2007 BUREAU OF RECLAMATION EXPERIMENTAL ACTIVITIES ON THE MIDDLE RIO GRANDE

PROJECT SUMMARY REPORT

Prepared for

U.S. BUREAU OF RECLAMATION, ALBUQUERQUE AREA OFFICE
555 Broadway N.E., Suite 100
Albuquerque, New Mexico 87102
Telephone: (505) 462-3540

Prepared by

SWCA ENVIRONMENTAL CONSULTANTS
5647 Jefferson Street N.E.
Albuquerque, New Mexico, 87109
Telephone: (505) 254-1115, Fax: (505) 254-1116
www.swca.com

Michael Hatch, M.S.
Eric Gonzales, M.S.
Joseph Fluder, M.S.
Jeanne Welch

SWCA Project No. 12881

March 2008

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This study assesses the vulnerability of Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow) to suboptimal conditions of drought in the Middle Rio Grande—specifically involving the critical juncture at which flow in the river becomes discontinuous and wetted habitat is reduced to ephemeral pools. This study represents an initial effort to quantify environmental variation among these pools and to assess their intrinsic value as prospective refugial habitats in sustaining populations of silvery minnow through brief periods of hydrologic scarcity. Additionally, this study seeks to determine whether opportunities exist for enhancing environmental attributes of these prospective refugial habitats, including through the strategic application of supplemental water supplies or return flow from irrigated agriculture. Results of surveys conducted between June 30, 2007, and October 23, 2007 are summarized and the significance of results is discussed in the context of relevant ecologic theory.

The most common species encountered in isolated pools include: *Cyprinella lutrensis*, *Carpiodes carpio*, *Ictalurus punctatus*, *Gambusia affinis*, and silvery minnow; piscivorous species (e.g., centrarchid and percid species) were less common. It seems logical that the less common fish species are disadvantaged in the general setting of the contemporary potamon of the Middle Rio Grande relative to the more common species.

The results of this study suggest that the silvery minnow is physiologically flexible—capable of surviving extremes and diel fluctuations in chemical and physical conditions. Short of complete or near desiccation of habitat, the silvery minnow exhibits a capacity to withstand the wide variety of environmental conditions common to the monitored pools over the periods of observation. Likewise, for the parameters monitored, the quality of water that returns to the Rio Grande at multiple points along the Middle Rio Grande Conservancy District irrigation system generally did not exceed provisional critical threshold values for silvery minnow survival. Additional investigation is needed to determine whether high ammonia concentration, especially coupled with high pH, is a recurring phenomenon in the Middle Rio Grande.

Longer and deeper pools with abruptly steep sides were found to be inherently superior as prospective refugial habitats for fish due primarily to their enhanced temporal environmental stability compared to smaller pools. Larger pools tended to support a greater diversity of fish species, which is conducive to the maintenance of stable and persistent fish assemblages. A similar relationship may exist between species abundance and habitat size; however, this study was not designed to yield quantitative expressions of species abundance. Study results do not indicate a relationship between pool size and fish health, although this is more likely a function of the relatively low observed incidence of health-impaired fish.

Pools adjacent to flowing river segments had a heightened degree of environmental stability and, due to proximity, had a heightened potential for rapid recolonization, especially by silvery minnows given their apparent high vagility as observed in this study. It is hypothesized that closely spaced pools, aligned with the thalweg and at intervals no greater than five to seven times the active channel width, are of particular importance to conservation purposes because they would allow for dispersal success of silvery minnows and would serve to reduce silvery minnow mortality that often attends pulsed (short-term), small volume, expansion–contraction flow disturbances.

The variability of flow characteristics of the contemporary Middle Rio Grande, resulting either from natural or regulated causes, imparts a patchiness of environmental types at the scale of river segments, including the extremes represented by hydrologic abundance and periodic discontinuity of flow, with a continuum of intermediate (or transitional) types between these extremes. Areas with long-term flow patterns that would rank among the wetter intermediate environmental types are of particular managerial interest because provision and periodic maintenance of wetted habitat, including in the form of large and deep refugial pools, is more feasible in such areas, especially when hydrological resources are limited.

An overarching theme of discussion pertains to the spatial structure of silvery minnow populations. Spatially structured populations are generically referred to as "metapopulations." Refugial habitat is an important aspect of metapopulation structure and is of critical concern for silvery minnow conservation. Pivotal concepts that pertain to the provision of refugial habitats for silvery minnow conservation are discussed, including: source–sink population structure, lateral distribution of refugial habitats, longitudinal spacing of refugial pools, refugial pool morphology, minimal suitable habitat coverage, and refugial habitat refreshing.

Information deficits presently preclude credible inferences about habitat limitation based on accurate information on the quantity and distribution of different habitats available to the silvery minnow along with direct measures of the consequences (growth, survival, fecundity, reproductive success) of occupying different habitat types. Planning for the provision of refugial habitats to overcome drought-associated habitat limitations requires that a quantitative relationship between habitat and population size be established for the species, and that sufficient habitat be maintained to meet an established recovery target based on the habitat-population relationship. The importance of each population segment to species persistence will depend on relative rates of birth, death, growth, and survival, and various expressions of habitat quality, including habitat size and stability, and a suite of associated natural and anthropogenic threats. Distinguishing between source and sink populations is fundamental in the process of identifying populations essential for species persistence. Options for providing refugia to protect against mortality-causing drought are briefly discussed.

INTRODUCTION

The U.S. Bureau of Reclamation (Reclamation), the U.S. Army Corps of Engineers, and non-federal stakeholders have proposed to implement experimental activities consistent with the monitoring and adaptive management provisions of the 2003 Biological Opinion (U.S. Fish and Wildlife Service 2003) to learn about the vulnerability of Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow) to suboptimal conditions of drought in the Middle Rio Grande—specifically involving the critical juncture at which flow in the river becomes discontinuous and wetted habitat is reduced to ephemeral pools. This study represents an initial effort to quantify environmental variation among these pools and to assess their intrinsic value as prospective refugial habitats in sustaining populations of silvery minnow through brief periods of hydrologic scarcity. Additionally, this study seeks to determine whether opportunities exist for enhancing environmental attributes of these prospective refugial habitats, including through the strategic application of supplemental water supplies or return flow from irrigated agriculture. This report summarizes results of surveys conducted between June 30, 2007, and October 23, 2007, and discusses the significance of results in the context of relevant ecologic theory.

RIO GRANDE SILVERY MINNOW LIFE HISTORY AND ECOLOGY

Silvery minnow are iteroparous, opportunistic, pelagic spawners. Generally, age I and older silvery minnow are reproductively mature, though it is plausible that sexual maturity might be delayed among age I silvery minnow if they were spawned late in the growing season of the preceding year. The species' early reproductive maturity correlates with its relatively short lifespan (life history theory reviewed by Wootton 1990). However, this does not preclude the existence of multiple age classes of silvery minnow comprising the pool of reproductively mature individuals.[1]

The timing of silvery minnow spawning and the apparent magnitude of the spawn, as indicated by contemporary rates of capture of downstream-drifting eggs, varies with the abundance of parental stock and typically coincides with high-discharge runoff events during spring and summer, notably including those that inundate lands adjacent to the active river channel. However, at least during times of below average spring runoff, the period of silvery minnow spawning may be protracted, conservatively extending from late March through July. The timing and duration of silvery minnow spawning is characteristic of a bet-hedging approach to reproduction—spanning a temporal and spatial range of environmental states with variable probabilities for species recruitment (in part, Lytel and Poff 2004).

Characteristic of their reproductive guild (i.e., pelagophil; defined by Balon 1975, 1987), silvery minnow spawn numerous nonadhesive, semi-buoyant eggs in the open water column. Silvery minnow egg and larvae retention in lateral habitats can be significant, dramatically affecting the trajectory of local population growth. During 2005, surveys for fish in floodplain pools in the Isleta Reach of the Middle Rio Grande following the recession of snowmelt floodwaters produced large (i.e., tens of thousands), nearly monotypic collections of young-of-year silvery minnow (U.S. Fish and Wildlife Service 2006). In some instances, these collections were made within approximately 65 to 75 km of the upstream limits of the species' contemporary range, implying that the eggs or

[1] Lehtinen and Layzer (1988) report that the breeding population of *Hybognathus placitus* (a species closely related to *H. amarus*) is made up of 1- and 2-year-old fish in the Cimarron River, Oklahoma.

larvae could not have drifted downstream farther than that distance. However, it seems unlikely that drift alone could account for the large collections of young-of-year silvery minnow in some of these floodplain pools. Instead, it seems equally plausible that the species adaptively spawns in the proximity of lateral habitats, including backwater and floodplain habitats when possible, to reduce downstream displacement of eggs and larvae. Michael D. Porter's (Reclamation, personal communication 2007) observation of silvery minnow eggs in low water exchange recesses of backwater habitats seems to corroborate this contention. Although understanding is provisional, the suggested association of silvery minnow spawning with lateral habitats, including the floodplain, is generally consistent with observations by Raney (1939) of *Hybognathus regius* spawning, and observations by Copes (1975) of *Hybognathus hankinsoni* spawning. Logically, silvery minnow reproduction and early-development in floodplain habitats of the Middle Rio Grande is dependent on the timing, duration, and magnitude of channel-floodplain coupling in relation to the species' physiological reproductive state.

The degree to which incubating silvery minnow embryos are retained in upstream habitats appears to vary with discharge. Although silvery minnow embryos are known to drift considerable distances when flow is confined to the active channel (Dudley and Platania 2007), there is evidence of reduced downstream drift as flow increases sufficiently for water to escape the active river channel and flood adjacent terraces. During such events, inorganic and organic materials, including silvery minnow eggs and larvae, can be retained (or detained for significant periods of time) in lateral habitats (Widmer et al. 2007), either as a result of channel morphology that allows hydrologic energy to dissipate laterally, or as a consequence of large lateral flow-deflecting objects in the floodplain along with the physical process of drifting material being strained by the vegetated and debris-laden riparian corridor. Usually, inundated floodplains provide heightened heterogeneity of habitat and structural refugia for developing stages of fish relative to the active channel (Valett et al. 2005). Many fish species native to low-gradient rivers of the Mississippi Basin are known to spawn on inundated floodplains, and the heightened productivity of these areas has been demonstrated to be important as nursery habitats (Galat et al. 2004; Bailey and Li 1992; Junk and Welcomme 1990; Junk et al. 1989; Copp 1989; Pease et al. 2006).

Based on the long coiled gut typical of other herbivorous Cyprinid species, Sublette et al. (1990) assumed the silvery minnow to be herbivorous. Shirey (2004) found that silvery minnow fed on organic detritus, tree pollen (*Pinus* sp.), cyanobacteria, and algae, including a wide diversity of diatoms associated with sand, mud, rock, and plant substrates. Aquatic and terrestrial insects have also been observed among the stomach contents of larger silvery minnow specimens (Michael Hatch, SWCA, personal communication 2007). Analysis of food habits for other species of *Hybognathus* generally agrees with Shirey's (2004) findings.

Environmental affinities of diatom species ingested by silvery minnows (i.e., related to trophic state, saprobity, oxygen saturation, pH, salinity, and nitrogen uptake metabolism) show that silvery minnow can tolerate nutrient enrichment, alkaline waters, and low oxygen concentrations (Cowley et al. 2006; Shirey et al. 2007). Studies of silvery minnow physiological tolerance are consistent with this finding. Maximum lethal limits (LL_{50}) for temperature and maximum lethal concentrations (LC_{50}) of dissolved oxygen and ammonia for silvery minnows have been investigated by Buhl (2006) for four age groups of silvery minnow (i.e., 3–4 day post-hatch [dph] larvae, 32–33 dph juveniles, 93–95 dph juveniles and 11-month old subadults) in reconstituted water that simulated conditions in the Middle Rio Grande. Larvae and juveniles were determined to be more tolerant of high temperatures and hypoxic conditions (LL_{50} 35–37ºC; LC_{50} 0.6–0.8 ppm DO) compared to subadults (LL_{50} 32–33ºC; LC_{50} 0.9–1.1 ppm DO). Based on nominal total ammonia concentrations, Buhl (2006) found larvae were about twice as sensitive (96-h LC_{50} for all pulses, 16–23 ppm as N) as both juvenile age groups (96- h LC_{50} for all pulses, 39–70 ppm as N).

Dudley and Platania (1997) studied habitat preferences of the silvery minnow in the Middle Rio Grande at Rio Rancho and Socorro. They characterize habitat preference and habitat availability in terms of water depth, water velocity, and stream substrate.[2] Both juvenile and adult silvery minnow primarily used mesohabitats with moderate depths (15 to 40 cm), low water velocities (4 to 9 cm/second) and silt/sand substrates (Dudley and Platania 1997). Avoidance of swift water velocities by the silvery minnow is one means of conserving energy, a general life strategy shared by many lotic fish species (Facey and Grossman 1992). But, without knowledge of habitat-specific demography, observations of spatial variation in density associated with habitat variation does not yield reliable inferences about species fitness or dynamics of populations inhabiting such areas (e.g., Pulliam 1998).

Contemporary assertions about the habitat preferences of silvery minnow are clearly predicated on there being a relative abundance of water. However, such conditions are exceptional or at best episodic in much of the species' contemporary range in the Middle Rio Grande. In fact, it seems that a monotonous wide channel and a shallow, low-velocity condition, so often cited as attributes of preferred habitat of the silvery minnow, may be disadvantageous during an ecologic crunch period associated with drought—a time during which habitat used by the silvery minnow is limited, both in terms of quantity and quality. During the height of summer and times of hydrologic scarcity, such habitats have the potential to become very warm with low levels of dissolved oxygen. Furthermore, they offer little protection from predation. In recent fish rescue collections, silvery minnow weren't commonly found in such habitats. Instead, the species sought out deeper habitats, generally in reaches relatively heterogeneous in channel features, often in association with relatively well-defined channels. During periods of extreme water scarcity, the species appears to seek out habitats that are cooler and deeper, including pools and an array of habitats in association with overhead cover, irrigation drain return flows, and shallow groundwater (U.S. Fish and Wildlife Service 2006).

[2] Stream depth, velocity, and substrate are often perceived as independent variables when in fact they covary. In many fisheries studies, available habitat is implicitly assumed to regulate fish abundance. Yet, many examples exist in which inter-annual variation in fish abundance is large even though available habitat is held constant (e.g., Moyle and Blatz 1985). During periods of high abundance, fish are often found in apparently marginal habitats from which they are otherwise missing. Other evidence suggests that short-term changes in flow, excluding events of total channel drying, either natural or experimental, cause disproportionate adjustment in the distribution of fish compared to their abundance.

PROJECT BACKGROUND

Environmental variation, both spatial and temporal, is known to be extreme in aquatic habitats of the Middle Rio Grande. Typically, periods of relative hydrologic abundance in this portion of the Rio Grande coincide with runoff from snowmelt and sporadic, often intense, monsoonal rains. Outside of these periods, flow in the river is often highly erratic, especially during the irrigation season, frequently resulting in intermittence over multiple expansive river segments. In recent years, intermittent conditions have prevailed over approximately 68 river miles, representing approximately 62 percent of the length of river between Isleta Diversion Dam and Elephant Butte Reservoir. Such loss of habitat represents a major threat to the maintenance of biodiversity in the Middle Rio Grande. Over the course of history, 13 native fish taxa, representing eight families (48 percent of the region's native fish fauna), have been extirpated from the Rio Grande of New Mexico or have become extinct (Sublette et al. 1990). Additionally, the expanse of river that has gone dry in recent years represents approximately 45 percent of the contemporary range of the silvery minnow that, although extant in the Middle Rio Grande, is listed as endangered by state and federal governments. Anthropogenic alteration of the natural flow regime has factored prominently in the decline of native fish species in the Middle Rio Grande, the incipient effects of which predate the 1900s for some species (Sublette et al. 1990).

The silvery minnow is currently listed as endangered by the state of New Mexico, having first been listed May 25, 1979, as an endangered endemic population of the Mississippi silvery minnow (*Hybognathus nuchalis*) (New Mexico Department of Game and Fish 1988). On July 20, 1994, the U.S. Fish and Wildlife Service published a final rule to list the silvery minnow as a federal endangered species with proposed critical habitat (Federal Register 1994). In 2003, the USFWS designated critical habitat for the silvery minnow in the Middle Rio Grande. The designation extends from Cochiti Dam downstream about 157 miles (252 km) to the utility line crossing the Rio Grande in Socorro County, which corresponds to the southern limit of the Middle Rio Grande Endangered Species Collaborative Program boundary. This location is at 4,450 feet of elevation, corresponding to the elevation of the spillway crest for Elephant Butte Dam. The lateral limits (width) of critical habitat extend between the existing levees or, in areas without levees, 300 feet (91.4 m) of riparian zone adjacent to each side of the bankfull stage of the Middle Rio Grande. Portions of the Pueblos of Santo Domingo, Santa Ana, Sandia, and Isleta fall within the broader area designated as critical habitat but are specifically excluded from the critical habitat designation.

Until the 1950s, the silvery minnow was distributed throughout many of the larger order streams of the Rio Grande Basin upstream of Brownsville, Texas, to points north in New Mexico, primarily below 5,500 feet (1,676 m) in elevation. This elevation coincides with the approximate vicinities of Abiquiu on the Chama River, Velarde on the Rio Grande, and Santa Rosa on the Pecos River (Sublette et al. 1990). Today, absent from much of its historic range, the silvery minnow is restricted to a variably perennial reach of the Rio Grande in New Mexico, from the vicinity of Bernalillo downstream to the head of Elephant Butte Reservoir, a distance that fluctuates as the size of the pool of water in storage in Elephant Butte Reservoir changes, but that approximates 150 river miles (RM) (241 km). Most descriptions of the contemporary range of silvery minnow cite the entire reach of the Rio Grande between Cochiti Dam and Elephant Butte Reservoir. However, that assertion cannot be made with certainty. The species' status in the Rio Grande between Cochiti Dam and Angostura Irrigation Diversion Dam is unknown; that reach of river has not been surveyed in recent years (U.S. Bureau of Reclamation and U.S. Army Corps of Engineers 2003).

The aerographical extent and variability of historically occupied habitats, along with the spatial arrangement of those historic silvery minnow populations, once afforded the species relative security against extinction. The former ability of silvery minnow populations to colonize empty habitat patches, especially potamon[3] habitats that are relatively environmentally benign, served to reduce the risk of extinction. Antithetical situations, typical within the contemporary range of the silvery minnow, have the expected effect of increasing the probability of extinction.

METHODS/STUDY AREA

This project is comprised primarily of three monitoring foci:

1) In-stream refugia monitoring
2) Wetted and drying reach monitoring in the Isleta Reach
3) Wasteway and outfall monitoring

For reference in this document, the "Middle Rio Grande" is defined as the Rio Grande downstream from Cochiti Dam to the headwaters of Elephant Butte Reservoir (Figure 1). The Middle Rio Grande below Cochiti Dam is further designated by five reaches defined by locations of mainstream irrigation diversion dams. The Angostura Reach extends from Cochiti Dam to Angostura Diversion Dam. The reach from Angostura Diversion Dam to Isleta Diversion Dam is called the Albuquerque Reach. The Isleta Reach is bounded upstream by Isleta Diversion Dam and downstream by San Acacia Diversion Dam. The reach below San Acacia Diversion Dam to the San Marcial is the San Acacia Reach. Finally, the reach below San Marcial to the headwaters of Elephant Butte Reservoir is the San Marcial Reach. By convention, each pool was given a unique identifying label comprised of the first letter of the river reach in which they were located, followed by the river mile (to the nearest tenth of a mile), followed by an alpha character to distinguish between pools that might exist in the same tenth of a mile.

Work occurred primarily in the Isleta Reach, although some monitoring of prospective refugial pools did occur in the San Acacia Reach.

[3] *Potamon* refers to the warmer and lower-gradient river of the lowlands. Unaltered, the potamon is characterized by slower currents, finer substrate materials, and variety of size, depth, and flow of the river channel, including large river channels, oxbows, sloughs, and habitats of the floodplain. Autochthonous inputs of organic materials support a preponderance of detritivores, herbivores, and planktivores.

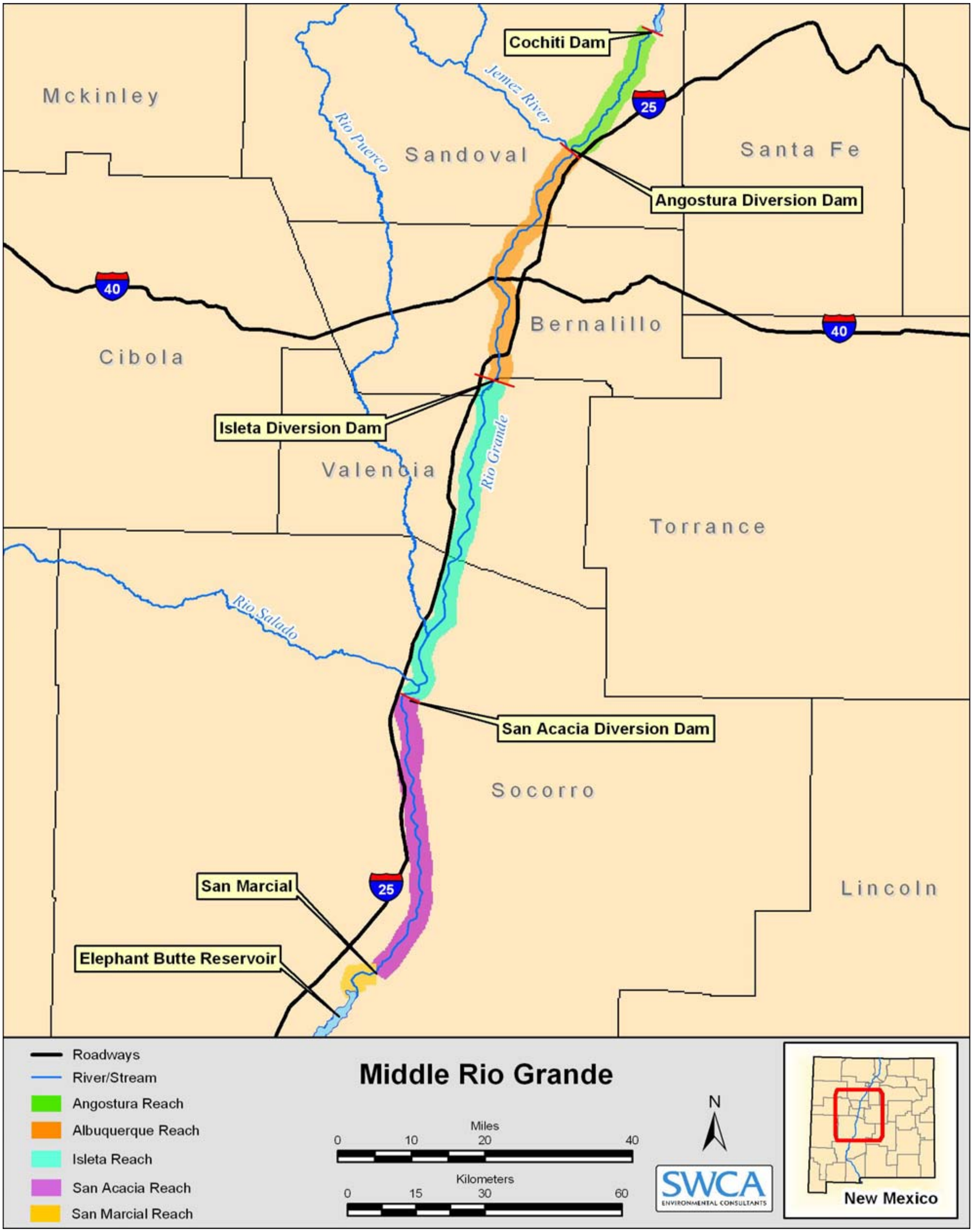

Figure 1. Overview of Middle Rio Grande.

DATA MANAGEMENT AND INSTRUMENTATION

A Trimble GeoXT handheld global positioning system (GPS) unit with sub-meter accuracy was used to monitor and record spatial characteristics of wetted pool perimeter, pool location, wetted and drying reach location, and irrigation outfalls.

Water quality parameters, including temperature (degrees Celcius [°C]), hydrogen ion concentration (pH), dissolved oxygen (parts per million [ppm]), conductivity (microsiemens per centimeter [µS/cm]), and ammonia (ppm), were measured with an In-Situ Troll 9000 Multi-Parameter Water Quality Meter (Troll 9000). Water quality parameters were also collected at each irrigation outfall and at wetted and drying reach locations. The Troll 9000 was calibrated according to manufacturer's specifications for field applications. Depth (meters [m]) and velocity (meters per second [m/s]) were obtained using a Marsh McBirney Portable Flow Meter and depth gage. Hobo event loggers were used to obtain hourly records of water temperature at several irrigation outfalls and isolated pools.

A digital camera was employed for all photo documentation. Maps depicting changes over time in pool surface area were created using ArcGIS 9.x. A relational database (Microsoft Access) was developed to assist with the storage, analysis and retrieval of fish survey data.

MONITORING PROSPECTIVE IN-STREAM REFUGIA

Environmental conditions were monitored in pools after they became isolated from running water habitats as a consequence of diminished flow in the river. Once an isolated pool formed, daily monitoring of environmental conditions was initiated. Monitoring continued over a two week period so long as the pool held water and so long as the pool remained isolated from running water habitats. Daily measurements included physical dimensions of the pool (using GPS) and water quality parameters, including pH, temperature, conductivity, dissolved oxygen, and ammonia. Water quality measures were recorded for each pool at the distal ends of the pool and at three intermediate locations that divided the pool into four approximately equal segments. At each monitoring point, water depth was noted and water quality parameters were recorded at or near the surface and bottom of the water column. Pools with a complex morphology, including varying depth and multiple segments delimited by a shallow water divide, were classified as "connected," otherwise, they were classified as "disconnected."

Scouting for candidate refugial pools in the main channel of the Rio Grande progressed in synchrony with river recession beginning on June 30th continuing over the course of the 2007 irrigation season. The portion of the San Acacia Reach with discontinuous flow totaled approximately 24 miles and was located generally between Socorro and the southern boundary of Bosque del Apache Wildlife Refuge (Appendix K). Within this river segment, only three pools, most marginal in their capacity to serve as in-stream refugia, were selected for monitoring (Figure 2). These pools were located at RM 94.1 (Figure 3), RM 81.5 (Figure 4), and RM 77.4 (Figure 5). Pool locations were also recorded by universal transverse mercator (UTM) coordinates. Judging from the depth and size of these pools, only the pool located at the mouth of Brown's Arroyo (RM 94.1) was anticipated to persist through the two-week monitoring period specified in the survey protocol.

Within the Isleta Reach, scouting for candidate refugial pools in the main channel progressed in synchrony with river recession beginning on August 12, 2007. The portion of the Isleta Reach with discontinuous flow totaled approximately 9.5 miles and was located generally between the Peralta Main Canal Wasteway (RM 152.5) and the NM 49 Bridge (RM 161.4) in Los Lunas (Appendix K). A total of five pools, mostly marginal in their capacity to serve as in-stream refugia, were selected for monitoring within this river segment (Figure 6). These pools were located at RM 152.6 (Figure 7), 154.4 (Figure 8), 158.3 (Figure 9, Figure 10), 158.4 (Figure 11), and 161.3 (Figure 12–Figure 15). Pool locations were also recorded by UTM coordinates.

All three of the pools within the San Acacia Reach were monitored for five consecutive days before they were reconnected with running water. Within the Isleta Reach, two pools (i152.6a and i158.4a) were monitored for one day, while one was monitored four days (i154.4a) before they dried. Multiple periods of observation exist for pools i158.3a and i161.3a (ranging from one to 11 consecutive days) due to recurring expansion–contraction cycles of flow.

Various probes of the Troll 9000 malfunctioned throughout the monitoring period. When the Troll 9000 was inoperable, water quality measurements were made using a YSI 556 for all parameters except ammonia (Appendix B). An hourly log of water temperature was collected for pools located at RM 76.8, 81.5, and 154.4 using Hobo event loggers (Appendix C). Hobo event loggers that were deployed in pools located at RM 94.1 and RM 161.3 were not located and recovered at the conclusion of monitoring.

Surveys for fish were conducted, with specific attention paid to fish presence/absence and fish health. A 3.7 × 1.2 m seine with 0.476-cm delta mesh was used for fish collections. Monitoring began after June 15, 2007, and continued until the end of the irrigation season in October 2007. Crews conducted seine hauls until a minimum of 100 fish were captured or 10 seine hauls were completed. For each pool, fish species composition was noted. The health of *Cyprinella lutrensis*, *H. amarus*, *Pimephales promelas*, and *Platygobio gracilis* was assessed in terms of the number that were dead, healthy, or exhibited signs of fungus, *Lernia*, hemorrhagic lesions, anemia (i.e., emaciation), or predation (Appendix A). All fish that were captured were returned to the water alive.

IRRIGATION OUTFALL MONITORING

Fourteen Middle Rio Grande Conservancy District (MRGCD) irrigation outfalls in the Isleta Reach between the Isleta Diversion Dam and the San Acacia Diversion Dam were selected for monthly monitoring (

Table 1; Figure 16). Individual maps of each irrigation outfall monitored are located in Appendix D. Data concerning discharge, water temperature, conductivity, pH, ammonia, and dissolved oxygen, were collected. Hourly records of water temperature were collected using Hobo event loggers in the Peralta Main Canal Wasteway (RM 152.5 E), the Lower Peralta Riverside Drain 1 (RM 149.6 E), the Lower Peralta Riverside Drain 2 (RM 144.7 E), the Feeder 3 Wasteway (RM 142.8 W), the Storrie Wasteway (RM 140.1 E), and the Lower San Juan Riverside Drain (RM 126.6 E). Hobo event loggers deployed in the Lower Peralta Riverside Drain 2 (RM 144.7 E) and Lower San Juan Riverside Drain (RM 126.6 E) could not be located and retrieved at the end of the monitoring period. Hobo event logger temperature data is presented in Appendix F. The Troll 9000 ammonia probe malfunctioned from July 9, 2007, through July 11, 2007. The malfunctioning probe was replaced and recalibrated per manufacturer's specifications.

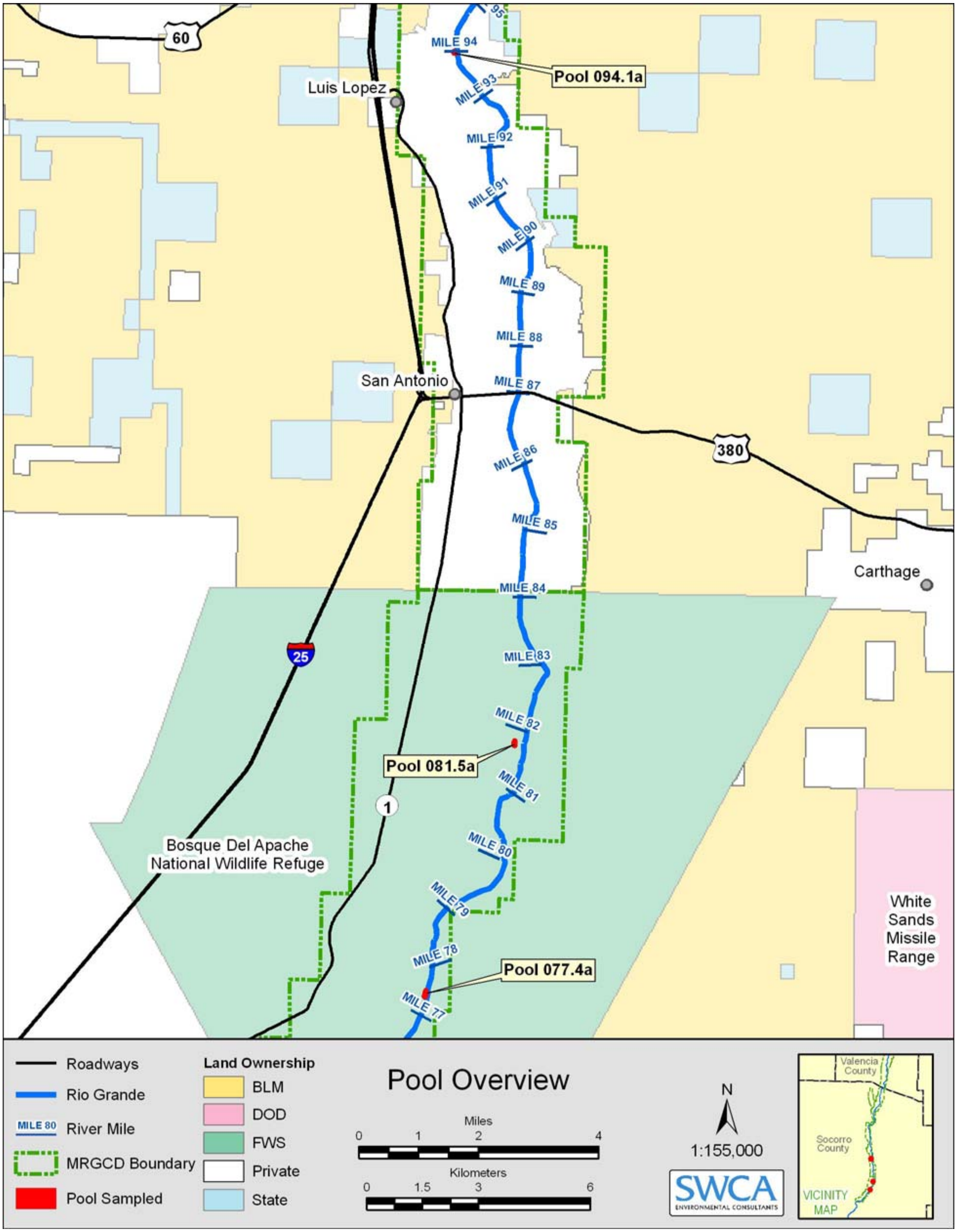

Figure 2. Overview of pools monitored within the San Acacia Reach.
Monitoring was conducted for five days until the pools were reconnected to main channel flow.

Figure 3. Pool at RM 94.1 (mouth of Brown's Arroyo).

Sample points depict locations where water quality data were collected.
Color depicts the date of sampling and the wetted area.

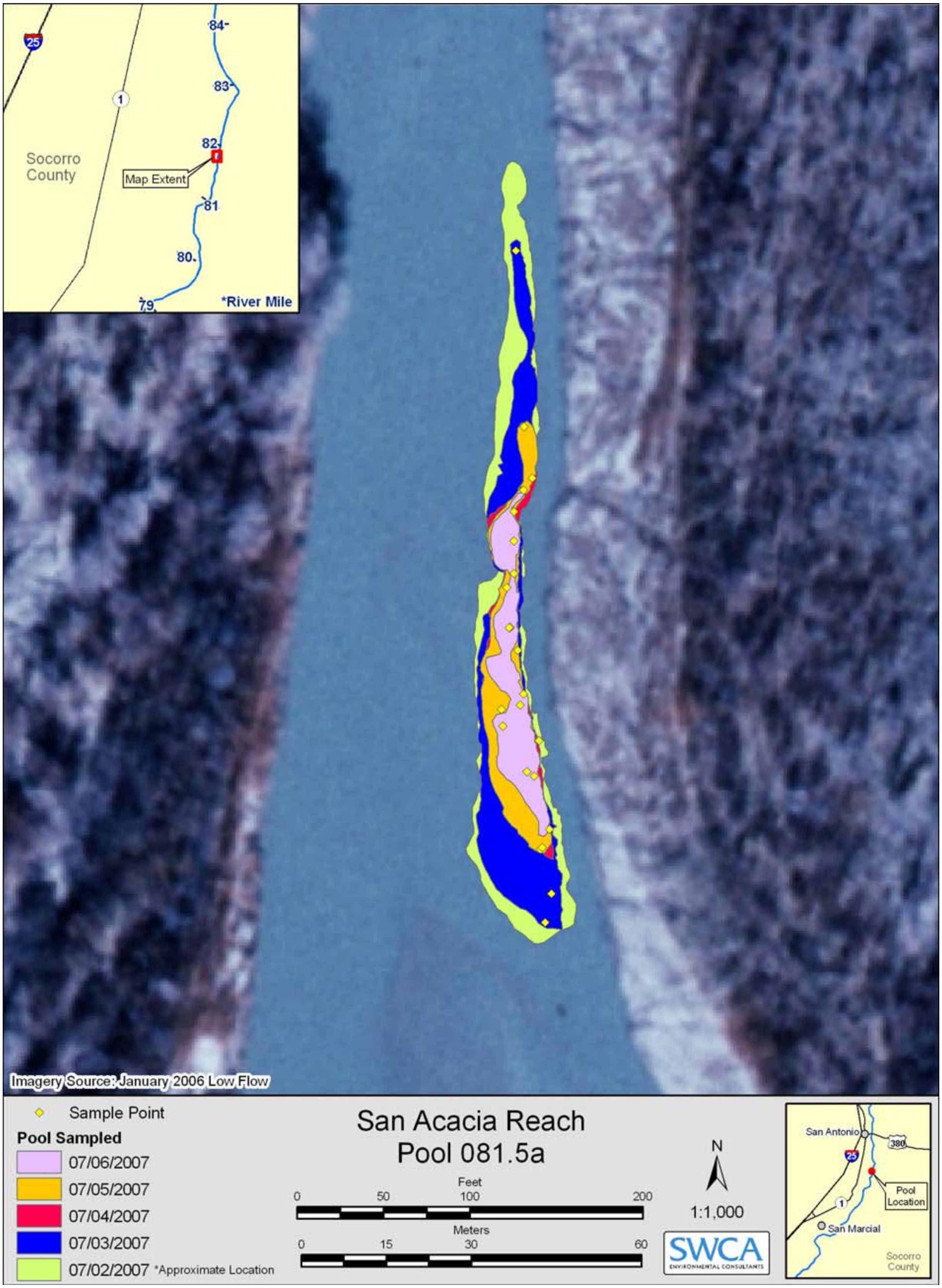

Figure 4. **Isolated pool at RM 81.5.**

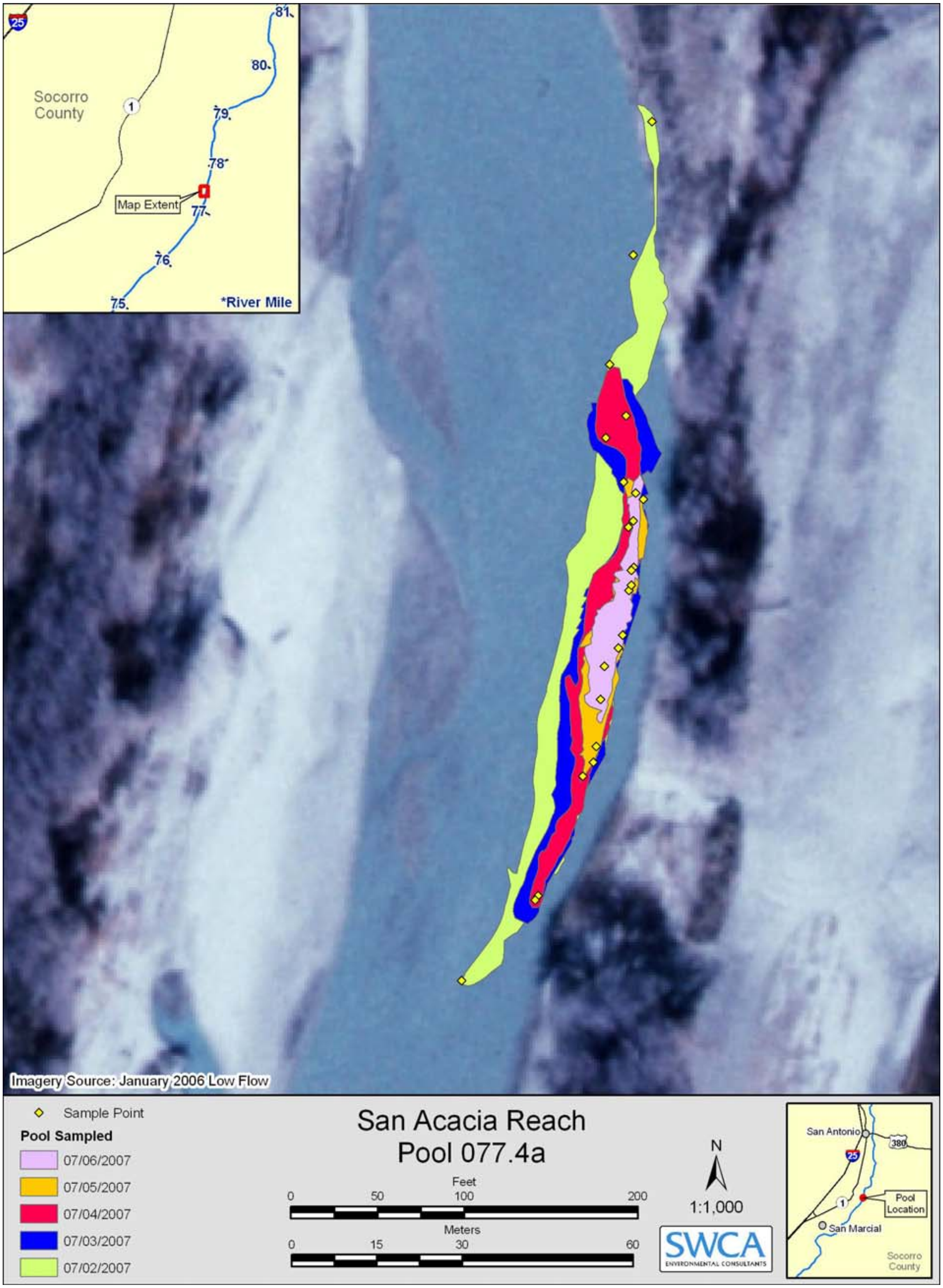

Figure 5. Pool at RM 77.4.

