Development of Rio Grande Silvery Minnow Refugia at Drain Outfalls in the Isleta Reach of the middle Rio Grande, New Mexico

Project Completion Report on
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EXECUTIVE SUMMARY

Our project goal has been to aid Rio Grande silvery minnow (*Hybognathus amarus*) conservation in the middle Rio Grande (MRG) through the implementation of habitat and flow enhancement measures at three drain outfalls in the Isleta Reach using large cottonwood snag structures. Project permitting and regulatory compliance was completed by August 2007, structure installation took place in November-December 2007, and post-installation monitoring began in February 2008 and was completed in September 2009. Sites selected for enhancement were the drain outfalls associated with the Lower Peralta #1 Drain (LP1DR), the Peralta Wasteway (PERWW), and the Los Chavez Wasteway (LCZWW), all operated by the Middle Rio Grande Conservancy District (MRGCD).

The twenty cottonwood snag structures were installed by MRGCD personnel under the supervision of the Principal Investigators. Monitoring was conducted five times during the winter and summer seasons and included a suite of physical, water quality and biological sampling including engineering surveys, habitat transects, routine chemical analyses, electrofishing and photographs.

The cottonwood snags were found to be structurally stable and capable of withstanding river flows in the range of 6000 cfs. Structural performance however, in terms of scouring and maintaining wetted pools over a range of flow conditions, was mixed due to sedimentation issues. Structures placed in the drain outfalls performed better than those installed in the MRG channel immediately downstream of the outfall mouth. When wetted, habitat conditions in the immediate vicinity of each snag were hydraulically diverse, structurally complex and cover-rich. Water quality conditions were generally consistent with those previously reported for the MRG. The fish assemblage across all three project sites included 19 species, with Rio Grande silvery minnow being the second most abundant species overall at two of the sites. Nonnative predators accounted for 4% of the total catch. We were not able to evaluate the created refugia under complete river drying as such conditions did not occur during our monitoring events.

At this time, we cannot yet conclude that we have achieved our project goal. As reported and discussed, our findings regarding both geomorphic and biologic responses are mixed and inconclusive following two years of monitoring. In the short-term, we recommend that visual and photographic monitoring continue at all three sites. When it becomes feasible for flow to be released into LCZWW and the river thalweg returns to river left at PERWW and river right at LCZWW, detailed physical and biological monitoring should be re-implemented to further evaluate achievement of the project goal.

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BACKGROUND

Introduction

The middle Rio Grande (MRG), with the exception of the Albuquerque Reach, has experienced channel dewatering on a relatively frequent basis. This can be a significant source of mortality for the endangered Rio Grande silvery minnow (*Hybognathus amarus,* RGSM). Recently, the U. S. Fish and Wildlife Service (USFWS) documented 2005 RGSM rescue and salvage efforts (USFWS 2006). Over the course of the 2005 irrigation season, surface water in the main channel of the Isleta Reach was reduced to isolated pools in a two mile section of river just downstream of the Los Chavez Wasteway. This section was bracketed by a total of four river miles in which the river entirely dried out on numerous occasions. Downstream, in the Socorro Reach, a total of 24.5 miles became dry. Perennial surface water in the form of isolated pools persisted over an additional five miles of this predominantly dry river section.

Rescue operations which consisted of seining pools as flow in the MRG became discontinuous began in main channel habitats in July 2005 and continued intermittently through September. Seining efforts in the adjacent floodplain habitats began in June 2005 and also continued through September. A total of 80,556 RGSM were rescued from the main channel of the Isleta Reach and 289,860 were rescued from the adjacent floodplain. Of the RGSM rescued during the 2005 irrigation season, 59% of the estimated total number from both main channel and floodplain habitats were captured in the Isleta Reach upstream of Belen, NM (USFWS 2006).

RGSM have been found using drains in the Middle Rio Grande Conservancy District (MRGCD) between Belen and Corrales, NM bringing to light the importance of drain outfalls in providing refugia for silvery minnows during periods of river-channel drying. During the summer of 2004, 122 silvery minnows were collected in the outfall from the irrigation drainage system into the dry bed of the MRG in the upper Isleta Reach (Ford 2004; Cowley et al 2007). The USFWS, Albuquerque, sampled from 800 to 1,000 RGSM in the Peralta Drain in the Isleta Reach and in 2005 found numerous minnows in the drain's outfall when river flows receded (M. Hatch, SWCA, pers. comm., 2006). These observations suggest that drain outfalls into the MRG can function as refugia for RGSM during periods of river channel dewatering and as important rearing habitat for species conservation. Drains can remain wet year round even when the MRG goes dry by intercepting underground flows (Tetra Tech 2004).

The Middle Rio Grande Conservancy District (MRGCD), with its project partners HabiTech, Inc., New Mexico State University, and the Bureau of Reclamation Denver Technical Service Center, initiated this project in 2005 to implement habitat enhancement measures using large woody debris at three drain outfalls in the upper Isleta Reach of the MRG to increase perennially wetted pool habitat. The goal of the effort has been to aid RGSM conservation, while project objectives have been to design, install and monitor large cottonwood snag structures at these three drain outfalls. The MRGCD has also modified the operation of the drain outfalls/wasteways to improve flows to these locations, when water is available, without impacting water deliveries.

Funding for this effort has been provided by the MRG Endangered Species Act Collaborative Program (the Program), with in-kind service contributed by MRGCD. The Habitat Restoration and Improvement Focus Area for the Program places emphasis on projects that aid in the prevention of RGSM extinction as well as on significant short term measures, including habitat restoration, that will benefit silvery minnow populations. The projects expected to benefit RGSM include those that establish still or slow-water aquatic habitat in and adjacent to the river channel, and those measures that increase aquatic habitat diversity, specifically through the use of woody debris in the river channels. Additionally, the Program identifies habitat restoration in the Isleta Reach as high priority. Our project has attempted to be responsive to these identified needs and priorities.

Role of Large Woody Debris in River Systems

There is an extensive body of literature available on the function of woody debris in providing aquatic habitat and increasing fish survival from which to draw inferences and design guidance for this project (Lassettre 1999; Bryant and Sedell 1995; Harmon et al. 1986). Research on sand bed rivers in the southeastern U.S. provides insight on how large woody debris may interact on sandy channels of the MRG. For example, Wallace and Burke (1984) demonstrated that snags and other woody habitats are the major stable substrate in sandy-bottomed streams of the Southeast, providing substrate for macroinvertebrates and habitat and cover for fish. Adding large woody debris to streams is a common restoration tool for enhancing fish habitat and survival (Talmage et al. 2002; Reeves et al. 1991; Hilderbrand et al. 1998; Wesche 1985).

A significant amount of research in North America has been done in determining the role of woody debris in providing habitat for fish in general and salmonids in particular. However, work in large, complex, highly modified desert rivers such as the Rio Grande in New Mexico is just beginning. The work done to date suggests a strong linkage between woody debris and RGSM relative abundance. Dudley and Platania (1996) found the majority (70%) of RGSM associated with debris piles during the winter, despite the rarity of such habitats in the MRG. Dudley and Platania (1997) also noted a dramatic shift from pool and backwater habitat use in summer to habitats having instream debris piles during the winter. Broderick (2000) found relatively large numbers of silvery minnow wintering beneath debris piles at the lower end of the Low Flow Conveyance Channel, but none were found in any other habitat type during January sampling. Wesche et al (2006) designed, installed and monitored three cottonwood snag structures in the Albuquerque Reach of the MRG and reported 1) the snags remained structurally stable after two years, 2) diverse habitats were provided, including those known to be used by RGSM, 3) numerous fish species utilized the snag habitat, including RGSM, and 4) rapid colonization by macroinvertebrates was observed.

The Habitat Restoration Plan for the MRG (Tetra Tech 2004) provides guidance for the Program. The Restoration Plan emphasizes the importance of large woody debris in restoring habitat for the silvery minnow and has listed placement of large woody debris as a restoration tool. The Restoration Plan indicates that the historic channel of the Rio Grande probably contained appreciable amounts of large woody debris resulting from channel avulsions and bank failures. However channelization and past river maintenance activities reduced habitat complexity. River maintenance activities included the removal of logs and trees to prevent the obstruction or deflection of river flows (USBR 1993), as well as mowing, root plowing, and herbicide treatments of bank and bar vegetation which reduced the amount of woody debris in the river. Snagging of standing trees was frequently practiced after high flow events, which commonly caused bank erosion and undermined trees (USBR 1993). These past activities limited the extent of woody debris, as well as islands and ephemeral side channels in the MRG and reduced complex, low velocity habitats (TetraTech 2004).

Pool Formation

An important function of large woody debris in rivers is the creation and enlargement of scour pools (Abbe et al. 2003). Large wood creates complex channel structure and strongly influences the formation of pools. Pool volume has been found to be directly related to the amount of woody debris in a stream (Carlson et al. 1990; Fausch and Northcote 1992). Stable instream wood accumulations can also increase pool frequency. In some sand-bed channels, virtually all pools can be attributed to either the direct or indirect control of wood (Brooks and Brierley 2002; Webb and Erskine 2003). Tetra Tech (2004) acknowledged that large woody debris may also cause downstream scour forming plunge pools that could be deep-water habitat for RGSM. Wesche et al (2006) found this to be the case, with RGSM comprising 13% of the 2005 catch and 30% of the 2006 catch at the Albuquerque snags. Also, the authors reported that scour depth at times was below the elevation of the shallow ground water table. At the scale of channel reaches, woody debris has a strong control on the frequency of pools and bars and can create significant hydraulic roughness, influencing flow velocity, discharge, shear stress, bed load transport rates and reach-average surface grain size (Montgomery 2003).

Scour depths around a snag or log-jam in a sand-bed channel can be substantially greater than in coarser alluvial channels. Once a rootwad becomes partially embedded in the channel bed it becomes more difficult to move (Abbe et al. 2003). A sediment buttress downstream of a root wad can form in situ by accumulation of sediment in the leeward eddy. Field observations show that sediment commonly accumulates downstream of the eddy created by the root wad and buries part or all of the tree bole. A key concern among many designers in regard to using wood structures is the longevity of wood as a material. How long wood lasts depends on factors such as the type of wood, the environment in which it is located, its size and the age of tree at death. If wood remains saturated in freshwater, it can last almost indefinitely (Abbe et al. 2003). Recent inspections of the Albuquerque cottonwood snags indicate that after five years, the integrity of the wood has remained satisfactory (T. Wesche, HabiTech, pers. comm., 2009).

Role in Creating Refugia in Drying Rivers

Pools formed by snags spanning the channel are particularly important for wildlife, especially in streams with low or no summer flow. When flow ceases, these pools provide the only habitat available for aquatic species, and are a source of recruitment for re-colonization when normal flow returns (Treadwell 1999).

Fine Woody Debris Accumulation and Predation

Large woody debris accumulations such as fallen trees, root wads and other mid-channel snags provide structure for periphyton (algal) growth and the retention of drifting organic matter (Treadwell 1999). Additionally smaller pieces of woody debris such as branches, sticks and twigs on the fallen trees or captured from stream drift create sieve-like accumulation structures that can be highly effective in trapping additional drifting materials (Gregory et al. 1991). Wesche et al (2006) hypothesized this accumulation of finer organic material could explain the rapid colonization of cottonwood snags by macroinvertebrates and also serve as a nutrient base for RGSM. As water levels recede, fish can become trapped and stranded, much as they do on the floodplain during flood recession. At low water levels increasing exposure of boulders, root masses and large woody debris, and decreasing depth of scour holes, could reduce the availability of sheltered places where fish can rest, forage, or conceal themselves from predators. However, habitat structure (especially structurally complex habitat such as submerged branches, leaf litter and aquatic vegetation) has been shown to positively influence fish-assemblage structure (Kennard 1995; Welcomme 2001) and fine woody debris has been found to provide structurally complex habitats that can act as refugia from predators as well as sites from which foraging forays can be staged (Arthington et al. 2005). Adding fine woody debris to a stream can increase carrying capacity for young fish and adult population density may increase as a result (Culp et al. 1996).

Substrate for Benthos

The general lack of channel structure in the MRG that provides stable substrates for algae and invertebrates suggests that introducing snags could enhance overall aquatic productivity and increase food sources for RGSM. The findings of Wesche et al (2006) presented above support this hypothesis. Likewise, Treadwell (1999) notes that the more numerous and complex the array of structures, the greater the likelihood of increasing aquatic productivity.

PROJECT DESCRIPTION

Timeline

Our project was initiated in September 2005 and was originally planned as a two year effort. However, due to unanticipated delays in the environmental compliance process and the opportunity following treatment installation to extend the monitoring period at no additional cost to the Program, four plus years were needed to complete project activities. Following is a timeline describing the schedule of completion for major project actions:

September 2005 -	Contracting completed and project initiated.
October 2005 -	Met with Program's Habitat Restoration Committee.
November 2005 -	Field evaluation of potential drain outfall sites.
February 2006 -	Selection of three drain outfall sites for treatment.
March-May 2006 -	Submitted draft Biological Assessment (BA) and Environmental Assessment(EA) to Bureau of Reclamation (BOR), Albuquerque.
July 2006 -	Presented treatment plans to Program's Habitat Restoration Committee.
February 2007 -	Received comments on draft BA from USFWS and submitted responses.
February 2007 -	Public review of EA completed.
June 2007 -	Met with USFWS and BOR regarding draft BA.
July 2007 -	Biological Opinion issued by USFWS.
July 2007 -	Re-surveyed field sites to update habitat and fish data.
August 2007 -	Finding of No Significant Impact (FONSI) issued by BOR.
August 2007 -	Applied for and received Army Corps of Engineer's 404 permit.
August 2007 -	Applied for and received 401 Water Quality Certification from NM Environment Department.
September 2007 -	Completed final pre-treatment field surveys.
Nov-Dec 2007 -	Installed treatments at project sites.
February 2008 -	Post-installation physical habitat monitoring.
July-Aug 2008 -	Post-installation habitat and fish monitoring.
February 2009 -	Post-installation habitat and fish monitoring.
July 2009 -	Post-installation habitat and fish monitoring.
Aug-Sept 2009 -	Post-installation habitat and fish monitoring.
February 2010 -	Submitted project completion report.

Quarterly progress reports were submitted throughout the project and are on file with the BOR, Albuquerque.

Site Selection Process

Based upon discussions with MRGCD, BOR, and USFWS personnel, a list of ten drains and wasteways within the Albuquerque and Isleta reaches of the MRG was developed as potential project sites. As shown on Figure 1, these included the Upper Corrales Drain (UCRDR), the Corrales Main Canal Wasteway (CORWW), the Lower Corrales Riverside Drain (LCRDR), the Central Avenue Wasteway (CENWW), the Los Chavez Wasteway (LCZWW), the Peralta Main

Canal Wasteway (PERWW), the Lower Peralta Riverside Drain #1(LP1DR), the Lower Peralta Riverside Drain #2 (LP2DR), the Feeder #3 Wasteway (FD3WW), and the Storey Wasteway (STYWW). We conducted a field visit to each of these drains in November 2005 to assess their physical, habitat, flow and biologic characteristics, as well as site access and construction materials availability. With assistance from agency personnel, we also evaluated the proximity of each drain and wasteway to river drying, RGSM salvage history, drain flow availability, and drain flow management flexibility. Based upon these evaluations, we selected three sites within the Isleta Reach for treatment, including LP1DR, PERWW, and LCZWW. MRGCD granted permission to pursue development of drain outfall refugia for RGSM at each of these sites.

Project Sites and Treatments

Our general project design consisted of anchoring large cottonwood snags in the MRG channel at or near the outfalls of the three selected drains as they enter the river channel, following the procedures described by Wesche et al (2006). The cottonwood snags have been anchored into the river or drain bank as shown in the conceptual engineering drawing presented in Figure 2. Placement of these habitat enhancement structures in the drain outfalls takes advantage of persistent drain flows, when available, to provide refugia at critical times, while not impairing the function of the drains. The snags can also help to assure fish access to the river channel when flow conditions allow, and at times of high flow in the MRG, can facilitate the scour of main channel pools to further enhance such habitats. The presence of large woody debris also creates slack water and slow water habitats which are extremely scarce in this river reach, thus improving adult habitat. Each treatment site has been designed to provide approximately 0.5 acres of improved wetted habitat, dependent upon local flow conditions.

The project is located at the outfalls of the LCZWW, the PERWW, and the LP1DR, as described above (Figure 1). These drains are located upstream of the Highway 309 bridge near Belen, NM.. The river in the upper Isleta Reach is a relatively narrow, confined channel with little sinuosity. Some braiding occurs in this section and unvegetated islands are common in the channel. Vegetation has encroached along the banks, further confining the flows, although the thalweg still meanders freely within these vegetated banks. The MRG has often experienced zero flow conditions in this section resulting in occasional fish kills.

