6.0 IMPACTS OF *ARUNDO: Fire*

Fire is one of the most discussed impacts related to *Arundo* invasion, yet there is little documentation of its occurrence in the literature. A few studies have looked at post-fire recovery of vegetation, but no studies have examined fuel loads, fuel characteristics and ignition sources, explicitly attempted to quantify fire events that start in *Arundo*, or quantified wildfire events that burn riparian areas with *Arundo* in them. All of these subjects will be explored in this chapter.

6.1 Fuel Load

Arundo stands have greatly increased the fuel load of riparian habitat. As outlined in section 2.3, *Arundo* stands in the study area had an average dry biomass of 69 tons/acre or 155 tons/hectare (Table 2-5). This is within the range of other studies on *Arundo* biomass. Studies have shown that *Arundo* produces biomass containing large amounts of energy per unit (17 to 19.8 MJ/Kg; Table 6-1). The high productivity of *Arundo* is why biofuel generation has focused on *Arundo* as a potential fuel source. It is significantly more productive than other species used for fuel generation. One study specifically growing willows for biofuel in riparian strips with high planted density of 15,300 trees/ha (6,200 trees/ac) generated 16.8GJ/ha (for 36.8t/ha biomass, Turhollow 1999). Compare this to *Arundo*: 810 GJ/ha (for 45 t/ha annual biomass, Williams et al. 2008) or 2,790GJ/ha for a mature *Arundo* stand (for 155t/ha biomass, this study). Based on annual yield, *Arundo*'s productivity is 400% higher than riparian vegetation (Turhollow 1999). This is in excess of estimates made by Scott (1993) who proposed that *Arundo* has doubled or tripled the fuel available for fires in the Santa Ana River Basin. Examination of mature stands during collection of *Arundo* biomass for this study also indicated that *Arundo* stands retain a significantly higher amount of dry, dead biomass compared to native woody and herbaceous vegetation, and it is held higher in the canopy. The *Arundo* stand has optimal, well-ventilated structure with both wet and dry fuel present throughout the stand profile. This introduction of a unique stand structure of *Arundo*, a clonal tall grass, into an ecosystem naturally dominated by woody trees and shrubs, herbaceous vegetation and open spaces, has altered fuel types, layers, and loads (Scott 1993, DiTomaso 1998, Brooks et al. 2004). The documentation of biomass loads in Spencer et al. (2006) and this study demonstrate the high levels of *Arundo* fuel. Later portions of this chapter focus on documentation of ignition sources and fire events in *Arundo*, which demonstrates how *Arundo* can be a direct or indirect factor contributing to an increase of fire occurrences.

Table 6-1. *Arundo* energy levels per unit of dry biomass.

Energy MJ/kg	Source
19.0	Williams et al. 2008
18.3	FAIR 2000
17.0	Angelini 2004
19.8	Dahl & Obernberger 2004
18.5	**Average**

Decreased moisture content and increased surface to volume ratio of *Arundo* versus native vegetation may lead to an altered or increased length of fire susceptibility and probability of ignition in these systems, although no data currently exists to document this assertion. Addition of this novel fuel

characteristic to the riparian ecosystem has increased vertical continuity (structure of fuel allows fire to spread from surface to crowns of shrubs and trees), which can in turn increase the frequency and extent of fires (Brooks et al. 2004).

Research still needs to investigate comparative moisture and surface to volume ratios, but current studies definitely indicate that *Arundo* has exceptionally high biomass levels. This directly translates into higher energy per acre.

6.2 Fire Intensity

Arundo stands contain a significant amount of energy and aboveground plant biomass, in addition to a well-ventilated, tall structure. *Arundo* stands always have large amounts of dry leaves, primary and secondary leaves that drop off canes as they grow. As it was discussed in sections 2.2 and 2.3, when a cane matures from the first year of growth to the second year, with the emergence of secondary branches, more than half of the leaves on the cane senesce (Figures 2-18 &6-1). Senescence of leaves on secondary branches also occurs periodically as the canes age. In addition to leaf senescence, both primary and secondary leaves frequently have portions of the leaf that are dry and non-photosynthetic (Figures 2-3 & 4). There is also a highly variable amount of dead cane material, in addition to the large amount of dry leaf material found both at the base of the stand and throughout the canopy. Within a stand, 0 -30% of the biomass is dead cane and leaf material (Spencer et al. 2006, Figure 6-1). This study did not directly measure dead cane biomass, but we observed a low density of dead canes within the plots sampled, averaging less than one cane per m^2 (n = 16, Table 2-4). However, sites can certainly be found with high amounts of dead cane biomass. Often these are areas where material has collected within the stand during flow events (photos in Chapter 5). Stands growing in dry areas will also have significant dead biomass, but these stands also have shorter stature and lower cane density (i.e. lower overall biomass). *Arundo* stand structure (tall height and high cane density per square meter) is an important factor in conveying fires high into the riparian canopy.

Movement and intensity of the fire are also related to weather, but conditions do not need to be favorable for a fire to occur in *Arundo*. *Arundo* can burn any time of the year under varying conditions. *Arundo* stands contain enough dead dry fuel that they can be ignited and carry a fire even under poor fire conditions, such as low wind speed, cool weather, and even when humidity is high or during light rains. This was demonstrated by the fire event on October 2006, which started at night during a light rain and low temperatures (Figure 6-2). Fires have also been observed during light rains and cool temperatures on the San Luis Rey River. Successive heavy rains will reduce *Arundo* stand flammability, but for many areas in the study region heavy rainfall only occurs for 6-10 weeks of the year. High fire threat weather conditions (low humidity and high winds) are not required to start or carry *Arundo* fires. The greatest risk of fire is still in the late summer/fall when stand moisture is low and Santa Ana conditions can exacerbate fire events.

The large amount of biomass per unit area along with a favorable structure for burning generates fires that burn intensively. This is illustrated by fire behavior and an examination of post-fire site conditions. Low intensity fires leave unburned material. Ash levels and color can also be used to gauge fire intensity. *Arundo* fires usually leave little unburned biomass and ash is usually white (Figures 6-3 & 4, also section 6.4 photos).

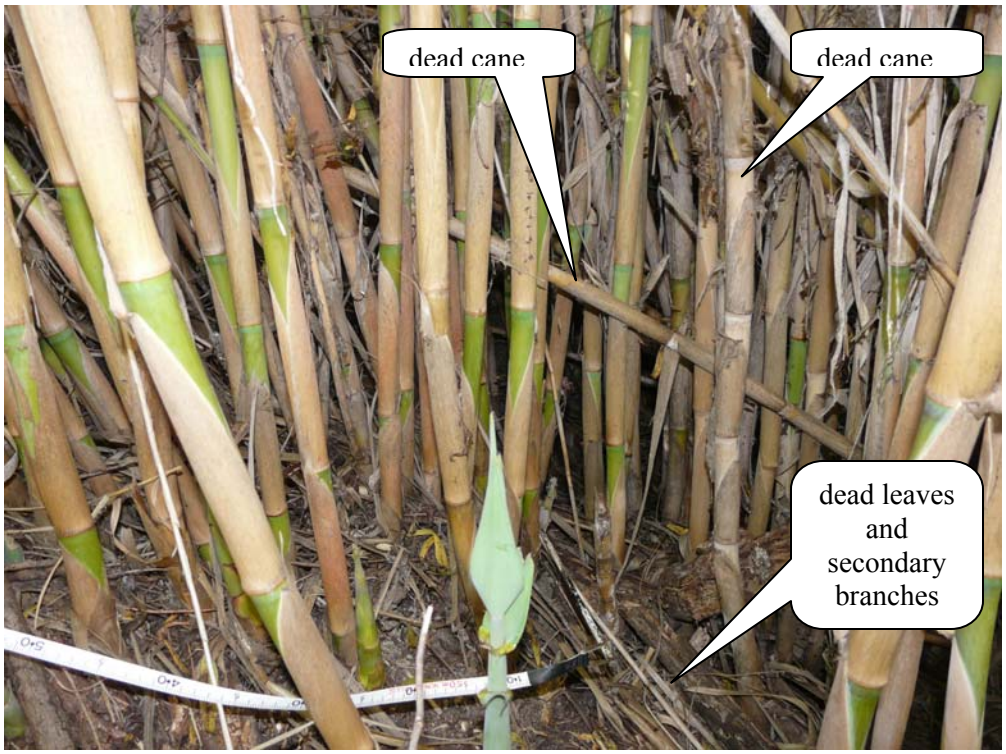

Figure 6-1. Large amount of dead/dry *Arundo* fuel.
While only a small percent of the overall stand biomass is dead and dry, it is enough to start and maintain fires.

Figure 6-2. This fire started in *Arundo* at night during a light rain in October 2006.
Photos from San Diego News outlets (Fires SLR#1-3).

Figure 6-3. Burned *Arundo* stands on the San Luis Rey River (Fire SLR #6).

Figure 6-4. Burned *Arundo* stands on the San Luis Rey River (Fire SLR #6).