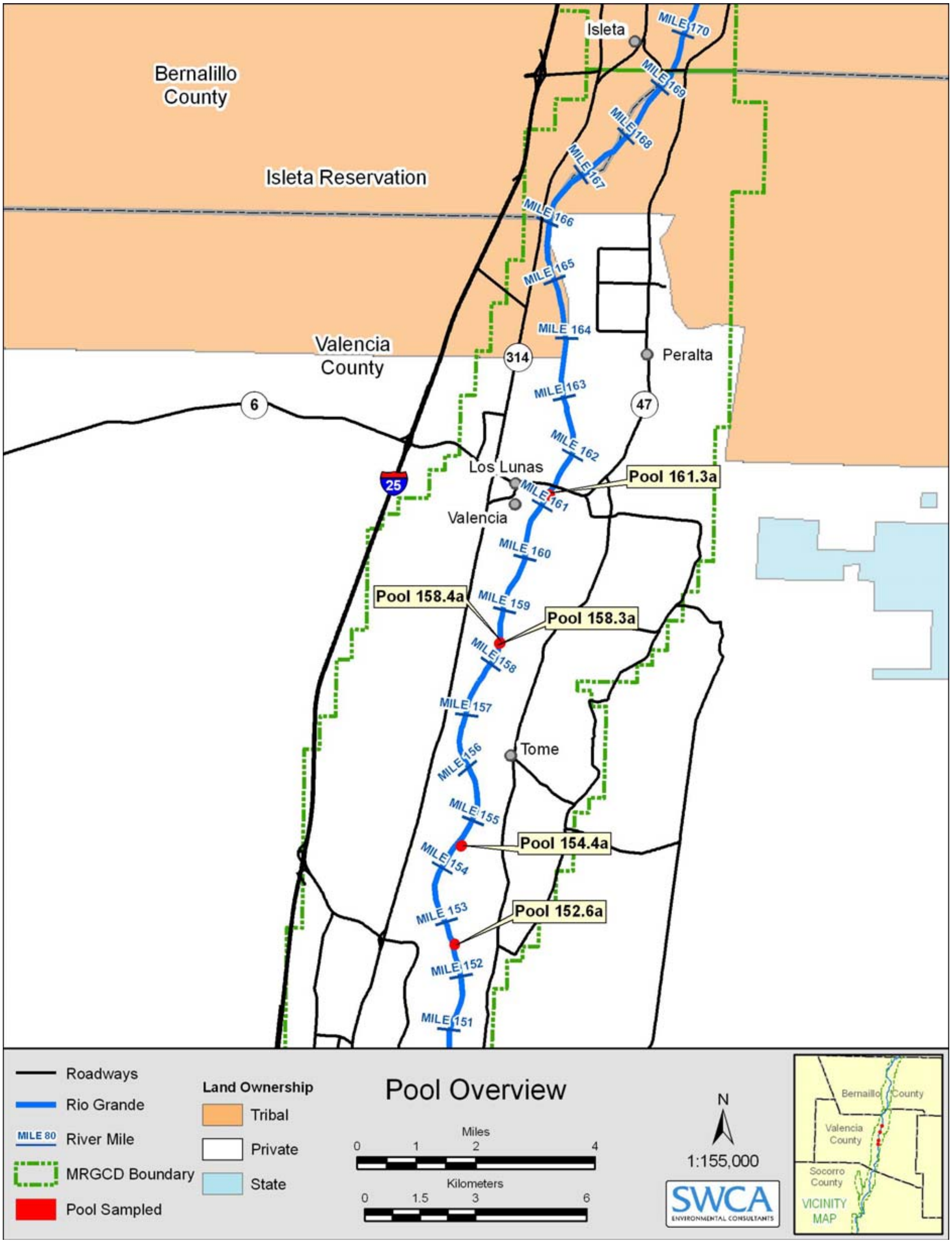

Figure 6. Overview of pools monitored within the Isleta Reach.
Pools i158.3a and i161.3a were monitored over multiple periods.

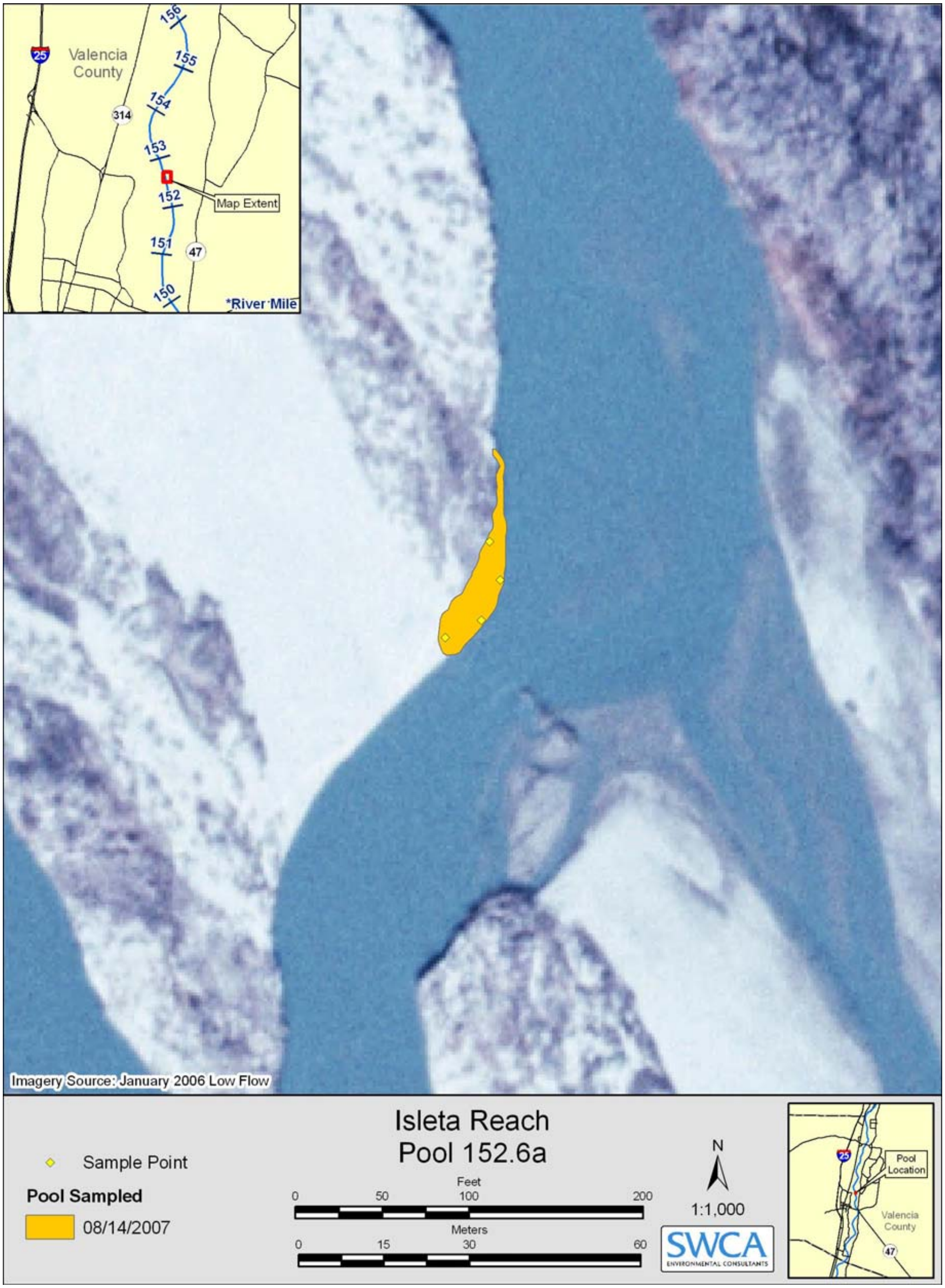

Figure 7. Pool i152.6a.
Monitoring was conducted only one day before it dried.
This pool was shallow and was a poor refugial habitat.

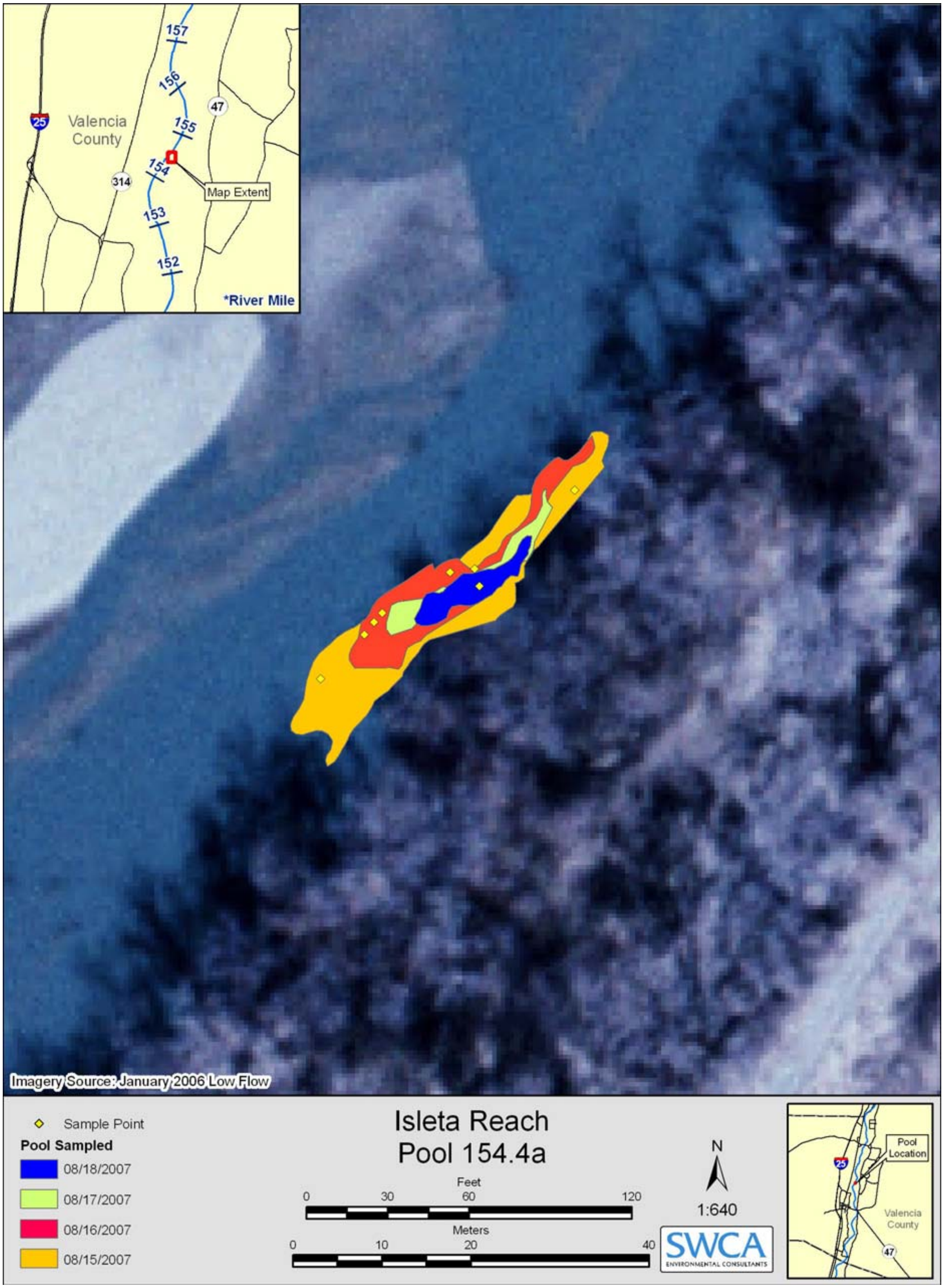

Figure 8. Pool i154.4a.
Monitoring extended over four days before it dried.

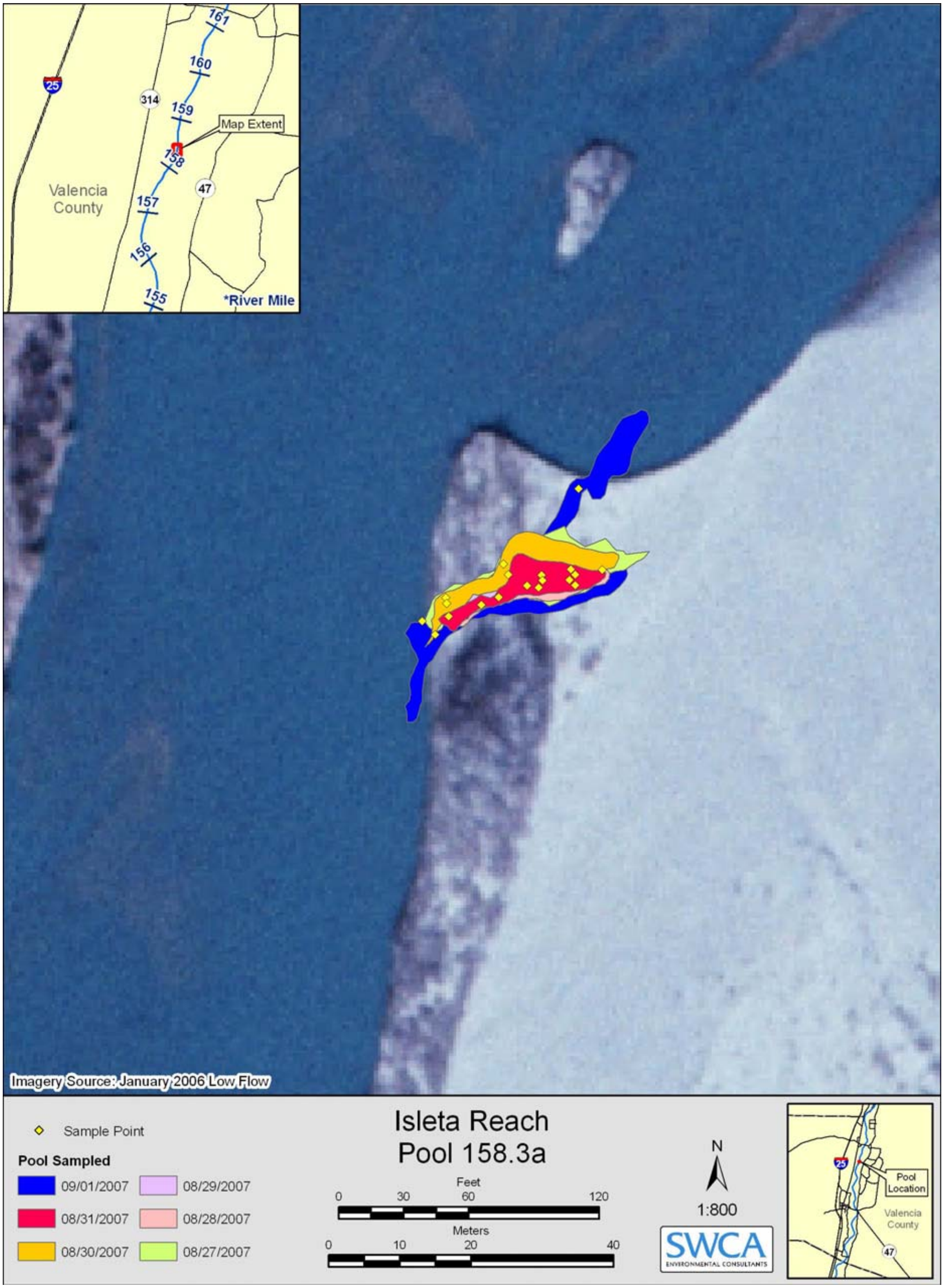

Figure 9. Pool i158.3a — first monitoring period.
Monitoring extended over six days until it reconnected with main channel flow.

Figure 10. Pool i158.3 — second monitoring period.
Monitoring extended over eight days.

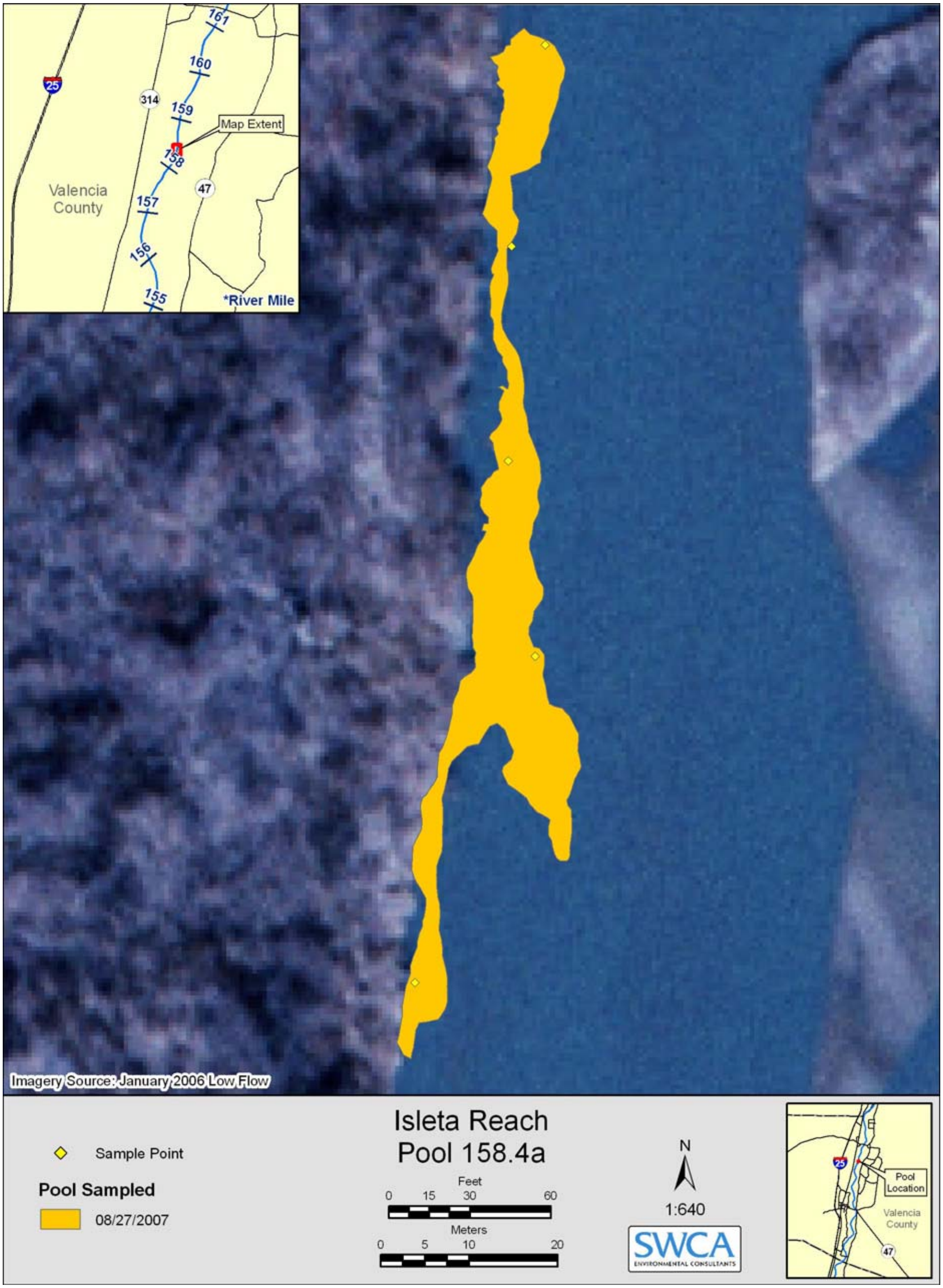

Figure 11. Pool i158.4a.
This pool was monitored only one day before it dried.

Figure 12. Pool i161.3a — first monitoring period.
Monitoring extended over seven days before it reconnected with main channel flow.

Figure 13. Pool i161.3a — second monitoring period.
Monitoring extended over two days before it was reconnected with main channel flow.

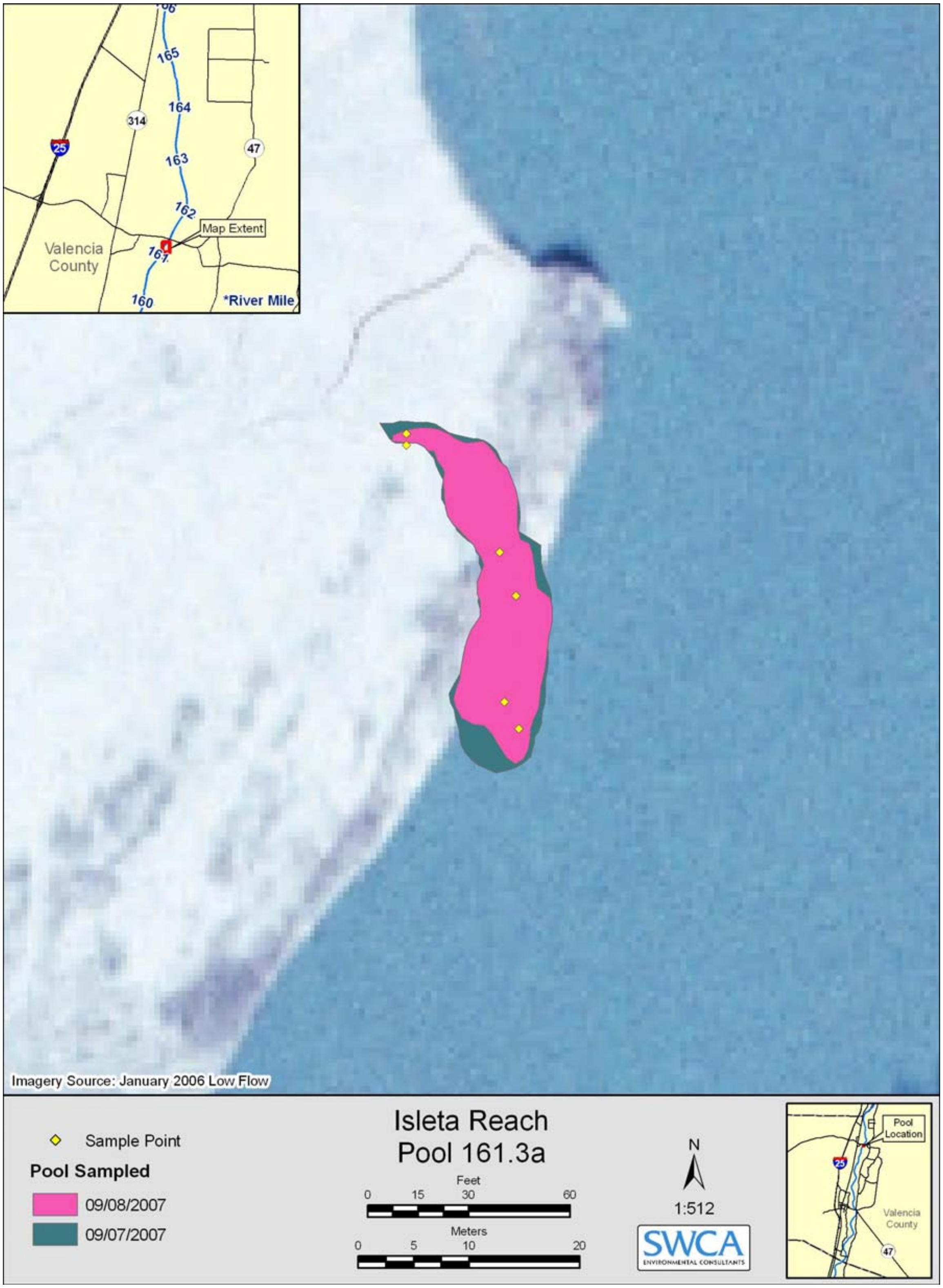

Figure 14. Pool i161.3a — third monitoring period.
Monitoring extended over two days until it reconnected with main channel flow.

Figure 15. Pool i161.3 — forth monitoring period.
Monitoring extended over 11 days until it reconnected with main channel flow.

Table 1. Middle Rio Grande Conservancy District Wasteway/Outfall Sites (listed in geographic order from north to south).

Wasteway / Outfall (acronym)	River-wasteway Confluence River Mile (lateral position: "E" or "W")
240 Wasteway (240WW)	165.2 (W)
Los Chavez Wasteway (LCZWW)	156.8 (W)
Peralta Main Canal Wasteway (PERWW)	152.5 (E)
Lower Peralta Riverside Drain (LP1DR)	149.6 (E)
Belen Riverside Drain (BELDR)	147.7 (W)
New Belen Wasteway (NBLWW)	147.1 (W)
Lower Peralta Riverside Drain (LP2DR)	144.7 (E)
Feeder 3 Wasteway (FD3WW)	142.8 (W)
Storrie Wasteway (STYWW)	140.1 (E)
Sabinal Drain Outfall (SABDR)	137.9 (W)
San Francisco Riverside Drain (SFRDR)	126.8 (W)
Lower San Juan Riverside Drain (LSJDR)	126.6 (E)
Unit 7 Drain (UN7DR)	115.0 (W)

WETTED AND DRYING REACH MONITORING

River conditions were monitored during and following the recession of running water to document trends in the development of pools and perennially wetted reaches below Isleta Diversion Dam. The rate and variation in river drying was monitored over a two-week period following the onset of river drying, once recession began. Sources of water supplying wetted reaches and pools were documented.

Flow diminished sufficiently to dry portions of the river in the Isleta Reach beginning August 12, 2007. Monitoring proceeded according to protocol. Twice-daily measurements, including water quality parameters (pH, temperature, conductivity, dissolved oxygen, and ammonia), end-of-flow waypoints, and photo documentation were taken for an initial two-week period or after the start of a new cycle of river rewetting and recession within the reach. Sources of water supplying pools and/or wetted reaches were documented (Appendix G).

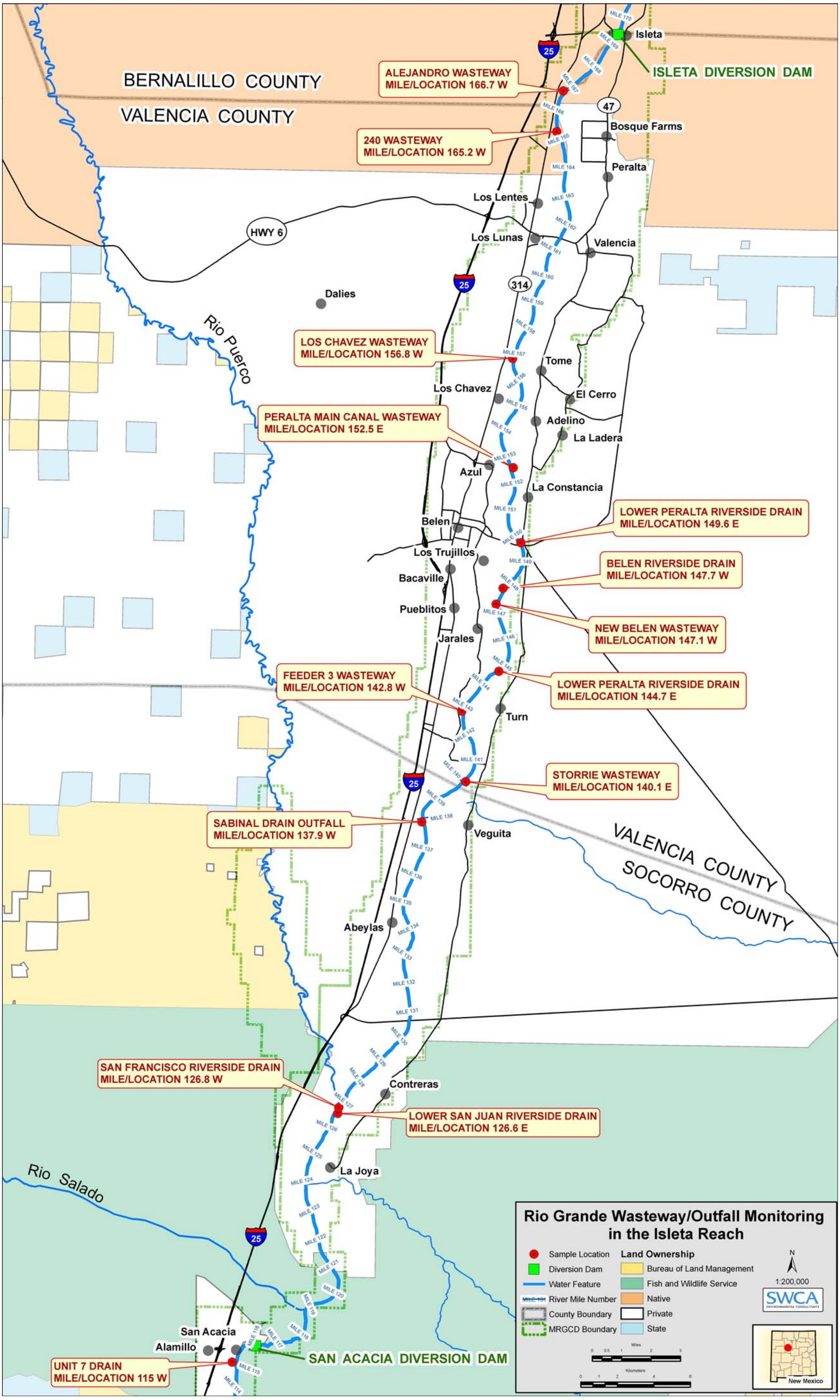

Figure 16. **Rio Grande wasteway/outfalls selected for monitoring within the Isleta Reach.**

RESULTS

MONITORING PROSPECTIVE IN-STREAM REFUGIA

The isolated pools encountered during this study were few in number, spaced widely apart, and were generally small and shallow. Part of this is due to the limited number of river miles that dried during 2007 and the restriction of river drying to actively aggrading river segments (a record of expansion-contraction flow disturbances appears in Appendix K). The virtual absence of large enduring pools in the Isleta and San Acacia reaches during the 2007 irrigation season is believed to be partially attributable to the large influx of silt to the river from upstream tributaries, arroyos, and ephemeral waterways coincidental to the high runoff that accompanied the unusually strong monsoonal precipitation pattern that settled over much of the upper Rio Grande basin beginning in late July 2006. The influx of silt to the river caused portions of the riverbed to aggrade, generally precluding the formation of large pools.

The eight pools that were monitored went dry or were reconnected to main channel flow before the two-week period of observation specified in the study plan. Figure 17 plots pool area against consecutive days of isolation for all pools and monitoring periods that lasted three consecutive days or longer. All plots revealed a similar pattern of surface area loss through time, with the exception of the first monitoring period for pool i158.3a, which actually increased in size due to heavy local rainfall and groundwater seepage from adjacent main channel flow.

Some 7,547 fish representing 20 species were collected from the monitored pools (Table 2). Fish community composition varied between pools and dates sampled (Appendix A1–5). Red shiners (*Cyprinella lutrensis*) comprised the largest percentage of fish captured (21.24 percent) followed closely by western mosquitofish (*Gambusia affinis*) (20.87 percent) and unidentified larval fish (18.25 percent). Silvery minnow was the sixth most abundant species observed, comprising 7.82 percent of the total number of fish captured. Despite the variation in fish community composition between sites, a correlation was found between the number of fish species observed and pool surface area ($F_{1,4} = 4.47$, $P = 0.10$, $R^2 = 0.53$) (Figure 18). Only pools that were monitored on multiple occasions were included in this analysis (pools i152.6a and i158.4a were excluded).

Silvery minnows were captured from seven of the eight monitored pools (no silvery minnows were captured from pool s94.1a). Although no silvery minnows were captured from pool i158.3-a during the initial sampling period, they comprised a relatively high percentage of the species sampled (5–33 percent) during subsequent sampling periods following pulsed (short-term) expansion-contraction flow disturbances. Likewise, silvery minnows initially comprised less than 7.5 percent of the catch in pool i161.3-a, but subsequently comprised up to 29 percent of the catch following pulsed expansion-contraction flow disturbances.

The health of four fish species was monitored in eight pools (Table 3). A total of 2,487 fish (33 percent of total) were visibly inspected for outward signs of disease. The majority of fish observed were healthy (2,199). In wetted habitat, only 21 of the observed fish were dead. Hemorrhagic lesions were the most common exhibited fish health affliction, probably caused by opportunistic, secondary bacterial or fungal agents. The second most common fish health affliction involved parasitic copepods (*Lernia* sp.). Only a few fish displayed signs of predation, anemia, fungal infections, and/or multiple symptoms. The data suggest that silvery minnows may be more susceptible to *Lernia* and opportunistic, secondary bacterial or fungal agents than the other species studied. Non-independent patterns of readily visible signs of impaired fish health linked to highly communicable pathogens, i.e., *Lernia* and opportunistic secondary bacterial or fungal agents, (chi-square $_{obs}$ 55.09; chi-square $_{crit}$ 16.81 at $\alpha = 0.01$; one tailed $P < 0.001$) may be attributable to species-specific health dynamics and vulnerabilities or to the relatively short duration of exposure through close confinement of species in isolated pools.

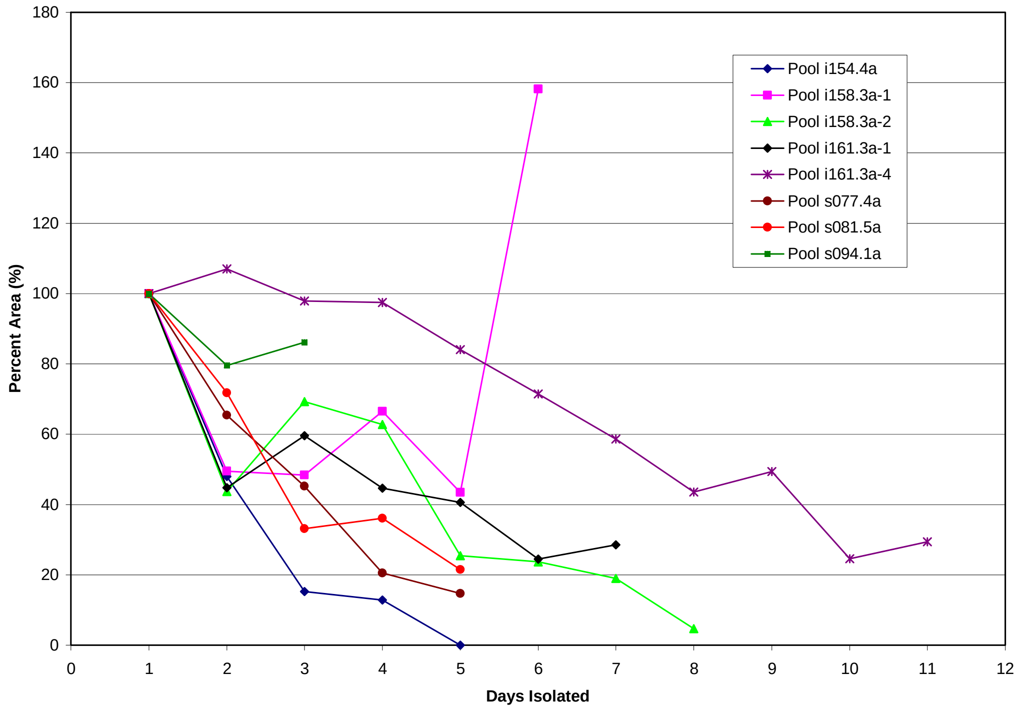

Figure 17. Time variable plots of pool surface area.
Percent of area remaining as a function of the number of days isolated for pools selected for monitoring. The initial starting value of 100% represents the pool's area on the first day of monitoring. Plot i158.3-a-1 and i158.3-a-2 represent the first and second monitoring periods for that pool. Plot i161.3-a-1 and i161.3-a-2 represent the first and fourth monitoring periods for that pool.

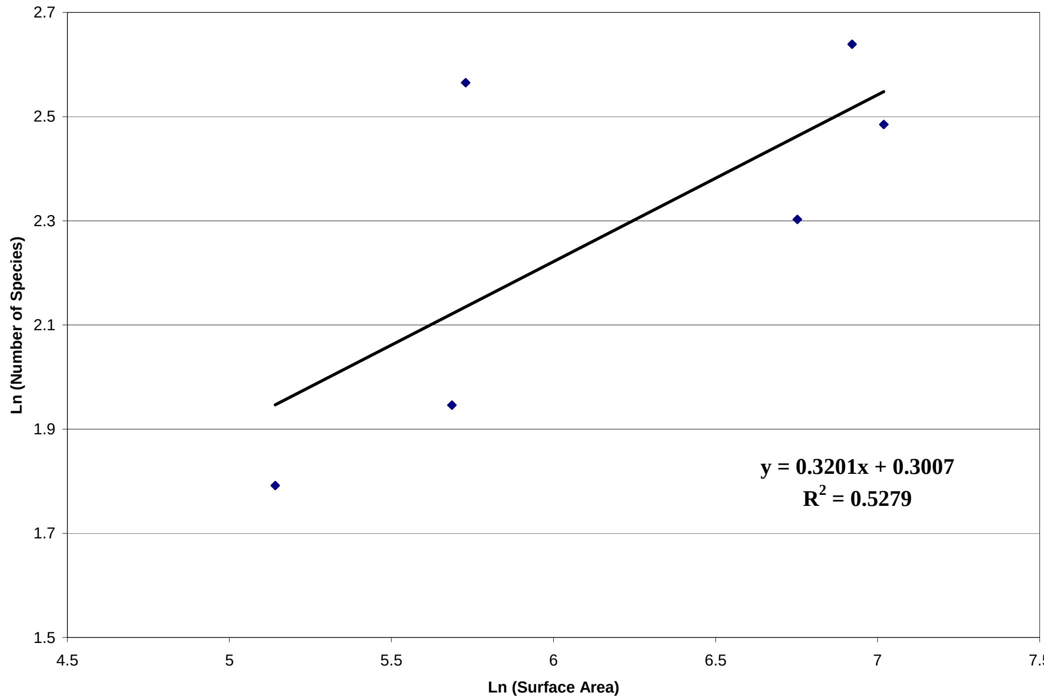

Figure 18. Species diversity as a function of pool surface area. Points represent natural log plots of the number of species present as a function of pool surface area. Pools i152.6a and i158.4a were not included in this analysis.

Table 2. Summary of Fish Observed in Monitored Pools. Occurrence by river reach is denoted as I (Isleta) and SA (San Acacia).

Rank	Species	Reach	Total Collected	Percent Composition
1	*Cyprinella lutrensis* (red shiner)	I, SA	1603	21.24
2	*Gambusia affinis* (western mosquitofish)	I, SA	1575	20.87
3	Larval sp.	SA	1377	18.25
4	*Carpiodes carpio* (river carpsucker)	I, SA	987	13.08
5	*Ictalurus punctatus* (channel catfish)	I, SA	708	9.38
6	*Hybognathus amarus* (Rio Grande silvery minnow)	I, SA	590	7.82
7	*Pimephales promelas* (fathead minnow)	I, SA	247	3.27
8	Unidentified	SA	194	2.57
9	*Cyprinus carpio* (common carp)	I, SA	88	1.17
10	*Platygobio gracilis (*flathead chub)	I, SA	47	0.62
11	*Dorosoma cepedianum* (gizzard shad)	SA	45	0.60
12	*Ictalurus furcatus* (blue catfish)	SA	45	0.60
13	*Morone chrysops* (white bass)	I	12	0.16
14	*Lepomis* (*Chaenobryttus*) *cyanellus* (green sunfish)	I	8	0.11
15	*Percina macrolepida* (bigscale logperch)	SA	4	0.05
16	*Catostomus commersonii* (white sucker)	I	4	0.05
17	*Pylodictis olivaris* (flathead catfish)	SA	4	0.05
18	*Micropterus salmoides salmoides* (northern largemouth bass)	SA	3	0.04
19	*Perca flavescens* (yellow perch)	I	2	0.03
20	*Ameiurus melas* (black bullhead)	I	2	0.03
21	*Lepomis (Lepomis) macrochirus* (bluegill)	I	1	0.01
22	*Micropterus dolomieu* (smallmouth bass)	SA	1	0.01
	Totals		**7547**	**100.00**

Table 3. Counts of Fish by Health Symptom Category.