Los Chavez Wasteway (LCZWW)

The LCZWW site is located at RM 156.8 at latitude 34^0 44' 46.39"N, longitude 106^0 44' 44.93"W at an elevation of about 4830 ft. above msl. An aerial view of the site (Figure 3) shows the relationship of the drain outfall to the main river channel, the general access point and the staging area used for treatment installation. The site plan is presented in Figure 4 showing the location and approximate configuration of the six cottonwood snags installed in and near the mouth of the outfall. A photograph of the staging area (about 100 ft. long and 50 ft. wide) used at this site is shown in Figure 5, while access to the site via an existing road as shown in Figure 6. Recreational and river management activities have kept the road clear of brush and debris and no vegetation removal was required to gain access.

Peralta Wasteway (PERWW)

The PERWW site is located at RM 152.5 at latitude 34^{0} 41' 21.53"N, longitude 106^{0} 44' 25.67"W at an elevation of about 4815 ft. above msl. An aerial view of the site (Figure 7) shows the relationship of the wasteway to the main river channel, as well as the access point and the staging area. The site plan is presented in Figure 8 with the location and configuration of the seven cottonwood snag structures installed at or near the mouth of the outfall. The well-developed access road, used primarily for recreation use and water management activities, is shown in Figure 9, while the staging area (about 100 ft. long by 50 ft. wide) is shown in Figure 10.

Lower Peralta Drain #1 (LP1DR)

The LP1DR site is located at RM 149.6 at latitude 34^{0} 39' 12.54"N, longitude 106^{0} 44' 22.29"W at an elevation of about 4790 ft. above msl. The relationship of the outfall to the main river channel, as well as the location of the access road and staging area is shown in the aerial view of the site presented in Figure 11. The site plan is presented in Figure 12 with the location and configuration of the seven cottonwood snags installed at or near the mouth of the outfall. The well-developed access road, used primarily for recreation use and water management activities, and staging area are shown in Figure 13.

Operation of Drain Outfalls/Wasteways

As much as feasible, the MRGCD operates the drain outfalls/wasteways to support the refugia created at the three sites. However it is essential to understand that there can be no changes to water deliveries, nor will any more water be consumed as a result of these changes. There will be no net depletions. Water deliveries continue to be made as in the past. The number of zero flow days in the Peralta Wasteway and Lower Peralta #1 Drain will likely be similar to that observed for 2003 through 2005, as summarized in Table 1. The changes in operations involve small improvements in efficiency that result in small increments of water that can be released through these three drain outfalls. Such small improvements result in focusing more water in these drains rather than spreading out releases among many drain outfalls as has been done in the past.

The following sections describe the water operations planned for each of the three project sites:

Peralta Main Wasteway

This site is located at the tail-end of the Peralta Main Canal. Small volumes of water are generally, but not always, available at this location. These small volumes of water are normally directed through a side gate off the wasteway into the Peralta Drain. The side gate is located about 30 feet upstream of the point where the wasteway discharges to the river. Discharge to the river (and the project site) originally occurred only when larger volumes of water (estimated greater than 40 cfs) went through the wasteway. The side gate was normally fully open, but couldn't fully divert the flow, so the excess spilled over the measuring weir and into the river.

The re-operation replaced the manually operated slide in the side gate to the drain with an automatic gate. This gate was purchased by MRGCD in 2006 and was recently installed. The gate was set to maintain a fixed water surface elevation in the wasteway channel, sufficient that the desired discharge to the habitat area falls over the measurement weir. Most water will still go through the side gate to the drain, but a small and relatively constant flow will be maintained to the habitat area. Normally, this will be a small flow, perhaps 2 to 4 cfs. Flows through the wasteway in excess of side gate capacity will also go to the river and the habitat area, providing some range of variability. Since this facility is fed solely from an MRG Project canal, it is also possible that flow to the habitat area could be zero. If MRGCD were not diverting, or if all water in the canal were being used, none would be available for the habitat area.

Lower Peralta #1 Drain

This site is located about three miles south of the Peralta Main Wasteway. It is an outfall from the drain which is fed from the side gate on the Peralta Wasteway. The drain also receives significant tail water returns from other canals in the area, in addition to groundwater returns from irrigated lands. There is also some component of flow which originates as groundwater leakage from the river. In the wintertime, base-flows of 40 to 60 cfs are typically seen in this drain. In the summer, groundwater base-flows may be much reduced, but are more than offset by increased irrigation returns. It is common for this drain to be carrying as much as 150 cfs at times during the irrigation season. At the outfall point, an automatic gate was used to control level. Normally, this gate was raised partly or completely, so that all water in the drain was retained, and only a small amount of gate leakage found its' way to the river through the outfall. Only at times of great excess in the drain did water discharge over the gate to the outfall point.

The re-operation uses the existing automated gate to maintain a small steady flow (estimated 2 to 4 cfs) over the gate to the outfall and the habitat area. This entailed only a simple programming change, and has little impact to other operations at the site. Excess flows are still released to the outfall and habitat area when necessary to prevent flooding or damage to the drain. These periodic increases in flow also introduce some degree of hydrologic variability to the habitat area. It is unlikely that the drain will ever be completely dry, although it is possible for the water surface elevation in the drain to drop to a point where it could no longer pass over the top of the automatic control gate in the outfall. Fortunately, there is a check structure in the drain, just downstream of the outfall, which could be operated when necessary to increase the water surface elevation.

Los Chavez Wasteway

This site is several miles north of the Peralta Main Wasteway, on the opposite (west) side of the river. It is a currently abandoned wasteway from the Belen Riverside Drain. The drain in this area functions as a part of the conveyance system for getting water to Socorro division via the Unit 7 Drain. It receives only scant groundwater inflows, and minor tail-water returns. However, the heading of the drain can, and generally is, fed water from the Belen High Line canal via the 240 Feeder. A gate at the end of the 240 Feeder allows up to about 80 cfs to be diverted into the drain. This water currently may supply Unit 7, be routed in to several small canals north of Belen, or be released to the river just south of Belen.

The proposed change, not yet implemented, would reactivate the abandoned wasteway (done temporarily in 2005). MRGCD will install an automatic gate in an existing check structure in the drain. The gate would maintain a constant water level in the drain, regardless of discharge. An overflow weir would be constructed at the heading of the wasteway with appropriate dimensions to maintain the desired discharge (estimated 2 to 4 cfs) to the river and habitat area. Changes to flow would be accomplished by changing the water level in the drain. It is not expected that flows would vary through the wasteway, so hydrologic variability of the habitat area would only result from water moving naturally through the river. It is possible, though not probable, that flows in the drain could naturally drop to the point that the desired discharge in the wasteway could no longer be met.

Environmental Compliance and Permitting

The project EA can be found at the following link: http://www.usbr.gov/uc/albuq/envdocs/ea/minnorRefugia/index.html; while the FONSI can be accessed at http://www.usbr.gov/uc/albuq/envdocs/ea/minnorRefugia/fonsi.pdf. The Biological Opinion was issued by the USFWS, New Mexico Ecological Services Office, Albuquerque on July 18, 2007 as Cons. #22420-2007-F-0021. The construction work for the project was conducted under Section 404 of the Clean Water Act, Nationwide Permit No. 27, Action No. SPA-2007-466-ABQ by the Albuquerque District, Army Corps of Engineers and under Clean Water Act Section 401 Water Quality Certification NMED SWQB File SF-313 from the NM Environment Department, Santa Fe.

Treatment Installation

The twenty cottonwood snag treatments at the three project sites were all installed in a similar manner following the procedures described by Wesche et al (2006) (Figure 14). Treatment installation took place from 26 November to 5 December 2007 under the on-site direction and supervision of Dr. Wesche and Ms. Broderick. Construction personnel and equipment were provided by MRGCD. Heavy equipment used for installation included a tracked excavator with thumb, a small bulldozer, and dump trucks. All reasonable and prudent measures required in the Biological Opinion were closely followed as were all conditions outlined in the 404 and 401 permits.

Each treatment consisted of at least one cottonwood log with rootwad attached (referred to as a “snag” log) and a shorter section of log that was used as a footer for bed stability. Each snag log was about 25 to 30 ft in length and about 1.5 to 2.0 ft in diameter, while footer logs were no more than 10 ft in length and about 1.0 ft in diameter. Most logs used were from recently fire-killed still-standing trees located near the sites. Several recently fallen trees were also used.

All snags were bank-anchored at the locations and in the configurations shown on Figures 4, 8 and 12, with all work performed in the dry. Bank anchoring was accomplished by excavating a trench about 4 ft wide by 10 to 15 ft long down to the elevation of the channel bed. The footer log was set in the bottom of the trench parallel to the channel with the snag log then set over top the footer perpendicular to the channel with the rootwad extending into the wetted channel at an angle of 15 to 20^{0} in the downstream direction. Once the logs were set, the trench was filled with sufficient rock to counter-balance the buoyant forces of the water and covered over with top soil. Following soil preparation, native vegetation removed from the installation site prior to excavation was re-planted.

Monitoring

Pre- and post-installation monitoring for habitat (H), fish (F) and water quality (WQ) at the three project sites was accomplished at the following times: 18-23 July 2007 (H, F, WQ); 27-28 September 2007 (H); 23-26 February 2008 (H, WQ); 30 July-1 August 2008 (H); 14 August 2008 (F, WQ); 12-14 February 2009 (H, F, WQ); 1-3 July 2009 (H, F, WQ); 19-21 August 2009 (H, WQ); 30 September 2009 (F). It was not always possible to sample habitat and fish on the same days due to variable stream flow conditions, travel schedules, and scientific collection permit issues.

Habitat monitoring typically consisted of the following:

1. Detailed engineering surveys from a permanent benchmark using a Topcon AT-G6 Auto Level transit to document key locations and elevations within each site such as scour pool characteristics, snag stability, and sediment deposition patterns.

2. Measurement of water depth (ft) and water velocity (ft/s) using a Marsh-McBirney Model 2000 Portable Flowmeter, substrate (following Wolman 1954) and cover availability (following Wesche et al 1987) along habitat transects located immediately downstream of each snag location, with measurements taken at either 1.0 or 2.0 ft spacing, dependent on transect width and wading conditions. These measurements of width, depth and velocity were used to calculate flow in cubic ft per second (cfs) within the drain outfalls.

3. Color 35 mm photographs taken from permanent photo stations.

4. Inspection of each treatment to assure structural stability and integrity.

Habitat transect data were entered into Microsoft Excel files while engineering survey data have been stored in AutoCad 2000 files for mapping purposes. Statistical analyses were conducted using STATISTIX 8 (Analytic Software 2003).

Fish collections were made at each project site using a Smith-Root LR-24 backpack electrofisher set to the lowest effective voltage so as to minimize harm to captured fish. Fish were collected with 4 mm mesh dip nets, retained in a bucket with aerated water and then field-identified, counted, and released at the site of capture. Electrofishing effort varied between 707 and 1132 seconds per sample. Numbers of each fish species captured were divided by the minutes of electrofishing to calculate catch per minute of sampling.

Water quality measurements for temperature, dissolved oxygen content, oxygen saturation, salinity, conductivity and pH were made using a Hach HQ portable meter (Hach Chemical Company 2006). Turbidity in formazin turbidity units (FTU) was measured using a portable Hach colorimeter where a water sample was compared to a distilled water reference. Additional water temperature measurements at each snag were periodically taken to compare temperatures in the MRG with those in the drains.

Hester-Dendy plate samplers were deployed several times during the course of the monitoring period to measure macroinvertebrate colonization of the cottonwood snag treatments. Unfortunately, all samplers were lost due to either high streamflow conditions or vandalism.

RESULTS

Physical

Stream Flow

Rio Grande stream flow during the study period was highly variable, ranging from mean daily peaks near 6000 cfs during the 2008 spring runoff down to daily low flows in the range of 10 to 20 cfs during late summer 2008 (Figure 15). Zero flow conditions were not observed at the project sites during the monitoring period. Flows at the drain outfalls during monitoring periods varied from 0.0 to greater than 19.1 cfs at LP1DR and from 0.0 to 9.3 cfs at PERWW (Table 2). Zero flow was encountered at LCZWW during all monitoring periods.

Structural Stability

All cottonwood snag structures remained stable and in position throughout the monitoring period at the three project sites, with none being dislodged or damaged by flood flows up to almost 6000 cfs. The photographic sequences of several structures at each site are presented in Figures 16, 17 and 18 to document structural stability and localized site dynamics over the monitoring period. Engineering surveys determined structures shifted only +/-0.2 ft in the vertical dimension and +/-1.0 ft in the horizontal dimension over the monitoring period, with only minor erosion observed at the log-stream bank interface of several treatments. No deterioration of log integrity was noted over the two year observation period.

Structural Performance

Structural performance was evaluated primarily on a structure's ability to maintain pool bed elevations, both immediately upstream and downstream of the snag, at adequate levels in relation to the water surface elevation for the snag to remain wetted and functioning over a range of flow conditions. Water surface and pool bed elevations for each treatment, site and monitoring time are presented in Table 3 and Figures 19, 20, and 21. A summary plot of mean elevations for each site over time is provided in Figure 22.

Structural performance varied between project sites and monitoring times. At LP1DR, the structures remained wetted throughout the monitoring period due to drain flow, backwater effects from river stage, or a combination of the two and consistently performed as anticipated (Table 3; Figures 19 and 22). Mean water surface elevation ranged from 94.68 ft in August 2009 to 96.89 ft in July 2009. Bed scour and fill based upon the results of engineering surveys typically varied less than +/- 2.0 ft between sampling times and treatments at LP1DR, with the lowest mean bed elevations (90.30 ft in downstream pools, 91.97 ft in upstream pools) observed during the summer 2008 monitoring event. The highest mean bed elevations were 93.33 ft in upstream pools and 93.26 ft in downstream pools during the February 2008 sampling, two months post-installation. Mean maximum scour pool water depths ranged from 2.77 ft in August 2009 to 4.76 ft in July 2009. Overall, the deepest scour pool water depth was 7.01 ft at Snag #3 in July 2009.

Structural performance varied between treatments and monitoring times at PERWW (Table 3; Figures 20 and 22). From February 2008 through July 2009 all snags remained at least partially wetted and functioning due to drain and river flows despite extensive sediment deposition along the stream margins downstream of Snags #2 through #7. Mean water surface elevations during this period ranged from 94.61 ft in summer 2008 to 96.46 ft in July 2009. Mean bed elevations in scour pools varied from a low of 92.04 ft in February 2009 to a high of 94.09 ft in July 2009, indicating over 2.0 ft of deposition over this five month period. By August 2009, mean maximum pool depth had declined to 0.86 ft from 4.14 ft in February 2009, with four of the seven snags totally dry. Only Snags #1 Left and Right, both located within the wasteway itself, maintained bed elevations and pool depths comparable to those of earlier monitoring events. Inspection of the main river channel well upstream of PERWW indicated a thalweg shift had occurred to river right earlier in 2009. This channel shift likely contributed to the accelerated sediment deposition observed at the site in August 2009.

Structural performance at LCZWW was severely hampered by the lack of flow through the drain outfall during the monitoring period as well as a shift in the river's thalweg above the site to the opposite side of the floodplain, similar to that observed at PERWW (Table 3; Figures 21 and 22). As a result, the river "bermed off" the mouth of the outfall with sediment deposits several feet high during spring runoff 2008, leaving Snags #1 Left and Right buried in sediment and dry for the remainder of the monitoring period. The remainder of the snags, all located along the right bank of the main river channel, functioned intermittently from July 2008 to August 2009. Snags #2, #3, #5 and #6 were wetted on two of four monitoring dates during this period, while Snag #4 was functioning on three of four occasions. Excluding February 2008, mean maximum pool depths ranged from 0.0 ft in August 2009 to 1.51 ft in July 2009, while the maximum pool depth measured was 2.83 ft at Snag #4 in July 2009. Until MRGCD is able to provide flow more routinely into the LCZWW, structural performance will remain well below potential at this site.

Habitat

When wetted, habitat conditions in the immediate vicinity of each cottonwood snag were hydraulically diverse, structurally complex, and cover rich. Habitat data for each structure and monitoring time are summarized in Table 4 for LP1DR, in Table 5 for PERWW, and in Table 6 for LCZWW.

At LP1DR (Table 4), which remained wetted throughout the monitoring period, mean water depths ranged from 0.69 ft along Transect 1 in July 2008 to over 4.0 ft at Transect 3 in July 2008, and February and July 2009. Mean water velocities varied from 0.0 ft/s at several transects and times to 0.77 ft/s along Transect 1 in February 2009. Cover availability, consisting primarily of the snag itself and other accumulated organic debris, ranged from 50 to 100% at each transect and time following snag installation, while pre-installation cover ranged from 0.0 to 21.1%. Silt was the predominant substrate type along 21 of 28 (75%) habitat transect measured post-installation, while sand was most common (60% of transects) during the September 2007 pre-installation sampling.

