Rio Grande silvery minnow Rescue and Salvage – 2010

Prepared For:
Middle Rio Grande Endangered Species Act Collaborative Program

Submitted To:
U.S. Bureau of Reclamation
555 Broadway NE, Suite 100
Albuquerque, NM 87102-2352
Interagency Agreement 06-AA-40-2491

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September 7, 2011

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Executive Summary

Between 28 June and 17 October 2010, 28.2 miles of the main channel of the Middle Rio Grande became intermittent, in the Isleta (8.5) and San Acacia (19.7) reaches. An estimated total of 9,667 Rio Grande silvery minnow were salvaged from isolated pools, transported, and released alive at a location upstream within the same reach as they were salvaged. The take of 95 Rio Grande silvery minnow was attributed to water operations in the Middle Rio Grande during the 2010 irrigation season and assigned as incidental take. This level of observed incidental take was well below the limits established under the determination of incidental take number of 255,390 individuals. The loss of 1,966 Rio Grande silvery minnow was attributed to U.S. Fish and Wildlife Service permit activities. Going into the 2010 salvage season, higher pre-salvage catch rates meant that the allowed Incidental Take number was set higher in 2010 than 2009. This information, along with the fact that we salvaged nearly twice as much in effort (both in river miles and days salvaged) in 2010 compared to 2009 would have suggested that the number of fish observed both alive and dead might have been higher in 2010, but in fact there were nearly half as many RGSM observed in 2010 compared with 2009. Spawning and early recruitment conditions in 2009 were slightly better as a result of higher peak flows and longer duration compared with 2010.

Introduction

Until the 1950s, RGSM was distributed throughout many of the larger order streams of the Rio Grande Basin upstream of Brownsville, Texas to points in northern New Mexico primarily below 5,500 ft elevation (1,676 m). 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. Today, absent from much of its historic range, RGSM is restricted to a variably perennial reach of the Rio Grande in New Mexico, from the vicinity of Algodones downstream to the headwaters of Elephant Butte Reservoir, a distance that fluctuates as the size of the pool of water in storage in Elephant Butte Reservoir changes, but is approximately 150 river miles (241 km).

RGSM 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). The species is also listed as endangered by the State of Texas (Sections 65.171 - 65.184 of Title 31 T.A.C.) and the Republic of Mexico (Secretaria de Desarrollo Social, 1994). On July 20, 1994, the U. S. Fish and Wildlife Service (Service) published a final rule to list RGSM as a Federal endangered species with proposed critical habitat. In 2003, the Service designated critical habitat for RGSM in the Middle Rio Grande. The critical habitat designation extends from Cochiti Dam downstream about 157 mi (252 km) to the utility line crossing the Rio Grande in Socorro County. This location is at 4,450 feet of elevation (1,356 m), 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, the riparian zone, extending 300 feet (91.4 m) laterally from 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 the Pueblos are specifically excluded from the critical habitat designation.

Every year since 2001, with the exception of 2008, salvage activities have been conducted on intermittent sections of the Rio Grande for RGSM (Smith 2001, Smith and Munoz 2002, Smith and Basham 2003, US Fish and Wildlife 2005b, 2006b, Remshardt 2008, Remshardt 2010). These activities have been conducted under a variety of protocols and management actions. On March 17, 2003, the Service issued a Biological Opinion 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, New Mexico," (U.S. Fish and Wildlife Service, 2003). The consultation involved two federal agencies, U. S. Bureau of Reclamation and the Army Corps of Engineers, and two non-federal entities. The Service concluded that water operations and river maintenance activities in the Middle Rio Grande, as proposed (Reclamation and Corps, 2003), were likely to jeopardize the continued existence of RGSM along with the southwestern willow flycatcher (*Empidonax traillii extimus*; flycatcher) and adversely modify critical habitat of RGSM (U.S. Fish and Wildlife Service, 2003). The March 17, 2003 BO describes a Reasonable and Prudent Alternative, Reasonable and Prudent Measures, and Conservation Measures that serve in part to secure baseline conditions for RGSM and flycatcher. As part of the March 17, 2003 BO, the Service established the annual incidental take limit for RGSM for water operations in the Middle Rio Grande. That limit was amended on August 15, 2005 (U.S. Fish and Wildlife Service, 2005a), June 15, 2006 (U.S. Fish and Wildlife Service, 2006a), and is updated annually, incorporating a formula that includes October standard monitoring data, habitat conditions during the spawn (spring runoff), and augmentation. Action