6.3 Ignition Sources

Fires must have an ignition source in order to burn. Two main groups of ignition sources have been observed for fires that burn *Arundo* stands: local ignition sources (people in or around *Arundo* stands) and wildland fires. Wildland fires may be started by humans, or may start from lightning, although this is an increasingly infrequent occurrence (Keeley & Fotheringham 2005). Most wildfires start from arson, campfires, vehicle fires, power lines, and other human activities (CalFire and Ventura incident reports, Keeley & Fotheringham 2001).

6.3.1 Human Ignition Sources:

This report documents that *Arundo* directly increases the probability of fire ignition due to *Arundo* stands supporting human activities that lead to fires. *Arundo* stands offer concealment and shelter, which results in encampments and use by transients (Figure 6-5). Activities by transients within *Arundo* stands directly start fires. The following examples are from the San Luis Rey watershed, which has had documented camps and fires within *Arundo* stands for the past 10 years. Camps often have open fires for cooking and heat (Figures 6-6 & 7). Some camps even have portable heaters and ovens (Figure 6-8). Humans frequently smoke and use substances that must be ignited or heated for use, or may process these materials in camps (Figure 6-9). Humans have also intentionally set fires to *Arundo* stands (NLF 2006/7). Fireworks and firearm discharge may also lead to fires. Concealment, availability of water, and remoteness in some areas has also led to the cultivating of cannabis on several watersheds (documented on the San Luis Rey and Santa Ana). These operations have resulted in at least one fire event from an area where the workers had an open campfire (Figure 6-10). Transient activities and encampments are the primary ignition source for fires that start in *Arundo* stands. Direct evidence of the ignition source is usually present at the fire site.

Figure 6-5. Camp on San Luis Rey River with *Arundo* folded over to make an enclosure.

Figure 6-6. Camp on San Luis Rey River in *Arundo* stands showing tent, tarp and fire ring. *Arundo* surrounds the camp.

Figure 6-7. Camp on San Luis Rey River within *Arundo*, showing multiple lighters, cooking area and burned *Arundo* canes.

Figure 6-8. Camp on San Luis Rey River in *Arundo* showing tent and cooking area with a portable oven connected to propane.

Figure 6-9. Small methamphetamine lab on the San Luis Rey River within *Arundo* stands.

Figure 6-10. Open fire associated with workers of a cannabis plantation.
This was the ignition source of a wildfire that started within *Arundo* on the San Luis Rey River (Fire SLR #6).

An excerpt from the North County Times on January 23, 2007, referred to the fires on the San Luis Rey River:

> "The fires all started in areas widely known as hideouts for transients that set up camps among the brush and 'bamboo' that clogs the riverbed," authorities said. "We've always had fires occur in the river bottom due to the homeless population," Lawrence said. "But transients normally go through great effort to keep fires from spreading, so we're surprised to find uncontained vegetation fires when we arrive. Normally they're small cooking fires." Patricia Clutter, who lives near the river, said that she has witnessed five fires in the last four years and many neighbors are concerned.

Between 2000 and 2009, 34 encampments in *Arundo* stands were documented on the San Luis Rey River (Figure 6-11, Table 6-2). San Luis Rey data indicate that approximately one camp occurs for every 2 miles of invaded river. Encampments in *Arundo* on other rivers were recorded as encountered through reports or during the mapping phase of this project. While this is an incomplete data set, it indicates that encampment use of *Arundo* stands occurs on all large watersheds (Figure 6-11): San Diego (6 recorded), Santa Ana (3), Los Angeles (3), and Ventura (5 recorded with very high density). More focused surveying over a longer time period would likely reveal similar levels of encampment use as seen on the San Luis Rey River. This study's data, coupled with the San Luis Rey long-term monitoring data, clearly show a fairly high density of encampments in *Arundo* stands occurring in urbanized areas (homeless transients) as well as agricultural areas (agricultural workers).

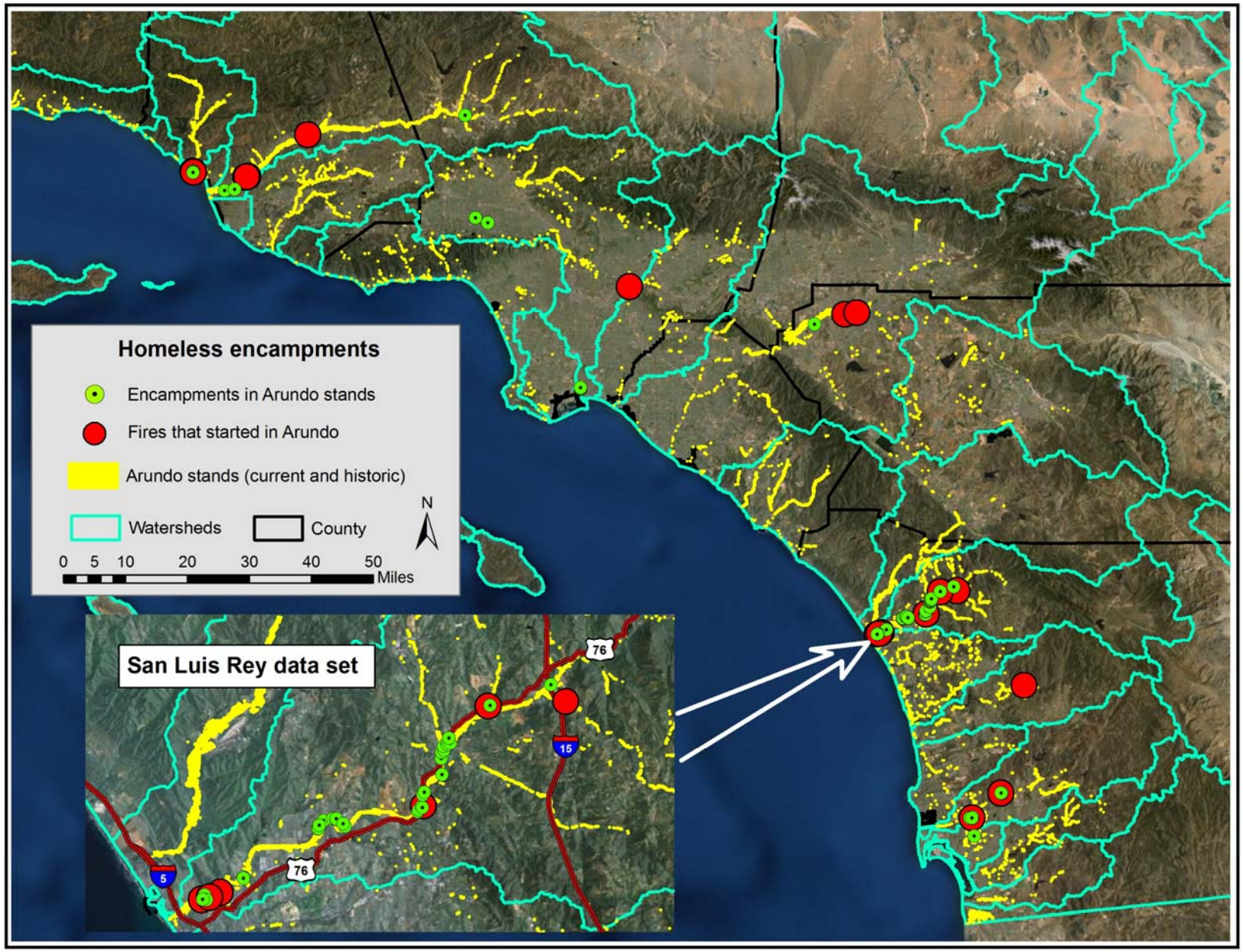

Figure 6-11. Location of *Arundo* fires for some southern California watersheds.

Table 6-2. Encampments found within *Arundo* stands on the San Luis Rey River.

Camps	People	Time Frame	Completeness
34	84	2000-2009	Very complete, but likely an underestimate

The second most common ignition source is likely from cigarettes being thrown out of vehicles on bridges above *Arundo* stands. This has resulted in frequent fires in the San Diego, San Luis Rey, and Santa Ana Rivers. Areas under bridges and overpasses are also high use areas for transients, so differentiating ignition sources can be difficult, but some fire events occurred in areas that have little use by transients.

Arundo fires started by human activities are usually suppressed quickly. The fires can occur at any time during the year. They frequently occur during conditions that are not optimal for fire events, helping fire suppression/response teams. These fires usually have smaller footprints than wildland fires. There is no recorded example of a fire that started in *Arundo* developing into a large wildland fire, but the number of *Arundo* fires that have already been documented increases the potential for this to occur.

6.3.2 Wildland Fire As An Ignition Source:

Wildfires that pass through an area where *Arundo* is present will ignite and burn *Arundo* stands. The presence of *Arundo* changes how the fire behaves within the riparian zone. *Arundo* can have three important impacts on wildfires: 1) *Arundo* causes the fire to burn hotter and more completely within the riparian area, 2) *Arundo* causes the wildfire to burn larger areas within the riparian zone, and 3) *Arundo* conveys the wildfire through the riparian area into adjacent landscapes, causing more area to burn (urban, rural, or wildland areas). These impacts will be explained in the next section.