At PERWW (Table 5), where snag drying occurred intermittently as described above, mean water depths, when wetted, ranged from 0.38 ft at Transect 3 in July 2008 to 2.99 ft along Transect 4 in February 2009. Mean water velocities varied from 0.0 ft/s at several transects and times to 1.11 ft/s along Transect 5 in July 2008. Cover availability along wetted transects where snags had been installed (Transects 1 through 7), ranged from 16 to 100% over the post-installation period, while pre-installation cover varied from 5 to 19% in September 2007. Sand was the predominant post-installation substrate at 71% of the habitat transects, while silt predominated along 57% of the pre-installation transects.

At LCZWW (Table 6), where snag drying occurred intermittently as described above, mean water depths, when wetted, ranged from 0.10 ft at Transect 2 in February 2009 to 1.61 ft at Transect 4 in February 2008. Mean water velocities varied from 0.0 ft/s at several transects and times to 1.32 ft/s at Transect 4 in February 2008. Cover availability along wetted transects ranged from 23.1 to 100.0% over the post-installation period, while pre-installation cover varied from 0.0 to 23.8% in September 2007. Sand was the predominant post-installation substrate type at 54% of the habitat transects, while sand also predominated along 57% of the pre-installation transects.

Water Quality

Water quality varied across monitoring dates as shown in Table 7. In general, dissolved oxygen levels were in the range of 5 to 7 mg/l during summer samples and approximately 9 to 10 mg/l in winter samples. The only dissolved oxygen concentration considered low was the 3.22 mg/l reading measured at PERWW in August 2009 under low flow conditions. Salinity was generally low across sites and times, ranging from 0.17 to 0.26 ppt, while pH was consistently slightly alkaline, varying from 7.59 to 8.22. Turbidity was typically low in the winter (46 to 66 FTU) and moderately higher during the summer season, ranging from 90 to 322 FTU. Winter water temperatures (Tables 7 and 8) typically varied from about 5 to 12^{0} C, while summer temperatures ranged up to 32^{0} C in the MRG at both LP1DR and PERWW in late July 2008. Drain temperatures were never found to exceed 30^{0} C.

Fish Collections

Fish sampling was conducted on five dates at LP1DR (Table 9) and PERWW (Table 10), and on three dates at LCZWW (Table 11). Across all sites and dates, a total of 1365 fish were captured, identified to species, and released (Table 12). Over all samples, native fishes comprised 54% of the fish assemblage with RGSM accounting for 19% of the total catch. Nonnative predators and other nonnative fishes were the remaining 4% and 42%, respectively, of the catch. A total of 19 fish species were represented in the samples. Species richness increased downstream, with 8 species at LCZWW, 13 at PERWW, and 18 at LP1DR. The number of fish species captured varied by sample date, with 3 to 10 species per sample at LP1DR, 5 to 8 species at PERWW, and 6 to 7 species at LCZWW.

Total fish abundance across samples increased with upstream location of the snags. A total of 310 fish were captured at LP1DR, 514 at PERWW, and 541 at LCZWW. A total of 256 RGSM were collected, 71 at LP1DR, 33 at PERWW, and 152 at LCZWW. RGSM was the second-most abundant species at the Lower Peralta and Los Chavez sites and the third most-abundant at the Peralta site. The high numbers of RGSM captured at LCZWW in the February and July 2009 samples were collected from slow velocity water immediately downstream of snags. The soft bottom sediments and slow velocity in these locations were consistent with foraging habitats noted by Shirey et al (2008) for RGSM, which included evidence of foraging on mud in eutrophic nutrient-enriched habitats with high oxygen demand and low oxygen levels.

The abundance and catch per minute for minnows *(C. lutrensis, H. amarus, P. promelas, P. vigilax,* and *P. gracilis)* were plotted against comparable values for nonnative predators (Figure 23). In general, samples containing more nonnative predators had substantially fewer numbers of minnows whereas samples with few or no nonnative predators had abundant minnow populations. The relationship between minnows and nonnative predators was nonlinear and clearly negative.

DISCUSSION

Our goal has been to aid RGSM conservation through the development of minnow refugia at drain outfalls entering the MRG in the Isleta Reach, a section of the river historically prone to dewatering and drying. To achieve this goal, our objectives have been to implement habitat enhancement measures at three outfall sites through the design, installation and monitoring of large cottonwood snag structures to provide wetted habitats for minnow survival during river drying events. We have met our design and installation objectives and have conducted two years of monitoring to evaluate progress toward achieving our goal. These efforts have been described earlier in the report. In this section, we describe some of the challenges we've encountered in attempting to attain the project goal and discuss possible future management implications of our findings to date.

Physical

All twenty cottonwood snags have been structurally stable over the two year monitoring period with no damage or displacement observed. This finding is supportive of the installation techniques we've developed and is in agreement with stability results reported by Wesche et al (2006) for three similar structures installed in the Albuquerque Reach of the MRG in 2003. Our 2009 observations of these Albuquerque structures indicate that after 6 years, the snags remain stable and the logs have maintained their structural integrity. While cottonwood is generally not considered as durable and long-lasting as more decay-resistant species such as douglas fir (*Pseudotsuga menziesii*) for in-channel restoration activities (Salix 2004), it is locally abundant and aesthetically fits well into the MRG riverscape. Continued observation of the Albuquerque as well as our drain outfall sites will provide important insights into the anticipated lifespan of cottonwood snags in the MRG.

The geomorphic effectiveness of the cottonwood snags has thus-far been variable, dependent at least in part on installation location. Our treatment design resulted in 10 snags being installed within drain channels with the remaining 10 placed in the MRG either at the outfall confluence or immediately downstream (see Figures 4, 8, and 12). Of the 10 drain snags, 8 have functioned as anticipated, scouring and maintaining pool bed elevations both immediately upstream and downstream of the rootwad fans, similar to the scour patterns reported by Hilderbrand et al (1998) for large woody debris placements and hypothesized by Kinzli and Myrick (2009) for rock bendway weirs in the MRG. These 8 were located in LP1DR and PERWW, both of which have experienced flow throughout much of the monitoring period. The two drain snags which did not function whatsoever were located in lower LCZWW. Here, no drain flow occurred during the monitoring period, allowing the MRG to 'berm off" the drain mouth and inundate the snags with sediment. This finding emphasize the importance of drain flow in helping to create refugial habitats and emphasizes the need for MRGCD to re-introduce small amounts of flow into the LCZWW at the earliest possible time, subject to water availability.

The geomorphic effectiveness of the 10 snags installed along the MRG channel varied substantially. Of these 10, only Snag #1 at LP1DR functioned consistently in scouring and maintaining pool bed elevations to remain wetted throughout the monitoring period. Each of the remaining 9 snags was dry for at least one monitoring event, suggesting that none had been able to scour and maintain an elevation below that of the shallow alluvial ground water table, as Wesche et al (2006) found at the Albuquerque site. At the LCZWW site the lack of flow from the drain undoubtedly contributed to this finding, once again emphasizing the importance of drain flow in maintaining refugial habitats. Another factor which likely contributed to the limited effectiveness of the main channel snags was their spacing. In our design, we followed the guidance provided in Salix (2004) to space structures such as the snags, which function much like a bendway weir or groyne, at a distance of 3 to 4L from each other, with L being the length of the snag's perpendicular projection from the bank out into the flow. While such spacing has been shown to be adequate for most streams, it appears that for a sand bed river such as the MRG, this distance is not suitable to prevent sediment entrained at an upstream structure from depositing at the next structure downstream and negatively influencing its' performance. In the future, should installation of additional cottonwood snags or similar structures such as rock bendway weirs (Kinzli and Myrick 2009) be considered, extending the spacing between treatment should be given careful consideration.

A third factor likely contributing to the aggradation which occurred at many of the main channel snags is the dynamic nature of the MRG itself. While the river has been physically constrained by numerous land use activities and the flow regime modified by water storage and use, the low flow channel is still free to migrate within the floodplain boundaries. Our observations upstream of both the PERWW and LCZWW sites indicated the low flow thalweg migrated to the opposite side of the active channel during the spring runoff periods of 2008 and 2009. This shift likely resulted in reduced sediment transport capacity on our side of the river leading to increased sediment deposition. As one experienced MRG water manager said, "....just give the river a couple years and it will be back on our side of the valley..." (D. Gensler, MRGCD, pers. comm. 2009). Given this set of circumstances, observational and photographic monitoring at these two sites would be useful in the short-term at a minimum to document future river dynamics. In the longer term, the use of pressure transducers, as described by Borg et al (2007), within the scour pools formed by the snags to document sedimentation processes and rates may allow scour dynamics to be closely linked to the MRG hydrograph. Such information could be useful in prescribing flow regime modifications to aid RGSM conservation. Overall, our findings to date indicate the probability of successful structural performance is enhanced by placement within the drain itself rather than in the more dynamic MRG channel.

When wetted, the aquatic habitat provided at each snag installation was hydraulically diverse, structurally complex, and cover-rich. These findings closely parallel those of Wesche et al (2006) in the Albuquerque Reach. The diverse mosaic of habitats created at the snags includes those described for RGSM habitat use by Dudley and Platania (1997).

Water Quality

Water quality measurements were generally consistent with results previously reported for the MRG (Ong et al. 1991; Cowley et al. 2003). Salinity, which has been shown to be harmful to RGSM eggs (Cowley et al. 2009), was low and consistent with prior reports (Anonymous 1979; Cowley et al 2009). Only one instance of low dissolved oxygen was found, that being at

PERWW in August 2009. However, analysis of RGSM food habits has suggested that the species is tolerant of low dissolved oxygen levels because the diatoms consumed were indicative of oxygen-stressed environments (Cowley et al. 2006; Shirey et al. 2008). Hence, this single low value for dissolved oxygen is likely of little concern. Summer water temperatures within the drain outfalls were typically found to be the same or slightly cooler than in the MRG and within the tolerances of the river's aquatic life. Future monitoring efforts should consider using recording thermographs to more thoroughly document and compare water temperature regimes within the drain outfalls and the MRG.

Fish Assemblages

Our fish collections yielded a total of 19 species, 86% of the 22 species previously known to occupy the Isleta Reach of the MRG (Cowley et al. 2007). In comparison, Dudley et al (2005 and 2006) report capturing 13 species in the reach. Fish species richness is generally consistent with fishes reported from the Peralta area canal system (Cowley et al. 2007) and is supportive of the diversity of habitat conditions created at the snag locations. Overall, our fish collections at the drain outfall sites were comprised of 4% nonnative predators, similar to the 4.5% and 7.0% reported by Dudley and Platania (2008 and 2009) for August 2008 and September 2009, respectively, at their monitoring site 6 near Belen, NM, the closest such site to the drain outfalls.

RGSM density at the drain outfall sites, while encouraging, was somewhat lower than that reported by Dudley and Platania (2008 and 2009). For our four post-installation monitoring events, RGSM density across all drain outfall sites averaged 3.0 per 100 sq. m sampled, while Dudley and Platania reported densities of 7.6 and 5.5 per 100 sq. m for their August 2008 and September 2009 samplings, respectively, at their Belen station. This finding is not unexpected for several reasons, including 1) low capture efficiency in the deep, turbid, complex habitat associated with some of the snags, 2) inclusion of dry portions of our drain outfall sites at several sampling times in our standard calculation of sampled area, and 3) the presence at all sampling times of wetted habitat in the main river channel.

The high numbers of RGSM collected at LCZWW in February and July 2009 were particularly encouraging and indicative of the importance of flow refuges created by large woody debris to the species. The slow current velocity immediately downstream of the snags concentrated soft sediments that are favored foraging locations for RGSM (Shirey et al. 2008). The minnows collected on these dates at the Los Chavez site were very closely associated with the cottonwood snags and the recently deposited soft sediments. This finding is similar to that for September 2006 at the Albuquerque snag sites where 83% of the RGSM captured were associated with the loosely consolidated, soft, gelatin-like sediments containing very fine organic material deposited immediately downstream of the cottonwood snags (Wesche et al. 2006). Results such as these suggest that additional installations of large wood could create more habitats favored by RGSM and other native minnows.

The negative relationship observed between minnow abundance and nonnative predator abundance suggests that managers should consider the potential impact of the nonnative predators on species such as RGSM. If predators do use habitats created by large woody debris, then their utility as refuge habitats for RGSM and other native fishes is compromised to some degree. Considerable recreational angling occurs in the river channel and drainage canals of the MRG (Muldoon 2007; Cowley et al. 2007). Thus, one management opportunity to control such predators could lie in focused recreational angling. Advertising the locations of large woody debris structures would ensure that anglers knew of potential fishing locations where their activity would have the greatest ecological benefit for an endangered species. Additionally, these locations could be focus areas for management agency nonnative removal efforts.

Fish screens and changes to state-supported stocking programs have been suggested as means for controlling nonnative predators (Cowley et al. 2007). Screens at the the outlets of the irrigation system back to the river might be used to control movements of nonnatives out of the canal system into the drain outfall and riverine habitats created by large woody debris installations. While screens could be used to control the movements of nonnative predators through canals, their use should be carefully considered because the irrigation canal system clearly plays a role in fish movements and re-colonization in the MRG (Cowley et al. 2007). Also, any screening system would need to carefully consider possible effects to water deliveries.

CONCLUSION AND RECOMMENDATION

At this time, we cannot yet conclude that we have achieved our project goal of aiding Rio Grande silvery minnow conservation through the implementation of habitat restoration measures using large woody debris at three drain outfalls in the Isleta Reach of the MRG. As reported and discussed, our findings regarding both geomorphic response and biologic response are mixed and inconclusive based upon two years of post-installation monitoring. In the short-term, we recommend that visual and photographic monitoring continue at all three drain outfall sites. When it becomes possible for flow to be released into the Los Chavez outfall and the river thalweg returns to river left at the Peralta Wasteway site and river right at the Los Chavez site, more detailed physical and biological monitoring should then be re-implemented at all three sites to further evaluate achievement of the project goal.

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Table 1. Drain flow analysis for Peralta Wasteway and Lower Peralta #1 Drain for average flow, peak flow and number of zero flow days for 2003 through 2005. Los Chavez is not gauged.

	Average Q (cfs) March-October	Peak Q (cfs) March -October	Number Zero Q Days July-September	Consecutive Zero Q Days July-September
Peralta Wasteway				
2003	12.0	84	76	52
2004	21.7	155	55	21
2005	60.6	157	17	13
Lower Peralta #1 Drain				
2003	5.9	79	51	10
2004	3.6	40	48	10
2005[1]	12.8	93	13	6

[1]Record through August 19, 2005

Table 2. Measured flow (cfs) at each drain outfall for each monitoring time.

Date	**Site**		
	LP1DR	**PERWW**	**LCZWW**
Sep 2007	0.03	9.31	0.00
Feb 2008	0.00	0.00	0.00
July/Aug 2008	0.64	0.00	0.00
Feb 2009	0.00	0.00	0.00
Jul 2009	>19.1[1]	0.00	0.00
Aug 2009	>6.06[1]	2.74	0.00

[1] Cross section too deep to wade in its entirety

Table 3. Water surface and pool bed elevations at the conttonwood snags by project site and monitoring period. (Note: Elevations are relative to an assigned elevation of 100.00 ft for each site's benchmark).