	Health Symptoms							
Species	**Healthy**	**Dead**	**Fungus**	**Lernia**	**Hemorrhagic Lesions**	**Anemia**	**Signs of Predation**	**Multiple Symptoms**
Cyprinella lutrensis	1504	4	0	27	14	52	0	2
Hybognathus amarus	448	16	0	33	71	2	10	10
Pimephales promelas	213	1	5	15	11	0	2	0
Platygobio gracilis	34	0	4	1	8	0	0	0
Total	2199	21	9	76	104	54	12	12

Water quality parameters were monitored daily in isolated pools. On multiple occasions the Troll 9000 was inoperative due to technical difficulties. Nevertheless, water quality data were still collected by using the remaining functional probes and/or a YSI 556 water quality meter on days where individual probes failed to calibrate within an acceptable range. Table 4 presents a summary analysis of water quality data from isolated pools.

Dissolved oxygen was the most variable of the water quality parameters monitored in pools within the San Acacia Reach. Diel pulses in dissolved oxygen tended to reflect cycles of photosynthesis by algae. Lowest readings generally followed periods of low illumination, while the highest readings generally followed periods of high illumination. Still, dissolved oxygen was consistently low in the Brown's Arroyo pool (RM 94.1, min = 1.3 parts per million [ppm]). Hydrogen ion concentration was consistently lowest in the Brown's Arroyo pool (mean 7.62, range 7–8.38), and highly variable in pools s077.4-a (mean 8.66, range 7.07–10) and s081.5-a (mean 8.75, range 7.63–9.45). Temperature in pools s081.5-a and s077.4-a varied about 10˚C throughout the day (Appendix C), while daily temperature only varied slightly in the Brown's Arroyo pool. Only slight daily variation in ammonia was observed in pools s081.5 and s077.4. Ammonia values were highest and most variable in the Brown's Arroyo pool.

Diel pulses in dissolved oxygen in pools within the Isleta Reach tended to reflect cycles of photosynthesis by algae. Among pools in the Isleta Reach, dissolved oxygen was consistently lowest in pool i161.3-a (min = 1.01 ppm) and was highest in pool i154.4-a (max = 17.79 ppm). No discernable patterns among sites were noted based on measures of pH (mean 8.33, range 6.92–10). Conductivity showed little variation between pools and days. A significant increase in ammonia concentration was observed for pool i161.3-a during the last five days of monitoring. It is unclear whether this reflects actual water quality conditions or if it is an artifact of ammonia probe malfunction (Appendix B).

WASTEWAY/OUTFALL MONITORING

Wasteway/outfalls were monitored once per month starting on June 30, 2007, through October 2007. The Alejandro Wasteway and the 240 Wasteway remained dry throughout the monitoring period. The Los Chavez irrigation outfall was blocked during the period of monitoring by an earthen plug that prevented the wasteway from functioning. The Sabinal Drain Outfall was dry during the first and second scheduled monitoring periods. The New Belen Wasteway was dry on the first, second, third, and fifth scheduled monitoring periods. Table 5 presents a summary analysis of water quality data collected from irrigation wasteways.

Due to a Trimble GeoXT malfunction, dissolved oxygen data from the first two scheduled monitoring periods could not be retrieved. Extreme diel fluctuations of up to 30˚C were recorded by Hobo Event Loggers in Storrie and LP1DR wasteways. It is likely that these extreme fluctuations occurred when the wasteways were dry and not flowing; however, information required to corroborate this observation (MRGCD irrigation outfall flow records) will not be available until early 2008. A complete tabulation of all water quality data collected from wasteways is provided in Appendix E, while hourly records of water temperatures collected from wasteways are provided in Appendix F.

WETTED AND DRYING REACH MONITORING

Wetted reach monitoring within the Isleta Reach was conducted downstream of the NM 6 Bridge in Los Lunas to the Peralta Wasteway (RM 152.5) (Appendix H). Although crews collected data from multiple locations within this segment of the river, more than 50 percent of all monitoring occurred within one mile of the NM 6 Bridge. Dissolved oxygen was the most variable of all water quality parameters collected, ranging from 5.56–16.37 ppm. Much of this variation can be attributed to cycles of photosynthesis. Ammonia concentration increased notably on September 15, 2007, and remained high throughout the remainder of the monitoring period. In addition, temporarily varying aberrant water characteristics were observed, including colors ranging from clear gray to yellowish brown, coupled with odors reminiscent of feces and chlorine. Table 6 presents a summary of water quality data collected during wetted and drying reach monitoring; Appendix F includes a complete tabulation of all water quality data collected during wetted and drying reach monitoring. A record of expansion-contraction flow disturbances appears in Appendix K.

TOXICITY OF WATER QUALITY TO SILVERY MINNOWS

Temperature data collected for this study rarely reached the upper 24-h and 96-h LL_{50} threshold values as provisionally defined by Buhl (2006). Maximum water temperature among wetted reach and irrigation outfall observations was 33˚C, while maximum water temperature of isolated pools was 37˚C (surface reading). Observations of critically high water temperature were rare. Only 17 out of 201 temperature measurements exceeded 30˚C, and of those only three were recorded in the critical range of 35–37˚C. In addition, hourly records of water temperature recorded by Hobo Data Loggers indicate a short time period of one to three hours (between 1600–1800hrs) when temperatures might exceed the critical range provisionally defined by Buhl (2006).

Dissolved oxygen rarely reached the provisional critical values given by Buhl (2006), including within isolated pools, near wasteways, or at the downstream end of main channel flow. Although a few values collected from isolated pools were at or below the critical range, multiple values collected from a single pool on any given sampling day were never consistently within this range.

Table 4. Isolated Pool Water Quality Summary Statistics.
Water quality summary statistics are arranged by sample site (north to south) and position in the water column. Mean values for each parameter are tabulated by sample site, with standard deviation and sample size given parenthetically.

SITE	Ammonia (ppm)		pH		Conductivity (µs/cm)		Dissolved Oxygen (ppm)		Water Temperature (˚C)	
	(Surface)	(Bottom)	(Surface)	(Bottom)	(Surface)	(Bottom)	(Surface)	(Bottom)	(Surface)	(Bottom)
i152.6-a	1.26 (0.09; 5)	1.20 (0.05; 5)	8.38 (0.23; 5)	8.40 (0.19; 5)	592.86 (8.89; 5)	588.04 (11.02; 5)	8.35 (0.73; 5)	8.13 (0.95; 5)	32.64 (0.38; 5)	32.42 (0.64; 5)
i154.4-a	0.89 (0.19; 14)	0.92 (0.34; 14)	8.96 (0.78; 14)	8.97 (0.80; 14)	439.70 (89.15; 14)	417.59 (34.26; 14)	7.15 (4.09; 14)	7.33 (4.10; 14)	20.78 (1.69; 14)	20.63 (1.51; 14)
i158.3-a	0.37 (0.45; 33)	0.38 (0.48; 33)	8.33 (0.47; 42)	8.07 (0.43; 42)	399.28 (134.05; 42)	425.80 (144.78; 42)	7.25 (3.08; 42)	6.85 (3.13; 42)	21.58 (3.40; 42)	21.18 (3.00; 42)
i158.4-a	0.69 (0.65; 5)	0.66 (0.67; 5)	8.28 (0.32; 5)	8.32 (0.34; 5)	329.94 (4.41; 5)	329.78 (4.49; 5)	7.54 (0.35; 5)	7.54 (0.35; 5)	25.64 (0.94; 5)	25.63 (0.97; 5)
i161.3-a	17.88 (41.34; 51)	17.89 (41.85; 51)	8.23 (0.48; 69)	8.13 (0.53; 69)	460.75 (56.42; 69)	480.91 (92.23; 69)	5.76 (2.52; 60)	5.56 (2.42; 60)	21.85 (3.28; 69)	21.42 (2.81; 69)
s077.4-a	0.40 (0.07; 20)	0.41 (0.08; 20)	8.68 (0.86; 25)	8.66 (0.84; 25)	595.35 (219.88; 25)	598.39 (132.41; 25)	5.29 (2.09; 25)	5.31 (1.46; 25)	24.39 (4.47; 25)	22.94 (2.23; 25)
s081.5-a	0.41 (0.11; 20)	0.41 (0.11; 20)	8.73 (0.48; 25)	8.77 (0.46; 25)	625.51 (221.76; 25)	578.01 (194.61; 25)	7.87 (2.67; 24)	7.72 (2.60; 25)	29.85 (3.79; 25)	28.91 (2.89; 25)
s094.1-a	0.77 (0.35; 16)	0.79 (0.36; 16)	7.65 (0.46; 16)	7.60 (0.42; 16)	927.06 (343.14; 16)	962.09 (431.69; 16)	3.05 (1.41; 16)	2.67 (0.82; 16)	25.96 (1.46; 16)	25.41 (0.58; 16)

Table 5. Wasteway Water Quality Summary Statistics.
Water quality summary statistics are arranged geographically (north to south). Standard deviation and sample size are given parenthetically.

Wasteway	***Flow*** ***(m/s)***	***Depth*** ***(m)***	***Ammonia*** ***(ppm)***	***pH***	***Conductivity*** ***(µs/cm)***	***Dissolved Oxygen*** ***(ppm)***	***Water Temperature*** ***(°C)***
Peralta Main Canal Wasteway	0.31 (0.22; 5)	0.38 (0.23; 5)	133.52 (153.94; 4)	7.67 (0.40; 5)	414.84 (63.12; 5)	8.80 (2.02; 3)	21.04 (8.98; 5)
Lower Peralta Riverside Drain 1	0.39 (0.33; 5)	0.61 (0.26; 5)	205.91 (269.71; 4)	7.49 (0.45; 5)	536.86 (111.13; 5)	7.25 (4.46; 3)	20.35 (3.68; 5)
Belen Riverside Drain	0.36 (0.19; 4)	0.64 (0.12; 4)	177.61 (174.80; 3)	7.97 (0.47; 4)	528.00 (25.34; 4)	8.94 (2.25; 3)	18.04 (5.62; 4)
New Belen Wasteway	0.40 (NA; 1)	0.54 (NA; 1)	204.50 (NA; 1)	7.64 (NA; 1)	514.00 (NA; 1)	6.45 (NA; 1)	17.76 (NA; 1)
Lower Peralta Riverside Drain 2	0.02 (0.04; 5)	0.56 (0.13; 5)	183.93 (230.31; 4)	7.81 (0.40; 5)	524.50 (50.21; 5)	8.44 (1.98; 3)	20.58 (6.05; 5)
Feeder 3 Wasteway	0.00 (0.00; 5)	0.94 (0.28; 5)	131.48 (199.35; 4)	7.66 (0.27; 5)	485.52 (95.47; 5)	8.02 (2.36; 3)	22.73 (6.93; 5)
Storrie Wasteway	0.22 (0.34; 4)	0.35 (0.11; 4)	118.39 (204.65; 3)	8.13 (0.34; 4)	521.98 (52.26; 4)	11.76 (3.56; 2)	22.06 (8.00; 4)
Sabinal Drain Outfall	0.27 (0.26; 3)	0.13 (0.05; 3)	198.96 (195.03; 3)	8.24 (0.76; 3)	590.30 (93.99; 3)	11.27 (4.92; 3)	21.58 (10.44; 3)
San Francisco Riverside Drain	0.15 (0.24; 3)	0.16 (0.12; 3)	0.80 (0.65; 2)	7.68 (0.33; 3)	616.80 (8.63; 2)	6.89 (3.74; 2)	22.08 (0.93; 3)
Lower San Juan Riverside Drain	0.78 (0.39; 5)	0.65 (0.19; 5)	47.70 (94.27; 4)	7.96 (0.30; 5)	588.48 (67.60; 5)	12.39 (5.22; 3)	20.76 (6.56; 5)
Unit 7 Drain	0.33 (0.12; 5)	0.94 (0.08; 5)	66.03 (130.98; 4)	7.60 (0.23; 5)	634.88 (115.16; 5)	8.89 (2.01; 3)	20.65 (6.15; 5)

Table 6. Isleta Wetted Reach Water Quality Summary Statistics.
Water quality summary statistics are arranged in ascending order by week. Standard deviation and sample size are given parenthetically.

Week	*Ammonia* (ppm)	*pH*	*Conductivity* (µs/cm)	*Dissolved Oxygen* (ppm)	*Water Temperature* (°C)
August 12 – August 18	2.00 (3.36; 14)	8.68 (0.66; 15)	580.88 (263.77; 15)	10.12 (3.50; 10)	25.78 (3.61; 15)
August 19 – August 24	0.99 (1.19; 11)	8.36 (0.33; 14)	473.53 (189.35; 14)	8.69 (2.56; 14)	23.29 (3.61; 14)
August 25 – September 1	0.33 (0.36; 9)	8.19 (0.37; 12)	471.31 (65.99; 12)	8.34 (2.24; 12)	24.93 (3.83; 12)
September 2 – September 8	0.08 (0.06; 3)	8.04 (0.74; 7)	533.01 (117.23; 7)	7.69 (1.00; 7)	22.08 (3.42; 7)
September 9 – September 15	23.73 (45.46; 13)	8.63 (0.51; 14)	443.23 (65.77; 14)	9.72 (2.99; 13)	22.53 (3.78; 14)
September 16 – September 22	173.81 (108.66; 4)	8.65 (0.65; 9)	403.69 (67.27; 9)	8.74 (1.95; 7)	20.96 (2.80; 9)
September 23 – September 29	17.17 (NA; 1)	8.19 (NA; 1)	512.30 (NA; 1)	7.63 (NA; 1)	19.25 (NA; 1)
September 30 – October 6	13.80 (3.00; 3)	8.32 (0.19; 3)	492.70 (42.03; 3)	8.01 (0.97; 3)	19.00 (1.75; 3)

Ammonia concentration was generally well below the critical values provisionally offered by Buhl (2006). A significant increase in ammonia concentration was observed among all samples taken after September 15, 2007. However, due to problems in calibrating the water quality probe, it is unknown whether these study results are indicative of the true existence of a water quality environmental stressor.

Often environmental stressors are defined on the basis of the synergistic effects of two or more variables (e.g., temperature and dissolved oxygen, and ammonia and pH). For this reason, bi-variate plots of water quality variables and water temperature were examined for extremes in paired values that could be linked to fish mortality (Appendix I). From these plots, it appears that high pH and high ammonia can at times be problematic in the Middle Rio Grande because the relative amounts of ammonia in the form of ammonium hydroxide (NH_4OH), which is highly toxic to fish, increases exponentially with pH. However, due to problems in calibrating the ammonia probe, it is equivocal if these results are indicative of a water quality environmental stressor. Additional investigation is needed to determine whether high ammonia concentration, especially coupled with high pH, is a recurring phenomenon in the Middle Rio Grande.

DISCUSSION

ENVIRONMENTAL VARIATION AND SPECIES ADAPTATION

Ecologically, floods and drought represent flow disturbance regimes in the Middle Rio Grande that serve to differentially advantage or disadvantage species, thereby regulating species diversity and species abundance over variable scales of time and space (e.g., Eby et al. 2003). Frequent and predictable extremes in flow tend to operate selectively to produce life history strategies in native fish species that optimize the allocation of resources to critical life functions, notably including maintenance, growth, and reproduction. Adaptive traits emerge over evolutionary time that enables species to survive flow disturbance regimes within the limits of natural selection (Lytle and Poff 2004), which for this paper is conceptually defined as frequent-occurring extremes in pre-development environmental variation.

The mode of adaptation determines an organism's vulnerability to flow patterns, including disturbance regimes. Generalist species tend to dominate variable discharge running water ecosystems in response to uncertainty of critical resources, whereas ecological specialists tend to be more common in streams that have predictable discharge (Horwitz 1978; Poff and Allan 1995). Species exposed to strong environmental variation within generations often exhibit a broad tolerance to diverse conditions through physiological flexibility (Levins 1968; Matthews 1987), generalized feeding strategies, and preference for low water velocity.

Understanding the links between species' fitness and flow regime is crucial for the effective management and restoration of running water ecosystems. Based on species relative abundance observed in pools of the Middle Rio Grande, it seems logical that the less common fish species (e.g., centrarchid and percid species) are disadvantaged in the specific areas sampled.[4] In contrast, the more common species (e.g., red shiner, river carpsucker, channel catfish, western mosquitofish, and silvery minnow) seem advantaged in this setting relative to the less common species. Ostrand

[4] A decrease in flow variability in a small Sonoran Desert stream has been linked to an increased likelihood of the establishment of exotic fish species (Eby et al. 2003).

and Wilde (2001) reached a similar conclusion about the links between the fitness of prairie stream fish species and select water chemistry parameters in isolated pools of the upper Brazos River, Texas.

The results of this study, coupled with those reported by Buhl (2006), suggest that the silvery minnow is physiologically flexible—capable of surviving absolute extremes and diel fluctuations in chemical and physical conditions. Short of complete or near desiccation of habitat, the silvery minnow exhibits a capacity to withstand the wide variety of environmental conditions common to the monitored pools over the periods of observation. Likewise, for the parameters monitored, the quality of water that returns to the Rio Grande at multiple points along the MRGCD irrigation system generally did not exceed provisional critical threshold values for silvery minnow survival (Buhl 2006). The exception to this generalization concerns high ammonia readings beginning September 15, 2007. However, due to problems in calibrating the ammonia probe, it is unknown whether these study results are indicative of the true existence of an environmental stressor. Additional investigation is needed to determine whether high ammonia concentration, especially coupled with high pH, is a recurring phenomenon in the Middle Rio Grande.

ENVIRONMENTAL STABILITY OF ISOLATED POOLS

Longer and deeper pools with abruptly steep sides (i.e., low surface area to depth ratio) were found to be inherently superior as refugial habitats for fish due primarily to their enhanced temporal environmental stability compared to smaller pools. Baker and Ross (1981), Gorman (1988a, 1988b), and Labbe and Fausch (2000) all reported similar relationships between environmental stability and water depth. We found that larger pools tended to support a greater diversity of fish species, which is conducive to the maintenance of stable and persistent fish assemblages. Plausible mechanistic explanations for this relationship include habitat selection coupled with habitat heterogeneity, and increased probabilities of local extinction in small areas (e.g., MacArthur and Wilson 1967). A similar relationship may exist between species abundance and habitat size; however, this study was not designed to yield quantitative expressions of species abundance. Our study results do not indicate a relationship between pool size and fish health, although this is more likely a function of the relatively low incidence of readily apparent health-impaired fish.

Logically, environmental stability of prospective refugial pools would be enhanced to the degree that they are periodically refreshed with water from unpolluted surface or groundwater sources. Likewise, the incidence of fish disease would be expected to be negatively correlated with increased rates of water exchange and reduced crowding of fish. Also, in concurrence with Power (1987), it was generally observed that deep, steep-sided pools offered greater protection against avian predators compared to shallow, high width-to-depth ratio pools.

Corroborating the findings of Detenbeck et al. (1992), we found that pools adjacent to flowing river segments had a heightened degree of environmental stability and, due to proximity, had a heightened potential for rapid fish recolonization, especially by silvery minnows given their apparent high vagility as observed in this study. It is hypothesized that closely spaced pools, aligned with the thalweg and at intervals no greater than five to seven times the active channel width,[5] are of particular importance to conservation purposes because they would allow for

[5] The theoretical longitudinal pool-riffle spatial sequencing in unbound rivers is five to seven times the stream width (Leopold and Langbein 1966).

dispersal success of silvery minnows and would serve to reduce silvery minnow mortality that often attends pulsed (short-term), small volume, expansion–contraction flow disturbances.[6] Such reserve design considerations are consistent in concept with the ideas advanced by Diamond (1975).

The variability of flow characteristics of the contemporary Middle Rio Grande, resulting either from natural or regulated causes, imparts a patchiness of environmental types at the scale of river segments, including the extremes represented by hydrologic abundance and periodic discontinuity of flow, with a continuum of intermediate (or transitional) types between these extremes. Areas with long-term flow patterns that would rank among the wetter intermediate environmental types are of particular managerial interest because provision and periodic maintenance of wetted habitat, including in the form of large and deep isolated pools, is more feasible in such areas, especially when hydrological resources are limited. In general terms, wetter transitional areas in the Isleta Reach include the segment from Isleta Diversion Dam to the approximate vicinity of Los Lunas, and the segment downstream of the Peralta irrigation wasteway (synthesized from multiple sources, including U.S.G.S. flow records; unpublished [River Eyes] observations of hydrologic conditions; and U.S. Fish and Wildlife Service 2006 and 2007). In the San Acacia Reach, these areas include the segment from San Acacia Diversion Dam to Socorro, and the segment downstream of the south boundary of Bosque Del Apache Wildlife Refuge (synthesized from multiple sources, including U.S.G.S. flow records; unpublished [River Eyes] observations of hydrologic conditions; Wilcox et al. 2007; and U.S. Fish and Wildlife Service 2006 and 2007). However, maintenance of wetted habitat in all of these segments will often require the release of water over irrigation diversion dams and/or periodic supplementation of water from the irrigation infrastructure or other sources by various mechanical means (e.g., pumping or via irrigation outfalls).

The fact that habitat patch quality in the Middle Rio Grande is heterogeneous and that the silvery minnow differentially occupies different kinds of patches is an important determinant of long-term population trajectories. It is important to understand how demographic processes that affect population size vary over the array of available habitat patch types. In simple terms, population growth can be regarded as a function of reproduction, recruitment, age-specific schedules of mortality, and rates of dispersal in the form of immigration and emigration. Areas or locations where local reproductive success is greater than local mortality are referred to as population *sources*.[7] Poorer quality patches that lead to low birth rates and high death rates are regarded as population *sinks*. To understand the patch-dynamics of a population in which some individuals reside in source habitats and others reside in sink habitats, it is necessary to consider the population dynamics of each source and sink subpopulation, and then consider how the distribution of

[6] The U. S. Fish and Wildlife Service (2006) reported that a diurnal expansion–contraction cycle often attends river recession. The rate and timing of this cycle varies with rates and timing of evaporation and transpiration. As such, the upstream extent of river recession generally fluctuates diurnally, sometimes by as much as a mile per day. This phenomenon generally serves to reduce mortality of silvery minnows by refreshing/replenishing the supply of water in isolated pools at the upstream terminus of river recession. However, silvery minnow mortality can attend any event of river contraction, including that associated with the diurnal expansion–contraction cycle (U. S. Fish and Wildlife Service 2006).

[7] Inference about habitat suitability requires knowledge about species abundance and rates of vital biological processes along with knowledge about how long-term patch-dynamics are structured by underlying physical, chemical, and climatic features of their environment.

individuals in sources and sinks influences the dynamics of the greater source–sink system. In reality, mapping of silvery minnow source-sink population segments exclusively on the basis of population demographics will be effectively impossible. However, incorporation of auxiliary information relevant to the mortality-causing disturbance mosaic and gradients of habitat conditions should provide a robust and managerially meaningful basis for partitioning silvery minnow population sources and sinks.

RISK OF EXTINCTION

Patterns of silvery minnow abundance by age class are consistent with a Type III survivorship curve (derived from U.S. Fish and Wildlife Service 2006, 2007), indicating that future population growth or decline will be modulated most profoundly by the younger age classes. Habitats designed to reduce the mortality of future parental stock, often by even a few percent, can have profound effects on future population trajectories. An exponential increase in the number of silvery minnows, observed in surveys for fish that coincided with channel-drying events over the period of 2003 to 2005 (U.S. Fish and Wildlife Service 2006, 2007), suggests that the species has an inherent capacity for high (exponential) rates of population growth, apparently operational over a wide range of parental stock abundance. However, periodic drought related perturbations have resulted in immediate reductions in silvery minnow abundance and weak age classes with negative consequences for population viability (i.e., viable population size increases with age class failures; Cowley 2007).

The number, quality, and spatial arrangement of habitat features, along with inter- and intra-patch dispersal capability, factor prominently in the ability of the silvery minnow to survive the effects of mortality-causing drought. In a temporally varying environment such as the Middle Rio Grande of New Mexico, the long-run population growth rate governs the vulnerability of a population to extinction. This concept is expressed mathematically as $r - Ve / 2$, where r is the intrinsic rate of population growth and Ve is the between-generation variance of population growth rate (National Research Council 1995). When $Ve / 2 > r$, the population will decline toward extinction deterministically. The expected time to extinction will vary with population size, depending on the ratio of the mean to the variance of the rate of population growth: $\sim r / Ve$ (National Research Council 1995). Age class strength and rates of population growth and mortality of the contemporary silvery minnow population are known to be highly variable in time and space, primarily due to stochastic environmental processes (e.g., drought) and density-dependent compensatory changes[8] in population growth rates. As a general rule of conservation biology, the greater the environmentally-driven fluctuations in population growth rate, the greater the risk of extirpation at early time horizons (Morris et al. 1999).

A SYNTHESIS OF KEY REFUGIAL HABITAT FEATURES

An overarching theme of the foregoing discussion pertains to the spatial structure of silvery minnow populations. Spatially structured populations are generically referred to as "metapopulations." The metapopulation concept is an important paradigm in conservation biology. A population's spatial structure depends fundamentally on habitat quality, spatial configuration of subpopulations, and dynamics of species abundance, as well as the dispersal characteristics of

[8] Deterministic density effects fall into two competing processes: compensation (an increase in productivity with decreasing density) and depensation (a decrease in productivity with decreasing density).

individuals in a population. Effective recovery efforts for species inhabiting variable environments require the consideration of processes operating at multiple scales, ranging from landscape-level processes that create and maintain refugia, to fine-scale processes that govern local features of habitat regardless of overarching patterns of the river continuum (Labbe and Fausch 2000; Vannote et al. 1980). Clearly, the foregoing discussion of refugial habitats for silvery minnow is pivotal to the species' metapopulation structure and is of critical concern for species conservation. These concepts represent a logical basis for formulating intervention strategies intended to enhance the short and long-term prospects of species survival—intervention strategies that complement the species' life history, targeting age-specific schedules of reproduction, recruitment, and mortality. Pivotal concepts that pertain to the provision of refugial habitats for silvery minnow conservation include the following:

Source–Sink Population Structure—Source–sink theory is dependent on the identification of habitat patch types and understanding how silvery minnow population dynamics are structured by underlying physical, chemical, and climatic features of the local environment. The spatio-temporal dynamics of wetted habitat offers clues of the relative ease (or difficulty) of maintaining refugia for the silvery minnow. The frequency and interval duration of river expansion–contraction cycles, along with the extent of perennial habitat created by a given volume of water, are metrics of evaluation that would likely be useful in identifying sites where the maintenance of refugia would prove to be most economical in terms of required water resources. Likewise, areas where the abundance of silvery minnows is greatest would theoretically represent areas where the development and maintenance of refugia would prove most beneficial to the species. The areas in which the paired values for the suggested metrics of evaluation are greatest would conceivably represent the locations where silvery minnow refugia can be developed and maintained most economically and advantageously.

The most important influence of the spatial arrangement of habitat types on overall species viability is the extent to which populations of silvery minnow at different sites share the same fate at the same time. The number, quality, and spatial arrangement of habitat patches factor prominently in the ability of the silvery minnow to withstand the effects of a mortality-causing drought. The risk of extinction is reduced with an increased number of high-quality (extinction resistant) populations with independent fates. The larger perennial patches offer a heightened level of resistance to mortality that often accompanies low or nonexistent river flows. Such habitats have the capacity to support silvery minnow across generations and often exist as the source stock to repatriate empty habitat patches (Lake 2003). Habitat patches that are subject to periodic discontinuity of flow are expected to vary in their ability to serve as silvery minnow refugia, as manifested in the frequency, magnitude, and predictability of mortality-causing events.

The implications of diminished wetted habitat for the conservation of the silvery minnow will be different for river segments designated as population sources versus population sinks. Naturally, the loss of habitat that affects source populations will have a greater impact on long-term population trajectories than it would on sink populations. It is imperative that every effort be made to identify and conserve source populations in an effort to maximize overall capacity for population growth.

Lateral Distribution of Prospective Refugial Habitats—The period of pool isolation is an important consideration in the provision and maintenance of refugial pools. As running water habitats recede in the Middle Rio Grande, the period of pool isolation tends to be longer for those positioned lateral and distal to the thalweg as opposed to those aligned with or adjacent to the thalweg. As such, pools associated with the thalweg will inevitably exhibit greater environmental stability over a longer period. They would certainly be aligned with dispersal corridors during periods of low flow.

However, inundated floodplains, including isolated pools in and adjacent to the floodplain, can factor prominently in silvery minnow conservation so long as connectivity with main channel running water habitats can be restored periodically to prevent silvery minnow mortality. Galat et al. (2004) found that larval fish taxa richness increased in lateral pools of the lower Missouri River with increased degrees of coupling with running water due largely to the addition of rheophilic larval taxa, including *Hybognathus* species. Usually, inundated floodplains provide heightened heterogeneity of habitat and structural refugia for developing fish species relative to the active channel (Valett et al. 2005). Growth of silvery minnows can be especially rapid in newly flooded habitats that support highly productive food chains founded on the bacterial conditioning of retained fine and course particulate organic material and newly inundated terrestrial vegetation. Heightened floodplain productivity is further enhanced by the lower water exchange rates, heightened allochthonous energy inputs, and heightened temperatures characteristic of such areas (Schlosser 1991; Valett et al. 2005). It has been observed that, barring habitat desiccation or extended periods (e.g., several consecutive days) of mortality-causing extremes of water quality, the overall health of silvery minnows from floodplain pools can be better than the health of silvery minnows from adjacent main channel habitats (Michael Hatch, SWCA, personal communication 2007). This observation seems logical considering that silvery minnows will focus much of their foraging on diatom-rich periphyton communities associated with finer sediments that typically characterize floodplain habitats (Cowley et al. 2006). It is believed that inundated floodplain habitats factor prominently in the survival and growth of larval and older silvery minnows, not just due to the heightened productivity of such areas, but also because reduced water velocity habitats that typify the margins of rivers, especially flood terraces, are conducive to energy conservation—a general life strategy shared by many lotic fish species (Facey and Grossman 1992).

Longitudinal Spacing of Pools—The theoretical longitudinal pool-riffle spatial sequencing in unbound rivers is five to seven times the stream width (Leopold and Langbein 1966). Earlier it was hypothesized that this spacing of refugial pools would allow for dispersal success of silvery minnows and would serve to reduce silvery minnow mortality that often attends pulsed (short-term), small volume, expansion–contraction flow disturbances. In sand bed rivers, high sediment transport discharges are required to rework geomorphic surfaces that constitute the silvery minnow's habitat, including large and deep refugial pools (approximately 50-75 cm s^{-1} for coarse sand; Allan 1995). This geomorphic process is enhanced by flow-deflecting objects (e.g., large woody debris), which serve to focus pool-scouring water velocity. Ideally, the incorporation of large woody debris (snags) in a restoration project would be guided by estimates of the density of such habitat features before the Middle Rio Grande was channelized. Unfortunately, we have been unable to locate similar data for the Rio Middle Rio Grande. As a surrogate, Sedell and Beschta (1991) offer early settlement records of the number of snags per kilometer for other large sand bed rivers, although that report includes few records for southwest rivers.

Pool Morphology—Longer and deeper pools with abruptly steep sides (low surface area to depth ratio) were found to be inherently superior as refugial habitats for fish due primarily to their enhanced temporal environmental stability compared to smaller pools. Pools that are at least 1.5 m deep and at least 25 m on their long axis are common in the Middle Rio Grande following sustained high discharge.

Functioning Condition and Habitat Coverage—Spatial characteristics of theoretical randomly generated landscape models suggest that a species should be able to disperse from one suitable habitat patch to another so long as such habitat patches constitute more than 58 percent of the total available patches (Gardner et al. 1987). However, the distribution of suitable habitat patches in the Middle Rio Grande deviates from random spatial patterns, especially as flow in the river becomes discontinuous. How the distribution of suitable habitat patches deviate from a random spatial pattern is useful for revealing how ecosystems function, or fail to function, without the confounding effects of other biological or physical processes. With absolute reduction and non-random distribution of suitable habitat patches, a significantly higher proportion of the remaining habitat (nearly 100 percent) must be maintained as suitable to effectively achieve a functioning condition nearly equivalent to that of a random spatial model with a suitable habitat threshold set at 58 percent (Figure 19).

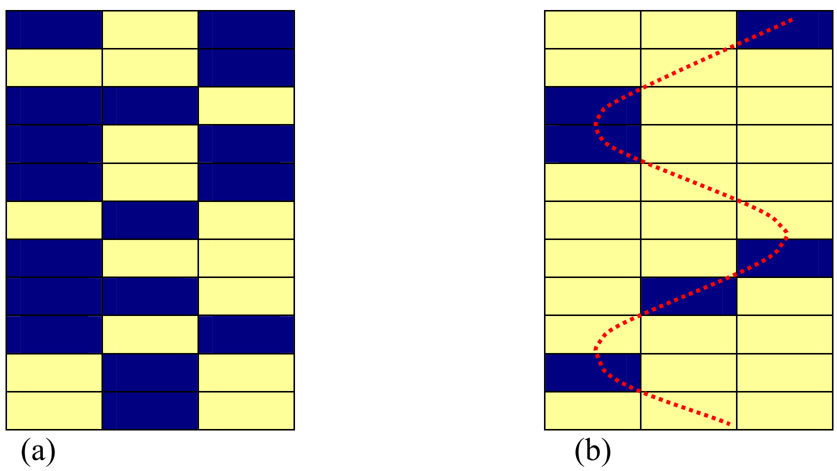

Figure 19. Hypothetical landscape model depictions of a river segment. Randomly generated landscape patterns created in Microsoft Excel depict relative degrees of habitable coverage (i.e., cells shaded blue) for a hypothetical river reach. Panel (a) represents a river segment with the potential for habitable cells that spans the bankfull width, whereas (b) depicts a river segment in which the potential for wetted habitat is reduced to the thalweg (depicted by the red dashed line). Connectivity between habitable cells is generally maintained at a coverage threshold of 0.58 in (a). Where the potential for wetted habitat is restricted to the thalweg as in (b), a probability of habitable coverage of nearly 1.0 is required to achieve a functional condition equivalent to (a).

Habitat Refreshing—Periodic influx of water to refugial pools from unpolluted surface or groundwater sources is necessary for the maintenance of suitable water quality and to reduce the incidence of fish mortality due to disease. The periodic need for water refreshing/replenishing will vary inversely with the longitudinal spacing of pools and with pool depth and size.

INFORMATION NEEDS AND FUTURE RESEARCH

Most contemporary investigations of silvery minnow life history are relevant to a limited subset of the environmental conditions that would have likely served as a selective basis for life-history adaptation. This incomplete perspective is largely a consequence of anthropogenic regulation of hydrologic conditions in the Middle Rio Grande, resulting in contemporary measures of central tendency and variation of discharge that deviate from pre-impoundment conditions, along with altered fluvial processes and basin geomorphology. Observations of the silvery minnow under such restrictive conditions can easily lead to misinterpretation of its needs and misidentification of causes for observed phenomenon.[9] Knowledge of the habitat conditions under which the silvery minnow would be reasonably expected to maintain viable populations is vital to efforts to manage for a functioning condition that is aligned with fitness characteristics of the species.

Information deficits presently preclude credible inferences about habitat limitation based on accurate information on the quantity and distribution of different habitats available to the silvery minnow along with direct measures of the consequences (growth, survival, fecundity, reproductive success) of occupying different habitat types. The role of habitat in limiting silvery minnow population abundance and growth can best be understood by considering habitat effects over successive life stages because of differential life stage utilization of available habitats over variable discharge regimes (Halpern et al. 2005). Silvery minnow spawning and recruitment to the juvenile stage tends to vary positively with high-discharge events during spring and summer, especially discharge levels that inundate the floodplain. Recruitment to the adult life stage varies with habitat type, habitat quantity and quality, and the continuity of surface water habitat in time and space. Conditions of drought coupled with extractive use of water frequently results in the loss of multiple expansive segments of running water habitat in the Middle Rio Grande as the principal proximate factor linked to significant silvery minnow mortality. In each instance, life stage dynamics are linked to population consequences of habitat loss or gain. The probability that an individual will survive to reproduce will be the product of a series of stage-specific survival probabilities that depend on habitat conditions experienced by each life stage. Under normal contemporary conditions of environmental variation, successive life cycle stages represent unique leverage opportunities for directed management to enhance the long-term probability of species survival.

Planning for the provision of refugial habitats to overcome drought-associated habitat limitations requires that a quantitative relationship between habitat and population size be established for the species, and that sufficient habitat be maintained to meet an established recovery target based on the habitat-population relationship. For silvery minnow, this relationship, although unquantified, is

[9] Some of the more pivotal advancements in elucidating adaptive aspects of the silvery minnow's life history and behavior come from recent observations of the species over successive years of contrasting and extreme hydrologic conditions — conditions unusual to the contemporary Middle Rio Grande, but nonetheless reflective of an undeveloped Middle Rio Grande. Only under such variable and extreme environmental circumstances can one hope to learn about silvery minnow life history traits and behaviors that appear to be adaptive to hydrologic extremes such as the occupation or avoidance of various drought or flood-prone habitats.

known to vary profoundly by life stage and with varying hydrologic circumstances. As such, habitat-population relationships will be complicated by the necessary consideration of stage-specific estimates of survival (i.e., the fraction of the population that successfully recruits to each life history stage) and separate relationships between habitat and abundance for each life stage over a range of hydrologic conditions.

The importance of each population segment to species persistence will depend on relative rates of birth, death, growth, and survival, and various expressions of habitat quality, including habitat size and stability, and a suite of associated natural and anthropogenic threats. Distinguishing between source and sink populations is fundamental in the process of identifying populations essential for species persistence. Failure to distinguish this dichotomy among silvery minnow populations may result in protection of sinks instead of sources and unrealistic assessments of extinction risk. Likewise, identification of threats for different populations is essential for determining which populations are critical for species persistence, and whether recovery actions need to focus on increasing population size and habitat quality or on reducing risk from human impacts.

Large water impoundments combine with sediment and flood control structures and large-scale extractive use of water to profoundly alter the landscape-level fluvial processes that formerly operated to maintain physical habitat features common to the pre-development Middle Rio Grande. From historic records of fish collections in the Middle Rio Grande (Sublette et al. 1990), we can surmise that pre-development habitat features of the Middle Rio Grande were aligned with fitness characteristics of a diverse native ichthyofauna, including the silvery minnow. Such discrete habitat features will persist only if the processes that generate them are maintained in a broader landscape context. Unfortunately, the practicality of this seems precluded by the contemporary constraints of large-scale water development on geomorphic processes in the basin coupled with water scarcity, a condition exacerbated by frequent recurring conditions of drought. As such, research is needed to identify alternate means of creating and maintaining desired discrete habitat features that will serve the needs of different life stages of the silvery minnow over a broad range of hydrologic conditions.

Several options exist to achieve a desired outcome involving refugia to protect against mortality-causing drought (emphasizing the need to conserve source populations). It seems possible that critical reaches of wetted surface habitat can be maintained over short periods of intermittent flow by strategic utilization of the irrigation infrastructure of the Middle Rio Grande to surgically convey water, ancillary to consumptive needs, to various delivery points along the river. Likewise, strategically placed wells could be used for the same purpose with a heightened assurance of water delivery to meet critical time- and space-dependent needs. These engineered hydrological measures can be coupled with measures to enhance geomorphic processes utilizing flow-deflecting structures (e.g., large woody debris or other revetment structures) which serve to focus pool-scouring water velocity. Experimental design should focus on a variety of refugial habitat designs comprising several spatial configurations. Fundamental aspects of evaluation should include considerations of efficiency and effectiveness including conditions under which a management alternative will succeed or fail and considerations of longevity of benefits. The best indices of habitat quality are direct measures of the fitness consequences to individuals (growth, survival, fecundity, reproductive success) of using different habitat types, ideally in the absence of competition (i.e., at low density).

REFERENCES CITED

Allan, J. D. 1995. Stream ecology – structure and function of running waters. Chapman and Hall. New York.

Baker, J. A. and S. T. Ross. 1981. Spatial and temporal resource utilization by southeastern Cyprinids. Copeia 1981:178–179.

Balon, E. K. 1975. Reproductive guilds of fishes: a proposal and definition. Journal of the Fisheries Research Board of Canada 32:821–864.

Balon, E. K. 1987. On decisive events in the early life history of fishes and the pertinence of such events to the functional grouping of fishes according to their susceptibility to impact. pp. 5-1–5-34. *In* Mechanisms of Compensatory Response of Fish Populations: Workshop Proceedings. Electric Power Research Institute, Inc.

Buhl, K. J. 2006. Toxicity of adverse water quality conditions of low dissolved oxygen, high temperature, and pulses of high ammonia concentrations to different life stages of the Rio Grande silvery minnow. Abstract. P324, 27th Annual Meeting Society of Environmental Toxicology and Chemistry, Montreal, Quebec.