6.4 Spatial Distribution and Frequency of *Arundo* Fires

Two types of fire events that burn *Arundo* were mentioned in the previous section: 1) fires that start in *Arundo* and 2) wildland fires that burn *Arundo* stands. The frequency and spatial distribution of these events within the study area will be discussed in this section.

6.4.1 Fires Starting in Arundo

Due to the difficulty of detecting fires on aerial imagery (unless they happen to be taken right after a fire event), only the San Luis Rey River watershed can be used as a comprehensive estimate of *Arundo* fire events over time. Boundaries of fires were captured by examining aerial imagery and ground-based photography, and digitizing the footprint of the fire. In some instances the fire line had been walked with a GPS immediately after the fire events to document the extent of the fire. The San Luis Rey River watershed is a good system to examine as it had abundant *Arundo* acreage and is fairly characteristic of coastal watersheds with various land uses (urban, rural, and open space). Additionally, as outlined in the previous section, data on ignition and encampments has been collected for the San Luis Rey. The number of fires, acreage of fires, and impacts associated with fire suppression were recorded.

6.4.1.1 San Luis Rey Watershed Case Study

A total of six separate fire events initiated in *Arundo* stands were recorded between 2000 and 2007 (Figure 6-12, Table 6-3). Fire events occurred within all reaches of the watershed where *Arundo* was abundant, from the coast to inland areas.

Three fires (SLR #1 to 3) occurred near the river mouth between October 2006 and March 2007 (Figures 6-2, 6-12 to14). These fires were reported in local newspapers and observed by Jason Giessow (this study). Fire suppression clear zones as well as fuel break strips were created to contain the fire (Figures 6-13&14). The ignition source for at least one fire was believed to be an arsonist. Transient use of the area was also high. The fires burned a total of 27.7 acres, and 5.6 acres of habitat were cleared during fire suppression activities (Table 6-3).

Proceeding upstream, the next fire (SLR #4) occurred at the Highway 76 bridge over the San Luis Rey River near East Vista Way in June 2005. This fire burned 1.40 acres (Figures 6-12 & 15). No specific ignition source was identified, but it was likely either a discarded cigarette from the highway overpass or a transient camp. Both uses occur in that specific area. No fire lines were cut around the fire because the river channel and a road surrounded it.

A large fire occurred on June 17, 2007 near Gird Road and Highway 76 (SLR #5; Figures 6-3 & 4, 6-12 & 16). This struck during high fire season and burned a larger area than the other fires on the river. The fire was 64.31 acres in size and fire suppression activities disturbed an additional 0.90 acres. This fire had active suppression, but would likely have been much larger were it not for a vertical 30-foot river bank that served as a natural fuel break on the southern edge of the fire line. The ignition source was likely a campfire related to cannabis cultivation within the central portion of the *Arundo* stand (Figure 6-10). Irrigation tubing was observed leading into the stand area from the river.

The most upstream fire within the study area occurred on a tributary near the confluence of the San Luis Rey River and Keys Creek (SLR #6; Figures 6-12 & 17). This fire occurred in 2001 and was 10.37 acres in size. Local residents speculated that it was kids playing with fire/fireworks/guns. The area has no use by transients and it is not close enough to the highway for cigarettes to have caused the fire. No fire suppression disturbance was recorded, but impacts could have occurred.

Table 6-3. San Luis Rey Watershed: Data on fire events fires that started in *Arundo* between 2000 and 2007.

Fire Name	Date	Fire acreage	Acreage of Impacts from suppression	Total
SLR Fire #1-3	Oct 2006-Mar 2007	27.7	5.6	33.3
SLR Fire #4	June 2005	1.4	0	1.4
SLR Fire #5	June 17, 2007	64.3	0.9	65.2
SLR Fire #6	May 2004	10.4	?	10.4
	Total:	**103.8**	**6.5**	**110.3**

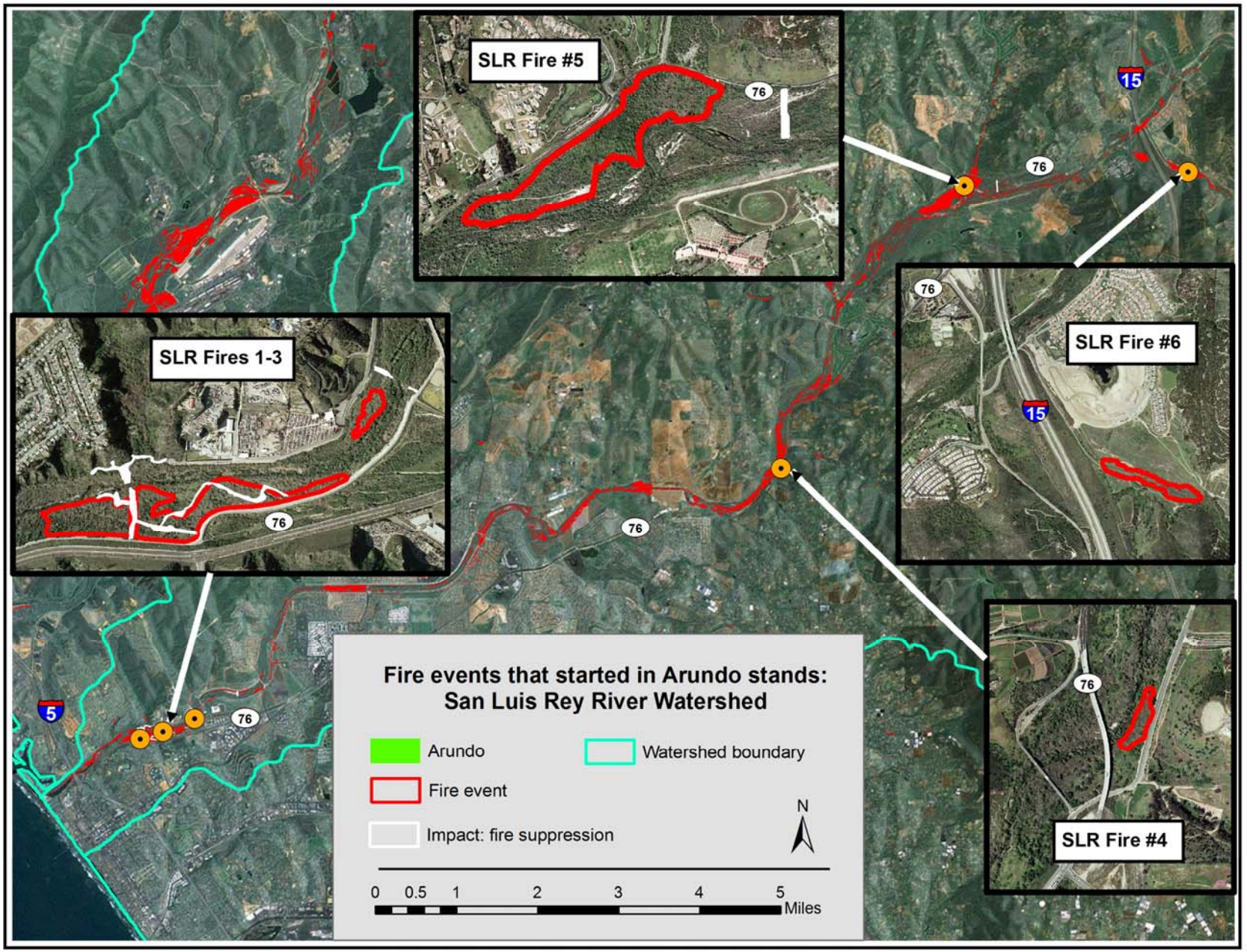

Figure 6-12. Fire events that started in *Arundo* stands on the San Luis Rey River from 2000 to 2007.