		February 2008				July/August 2008				February 2009				July 2009				August 2009			
		WSE	UPBE	DPBE	MPD	WSE	UPBE	DPBE	MPD	WSE	UPBE	DPBE	MPD	WSE	UPBE	DPBE	MPD	WSE	UPBE	DPBE	MPD
		(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
LP1DR	Snag #1	96.41	92.32	91.58	4.83	94.91	93.35	93.79	1.56	95.94	92.43	91.41	4.53	96.82	92.33	92.63	4.49	94.56	91.73	92.68	2.83
	Snag #2	96.38	93.48	94.24	2.90	94.87	92.06	92.61	2.81	95.92	92.19	93.24	3.73	96.85	92.26	92.90	4.59	94.67	91.57	92.76	3.10
	Snag #3	96.37	92.62	92.89	3.75	94.88	89.95	88.91	5.97	95.99	91.35	90.70	5.29	96.85	89.84	91.54	7.01	94.69	92.35	90.48	4.21
	Snag #4	96.41	93.72	93.27	3.14	94.90	92.64	92.64	2.26	95.91	92.80	92.54	3.37	96.88	93.38	93.03	3.85	94.69	92.72	92.61	2.08
	Snag #5 - Upper	96.39	93.44	93.78	2.95	94.91	91.81	91.46	3.45	95.98	92.38	92.54	3.60	96.92	91.94	91.92	5.00	94.70	91.89	92.03	2.81
	Snag #5 - Lower	96.39	94.06	93.83	2.56	94.91	91.46	93.40	3.45	95.98	92.54	93.66	3.44	96.92	91.92	93.90	5.00	94.70	92.03	93.87	2.67
	Snag #6	96.39	93.14	92.66	3.73	94.93	92.11	91.81	3.12	96.01	92.96	92.18	3.83	96.95	92.98	93.03	3.97	94.70	92.18	92.38	2.53
	Snag #7	96.38	93.88	93.86	2.52	94.94	92.41	92.73	2.53	95.98	93.67	93.24	2.74	96.96	92.83	93.70	4.13	94.71	92.81	93.03	1.90
	Mean	**96.39**	**93.33**	**93.26**	**3.30**	**94.91**	**91.97**	**92.17**	**3.14**	**95.96**	**92.54**	**92.44**	**3.82**	**96.89**	**92.19**	**92.83**	**4.76**	**94.68**	**92.16**	**92.48**	**2.77**
	St.Dev	**0.01**	**0.57**	**0.81**	**0.72**	**0.02**	**0.93**	**1.42**	**1.22**	**0.03**	**0.62**	**0.93**	**0.73**	**0.05**	**1.01**	**0.75**	**0.94**	**0.05**	**0.42**	**0.91**	**0.66**
PERWW	Snag #1 - Left	96.24	93.43	93.23	3.01	94.72	90.66	90.68	4.06	96.16	91.09	90.69	5.47	96.54	92.95	93.28	3.59	94.51	92.22	91.37	3.14
	Snag #1 - Right	96.24	92.93	93.51	3.31	94.70	92.72	92.08	2.62	96.09	91.03	90.77	5.32	96.47	93.83	93.75	2.72	94.51	92.38	91.11	3.40
	Snag #2	96.24	94.06	93.21	3.03	94.73	93.98	94.05	0.75	96.21	93.46	93.75	2.75	96.48	95.15	95.65	1.33	94.46	95.03	95.01	0.00
	Snag #3	96.22	92.11	94.71	4.11	94.70	93.36	94.00	1.34	96.18	93.09	92.89	3.29	96.47	94.20	95.25	2.27	94.47	94.51	95.54	0.00
	Snag #4	96.13	92.04	91.30	4.83	94.60	92.11	92.32	2.49	96.05	91.99	90.80	5.25	96.43	94.37	94.60	2.06	94.45	94.53	94.58	0.00
	Snag #5	96.08	90.71	91.27	5.37	94.48	91.81	92.55	2.67	96.04	92.11	92.51	3.93	96.43	94.09	93.99	2.44	94.41	94.41	94.63	0.00
	Snag #6	96.03	93.07	93.46	2.96	94.47	91.98	93.08	2.49	95.97	92.29	92.01	3.96	96.42	93.44	92.95	3.47	94.40	94.46	94.35	0.05
	Snag #7	95.87	94.73	93.57	2.30	94.45	92.95	92.73	1.72	95.99	92.81	92.86	3.18	96.40	92.50	93.27	3.90	94.37	94.12	94.53	0.25
	Mean	**96.13**	**92.89**	**93.03**	**3.62**	**94.61**	**92.45**	**92.69**	**2.27**	**96.09**	**92.23**	**92.04**	**4.14**	**96.46**	**93.82**	**94.09**	**2.72**	**94.45**	**93.96**	**93.89**	**0.86**
	St.Dev	**0.13**	**1.26**	**1.18**	**1.05**	**0.12**	**1.03**	**1.09**	**1.00**	**0.09**	**0.88**	**1.17**	**1.07**	**0.04**	**0.84**	**0.99**	**0.88**	**0.05**	**1.05**	**1.68**	**1.49**
LCZWW	Snag #1 - Left	97.94	95.20	95.66	2.74	-	96.45	96.86	0.00	-	96.19	96.88	0.00	-	97.44	98.36	0.00	-	97.54	98.14	0.00
	Snag #1 - Right	97.94	95.69	95.81	2.25	-	96.56	97.14	0.00	-	96.38	97.12	0.00	-	97.57	98.49	0.00	-	97.77	97.98	0.00
	Snag #2	97.92	96.29	95.64	2.28	96.10	97.09	96.72	0.00	97.42	97.21	97.48	0.21	97.76	97.27	97.91	0.49	-	97.39	97.96	0.00
	Snag #3	97.96	95.10	94.98	2.98	96.12	96.19	96.50	0.00	97.40	96.79	96.74	0.66	97.74	95.78	95.89	1.96	-	95.78	96.17	0.00
	Snag #4	97.95	94.40	94.27	3.68	96.13	95.16	95.40	0.97	97.31	96.65	96.02	1.29	97.68	94.85	95.44	2.83	-	95.46	95.89	0.00
	Snag #5	97.82	95.18	94.33	3.49	-	95.81	95.75	0.00	97.35	96.21	96.19	1.16	97.60	95.31	95.00	2.60	-	96.26	95.69	0.00
	Snag #6	97.79	94.84	94.98	2.95	94.87	96.63	96.70	0.00	97.40	96.74	96.73	0.67	97.64	95.16	94.96	2.68	-	95.34	96.24	0.00
	Mean	**97.90**	**95.24**	**95.10**	**2.91**	**95.81**	**96.27**	**96.44**	**0.14**	**97.38**	**96.60**	**96.74**	**0.57**	**97.68**	**96.20**	**96.58**	**1.51**	**-**	**96.51**	**96.87**	**0.00**
	St.Dev	**0.07**	**0.60**	**0.64**	**0.55**	**0.62**	**0.63**	**0.63**	**0.37**	**0.05**	**0.36**	**0.51**	**0.53**	**0.07**	**1.19**	**1.61**	**1.30**	**-**	**1.04**	**1.10**	**0.00**

WSE = Water surface elevation
UPBE = Upstream pool bed elevation
DPBE = Downstream pool bed elevation
MPD = Maximum pool water depth
(-) Location dry, no measurement possible

Table 4. Summary of physical habitat data for each transect monitored at the lower Peralta #1 Drain project site. Note: (-) indicates no data collected; (+) indicates unwadable conditions.

	Sampling Date					
	Sep 2007	**Feb 2008**	**Jul 2008**	**Feb 2009**	**Jul 2009**	**Aug 2009**
Transect #1						
Mean D (ft)	1.38	+	0.69	2.22	2.92	1.31
D_{Max} (ft)	2.80	+	1.05	3.45	4.20	2.27
Mean V (ft/sec)	0.30	+	0.36	0.77	0.72	0.47
V_{Max} (ft/sec)	0.79	+	0.95	1.92	2.65	1.62
Predominate Substrate	Sd	+	St	Sd	Sd	St
% Cover	0.0	+	62.5	66.7	68.4	64.7
Transect #2						
Mean D (ft)	1.30	+	1.48	2.12	3.39	1.73
D_{Max} (ft)	2.46	+	2.25	3.30	>5.0	3.12
Mean V (ft/sec)	0.01	+	0.03	0.00	0.19	0.14
V_{Max} (ft/sec)	0.05	+	0.09	0.00	0.71	0.44
Predominate Substrate	Sd	+	St	St	St	St
% Cover	0.0	+	68.8	63.2	68.4	50.0
Transect #3						
Mean D (ft)	1.33	+	4.58	>4.0	>4.0	2.79
D_{Max} (ft)	2.82	+	6.81	>5.0	>5.0	4.50
Mean V (ft/sec)	<0.01	+	0.03	0.00	+	0.16
V_{Max} (ft/sec)	0.02	+	0.09	0.00	+	0.58
Predominate Substrate	St	+	St	St	St	St
% Cover	7.7	+	62.5	57.9	60.0	78.9
Transect #4						
Mean D (ft)	1.37	+	1.66	2.44	3.29	1.35
D_{Max} (ft)	2.70	+	2.43	3.33	>5.0	3.08
Mean V (ft/sec)	0.01	+	0.03	0.00	0.15	0.06
V_{Max} (ft/sec)	0.05	+	0.11	0.00	0.54	0.40
Predominate Substrate	Sd	+	St	St	St	St
% Cover	15.4	+	71.4	76.2	76.5	93.3
Transect #5						
Mean D (ft)	1.35	+	2.20	2.20	2.92	1.27
D_{Max} (ft)	1.86	+	3.17	2.95	4.30	2.00
Mean V (ft/sec)	0.01	+	0.02	0.00	0.33	0.34
V_{Max} (ft/sec)	0.03	+	0.05	0.00	1.27	0.70
Predominate Substrate	St	+	St	St	St	FG
% Cover	21.1	+	75.0	68.8	94.1	62.5
Transect #6						
Mean D (ft)	-	+	2.30	2.97	3.44	1.47
D_{Max} (ft)	-	+	3.25	3.92	>5.0	3.00
Mean V (ft/sec)	-	+	0.02	0.00	+	0.24
V_{Max} (ft/sec)	-	+	0.08	0.00	+	0.73
Predominate Substrate	-	+	Sd	St	St	St
% Cover	-	+	75.0	61.1	60.0	89.5
Transect #7						
Mean D (ft)	-	+	1.14	1.43	2.38	0.86
D_{Max} (ft)	-	+	2.33	2.68	4.20	1.77
Mean V (ft/sec)	-	+	0.05	0.00	0.39	0.18
V_{Max} (ft/sec)	-	+	0.19	0.00	1.36	1.07
Predominate Substrate	-	+	Sd	St	Sd	Sd
% Cover	-	+	76.5	88.9	100.0	90.0

Table 5. Summary of physical habitat data for each transect monitored at the Peralta Wasteway Drain project site. Note: (-) indicates no data collected; (+) indicates unwadable conditions.

	Sampling Date					
	Sep 2007	**Feb 2008**	**Jul 2008**	**Feb 2009**	**Jul 2009**	**Aug 2009**
Transect #0						
Mean D (ft)	-	2.82	0.99	2.29	2.24	0.80
D_{Max} (ft)	-	3.82	1.48	3.00	3.00	1.34
Mean V (ft/sec)	-	0.00	0.00	0.00	0.00	0.18
V_{Max} (ft/sec)	-	0.00	0.00	0.00	0.00	0.32
Predominate Substrate	-	St	Cl	St	St	St
% Cover	-	5.6	0.0	0.0	0.0	11.8
Transect #1						
Mean D (ft)	1.53	2.31	2.16	2.17	>2.86	1.95
D_{Max} (ft)	2.97	3.10	3.90	3.20	>4.50	3.20
Mean V (ft/sec)	0.19	0.00	0.00	0.00	0.00	0.04
V_{Max} (ft/sec)	0.57	0.00	0.00	0.00	0.00	0.08
Predominate Substrate	St	St	Cl	St	St	St
% Cover	11.5	100.0	100.0	100.0	100.0	100.0
Transect #2						
Mean D (ft)	0.04	1.83	0.44	1.19	0.40	0.00
D_{Max} (ft)	0.16	3.15	1.66	2.23	0.74	0.00
Mean V (ft/sec)	<0.01	1.08	0.33	0.82	0.53	0.00
V_{Max} (ft/sec)	0.04	2.14	1.51	2.37	1.66	0.00
Predominate Substrate	Sd	Sd	St	Sd	Sd	Sd
% Cover	6.7	47.4	30.4	56.0	70.0	0.0
Transect #3						
Mean D (ft)	0.55	+	0.38	0.74	0.86	0.00
D_{Max} (ft)	1.42	+	0.90	2.85	1.97	0.00
Mean V (ft/sec)	0.30	+	0.52	0.93	0.22	0.00
V_{Max} (ft/sec)	0.96	+	1.33	2.23	0.73	0.00
Predominate Substrate	Sd	+	Sd	Sd	Sd	Sd
% Cover	5.0	+	0.0	18.2	40.0	0.0
Transect #4						
Mean D (ft)	0.61	+	1.19	2.99	1.12	0.00
D_{Max} (ft)	1.25	+	2.00	4.80	1.75	0.00
Mean V (ft/sec)	0.86	+	0.90	0.89	0.30	0.00
V_{Max} (ft/sec)	1.82	+	1.90	2.36	0.79	0.00
Predominate Substrate	Sd	+	Sd	Sd	Sd	Sd
% Cover	13.3	+	58.3	56.0	70.0	0.0
Transect #5						
Mean D (ft)	1.06	+	1.17	1.71	1.78	0.00
D_{Max} (ft)	2.02	+	2.40	2.80	2.95	0.00
Mean V (ft/sec)	0.22	+	1.11	0.97	0.35	0.00
V_{Max} (ft/sec)	0.54	+	2.44	2.33	1.14	0.00
Predominate Substrate	St	+	Sd	Sd	Sd	Sd
% Cover	15.8	+	34.8	45.8	70.0	0.0
Transect #6						
Mean D (ft)	0.53	+	0.73	1.70	2.55	0.00
D_{Max} (ft)	0.94	+	1.73	3.69	3.20	0.00
Mean V (ft/sec)	0.53	+	0.73	0.89	0.45	0.00
V_{Max} (ft/sec)	0.85	+	2.25	2.27	1.27	0.00
Predominate Substrate	St	+	Sd	St	Sd	Sd
% Cover	7.7	+	16.0	36.0	75.0	0.0
Transect #7						
Mean D (ft)	0.57	1.51	0.57	1.47	1.51	0.00
D_{Max} (ft)	1.84	2.10	1.93	3.40	2.63	0.00
Mean V (ft/sec)	0.21	1.50	0.27	0.50	0.36	0.00
V_{Max} (ft/sec)	0.50	3.17	1.16	1.72	1.82	0.00
Predominate Substrate	St	Sd	St	St	Sd	Sd
% Cover	19.0	42.1	16.0	41.7	70.0	0.0

Table 6. Summary of physical habitat data for each transect monitored at the Los Chavez Wasteway Drain project site. Note: (-) indicates no data collected; (+) indicates unwadable conditions.

	Sampling Date					
	Sep 2007	Feb 2008	Jul 2008	Feb 2009	Jul 2009	Aug 2009
Transect #0						
Mean D (ft)	0.00	1.48	0.00	0.00	0.00	0.00
D_{Max} (ft)	0.00	2.40	0.00	0.00	0.00	0.00
Mean V (ft/sec)	0.00	0.00	0.00	0.00	0.00	0.00
V_{Max} (ft/sec)	0.00	0.00	0.00	0.00	0.00	0.00
Predominate Substrate	Sd	St	St	St	St	St
% Cover	0.0	23.1	0.0	0.0	0.0	0.0
Transect #1						
Mean D (ft)	0.00	1.37	0.00	0.00	0.00	0.00
D_{Max} (ft)	0.00	1.90	0.00	0.00	0.00	0.00
Mean V (ft/sec)	0.00	0.00	0.00	0.00	0.00	0.00
V_{Max} (ft/sec)	0.00	0.00	0.00	0.00	0.00	0.00
Predominate Substrate	Sd	St	St	St	St	St
% Cover	0.0	100.0	0.0	0.0	0.0	0.0
Transect #2						
Mean D (ft)	0.20	1.01	0.00	0.10	0.12	0.00
D_{Max} (ft)	0.46	1.92	0.00	0.26	1.28	0.00
Mean V (ft/sec)	0.02	0.75	0.00	0.01	0.06	0.00
V_{Max} (ft/sec)	0.11	1.78	0.00	0.12	1.06	0.00
Predominate Substrate	Sd	Sd	Sd	Cl	Sd	Sd
% Cover	4.8	28.6	0.0	0.0	0.0	0.0
Transect #3						
Mean D (ft)	0.16	1.46	0.00	0.34	0.46	0.00
D_{Max} (ft)	0.38	3.05	0.00	0.76	1.22	0.00
Mean V (ft/sec)	0.02	0.89	0.00	0.20	0.53	0.00
V_{Max} (ft/sec)	0.13	2.24	0.00	1.27	1.98	0.00
Predominate Substrate	St	St	Sd	Cl	Sd	Sd
% Cover	0.0	42.9	0.0	42.9	52.4	0.0
Transect #4						
Mean D (ft)	0.08	1.61	0.00	0.73	0.98	0.00
D_{Max} (ft)	0.23	3.08	0.00	1.60	1.35	0.00
Mean V (ft/sec)	0.03	1.32	0.00	0.57	0.90	0.00
V_{Max} (ft/sec)	0.13	2.26	0.00	2.01	1.74	0.00
Predominate Substrate	Sd	Sd	Sd	St	Sd	Sd
% Cover	0.0	28.6	0.0	52.4	47.6	0.0
Transect #5						
Mean D (ft)	0.10	1.40	0.00	0.50	0.91	0.00
D_{Max} (ft)	0.46	3.24	0.00	1.57	1.80	0.00
Mean V (ft/sec)	0.03	0.91	0.00	0.16	0.29	0.00
V_{Max} (ft/sec)	0.27	2.05	0.00	1.85	1.41	0.00
Predominate Substrate	St	Sd	Sd	St	Sd	Sd
% Cover	4.8	42.9	0.0	66.7	47.6	0.0
Transect #6						
Mean D (ft)	0.08	1.00	0.00	0.13	0.66	0.00
D_{Max} (ft)	0.29	2.40	0.00	0.66	1.65	0.00
Mean V (ft/sec)	0.06	0.78	0.00	0.00	0.25	0.00
V_{Max} (ft/sec)	0.40	2.24	0.00	0.00	1.49	0.00
Predominate Substrate	St	Sd	Sd	St	Sd	Sd
% Cover	23.8	61.9	0.0	35.5	41.9	0.0

Table 7. Water quality measurements at three drain outfall sites by monitoring date.