Copes, F. A. 1975. Ecology of the brassy minnow, *Hybognathus hankinsoni* (Cyprinidae). University of Wisconsin Stevens Point Museum of Natural History Reports on the Fauna and Flora of Wisconsin 10. Contributions to Ichthyology: 47–72.

Copp, G. H. 1989. The habitat diversity and fish reproductive function of floodplain ecosystems. Environmental Biology of Fishes. 26:1-27.

Cowley, D. E. 2007. Estimating required habitat size for fish conservation in streams. Aquatic Conservation: Marine and Freshwater Ecosystems.

Cowley, D. E., P. D. Shirey, and M. D. Hatch. 2006. Ecology of the Rio Grande Silvery Minnow (Cyprinidae: *Hybognathus amarus*) inferred from specimens collected in 1874. Reviews in Fisheries Science 14:111–125.

Detenbeck, N. E, P. W. DeVore, G. J. Niemi, and A. Lima. 1992. Recovery of temperate-stream fish communities from disturbance: a review of case studies and synthesis of theory. Environmental Management 16:33–53.

Diamond, J. M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of natural reserves. Biol. Conserv. 7:129–146.

Dudley, R. K. and S. P. Platania. 1997. Habitat use of Rio Grande silvery minnow. Report to U.S. Bureau of Reclamation, Albuquerque, New Mexico. 88 pp.

Dudley, R. K., and S. P. Platania. 2007. Flow regulation and fragmentation imperil pelagic spawning riverine fishes. Ecological Applications 17(7), 2007, 2074–2086.

Eby, L. A. W. F. Fagan, and W. L. Minckley. 2003. Variability and dynamics of a desert stream community. Ecological Applications. 13(6):1566-1579.

Facey, D. E. and G. D. Grossman. 1992. The relationship between water velocity, energetic costs, and microhabitat in four North American stream fishes. Hydrobiologica 239:1–6.

Federal Register. 1994. Endangered and threatened wildlife and plants: final rule to list the Rio Grande silvery minnow as an endangered species. 50 CFR Part 17, RIN 1018-AB88. July 20, 1994. 59(138):36988–36995.

Galat, D. L., G. W. Whitledge, L. D. Tatton, and J. Hooker. 2004. Larval fish use of lower Missouri River scour basins in relation to connectivity. Final report to Missouri Department of Conservation. Columbia, Mo.

Gardner, R. H., B. T. Milne, M. G. Turner and R. V. O'Neill. 1987. Neutral models for the analysis of broad-scale landscape patterns. Landscape Ecology 61:603–610.

Gorman, O. T. 1988a. An experimental study of habitat use in a guild of Ozark minnows. Ecology 69:1239–1250.

Gorman, O. T. 1988b. The dynamics of habitat use in a guild of Ozark minnows. Ecological Monographs 58:1–18.

Halpern, B. S., S. D. Gaines, and R. R. Warner. 2005. Habitat size, recruitment, and longevity as factors limiting population size in stage-structured species. American Naturalist 165:82–94.

Horwitz, R. J. 1978. Temporal variability patterns and the distribution patterns of stream fishes. Ecological Monographs 48:307–321.

Junk, W. J., P. B. Bayley and R. E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Pages 110-127 in D. P. Dodge (ed.). Proceedings of the International Large River Symposium. Canadian Special Publication of Fisheries and Aquatic Science 106.

Junk, W. J. and R. L. Welcomme. 1990. Floodplains. Pages 491-524 in B. C. Patten et al. (eds.). Wetlands and Shallow Continental Water Bodies. SPB Academic Publishing, The Hague, Netherlands.

Labbe, T. R. and K. D. Fausch. 2000. Dynamics of intermittent stream habitat regulate persistence of a threatened fish at multiple scales. Ecological Applications, 10(6), 2000, 1774-1791.

Lake, P. S. 2003. Ecological effects of perturbation by drought in flowing waters. Freshwater Biology (2003) 48, 1161-1172.

Lehtinen, S. F. and J. B. Layzer. 1988. Reproductive cycle of the plains minnow, *Hybognathus placitus* (Cyprinidae), in the Cimarron River, Oklahoma. The Southwestern Naturalist 33(1):27-33.

Leopold, L. B. and W. B. Langbein. 1966. River meanders. Scientific American 214:60–70.

Levins, R. 1968. Evolution in changing environments: some theoretical explorations. Monographs of Population Biology 2, Princeton University Press, Princeton, New Jersey.

Lytle D. A., and N. L. Poff. 2004. Adaptation to natural flow regimes. Trends in Ecology and Evolution. 19:2.

MacArthur, R. H., and E. O. Wilson.1967. The theory of island biogeography. Princeton Univ. Press, Princeton, N.J.

Matthews, W. J. 1987. Physicochemical tolerance and selectivity of stream fishes as related to their geographic ranges and local distributions. *In* Community and Evolutionary Ecology of North American Stream Fishes, W. J. Matthews and D. C. Heins, eds. University of Oklahoma Press, Norman. pp. 111–120.

Morris, W., D. Doak, M. Groom, P. Kareiva, J. Fieberg, L. Gerber, P. Murphy, and D. Thomson. 1999. A practical handbook for population viability analysis. The Nature Conservancy.

Moyle, P. B. and D. M. Baltz. 1985. Microhabitat use by an assemblage of California stream fishes: developing criteria for instream flow determinations. Transactions of the American Fisheries Society 114:695–704.

National Research Council. 1995. Science and the Endangered Species Act. National Academy Press. Washington D.C.

New Mexico Department of Game and Fish. 1988. Handbook of Species Endangered in New Mexico. Santa Fe, New Mexico.

Ostrand, K. G., and G. R. Wilde. 2001. Temperature, dissolved oxygen, and salinity tolerances of five prairie stream fishes and their role in explaining fish assemblage patterns. Transactions of the American Fisheries Society. 130:742-749.

Pease, A. A., J. J. Davis, M. S. Edwards and T. F. Turner. 2006. Habitat and resource use by larval and juvenile fishes in an arid-land river (Rio Grande, New Mexico). Freshwater Biology: 1–12.

Poff, N. L. and J. D. Allan. 1995. Functional organization of stream fish assemblages in relation to hydrological variability. Ecology 76:606–627.

Power, M. E. 1987. Predator avoidance by grazing fishes in temperate and tropical streams: importance of stream depth and prey size. *In* Predation, W. C. Kerfoot and A. Sih, eds. University Press of New England, Hanover, New Hampshire. pp. 333–351.

Pulliam, H. R. 1988. Sources, sinks, and population regulation. American Naturalist. 132: 652-661.

Raney, E. C. 1939. The breeding habits of the silvery minnow, *Hybognathus regius*. American Midland Naturalist 21:674–680.

Schlosser, I. J. 1991. Stream fish ecology: a landscape perspective. Bioscience. 41, 704-712.

Sedell, J. R. and R. L. Beschta. 1991. Bringing back the “Bio” in Bioengineering. American Fisheries Society Symposium 10:160-175.

Shirey, P. D. 2004. Foraging habits and habitat utilization of Rio Grande silvery minnow (*Hybognathus amarus*) as inferred by diatom frustules. Thesis, New Mexico State University.

Shirey, P. D., D. E. Cowley, and R. Sallenave. 2007. Diatoms from gut contents of museum specimens of an endangered minnow suggest long-term ecological changes in the Rio Grande (USA). J. Paleolimnol. DOI 10.1007/s10933-007-9156-4.

Starrett, W. C. 1950. Food relationships of the minnows of the Des Moines River, Iowa. Ecology 31:216–233.

Sublette, J. E., M. D. Hatch, and M. Sublette. 1990. The Fishes of New Mexico. University of New Mexico Press. Albuquerque.

U.S. Bureau of Reclamation and U. S. Army Corps of Engineers. 2003. Programmatic Biological Assessment of Bureau of Reclamation's Water and River Maintenance Operations, Army Corps of Engineers' Flood Control Operation, and Non-Federal Actions on the Middle Rio Grande, New Mexico March 1, 2003–February 28, 2013. Albuquerque, New Mexico.

U.S. Fish and Wildlife Service. 2003. Biological and Conference Opinions on the Effects of Actions Associated with the Programmatic Biological Assessment of Bureau of Reclamation's Water and River Maintenance Operations, Army Corps of Engineers' Flood Control Operation, and Related Non-Federal Actions on the Middle Rio Grande, Albuquerque, New Mexico. Consultation No. 2-22-03-F-0129. March 17, 2003.

U.S. Fish and Wildlife Service. 2006. Rio Grande Silvery Minnow Rescue and Salvage—Fiscal Year 2005. Interagency Agreement 02-AA-40-8190. U. S. Fish and Wildlife Service, N.M. Ecological Services Field Office, Albuquerque, New Mexico.

U.S. Fish and Wildlife Service. 2007. Rio Grande silvery minnow rescue and salvage—Fiscal Year 2006. Interagency Agreement 02-AA-40-8190. U. S. Fish and Wildlife Service. New Mexico Ecological Services Field Office, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

Valett, H. M., M. A. Baker, J. A. Morrice, C. S. Crawford, M. C. Molles, Jr., C. N. Dahm, D. L. Moyer, J. R. Thibault, and L. M. Ellis. 2005. Biological and metabolic responses to the flood pulse in a semiarid floodplain. Ecology 86(1):220–234.

Van Dam, H,. A. Mertens, and J. Sinkeldam. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Science 28:117–133.

Vanote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. Canadian Journal of Aquatic Science.37:130-137.

Widmer, A. E., J. W. Kehmeier, and J. J. Fluder. 2007. Characterization of Rio Grande Silvery Minnow Egg and Larval Drift and Retention in the Middle Rio Grande. SWCA Environmental Consultants, Albuquerque, N.M.

Wilcox, L. J., R. S. Bowman, and N. G. Shafike. 2007. Evaluation of Rio Grande management alternatives using a surface-water/ground-water model. Journal of the American Water Resources Association. Vol. 43, No. 6: 1595–1603.

Wootton, R, J, 1990. Ecology of teleost fishes. Chapman and Hall. New York.

Appendix A
Isolated Pool Fish Community Health Data

Appendix A1. Report of the Number of Fish Observed by Species and Site during July 2007 Monitoring.

			Day of Month																														
Site		**Species**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
S076.8-A	1	*Carpiodes carpio*	---	10	12	4	26	7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	2	*Cyprinella lutrensis*	---	26	47	54	102	26	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	3	*Cyprinus carpio*	---	9	10	5	---	15	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	4	*Dorosoma cepedianum*	---	2	1	3	3	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	5	*Gambusia affinis*	---	45	20	13	50	9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	6	*Hybognathus amarus*	---	---	11	41	1	39	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	7	*Ictalurus furcatus*	---	4	4	2	4	8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	8	*Ictalurus punctatus*	---	5	2	11	6	11	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	9	*Micropterus dolomieu*	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	10	*Micropterus salmoides salmoides*	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	11	*Percina macrolepida*	---	1	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	12	*Pimephales promelas*	---	---	4	---	---	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	13	*Platygobio gracilis*	---	2	2	---	1	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	14	*Pylodictis olivaris*	---	---	1	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	15	*Unknown*	---	44	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S081.5-A	1	*Carpiodes carpio*	---	13	12	111	48	23	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	2	*Cyprinella lutrensis*	---	73	35	47	24	36	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	3	*Cyprinus carpio*	---	8	---	16	2	6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	4	*Dorosoma cepedianum*	---	2	2	1	11	11	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	5	*Gambusia affinis*	---	11	8	18	38	9	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	6	*Hybognathus amarus*	---	1	2	3	---	23	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	7	*Ictalurus furcatus*	---	8	---	3	4	8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	8	*Ictalurus punctatus*	---	1	40	142	---	45	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	9	*Percina macrolepida*	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	10	*Pimephales promelas*	---	---	---	3	5	7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	11	*Platygobio gracilis*	---	1	2	10	---	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	12	*Pylodictis olivaris*	---	---	---	---	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	13	*Unknown*	---	150	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
S094.1-A	1	*Carpiodes carpio*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	4	10	---	---	---	---	---	---	---	---	---
	2	*Cyprinella lutrensis*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	57	---	---	---	---	---	---	---	---	---	---
	3	*Cyprinus carpio*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	3	2	---	---	---	---	---	---	---	---	---
	4	*Dorosoma cepedianum*	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	3	---	2	---	---	---	---	---	---	---	---
	5	*Gambusia affinis*	---	15	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	4	2	---	---	---	---	---	---	---	---
	6	*Ictalurus punctatus*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	2	2	---	---	---	---	---	---	---	---	---
	7	*Larval sp*	---	725	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	120	200	332	---	---	---	---	---	---	---	---	---
	8	*Micropterus salmoides salmoides*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	1	---	---	---	---	---	---	---	---
	9	*Percina macrolepida*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---
	10	*Pimephales promelas*	---	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	16	17	1	---	---	---	---	---	---	---	---
	11	*Platygobio gracilis*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	6	12	2	---	---	---	---	---	---	---	---

Appendix A2. Report of the Number of Fish Observed by Species and Site during August 2007 Monitoring.

Site	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
															Day of Month																	
I152.6-A																																
	1 *Ameiurus melas*	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	2 *Carpiodes carpio*	---	---	---	---	---	---	---	---	---	---	---	---	---	120	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	3 *Cyprinella lutrensis*	---	---	---	---	---	---	---	---	---	---	---	---	---	25	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	4 *Gambusia affinis*	---	---	---	---	---	---	---	---	---	---	---	---	---	8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	5 *Hybognathus amarus*	---	---	---	---	---	---	---	---	---	---	---	---	---	5	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	6 *Ictalurus punctatus*	---	---	---	---	---	---	---	---	---	---	---	---	---	67	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	7 *Pimephales promelas*	---	---	---	---	---	---	---	---	---	---	---	---	---	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
I154.4-A																																
	1 *Carpiodes carpio*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	49	32	22	20	---	---	---	---	---	---	---	---	---	---	---	---	---
	2 *Cyprinella lutrensis*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	17	27	13	53	---	---	---	---	---	---	---	---	---	---	---	---	---
	3 *Cyprinus carpio*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	4	---	---	---	---	---	---	---	---	---	---	---	---	---
	4 *Gambusia affinis*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	7	14	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---
	5 *Hybognathus amarus*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---
	6 *Ictalurus punctatus*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	55	59	66	21	---	---	---	---	---	---	---	---	---	---	---	---	---
	7 *Pimephales promelas*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	2	4	1	---	---	---	---	---	---	---	---	---	---	---	---	---
I158.3-A																																
	1 *Gambusia affinis*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	89	7	7	5	14
I158.4-A																																
	1 *Carpiodes carpio*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---
	2 *Cyprinella lutrensis*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	82	---	---	---	---
	3 *Gambusia affinis*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	7	---	---	---	---
	4 *Hybognathus amarus*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	5	---	---	---	---
	5 *Ictalurus punctatus*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	9	---	---	---	---
I161.3-A																																
	1 *Ameiurus melas*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---
	2 *Carpiodes carpio*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	36	23	22	17	16	28	4	---	---	---	---	13	4	---
	3 *Catostomus commersonii*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	1	---	---	---	---	---	---	---	---	---	---
	4 *Cyprinella lutrensis*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	31	36	28	28	14	22	48	---	---	---	---	30	31	---
	5 *Cyprinus carpio*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	1	---	1	---	---	---	---	---	---	3	---	---
	6 *Gambusia affinis*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	13	14	23	15	5	17	34	---	---	---	---	20	50	---
	7 *Hybognathus amarus*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	8	9	2	3	8	4	2	---	---	---	---	31	7	---
	8 *Ictalurus punctatus*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	13	18	13	15	31	17	4	---	---	---	---	5	8	---
	9 *Lepomis (Chaenobryttus) cyanellus*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---
	10 *Morone chrysops*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	4	---	1	1	3	---	---	---	---	---	---	---	---
	11 *Pimephales promelas*	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	6	9	18	19	29	23	10	---	---	---	---	4	1	---

Appendix A3. Report of the Number of Fish Observed by Species and Site during September 2007 Monitoring

Site	Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
															Day of Month																
I158.3-A																															
1	*Carpiodes carpio*	1	---	---	---	---	---	---	---	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
2	*Cyprinella lutrensis*	---	---	---	---	---	---	13	9	1	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
3	*Gambusia affinis*	4	---	---	---	---	---	66	34	13	15	29	17	6	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
4	*Hybognathus amarus*	3	---	---	---	---	---	11	11	5	1	4	1	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
5	*Lepomis (Lepomis) macrochirus*	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6	*Pimephales promelas*	1	---	---	---	---	---	3	3	8	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
I158.4-A																															
1	*Carpiodes carpio*	---	---	---	---	---	---	---	---	---	---	---	---	---	15	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
2	*Cyprinella lutrensis*	---	---	---	---	---	---	---	---	---	---	---	---	---	24	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
3	*Gambusia affinis*	---	---	---	---	---	---	---	---	---	---	---	---	---	91	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
4	*Hybognathus amarus*	---	---	---	---	---	---	---	---	---	---	---	---	---	14	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
5	*Ictalurus punctatus*	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
6	*Pimephales promelas*	---	---	---	---	---	---	---	---	---	---	---	---	---	7	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
I161.3-A																															
1	*Carpiodes carpio*	---	---	---	---	---	---	41	34	---	1	2	14	31	---	26	26	54	26	24	1	---	---	---	---	---	---	---	---	---	---
2	*Catostomus commersonii*	---	---	---	---	---	---	---	---	---	---	---	---	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
3	*Cyprinella lutrensis*	---	---	---	---	---	---	22	45	---	30	38	59	59	---	49	38	82	48	32	41	---	---	---	---	---	---	---	---	---	---
4	*Cyprinus carpio*	---	---	---	---	---	---	0	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
5	*Gambusia affinis*	---	---	---	---	---	---	12	25	---	73	30	70	62	---	43	36	162	62	50	83	---	---	---	---	---	---	---	---	---	---
6	*Hybognathus amarus*	---	---	---	---	---	---	68	37	---	19	26	26	25	---	23	40	36	10	20	1	---	---	---	---	---	---	---	---	---	---
7	*Ictalurus punctatus*	---	---	---	---	---	---	2	4	---	4	1	3	3	---	4	11	2	2	2	---	---	---	---	---	---	---	---	---	---	---
8	*Lepomis (Chaenobryttus) cyanellus*	---	---	---	---	---	---	---	---	---	---	1	1	1	---	1	---	2	1	---	---	---	---	---	---	---	---	---	---	---	---
9	*Morone chrysops*	---	---	---	---	---	---	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
10	*Perca flavescens*	---	---	---	---	---	---	---	---	---	2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
11	*Pimephales promelas*	---	---	---	---	---	---	4	1	---	2	---	---	---	---	7	7	10	3	2	---	---	---	---	---	---	---	---	---	---	---
12	*Platygobio gracilis*	---	---	---	---	---	---	---	---	---	---	---	---	3	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites.

Bureau of Reclamation's Experimental Activities

General Report of Fish Species Observed

Site ID	Northing	Easting	River Mile		Species	Number Observed	Relative Abundance (%)
S076.8-A	3738115	326445	76.8				
		Date: 02-Jul-2007					
		Seine	7				
				1	*Carpiodes carpio*	10	6.76
				2	*Cyprinella lutrensis*	26	17.57
				3	*Cyprinus carpio*	9	6.08
				4	*Dorosoma cepedianum*	2	1.35
				5	*Gambusia affinis*	45	30.41
				6	*Ictalurus furcatus*	4	2.70
				7	*Ictalurus punctatus*	5	3.38
				8	*Percina macrolepida*	1	0.68
				9	*Platygobio gracilis*	2	1.35
				10	*Unknown*	44	29.73
		Date: 03-Jul-2007					
		Seine	5				
				1	*Carpiodes carpio*	12	10.34
				2	*Cyprinella lutrensis*	47	40.52
				3	*Cyprinus carpio*	10	8.62
				4	*Dorosoma cepedianum*	1	0.86
				5	*Gambusia affinis*	20	17.24
				6	*Hybognathus amarus*	11	9.48
				7	*Ictalurus furcatus*	4	3.45
				8	*Ictalurus punctatus*	2	1.72
				9	*Micropterus dolomieu*	1	0.86
				10	*Percina macrolepida*	1	0.86
				11	*Pimephales promelas*	4	3.45
				12	*Platygobio gracilis*	2	1.72
				13	*Pylodictis olivaris*	1	0.86

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

			Species	Number Observed	Relative Abundance (%)
Date: 04-Jul-2007					
Seine	2				
		1	*Carpiodes carpio*	4	3.01
		2	*Cyprinella lutrensis*	54	40.60
		3	*Cyprinus carpio*	5	3.76
		4	*Dorosoma cepedianum*	3	2.26
		5	*Gambusia affinis*	13	9.77
		6	*Hybognathus amarus*	41	30.83
		7	*Ictalurus furcatus*	2	1.50
		8	*Ictalurus punctatus*	11	8.27
Date: 05-Jul-2007					
Seine	4				
		1	*Carpiodes carpio*	26	13.40
		2	*Cyprinella lutrensis*	102	52.58
		3	*Dorosoma cepedianum*	3	1.55
		4	*Gambusia affinis*	50	25.77
		5	*Hybognathus amarus*	1	0.52
		6	*Ictalurus furcatus*	4	2.06
		7	*Ictalurus punctatus*	6	3.09
		8	*Platygobio gracilis*	1	0.52
		9	*Pylodictis olivaris*	1	0.52
Date: 06-Jul-2007					
Seine	2				
		1	*Carpiodes carpio*	7	5.74
		2	*Cyprinella lutrensis*	26	21.31
		3	*Cyprinus carpio*	15	12.30
		4	*Dorosoma cepedianum*	2	1.64
		5	*Gambusia affinis*	9	7.38
		6	*Hybognathus amarus*	39	31.97
		7	*Ictalurus furcatus*	8	6.56
		8	*Ictalurus punctatus*	11	9.02
		9	*Micropterus salmoides salmoides*	1	0.82
		10	*Pimephales promelas*	3	2.46
		11	*Platygobio gracilis*	1	0.82

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

Site ID	Northing	Easting	River Mile		Species	Number Observed	Relative Abundance (%)
S081.5-A	3738329	326354	81.5				
		Date: 02-Jul-2007					
		Seine	5				
				1	*Carpiodes carpio*	13	4.85
				2	*Cyprinella lutrensis*	73	27.24
				3	*Cyprinus carpio*	8	2.99
				4	*Dorosoma cepedianum*	2	0.75
				5	*Gambusia affinis*	11	4.10
				6	*Hybognathus amarus*	1	0.37
				7	*Ictalurus furcatus*	8	2.99
				8	*Ictalurus punctatus*	1	0.37
				9	*Platygobio gracilis*	1	0.37
				10	*Unknown*	150	55.97
		Date: 03-Jul-2007					
		Seine	4				
				1	*Carpiodes carpio*	12	11.88
				2	*Cyprinella lutrensis*	35	34.65
				3	*Dorosoma cepedianum*	2	1.98
				4	*Gambusia affinis*	8	7.92
				5	*Hybognathus amarus*	2	1.98
				6	*Ictalurus punctatus*	40	39.60
				7	*Platygobio gracilis*	2	1.98
		Date: 04-Jul-2007					
		Seine	3				
				1	*Carpiodes carpio*	111	31.27
				2	*Cyprinella lutrensis*	47	13.24
				3	*Cyprinus carpio*	16	4.51
				4	*Dorosoma cepedianum*	1	0.28
				5	*Gambusia affinis*	18	5.07
				6	*Hybognathus amarus*	3	0.85
				7	*Ictalurus furcatus*	3	0.85
				8	*Ictalurus punctatus*	142	40.00
				9	*Percina macrolepida*	1	0.28
				10	*Pimephales promelas*	3	0.85
				11	*Platygobio gracilis*	10	2.82

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

			Species	Number Observed	Relative Abundance (%)
Date: 05-Jul-2007					
Seine	1				
		1	*Carpiodes carpio*	48	35.82
		2	*Cyprinella lutrensis*	24	17.91
		3	*Cyprinus carpio*	2	1.49
		4	*Dorosoma cepedianum*	11	8.21
		5	*Gambusia affinis*	38	28.36
		6	*Ictalurus furcatus*	4	2.99
		7	*Pimephales promelas*	5	3.73
		8	*Pylodictis olivaris*	2	1.49
Date: 06-Jul-2007					
Seine	2				
		1	*Carpiodes carpio*	23	13.45
		2	*Cyprinella lutrensis*	36	21.05
		3	*Cyprinus carpio*	6	3.51
		4	*Dorosoma cepedianum*	11	6.43
		5	*Gambusia affinis*	9	5.26
		6	*Hybognathus amarus*	23	13.45
		7	*Ictalurus furcatus*	8	4.68
		8	*Ictalurus punctatus*	45	26.32
		9	*Pimephales promelas*	7	4.09
		10	*Platygobio gracilis*	3	1.75

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

Site ID	Northing	Easting	River Mile		Species	Number Observed	Relative Abundance (%)
S094.1-A	3764011	327190	94.1				
		Date: 02-Jul-2007 Seine 10					
				1	*Dorosoma cepedianum*	1	0.13
				2	*Gambusia affinis*	15	2.02
				3	*Larval sp.*	725	97.45
				4	*Pimephales promelas*	3	0.40
		Date: 20-Jul-2007 Seine 10					
				1	*Carpiodes carpio*	1	0.79
				2	*Cyprinus carpio*	1	0.79
				3	*Dorosoma cepedianum*	1	0.79
				4	*Ictalurus punctatus*	1	0.79
				5	*Larval sp.*	120	95.24
				6	*Platygobio gracilis*	2	1.59
		Date: 21-Jul-2007 Seine 10					
				1	*Carpiodes carpio*	4	1.37
				2	*Cyprinella lutrensis*	57	19.45
				3	*Cyprinus carpio*	3	1.02
				4	*Dorosoma cepedianum*	3	1.02
				5	*Ictalurus punctatus*	2	0.68
				6	*Larval sp.*	200	68.26
				7	*Micropterus salmoides salmoides*	1	0.34
				8	*Percina macrolepida*	1	0.34
				9	*Pimephales promelas*	16	5.46
				10	*Platygobio gracilis*	6	2.05

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

Site ID	Northing	Easting	River Mile		Species	Number Observed	Relative Abundance (%)
		Date: 22-Jul-2007					
		Seine	10				
				1	*Carpiodes carpio*	10	2.64
				2	*Cyprinus carpio*	2	0.53
				3	*Gambusia affinis*	4	1.06
				4	*Ictalurus punctatus*	2	0.53
				5	*Larval sp.*	332	87.60
				6	*Pimephales promelas*	17	4.49
				7	*Platygobio gracilis*	12	3.17
		Date: 23-Jul-2007					
		Seine	10				
				1	*Dorosoma cepedianum*	2	25.00
				2	*Gambusia affinis*	2	25.00
				3	*Micropterus salmoides salmoides*	1	12.50
				4	*Pimephales promelas*	1	12.50
				5	*Platygobio gracilis*	2	25.00
I152.6-A	3840300	340171	152.6				
		Date: 14-Aug-2007					
		Seine	1				
				1	*Ameiurus melas*	1	0.44
				2	*Carpiodes carpio*	120	52.40
				3	*Cyprinella lutrensis*	25	10.92
				4	*Gambusia affinis*	8	3.49
				5	*Hybognathus amarus*	5	2.18
				6	*Ictalurus punctatus*	67	29.26
				7	*Pimephales promelas*	3	1.31

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

Site ID	Northing	Easting	River Mile		Species	Number Observed	Relative Abundance (%)
I154.4-A	3842972	340341	154.4				
		Date: 15-Aug-2007					
		Seine	3				
				1	*Carpiodes carpio*	49	37.69
				2	*Cyprinella lutrensis*	17	13.08
				3	*Gambusia affinis*	7	5.38
				4	*Hybognathus amarus*	1	0.77
				5	*Ictalurus punctatus*	55	42.31
				6	*Pimephales promelas*	1	0.77
		Date: 16-Aug-2007					
		Seine	1				
				1	*Carpiodes carpio*	32	23.88
				2	*Cyprinella lutrensis*	27	20.15
				3	*Gambusia affinis*	14	10.45
				4	*Ictalurus punctatus*	59	44.03
				5	*Pimephales promelas*	2	1.49
		Date: 17-Aug-2007					
		Seine	1				
				1	*Carpiodes carpio*	22	20.75
				2	*Cyprinella lutrensis*	13	12.26
				3	*Gambusia affinis*	1	0.94
				4	*Ictalurus punctatus*	66	62.26
				5	*Pimephales promelas*	4	3.77
		Date: 18-Aug-2007					
		Seine	2				
				1	*Carpiodes carpio*	20	20.00
				2	*Cyprinella lutrensis*	53	53.00
				3	*Cyprinus carpio*	4	4.00
				4	*Hybognathus amarus*	1	1.00
				5	*Ictalurus punctatus*	21	21.00
				6	*Pimephales promelas*	1	1.00

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

Site ID	Northing	Easting	River Mile		Species	Number Observed	Relative Abundance (%)
I158.3-A	3848455	341385	158.3				
		Date: 27-Aug-2007 **Seine** 5					
				1	*Gambusia affinis*	89	100.00
		Date: 28-Aug-2007 **Seine** 5					
				1	*Gambusia affinis*	7	100.00
		Date: 29-Aug-2007 **Seine** 10					
				1	*Gambusia affinis*	7	100.00
		Date: 30-Aug-2007 **Seine** 10					
				1	*Gambusia affinis*	5	100.00
		Date: 31-Aug-2007 **Seine** 10					
				1	*Gambusia affinis*	14	100.00
		Date: 01-Sep-2007 **Seine** 10					
				1	*Carpiodes carpio*	1	11.11
				2	*Gambusia affinis*	4	44.44
				3	*Hybognathus amarus*	3	33.33
				4	*Pimephales promelas*	1	11.11
		Date: 07-Sep-2007 **Seine** 10					
				1	*Cyprinella lutrensis*	13	13.83
				2	*Gambusia affinis*	66	70.21
				3	*Hybognathus amarus*	11	11.70
				4	*Lepomis (Lepomis) macrochirus*	1	1.06
				5	*Pimephales promelas*	3	3.19

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

		Species	Number Observed	Relative Abundance (%)
Date: 08-Sep-2007 **Seine** 10				
	1	*Cyprinella lutrensis*	9	15.79
	2	*Gambusia affinis*	34	59.65
	3	*Hybognathus amarus*	11	19.30
	4	*Pimephales promelas*	3	5.26
Date: 09-Sep-2007 **Seine** 10				
	1	*Carpiodes carpio*	3	10.00
	2	*Cyprinella lutrensis*	1	3.33
	3	*Gambusia affinis*	13	43.33
	4	*Hybognathus amarus*	5	16.67
	5	*Pimephales promelas*	8	26.67
Date: 10-Sep-2007 **Seine** 10				
	1	*Gambusia affinis*	15	93.75
	2	*Hybognathus amarus*	1	6.25
Date: 11-Sep-2007 **Seine** 10				
	1	*Cyprinella lutrensis*	1	2.94
	2	*Gambusia affinis*	29	85.29
	3	*Hybognathus amarus*	4	11.76
Date: 12-Sep-2007 **Seine** 10				
	1	*Gambusia affinis*	17	94.44
	2	*Hybognathus amarus*	1	5.56
Date: 13-Sep-2007 **Seine** 10				
	1	*Gambusia affinis*	6	75.00
	2	*Hybognathus amarus*	2	25.00

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

Site ID	Northing	Easting	River Mile		Species	Number Observed	Relative Abundance (%)
I158.4-A	3848633	341339	158.4				
		Date: 27-Aug-2007 **Seine** 5					
				1	*Carpiodes carpio*	1	0.96
				2	*Cyprinella lutrensis*	82	78.85
				3	*Gambusia affinis*	7	6.73
				4	*Hybognathus amarus*	5	4.81
				5	*Ictalurus punctatus*	9	8.65
		Date: 14-Sep-2007 **Seine** 2					
				1	*Carpiodes carpio*	15	9.87
				2	*Cyprinella lutrensis*	24	15.79
				3	*Gambusia affinis*	91	59.87
				4	*Hybognathus amarus*	14	9.21
				5	*Ictalurus punctatus*	1	0.66
				6	*Pimephales promelas*	7	4.61

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

Site ID	Northing	Easting	River Mile		Species	Number Observed	Relative Abundance (%)
I161.3-A	3852471	342735	161.3				
		Date: 18-Aug-2007					
		Seine	4				
				1	*Carpiodes carpio*	36	33.33
				2	*Cyprinella lutrensis*	31	28.70
				3	*Gambusia affinis*	13	12.04
				4	*Hybognathus amarus*	8	7.41
				5	*Ictalurus punctatus*	13	12.04
				6	*Morone chrysops*	1	0.93
				7	*Pimephales promelas*	6	5.56
		Date: 19-Aug-2007					
		Seine	5				
				1	*Carpiodes carpio*	23	19.83
				2	*Catostomus commersonii*	1	0.86
				3	*Cyprinella lutrensis*	36	31.03
				4	*Cyprinus carpio*	2	1.72
				5	*Gambusia affinis*	14	12.07
				6	*Hybognathus amarus*	9	7.76
				7	*Ictalurus punctatus*	18	15.52
				8	*Morone chrysops*	4	3.45
				9	*Pimephales promelas*	9	7.76
		Date: 20-Aug-2007					
		Seine	4				
				1	*Carpiodes carpio*	22	20.37
				2	*Cyprinella lutrensis*	28	25.93
				3	*Cyprinus carpio*	1	0.93
				4	*Gambusia affinis*	23	21.30
				5	*Hybognathus amarus*	2	1.85
				6	*Ictalurus punctatus*	13	12.04
				7	*Lepomis (Chaenobryttus) cyanellus*	1	0.93
				8	*Pimephales promelas*	18	16.67

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

		Species	Number Observed	Relative Abundance (%)
Date: 21-Aug-2007				
Seine 7				
	1	*Carpiodes carpio*	17	17.17
	2	*Catostomus commersonii*	1	1.01
	3	*Cyprinella lutrensis*	28	28.28
	4	*Gambusia affinis*	15	15.15
	5	*Hybognathus amarus*	3	3.03
	6	*Ictalurus punctatus*	15	15.15
	7	*Morone chrysops*	1	1.01
	8	*Pimephales promelas*	19	19.19
Date: 22-Aug-2007				
Seine 5				
	1	*Ameiurus melas*	1	0.94
	2	*Carpiodes carpio*	16	15.09
	3	*Cyprinella lutrensis*	14	13.21
	4	*Cyprinus carpio*	1	0.94
	5	*Gambusia affinis*	5	4.72
	6	*Hybognathus amarus*	8	7.55
	7	*Ictalurus punctatus*	31	29.25
	8	*Morone chrysops*	1	0.94
	9	*Pimephales promelas*	29	27.36
Date: 23-Aug-2007				
Seine 6				
	1	*Carpiodes carpio*	28	24.56
	2	*Cyprinella lutrensis*	22	19.30
	3	*Gambusia affinis*	17	14.91
	4	*Hybognathus amarus*	4	3.51
	5	*Ictalurus punctatus*	17	14.91
	6	*Morone chrysops*	3	2.63
	7	*Pimephales promelas*	23	20.18

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

			Species	Number Observed	Relative Abundance (%)
Date: 24-Aug-2007					
Seine	2				
		1	*Carpiodes carpio*	4	3.92
		2	*Cyprinella lutrensis*	48	47.06
		3	*Gambusia affinis*	34	33.33
		4	*Hybognathus amarus*	2	1.96
		5	*Ictalurus punctatus*	4	3.92
		6	*Pimephales promelas*	10	9.80
Date: 29-Aug-2007					
Seine	10				
		1	*Carpiodes carpio*	13	12.26
		2	*Cyprinella lutrensis*	30	28.30
		3	*Cyprinus carpio*	3	2.83
		4	*Gambusia affinis*	20	18.87
		5	*Hybognathus amarus*	31	29.25
		6	*Ictalurus punctatus*	5	4.72
		7	*Pimephales promelas*	4	3.77
Date: 30-Aug-2007					
Seine	2				
		1	*Carpiodes carpio*	4	3.96
		2	*Cyprinella lutrensis*	31	30.69
		3	*Gambusia affinis*	50	49.50
		4	*Hybognathus amarus*	7	6.93
		5	*Ictalurus punctatus*	8	7.92
		6	*Pimephales promelas*	1	0.99
Date: 07-Sep-2007					
Seine	1				
		1	*Carpiodes carpio*	41	27.15
		2	*Cyprinella lutrensis*	22	14.57
		3	*Cyprinus carpio*	0	0.00
		4	*Gambusia affinis*	12	7.95
		5	*Hybognathus amarus*	68	45.03
		6	*Ictalurus punctatus*	2	1.32
		7	*Morone chrysops*	2	1.32
		8	*Pimephales promelas*	4	2.65

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

		Species	Number Observed	Relative Abundance (%)
Date: 08-Sep-2007 **Seine** 2				
	1	*Carpiodes carpio*	34	23.29
	2	*Cyprinella lutrensis*	45	30.82
	3	*Gambusia affinis*	25	17.12
	4	*Hybognathus amarus*	37	25.34
	5	*Ictalurus punctatus*	4	2.74
	6	*Pimephales promelas*	1	0.68
Date: 10-Sep-2007 **Seine** 1				
	1	*Carpiodes carpio*	1	0.76
	2	*Cyprinella lutrensis*	30	22.90
	3	*Gambusia affinis*	73	55.73
	4	*Hybognathus amarus*	19	14.50
	5	*Ictalurus punctatus*	4	3.05
	6	*Perca flavescens*	2	1.53
	7	*Pimephales promelas*	2	1.53
Date: 11-Sep-2007 **Seine** 1				
	1	*Carpiodes carpio*	2	2.04
	2	*Cyprinella lutrensis*	38	38.78
	3	*Gambusia affinis*	30	30.61
	4	*Hybognathus amarus*	26	26.53
	5	*Ictalurus punctatus*	1	1.02
	6	*Lepomis (Chaenobryttus) cyanellus*	1	1.02
Date: 12-Sep-2007 **Seine** 1				
	1	*Carpiodes carpio*	14	8.09
	2	*Cyprinella lutrensis*	59	34.10
	3	*Gambusia affinis*	70	40.46
	4	*Hybognathus amarus*	26	15.03
	5	*Ictalurus punctatus*	3	1.73
	6	*Lepomis (Chaenobryttus) cyanellus*	1	0.58

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

		Species	Number Observed	Relative Abundance (%)
Date: 13-Sep-2007 **Seine** 1				
	1	*Carpiodes carpio*	31	16.67
	2	*Catostomus commersonii*	2	1.08
	3	*Cyprinella lutrensis*	59	31.72
	4	*Gambusia affinis*	62	33.33
	5	*Hybognathus amarus*	25	13.44
	6	*Ictalurus punctatus*	3	1.61
	7	*Lepomis (Chaenobryttus) cyanellus*	1	0.54
	8	*Platygobio gracilis*	3	1.61
Date: 15-Sep-2007 **Seine** 1				
	1	*Carpiodes carpio*	26	16.99
	2	*Cyprinella lutrensis*	49	32.03
	3	*Gambusia affinis*	43	28.10
	4	*Hybognathus amarus*	23	15.03
	5	*Ictalurus punctatus*	4	2.61
	6	*Lepomis (Chaenobryttus) cyanellus*	1	0.65
	7	*Pimephales promelas*	7	4.58
Date: 16-Sep-2007 **Seine** 1				
	1	*Carpiodes carpio*	26	16.46
	2	*Cyprinella lutrensis*	38	24.05
	3	*Gambusia affinis*	36	22.78
	4	*Hybognathus amarus*	40	25.32
	5	*Ictalurus punctatus*	11	6.96
	6	*Pimephales promelas*	7	4.43

Table A.4. Fish Community Data Collected at Monitored In-stream Refugia Sites, continued

		Species	Number Observed	Relative Abundance (%)
Date: 17-Sep-2007 **Seine** 1				
	1	*Carpiodes carpio*	54	15.52
	2	*Cyprinella lutrensis*	82	23.56
	3	*Gambusia affinis*	162	46.55
	4	*Hybognathus amarus*	36	10.34
	5	*Ictalurus punctatus*	2	0.57
	6	*Lepomis (Chaenobryttus) cyanellus*	2	0.57
	7	*Pimephales promelas*	10	2.87
Date: 18-Sep-2007 **Seine** 1				
	1	*Carpiodes carpio*	26	17.11
	2	*Cyprinella lutrensis*	48	31.58
	3	*Gambusia affinis*	62	40.79
	4	*Hybognathus amarus*	10	6.58
	5	*Ictalurus punctatus*	2	1.32
	6	*Lepomis (Chaenobryttus) cyanellus*	1	0.66
	7	*Pimephales promelas*	3	1.97
Date: 19-Sep-2007 **Seine** 2				
	1	*Carpiodes carpio*	24	18.46
	2	*Cyprinella lutrensis*	32	24.62
	3	*Gambusia affinis*	50	38.46
	4	*Hybognathus amarus*	20	15.38
	5	*Ictalurus punctatus*	2	1.54
	6	*Pimephales promelas*	2	1.54
Date: 20-Sep-2007 **Seine** 2				
	1	*Carpiodes carpio*	1	0.79
	2	*Cyprinella lutrensis*	41	32.54
	3	*Gambusia affinis*	83	65.87
	4	*Hybognathus amarus*	1	0.79