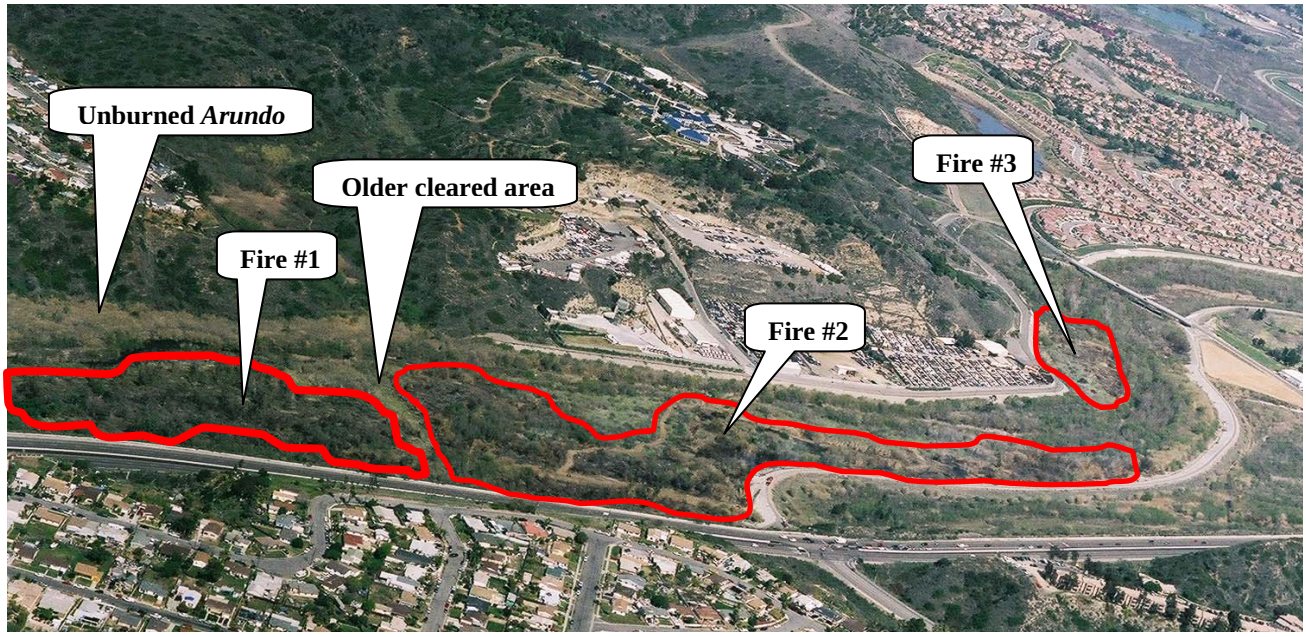

Figure 6-13. Footprint of fires # SLR 1-3 on the San Luis Rey River.

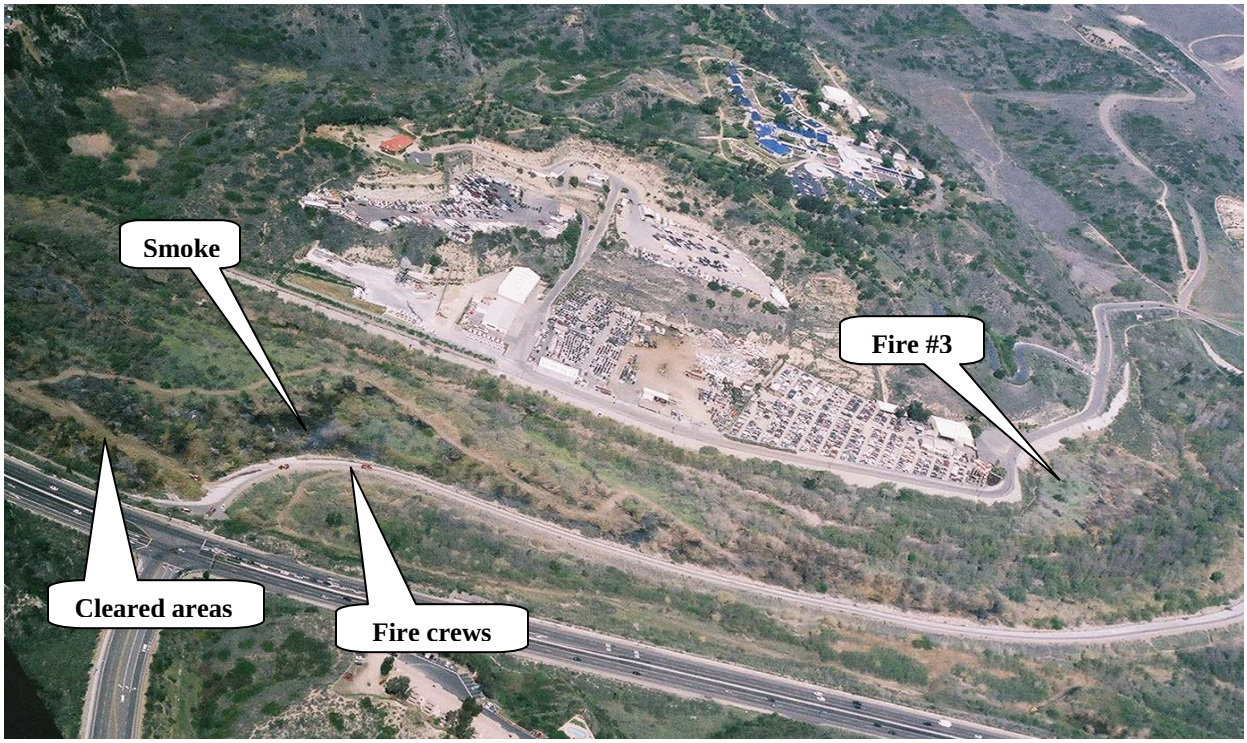

Figure 6-14. Location of fires # SLR 1-3 and fire containment cleared areas on the San Luis Rey River.

Figure 6-15. *Arundo* resprouting after a fire on the San Luis Rey River. Native trees are either dead, or still dormant (Fire SLR #5).

Figure 6-16. Immediately after a fire that burned an *Arundo* stand on the San Luis Rey River, leaving only ash and very little unburned material (Fire SLR #6).

Figure 6-17. Shortly after a fire through *Arundo*-infested riparian habitat on the San Luis Rey River. This demonstrates the quick and dense resprouting of *Arundo* before any native vegetation (Fire SLR #7).

6.4.1.2 Summary of Fire Impacts: Fires Initiated in *Arundo* Stands

For the eight-year period between 2000 and 2007, a total of 103.8 acres of riparian habitat burned during six recorded events (Table 6-4). *Arundo* dominated stands were 43.28 acres of the burned area and native dominated vegetation was 60.54 acres. *Arundo* stands on the San Luis Rey totaled 684.2 acres. During the eight-year period, 6.3% of the *Arundo* stands burned in fires that started in *Arundo* (Table 6-5). A total of 6.9% of *Arundo* stands either burned or were impacted during fire suppression for these events. The average acreage burned each year was 13.0 acres with an additional 0.8 acres impacted during fire suppression. These relationships will be used to extrapolate the fire and fire suppression impacts to other watersheds.

Table 6-4. San Luis Rey Watershed: Acreage summary of impacted vegetation for fires started within *Arundo* stands over an eight-year period (2000 to 2007).

Interval	**Acreage Burned: Fires Started in *Arundo***			**Acreage impacted during fire suppression**			**Total riparian acreage**
	Arundo	*Native*	*Riparian*	*Arundo*	*Native*	*Riparian*	*Total*
8 yr	43.3	60.5	103.8	3.7	2.8	6.5	110.3
Annual	5.4	7.6	13.0	0.5	0.4	0.8	13.9

Table 6-5. San Luis Rey Watershed: Acreage of *Arundo* that burned in fires started within *Arundo* stands over an eight-year period (2000-2007).

Fires started in *Arundo* (documented)	Gross *Arundo* Acres	*Arundo* burned acres over 8yrs	% *Arundo* burned in 8 yrs	Annual % *Arundo* burned in 8 yrs
San Luis Rey	683.9	43.28	6.3%	0.8%

A key finding in this San Luis Rey River fire history is that *all recorded fires that started in the river were initiated in Arundo.* This does not mean that riparian habitat lacking *Arundo* cannot burn. The fires that started in *Arundo* burned large sections of riparian habitat (60.54 acres) that had little or no *Arundo*. What this shows is that un-invaded riparian habitat is not typically ignitable and usually only burns if a hot, well-developed fire is actively burning. This happens when *Arundo*-initiated fires start or when wildland fires occur.

6.4.1.3 Fires That Started Within *Arundo* Stands: Other Watersheds

A second data set was also prepared on behalf of the San Diego River Watershed for known fires that began within *Arundo* stands. The data set is most likely incomplete as less background information was found for the system. Two fires were mapped: 1) a 1990 8.4-acre fire that occurred on the lower watershed and 2) a January 2008 0.9-acre fire on the upper watershed. Over this 19 year time there were 9.3 acres of *Arundo* fires. This represents 6.2% of the *Arundo* stands on the San Diego River (150.5 acres), but over a longer time frame then the San Luis Rey fire documentation. There are more reports of fire events on the lower and upper San Diego River, but it was not possible to quantify them. Operators of a golf course along 1.5 miles of the heavily invaded upper river report frequent fire events over the past 15 years. Ignition source was likely a mix of transient use (which is high in that area) and discarded cigarettes from the highway that runs over the river. The lower San Diego River also has had additional fire events that are tied to homeless activity, but these could not be tied to specific locations and/or *Arundo* stands. The San Diego River *Arundo* fires show the same general pattern of ignition and fire pattern as the San Luis Rey River.