MEASUREMENT	DATE				
	7/26/07	**8/14/08**	**2/13/09**	**7/1/09**	**8/21/09**
Lower Peralta Wasteway #1 - LP1DR					
temperature (C)	22.6	26.9	4.9	21.5	21.2
dissolved oxygen (mg/l)	5.82	6.00	10.02	6.31	6.79
oxygen saturation (%)	80.6	90.2	93.5	-	91
salinity (ppt)	-	0.21	0.20	0.23	0.26
conductivity (S/cm)	47.7	-	-	-	-
pH	-	-	7.59	-	-
turbidity (FTU)	-	321	53	250	90
Peralta Wasteway - PERWW					
temperature (C)	29.3	26.4	6.6	24.0	23.0
dissolved oxygen (mg/l)	5.98	6.91	9.79	6.86	3.22
oxygen saturation (%)	94.0	102.5	95.8	97.7	44.8
salinity (ppt)	-	0.17	0.20	0.18	0.19
conductivity (S/cm)	53.6	-	-	-	-
pH	-	-	7.69	-	-
turbidity (FTU)	-	299	66	322	92
Los Chavez Wasteway - LCZWW					
temperature (C)	29.0	-	8.3	28.3	-
dissolved oxygen (mg/l)	5.94	-	9.70	6.48	-
oxygen saturation (%)	93.7	-	98.8	100.2	-
salinity (ppt)	-	-	0.20	0.18	-
conductivity (S/cm)	53.1	-	-	-	-
pH	-	-	8.22	-	-
turbidity (FTU)	-	-	46	186	-

Table 8. Additional water temperature (°C) data collected at the three drain outfall sites.

Date	Time	LP1DR		PERWW		LCZWW	
		River	Drain	River	Drain	River	Drain
7/18/2007	0955	23.3	21.1				
7/18/2007	1400	28.9	24.4				
7/19/2007	0935			Dry	26.7		
7/19/2007	1315			Dry	28.9		
7/20/2007	1000					24.4	Dry
7/20/2007	1250					30.0	Dry
9/27/2007	1140	18.3	20.0				
9/27/2007	1445			Dry	21.7		
9/28/2007	1000					16.7	Dry
2/25/2008	0840	8.3	8.3				
2/25/2008	1020			8.9	9.4		
2/25/2008	1250					11.1	12.2
7/30/2008	1500	32.2	27.2				
7/31/2008	1400			32.2	29.4		
8/1/2008	1045					28.9	Dry
2/12/2009	1200	7.2	12.2				
2/13/2009	1130			6.7	6.1		
2/14/2009	1250			7.8	4.4		
7/2/2009	1130	21.1	22.2				
7/2/2009	1230			25.6	26.7		
7/2/2009	1445			28.9			
7/2/2009	1615					28.9	Dry
8/19/2009	1040	20.6	21.1				
8/19/2009	1430			25.0	25.0		

Table 9. Total fish collected by species and fish catch per minute at the Lower Peralta Wasteway #1 site.

	DATE									
	7/26/07		8/14/08		2/13/09		7/1/09		9/30/09*	
SPECIES	**#**	**#/min**	**#**	**#/min**	**#**	**#/min**	**#**	**#/min**	**#**	**#/min**
Ameiurus melas (NNP)			1	0.078						
Ameiurus natalis (NNP)			1	0.078						
Carpiodes carpio	30	1.590							3	0.180
Catostomus commersoni (NN)	7	0.371	2	0.157	1	0.063				
Catostomus plebeius										
Cyprinella lutrensis (M)	32	1.696	4	0.314	6	0.376	7	0.420	13	0.780
Cyprinus carpio (NN)			5	0.392					2	0.120
Gambusia affinis (NN)	10	0.530	1	0.078	10	0.627	2	0.120	57	3.420
Hybognathus amarus (M)	63	3.339	1	0.078	7	0.439				
Ictalurus punctatus (NNP)	1	0.053							1	0.060
Lepomis cyanellus (NNP)			1	0.078					3	0.180
Lepomis macrochirus (NNP)									1	0.060
Micropterus salmoides (NNP)	1	0.053	6	0.471			3	0.180	2	0.120
Micropterus punctulatus (NNP)									1	0.060
Pimephales promelas (M)	20	1.060			1	0.063				
Pimephales vigilax (NN) (M)			1	0.078						
Platygobio gracilis (M)			1	0.078						
Pomoxis annularis (NNP)					1	0.063				
Sander vitreus (NNP)									1	0.060
TOTALS	164	8.693	24	1.882	26	1.630	12	0.719	84	5.040
Total Native Fishes	145	7.686	6	0.471	14	0.878	7	0.420	17	1.020
Total Minnows	115	6.095	7	0.549	14	0.878	7	0.420	13	0.780
Total Nonnative Predators	2	0.106	9	0.706	1	0.063	3	0.180	9	0.540
Number of Species	8		11		6		3		10	
NOTES: * sampling conducted by SWCA Inc.; NNP = nonnative predator; NN = nonnative; M = minnow										

Table 10. Total fish collected by species and fish catch per minute at the Peralta Wasteway site.

	DATE									
	7/26/07		8/14/08		2/13/09		7/1/09		9/30/09*	
SPECIES	**#**	**#/min**	**#**	**#/min**	**#**	**#/min**	**#**	**#/min**	**#**	**#/min**
Ameiurus melas (NNP)										
Ameiurus natalis (NNP)			2	0.064	1	0.064				
Carpiodes carpio	4	0.201								
Catostomus commersoni (NN)	3	0.151	1	0.065						
Catostomus plebeius										
Cyprinella lutrensis (M)	2	0.010	18	1.170	15	0.961	15	0.892	1	0.060
Cyprinus carpio (NN)			9	0.585					1	0.060
Gambusia affinis (NN)	5	0.251	11	0.715	15	0.961	11	0.654	326	19.560
Hybognathus amarus (M)	14	0.702	5	0.325	9	0.576	5	0.297		
Ictalurus punctatus (NNP)	4	0.201	2	0.130						
Lepomis cyanellus (NNP)	1	0.050					1	0.059	4	0.240
Lepomis macrochirus (NNP)							3	0.178	4	0.240
Micropterus salmoides (NNP)			1	0.065			7	0.416		
Micropterus punctulatus (NNP)										
Pimephales promelas (M)	5	0.251			3	0.192	2	0.119		
Pimephales vigilax (NN) (M)										
Platygobio gracilis (M)										
Pomoxis annularis (NNP)							2	0.119	2	0.120
Sander vitreus (NNP)										
TOTALS	38	1.906	49	3.185	43	2.753	46	2.735	338	20.280
Total Native Fishes	25	1.254	23	1.495	27	1.729	25	1.487	5	0.300
Total Minnows	21	1.054	29	1.885	27	1.729	22	1.308	1	0.060
Total Nonnative Predators	5	0.251	5	0.325	1	0.064	13	0.773	10	0.600
Number of Species	8		8		5		8		6	
NOTES: sampling conducted by SWCA Inc.; NNP = nonnative predator; NN = nonnative; M = minnow										

Table 11. Total fish collected by species and fish catch per minute at the Los Chavez Wasteway site.

	DATE									
	7/26/07		**8/14/08***		**2/13/09**		**7/1/09**		**9/30/09***	
SPECIES	**#**	**#/min**	**#**	**#/min**	**#**	**#/min**	**#**	**#/min**	**#**	**#/min**
Ameiurus melas (NNP)										
Ameiurus natalis (NNP)										
Carpiodes carpio	1	0.085			1	0.071				
Catostomus commersoni (NN)										
Catostomus plebeius							2	0.120		
Cyprinella lutrensis (M)	71	6.025			58	4.089	97	5.797		
Cyprinus carpio (NN)	1	0.085			2	0.141	6	0.359		
Gambusia affinis (NN)	26	2.207			17	1.199	8	0.478		
Hybognathus amarus (M)					76	5.358	76	4.542		
Ictalurus punctatus (NNP)	41**	3.479								
Lepomis cyanellus (NNP)										
Lepomis macrochirus (NNP)										
Micropterus salmoides (NNP)										
Micropterus punctulatus (NNP)										
Pimephales promelas (M)	21	1.782			13	0.917	24	1.434		
Pimephales vigilax (NN) (M)										
Platygobio gracilis (M)										
Pomoxis annularis (NNP)										
Sander vitreus (NNP)										
TOTALS	161	13.663			167	11.774	213	12.729		
Total Native Fishes	93	7.893			148	10.435	199	11.892		
Total Minnows	92	7.808			147	10.364	197	11.773		
Total Nonnative Predators	1	0.085			0	0.000	0	0.000		
Number of Species	6				7		6			

NOTES: * not sampled, river channel located away from snags; 9/30/09 sampling conducted by SWCA Inc.; ** 40 were young-of-year (~50 mm) too small to be counted as predators; NNP = nonnative predator; NN = nonnative; M = minnow

Table 12. Total number of fish collected at the three project sites by sampling date (# in parentheses is % of total for date).

	[1]Sampling Date					
	Jul 2007	**Aug 2008**	**Feb 2009**	**Jul 2009**	**Sep 2009**	**Total**
Total Fish	363	73	236	271	422	1365
Total RGSM	77 (25.1)	6 (8.2)	92 (39.0)	81 (29.9)	0 (0.0)	256 (18.8)
Total Native Fishes	263 (72.5)	29 (39.7)	189 (80.1)	231 (85.2)	22 (5.2)	734 (53.8)
Total Cyprinids	228 (62.8)	36 (49.3)	188 (79.7)	226 (83.4)	14 (3.3)	692 (50.7)
Total non-native predators	8 (2.2)	14 (19.2)	2 (0.8)	16 (5.9)	19 (4.5)	59 (4.3)
# of Species	10	12	9	8	11	19

[1] No sampling conducted in February 2008 due to collection permit issues and high flow conditions.

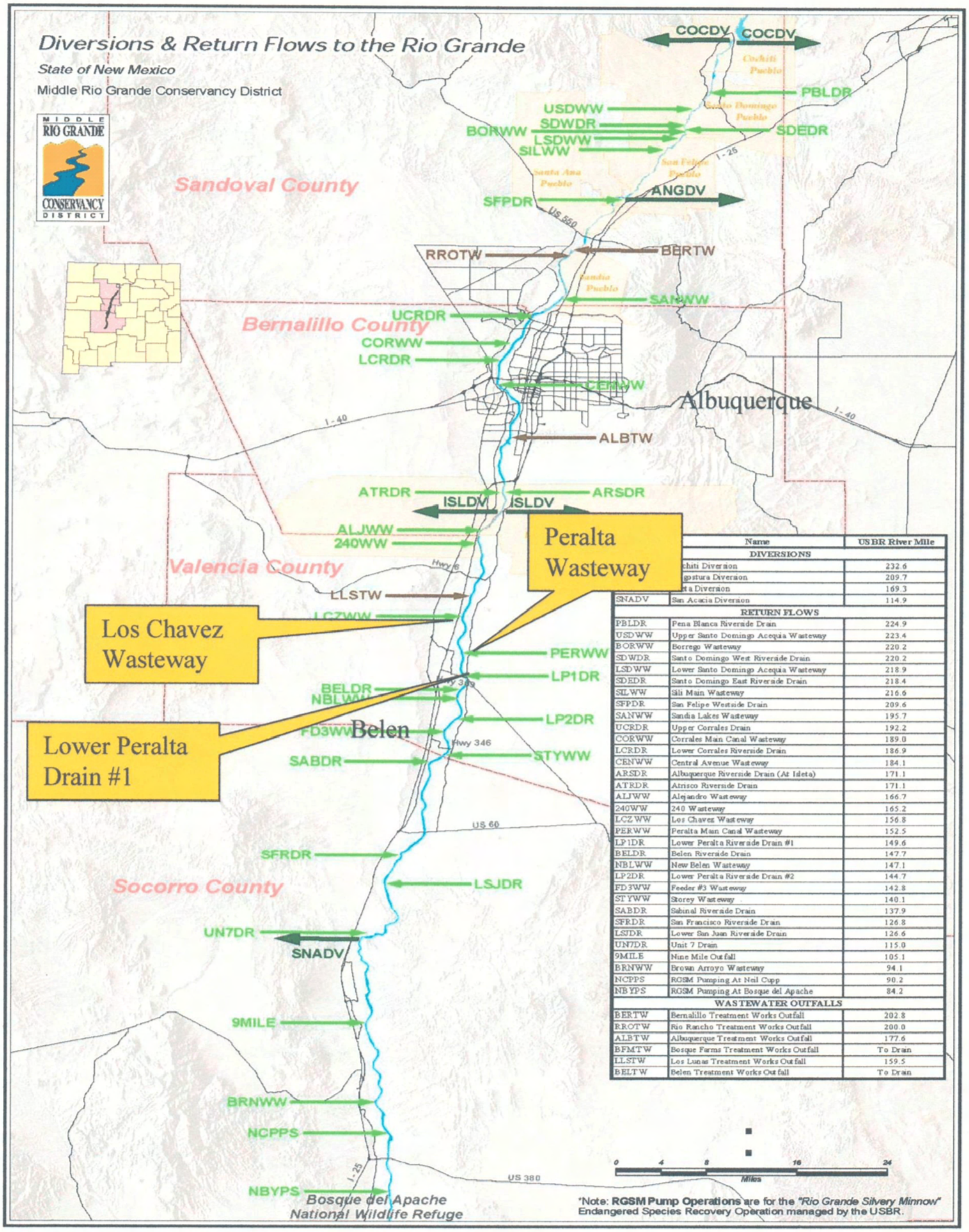

Figure 1. Project area map highlighting the location of the drain outfalls where cottonwood snags were installed in November and December, 2007.

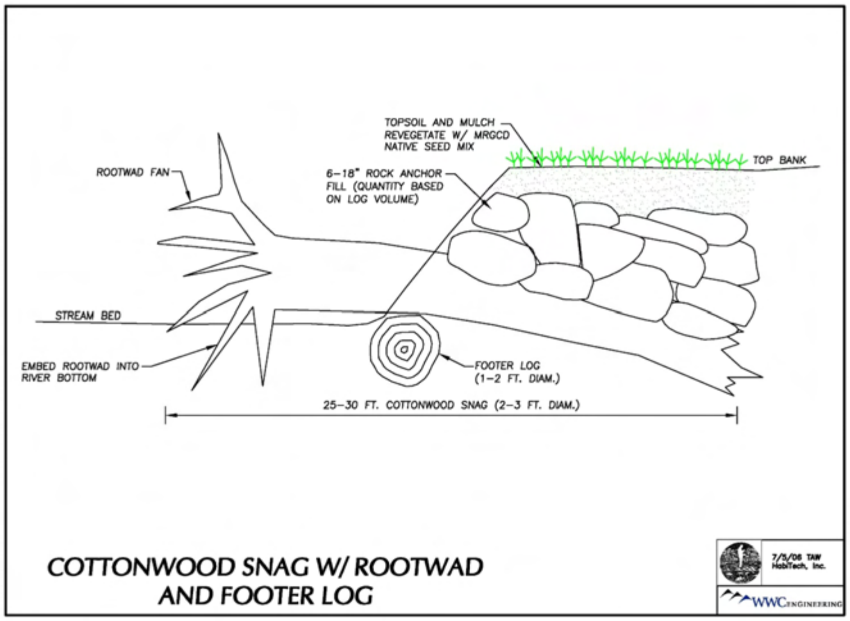

Figure 2. Conceptual engineering drawing illustrating how a large cottonwood snag was anchored on the river bank.

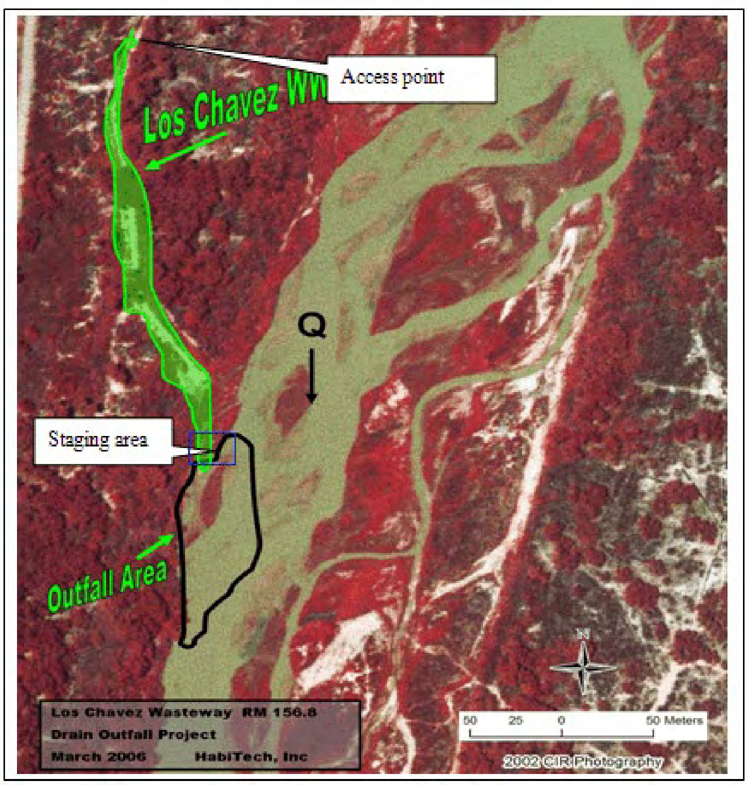

Figure 3. Aerial view of the Los Chavez Wasteway outfall showing the access point, staging area and outfall area where the habitat enhancement occurred.