agencies are apprised of the limit for incidental take by April 1 each year. Estimates of incidental take in the field are derived from surveys in which observed mortality is multiplied by 50, based on the assumption that the probability of observing a single mortality is 0.02. This value was an estimated value determined by USFWS Biologists. The August 15, 2005 amendment also specified that the incidental take statement applies to RGSM greater than 30 mm standard length. The amended incidental take limit for the 2010 irrigation season was 12,769,514 which is equivalent to 255,390 RGSM that are found dead.

This report documents efforts during 2010 to reduce the mortality of post-larval RGSM when flow in the Middle Rio Grande became intermittent. This report also discusses the effectiveness of those efforts using the permitted limit of incidental take defined in the April 29, 2010 letter of determination for incidental take (USFWS, 2010).

Methods

Location

The Middle Rio Grande below Cochiti Dam is designated by four divisions/reaches defined by locations of mainstream irrigation diversion dams (Figure 1). The Cochiti Reach extends from Cochiti Dam to Angostura Diversion Dam. The reach from Angostura Diversion Dam to Isleta Diversion Dam is called the Angostura Reach. The Isleta Reach is bounded upstream by Isleta Diversion Dam and downstream by San Acacia Diversion Dam. Finally, the reach below San Acacia Diversion Dam to the headwaters of Elephant Butte Reservoir is the San Acacia Reach.