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites

Bureau of Reclamation's Experimental Activities
General Report of Fish Health *

Site ID: S076.8-A
Northing: 3738115
Easting: 326445

Date: 02 July 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 7

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	0	26	0	0	0	0	0	0	26	100.00
2 *Platygobio gracilis*	0	2	0	0	0	0	0	0	2	100.00

Date: 03 July 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 5

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	1	46	0	0	0	0	0	0	47	97.87
2 *Hybognathus amarus*	0	9	0	0	2	0	0	0	11	81.82
3 *Pimephales promelas*	0	3	0	0	1	0	0	0	4	75.00
4 *Platygobio gracilis*	0	1	0	0	1	0	0	0	2	50.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 04 July 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 2										
1 *Cyprinella lutrensis*	1	49	0	4	0	0	0	0	54	90.74
2 *Hybognathus amarus*	0	38	0	0	3	0	0	0	41	92.68
Date: 05 July 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 4										
1 *Cyprinella lutrensis*	0	102	0	0	0	0	0	0	102	100.00
2 *Hybognathus amarus*	0	0	0	0	1	0	0	0	1	0.00
3 *Platygobio gracilis*	0	1	0	0	0	0	0	0	1	100.00
Date: 06 July 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 2										
1 *Cyprinella lutrensis*	1	14	0	7	4	0	0	0	26	53.85
2 *Hybognathus amarus*	5	22	0	1	11	0	0	0	39	56.41
3 *Pimephales promelas*	0	3	0	0	0	0	0	0	3	100.00
4 *Platygobio gracilis*	0	0	0	0	1	0	0	0	1	0.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Site ID: S081.5-A										
Northing: 3738329										
Easting: 326354										
Date: 02 July 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 5										
1 *Cyprinella lutrensis*	0	73	0	0	0	0	0	0	73	100.00
2 *Hybognathus amarus*	0	0	0	0	1	0	0	0	1	0.00
3 *Platygobio gracilis*	0	1	0	0	0	0	0	0	1	100.00
Date: 03 July 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 4										
1 *Cyprinella lutrensis*	0	35	0	0	0	0	0	0	35	100.00
2 *Hybognathus amarus*	0	0	0	0	2	0	0	0	2	0.00
3 *Platygobio gracilis*	0	1	0	0	1	0	0	0	2	50.00
Date: 04 July 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 3										
1 *Cyprinella lutrensis*	0	44	0	2	1	0	0	0	47	93.62
2 *Hybognathus amarus*	0	2	0	0	0	0	0	1	3	66.67
3 *Pimephales promelas*	0	2	0	0	1	0	0	0	3	66.67
4 *Platygobio gracilis*	0	10	0	0	0	0	0	0	10	100.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 05 July 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	24	0	0	0	0	0	0	24	100.00
2 *Pimephales promelas*	1	4	0	0	0	0	0	0	5	80.00
Date: 06 July 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 2										
1 *Cyprinella lutrensis*	0	36	0	0	0	0	0	0	36	100.00
2 *Hybognathus amarus*	3	10	0	0	10	0	0	0	23	43.48
3 *Pimephales promelas*	0	6	0	1	0	0	0	0	7	85.71
4 *Platygobio gracilis*	0	2	0	0	1	0	0	0	3	66.67

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

Site ID: S094.1-A
Northing: 3764011
Easting: 327190

Date: 02 July 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 10

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Pimephales promelas*	0	2	0	0	1	0	0	0	3	66.67

Date: 20 July 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 10

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Platygobio gracilis*	0	1	0	0	1	0	0	0	2	50.00

Date: 21 July 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 10

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	0	57	0	0	0	0	0	0	57	100.00
2 *Pimephales promelas*	0	10	0	5	1	0	0	0	16	62.50
3 *Platygobio gracilis*	0	4	0	1	1	0	0	0	6	66.67

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 22 July 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 10										
1 *Pimephales promelas*	0	10	5	0	2	0	0	0	17	58.82
2 *Platygobio gracilis*	0	6	4	0	2	0	0	0	12	50.00
Date: 23 July 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 10										
1 *Pimephales promelas*	0	1	0	0	0	0	0	0	1	100.00
2 *Platygobio gracilis*	0	2	0	0	0	0	0	0	2	100.00
Site ID: I152.6-A										
Northing: 3840300										
Easting: 340171										
Date: 14 August 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	25	0	0	0	0	0	0	25	100.00
2 *Hybognathus amarus*	0	4	0	0	1	0	0	0	5	80.00
3 *Pimephales promelas*	0	1	0	1	1	0	0	0	3	33.33

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

Site ID: I154.4-A
Northing: 3842972
Easting: 340341

Date: 15 August 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 3

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	0	16	0	0	1	0	0	0	17	94.12
2 *Hybognathus amarus*	0	0	0	1	0	0	0	0	1	0.00
3 *Pimephales promelas*	0	1	0	0	0	0	0	0	1	100.00

Date: 16 August 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 1

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	0	27	0	0	0	0	0	0	27	100.00
2 *Pimephales promelas*	0	2	0	0	0	0	0	0	2	100.00

Date: 17 August 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 1

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	0	13	0	0	0	0	0	0	13	100.00
2 *Pimephales promelas*	0	4	0	0	0	0	0	0	4	100.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 18 August 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 2										
1 *Cyprinella lutrensis*	0	51	0	0	2	0	0	0	53	96.23
2 *Hybognathus amarus*	0	1	0	0	0	0	0	0	1	100.00
3 *Pimephales promelas*	0	1	0	0	0	0	0	0	1	100.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

Site ID: I158.3-A
Northing: 3848455
Easting: 341385

Date: 01 September 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 10

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Hybognathus amarus*	0	0	0	1	1	0	0	1	3	0.00
2 *Pimephales promelas*	0	1	0	0	0	0	0	0	1	100.00

Date: 07 September 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 10

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	0	12	0	1	0	0	0	0	13	92.31
2 *Hybognathus amarus*	0	7	0	2	1	0	0	1	11	63.64
3 *Pimephales promelas*	0	1	0	2	0	0	0	0	3	33.33

Date: 08 September 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 10

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	1	3	0	3	0	2	0	0	9	33.33
2 *Hybognathus amarus*	4	2	0	0	1	1	3	0	11	18.18
3 *Pimephales promelas*	0	1	0	2	0	0	0	0	3	33.33

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 09 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 10										
1 *Cyprinella lutrensis*	0	1	0	0	0	0	0	0	1	100.00
2 *Hybognathus amarus*	0	3	0	0	2	0	0	0	5	60.00
3 *Pimephales promelas*	0	3	0	0	3	0	2	0	8	37.50
Date: 10 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 10										
1 *Hybognathus amarus*	1	0	0	0	0	0	0	0	1	0.00
Date: 11 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 10										
1 *Cyprinella lutrensis*	0	0	0	1	0	0	0	0	1	0.00
2 *Hybognathus amarus*	0	0	0	0	1	0	1	2	4	0.00
Date: 12 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 10										
1 *Hybognathus amarus*	0	1	0	0	0	0	0	0	1	100.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 13 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 10										
1 *Hybognathus amarus*	0	2	0	0	0	0	0	0	2	100.00

Site ID: I158.4-A

Northing: 3848633

Easting: 341339

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 27 August 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 5										
1 *Cyprinella lutrensis*	0	81	0	0	1	0	0	0	82	98.78
2 *Hybognathus amarus*	0	5	0	0	0	0	0	0	5	100.00
Date: 14 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 2										
1 *Cyprinella lutrensis*	0	24	0	0	0	0	0	0	24	100.00
2 *Hybognathus amarus*	0	13	0	1	0	0	0	0	14	92.86
3 *Pimephales promelas*	0	7	0	0	0	0	0	0	7	100.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

Site ID: I161.3-A
Northing: 3852471
Easting: 342735

Date: 18 August 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 4

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	0	29	0	2	0	0	0	0	31	93.55
2 *Hybognathus amarus*	0	4	0	1	3	0	0	0	8	50.00
3 *Pimephales promelas*	0	5	0	1	0	0	0	0	6	83.33

Date: 19 August 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 5

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	0	36	0	0	0	0	0	0	36	100.00
2 *Hybognathus amarus*	0	6	0	1	1	0	1	0	9	66.67
3 *Pimephales promelas*	0	9	0	0	0	0	0	0	9	100.00

Date: 20 August 2007
Habitat Type: Disconnected Instream Refugia
Seine Hauls: 4

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
1 *Cyprinella lutrensis*	0	28	0	0	0	0	0	0	28	100.00
2 *Hybognathus amarus*	1	0	0	1	0	0	0	0	2	0.00
3 *Pimephales promelas*	0	18	0	0	0	0	0	0	18	100.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 21 August 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 7										
1 *Cyprinella lutrensis*	0	28	0	0	0	0	0	0	28	100.00
2 *Hybognathus amarus*	0	2	0	0	0	0	1	0	3	66.67
3 *Pimephales promelas*	0	19	0	0	0	0	0	0	19	100.00
Date: 22 August 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 5										
1 *Cyprinella lutrensis*	0	14	0	0	0	0	0	0	14	100.00
2 *Hybognathus amarus*	0	6	0	0	1	0	1	0	8	75.00
3 *Pimephales promelas*	0	28	0	1	0	0	0	0	29	96.55
Date: 23 August 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 6										
1 *Cyprinella lutrensis*	0	21	0	0	1	0	0	0	22	95.45
2 *Hybognathus amarus*	0	3	0	1	0	0	0	0	4	75.00
3 *Pimephales promelas*	0	22	0	1	0	0	0	0	23	95.65

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 24 August 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 2										
1 *Cyprinella lutrensis*	0	48	0	0	0	0	0	0	48	100.00
2 *Hybognathus amarus*	0	2	0	0	0	0	0	0	2	100.00
3 *Pimephales promelas*	0	10	0	0	0	0	0	0	10	100.00
Date: 29 August 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 10										
1 *Cyprinella lutrensis*	0	30	0	0	0	0	0	0	30	100.00
2 *Hybognathus amarus*	2	26	0	3	0	0	0	0	31	83.87
3 *Pimephales promelas*	0	3	0	1	0	0	0	0	4	75.00
Date: 30 August 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 2										
1 *Cyprinella lutrensis*	0	30	0	0	0	1	0	0	31	96.77
2 *Hybognathus amarus*	0	6	0	1	0	0	0	0	7	85.71
3 *Pimephales promelas*	0	1	0	0	0	0	0	0	1	100.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 07 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	21	0	0	1	0	0	0	22	95.45
2 *Hybognathus amarus*	0	58	0	7	3	0	0	0	68	85.29
3 *Pimephales promelas*	0	4	0	0	0	0	0	0	4	100.00
Date: 08 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 2										
1 *Cyprinella lutrensis*	0	44	0	0	0	1	0	0	45	97.78
2 *Hybognathus amarus*	0	30	0	4	2	0	1	0	37	81.08
3 *Pimephales promelas*	0	1	0	0	0	0	0	0	1	100.00
Date: 10 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	29	0	0	0	0	0	1	30	96.67
2 *Hybognathus amarus*	0	14	0	1	3	0	0	1	19	73.68
3 *Pimephales promelas*	0	2	0	0	0	0	0	0	2	100.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 11 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	33	0	3	1	1	0	0	38	86.84
2 *Hybognathus amarus*	0	24	0	1	1	0	0	0	26	92.31
Date: 12 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	59	0	0	0	0	0	0	59	100.00
2 *Hybognathus amarus*	0	21	0	1	3	1	0	0	26	80.77
Date: 13 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	57	0	0	0	1	0	1	59	96.61
2 *Hybognathus amarus*	0	19	0	1	1	0	2	2	25	76.00
3 *Platygobio gracilis*	0	3	0	0	0	0	0	0	3	100.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 15 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	49	0	0	0	0	0	0	49	100.00
2 *Hybognathus amarus*	0	15	0	3	5	0	0	0	23	65.22
3 *Pimephales promelas*	0	6	0	0	1	0	0	0	7	85.71
Date: 16 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	38	0	0	0	0	0	0	38	100.00
2 *Hybognathus amarus*	0	36	0	1	3	0	0	0	40	90.00
3 *Pimephales promelas*	0	7	0	0	0	0	0	0	7	100.00
Date: 17 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	69	0	0	0	13	0	0	82	84.15
2 *Hybognathus amarus*	0	27	0	0	7	0	0	2	36	75.00
3 *Pimephales promelas*	0	10	0	0	0	0	0	0	10	100.00

Table A.5. Fish Community Health Data Collected at Monitored In-stream Refugia Sites, continued

	Dead	Healthy	Fungus	Lernia	Hemorrhagic Lesions	Anemia	Predation	Multiple Symptoms	Total	Percent Healthy
Date: 18 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 1										
1 *Cyprinella lutrensis*	0	21	0	1	1	25	0	0	48	43.75
2 *Hybognathus amarus*	0	9	0	0	1	0	0	0	10	90.00
3 *Pimephales promelas*	0	3	0	0	0	0	0	0	3	100.00
Date: 19 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 2										
1 *Cyprinella lutrensis*	0	29	0	3	0	0	0	0	32	90.63
2 *Hybognathus amarus*	0	20	0	0	0	0	0	0	20	100.00
3 *Pimephales promelas*	0	2	0	0	0	0	0	0	2	100.00
Date: 20 September 2007										
Habitat Type: Disconnected Instream Refugia										
Seine Hauls: 2										
1 *Cyprinella lutrensis*	0	32	0	0	1	8	0	0	41	78.05
2 *Hybognathus amarus*	0	1	0	0	0	0	0	0	1	100.00

Appendix B
Isolated Pool Water Quality Data

Table B.1. Water quality data collected from isolated pools. "S" and "B" signify measurements taken at the surface and bottom of the water column. "Sample" signifies map points. "m" denotes where water quality data is missing.

Site ID	Date	Sample	Depth (m)	Ammonia (ppm) B	Ammonia (ppm) S	pH B	pH S	Conductivity (µs/cm) B	Conductivity (µs/cm) S	DO (ppm) B	DO (ppm) S	Temperature (°C) B	Temperature (°C) S
s077.4-a	7/2/2007	1	0.183	0.3439	0.3319	10	10	620.5	224.2	6.01	9.01	20.58	20.72
s077.4-a	7/2/2007	2	0.366	0.3064	0.3036	10	10	619.3	621	4.79	4.92	21.23	21.35
s077.4-a	7/2/2007	3	0.201	0.2972	0.2947	10	10	621.1	620.7	5.34	5.02	21.94	21.95
s077.4-a	7/2/2007	4	0.472	0.295	0.3	10	10	641.3	632.1	4.40	4.32	22.88	22.91
s077.4-a	7/2/2007	5	0.061	0.2601	0.2601	10	10	1.314	1.314	6.24	6.24	19.39	19.39
s081.5-a	7/2/2007	6	0.000	0.3587	0.3644	9.01	9.04	774.3	790.6	9.56	9.60	31.75	32.44
s081.5-a	7/2/2007	7	0.305	0.3609	0.3945	9	9.1	771.7	773.9	0.09	0.09	31.56	31.84
s081.5-a	7/2/2007	8	0.579	0.2853	0.2826	9.02	9.01	726.4	36.1	8.20	8.46	28.47	29.27
s081.5-a	7/2/2007	9	0.533	0.2827	0.2676	9	9.02	719	725.4	8.49	8.59	28.17	28.62
s081.5-a	7/2/2007	10	0.101	0.2812	0.2812	9.03	9.03	738.9	738.9	8.68	8.68	29.33	29.33
s077.4-a	7/3/2007	11	0.137	0.4734	0.452	8.66	8.63	693.8	703.5	6.33	6.32	26.39	27.14
s077.4-a	7/3/2007	12	0.381	0.4179	0.4069	8.58	8.61	668.5	67.8	4.13	4.30	24.18	24.79
s077.4-a	7/3/2007	13	0.518	0.411	0.4124	8.54	8.55	677.7	684.3	3.99	4.11	24.82	25.24
s077.4-a	7/3/2007	14	0.183	0.4089	0.4125	8.61	8.61	685.4	690	5.13	5.12	25.45	25.76
s077.4-a	7/3/2007	15	0.137	0.4106	0.4092	8.68	8.66	671.2	680.1	6.21	6.56	24.32	24.81
s081.5-a	7/3/2007	16	0.518	0.5613	0.5356	8.92	8.96	733.2	747.5	8.15	9.39	31.46	32.50
s081.5-a	7/3/2007	17	0.305	0.496	0.4915	8.98	9	732.2	742.3	8.82	9.20	31.32	32.55
s081.5-a	7/3/2007	18	0.549	0.4089	0.4182	9.04	9	708.7	726.9	8.18	8.94	29.41	31.51
s081.5-a	7/3/2007	19	0.366	0.4506	0.431	9	9.04	726	744	8.56	9.42	30.89	32.31
s081.5-a	7/3/2007	20	0.122	0.4698	0.5019	9.05	9.03	761.8	780	10.78	10.91	34.06	35.56
s077.4-a	7/4/2007	21	0.091	0.5161	0.5124	8.83	8.83	616.5	617.1	4.91	4.89	21.92	22.02
s077.4-a	7/4/2007	22	0.152	0.5294	0.5251	8.65	8.65	661.9	661.9	3.26	3.23	22.88	22.91
s077.4-a	7/4/2007	23	0.518	0.4854	0.467	8.53	8.52	659.6	659.6	2.82	2.81	22.94	22.92
s077.4-a	7/4/2007	24	0.091	0.4719	0.4657	8.66	8.66	679.5	682.4	5.77	5.82	24.39	24.34
s077.4-a	7/4/2007	25	0.091	0.461	0.4456	8.63	8.64	650.8	656.5	5.41	5.23	21.61	21.85
s081.5-a	7/4/2007	26	0.213	0.5693	0.5742	8.73	8.79	713	713.5	8.31	8.30	30.45	30.46
s081.5-a	7/4/2007	27	0.244	0.5801	0.5671	8.78	8.8	712.2	716.8	8.16	8.22	30.34	30.46
s081.5-a	7/4/2007	28	0.213	0.5322	0.5357	8.83	8.87	8.86	697.9	8.61	8.60	29.27	29.24
s081.5-a	7/4/2007	29	0.640	0.4959	0.4981	8.8	8.77	686.9	688.3	5.84	5.86	28.26	28.37
s081.5-a	7/4/2007	30	0.091	0.508	0.5417	8.57	8.49	722.9	723.8	7.53	7.74	30.78	30.88
s077.4-a	7/5/2007	36	0.076	0.4093	0.4093	7.07	7.12	573.3	573.3	4.68	4.68	22.18	22.18
s077.4-a	7/5/2007	37	0.152	0.4134	0.4128	7.49	7.48	579.3	580.7	4.85	4.99	22.94	23.17

Table B.1. Water quality data collected from isolated pools. "S" and "B" signify measurements taken at the surface and bottom of the water column. "Sample" signifies map points. "m" denotes where water quality data is missing. (continued).

			Depth	Ammonia (ppm)		pH		Conductivity (µs/cm)		DO (ppm)		Temperature (°C)	
Site ID	Date	Sample	(m)	B	S	B	S	B	S	B	S	B	S
s077.4-a	7/5/2007	38	0.457	0.3916	0.4029	7.55	7.22	581	583.3	5.76	5.21	23.17	23.23
s077.4-a	7/5/2007	39	0.244	0.412	0.418	7.5	7.5	602.7	609.7	6.80	6.54	25.07	25.27
s077.4-a	7/5/2007	40	0.030	0.4561	0.4561	7.53	7.53	646.6	646.6	10.08	10.08	29.67	29.67
s081.5-a	7/5/2007	31	0.122	0.38	0.38	8.15	8.12	412	412	6.80	6.80	27.28	27.28
s081.5-a	7/5/2007	32	0.201	0.3119	0.3038	8.16	8.13	391.1	386.8	7.81	m	24.83	25.38
s081.5-a	7/5/2007	33	0.201	0.2901	0.2975	7.86	7.71	391.7	380	7.79	8.01	24.99	25.19
s081.5-a	7/5/2007	34	0.351	0.2742	0.2773	7.84	7.63	386.7	387.6	5.26	5.34	22.95	23.13
s081.5-a	7/5/2007	35	0.259	0.2792	0.2864	7.8	7.79	410.7	409.6	2.68	3.27	23.26	23.48
s077.4-a	7/6/2007	41	0.061	m	m	8.59	9	558.4	999	5.55	1.00	20.91	37.22
s077.4-a	7/6/2007	42	0.183	m	m	8.59	8.64	561.4	560.5	6.02	5.20	20.97	21.13
s077.4-a	7/6/2007	43	0.305	m	m	8.44	8.5	565	564.8	3.96	2.95	21.33	21.31
s077.4-a	7/6/2007	44	0.274	m	m	8.57	8.53	563.1	564.3	3.64	3.73	21.12	21.13
s077.4-a	7/6/2007	45	0.061	m	m	8.71	9	560.5	999	6.71	10.00	21.14	37.22
s081.5-a	7/6/2007	46	0.061	m	m	9.25	9	460.6	999	11.32	10.00	31.86	37.22
s081.5-a	7/6/2007	47	0.183	m	m	9.25	9.4	438.8	440.3	11.20	12.22	29.62	29.80
s081.5-a	7/6/2007	48	0.091	m	m	9.45	9	448.8	999	10.76	10.00	30.57	37.22
s081.5-a	7/6/2007	49	0.274	m	m	9.05	9.02	436.6	438.6	7.54	7.87	26.29	26.50
s081.5-a	7/6/2007	50	0.152	m	m	8.68	8.58	437.2	439	3.76	3.40	25.47	25.63
s094.1-a	7/20/2007	51	0.518	0.7338	0.4714	7.95	7.98	2262	1587	2.76	3.10	26.29	26.84
s094.1-a	7/20/2007	52	0.792	0.4023	0.3901	8.07	8.2	1536	1545	2.79	3.34	25.39	25.97
s094.1-a	7/20/2007	53	1.158	0.4833	0.5558	8.24	8.38	1521	1714	3.15	7.74	24.90	30.88
s094.1-a	7/21/2007	54	0.396	1.349	1.248	7.71	7.83	760.3	758.6	2.04	2.61	25.70	25.84
s094.1-a	7/21/2007	55	0.823	0.7213	0.7422	7.81	7.85	747.5	754	2.27	2.36	25.12	25.65
s094.1-a	7/21/2007	56	1.097	0.588	0.609	7.74	7.93	746.9	770.1	3.29	3.15	25.13	26.22
s094.1-a	7/22/2007	57	1.067	0.3769	0.3956	7.73	7.6	774.4	774.4	1.59	1.33	24.43	24.41
s094.1-a	7/22/2007	58	0.396	0.3991	0.3843	7.73	7.81	788.8	790.2	2.39	2.33	25.31	25.49
s094.1-a	7/22/2007	59	0.914	0.3615	0.3551	7.79	7.81	778.1	777.4	1.86	1.88	24.61	24.62
s094.1-a	7/23/2007	60	0.396	0.8951	0.8951	7	7	775.7	777.2	3.49	3.63	25.68	25.83
s094.1-a	7/23/2007	61	0.945	0.8923	0.892	7	7	769.1	767.9	2.26	2.37	24.94	24.98
s094.1-a	7/23/2007	62	1.067	0.8958	0.8966	7	7	795.3	767.4	4.57	2.65	26.53	24.95
s094.1-a	7/24/2007	63	0.244	0.9009	0.8816	7.88	7.92	763.4	759.1	3.81	4.07	26.09	26.20
s094.1-a	7/24/2007	64	0.762	0.8786	0.8465	7.77	7.87	753.2	748.9	1.94	2.90	25.48	25.46

Table B.1. Water quality data collected from isolated pools. "S" and "B" signify measurements taken at the surface and bottom of the water column. "Sample" signifies map points. "m" denotes where water quality data is missing. (continued).

			Depth	Ammonia (ppm)		pH		Conductivity (µs/cm)		DO (ppm)		Temperature (°C)	
Site ID	Date	Sample	(m)	B	S	B	S	B	S	B	S	B	S
s094.1-a	7/24/2007	65	1.158	1.362	1.362	7.11	7.12	772	777.8	1.83	2.71	25.32	25.74
s094.1-a	7/24/2007	66	1.219	1.43	1.396	7.09	7.11	849.8	764	2.70	2.69	25.63	26.29
i152.6-a	8/14/2007	67	0.122	1.268	1.404	8.09	7.98	571.1	578.3	7.45	7.29	33.01	32.72
i152.6-a	8/14/2007	68	0.274	1.149	1.224	8.37	8.44	586	594.7	6.87	7.99	31.71	32.46
i152.6-a	8/14/2007	69	0.152	1.23	1.268	8.51	8.49	591.2	594.2	8.47	8.50	32.09	32.36
i152.6-a	8/14/2007	70	0.183	1.163	1.229	8.5	8.48	590.5	594.4	8.70	8.79	32.11	32.40
i152.6-a	8/14/2007	71	0.122	1.192	1.158	8.54	8.52	601.4	602.7	9.18	9.17	33.19	33.26
i154.4-a	8/15/2007	72	0.213	0.9828	0.9063	9.68	9.78	446.1	438.1	7.34	8.01	21.21	21.46
i154.4-a	8/15/2007	73	0.213	0.8715	0.9415	9.82	9.75	449	449.1	5.64	5.89	21.38	21.43
i154.4-a	8/15/2007	74	0.427	0.7988	0.9435	9.79	9.72	452.3	452.4	3.62	6.75	21.67	21.75
i154.4-a	8/15/2007	75	0.274	0.8279	0.8431	9.84	9.72	452.6	461.5	6.83	7.72	21.84	22.63
i154.4-a	8/15/2007	76	0.122	0.795	0.9134	10	9.92	478.7	483.2	17.97	16.05	24.87	25.45
i154.4-a	8/16/2007	77	0.061	0.799	0.8631	8.86	8.76	372.7	372.7	9.82	9.58	19.70	19.75
i154.4-a	8/16/2007	78	0.366	0.7489	0.861	8.74	8.77	383.4	384.4	7.62	6.08	20.18	20.30
i154.4-a	8/16/2007	79	0.061	0.6907	0.6619	9.36	9.4	383.6	383.8	12.88	13.80	20.36	20.39
i154.4-a	8/17/2007	80	0.076	1.358	1.358	8.47	8.47	388.1	388.1	8.06	8.06	19.00	19.00
i154.4-a	8/17/2007	81	0.274	1.96	1.18	8.35	8.44	388.5	388.6	5.12	3.42	19.67	19.72
i154.4-a	8/17/2007	82	0.061	0.8631	0.8631	9.1	9.1	384.4	384.4	7.21	7.21	19.38	19.38
i154.4-a	8/18/2007	85	0.030	0.7089	0.7031	7.91	7.95	427.5	427.7	4.35	4.24	19.45	19.46
i154.4-a	8/18/2007	86	0.140	0.7185	0.7561	7.85	7.8	415.6	417.4	3.53	1.57	20.07	20.18
i154.4-a	8/18/2007	87	0.030	0.7186	0.6259	7.81	7.8	423.8	724.4	2.63	1.69	20.05	20.07
i161.3-a	8/18/2007	88	0.372	0.0325	0.0369	7.14	8.77	496	524.4	4.06	6.76	25.69	31.58
i161.3-a	8/18/2007	89	0.671	0.0387	0.0401	7.34	7.9	731.6	765.9	3.52	4.91	24.47	25.33
i161.3-a	8/18/2007	90	0.823	0.0216	0.0153	8.23	8.87	458.7	499.2	3.33	6.35	24.14	28.58
i161.3-a	8/18/2007	91	0.372	0.0313	0.0983	8.6	8.6	485.6	511.7	6.60	7.48	26.87	29.71
i161.3-a	8/18/2007	92	0.244	0.4436	0.4909	8.72	8.46	511.3	505.1	8.29	8.41	30.45	30.57
i161.3-a	8/19/2007	93	0.152	0.7264	0.5844	8.58	8.47	472.8	470.4	3.02	2.42	23.61	23.77
i161.3-a	8/19/2007	94	0.732	0.9433	0.6831	7.25	7.13	478.4	474.3	2.01	1.78	24.13	24.15
i161.3-a	8/19/2007	95	0.427	0.547	0.641	8.03	8.2	472.7	473.9	3.07	2.16	23.96	24.12
i161.3-a	8/19/2007	96	0.213	0.4972	0.5988	8.27	8.37	351.6	469.5	3.33	2.61	23.54	23.51
i161.3-a	8/19/2007	97	0.122	0.4692	0.527	8.29	8.4	552.3	458.6	3.64	3.48	22.43	22.46
i161.3-a	8/20/2007	98	0.091	m	m	8.42	8.36	496.8	496.8	6.89	6.89	23.59	23.59

Table B.1. Water quality data collected from isolated pools. "S" and "B" signify measurements taken at the surface and bottom of the water column. "Sample" signifies map points. "m" denotes where water quality data is missing. (continued).

			Depth	Ammonia (ppm)		pH		Conductivity (µs/cm)		DO (ppm)		Temperature (°C)	
Site ID	Date	Sample	(m)	B	S	B	S	B	S	B	S	B	S
i161.3-a	8/20/2007	99	0.610	m	m	8.38	8.18	492.8	518.6	3.77	2.61	24.06	24.15
i161.3-a	8/20/2007	100	0.091	m	m	8.44	8.51	480.3	480.3	7.49	7.49	22.24	22.24
i161.3-a	8/21/2007	103	0.152	0.6248	0.7049	8.79	8.58	514.1	524.9	7.72	7.55	25.18	27.12
i161.3-a	8/21/2007	104	0.671	1.355	0.7357	7.94	8.48	853.3	481.5	3.94	5.00	22.84	22.89
i161.3-a	8/21/2007	105	0.183	0.497	0.5126	8.93	8.83	500.9	524.2	7.81	10.43	25.58	27.24
i161.3-a	8/22/2007	106	0.091	0.3052	0.3052	8.96	8.96	461.8	461.8	5.51	5.51	20.08	20.08
i161.3-a	8/22/2007	107	0.457	0.3075	0.2909	8.64	8.67	471.6	471.6	3.42	2.81	20.95	20.99
i161.3-a	8/22/2007	108	0.091	0.2691	0.2691	8.74	8.74	456	456	5.54	5.54	19.46	19.46
i161.3-a	8/23/2007	109	0.610	0.5167	0.5131	8.28	8.43	470.3	470.2	3.04	3.15	20.21	20.24
i161.3-a	8/23/2007	110	0.122	0.3783	0.3142	8.93	8.85	471.5	481.3	9.03	6.97	20.96	21.14
i161.3-a	8/24/2007	111	0.183	0.5402	0.5505	7.95	7.87	468.2	456.1	4.17	3.72	20.13	20.42
i161.3-a	8/24/2007	112	0.671	0.7735	0.6112	7.32	7.46	472.2	465.8	2.20	2.20	20.51	20.42
i161.3-a	8/24/2007	113	0.091	0.339	0.3911	8.15	8.25	473.2	457.7	4.67	5.03	19.43	19.51
i158.3-a	8/27/2007	114	0.091	1.556	1.556	7.79	7.79	252.7	252.7	8.98	8.98	24.40	24.40
i158.3-a	8/27/2007	115	0.244	1.477	1.507	7.79	7.79	277.5	772.9	7.92	8.13	23.68	23.77
i158.3-a	8/27/2007	116	0.366	0.5956	1.04	7.89	8.3	287.8	245.2	7.94	8.86	23.39	23.89
i158.3-a	8/27/2007	117	0.549	1.48	0.8919	7.79	8.04	256.5	247.9	1.95	1.30	23.72	23.75
i158.3-a	8/27/2007	118	0.152	0.6048	0.6048	8.51	8.47	245	245	3.95	3.95	23.33	23.33
i158.4-a	8/27/2007	119	0.152	0.0322	0.0322	8.43	8.36	325.1	325.1	7.06	7.06	26.67	26.67
i158.4-a	8/27/2007	120	0.229	1.776	1.776	7.79	7.79	326.9	326.9	7.67	7.67	26.42	26.42
i158.4-a	8/27/2007	121	0.457	0.3217	0.4873	8.21	8.19	327.8	328.6	7.52	7.48	24.27	24.36
i158.4-a	8/27/2007	122	0.152	0.6953	0.6953	8.51	8.45	335.2	335.2	7.45	7.45	25.15	25.15
i158.4-a	8/27/2007	123	0.152	0.4699	0.4699	8.68	8.63	333.9	333.9	8.03	8.03	25.62	25.62
i158.3-a	8/28/2007	124	0.122	m	m	9.29	9.32	388	387	13.07	13.43	22.86	22.90
i158.3-a	8/28/2007	125	0.396	m	m	8.42	9.26	391	389	12.93	12.93	22.42	22.47
i158.3-a	8/28/2007	126	0.244	m	m	7.91	9.1	468	387	12.38	13.17	22.61	22.40
i158.3-a	8/29/2007	130	0.122	0.0863	0.0828	8.31	8.48	432.3	399.3	9.73	9.38	24.12	24.65
i158.3-a	8/29/2007	131	0.366	0.1158	0.1057	8.05	8.39	441.9	410.1	4.46	6.21	24.08	25.53
i158.3-a	8/29/2007	132	0.122	0.1174	0.1199	8.45	9.13	435.5	423.7	5.99	6.12	25.56	25.64
i161.3-a	8/29/2007	127	0.091	0.0856	0.0745	8.98	8.96	388.4	389.4	11.59	11.26	22.60	22.89
i161.3-a	8/29/2007	128	0.671	0.0771	0.0619	8.75	7.62	451.2	395.8	9.90	1.02	22.68	23.30
i161.3-a	8/29/2007	129	0.107	0.0668	0.0636	8.91	9.7	652.4	508.5	9.86	12.12	23.04	24.19

Table B.1. Water quality data collected from isolated pools. "S" and "B" signify measurements taken at the surface and bottom of the water column. "Sample" signifies map points. "m" denotes where water quality data is missing. (continued).

Site ID	Date	Sample	Depth (m)	Ammonia (ppm) B	Ammonia (ppm) S	pH B	pH S	Conductivity (µs/cm) B	Conductivity (µs/cm) S	DO (ppm) B	DO (ppm) S	Temperature (°C) B	Temperature (°C) S
i158.3-a	8/30/2007	136	0.518	0.3411	0.4027	7.71	7.81	864	849.2	2.88	2.75	21.95	22.06
i158.3-a	8/30/2007	137	0.122	0.3224	0.3963	7.85	7.82	193.2	190.3	3.32	4.13	23.77	24.11
i158.3-a	8/30/2007	138	0.091	0.424	0.2654	8.01	8.05	177	156.8	5.82	5.96	21.34	19.22
i161.3-a	8/30/2007	133	0.152	0.295	0.2888	8.28	8.21	446.8	451.7	5.54	5.43	22.51	22.80
i161.3-a	8/30/2007	134	0.945	0.3768	0.3519	7.61	7.98	874.4	443	1.58	2.53	22.01	21.67
i161.3-a	8/30/2007	135	0.213	0.3954	0.3671	7.89	7.92	445.8	445.7	3.74	3.35	21.98	22.04
i158.3-a	8/31/2007	139	0.091	0.2177	0.244	7.81	7.78	239.3	236.7	4.47	4.25	22.44	22.53
i158.3-a	8/31/2007	140	0.305	0.6259	0.2506	7.34	7.67	306.3	206	1.49	1.24	21.56	21.92
i158.3-a	8/31/2007	141	0.183	0.2686	0.2437	7.72	7.74	211.8	211.4	2.54	2.19	21.02	21.04
i158.3-a	9/1/2007	142	0.091	0.2637	0.2444	8.35	8.25	477.5	479.1	12.14	12.68	29.44	29.67
i158.3-a	9/1/2007	144	0.640	m	m	8.45	8.72	430	423	7.85	7.53	22.52	28.70
i158.3-a	9/1/2007	145	0.427	m	m	7.79	8.6	432	428	6.98	7.56	22.52	27.51
i158.3-a	9/1/2007	146	0.061	m	m	8.67	8.66	428	431	6.94	7.03	29.26	29.57
i158.3-a	9/7/2007	147	0.122	m	m	8.88	8.94	504	505	10.56	10.49	19.19	19.48
i158.3-a	9/7/2007	148	0.244	m	m	8.18	8.99	593	447	2.54	7.97	19.33	18.51
i158.3-a	9/7/2007	149	0.122	m	m	8.9	9.01	448	446	7.71	7.71	18.25	18.49
i161.3-a	9/7/2007	150	0.122	m	m	8.2	8.36	441	457	5.65	6.38	21.13	22.35
i161.3-a	9/7/2007	151	0.335	m	m	8.18	8.37	473	458	5.49	6.02	19.93	22.33
i161.3-a	9/7/2007	152	0.213	m	m	8.37	8.48	456	457	6.40	6.61	23.28	23.71
i158.3-a	9/8/2007	153	0.305	0.0468	0.0451	7.89	8.43	771.9	427.7	5.62	7.75	20.11	19.74
i158.3-a	9/8/2007	154	0.122	0.0337	0.0277	7.43	8.67	436.1	439.3	6.49	6.86	20.09	20.27
i158.3-a	9/8/2007	155	0.183	0.0545	0.0343	8.36	8.78	433.3	431.5	3.96	7.66	20.13	20.34
i161.3-a	9/8/2007	156	0.183	0.0758	0.0504	7.34	7.31	509.6	472	7.14	7.42	23.10	23.43
i161.3-a	9/8/2007	157	0.366	0.0434	0.0389	7.99	8.14	460.8	458	6.55	6.78	22.25	22.18
i161.3-a	9/8/2007	158	0.183	0.0362	0.0357	8.14	8.07	450.7	447.9	6.82	6.74	22.45	22.54
i158.3-a	9/9/2007	159	0.122	0.0459	0.0463	7.95	8.17	380	374.8	2.49	4.31	17.74	17.76
i158.3-a	9/9/2007	160	0.274	0.0384	0.422	8.08	8.3	383.5	377	5.50	5.76	18.28	18.36
i158.3-a	9/9/2007	161	0.122	0.0308	0.0308	8.3	8.3	387.2	387.2	6.71	6.71	18.06	18.06
i158.3-a	9/10/2007	165	0.091	0.0586	0.0564	8.34	8.22	407.9	409.9	7.97	7.93	18.51	18.61
i158.3-a	9/10/2007	167	0.091	0.0749	0.0463	7.49	7.79	591.3	425.3	5.68	2.77	19.63	20.47
i158.3-a	9/10/2007	166	0.122	0.0388	0.0354	7.94	8.3	414.1	417.2	6.34	6.93	19.04	19.52
i161.3-a	9/10/2007	162	0.152	0.0569	0.0566	7.85	8.09	579	424.2	5.28	6.62	18.69	18.63

Table B.1. Water quality data collected from isolated pools. "S" and "B" signify measurements taken at the surface and bottom of the water column. "Sample" signifies map points. "m" denotes where water quality data is missing. (continued).