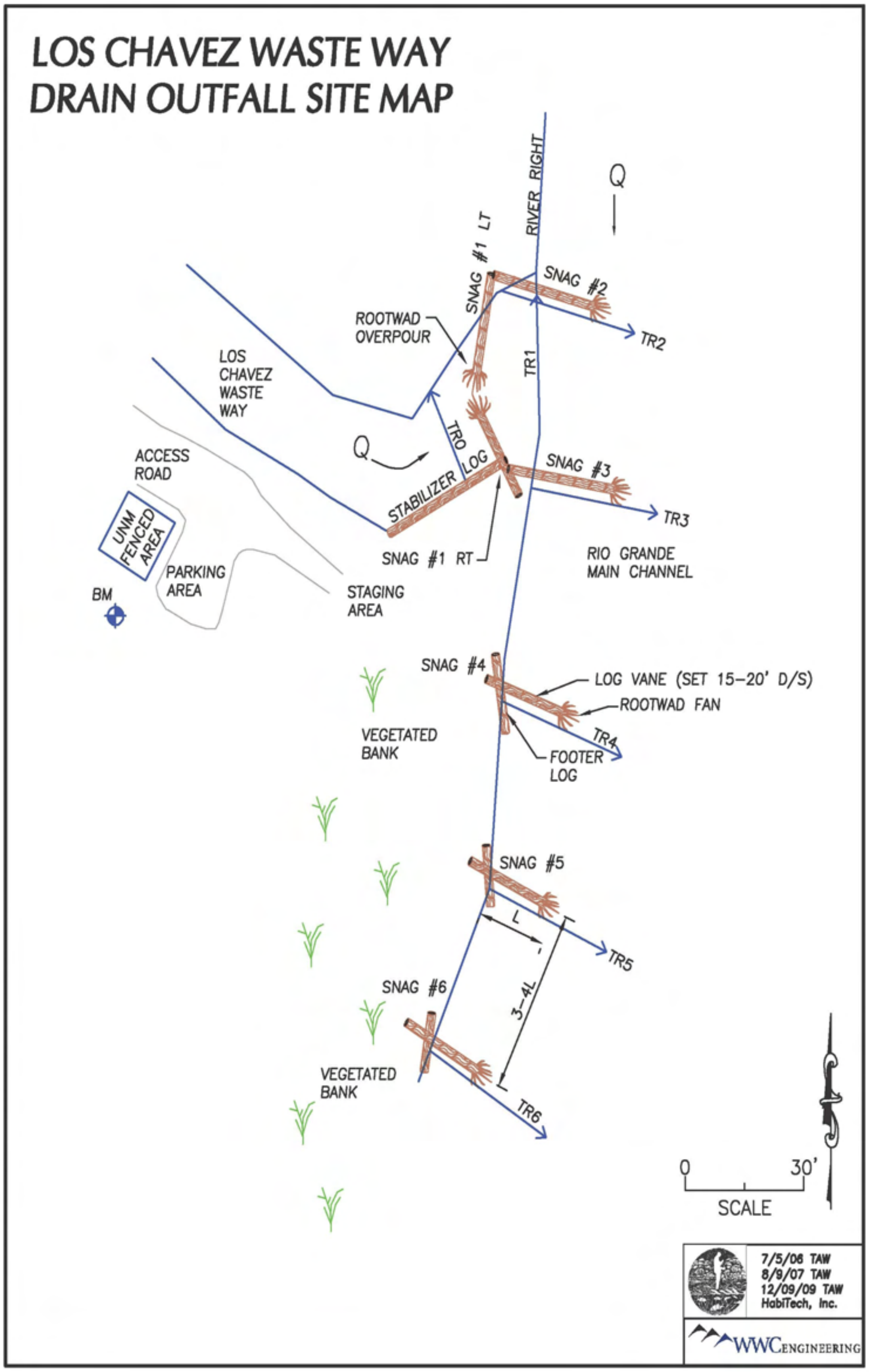

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Figure 4. Site plan showing the location and configuration of the cottonwood snags placed in the mouth of the Los Chavez Wasteway outfall.

Figure 5. Close up of the staging area used at the Los Chavez Wasteway outfall.

Figure 6. Access road to the Los Chavez Wasteway outfall. Recreational and river management activities kept the road clear of vegetation and no additional clearing was needed.

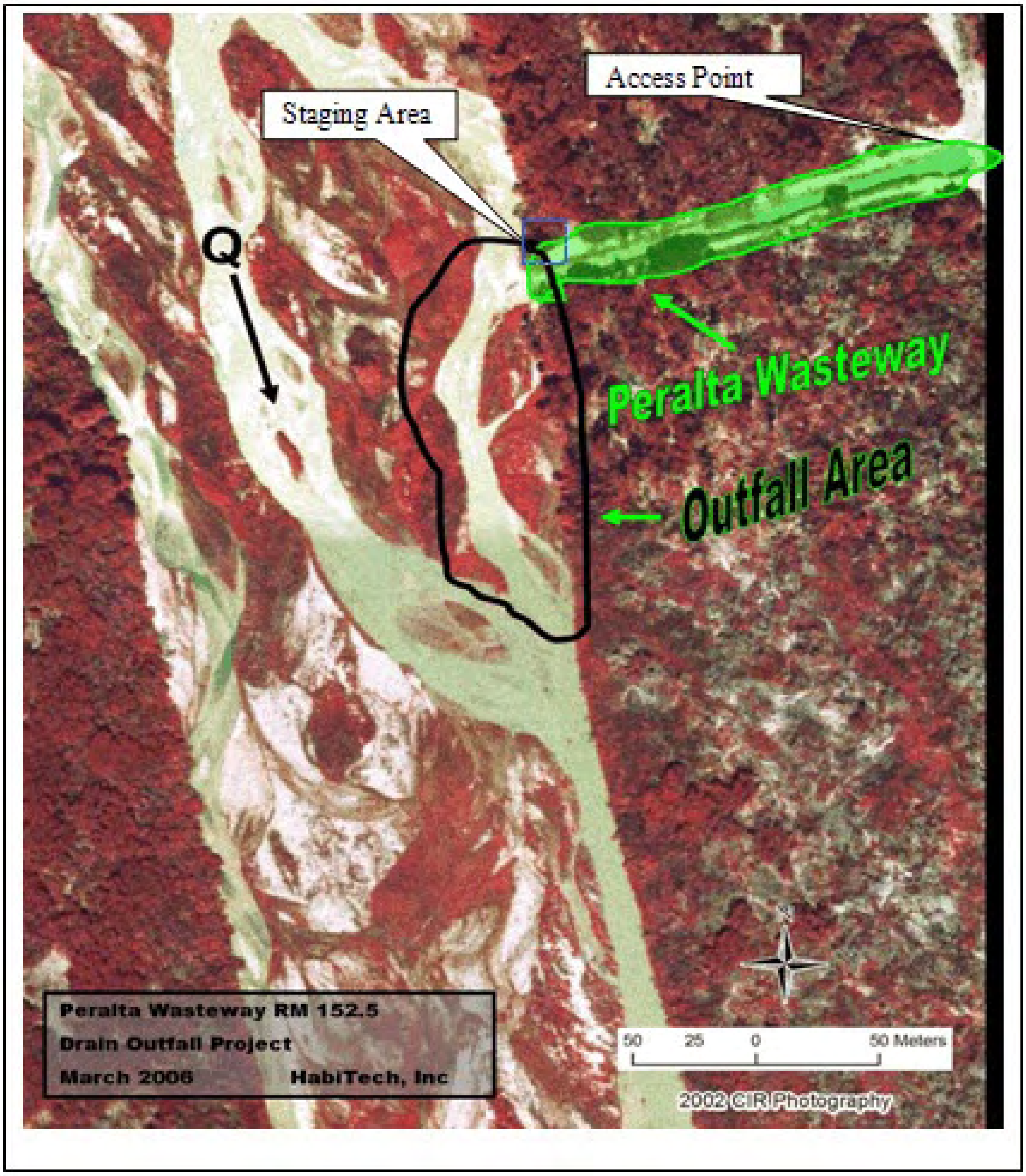


Figure 7. Aerial view of the Peralta Wasteway showing the relationship of the drain to the main river channel as well as access point and staging area.

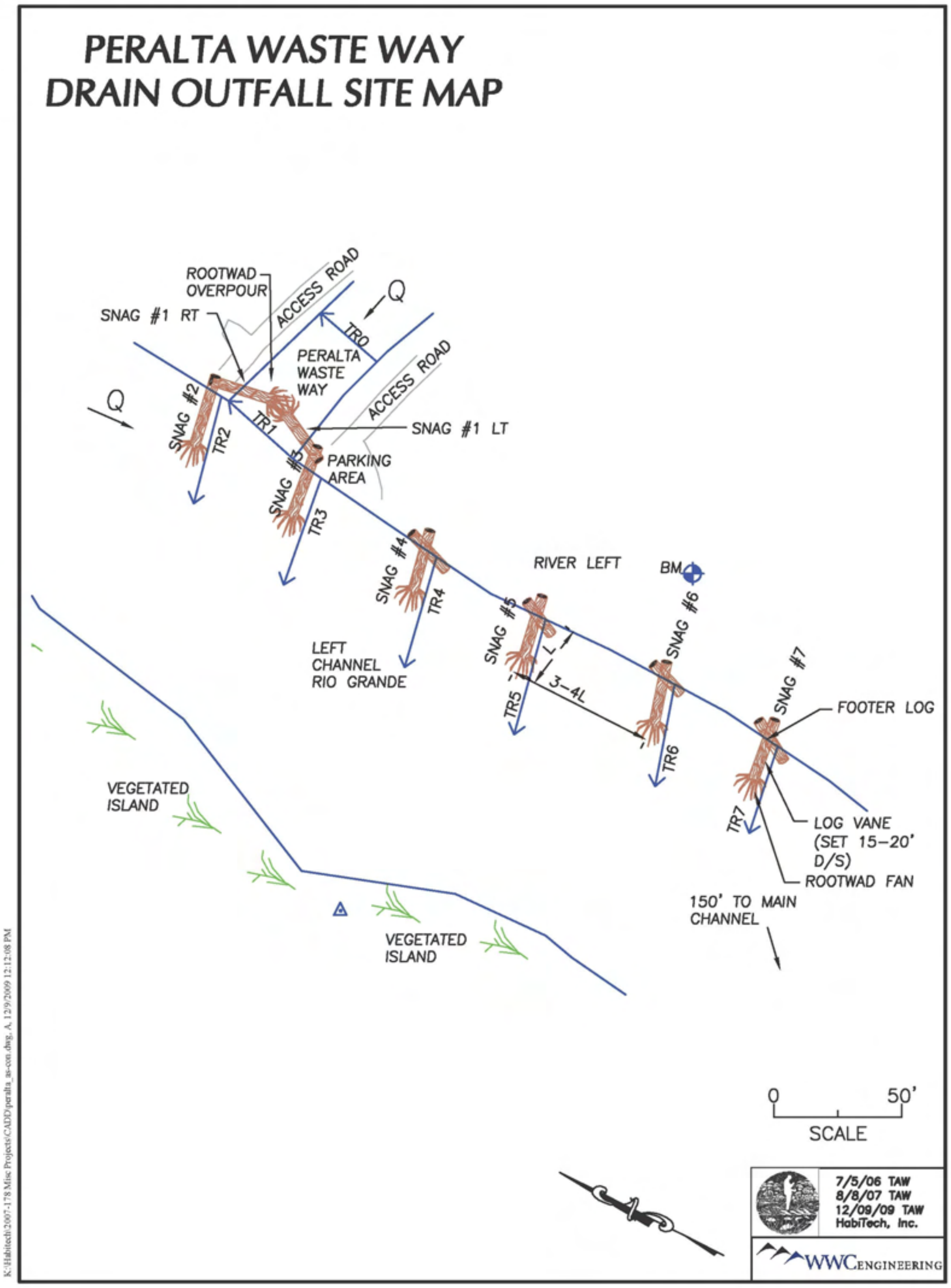


Figure 8. Site plan for Peralta Wasteway outfall showing the location and configuration of cottonwood snags.

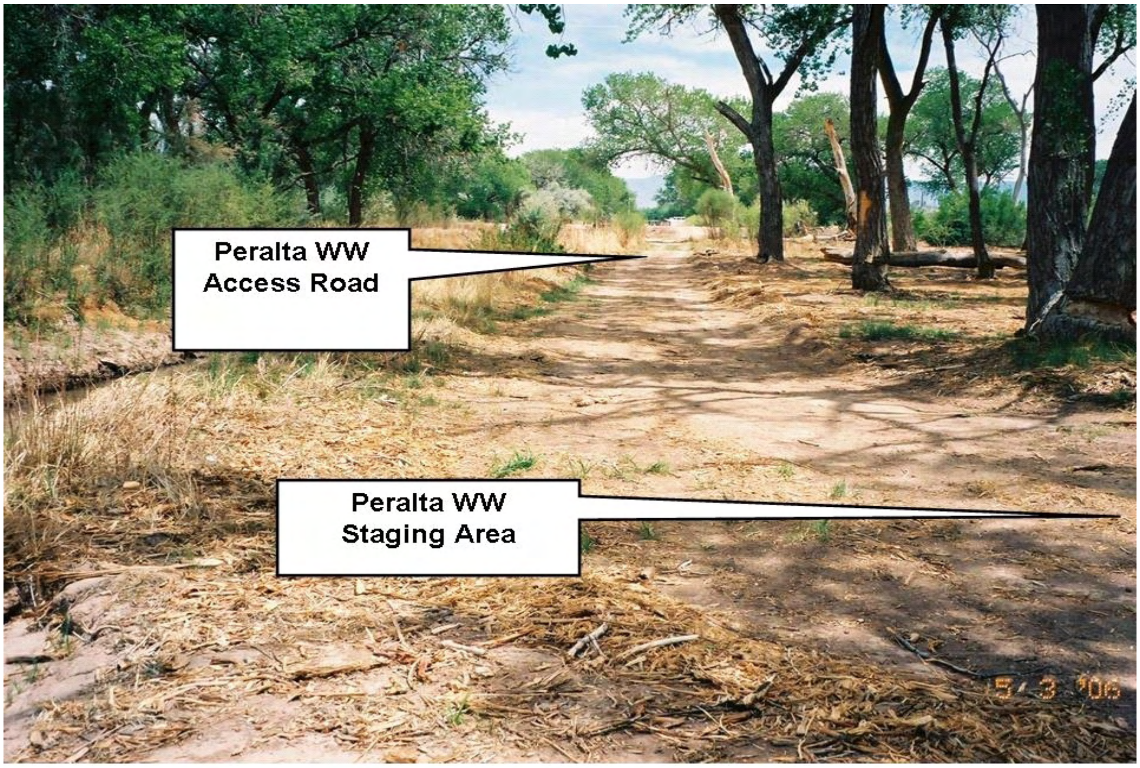


Figure 9. Peralta Wasteway, left of the road, showing the access point as well as staging area used for construction of cottonwood snags.

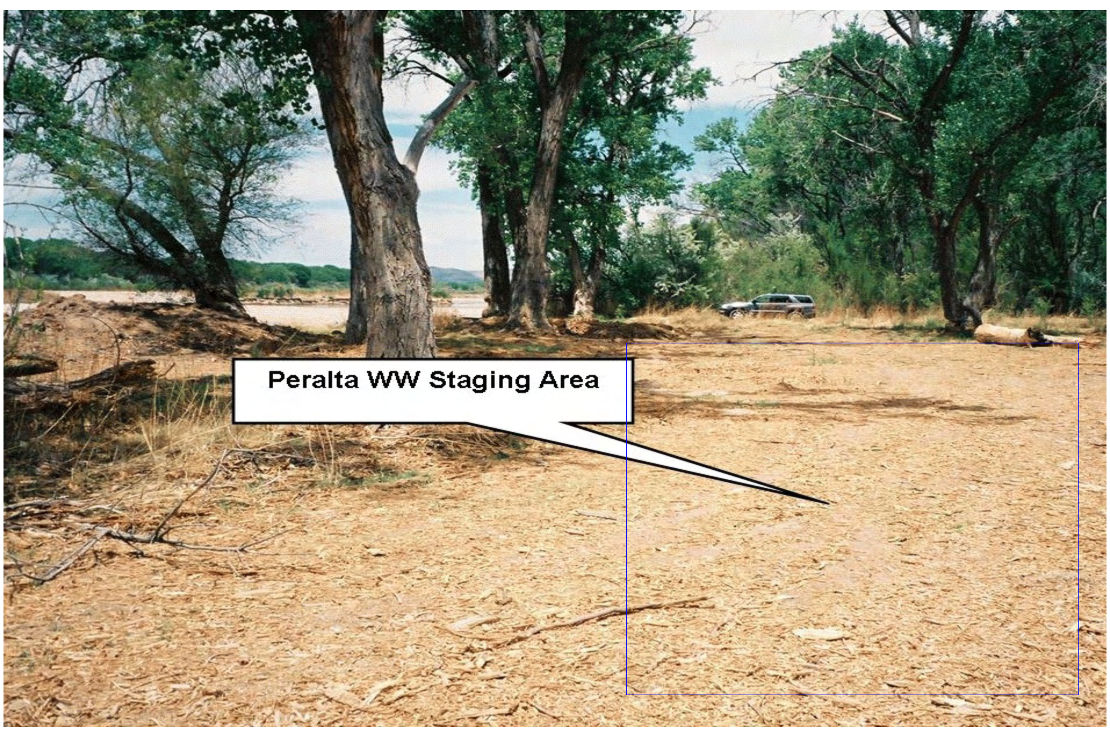


Figure 10. The staging area used for construction of cottonwood snags at Peralta Wasteway.

