2 on lower south fork = 12000

Once the structures are established, the old flood channels should be planted with species appropriate for the new hydrologic regime.

Total linear feet of flood channel plantings on upper south fork = 1600

Total linear feet of flood channel plantings on lower south fork = 1400

FIGURE 7 – Location of restoration treatments upstream of the north fork road crossing. Weed removal location footprint is within the broadcast riparian planting areas. Gully wall sloping would in areas along the left bank of the creek upstream from the road crossing to the private property boundary

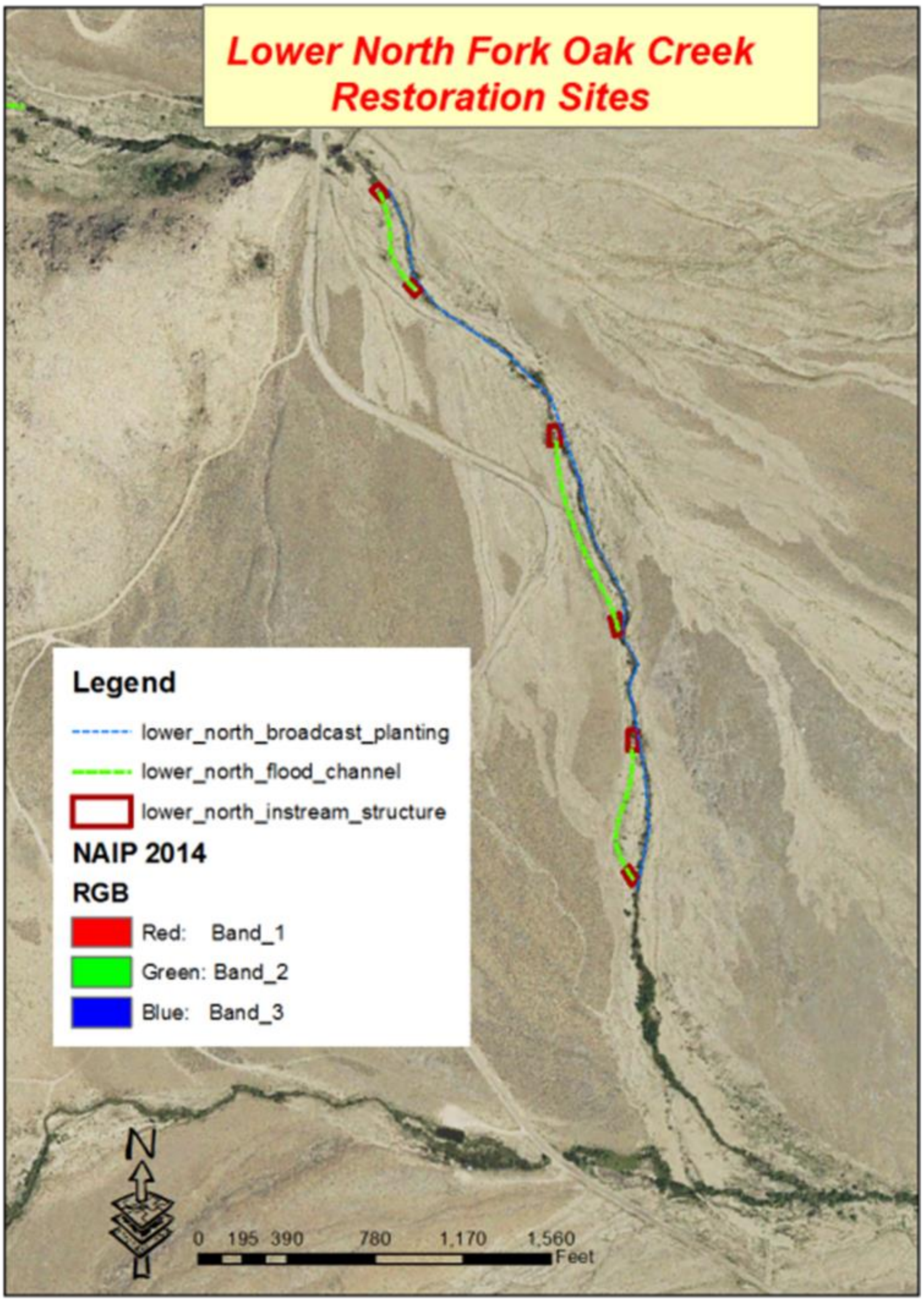


FIGURE 8 – Location of restoration treatments downstream of the north fork road crossing. Weed removal location footprint is within the broadcast riparian planting areas.