			Depth	Ammonia (ppm)		pH		Conductivity (µs/cm)		DO (ppm)		Temperature °C)	
Site ID	Date	Sample	(m)	B	S	B	S	B	S	B	S	B	S
i161.3-a	9/10/2007	163	0.244	0.0352	0.0379	8.47	8.44	432.9	434.4	6.07	6.06	19.90	20.02
i161.3-a	9/10/2007	164	0.213	0.0307	0.0331	8.36	8.44	432.2	433.3	6.45	6.31	19.87	19.96
i158.3-a	9/11/2007	171	0.091	0.1619	0.1835	7.39	8.18	478.1	450.6	4.67	8.25	19.34	19.79
i158.3-a	9/11/2007	172	0.122	0.0551	0.0769	7.64	7.97	512.8	399.5	5.65	5.65	18.21	18.78
i158.3-a	9/11/2007	173	0.091	0.0535	0.0635	7.66	7.86	658.5	450.3	9.04	9.78	17.78	17.66
i161.3-a	9/11/2007	168	0.244	0.0732	0.0686	7.43	7.96	423.4	422.3	2.43	4.11	18.84	18.83
i161.3-a	9/11/2007	169	0.183	0.0793	0.0949	8.43	8.45	419.3	423.4	5.69	5.56	18.44	18.60
i161.3-a	9/11/2007	170	0.122	0.0949	0.0849	8.42	8.36	441.1	417.2	5.90	5.64	17.89	18.09
i158.3-a	9/12/2007	174	0.091	0.043	0.043	7.79	7.79	389.9	389.9	7.56	7.56	19.11	19.11
i158.3-a	9/12/2007	175	0.152	0.0236	0.0299	7.84	8.14	412.8	405.6	5.04	6.34	19.78	20.16
i158.3-a	9/12/2007	176	0.061	0.0358	0.0374	7.77	7.72	555.1	415.6	9.48	8.18	20.26	20.84
i161.3-a	9/12/2007	177	0.091	0.0444	0.0393	7.96	8.07	469.8	472	5.84	5.42	24.17	23.21
i161.3-a	9/12/2007	178	0.244	0.0412	0.033	7.97	8.1	469.6	473.1	5.20	5.15	22.67	22.81
i161.3-a	9/12/2007	179	0.213	0.0332	0.0338	8.01	7.98	471.6	473.7	3.85	4.26	23.04	22.90
i158.3-a	9/13/2007	180	0.061	0.9474	1.001	8.16	8.51	640.7	365.7	11.60	11.75	16.66	16.87
i158.3-a	9/13/2007	181	0.091	1.207	1.07	8.28	8.4	431.3	383.3	8.43	5.31	17.17	17.38
i158.3-a	9/13/2007	182	0.030	1.064	1.07	8.71	8.34	418.8	650	10.87	10.84	17.11	17.22
i161.3-a	9/13/2007	183	0.061	1.353	1.164	8.2	8.14	450.6	593.6	7.20	7.31	21.20	21.08
i161.3-a	9/13/2007	184	0.152	1.143	1.048	8.16	8.25	440.9	456.2	6.50	6.47	19.95	21.46
i161.3-a	9/13/2007	185	0.091	1.034	1.063	8.16	8.31	449.3	455.3	5.94	5.42	20.68	21.37
i161.3-a	9/14/2007	186	0.152	m	m	8.73	8.91	460	436	m	m	22.20	23.12
i161.3-a	9/14/2007	187	0.701	m	m	8.47	8.6	461	461	m	m	18.35	19.25
i161.3-a	9/14/2007	188	0.091	m	m	8.39	8.35	467	462	m	m	21.50	21.73
i161.3-a	9/15/2007	1	0.091	80.75	73.56	7.05	6.92	463.1	484	10.79	11.92	26.66	26.49
i161.3-a	9/15/2007	2	0.518	82.83	84.42	7.74	7.92	462.2	462.6	9.25	9.81	23.31	23.98
i161.3-a	9/15/2007	3	0.122	74.82	80.76	7.32	7.83	513	466.8	10.18	10.04	25.50	24.90
i161.3-a	9/16/2007	4	0.122	58.11	72.59	7.59	7.62	408.2	432.7	7.43	7.30	17.23	17.33
i161.3-a	9/16/2007	5	0.579	77.99	78.64	7.61	7.55	432.7	431.5	3.92	3.37	18.67	18.66
i161.3-a	9/16/2007	6	0.122	65.84	64.05	7.71	7.94	436.1	435.8	4.48	4.59	18.90	19.04
i161.3-a	9/17/2007	7	0.061	m	m	9.33	9.33	313	454	m	m	19.72	19.72
i161.3-a	9/17/2007	8	0.427	m	m	8.2	8.17	473	459	m	m	20.06	20.11
i161.3-a	9/17/2007	9	0.061	m	m	8.23	8.2	447	457	m	m	20.27	20.60

Table B.1. Water quality data collected from isolated pools. "S" and "B" signify measurements taken at the surface and bottom of the water column. “Sample” signifies map points. "m" denotes where water quality data is missing. (continued).

Site ID	Date	Sample	Depth (m)	Ammonia (ppm)		pH		Conductivity (µs/cm)		DO (ppm)		Temperature (°C)	
				B	S	B	S	B	S	B	S	B	S
i161.3-a	9/18/2007	10	0.030	m	m	8.41	8.11	437	434	m	m	16.22	16.33
i161.3-a	9/18/2007	11	0.427	m	m	7.92	7.96	431	429	m	m	17.66	17.71
i161.3-a	9/18/2007	12	0.061	m	m	8.04	8.08	430	426	m	m	17.82	17.90
i161.3-a	9/19/2007	13	0.366	m	m	8.41	8.35	421	421	3.95	3.95	16.50	16.50
i161.3-a	9/19/2007	14	0.457	m	m	7.65	8.27	602	421	1.01	4.27	17.39	16.50
i161.3-a	9/19/2007	15	0.152	m	m	8.11	8.28	433	408	4.43	6.69	16.20	16.78
i161.3-a	9/20/2007	16	0.061	159.5	176.9	7.13	7.55	393	266.2	8.78	8.52	19.06	19.24
i161.3-a	9/20/2007	17	0.503	175	144.7	6.94	7.47	677.4	398.6	2.19	2.71	19.22	18.82
i161.3-a	9/20/2007	18	0.183	122.6	122.1	7.61	7.7	398.5	383	4.73	7.28	18.72	19.05

Appendix C
Isolated Pool Hobo Event Logger Data

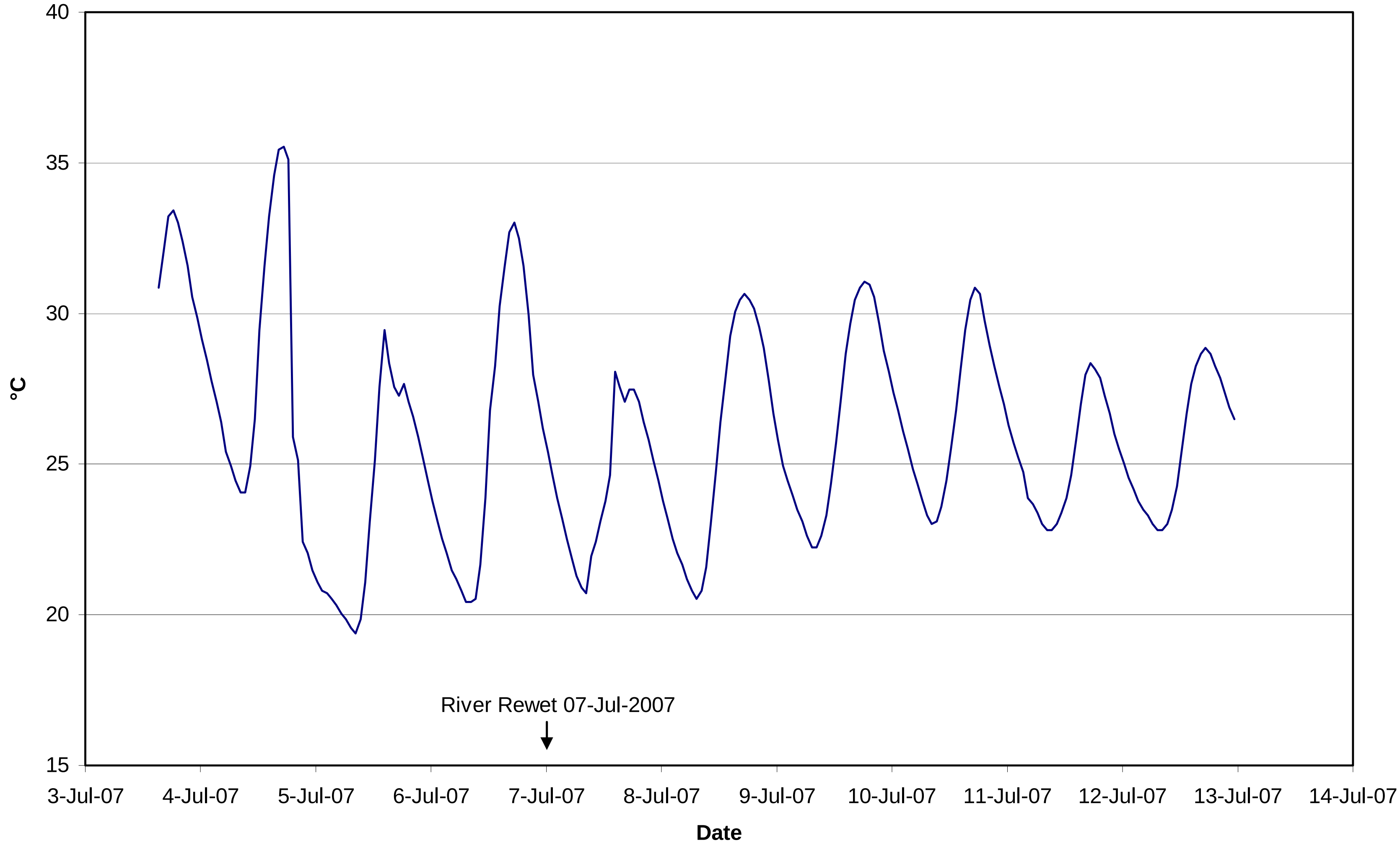

Figure C.1. Hourly temperature (°C) of pool s081.5-a during the monitoring period.

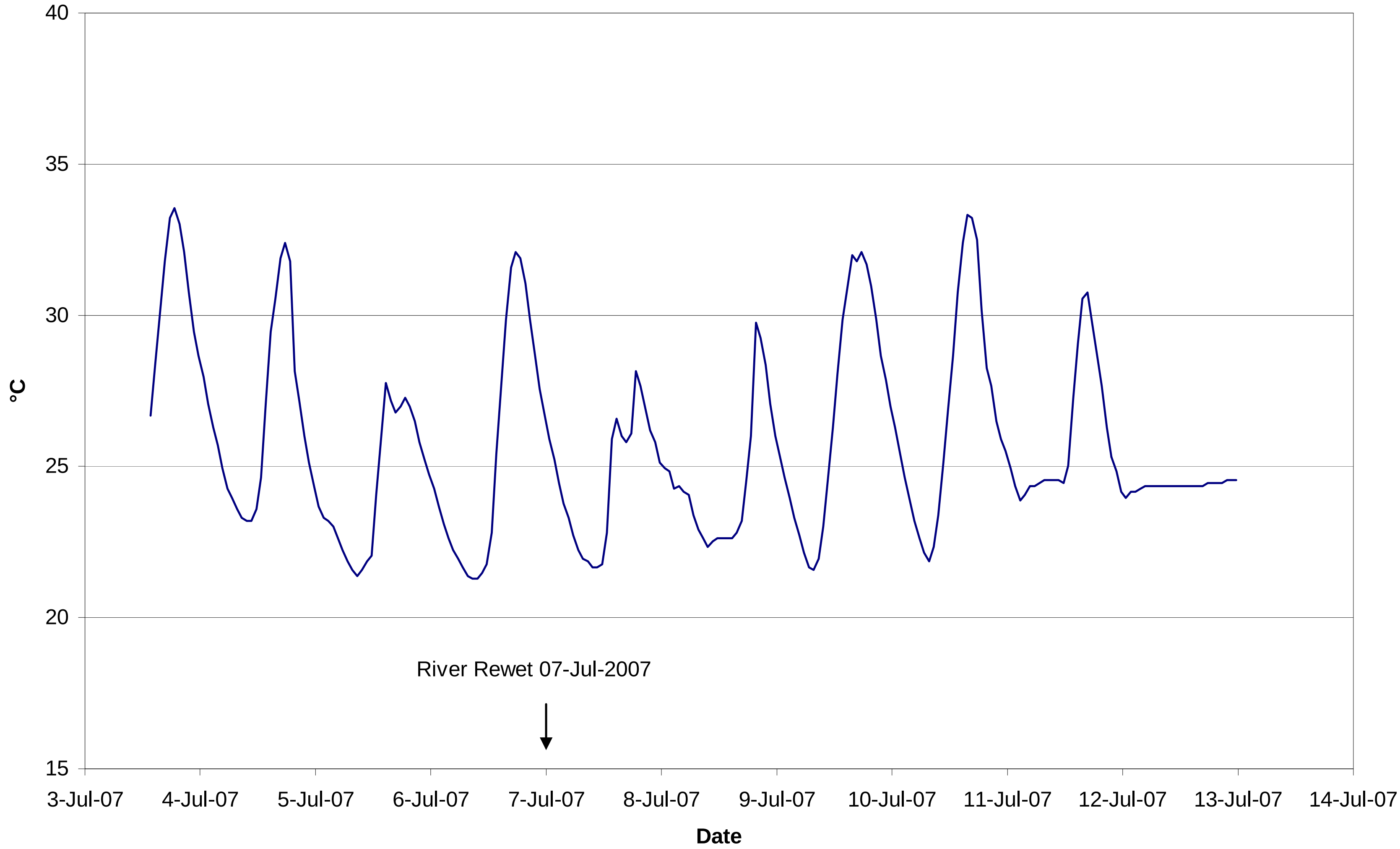

Figure C.2. Hourly temperature (°C) of pool s077.4.-a during the monitoring period.

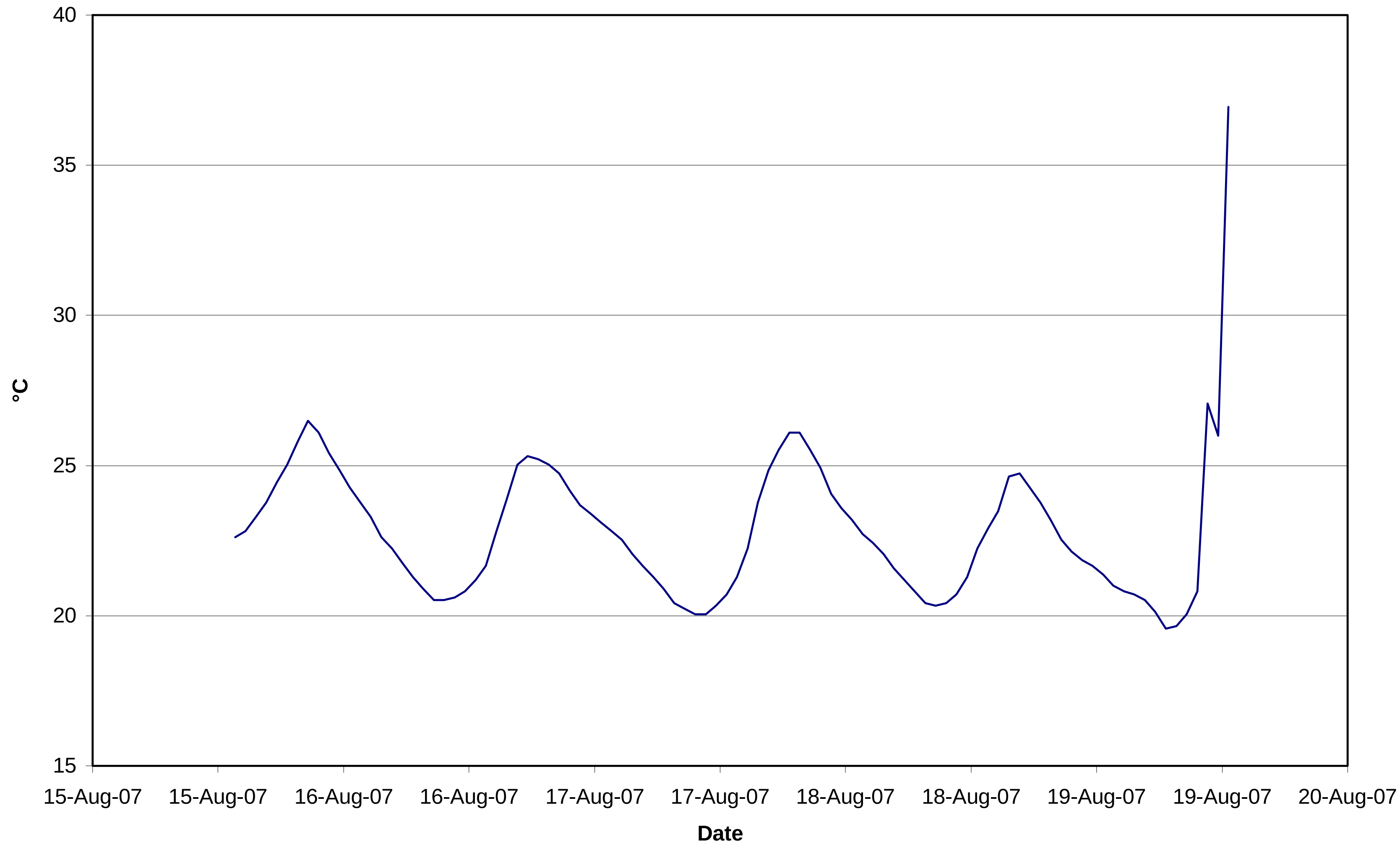

Figure C.3. Hourly temperature (°C) of pool i154.4.-a during the monitoring period.

Appendix D
Maps of Wasteway/Outfalls Monitored

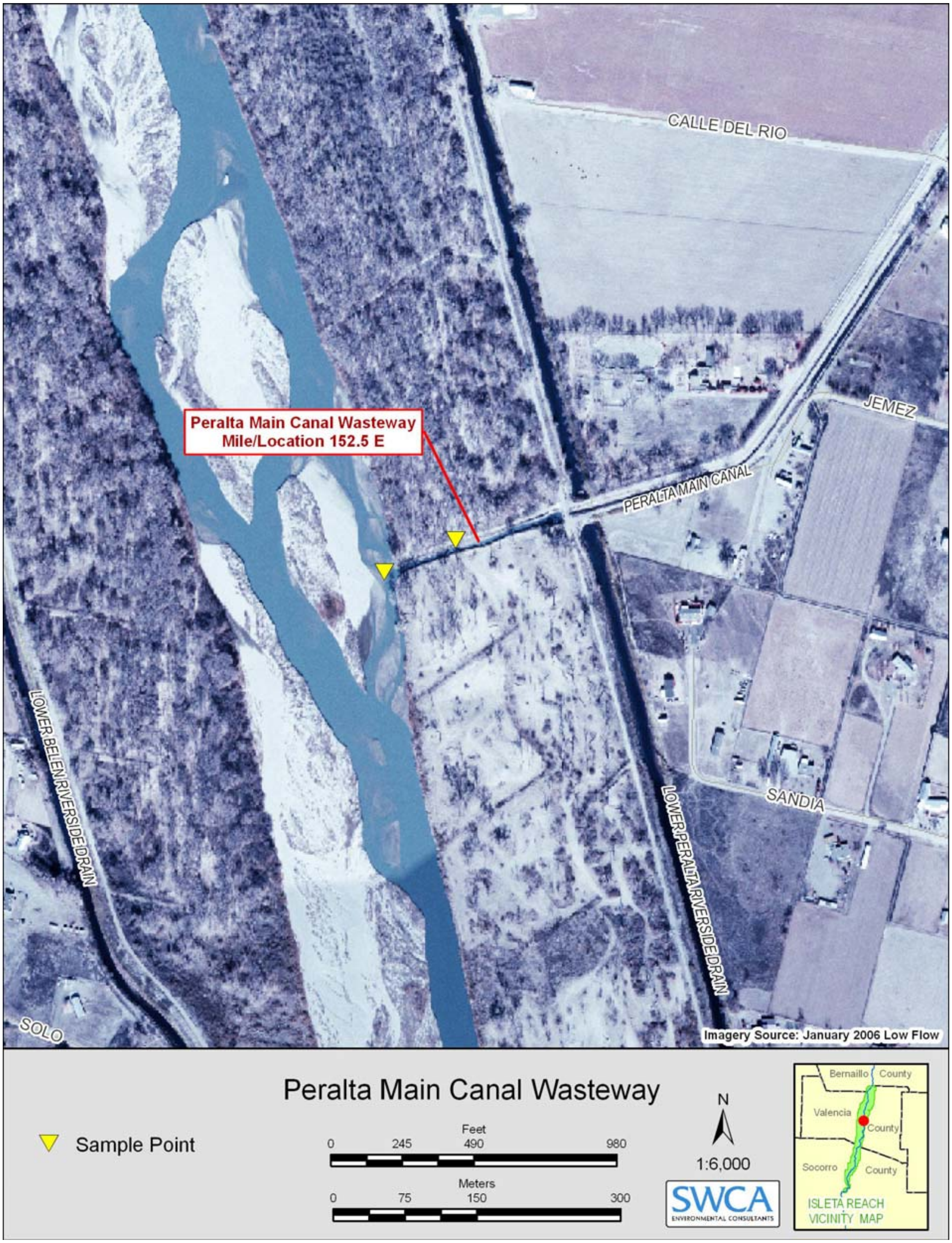

Figure D.1. Peralta Main Canal Wasteway, located at RM 152.5 E, was monitored for water quality, depth, flow, and fish presence or absence, if observed.

Figure D.2. The Lower Peralta Riverside Drain (LP1DR), located at RM 149.6 E.

Figure D.3. The Belen Riverside Drain is located at RM 147.7 W and was monitored July 9, 2007, and August 2, 2007.

Figure D.4. The New Belen Wasteway is located at RM 147.1 W and was monitored on September 21, 2007.

Figure D.5. Lower Peralta Riverside Drain (LP2DR), located at RM 144.7 E, was monitored on July 1, July 10, August 2, September 27, and October 24, 2007.

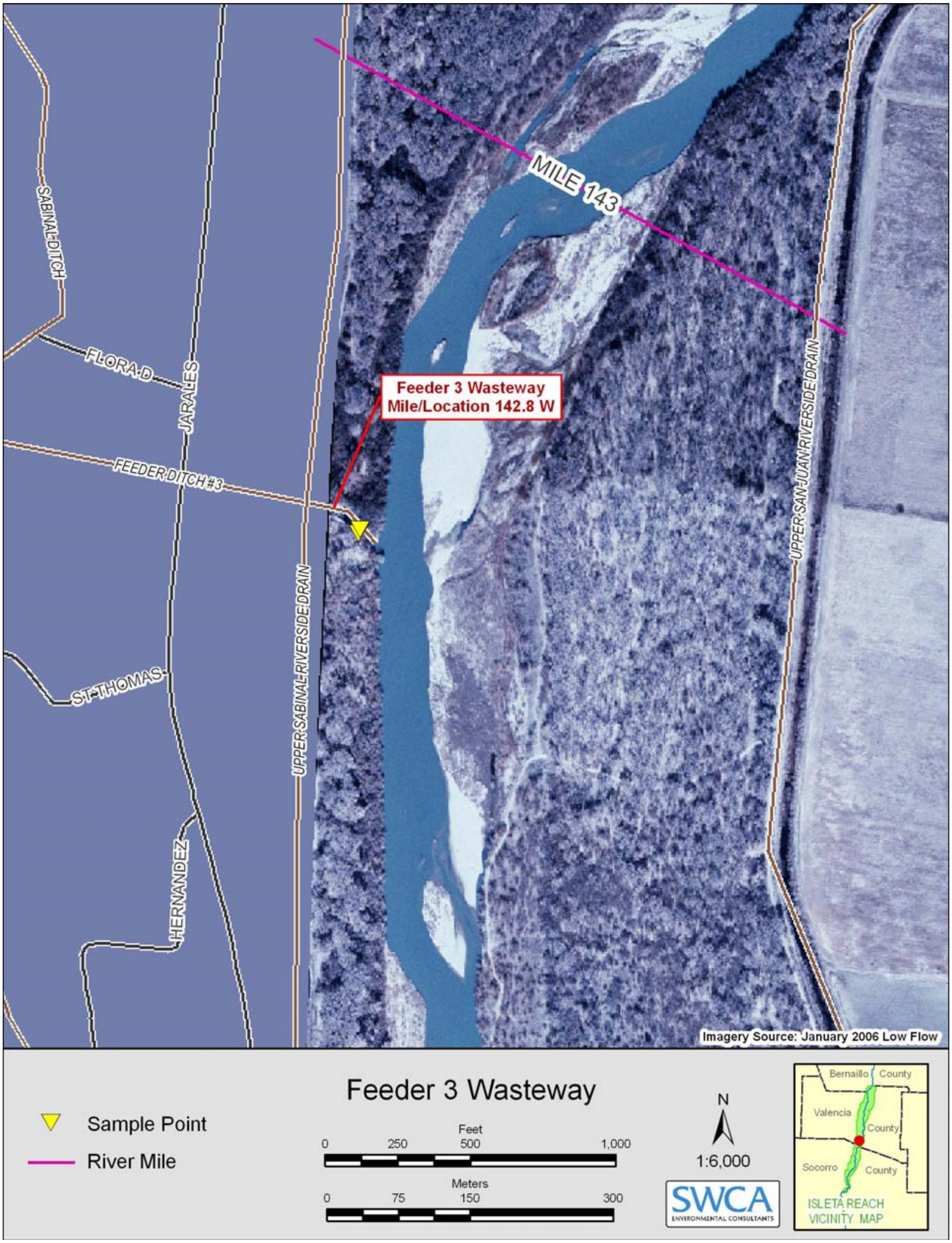

Figure D.6. Feeder 3 Wasteway is located at RM 142.8 W.

Figure D.7. Storrie Wasteway (RM 140.1 E) was monitored on July 1, July 10, August 2, and October 23, 2007.

Figure D.8. The Sabinal Drain Outfall (RM 137.9 W) did not contain water during the months of June or July 2007. The Sabinal Drain Outfall was monitored on August 3, September 27, and October 24, 2007.

Figure D.9. The San Francisco Riverside Drain (RM 126.8 W) and the Lower San Juan Riverside Drain (RM 126.6 E) are depicted on the same map due to their proximity.

Figure D.10. The Unit 7 Drain sampling site actually lies nearer to the RM 116 than RM 115. The location of the sample points depicted on this map illustrates the location specified by client from which water quality parameters should be monitored.

Appendix E
Wasteway/Outfall Water Quality Data

Table E.1. Wasteway/Outfall Water Quality Data Collected from Each Site by Date. "m" denotes missing data.

Site	Date	Sample	Flow (m/s)	pH	Conductivity (µs/cm)	Ammonia (ppm)	Depth (m)	Temp. (°C)	DO (ppm)
Peralta Main Canal Wasteway	7/1/2007	4	0.186	7.17	467	0.4823	0.366	25.27	m
Peralta Main Canal Wasteway	7/10/2007	16	0.549	8.27	490.4	m	0.073	28.26	m
Peralta Main Canal Wasteway	8/2/2007	25	0.378	7.8	395.2	0.1949	0.610	26.39	11.13
Peralta Main Canal Wasteway	9/21/2007	12	0.442	7.53	386.1	258.1	0.610	19.03	7.63
Peralta Main Canal Wasteway	10/23/2007		0.000	7.59	335.5	275.3	0.244	6.22	7.63
Lower Peralta Riverside Drain 1	7/1/2007	5	0.853	7.12	517.5	0.3886	0.817	22.34	m
Lower Peralta Riverside Drain 1	7/10/2007	15	0.158	8.14	535.8	m	0.579	24.19	m
Lower Peralta Riverside Drain 1	8/2/2007	20	0.539	7.61	453.6	0.1417	0.762	22.12	11.70
Lower Peralta Riverside Drain 1	9/21/2007	13	0.421	7.56	453.2	254.9	0.732	17.82	7.28
Lower Peralta Riverside Drain 1	10/23/2007		0.000	7	724.2	568.2	0.183	15.26	2.78
Belen Riverside Drain	7/9/2007	11	0.104	8.64	552.8	m	0.762	21.94	m
Belen Riverside Drain	8/2/2007	21	0.491	7.93	539.9	0.1353	0.488	22.14	11.25
Belen Riverside Drain	9/21/2007	15	0.506	7.75	525.4	183.1	0.701	17.97	6.75
Belen Riverside Drain	10/23/2007		0.335	7.57	493.9	349.6	0.610	10.12	8.84
New Belen Wasteway	9/21/2007	14	0.396	7.64	514	204.5	0.536	17.76	6.45
Lower Peralta Riverside Drain 2	7/1/2007	7	0.000	7.22	580.8	0.4299	0.549	24.57	m
Lower Peralta Riverside Drain 2	7/10/2007	14	0.003	8.2	538.7	m	0.701	24.88	m
Lower Peralta Riverside Drain 2	8/2/2007	24	0.000	7.74	556.8	0.2056	0.671	25.18	10.67
Lower Peralta Riverside Drain 2	9/27/2007		0.082	7.7	487	477.7	0.396	16.10	6.89
Lower Peralta Riverside Drain 2	10/24/2007		0.000	8.17	459.2	257.4	0.488	12.17	7.77
Feeder 3 Wasteway	7/1/2007	6	0.000	7.33	571.3	0.4367	1.036	26.24	m
Feeder 3 Wasteway	7/10/2007	13	0.000	8.07	483.7	m	0.853	25.57	m
Feeder 3 Wasteway	8/2/2007	22	0.000	7.65	396.7	0.1831	1.372	24.94	9.74
Feeder 3 Wasteway	9/15/2007	2	0.000	7.58	590.9	103.9	0.671	26.53	5.34
Feeder 3 Wasteway	10/23/2007		0.000	7.68	385	421.4	0.762	10.38	8.99
Storrie Wasteway	7/1/2007	3	0.098	7.84	550.1	0.3116	0.305	25.42	m
Storrie Wasteway	7/10/2007	12	0.024	8.38	537.7	m	0.305	25.91	m
Storrie Wasteway	8/2/2007	23	0.046	8.46	555.7	0.1685	0.274	26.84	14.28
Storrie Wasteway	10/23/2007		0.728	7.83	444.4	354.7	0.518	10.09	9.25
Sabinal Drain Outfall	8/3/2007	29	0.006	9.05	698.7	0.1702	0.076	33.61	16.35
Sabinal Drain Outfall	9/27/2007	1	0.299	7.54	531.5	390	0.183	16.18	6.51
Sabinal Drain Outfall	10/24/2007		0.518	8.14	540.7	206.7	0.122	14.94	10.94
San Francisco Riverside Drain	7/11/2007	18	0.012	7.36	622.9	m	0.091	22.31	m
San Francisco Riverside Drain	8/3/2007	27	0.000	7.67	m	0.3387	0.305	22.88	4.25

Table E.1. Wasteway/Outfall Water Quality Data Collected from Each Site by Date. "m" denotes missing data (continued).

Site	Date	Sample	Flow (m/s)	pH	Conductivity (µs/cm)	Ammonia (ppm)	Depth (m)	Temp. (°C)	DO (ppm)
San Francisco Riverside Drain	9/13/2007	86	0.430	8.01	610.7	1.264	0.091	21.06	9.54
Lower San Juan Riverside Drain	6/30/2007	2	0.863	7.43	687.5	0.3202	0.853	27.56	m
Lower San Juan Riverside Drain	7/11/2007	19	0.238	8.07	571.6	m	0.366	22.22	m
Lower San Juan Riverside Drain	8/3/2007	28	1.323	8.13	569.5	0.1774	0.762	23.03	18.41
Lower San Juan Riverside Drain	9/13/2007	87	0.786	8.03	610.9	1.206	0.701	21.11	9.54
Lower San Juan Riverside Drain	10/24/2007		0.701	8.16	502.9	189.1	0.549	9.88	9.22
Unit 7 Drain	6/30/2007	1	0.402	7.38	818.7	0.3642	0.914	25.57	m
Unit 7 Drain	7/11/2007	17	0.140	7.54	586.3	m	1.006	23.07	m
Unit 7 Drain	8/3/2007	26	0.287	7.97	634.6	0.1722	1.006	23.69	10.89
Unit 7 Drain	9/13/2007	85	0.430	7.46	629.8	1.088	0.975	20.83	6.86
Unit 7 Drain	10/24/2007		0.372	7.63	505	262.5	0.823	10.08	8.93

Appendix F
Wasteway/Outfall Hobo Event Logger Data

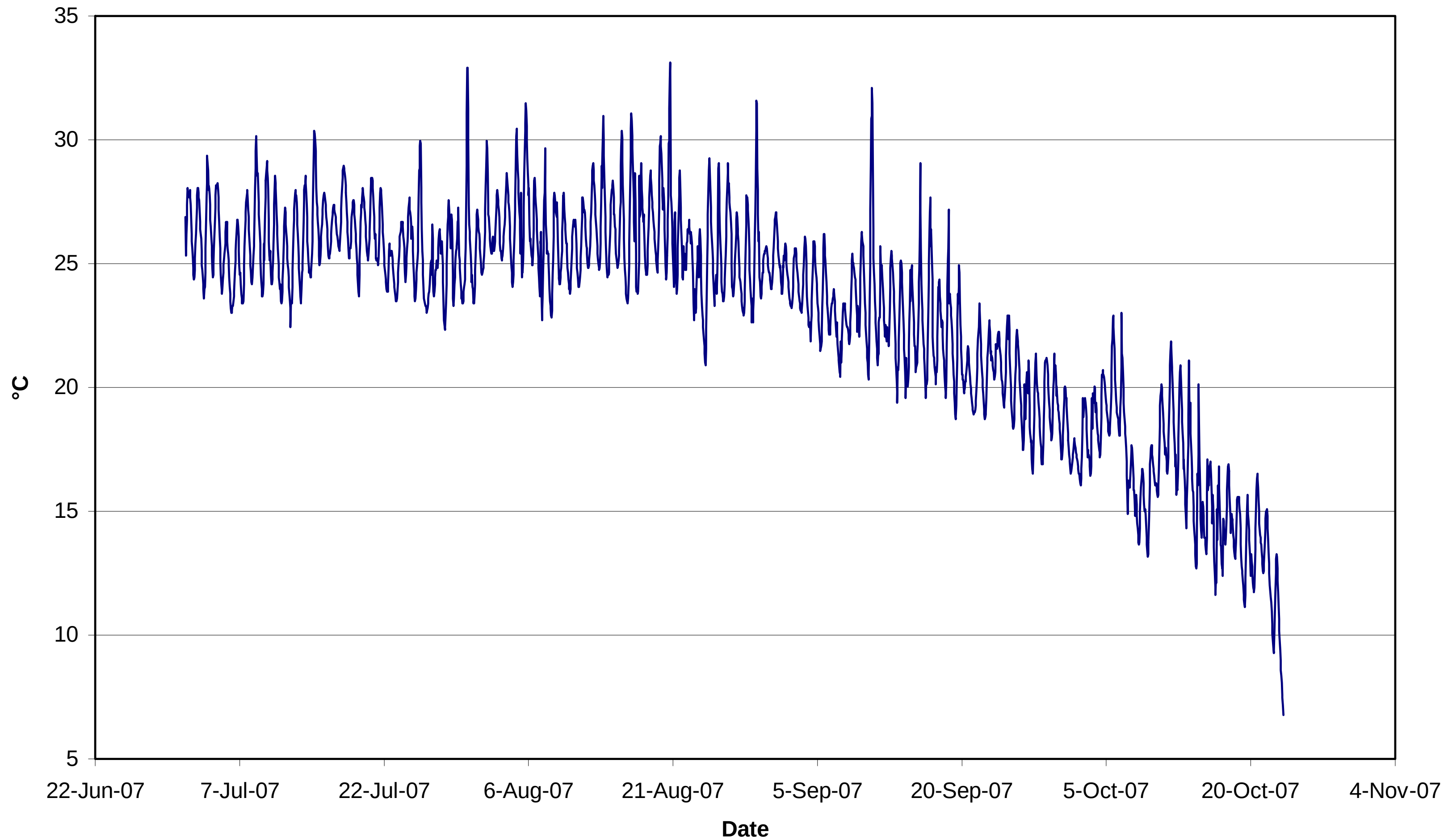

Figure F.1. Hourly temperature (°C) of Peralta Main Canal Wasteway (RM 152.5 E) during monitoring period.

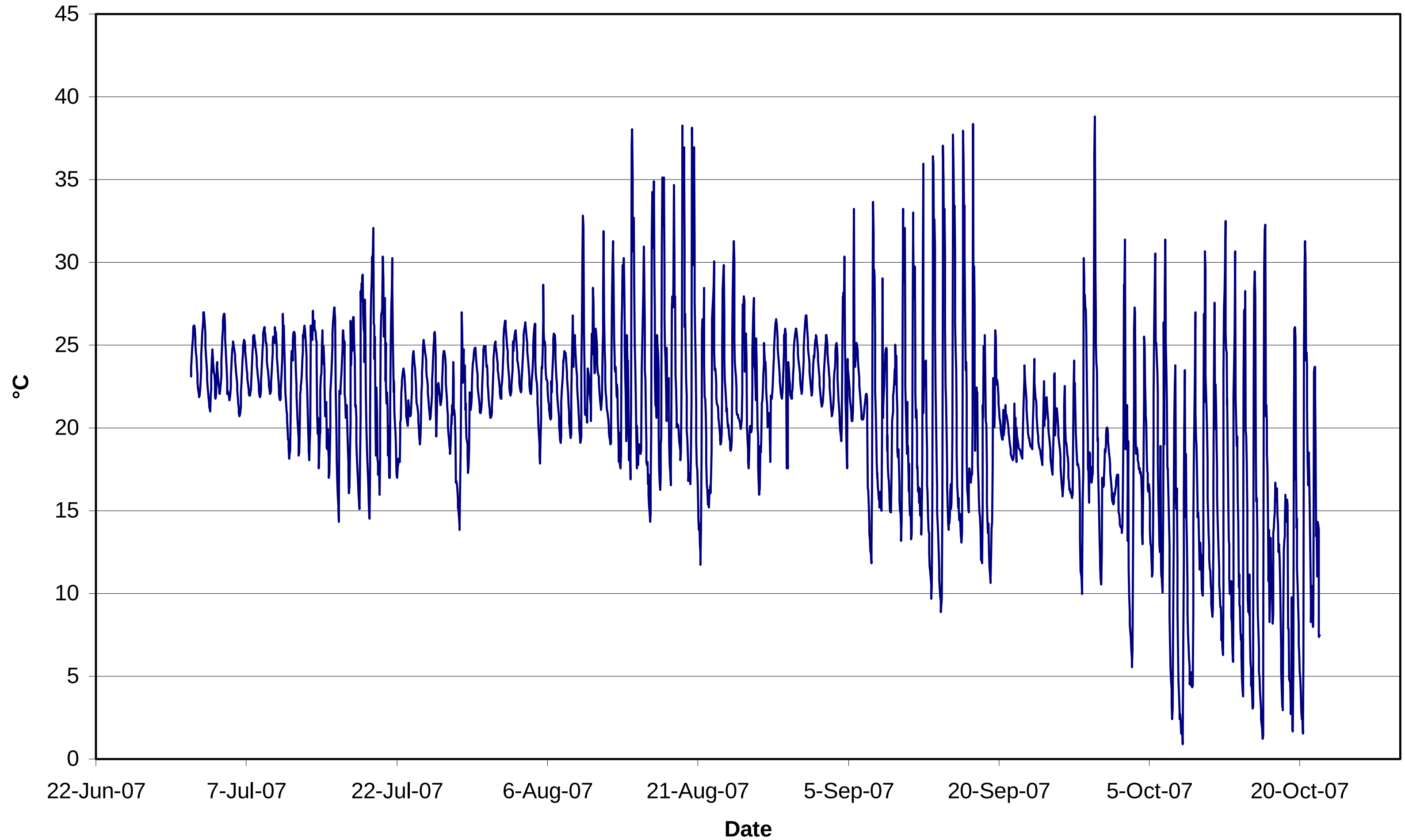

Figure F.2. Hourly temperature (°C) of Lower Peralta Riverside Drain (RM 149.6 E) during monitoring period.