To help illustrate those fires that originate in *Arundo* stands are not isolated occurrences, we prepared a data set of all fires reported/encountered within *Arundo* for the project area (Figure 6-11). We mapped 12 fires that started in *Arundo* stands on other watersheds. This data set grossly underestimates the number of fires starting in *Arundo*, as it is limited to citations in reports, media coverage, fire response reporting, and discussion with program proponents on other watersheds. Even as a conservative representation of *Arundo* fire events, it shows that fires initiated within *Arundo* are indeed common events that have been observed on most watersheds with dense stands of *Arundo*. A brief qualitative overview demonstrates that each affected watershed has similar fire patterns - fires tend to occur where there are dense *Arundo* stands and ignition sources (encampments, bridges). Level of urbanization and transient use is highest along the coast for select watersheds (Ventura, San Luis Rey, San Diego), although interior cities and towns are found along rivers on others (Santa Ana, Santa Clara, Salinas). Agricultural use and migrant worker camps are found in the centralized portions of the watersheds (San Luis Rey, Santa Clara, Salinas). Remoteness, allowing cannabis cultivation and its associated fire impacts, has been observed in San Luis Rey and Santa Ana. These operations usually are not discovered until *Arundo* control is initiated. Highway and road overpasses occur at numerous points along each

watershed creating conditions where stands can burn from discarded cigarettes. Highway bridges in dense and moderate urban/agricultural areas are particular attractants for transients and homeless use.

Since the pattern and frequency of fires appears to be similar across watersheds, applying the relationships outlined on the San Luis Rey Watershed seems reasonable. This holds true as an approximation of acreage burned on an annual and decade basis for each watershed and the overall study area, with two exceptions (Table 6-7). The Salinas Watershed was adjusted downward as humans report fewer fires there, likely due to a combination of different climatic conditions and lower use of the river. Also, the Santa Margarita River is mostly owned and managed by the Department of Defense, so there is limited use by transients in riparian areas. The lack of fires initiated within *Arundo* on the Santa Margarita River, where there are no encampments, supports that this is a primary ignition source.

6.4.2 Wildland Fires That Burn Arundo Stands

Arundo stands have two main effects on wildfires: 1) when a wildfire burns riparian habitat containing *Arundo*, it burns hotter than the habitat would have without the presence of *Arundo* and 2) *Arundo*-infested riparian habitat can act as a fire conveyor across the landscape. This can increase the size of riparian fires and may spread fires to upland areas that would normally have been separated by less flammable native riparian vegetation.

Wildland fires that burned riparian habitat containing *Arundo* stands are noted in Figure 6-18 and Table 6-6. Events that burned large riparian areas on San Dieguito, Santa Margarita, Santa Ana, and Santa Clara watersheds, as well as smaller events on San Luis Rey, San Diego and Otay watersheds, are noted. These are events that started in upland areas, and then developed into large wildland fires. These large wildfire events will often burn riparian vegetation regardless of how much *Arundo* is present. However, when an area infested with *Arundo* does burn, there is significantly more biomass present than would occur in comparison to uninvaded habitat (see section 6.1 on biomass). *Arundo* fuel loads are more vertical and well ventilated than native vegetation. Wildland fire events frequently have unburned patches within them, and vegetation with higher water content does not burn as well. For this reason, riparian zones often have more unburned or lightly burned areas. Presence of *Arundo* within the riparian zone increases the completeness of the burn, as well as the intensity. Wildland fire events that burn *Arundo* stands also lead to type conversion of those sites to *Arundo* dominated habitat (section 6.5.1).

The increased fuel load within *Arundo*-infested riparian habitat, and the resulting hotter and more complete fire, likely leads to riparian areas acting as fire corridors or areas of connectivity. This was documented for a fire on the Santa Clara River in June 2006 (Figure 6-19). This fire started on the north side of the river, burning 8,474 acres of uplands (A). The fire then moved into a riparian area with dense *Arundo*, crossed the 0.43 mile wide river, and then set the southern upland mountain range on fire (B). This fire burned an additional 107,560 acres, including setting the river on fire again 40 miles downstream (C). The fire crossed the river again, but did not set the north range uplands on fire. Agriculture and development blocked the fire's path (D). *Arundo*-infested riverine areas acting as fire corridors could be occurring in other areas, but it is difficult to prove because the effect of the *Arundo* is not always known. For the 2007 San Dieguito Watershed fire that burned 197,990 acres, there could have been areas that would not have conveyed the fire if *Arundo* had not been present, or there may have been larger central portions within the fire boundary that would not have burned (Figure 6-18). Similar patterns occurred in the 'freeway complex fire' that burned upland, riparian, and urban areas on the Santa Ana (Figure 6-18). The fire moved through *Arundo*-infested riparian habitat areas during early stages of the fire.

Table 6-6. Acreage of *Arundo* by watershed that burned during documented wildfires over a ten-year period.

Watershed	Gross *Arundo* Acres	*Arundo* acreage burned over 10 yrs (gross)	% *Arundo* burned over 10 yrs	Annual % *Arundo* burned over 10 yrs
Calleguas	231.5	71.5	30.9%	3.1%
Otay	18.6	0.5	2.5%	0.3%
San Dieguito	175.0	134.9	77.1%	7.7%
San Luis Rey	683.9	15.6	2.3%	0.2%
Santa Ana	2,723.9	95.7	3.5%	0.4%
Santa Clara	1,081.3	220.5	20.4%	2.0%
Sweetwater	42.3	6.0	14.2%	1.4%
Total:	**4,956.5**	**544.6**	**11.0%**	**1.1%**

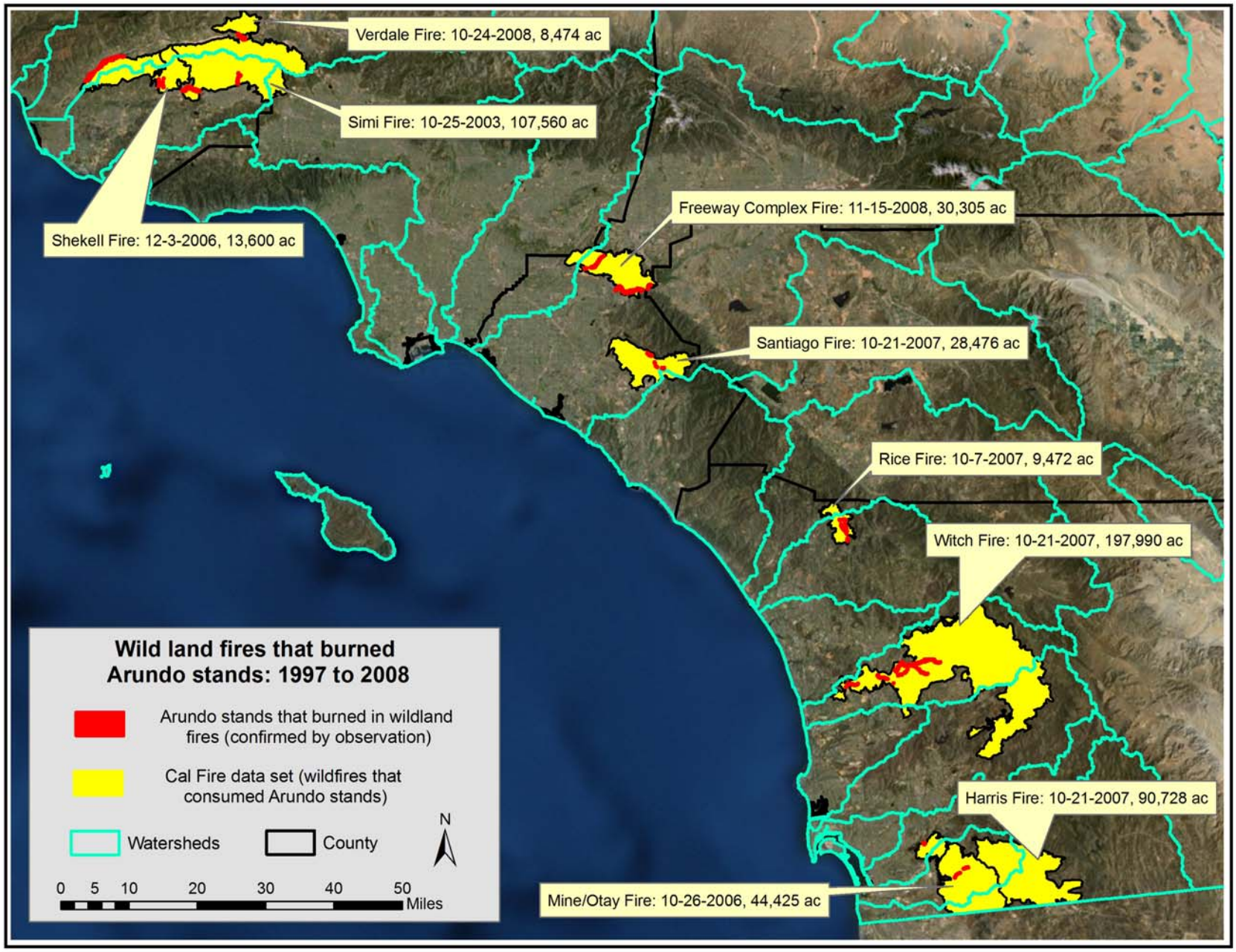

Figure 6-18. Location of wildland fires that burned *Arundo* stands within the project area from 1997 to 2008.