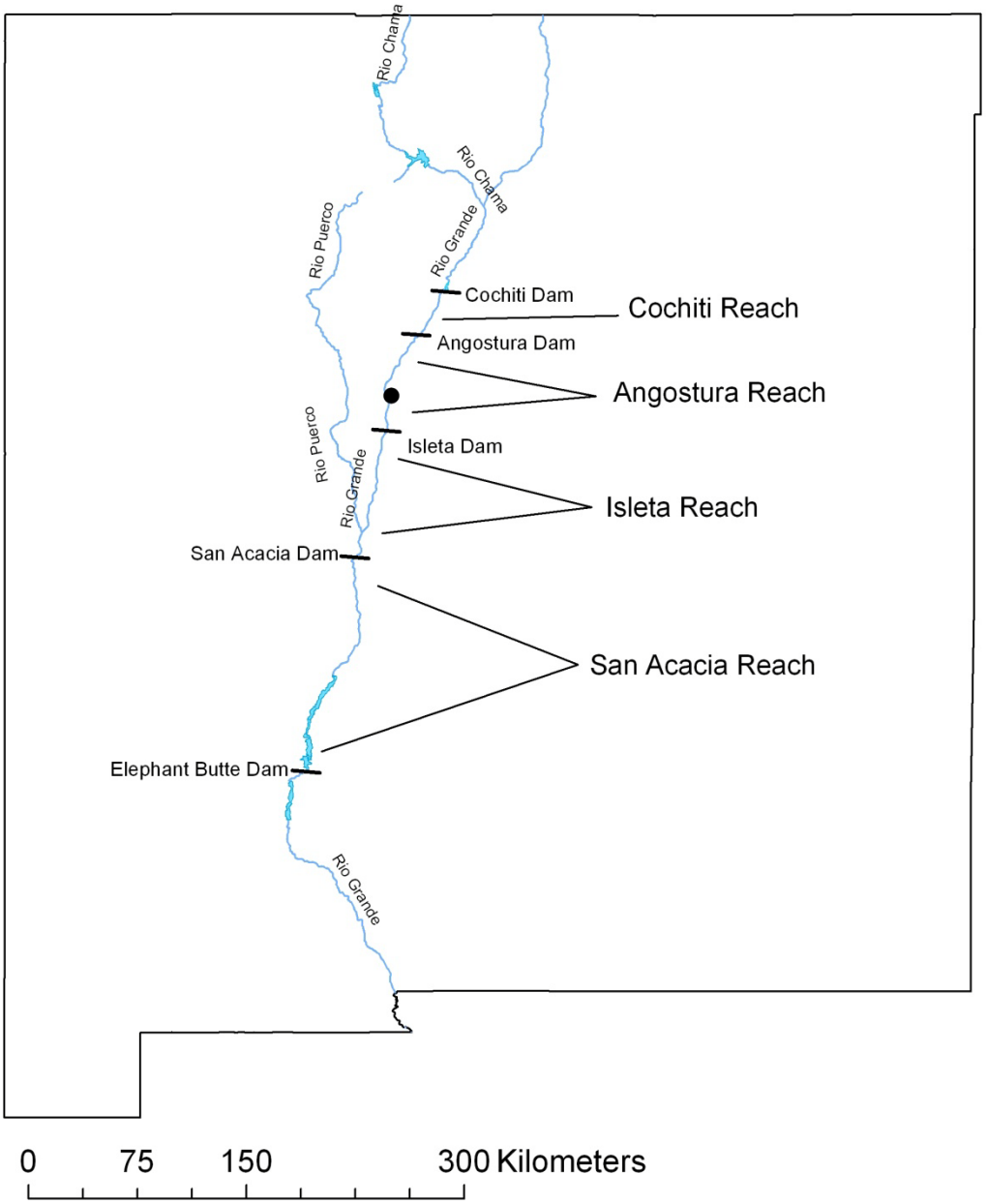

Figure 1-Reaches of the Middle Rio Grande in New Mexico.

Determination of Incidental Take

RGSM mortality can occur with channel drying resulting from excessive drought conditions, and conditions resulting from federal mediated water operations. In the recent past, intermittent conditions have existed in significant portions (e.g., up to 68.0 miles – approximately 45 percent of the RGSM's contemporary range) of the river between Isleta Diversion Dam and Elephant Butte Reservoir. Efforts to salvage RGSM from intermittent reaches of river are intended to reduce RGSM mortality that occurs with channel drying resulting from water operations and drought conditions. In addition, salvage is meant to reduce the probability that mortality associated with water operations will exceed the limit for incidental take.

RGSM rescue operations progressed in synchrony with river recession, with priority given to river reaches in which the death of RGSM due to federal water operations would be considered incidental take. Incidental take of post embryonic RGSM is defined for two size classes, i.e., for those shorter than or equal to 30 mm SL and those longer than 30 mm SL. All smaller sized post embryonic RGSM (≤ 30 mm SL) are presumed to be taken as a result of federal water operations when the river dries downstream of Isleta Diversion (U. S. Fish and Wildlife Service, 2003), but no limit on the amount of incidental take is calculated.

Determination of incidental take of the larger size class of post embryonic RGSM (> 30 mm SL) was conditional. Mortality of the larger sized post embryonic RGSM that occurs in portions of the river that are rewetted due to forces that are not directly or indirectly related to the operations of the Action Agencies was not considered to be incidental take under the March 17, 2003 BO (U. S. Fish and Wildlife Service, 2003). In contrast, rewetting and subsequent re-drying of river reaches that were previously dried in violation of the BO and was directly or indirectly related to the operations of the Action Agencies was regarded as incidental take. RGSM mortality, involving the larger sized individuals, that occurred outside of the active river channel was generally not considered to be incidental take under the March 17, 2003 BO (U. S. Fish and Wildlife Service, 2003); the exception to this generalization involves areas outside of the active channel that are wetted as a consequence of federal water pumping operations (i.e., water pumped from the low flow conveyance channel in an effort to maintain specified flows in the river) or river maintenance activities. Finally, the larger sized RGSM that are "rescued" and that die in transit to relocation sites were not considered to be incidental take. Likewise RGSM that exhibited advanced clinical signs of poor health were deemed not salvageable and also (e.g., lethargy and hemorrhagic lesions) were not considered incidental take.

Rescue of RGSM

Transport tanks equipped with water-tight lids were filled with water to near capacity with water from flowing sections prior to the day's salvage. Salt (NaCl) was added to water in hauling vessels at the rate of 1.0 % NaCl solution, and Stress Coat was added at the rate of 0.26 ml/liter (1 ml/gallon) (Appendix A).