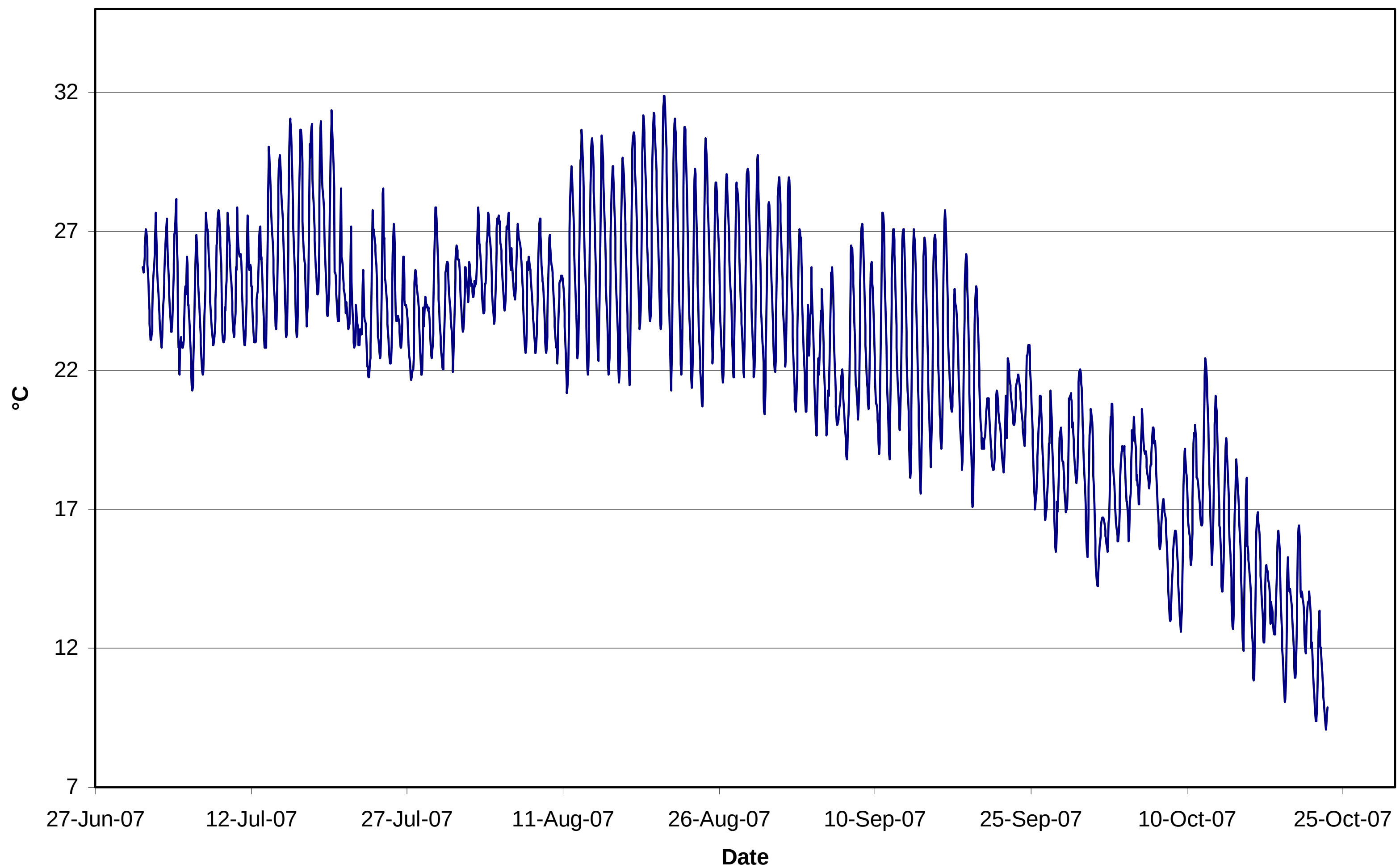

Figure F.3. Hourly temperature (°C) of Feeder 3 Wasteway (RM 142.8 W) during monitoring period.

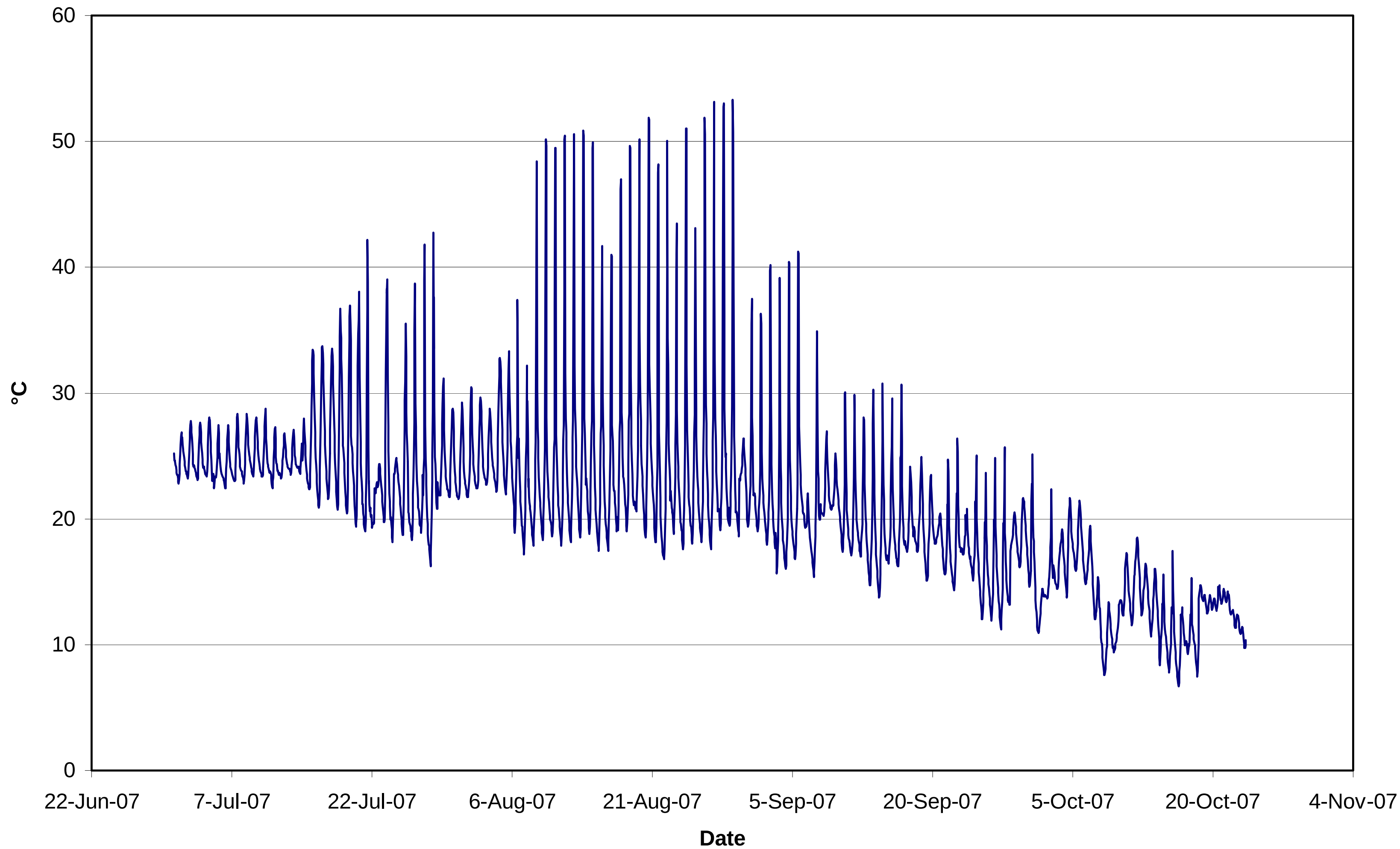

Figure F.4. Hourly temperature (°C) of Storrie Wasteway (RM 140.1 E) during monitoring period.

Appendix G
Wetted Reach Monitoring Water Quality Data

Table G.1. Water Quality Data Collected within the Isleta Reach During Wetted Reach Monitoring. Site IDs are only an approximation of the river mile indicated.

Site	Date	Sample	Water Source	flow(m/s)	Ph	Conductivity	Ammonia	Depth(m)	Temp °C	DO ppm
i153.5a	8/12/2007	30	Multiple Sources	0.00	7.31	535.7	0.542	0.442	26.41	11.19
i153.5a	8/13/2007	32	Rio Grande	0.00	9.57	474	0.3954	0.000	23.44	m
i152.5a	8/13/2007	33	Lower Peralta Rivers	0.00	8.63	484.1	0.609	0.000	25.17	m
i153.0a	8/13/2007	34	Rio Grande	0.00	8.95	1.35	0.4208	0.000	29.38	m
i153.4a	8/14/2007	35	Rio Grande	0.06	9.71	520.5	1.125	0.061	26.24	m
i154.4b	8/14/2007	36	Groundwater	0.08	8.91	593.7	1.119	0.091	27.42	m
i155.4a	8/15/2007	37	Rio Grande	0.12	9.04	532.9	0.9925	0.091	25.76	13.36
i155.6a	8/15/2007	38	Rio Grande	0.07	9.02	582.9	1.014	0.091	27.97	16.37
i157.8a	8/16/2007	39	Rio Grande	0.09	9.01	478.5	m	0.192	19.28	7.57
i157.8a	8/16/2007	40	Rio Grande	0.09	8.21	539.5	0.8553	0.091	22.95	10.06
i158.8a	8/16/2007	41	Rio Grande	0.12	7.85	980.5	2.606	0.122	29.66	10.27
i158.2a	8/17/2007		Rio Grande	0.00	7.78	838.6	2.525	0.061	21.56	6.05
i158.1a	8/17/2007		Rio Grande	0.00	9.04	1171	2.405	0.061	30.91	6.62
i161.4a	8/18/2007	42	Rio Grande	0.16	8.68	434.3	13.33	0.171	20.46	6.38
i161.4b	8/18/2007	43	Rio Grande	0.01	8.44	545.7	0.0457	0.018	30.02	13.30
i161.4a	8/19/2007	44	Rio Grande	0.10	8.24	443.1	0.8901	0.122	21.20	6.15
i161.3a	8/19/2007	45	Rio Grande	0.64	8.51	267.5	0.8689	0.091	26.99	13.38
i161.5a	8/20/2007		Rio Grande	0.35	8.23	455.7	m	0.046	20.88	7.16
i161.5b	8/20/2007		Rio Grande	0.00	8.28	521.4	m	0.061	24.84	6.88
i161.3a	8/21/2007	46	Rio Grande	0.09	7.95	428.3	0.7477	0.091	20.17	8.69
161.5a	8/21/2007	47	Rio Grande	0.05	8.21	544	4.505	0.183	28.59	9.46
161.6a	8/22/2007	48	Rio Grande	0.05	8.9	409.9	0.2269	0.061	19.39	7.41
i161.5b	8/22/2007	49	Rio Grande	0.34	8.69	492.3	0.4596	0.003	25.50	7.11
i161.4a	8/23/2007	50	Rio Grande	0.56	8.35	413.5	0.4766	0.152	19.05	7.18
i161.3a	8/23/2007	51	Rio Grande	0.21	8.02	523.3	0.5972	0.091	25.79	9.25
i161.5a	8/24/2007	52	Rio Grande	0.08	7.82	392.3	0.3325	0.168	18.83	7.05
i161.5a	8/24/2007	53	Rio Grande	0.12	8.4	482.9	0.6665	0.091	25.73	10.75
i158.8a	8/24/2007	54	Rio Grande	0.02	8.42	1045	m	0.122	28.54	14.44
i152.7a	8/25/2007	55	Rio Grande	0.15	8.96	210.2	1.068	0.774	20.61	6.70
i158.5a	8/27/2007	56	Rio Grande	0.00	8.01	509.4	0.345	0.610	24.15	6.33
i158.3a	8/27/2007	57	Rio Grande	0.00	8.38	458.4	0.0872	0.000	28.08	7.10
i157.3a	8/28/2007	58	Rio Grande	0.34	8.63	442	m	0.152	20.94	8.38
i156.7a	8/28/2007	59	Rio Grande	0.36	8.79	453	m	0.091	25.47	10.61
i161.3a	8/29/2007	60	Rio Grande	0.00	7.62	432.4	1.234	0.122	20.74	5.56
i161.3a	8/29/2007	61	Rio Grande	0.00	8.5	581.9	0.0976	0.030	29.65	9.19
i161.4a	8/30/2007	62	Rio Grande	0.01	7.82	374.2	0.3671	0.061	19.75	7.85
i161.5a	8/30/2007	63	Rio Grande	0.05	8.13	525.9	0.3576	0.030	29.16	13.61

Site	Date	Sample	Water Source	flow(m/s)	Ph	Conductivity	Ammonia	Depth(m)	Temp °C	DO ppm
i159.3a	8/31/2007	64	Rio Grande	0.05	8.03	420.6	0.1404	0.274	21.50	7.57
i158.3a	8/31/2007	65	Rio Grande	0.37	7.95	586.6	0.1841	0.091	28.57	9.98
i154.8a	9/1/2007	67	Rio Grande	0.21	7.82	419.3	0.15	0.274	22.09	7.59
i154.4a	9/1/2007	68	Rio Grande	0.05	8.56	452	m	0.061	29.10	6.36
i152.5a	9/2/2007	69	Rio Grande	0.87	6.58	741.7	0.0414	0.091	20.77	7.12
i158.8a	9/6/2007	70	Rio Grande	0.02	8.34	624	m	0.061	21.00	6.21
i160.4a	9/6/2007	71	Rio Grande	0.00	8.54	462	m	0.061	21.07	7.45
i159.4a	9/7/2007	72	Rio Grande	0.09	8.51	451	m	0.122	18.26	8.80
i159.4a	9/7/2007	73	Rio Grande	0.14	8.6	450	m	0.061	25.90	7.69
i159.7a	9/8/2007	74	Rio Grande	0.02	7.53	430.7	0.1426	0.091	19.84	7.43
i159.7a	9/8/2007	75	Rio Grande	0.07	8.17	571.7	0.0455	0.000	27.74	9.15
i160.8a	9/9/2007	76	Rio Grande	0.00	8.63	426.5	0.0863	0.030	19.67	6.86
i160.8a	9/9/2007	77	Rio Grande	0.00	8.95	524.3	0.0636	0.030	25.97	9.60
i160.9a	9/10/2007	78	Rio Grande	0.00	8.42	407.5	0.0457	0.061	19.11	6.74
i160.2a	9/10/2007	79	Rio Grande	0.01	8.77	512.4	0.0521	0.061	26.45	14.67
i161.3a	9/11/2007	80	Rio Grande	0.00	7.92	379.1	0.085	0.030	17.89	7.02
i161.2a	9/11/2007	81	Rio Grande	0.02	8.93	524.4	0.2491	0.061	26.26	12.97
i161.3a	9/12/2007	82	Rio Grande	0.00	8.06	424.4	0.0741	0.030	19.61	5.77
i161.3a	9/12/2007	83	Rio Grande	0.03	8.62	486.6	0.047	0.000	24.80	10.43
i161.5a	9/13/2007	84	Rio Grande	0.16	7.76	380.9	1.343	0.030	17.00	7.99
i161.4a	9/13/2007	88	Rio Grande	0.02	8.92	531.4	1.277	0.061	27.69	14.28
i161.6a	9/14/2007	89	Rio Grande	0.16	8.18	405.1	119.2	0.061	18.93	7.72
i161.5a	9/14/2007	90	Rio Grande	0.01	9.11	442	m	0.061	22.36	m
i161.6a	9/15/2007	1	Rio Grande	0.02	8.95	448.7	110.4	0.152	22.73	11.17
i161.4a	9/15/2007	3	Rio Grande	0.17	9.59	311.9	75.61	0.061	26.95	11.10
i161.6a	9/16/2007	4	Rio Grande	0.11	8.36	412.7	56.02	0.061	18.51	7.84
i161.6b	9/16/2007	5	Rio Grande	0.10	9.13	428	m	0.061	24.87	11.61
i161.7a	9/17/2007	6	Rio Grande	0.08	8.75	383	m	0.030	19.84	9.77
i161.5a	9/17/2007	7	Rio Grande	0.21	9.36	240	m	0.061	23.63	m
i161.2a	9/18/2007	8	Rio Grande	0.07	8.76	442	m	0.061	21.26	m
i161.6a	9/19/2007	9	Rio Grande	0.00	8.77	448	m	0.030	16.86	7.32
i161.5a	9/19/2007	10	Rio Grande	0.00	9.27	469.8	309	0.030	24.40	10.73
i161.6a	9/20/2007	11	Rio Grande	0.28	7.26	389	125.6	0.152	18.97	6.51
i161.4a	9/20/2007		Rio Grande	0.00	8.17	420.7	204.6	0.122	20.30	7.39
i159.4a	9/29/2007	2	Rio Grande	0.00	8.19	512.3	17.17	0.030	19.25	7.63
i159.5a	9/30/2007	3	Rio Grande	0.00	8.11	529.9	15.61	0.152	19.28	7.62
i159.9a	9/30/2007	4	Rio Grande	0.02	8.49	501.1	15.46	0.152	17.12	7.30
i161.4a	9/30/2007	5	Rio Grande	0.02	8.35	447.1	10.34	0.091	20.60	9.12

Appendix H
Maps of Wetted Reach Monitoring

Figure H.1. River mile 152 was the downstream end of drying within the Isleta Reach in 2007. The Peralta Main Canal Wasteway is in the center of the photo and was a significant source of supplemental flow throughout the monitoring period.

Figure H.2. Map of river mile 153 depicting wetted drying reach monitoring locations.

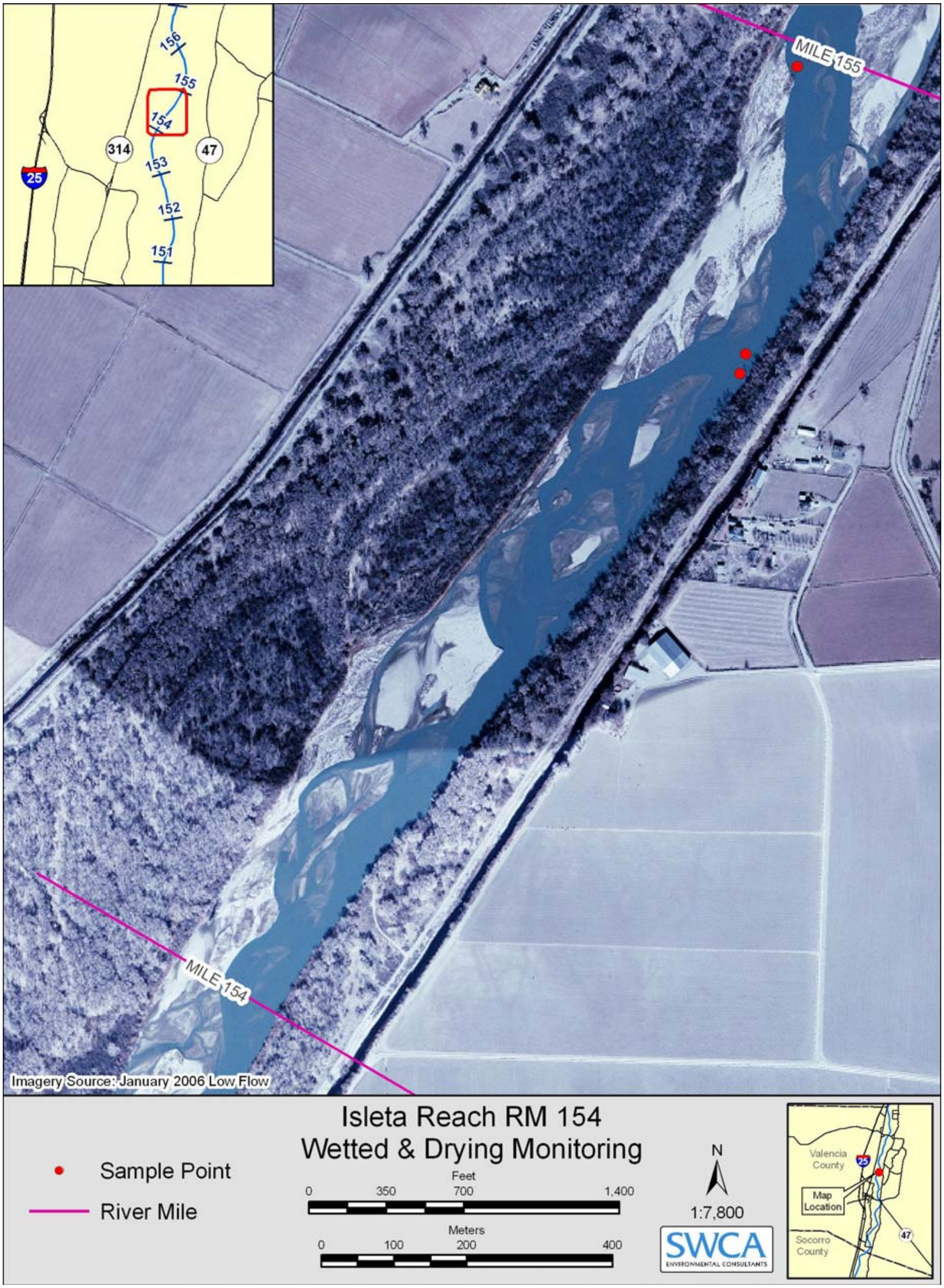

Figure H.3. Map of river mile 154 depicting wetted drying reach monitoring locations.

Figure H.4. Map of river mile 155 depicting wetted drying reach monitoring locations.

Figure H.5. Map of river mile 156. No wetted drying reach monitoring occurred within this river mile.

Figure H.6. Map of river mile 157 depicting wetted drying reach monitoring locations.

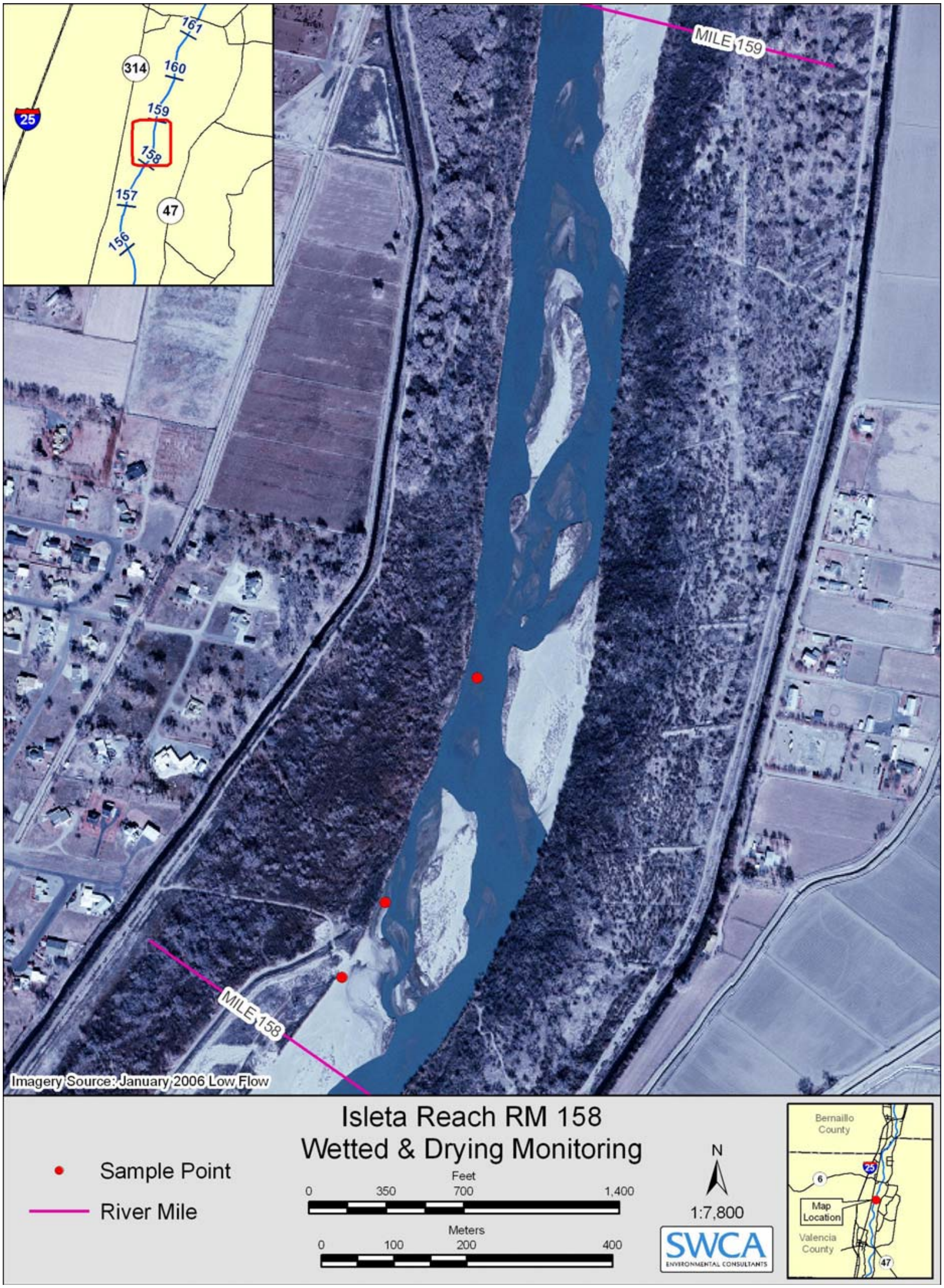

Figure H.7. Map of river mile 158 depicting wetted drying reach monitoring locations.

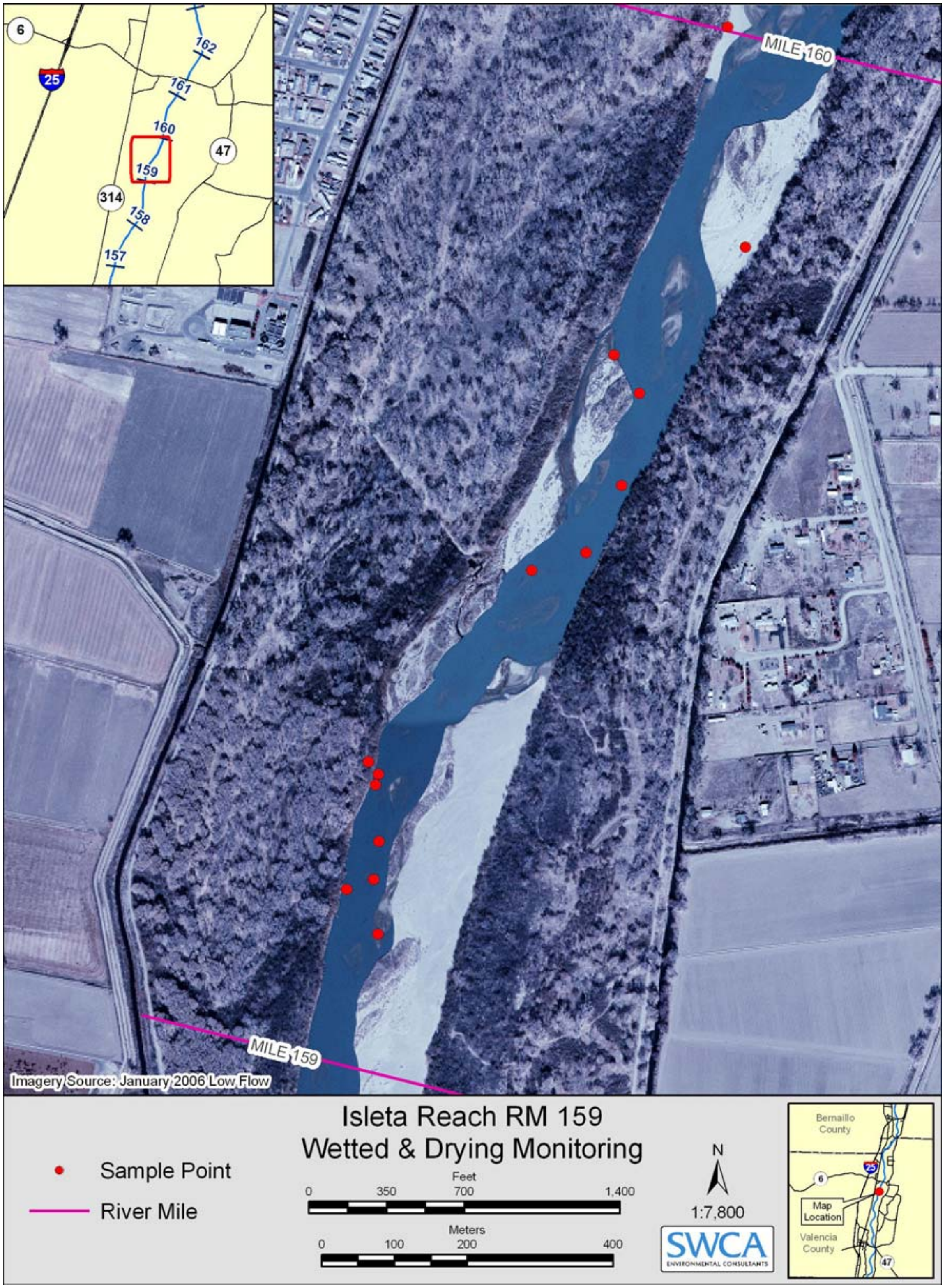

Figure H.8. Map of river mile 159 depicting wetted drying reach monitoring locations.

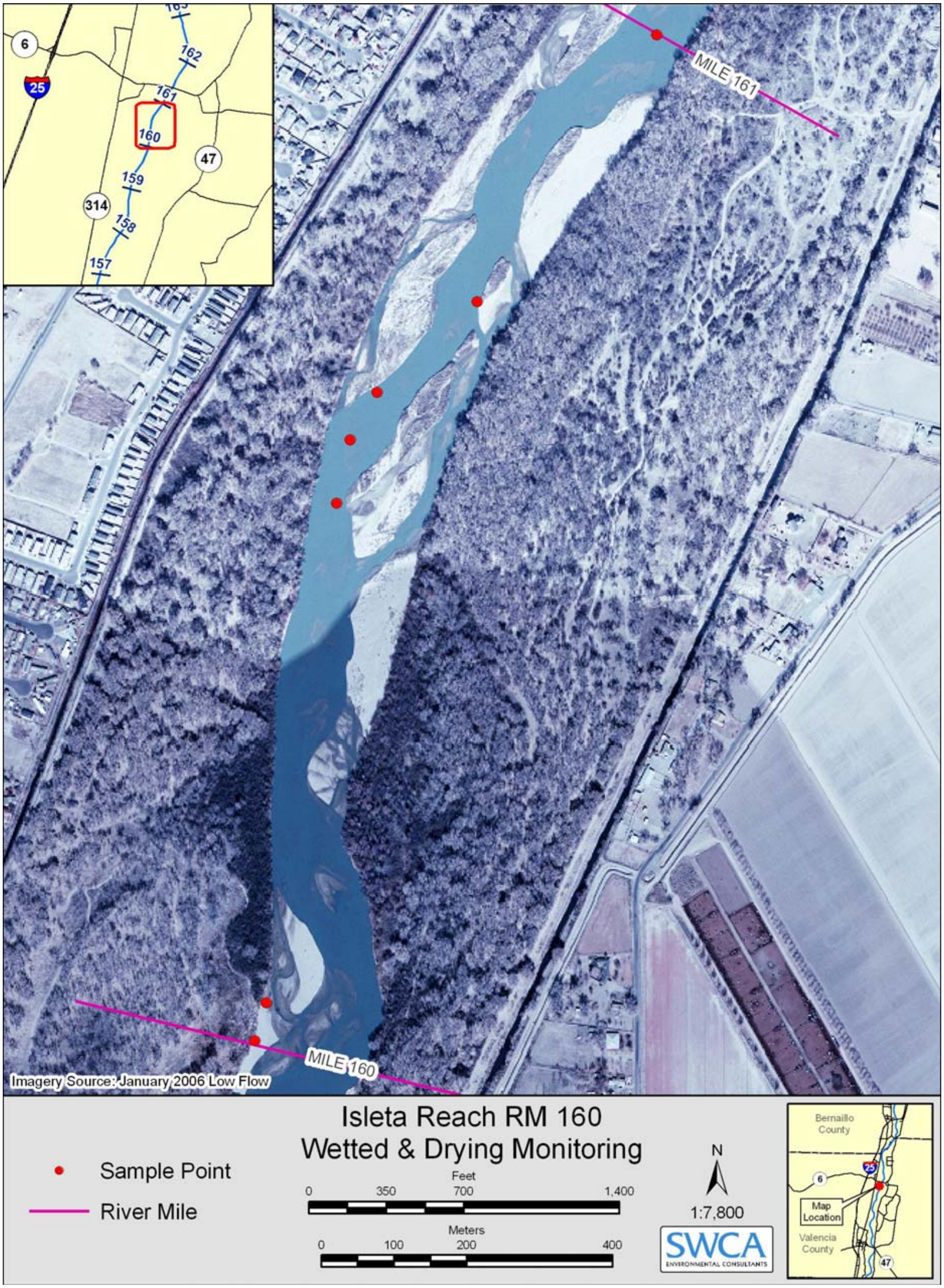

Figure H.9. Map of river mile 160 depicting wetted drying reach monitoring locations.

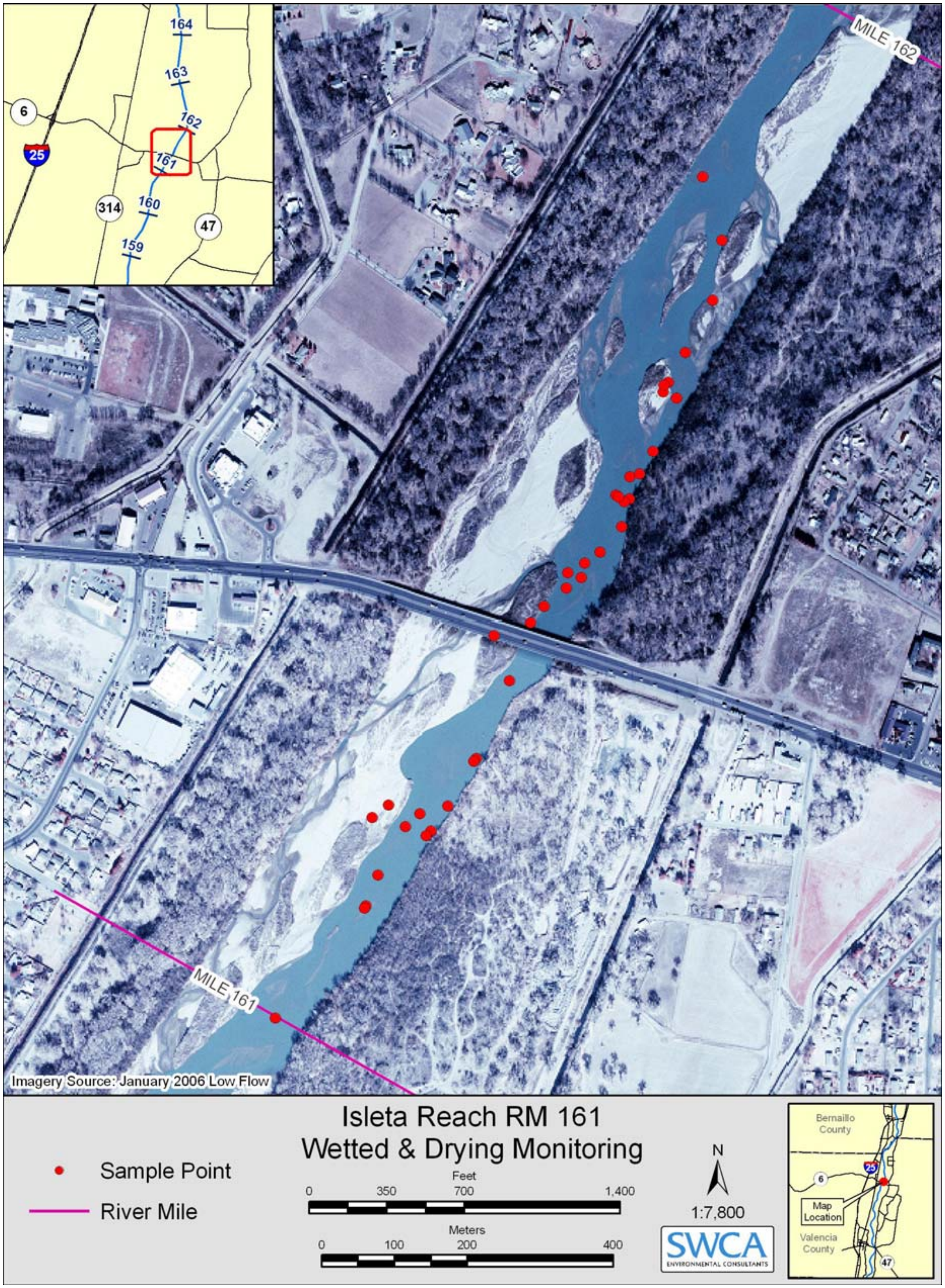

Figure H.10. River mile 161 was the upstream end of drying within the Isleta Reach in 2007. More than 50 percent of all wetted reach monitoring was conducted within this river mile.

Appendix I
Water Quality Bi-Variate Plots

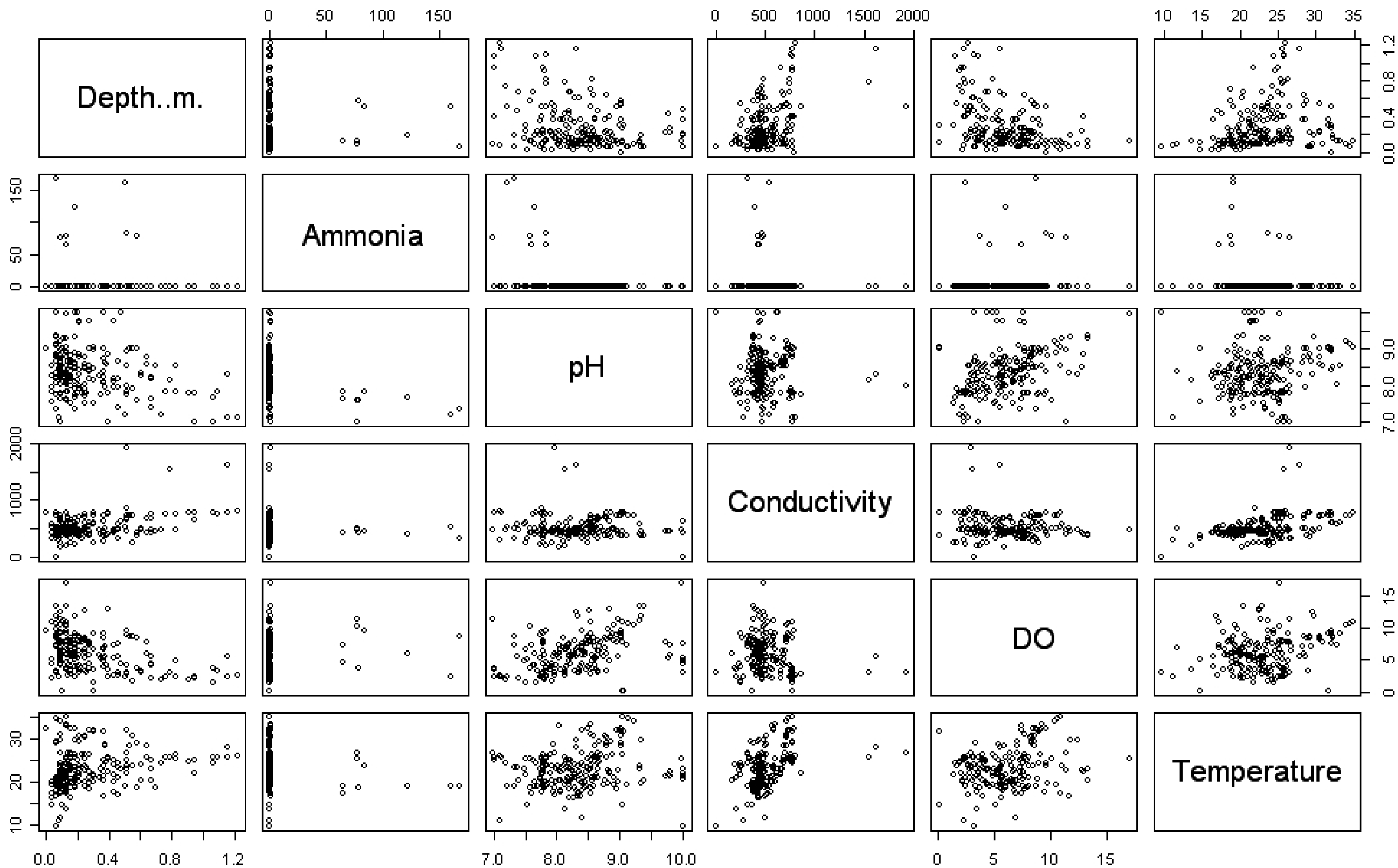

Figure I.1. Bi-variate plots of water quality parameters collected from in-stream refugia during the monitoring period. Values used are the mean value of the upper and lower water quality readings taken from each point within the isolated pool. Days with missing values are not included. Plots are arranged in a matrix with plot scales constant over the rows and columns of the matrix.