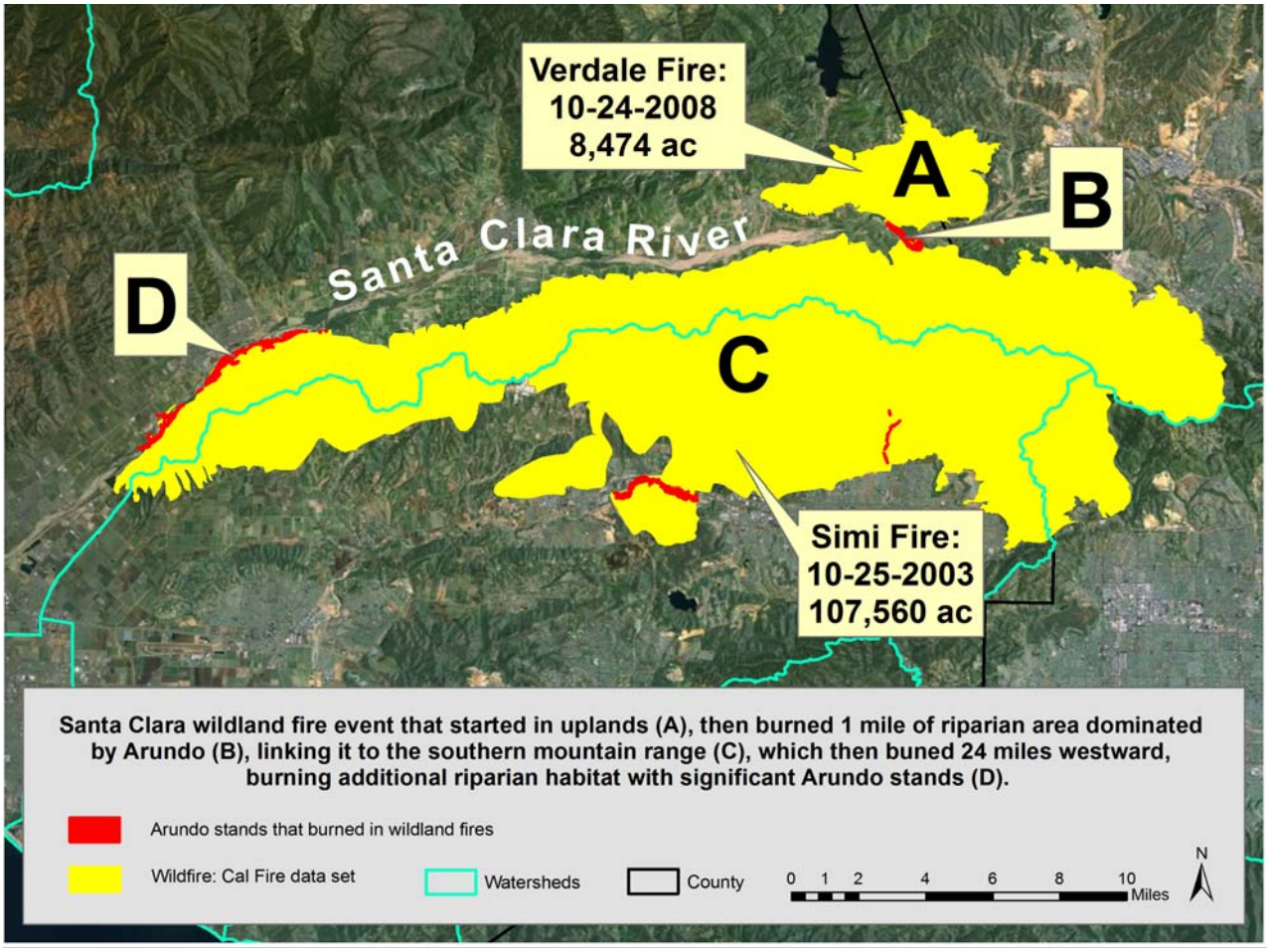

Figure 6-19. Wildfire on the Santa Clara with points A, B, C and D marked.

Conclusions:

- Watersheds with significant *Arundo* stands experience fire events that are due to the presence of *Arundo* (this study). The occurrence of these *Arundo*-initiated fires is quantifiable, both as percent of stands burned and acreage burned (this study).
- *Arundo* is a significant fire threat due to high fuel levels (Spencer et al. 2006, this study) in combination with harboring ignition sources. Fires that start in *Arundo* stands are observed on nearly all watersheds in the project area (this study).
- Wildland fires that burn riparian areas containing *Arundo* burn hotter and more completely due to higher fuel levels associated with the presence of *Arundo* (based on higher fuel loads – Spencer et al. 2006, this study).

Although fire was once a natural part of shrubland ecosystems that characterize the coastal southern California landscape, large riparian ecosystems provided natural firebreaks because native vegetation retains foliar water that resists ignition (Hanes 1971, Naveh 1975, Bell 1997, Rundel 1998, Keeley and Fotheringham 2001). This 'firebreak' function is lost if *Arundo* is present, and is even reversed, whereby riparian areas become 1) a fire source, or 2) a corridor of fire conveyance. Riparian ecosystems infested by *A. donax* adjacent to fire-prone shrublands in southern California appear to be on

a trajectory to an invasive plant-fire regime cycle (Brooks et al. 2004). Clearly wildland fires are burning *Arundo* stands in riparian areas. While it was not documented in this study, it is also likely that *Arundo*-initiated fires will lead to wildland fires given the frequency and intensity of *Arundo* fire events.

Fire Districts/Departments are keenly aware of the fire risks associated with *Arundo* stands. This led the City of Oceanside (San Luis Rey) to enact an ordinance under its code enforcement allowing action to be taken if private property has *Arundo* stands that are a fire risk. This action was driven by two factors: fires occurring in *Arundo* and the identification of wildland fire risk due to fires moving down *Arundo*-infested riparian corridors into urban areas.

6.5 Fire Impacts

In the previous section, it was established that *Arundo* impacts fire events in two general situations: fires that originate in *Arundo* stands (resulting from high fuel load combined with ignition sources) and wildland fires that burn *Arundo*-infested riparian habitat. This chapter will examine and quantify, based on the *Arundo* spatial data set, the impacts that these *Arundo*-driven fires cause.

6.5.1 Type Conversion to Arundo-Dominated Habitat

Arundo stands have high fuel loads and a tall growth form. Infestations of *Arundo* mixed with native species spread fire vertically into the canopy of riparian trees, as well as burning trunks (Figures 6-15 to 17 & 6-20; Ambrose and Rundel 2007). After a fire, *Arundo* immediately (1-2 weeks) begins regrowth from its rhizomes, whereas native riparian plants can remain dormant for several months. High mortality of native trees and shrubs is frequent in comparison to *Arundo*. Furthermore, *Arundo* grows much faster than native plants, up to 3-4 times faster than native riparian plants after fire on the Santa Clara River (Ambrose and Rundel 2007). A year after the fire, *Arundo* dominated the area, comprising 99% relative cover and a 24% increase in relative cover compared to pre-fire conditions (Ambrose and Rundel 2007).

Figure 6-20. *Arundo* one year after a fire, already 2-3 feet high, at the site of fire SLR #6.

A positive-feedback cycle is created whereby the high growth rate of *Arundo*, the fire adapted phenology of *Arundo*, and increased nutrient levels after fire contribute to type conversion. This domination by *Arundo*, in turn leads to more fires, creating an invasive plant-fire regime cycle (Ambrose and Rundel 2007, this study). Results from the mapping data also show that areas with mixed-*Arundo*/native vegetation prior to fire events are dominated by *Arundo* after the fires. This type conversion is important because it is a significant reduction in habitat value (section 7.1, Table 6-5). Fires started within *Arundo* combined with wildfires burned 12% (1,058 ac) of the *Arundo* acreage on all watersheds over a ten-year period (Table 6-7). Type conversion feeds the positive feedback loop. *Arundo*-dominated sites have higher biomass than mixed or patchy stands, increasing the likelihood of fire.

It should be noted that fire only affects within site spread/invasion. It does not allow or cause invasion to the broader system. Invasion outside the site still only occurs through movement of live plant material (flood action and/or human movement of rhizomes). However, the larger the *Arundo* sites, the more material there is for flood-based dispersal.

Table 6-7. Burned *Arundo* acreage from fires that start in *Arundo* and wildfires that burn *Arundo* (for one year and ten-year periods).
Acreages are calculated based on San Luis Rey watershed documented fire events, which is 0.8% of the gross *Arundo* acreage burned annually.