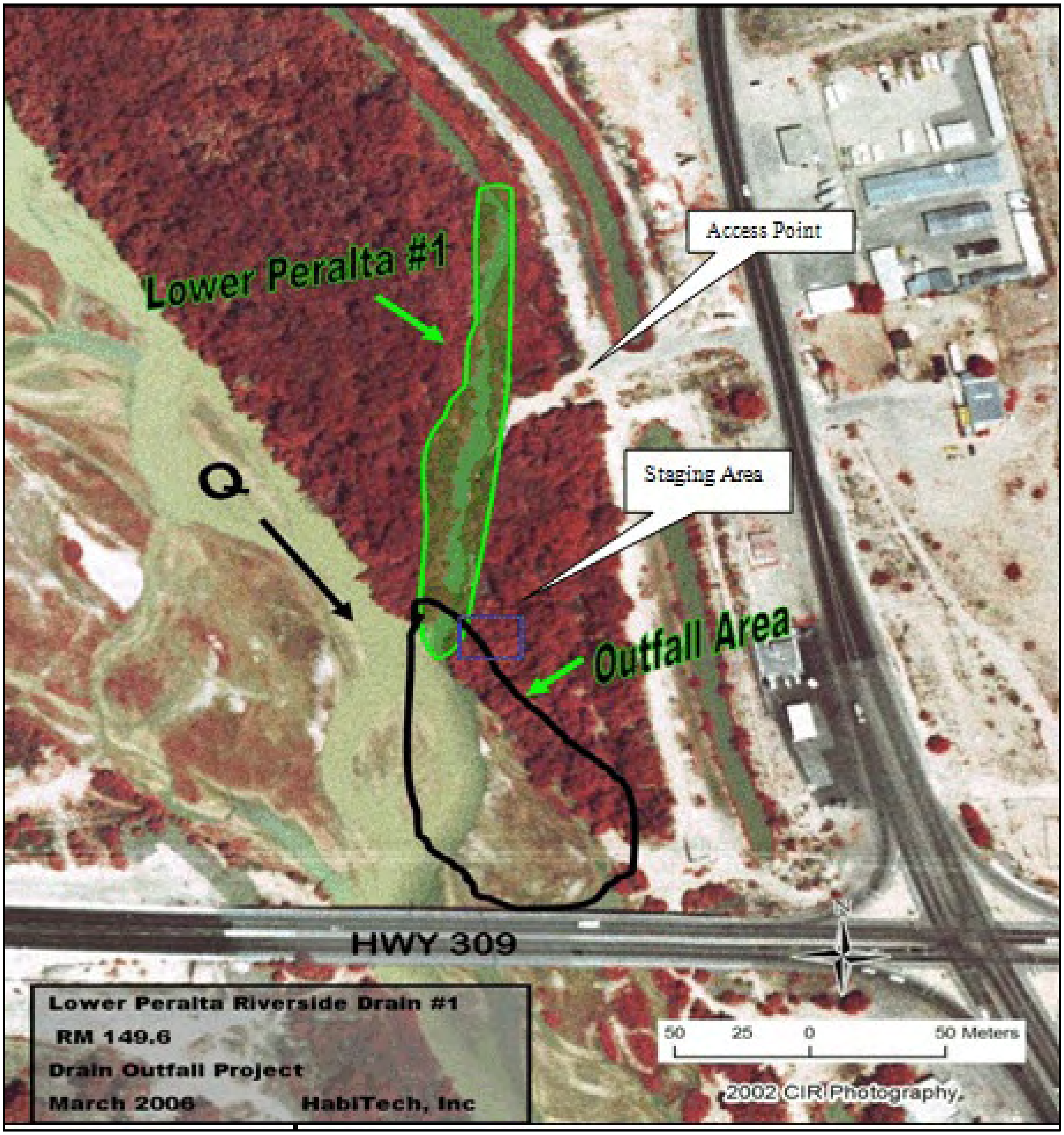


Figure 11. Aerial photo of Lower Peralta #1 Drain showing access and drain outfall area.

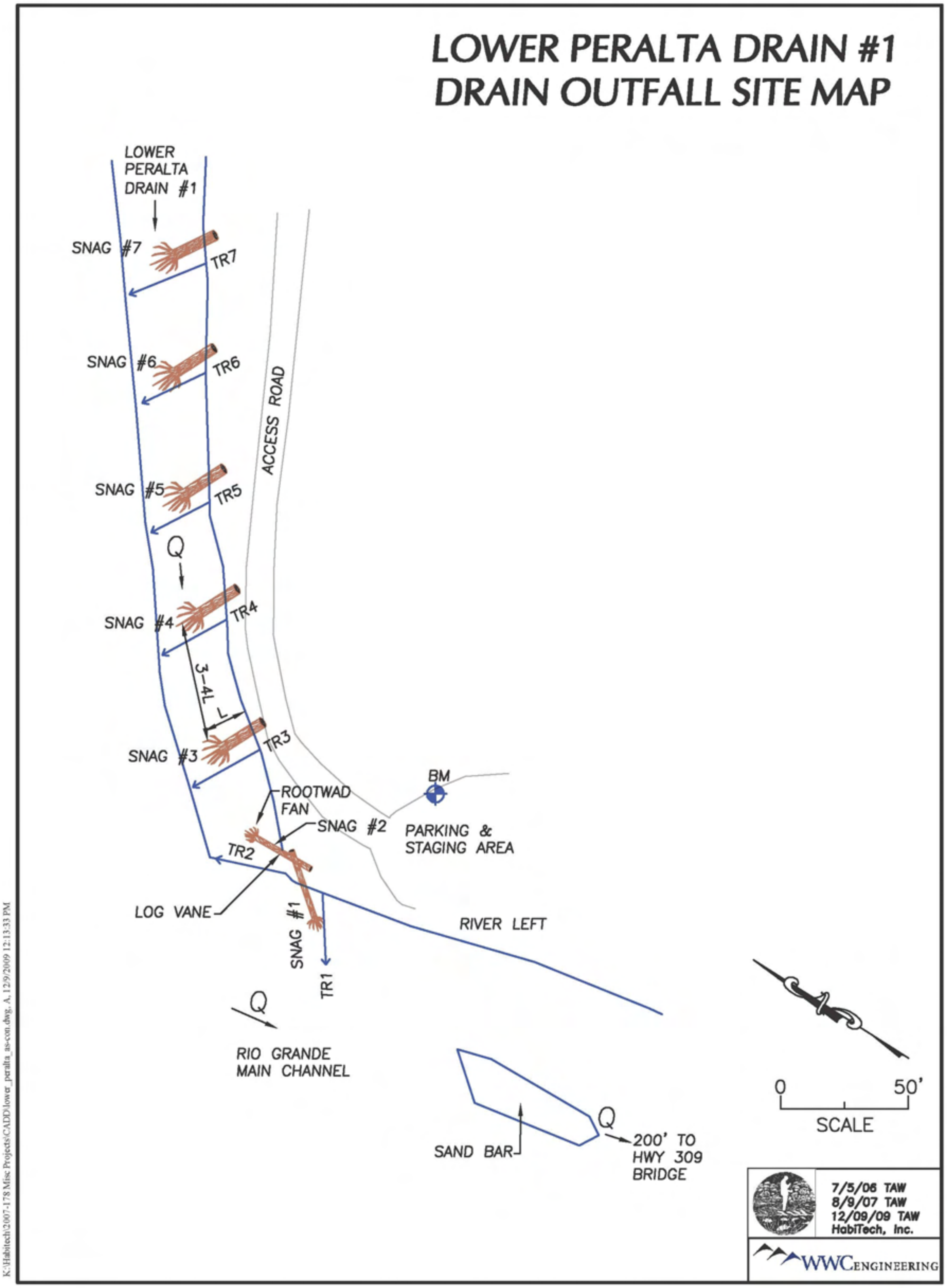


Figure 12 Site plan showing location and configuration of cottonwood snags at Lower Peralta #1 Drain.

Figure 13. Location of the access and staging area used for construction of cottonwood snags at Lower Peralta #1 Drain.

Figure 14. Installation of cottonwood snag structures. Top Left: Snag is uprooted and transported to stream bank. Top Right: Snag placed in excavated trench with rootwad streamside. Bottom Left: Trench is re-filled with soil and rock. Bottom Right : Banks are re-sloped and rock armor placed. Site is ready for revegetation.

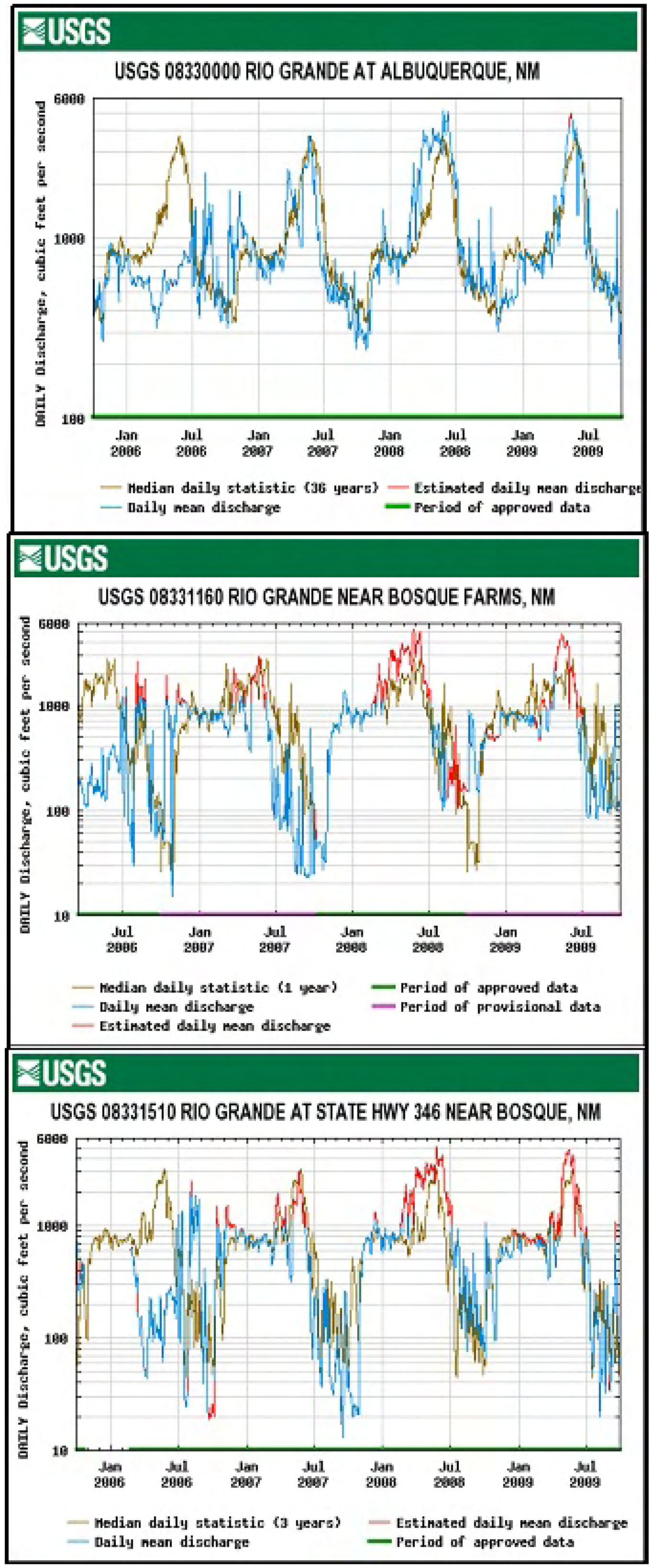


Figure 15. Streamflow hydrographs for 2006-2009 from three U.S. Geological Survey gage stations on the Rio Grande in the vicinity of the three drain outfall project sites.

July 2007

February 2008

July 2008

February 2009

July 2009

August 2009

Figure 16. Monitoring photographs sequence for the Lower Peralta #1 Drain outfall project site. July 2007 (upper left) is pre-construction.

July 2007

February 2008

July 2008

February 2009

July 2009

August 2009

Figure 17. Monitoring photographs sequence for the Peralta Wasteway project site at the confluence of the outfall with the Rio Grande. July 2007 (upper left) is pre-construction.

July 2007

February 2008

July 2008

February 2009

July 2009

August 2009

Figure 18. Monitoring photographs sequence for the Los Chavez Wasteway outfall project site. July 2007 (upper left) is pre-construction.

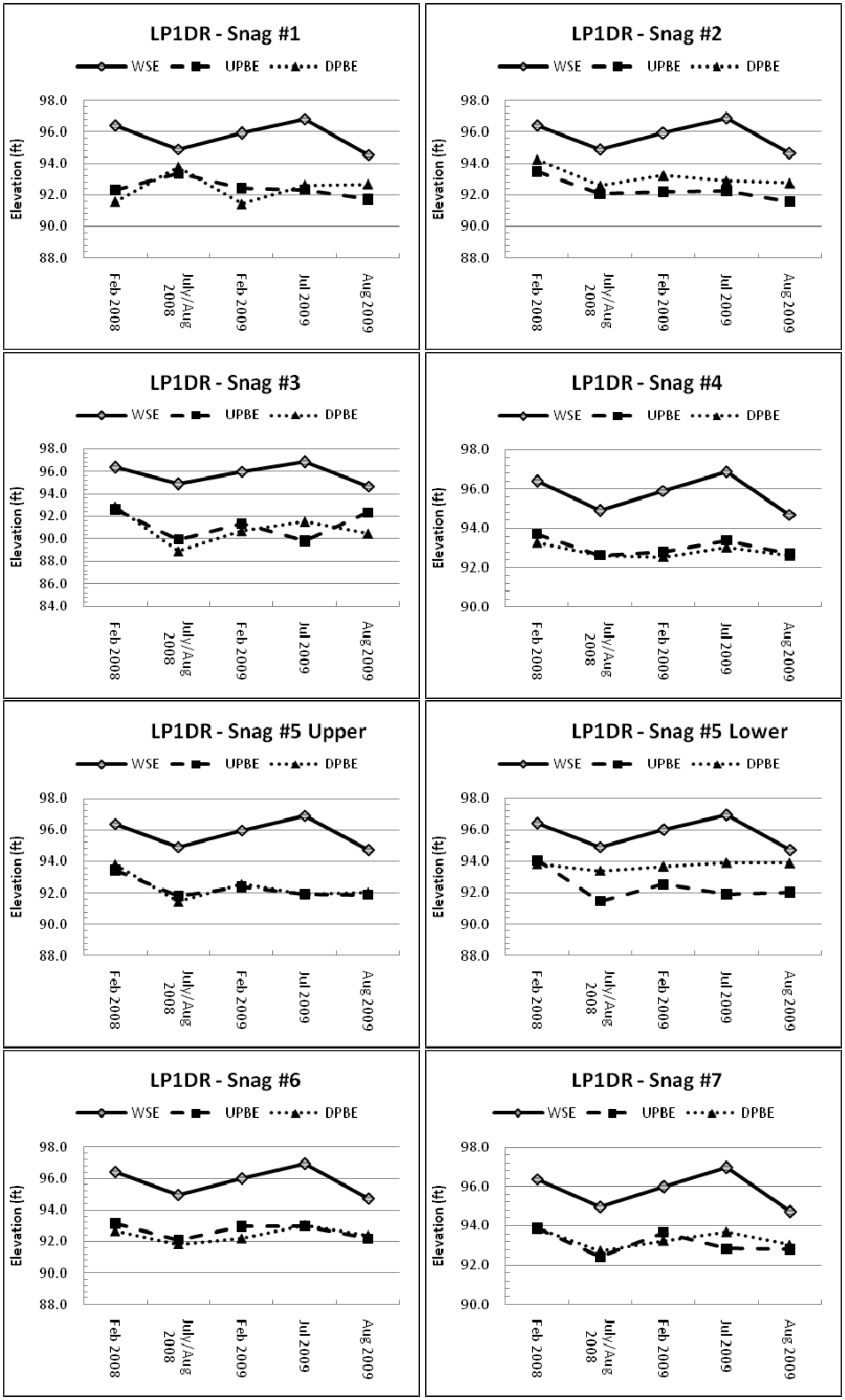


Figure 19. Relation of water surface elevation (WSE) to upstream and downstream pool bed elevations (UPBE, DPBE) at each cottonwood snag installed at Lower Peralta #1 drain outfall site.