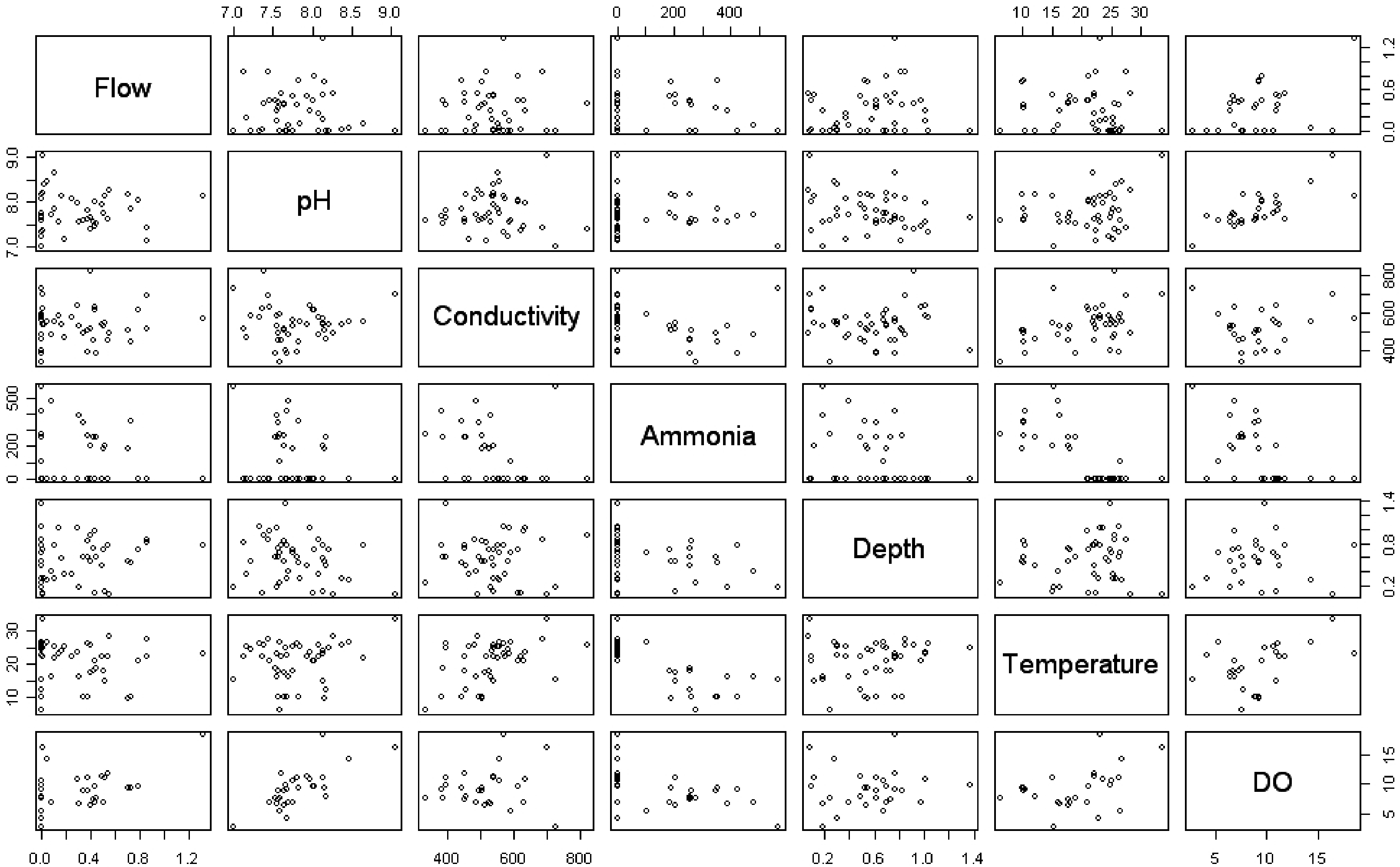

Figure I.2. Bi-variate plots of water quality parameters collected from wasteway/outfalls during the monitoring period. Days with missing values are not included. Plots are arranged in a matrix with plot scales constant over the rows and columns of the matrix.

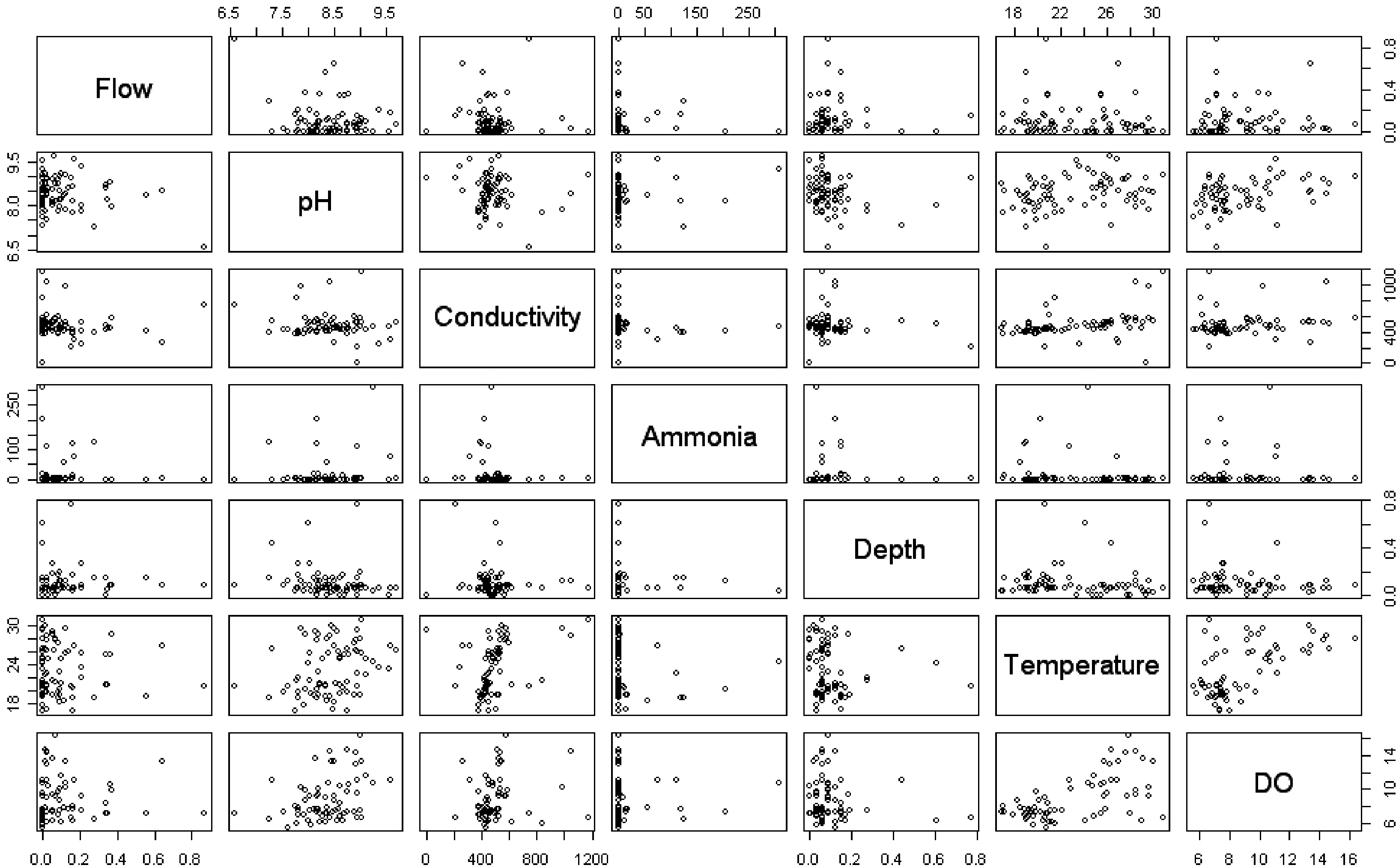

Figure I.3. Bi-variate plots of water quality parameters collected during wetted reach monitoring. Days with missing values are not included. Plots are arranged in a matrix with plot scales constant over the rows and columns of the matrix.

Appendix J
Project Photos

Picture J.1. Los Chavez Wasteway (LCZWW), located at river mile (RM) 156.8 W on June 26, 2007. Note earthen plug center right.

Picture J.2. Peralta Main Canal Wasteway (PERWW) at RM 152.5 E on September 21, 2007. Looking downstream. Flagging denotes sampling location.

Picture J.3. Lower Peralta Riverside Drain (LP1DR) at RM 149.6 E on June 26, 2007.

Picture J.4. Belen Riverside Drain (BELDR) at RM 147.7 W on July 9, 2007

Picture J.5. New Belen Wasteway (NBLWW) on September 21, 2007. Located at RM 147.1 W. This wasteway did not contain water June 1 through September 21, 2007.

Picture J.6. New Belen Wasteway on October 23, 2007.

Picture J.7. Lower Peralta Riverside Drain (LP2DR) located at RM 144.7 E. Photo taken on September 27, 2007. Looking upstream.

Picture J.8 Feeder 3 Wasteway (FD3WW), located at RM 142.8 W, on October 23, 2007.

Picture J.9. Located at RM 140.1 E, the Storrie Wasteway (STYWW) on October 23, 2007.

Picture J.10. Sabinal Drain Outfall (SABDR) at RM 137.9 W, on June 26, 2007.

Picture J.11. San Francisco Riverside Drain (SFRDR) at RM 126.8 W on September 23, 2007.

Picture J.12. San Francisco Riverside Drain on September 13, 2007.

Picture J.13. San Francisco Riverside Drain on October 24, 2007.

Picture J.14. Lower San Juan Riverside Drain (LSJDR), located at RM 126.6 E, on September 13, 2007.

Picture J.15. Unit 7 Drain (UN7DR) at RM 155.0 W on October 24, 2007.

Picture J.16. Isolated pool at Brown's Arroyo (RM 94.1) disconnected from main channel July 20–24, 2007, during which time it was monitored daily for water quality, fish community, and extent of wetted area.

Picture J 17. In-stream refugia at mouth of Brown's Arroyo (RM 94.1) reconnected with the main river channel on July 25, 2007, halting daily monitoring efforts.

Picture J.18. First day of daily monitoring of in-stream refugia at Pool s081.5-a on July 2, 2007. This pool reconnected with the main channel on July 7, 2007. Photo taken from southern end of pool.

Picture J.19. Blue catfish (*Ictalurus furcatus*) captured while conducting a fish community survey of pool s081.5-a on July 2, 2007.

Picture J.20. Fifth, and final, day of monitoring at Pool s081.5-a on July 6, 2007. Photo taken from southern end of pool, looking north. Fish depicted in photo are gizzard shad (*Dorosoma cepedianum*) and common carp (*Cyprinus carpio*).

Picture J.21. July 6, 2007; last day on monitoring at Pool s081.5-a before it reconnected with main channel flows. Photo taken from center of pool, looking north. Pin flag depicts water's edge on July 2, 2007.

Picture J.22. Pool s077.4-a became isolated from main channel on July 2, 2007. Daily monitoring ensued through July 6, 2007, when the pool was reconnected. Photo depicting northern end of Pool .s077.4-a. on July 2, 2007.

Picture J.23. July 2, 2007; first of five days of daily monitoring at Pool s077.4-a. Photo taken from southern end of pool, looking north. Note pin flags located at water's edge.

Picture J.24. Second of five days of daily monitoring at Pool s077.4-a. Photo depicts amount of drying that occurred in 24-hour period. Pin flag in left corner indicates water's edge from previous day. Photo taken from southern end of pool, facing north.

Picture J.25. Single day of monitoring of Pool 152.6-a. on August 14, 2007. Pool dried following day.

Picture J.26. First of four days of monitoring of Pool 154.4-a on August 15, 2007.

Picture J.27. Last day of monitoring at Pool 154.4-a. on August 18, 2007. Pink flagging line denotes center of pool. Pin flag depicts water's edge on August 15, 2007.

Picture J.28. First of 22 days of non-consecutive daily monitoring of Pool 161.3-a on August 18, 2007. Photo depicting western end of pool. Pin flags denote water's edge.

Picture J.29. Aug 18, 2007. Pool 161.3-a. Photo depicting eastern end of pool.

Picture J.30. Pool 161.3-a on August 23, 2007, the fifth day of monitoring.

Picture J.31. August 25, 2007. River reconnects, halting daily monitoring efforts on Pool 161.3-a.

Picture J.32. August 29, 2007. River disconnects and daily monitoring of pool 161.3-a resumes.

Picture J.33. Pool 161.3-a on September 19, 2007. Day 21 of 22 days of non-consecutive daily monitoring.

Picture J.34. Final day of monitoring of Pool 161.3-a on September 20, 2007.

Picture J.35. September 21, 2007. River reconnects.

Picture J.36. First of 13 days of monitoring of Pool 158.3-a on August 27, 2007. Pin flags denote water's edge.

Picture J.37. Day four of monitoring of Pool 158.3 on August 30, 2007.

Picture J.38. Day 10 of 13 of monitoring of Pool 158.3 on September 10, 2007.

Picture J.39. September 14, 2007; Pool 158.3 is found too shallow to sample, making previous day (September 13, 2007) final day of data collection at this location.

Picture J.40. Afternoon wetted reach north of Hwy 6 Bridge in Los Lunas on August 22, 2007.

Picture J.41. Afternoon wetted reach just south of Hwy 6 Bridge in Los Lunas on Aug 23, 2007.

Picture J.42. Afternoon wetted reach on September 1, 2007.

Picture J.43. Morning wetted reach on September 11, 2007, just south of the Hwy 6 Bridge in Los Lunas.

Appendix K
Observations of River Drying (River Eyes Observations)

River Drying

Red shading signifies a dry river segment.

Average daily USGS estimates of flow are provided at Bosque Farms (RM 164) and downstream of San Acacia (RM 116).

June 2007

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Isleta Diversion 169.3	169.0																														
	168.5																														
	168.0																														
	167.5																														
	167.0																														
Alehandro Drain 166.5	166.5																														
	166.0																														
240 W W 165.5	165.5																														
	165.0																														
Cottonwood Rd 164.5	164.5																														
USGSS Gauge at Bosque Farms(CFS)	164.0	1750	1410	1020	958	1290	1430	1190	957	796	794	569	539	413	471	429	429	529	561	515	433	254	142	121	105	126	133	133	94	248	183
	163.5																														
	163.0																														
	162.5																														
	162.0																														
Los Lunas (NM 49) 161.4	161.5																														
	161.0																														
	160.5																														
	160.0																														
	159.5																														
	159.0																														
	158.5																														
El Cerro Tome / Los Lunas Airport	158.0																														
	157.5																														
Los Lunas River Widening	157.0																														
	156.5																														
Los Chavez WW	156.0																														
	155.5																														
	155.0																														
	154.5																														
	154.0																														
	153.5																														
	153.0																														
Peralta W W 152.5	152.5																														
	152.0																														
	151.5																														
	151.0																														
	150.5																														
LP1DR (Allsups)	150.0																														

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Belen Br (NM 6 Hwy 309) 149.5	**149.5**																														
	149.0																														
	148.5																														
	148.0																														
AT&SF RR 147.7	**147.5**																														
	147.0																														
	146.5																														
	146.0																														
	145.5																														
	145.0																														
LP2DR 144.7	**144.5**																														
	144.0																														
Aerial Gas Line 143.8	**143.5**																														
	143.0																														
	142.5																														
	142.0																														
	141.5																														
	141.0																														
Jarales Rd Br 140.8	**140.5**																														
Storrie W W 140.1	**140.0**																														
	139.5																														
	139.0																														
Abo Arroyo 138.8	**138.5**																														
	138.0																														
	137.5																														
	137.0																														
	136.5																														
	136.0																														
	135.5																														
	135.0																														
	134.5																														
Abeytas Heading 134.3	**134.0**																														
	133.5																														
	133.0																														
	132.5																														
	132.0																														
	131.5																														
Just Upstream of Bernardo	**131.0**																														

		RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Bernardo (U.S. 60 Br) 130.6		**130.5**																														
		130.0																														
		129.5																														
		129.0																														
		128.5																														
		128.0																														
		127.5																														
		127.0																														
Rio Puerco 126.5		**126.5**																														
		126.0																														
		125.5																														
		125.0																														
		124.5																														
La Joya 124		**124.0**																														
		123.5																														
		123.0																														
		122.5																														
		122.0																														
		121.5																														
		121.0																														
		120.5																														
		120.0																														
		119.5																														
		119.0																														
Rio Salado 118.5		**118.5**																														
		118.0																														
		117.5																														
		117.0																														
Just Upstream of San Acacia		**116.5**																														

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
San Acacia 116.2 (CFS)	**116.0**	1670	1620	1370	1120	1060	1190	1340	1170	1020	?	?	?	?	619	612	551	554	622	618	551	488	374	359	359	282	198	181	166	145	128
	115.5																														
	115.0																														
One Mile Stop 114.8	**114.5**																														
	114.0																														
	113.5																														
	113.0																														
	112.5																														
	112.0																														
	111.5																														
	111.0																														
	110.5																														
	110.0																														
	109.5																														
	109.0																														
	108.5																														
	108.0																														
	107.5																														
Lemitar Diversion 107.1	**107.0**																														
	106.5																														
	106.0																														
	105.5																														
LFCC Outfall (9 mile)	**105.0**																														
Escondida Br 104.8	**104.5**																														
	104.0																														
	103.5																														
	103.0																														
N. Socorro Div. Channel 102.5	**102.5**																														
	102.0																														
	101.5																														
Escondida Drain Outfall 101.1	**101.0**																														
	100.5																														
	100.0																														
	99.5																														

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Otero Street 99.2	**99.0**																														
	98.5																														
	98.0																														
	97.5																														
	97.0																														
	96.5																														
	96.0																														
	95.5																														
	95.0																														
	94.5																														
Brown Arroyo 94.1	**94.0**																														
	93.5																														
	93.0																														
	92.5																														
	92.0																														
	91.5																														
	91.0																														
Neil Cupp	**90.5**																														
	90.0																														
	89.5																														
	89.0																														
	88.5																														
	88.0																														
	87.5																														

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
San Antonio (U.S. 380) 87.1	**87.0**																														
	86.5																														
	86.0																														
	85.5																														
	85.0																														
	84.5																														
N BDA 84.2	**84.0**																														
	83.5																														
	83.0																														
	82.5																														
	82.0																														
	81.5																														
	81.0																														
	80.5																														
	80.0																														
	79.5																														
	79.0																														
BDA HQ 78.75	**78.5**																														
	78.0																														
	77.5																														
	77.0																														
Mid BDA Pumps (Old Site)	**76.5**																														
	76.0																														
	75.5																														
	75.0																														
	74.5																														
S BDA	**74.0**																														

		RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Immediately S of S BDA		**73.5**																														
		73.0																														
		72.5																														
		72.0																														
		71.5																														
		71.0																														
		70.5																														
		70.0																														
		69.5																														
		69.0																														
San Marcial RR Bridge 68.6		**68.5**																														
		68.0																														
		67.5																														
		67.0																														
		66.5																														
		66.0																														
		65.5																														
		65.0																														
Ft Craig 64.8		**64.5**																														
		64.0																														
		63.5																														
		63.0																														
		62.5																														
		62.0																														
		61.5																														
		61.0																														
		60.5																														
White Gate		**60.0**																														
		59.5																														
		59.0																														
		58.5																														
		58.0																														
Power Line		**57.5**																														

River Drying

Red shading signifies a dry river segment.

Average daily USGS estimates of flow are provided at Bosque Farms (RM 164) and downstream of San Acacia (RM 116).

July 2007

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Isleta Diversion 169.3	169.0																															
	168.5																															
	168.0																															
	167.5																															
	167.0																															
Alehandro Drain 166.5	166.5																															
	166.0																															
240 W W 165.5	165.5																															
	165.0																															
Cottonwood Rd 164.5	164.5																															
USGSS Gauge at Bosque Farms(CFS)	164.0	153	151	151	103	222	267	143	170	131	88	82	74	76	83	89	93	91	95	85	81	92	114	115	80	388	308	73	61	105	213	141
	163.5																															
	163.0																															
	162.5																															
	162.0																															
Los Lunas (NM 49) 161.4	161.5																															
	161.0																															
	160.5																															
	160.0																															
	159.5																															
	159.0																															
	158.5																															
El Cerro Tome / Los Lunas Airport	158.0																															
	157.5																															
Los Lunas River Widening	157.0																															
	156.5																															
Los Chavez WW	156.0																															
	155.5																															
	155.0																															
	154.5																															
	154.0																															
	153.5																															
	153.0																															
Peralta W W 152.5	152.5																															
	152.0																															
	151.5																															
	151.0																															
	150.5																															
LP1DR (Allsups)	150.0																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Belen Br (NM 6 Hwy 309) 149.5	**149.5**																															
	149.0																															
	148.5																															
	148.0																															
AT&SF RR 147.7	**147.5**																															
	147.0																															
	146.5																															
	146.0																															
	145.5																															
	145.0																															
LP2DR 144.7	**144.5**																															
	144.0																															
Aerial Gas Line 143.8	**143.5**																															
	143.0																															
	142.5																															
	142.0																															
	141.5																															
	141.0																															
Jarales Rd Br 140.8	**140.5**																															
Storrie W W 140.1	**140.0**																															
	139.5																															
	139.0																															
Abo Arroyo 138.8	**138.5**																															
	138.0																															
	137.5																															
	137.0																															
	136.5																															
	136.0																															
	135.5																															
	135.0																															
	134.5																															
Abeytas Heading 134.3	**134.0**																															
	133.5																															
	133.0																															
	132.5																															
	132.0																															
	131.5																															
Just Upstream of Bernardo	**131.0**																															

		RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Bernardo (U.S. 60 Br) 130.6		**130.5**																															
		130.0																															
		129.5																															
		129.0																															
		128.5																															
		128.0																															
		127.5																															
		127.0																															
Rio Puerco 126.5		**126.5**																															
		126.0																															
		125.5																															
		125.0																															
		124.5																															
La Joya 124		**124.0**																															
		123.5																															
		123.0																															
		122.5																															
		122.0																															
		121.5																															
		121.0																															
		120.5																															
		120.0																															
		119.5																															
		119.0																															
Rio Salado 118.5		**118.5**																															
		118.0																															
		117.5																															
		117.0																															
Just Upstream of San Acacia		**116.5**																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
San Acacia 116.2 (CFS)	116.0	146	108	91	80	116	244	275	218	179	175	144	113	93	84	83	75	66	58	49	39	31	29	58	163	130	178	259	99	55	77	106
	115.5																															
	115.0																															
One Mile Stop 114.8	114.5																															
	114.0																															
	113.5																															
	113.0																															
	112.5																															
	112.0																															
	111.5																															
	111.0																															
	110.5																															
	110.0																															
	109.5																															
	109.0																															
	108.5																															
	108.0																															
	107.5																															
Lemitar Diversion 107.1	107.0																															
	106.5																															
	106.0																															
	105.5																															
LFCC Outfall (9 mile)	105.0																															
Escondida Br 104.8	104.5																															
	104.0																															
	103.5																															
	103.0																															
N. Socorro Div. Channel 102.5	102.5																															
	102.0																															
	101.5																															
Escondida Drain Outfall 101.1	101.0																															
	100.5																															
	100.0																															
	99.5																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Otero Street 99.2	**99.0**																															
	98.5																															
	98.0																															
	97.5																															
	97.0																															
	96.5																															
	96.0																					?	?									
	95.5																															
	95.0																															
	94.5																															
Brown Arroyo 94.1	**94.0**																															
	93.5																															
	93.0																															
	92.5																															
	92.0																															
	91.5																															
	91.0																															
Neil Cupp	**90.5**																															
	90.0																															
	89.5																															
	89.0																															
	88.5																															
	88.0																															
	87.5																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
San Antonio (U.S. 380) 87.1	**87.0**																															
	86.5																															
	86.0																															
	85.5																															
	85.0																															
	84.5																															
N BDA 84.2	**84.0**																															
	83.5																															
	83.0																															
	82.5																															
	82.0																															
	81.5																															
	81.0																															
	80.5																															
	80.0																															
	79.5																															
	79.0																															
BDA HQ 78.75	**78.5**					?																										
	78.0					?																										
	77.5					?																										
	77.0					?																										
Mid BDA Pumps (Old Site)	**76.5**					?																										
	76.0					?																										
	75.5																															
	75.0																															
	74.5																															
S BDA	**74.0**																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Immediately S of S BDA	**73.5**																															
	73.0																															
	72.5																															
	72.0																															
	71.5																															
	71.0																															
	70.5																															
	70.0																															
	69.5																															
	69.0																															
San Marcial RR Bridge 68.6	**68.5**																															
	68.0																															
	67.5																															
	67.0																															
	66.5																															
	66.0																															
	65.5																															
	65.0																															
Ft Craig 64.8	**64.5**																															
	64.0																															
	63.5																															
	63.0																															
	62.5																															
	62.0																															
	61.5																															
	61.0																															
	60.5																															
White Gate	**60.0**																															
	59.5																															
	59.0																															
	58.5																															
	58.0																															
Power Line	**57.5**																															

River Drying

Red shading signifies a dry river segment.

Average daily USGS estimates of flow are provided at Bosque Farms (RM 164) and downstream of San Acacia (RM 116).

Aug 2007

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Isleta Diversion 169.3	169.0																															
	168.5																															
	168.0																															
	167.5																															
	167.0																															
Alehandro Drain 166.5	166.5																															
	166.0																															
240 W W 165.5	165.5																															
	165.0																															
Cottonwood Rd 164.5	164.5																															
USGSS Gauge at Bosque Farms(CFS)	164.0	388	120	105	77	243	169	187	141	69	55	57	58	57	52	39	20	20	18	24	19	17	17	22	169	71	31	32	30	17	23	90
	163.5																															
	163.0																															
	162.5																															
	162.0																															
Los Lunas (Hwy 6) 161.4	161.5																															
	161.0																															
	160.5																															
	160.0																															
	159.5																															
	159.0																															
	158.5																															
El Cerro Tome / Los Lunas Airport	158.0																															
	157.5																															
Los Lunas River Widening	157.0																															
	156.5																															
Los Chavez WW	156.0																															
	155.5																															
	155.0																															
	154.5																															
	154.0																															
	153.5																															
	153.0																															
Peralta W W 152.5	152.5																															
	152.0																															
	151.5																															
	151.0																															
	150.5																															
LP1DR (Allsups)	150.0																															

		RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Belen Br (NM 6 Hwy 309) 149.5		**149.5**																															
		149.0																															
		148.5																															
		148.0																															
AT&SF RR 147.7		**147.5**																															
		147.0																															
		146.5																															
		146.0																															
		145.5																															
		145.0																															
LP2DR 144.7		**144.5**																															
		144.0																															
Aerial Gas Line 143.8		**143.5**																															
		143.0																															
		142.5																															
		142.0																															
		141.5																															
		141.0																															
Jarales Rd Br 140.8		**140.5**																															
Storrie W W 140.1		**140.0**																															
		139.5																															
		139.0																															
Abo Arroyo 138.8		**138.5**																															
		138.0																															
		137.5																															
		137.0																															
		136.5																															
		136.0																															
		135.5																															
		135.0																															
		134.5																															
Abeytas Heading 134.3		**134.0**																															
		133.5																															
		133.0																															
		132.5																															
		132.0																															
		131.5																															
Just Upstream of Bernardo		**131.0**																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Bernardo (U.S. 60 Br) 130.6	**130.5**																															
	130.0																															
	129.5																															
	129.0																															
	128.5																															
	128.0																															
	127.5																															
	127.0																															
Rio Puerco 126.5	**126.5**																															
	126.0																															
	125.5																															
	125.0																															
	124.5																															
La Joya 124	**124.0**																															
	123.5																															
	123.0																															
	122.5																															
	122.0																															
	121.5																															
	121.0																															
	120.5																															
	120.0																															
	119.5																															
	119.0																															
Rio Salado 118.5	**118.5**																															
	118.0																															
	117.5																															
	117.0																															
Just Upstream of San Acacia	**116.5**																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
San Acacia 116.2 (CFS)	**116.0**	140	207	312	194	154	128	583	503	317	226	191	159	171	49	8	11	23	23	23	23	20	18	16	30	32	24	18	30	30	124	220
	115.5																															
	115.0																															
One Mile Stop 114.8	**114.5**																															
	114.0																															
	113.5																															
	113.0																															
	112.5																															
	112.0																															
	111.5																															
	111.0																															
	110.5																															
	110.0																															
	109.5																															
	109.0																															
	108.5																															
	108.0																															
	107.5																															
Lemitar Diversion 107.1	**107.0**																															
	106.5																															
	106.0																															
	105.5																															
LFCC Outfall (9 mile)	**105.0**																															
Escondida Br 104.8	**104.5**																															
	104.0																															
	103.5																															
	103.0																															
N. Socorro Div. Channel 102.5	**102.5**																															
	102.0																															
	101.5																															
Escondida Drain Outfall 101.1	**101.0**																															
	100.5																															
	100.0																															
	99.5																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Otero Street 99.2	**99.0**																															
	98.5																															
	98.0																															
	97.5																															
	97.0																															
	96.5																															
	96.0																															
	95.5																															
	95.0																															
	94.5																															
Brown Arroyo 94.1	**94.0**																															
	93.5																															
	93.0																															
	92.5																															
	92.0																															
	91.5																															
	91.0																								?							
Neil Cupp	**90.5**																															
	90.0																															
	89.5																															
	89.0																															
	88.5																															
	88.0																															
	87.5																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
San Antonio (U.S. 380) 87.1	**87.0**																															
	86.5																															
	86.0																															
	85.5																															
	85.0																															
	84.5																															
N BDA 84.2	**84.0**																															
	83.5																															
	83.0																															
	82.5																															
	82.0																															
	81.5																															
	81.0																															
	80.5																															
	80.0																															
	79.5																															
	79.0																															
BDA HQ 78.75	**78.5**																															
	78.0																															
	77.5																															
	77.0																															
Mid BDA Pumps (Old Site)	**76.5**																															
	76.0																															
	75.5																															
	75.0																															
	74.5																															
S BDA	**74.0**	?																											?			

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Immediately S of S BDA	**73.5**																															
	73.0																															
	72.5																															
	72.0																															
	71.5																															
	71.0																															
	70.5																															
	70.0																															
	69.5																															
	69.0																															
San Marcial RR Bridge 68.6	**68.5**																															
	68.0																															
	67.5																															
	67.0																															
	66.5																															
	66.0																															
	65.5																															
	65.0																															
Ft Craig 64.8	**64.5**																															
	64.0																															
	63.5																															
	63.0																															
	62.5																															
	62.0																															
	61.5																															
	61.0																															
	60.5																															
White Gate	**60.0**																															
	59.5																															
	59.0																															
	58.5																															
	58.0																															
Power Line	**57.5**																															

River Drying

Red shading signifies a dry river segment.

Average daily USGS estimates of flow are provided at Bosque Farms (RM 164) and downstream of San Acacia (RM 116).

Sep 2007

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Isleta Diversion 169.3	169.0																														
	168.5																														
	168.0																														
	167.5																														
	167.0																														
Alehandro Drain 166.5	166.5																														
	166.0																														
240 W W 165.5	165.5																														
	165.0																														
Cottonwood Rd 164.5	164.5																														
USGSS Gauge at Bosque Farms(CFS)	164.0	91	283	100	53	30	17	17	16	16	17	16	16	15	14	14	15	15	15	15	52	614	351	278	248	216	131	48	16	16	52
	163.5																														
	163.0																														
	162.5																														
	162.0																														
Los Lunas (NM 49) 161.4	161.5																														
	161.0																														
	160.5																														
	160.0																														
	159.5																														
	159.0																														
	158.5																														
El Cerro Tome / Los Lunas Airport	158.0																														
	157.5																														
Los Lunas River Widening	157.0																														
	156.5																														
Los Chavez WW	156.0																														
	155.5																														
	155.0																														
	154.5																														
	154.0																														
	153.5																														
	153.0																														
Peralta W W 152.5	152.5																														
	152.0																														
	151.5																														
	151.0																														
	150.5																														
LP1DR (Allsups)	150.0																														

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Belen Br (NM 6 Hwy 309) 149.5	**149.5**																														
	149.0																														
	148.5																														
	148.0																														
AT&SF RR 147.7	**147.5**																														
	147.0																														
	146.5																														
	146.0																														
	145.5																														
	145.0																														
LP2DR 144.7	**144.5**																														
	144.0																														
Aerial Gas Line 143.8	**143.5**																														
	143.0																														
	142.5																														
	142.0																														
	141.5																														
	141.0																														
Jarales Rd Br 140.8	**140.5**																														
Storrie W W 140.1	**140.0**																														
	139.5																														
	139.0																														
Abo Arroyo 138.8	**138.5**																														
	138.0																														
	137.5																														
	137.0																														
	136.5																														
	136.0																														
	135.5																														
	135.0																														
	134.5																														
Abeytas Heading 134.3	**134.0**																														
	133.5																														
	133.0																														
	132.5																														
	132.0																														
	131.5																														
Just Upstream of Bernardo	**131.0**																														

		RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Bernardo (U.S. 60 Br) 130.6		**130.5**																														
		130.0																														
		129.5																														
		129.0																														
		128.5																														
		128.0																														
		127.5																														
		127.0																														
Rio Puerco 126.5		**126.5**																														
		126.0																														
		125.5																														
		125.0																														
		124.5																														
La Joya 124		**124.0**																														
		123.5																														
		123.0																														
		122.5																														
		122.0																														
		121.5																														
		121.0																														
		120.5																														
		120.0																														
		119.5																														
		119.0																														
Rio Salado 118.5		**118.5**																														
		118.0																														
		117.5																														
		117.0																														
Just Upstream of San Acacia		**116.5**																														

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
San Acacia 116.2 (CFS)	**116.0**	251	494	491	494	312	156	132	175	110	111	114	151	74	40	37	34	27	22	28	35	104	172	291	313	299	300	214	155	138	130
	115.5																														
	115.0																														
One Mile Stop 114.8	**114.5**																														
	114.0																														
	113.5																														
	113.0																														
	112.5																														
	112.0																														
	111.5																														
	111.0																														
	110.5																														
	110.0																														
	109.5																														
	109.0																														
	108.5																														
	108.0																														
	107.5																														
Lemitar Diversion 107.1	**107.0**																														
	106.5																														
	106.0																														
	105.5																														
LFCC Outfall (9 mile)	**105.0**																														
Escondida Br 104.8	**104.5**																														
	104.0																														
	103.5																														
	103.0																														
N. Socorro Div. Channel 102.5	**102.5**																														
	102.0																														
	101.5																														
Escondida Drain Outfall 101.1	**101.0**																														
	100.5																														
	100.0																														
	99.5																														

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Otero Street 99.2	**99.0**																														
	98.5																														
	98.0																														
	97.5																														
	97.0																														
	96.5																														
	96.0																														
	95.5																														
	95.0																														
	94.5																														
Brown Arroyo 94.1	**94.0**																														
	93.5																														
	93.0																														
	92.5																														
	92.0																														
	91.5																														
	91.0																														
Neil Cupp	**90.5**																														
	90.0																														
	89.5																														
	89.0																														
	88.5																														
	88.0																														
	87.5																														

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
San Antonio (U.S. 380) 87.1	**87.0**																														
	86.5																														
	86.0																														
	85.5																														
	85.0																														
	84.5																														
N BDA 84.2	**84.0**																														
	83.5																														
	83.0																														
	82.5																														
	82.0																														
	81.5																														
	81.0																														
	80.5																														
	80.0																														
	79.5																														
	79.0																														
BDA HQ 78.75	**78.5**																														
	78.0																														
	77.5																														
	77.0																														
Mid BDA Pumps (Old Site)	**76.5**																														
	76.0																														
	75.5																														
	75.0																														
	74.5																														
S BDA	**74.0**																														

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Immediately S of S BDA	**73.5**																														
	73.0																														
	72.5																														
	72.0																														
	71.5																														
	71.0																														
	70.5																														
	70.0																														
	69.5																														
	69.0																														
San Marcial RR Bridge 68.6	**68.5**																														
	68.0																														
	67.5																														
	67.0																														
	66.5																														
	66.0																														
	65.5																														
	65.0																														
Ft Craig 64.8	**64.5**																														
	64.0																														
	63.5																														
	63.0																														
	62.5																														
	62.0																														
	61.5																														
	61.0																														
	60.5																														
White Gate	**60.0**																														
	59.5																														
	59.0																														
	58.5																														
	58.0																														
Power Line	**57.5**																														

River Drying

Red shading signifies a dry river segment.

Average daily USGS estimates of flow are provided at Bosque Farms (RM 164) and downstream of San Acacia (RM 116).

Oct 2007

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Isleta Diversion 169.3	169.0																															
	168.5																															
	168.0																															
	167.5																															
	167.0																															
Alehandro Drain 166.5	166.5																															
	166.0																															
240 W W 165.5	165.5																															
	165.0																															
Cottonwood Rd 164.5	164.5																															
USGSS Gauge at Bosque Farms(CFS)	164.0	29	138	?	?	?	55	59	63	66	67	67	68	68	70	70	69	65	58	48	44	32	34	64	62	41	38	37	37	37	37	135
	163.5																															
	163.0																															
	162.5																															
	162.0																															
Los Lunas (NM 49) 161.4	161.5																															
	161.0																															
	160.5																							?								
	160.0																															
	159.5																															
	159.0																															
	158.5																															
El Cerro Tome / Los Lunas Airport	158.0																															
	157.5																															
Los Lunas River Widening	157.0																															
	156.5																															
Los Chavez WW	156.0							?	?																							
	155.5																															
	155.0																															
	154.5																															
	154.0																															
	153.5																															
	153.0																															
Peralta W W 152.5	152.5																															
	152.0																															
	151.5																															
	151.0																															
	150.5																															
LP1DR (Allsups)	150.0																															

		RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Belen Br (NM 6 Hwy 309) 149.5		**149.5**																															
		149.0																															
		148.5																															
		148.0																															
AT&SF RR 147.7		**147.5**																															
		147.0																															
		146.5																															
		146.0																															
		145.5																															
		145.0																															
LP2DR 144.7		**144.5**																															
		144.0																															
Aerial Gas Line 143.8		**143.5**																															
		143.0																															
		142.5																															
		142.0																															
		141.5																															
		141.0																															
Jarales Rd Br 140.8		**140.5**																															
Storrie W W 140.1		**140.0**																															
		139.5																															
		139.0																															
Abo Arroyo 138.8		**138.5**																															
		138.0																															
		137.5																															
		137.0																															
		136.5																															
		136.0																															
		135.5																															
		135.0																															
		134.5																															
Abeytas Heading 134.3		**134.0**																															
		133.5																															
		133.0																															
		132.5																															
		132.0																															
		131.5																															
Just Upstream of Bernardo		**131.0**																															

		RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Bernardo (U.S. 60 Br) 130.6		**130.5**																															
		130.0																															
		129.5																															
		129.0																															
		128.5																															
		128.0																															
		127.5																															
		127.0																															
Rio Puerco 126.5		**126.5**																															
		126.0																															
		125.5																															
		125.0																															
		124.5																															
La Joya 124		**124.0**																															
		123.5																															
		123.0																															
		122.5																															
		122.0																															
		121.5																															
		121.0																															
		120.5																															
		120.0																															
		119.5																															
		119.0																															
Rio Salado 118.5		**118.5**																															
		118.0																															
		117.5																															
		117.0																															
Just Upstream of San Acacia		**116.5**																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
San Acacia 116.2 (CFS)	**116.0**	?	?	?	?	46	57	59	58	74	189	203	160	174	183	180	189	181	153	184	193	184	194	179	154	142	111	118	117	118	99	124
	115.5																															
	115.0																															
One Mile Stop 114.8	**114.5**																															
	114.0																															
	113.5																															
	113.0																															
	112.5																															
	112.0																															
	111.5																															
	111.0																															
	110.5																															
	110.0																															
	109.5																															
	109.0																															
	108.5																															
	108.0																															
	107.5																															
Lemitar Diversion 107.1	**107.0**																															
	106.5																															
	106.0																															
	105.5																															
LFCC Outfall (9 mile)	**105.0**																															
Escondida Br 104.8	**104.5**																															
	104.0																															
	103.5																															
	103.0																															
N. Socorro Div. Channel 102.5	**102.5**																															
	102.0																															
	101.5																															
Escondida Drain Outfall 101.1	**101.0**																															
	100.5																															
	100.0																															
	99.5																															

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Otero Street 99.2	**99.0**																															
	98.5																															
	98.0																															
	97.5																															
	97.0																															
	96.5																															
	96.0																															
	95.5																															
	95.0																															
	94.5																															
Brown Arroyo 94.1	**94.0**																															
	93.5																															
	93.0																															
	92.5																															
	92.0																															
	91.5																															
	91.0																															
Neil Cupp	**90.5**																															
	90.0																															
	89.5																															
	89.0																															
	88.5																															
	88.0																															
	87.5																															

		RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
San Antonio (U.S. 380) 87.1		**87.0**																															
		86.5																															
		86.0																															
		85.5																															
		85.0																															
		84.5																															
N BDA 84.2		**84.0**																															
		83.5																															
		83.0																															
		82.5																															
		82.0																															
		81.5																															
		81.0																															
		80.5																															
		80.0																															
		79.5																															
		79.0																															
BDA HQ 78.75		**78.5**																															
		78.0																															
		77.5																															
		77.0																															
Mid BDA Pumps (Old Site)		**76.5**																															
		76.0																															
		75.5																															
		75.0																															
		74.5																															
S BDA		**74.0**							?	?																							

	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Immediately S of S BDA	**73.5**																															
	73.0																															
	72.5																															
	72.0																															
	71.5																															
	71.0																															
	70.5																															
	70.0																															
	69.5																															
	69.0																															
San Marcial RR Bridge 68.6	**68.5**																															
	68.0																															
	67.5																															
	67.0																															
	66.5																															
	66.0																															
	65.5																															
	65.0																															
Ft Craig 64.8	**64.5**																															
	64.0																															
	63.5																															
	63.0																															
	62.5																															
	62.0																															
	61.5																															
	61.0																															
	60.5																															
White Gate	**60.0**																															
	59.5																															
	59.0																															
	58.5																															
	58.0																															
Power Line	**57.5**																															