Watershed	Gross *Arundo* Acres	Fires that start in *Arundo*		Wildfires that burn *Arundo*		Combined *Arundo* fire totals	
		Burned *Arundo* acreage* (1 yr)	Burned *Arundo* acreage (10 yrs)	Burned *Arundo* acreage (1 yr)	Burned *Arundo* acreage (10 yrs)	Burned *Arundo* acreage (1 yr)	Burned *Arundo* acreage (10 yrs)
Calleguas	231.5	1.9	18.5	7.2	71.5	9.00	90.0
Carlsbad	147.9	1.2	11.8	-	-	1.18	11.8
Los Angeles River	132.8	1.1	10.6	-	-	1.06	10.6
Otay	18.6	0.1	1.5	0.1	0.5	0.20	2.0
Penasquitos	23.6	0.2	1.9	-	-	0.19	1.9
Salinas[1]	2,006.1	1.6	16.0	-	-	1.60	16.0
San Diego	150.2	1.2	12.0	-	-	1.20	12.0
San Dieguito	175.0	1.4	14.0	13.5	134.9	14.89	148.9
San Gabriel	44.6	0.4	3.6	-	-	0.36	3.6
San Juan	175.2	1.4	14.0	-	-	1.40	14.0
San Luis Rey	683.9	5.5	54.7	1.6	15.6	7.03	70.3
Santa Ana	2,723.9	21.8	217.9	9.6	95.7	31.36	313.6
Santa Clara	1,081.3	8.7	86.5	22.1	220.5	30.70	307.0
Santa Margarita [2,3]	688.9	0.6	5.5	-	-	0.55	5.5
Santa Monica	18.6	0.1	1.5	-	-	0.15	1.5
South Coast	29.8	0.2	2.4	-	-	0.24	2.4
Sweetwater	42.3	0.3	3.4	0.6	6.0	0.94	9.4
Tijuana	135.6	1.1	10.8	-	-	1.08	10.8
Ventura	332.0	2.7	26.6	-	-	2.66	26.6
Total:	**8,841.7**	**51.3**	**513.3**	**54.5**	**544.7**	**105.8**	**1,058.0**
% of Gross Ac:			**5.8%**		**6.1%**		**12%**

[1]Annual fire rate lowered to 10% of that for southern California due to weather conditions and lack of fire reports.
[2]Fires starting in *Arundo* are less common on Camp Pendleton (DoD facility), lowered to 10% for the watershed.
[3]Most *Arundo* had been removed in areas where wildfires burned riverine areas, so no acreage was counted.

6.5.2 Impacts to Fauna,

Fires that are started within *Arundo* stands and wildfires made worse by *Arundo* stands can result in direct mortality of fauna, especially species that cannot escape rapidly. Mortality will vary depending on the season in which the fire occurs. During nesting season, fires may result in direct loss of eggs and young birds. Arroyo toads remain buried during portions of the non-breeding season, and may not survive a fire, depending on the intensity. The addition of ash and other mobilized material (erosion) into breeding pools/ponds may impact fish and amphibians, and the loss of vegetation along waterways may impact shading and water temperature regulation.

After a fire, the habitat is degraded to a condition that does not support species for an amount of time that depends on the fire's intensity and season. One year of functional loss and a degraded condition for 2-5 years are evident on most sites. When the habitat does come back, it may not return to pre-fire conditions and may not be able to support the same abundance and diversity of fauna and flora. Areas that burned may be more open and have more weedy species. If *Arundo* was present before the fire, this is especially a concern, as it re-grows faster than the native species (see Sec 6.5.1).

The degradation of riparian habitat from *Arundo*-initiated fires is estimated for all watersheds based on data from San Luis Rey (Table 6-8). Riparian areas that burn during *Arundo*-initiated fires exceed the *Arundo* acreage that burns (705.8 ac vs. 513.3 ac). Suppression activities impact 32.1 acres of riparian habitat and 43.6 acres of *Arundo* habitat. Cumulatively this covers 1,200 acres of riparian habitat over a ten-year period. This is a significant amount of acreage and it does not include wildfire impacts.

Estimation of the *Arundo* acreage that burns is presented in Table 6-5. Wildfires can burn riparian vegetation during certain conditions, so the entire event cannot be ascribed as an *Arundo* fire impact. The presence of *Arundo* does increase the intensity, and *Arundo* may convey wildfires. These impacts are difficult to quantify and to identify spatially, complicating exploration of their impacts on flora and fauna. No specific accounting of these impacts is presented.

However, fires initiated *within Arundo* stands that result in mortality of fauna and flora are fully ascribed as impacts caused by the *Arundo*. Quantifying this presents challenges, but detailed mapping of fires on the San Luis Rey watershed (Section 6.4.1) present an opportunity to explore this. Very detailed survey data (aggregated from USGS, CalTrans, and ACOE) for least Bell's vireos, Southwestern willow flycatchers, and Arroyo toads indicate that *Arundo* fires that burn riparian habitat have directly impacted occupied habitat for endangered wildlife species (Figure 6-21, Table 6-9). These *Arundo*-dominated areas are of moderate habitat quality to begin with, but flora and fauna utilize pockets of native vegetation. *Arundo* fires can also spread into adjacent higher quality native riparian habitat. Fire suppression activities impact both *Arundo* and native habitat. The area of fires SLR#1, #2 and #3 is very near the mouth of the river, which is at the edge of least Bell's vireo habitat range. Least Bell's vireos were present on the edges of all the fire areas. Fire SLR#4 had least Bell's vireo use on the upstream edge of the fire area. Fire SLR#5 was a fire that occurred during breeding season in a high-use least Bell's vireo area. Mortality likely occurred. Arroyo toads could also have occurred on-site in low numbers. Site SLR#6 is in core, high density Arroyo toad habitat, and mortality likely occurred. Least Bell's vireo use could also occur in this area (only limited surveying was completed for this site, but they are abundant nearby).

In addition to direct take of fauna, habitat that was burned in all of the areas has a significantly reduced habitat value and function. Areas with *Arundo* present would have nearly 100% *Arundo* cover post-fire, while burned native vegetation takes over five years to recover structure and productivity.

Table 6-8. Summary of acreage impacted by burning and fire suppression from fires that start in *Arundo*.
Burned acreage and suppression acreage for watersheds is calculated based on San Luis Rey watershed-documented fire events (multiplying percentage from San Luis Rey by gross *Arundo* acreage for each watershed).

Fires that start in *Arundo*		Fire: *Arundo*		Fire: Riparian		Suppression: *Arundo*		Suppression: Riparian		All Riparian Impacts	
Watershed	**Gross *Arundo* Acres**	**Annual burn ac (0.8%)**	**10 year total**	**Annual burn ac (1.1%)**	**10 year total**	**Annual impacted ac (0.068%)**	**10 year total**	**Annual impacted ac (0.051%)**	**10 year total**	**Annual ac**	**10 year total**
Calleguas	231.5	1.9	18.5	2.5	25.5	0.2	1.6	0.1	1.2	4.7	46.7
Carlsbad	147.9	1.2	11.8	1.6	16.3	0.1	1.0	0.1	0.7	3.0	29.8
Los Angeles River	132.8	1.1	10.6	1.5	14.6	0.1	0.9	0.1	0.7	2.7	26.8
Otay	18.6	0.1	1.5	0.2	2.1	0.0	0.1	0.0	0.1	0.4	3.8
Penasquitos	23.6	0.2	1.9	0.3	2.6	0.0	0.2	0.0	0.1	0.5	4.8
Salinas[1]	2006.1	1.6	16.0	2.2	22.1	0.1	1.4	0.1	1.0	4.0	40.5
San Diego	150.2	1.2	12.0	1.7	16.5	0.1	1.0	0.1	0.8	3.0	30.3
San Dieguito	175.0	1.4	14.0	1.9	19.2	0.1	1.2	0.1	0.9	3.5	35.3
San Gabriel	44.6	0.4	3.6	0.5	4.9	0.0	0.3	0.0	0.2	0.9	9.0
San Juan	175.2	1.4	14.0	1.9	19.3	0.1	1.2	0.1	0.9	3.5	35.3
San Luis Rey	683.9	5.5	54.7	7.5	75.2	0.5	4.7	0.3	3.4	13.8	138.0
Santa Ana	2723.9	21.8	217.9	30.0	299.6	1.9	18.5	1.4	13.6	55.0	549.7
Santa Clara	1081.3	8.7	86.5	11.9	118.9	0.7	7.4	0.5	5.4	21.8	218.2
Santa Margarita [2]	688.9	0.6	5.5	0.8	7.6	0.0	0.5	0.0	0.3	1.4	13.9
Santa Monica	18.6	0.1	1.5	0.2	2.0	0.0	0.1	0.0	0.1	0.4	3.8
South Coast	29.8	0.2	2.4	0.3	3.3	0.0	0.2	0.0	0.1	0.6	6.0
Sweetwater	42.3	0.3	3.4	0.5	4.7	0.0	0.3	0.0	0.2	0.9	8.5
Tijuana	135.6	1.1	10.8	1.5	14.9	0.1	0.9	0.1	0.7	2.7	27.4
Ventura	332.0	2.7	26.6	3.7	36.5	0.2	2.3	0.2	1.7	6.7	67.0
Totals:	**8,841.7**	**51.3**	**513.3**	**70.6**	**705.8**	**4.4**	**43.6**	**3.2**	**32.1**	**129.5**	**1,294.8**

[1]Annual fire rate lowered to 10% of that for southern CA due to weather conditions and lack of fire reports.
[2]Fires starting in *Arundo* are less common on Camp Pendleton (DoD facility), lowered to 10% for the watershed.