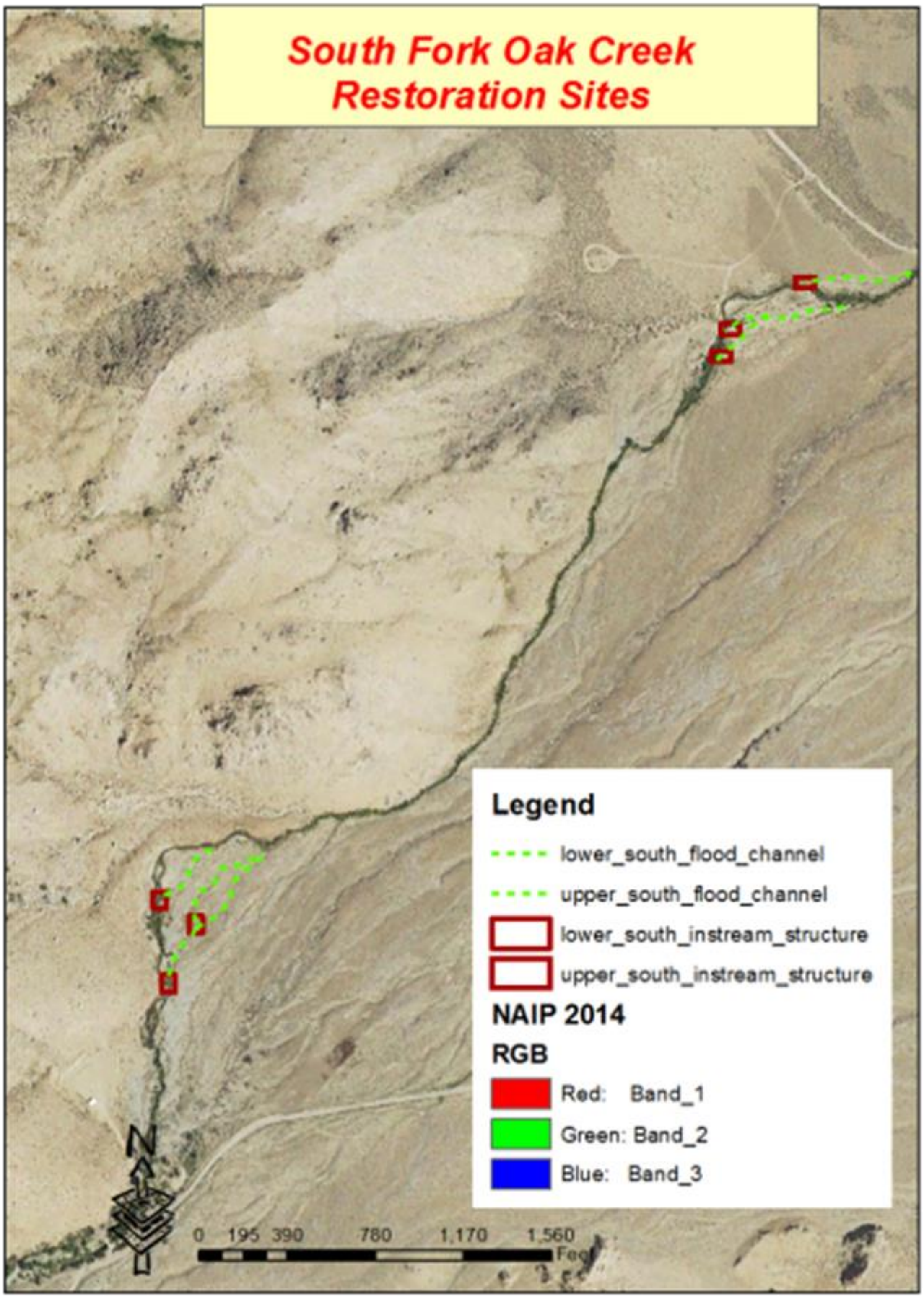


FIGURE 9 – Location of restoration treatments on the south fork downstream of the Bright ranch.

NATIVE FISH

The Mount Whitney Fish Hatchery is no longer operated by the California Department of Fish and Wildlife. It is currently manned by the Friends of the Mount Whitney Fish Hatchery. This organization runs the site as a historic attraction destination and conducts an educational program called "trout in the classroom".

Personal conversations with Inyo National Forest personnel revealed that the debris torrent may have left Oak Creek fishless, at least in the lower sections of all three forks; no fish has been seen in these areas since 2008. With Oak Creek on a trend to become stable in the future, the fish hatchery could expand to volunteer operations that could include the nursing of native fish (golden trout), or even go further by nursing the rare Paiute Cutthroat, creating another rookery for the cottonwood creek population located in the White Mountains nearby. The raised trout could then be released into Oak Creek to establish a fluvial population and expand the rookery further.

A fish reintroduction could be considered as the stream begins to develop fluvial structures that better support salmonids. Structural recovery could be enhanced through pro-active restoration of fish habitat using structural or non-structural means. Prior to an introduction, the entire stream would have to be sampled and possibly removed so there would be no introduced fishes to breed with the native trout (any surviving rainbows) if possible.

Such an endeavor would ultimately require strong partnerships with Trout Unlimited, Cal Trout, CDFW, LADWP, The Paiute Tribe, and the Friends of the Mount Whitney Fish Hatchery.

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