Using seines of various sizes, fish were collected from isolated pools that formed as flow in the Middle Rio Grande becomes discontinuous. Prior to handling RGSM, personnel washed their hands to remove the residue of lotions (e.g., suntan lotions and mosquito repellant). Fish were handled with care using wetted hands. RGSM that exhibited advanced clinical signs of poor health (e.g., lethargy and hemorrhagic lesions) were not salvaged. Salvaged RGSM were

immediately placed into five-gallon buckets filled with transport tank water and subsequently transferred to 30-gallon transport tanks attached to utility terrain vehicles.

Pure oxygen was supplied to transport tanks through micro-bubble oxygen diffusers. Flow of oxygen was adjusted with varying water temperatures and loading rates of fish to maintain dissolved oxygen levels at or above 100% saturation. Rescued RGSM were transported to the nearest section of perennial flow within their reach of origin and released to the river. Prior to releasing RGSM into the river, water in the transport tanks was tempered (by slowly adding river water to the transport tanks) until it was within 1° C of the water temperature of the river at the release site. Daily counts of salvaged RGSM rescued were made. Other species of fishes encountered while salvaging RGSM are left in isolated pools.

Once a location was identified as a potential salvage site, a set of primary and secondary biological criteria were applied to determine whether salvage should occur. These criteria were defined using field experience (water quality parameters) and tolerance limits of RGSM to environmental variables (secondary water quality, K. Buhl, unpublished data). Documentation of conditions, incidental take (if appropriate), and preservation of individuals followed.

Criteria for Salvaging

Primary (Water Quality)	1. Water temperature < 34°C 2. Dissolved Oxygen > 2.0 mg/liter 3. pH < 9.0
Secondary (Fish Health)	1. No Dead Rio Grande silvery minnow in pool 2. No lethargy and/or hemorrhagic lesions noticed from Rio Grande silvery minnow in pool

In the instances where salvage was deemed necessary and feasible, every effort was made to ensure that any fish to be moved had the highest probability of survival.

Monitoring Activities

During salvage, a variety of data were collected to document the conditions at the pools, including those data necessary to determine whether or not salvage would occur. These parameters included estimated size of pool (m^2), depth (nearest 0.1m), dissolved oxygen (mg/l), water temperature (C), and pH, and location (nearest 0.1 river mile), documentation of FWS permit take, and the presence of VIE-marked hatchery fish. These activities also included the documentation and preservation of dead fish or salvaged when these pools otherwise met the criteria. Preserved specimens were returned to the lab for verification. Preserved specimens were processed similar to methods described for enumeration of incidental take.

Analysis of Data

We summarized RGSM numbers by disposition (salvaged, dead, etc.), river mile and date. After each re-wetting, pools may have formed in the same location, but we assumed that each re-wetting created an independent set of pools. Individual pools were not monitored over time, all relations between variables and time are from separate re-wetting events, e.g., pool size over time indicates size of pools after each re-wetting, not the size of an individual pool through time.

To detect trends over time and relations between pool characteristics, we created plotted pool characteristics against each other and used locally-weighted regression (LOWESS) to fit a line to each scatterplot. The relation between estimated surface area, maximum depth, and time was explored with linear models. Count data between RGSM numbers, number of pools, and pool environmental characteristics were examined with negative binomial models (O'Hara and Kotze 2010; Crawley 2007). We examined relationships between RGMS counts (adults salvaged, young-of-year (YOY) salvaged, and total minnows encountered) per pool, RGSM counts per day, and number of pools evaluated per day. Covariates included were depth of pool, estimated size of pool, date, distance to top of drying and reach. Transformations (e.g., log+1 transformation) to the data were applied as necessary to meet the assumptions of the models. For analyses including a date term, we used the Julian date with the origin set at 28 June 2010 (first day of salvage). Distance to top of drying was established for each day of salvage. We used program R (version 2.10.0) for all statistical analyses.

Results

Documentation of Incidental Take of RGSM

Incidental take of RGSM (larger than 30 mm SL) that occurred as a result of water operations in the Middle Rio Grande was documented and evaluated under limitations established in the March 17, 2003 BO (U. S. Fish and Wildlife Service, 2003) and as modified on August 15, 2005 (U. S. Fish and Wildlife Service, 2005a) and June 15, 2006 (U. S. Fish and Wildlife Service, 2006a).