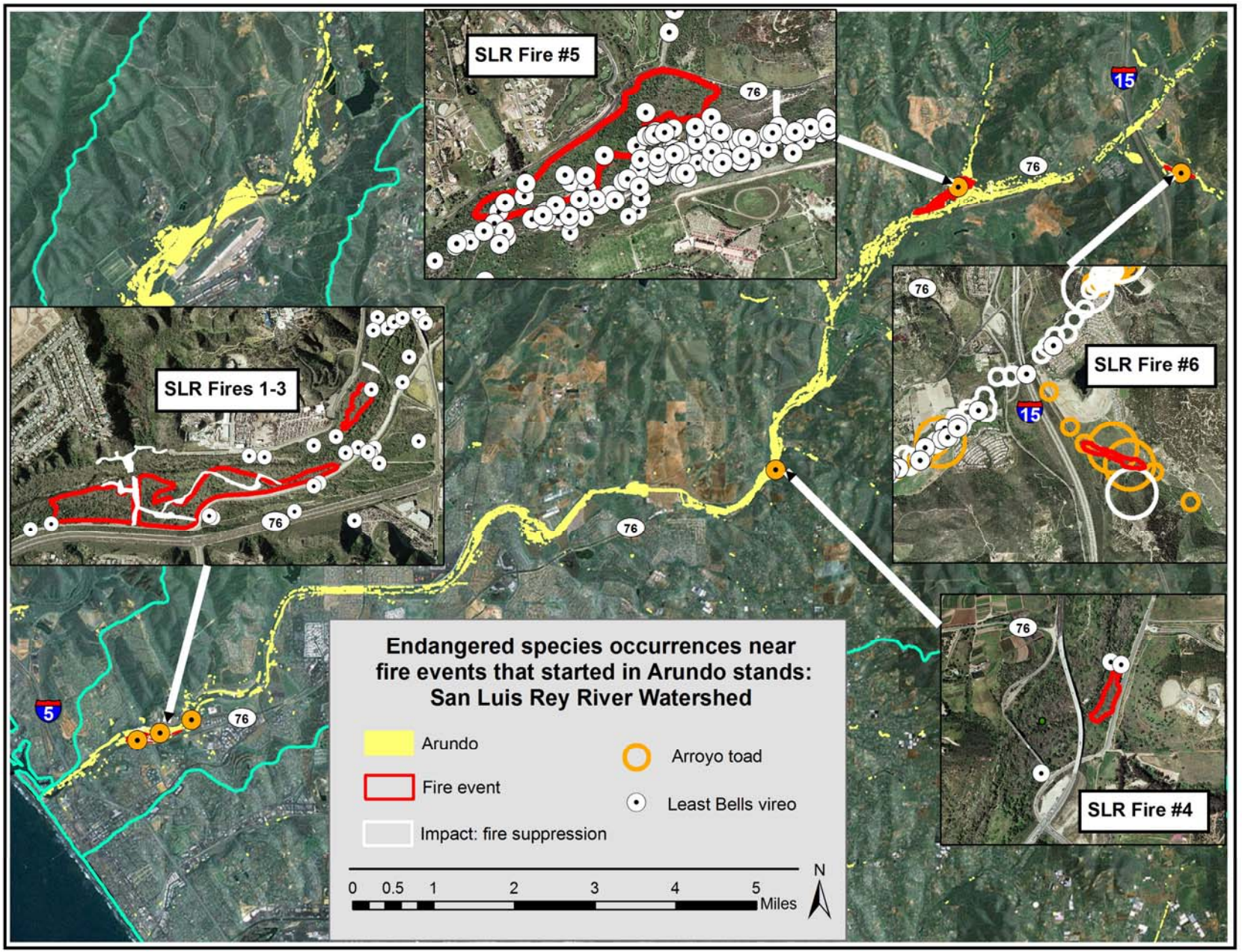

Figure 6-21. Fire events that started in *Arundo* stands on the San Luis Rey River showing sensitive species locations.

Table 6-9. Summary of San Luis Rey River *Arundo* fire impacts on federally endangered species.

Fire Event	Least Bell's vireo	Arroyo toad	Tidewater goby	Southwestern willow flycatcher
SLR#1,2&3	Low	None	Low	Possible
SLR#4	Medium	None	None	Possible
SLR#5	High	Low	None	Possible
SLR#6	Low	High	None	Possible

6.5.3 Impacts from Emergency Acts

Prior to or during fire events, actions are sometimes carried out to reduce the spread of a fire. These actions generally involve clearing vegetated areas to form fire breaks. These cleared areas tend to become weedy due to the disturbance of the soil and removal of established vegetation. If cleared areas are within or near *Arundo* stands, their creation may spread *Arundo* fragments throughout the area and establish new *Arundo* populations. Disturbed areas retain modified topography and poor quality habitat until there is a flow event that resets the geomorphology and allows native recruitment to occur. Depending on the location of the cleared area within the profile, this may occur quickly or after a prolonged period of time.

Emergency actions may also directly impact flora and fauna, as seen in Figure 6-21, where cleared areas were within least Bell's vireo (SLR#1,2,3 & 5) and arroyo toad habitat (SLR#5). The federally endangered plant *Ambrosia pumila* (San Diego ambrosia) also occurred near the disturbance on fire SLR#5.

Although acreage impacted seems minor at first, fire suppression impacts of 43.6 acres of *Arundo* and 32.1 acres of native riparian habitat (Table 6-8) are generated for the study area over 10 years. Many of these impacts are severe modifications (e.g. grading) of occupied threatened and endangered species' habitat.

6.6 Conclusions: Fire Impacts

Arundo significantly changes the intensity, frequency and behavior of fires. It has transformed heavily invaded riparian habitat, which includes many coastal river systems in southern California, from a vegetation type that is normally resistant to fire to a source of fire events. Areas invaded with *Arundo* are flammable, harbor ignition sources, and spread fires both within riparian habitat as well as across the landscape.

- *Arundo* stands are highly flammable throughout the year with large amounts of fuel (15.5 kg/m^2 of biomass), a large amount of energy (287.1 MJ/m^2), and a tall well-ventilated structure with dry fuels distributed throughout the height profile. (Section 6.1)
- Fires frequently start in *Arundo* stands. The primary ignition sources are transient encampments and discarded cigarettes from highway overpasses. (Section 6.1)

- *Arundo* stands strongly attract transient use (dense cover and shelter). This was documented throughout the study area with numerous high use locations noted in both urban and agricultural areas. (Section 6.3.1)
- Fires initiated in *Arundo* stands occur due to fuel and ignition source occurring at the same location. This is a newly defined class of fire events. (Section 6.4.1)
- Fires that are initiated in *Arundo* burn both *Arundo* stands and native riparian areas. In addition, suppression of fires also impacts riparian habitat. Impacts were calculated for all watersheds using San Luis Rey as a case study. Over a ten-year period for the study area, *Arundo*-initiated fire events are estimated to have burned 513 acres of *Arundo* and 706 acres of native riparian habitat. Fire suppression over a ten-year period has impacted 44 acres of *Arundo* and 32 acres of native riparian vegetation. (Section 6.5)
- Wildfires burn a significant acreage of *Arundo* stands. Over ten years, 11% of *Arundo* stands (544 acres) burned within the study area. (Section 6.4.2)
- Due to high fuel load and stand structure, areas with *Arundo* burn hotter and more completely then native vegetation during wildfire events. (Section 6.4.2)
- *Arundo* stands appear to be conveying fires across riparian zones- linking upland vegetation areas that would have been separated by less flammable riparian vegetation. This can have catastrophic impacts like those observed in the 2008 Simi fire. The 8,474-acre fire crossed the Santa Clara River and then burned an additional 107,560 acres. (Section 6.4.2)
- *Arundo* fires accelerate the dominance of *Arundo* in invaded areas due to rapid re-growth and low mortality of *Arundo*. (Section 6.5.1)
- *Arundo* fire events lead to both direct mortality of wildlife and plants (some of which are sensitive) as well as a longer-term quality reduction of burned riparian areas (post-fire recovery of vegetation and structure). (Section 6.5.2)
- Emergency actions tied to *Arundo* fire suppression also result in impacts (disturbance of both *Arundo* and riparian vegetation) that degrade riparian habitat and/or may result in mortality of species. (Section 6.5.4)