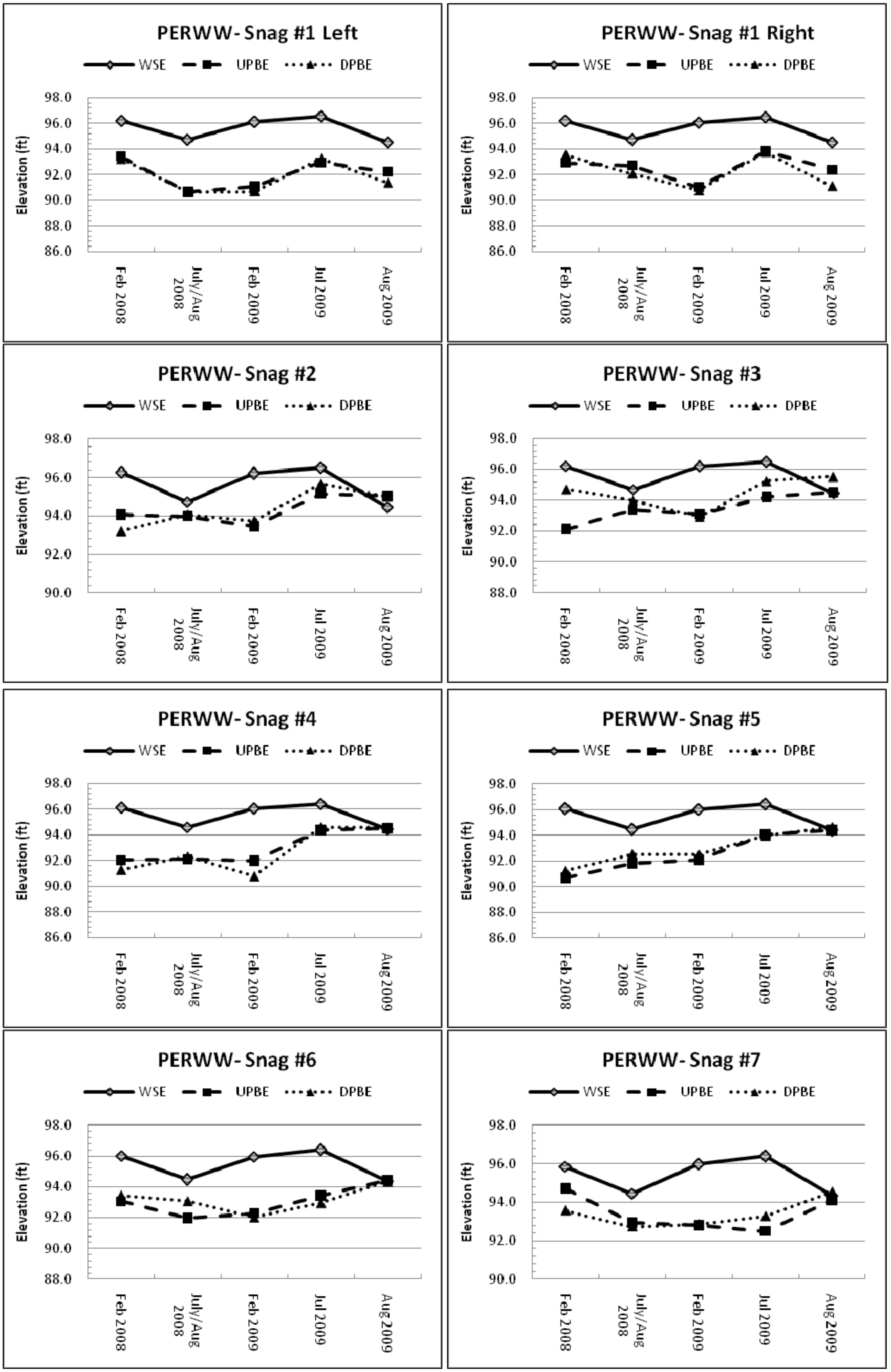


Figure 20. Relation of water surface elevation (WSE) to upstream and downstream pool bed elevations (UPBE, DPBE) at each cottonwood snag installed at Peralta Wasteway drain outfall site.

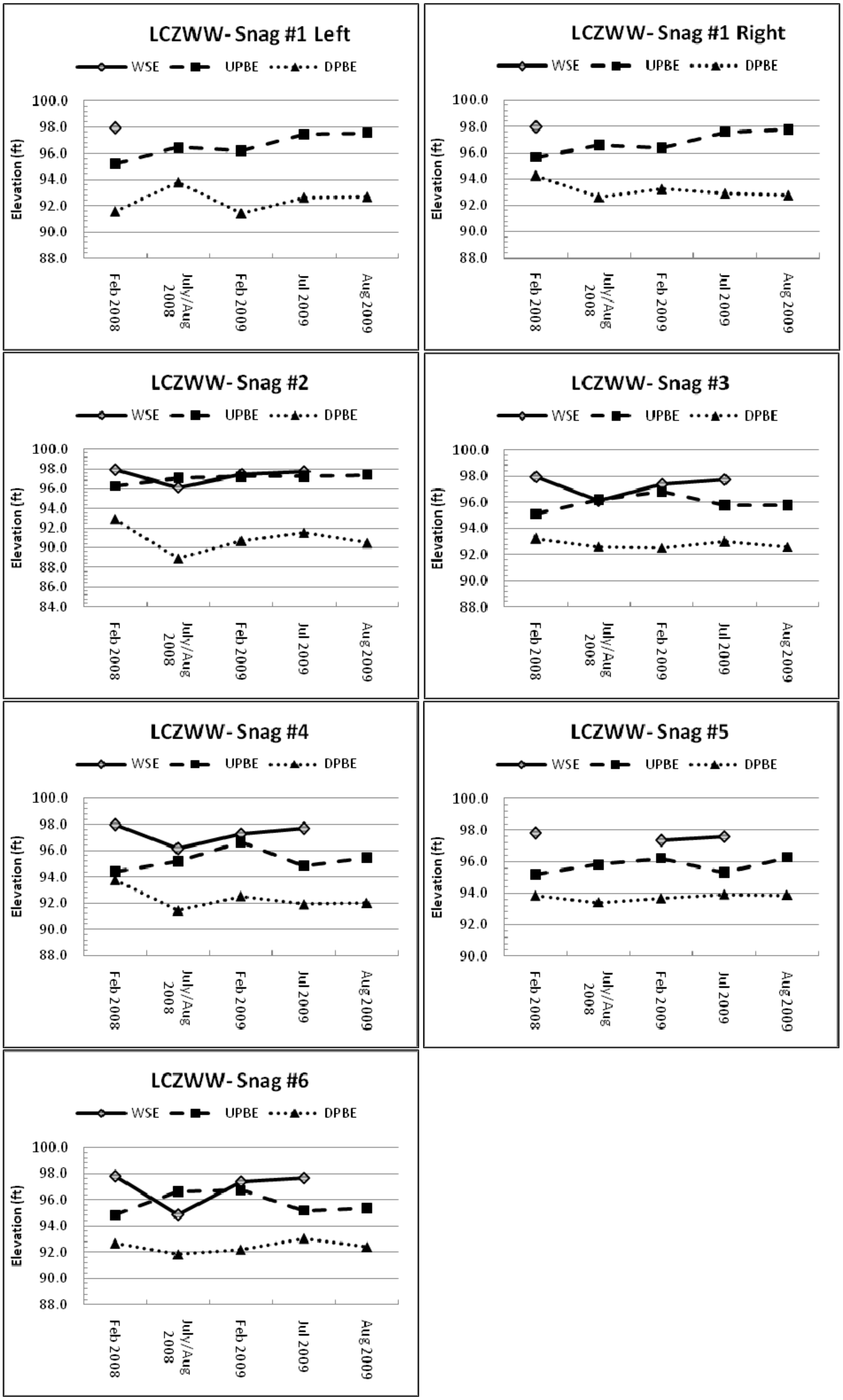


Figure 21. Relation of water surface elevation (WSE) to upstream and downstream pool bed elevations (UPBE, DPBE) at each cottonwood snag installed at Los Chavez drain outfall site.

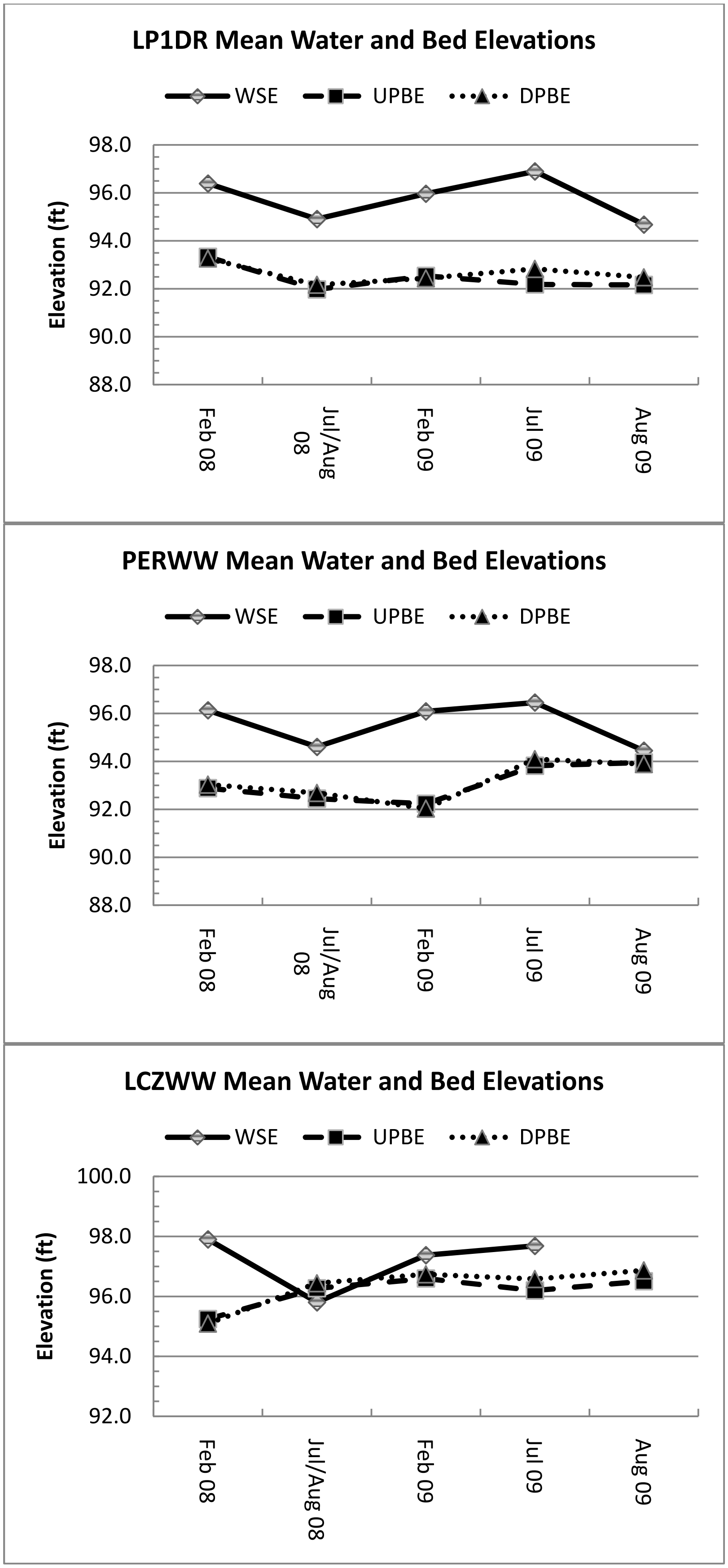
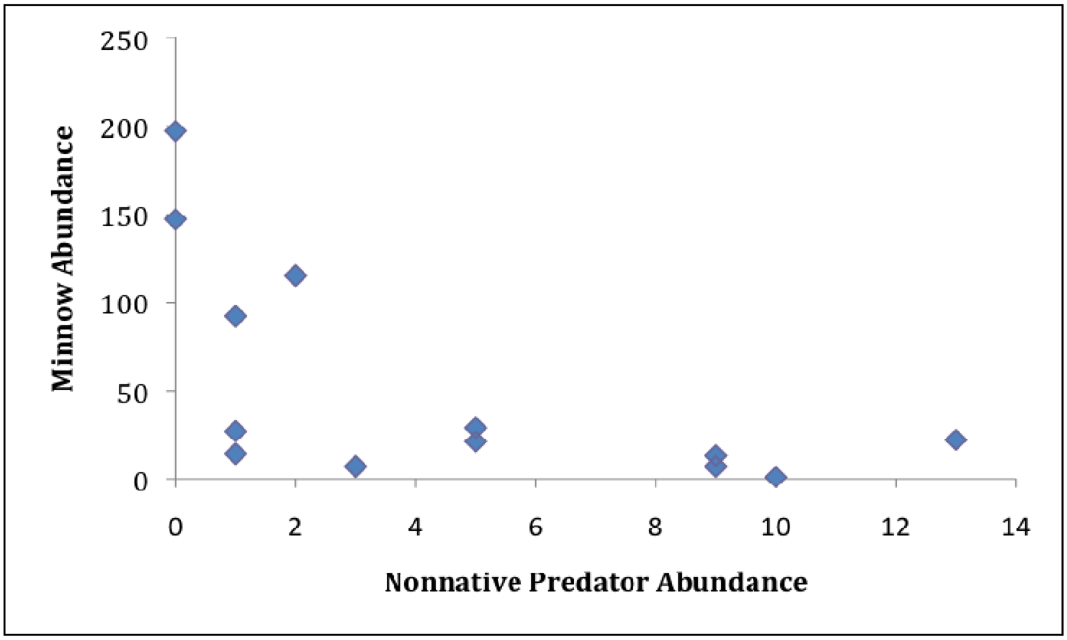
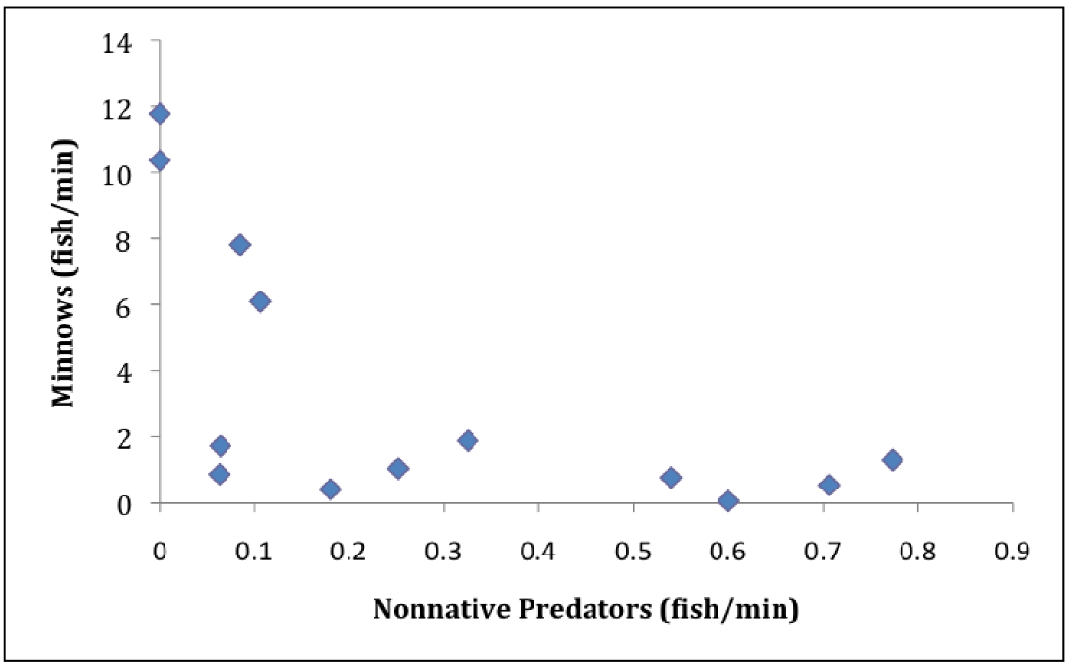


Figure 22. Relation of mean water surface (WSE) to mean upstream and downstream pool bed elevations (UPBE, DPBE) at the three drain outfall sites over the monitoring period.



(a)



(b)

Figure 23. Abundance (a) and catch per minute (b) of minnows relative to nonnative predators across three drain outfall sites and across all samples.