Channel drying resulted in the incidental take of 95 RGSM. This level of incidental take was below the limit established in the March 17, 2003 BO (U. S. Fish and Wildlife Service, 2003), and as modified for the 2010 season (255,390) on July 7, 2010 (U. S. Fish and Wildlife Service, 2010).

Channel Drying

RGSM rescue operations generally progressed in synchrony with river recession over the course of the 2009 irrigation season in main channel habitats. Ultimately, 28.2 miles of the main channel of the Middle Rio Grande were dried, 19.7 in the San Acacia Reach and 8.5 miles in the Isleta. Discontinuous main channel segments of the San Acacia Reach of the Middle Rio Grande occurred between Neil Cupp's and the south boundary of Bosque Del Apache Wildlife Refuge, and between the Peralta wasteway and Los Lunas bridge during the 2010 irrigation season

Rescue operations were conducted 46 days during the 2010 irrigation season, 27 days in the San Acacia Reach, and 19 days in the Isleta Reach. Rescue operations were restricted to main channel pools during the period of 28 June 2010 to 17 October 2010, though many subsections re-wetted and were subsequently re-salvaged. In total, 87.6 river miles were salvaged in the San Acacia Reach, and 47.6 in the Isleta Reach from June to October (Table 1).

Rescue of Rio Grande silvery minnow

A total of 10,273 RGSM was captured in isolated pools within the river (Table 1). Of these, 9,667 were transported to flowing sections within the same reach and released live (94% survival at time of release). In 2010, the release location was approximately 1 mile downstream of San Acacia Diversion Dam or the San Marcial railroad crossing for fish salvaged in the San Acacia reach, and below Isleta Dam or the U.S. Highway 60 crossing for fish salvaged in the Isleta Reach (Appendix A). The average daily longitudinal extent of aquatic habitat involved in rescue operations per day was at or below the 8.0 miles/day rate allowed in the March 17, 2003 BO; U. S. Fish and Wildlife Service, 2003), as modified on June 15, 2006 (U. S. Fish and Wildlife Service, 2006a). This relates to an estimated 76 salvaged RGSM/ river mile dried.

A total of 1,966 Rio Grande silvery minnow was counted towards the FWS permit (Table 1). These individuals included those that perished between the act of salvage and when they were to be released back to the river, were preserved for salvage research, and those that were deemed not salvageable based on the criteria mentioned previously. A total of 1,139 YOY under 30 mm SL were collected, all in the San Acacia reach.

Monitoring Activities

Mean size of isolated pools was 156 m^2 (Min. 0.1 m^2, Max. 5,000 m^2). Mean dissolved oxygen in isolated pools was 7.3 mg/liter (Min. 0.6 mg/liter, Max. 18.6 mg/liter). Mean water temperature of isolated pools was 23.2 ° C (Min. 9.1, Max. 38.27). Scatter plots between pool characteristics suggest cooler pool temperatures and smaller pools as the salvage season progressed (Figure 2). Estimated surface area and maximum depth were moderately correlated (Figure 2), but there was much variability in the data. Because depth and size were correlated, and depth was measured and not estimated, we used depth but not estimated surface area when modeling RGSM counts from pools.

Average pool surface area decreased on each subsequent salvage event, was smaller in the San Acacia reach, and increased with depth (Table 2).

The average number of YOY RGSM salvaged from a pool increased with depth of pool, was higher in the San Acacia reach, decreased with distance from top of drying, but was not related to date (Table 3). The average number of adult RGSM salvaged from a pool also increased with depth and decreased with distance from top of drying, but was not related to either reach or date (Table 4). The average number of minnows encountered in a pool (alive or dead, salvaged or not salvaged) increased with pool depth, decreased over time and distance from top of drying, and was higher in the San Acacia reach (Table 5).

On a daily basis, the average number of pools evaluated increased with the number of river miles salvaged, and was different between the two reaches, with San Acacia having more pools (Figure 4). However, the number of pools evaluated did not change over time, when accounting for differences in miles salvaged and reach (Table 6).

The average number of both YOY salvaged from a pool was higher in the San Acacia reach, but was not related to the number of miles salvaged or the date (residual deviance 55.837 on 43

degrees of freedom; Table 7). The number of adults salvaged from a pool was not related to the number of miles salvaged, the date, or the reach (Table 8). The total number of minnows (alive, dead, etc.) encountered in a day was significantly related to reach, but not to date or number of miles salvaged (Figures 3 and 5, Table 9).

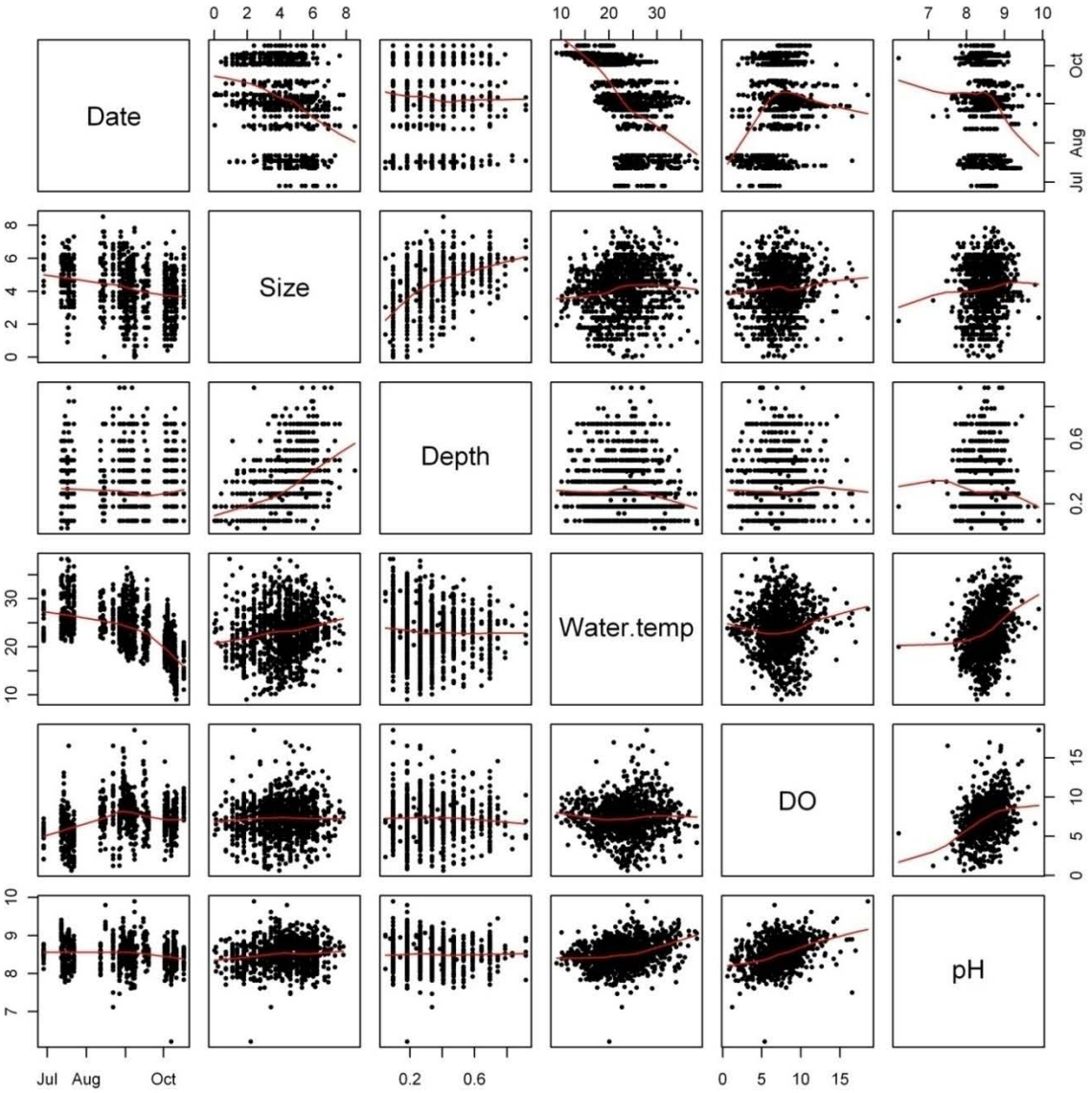

Figure 2-Scatter plots of environmental variables collected from isolated pools in the Middle Rio Grande in 2010. Scatter plots have been fitted with a smoothing parameter. Size in m2, depth in m, temperature in C°.

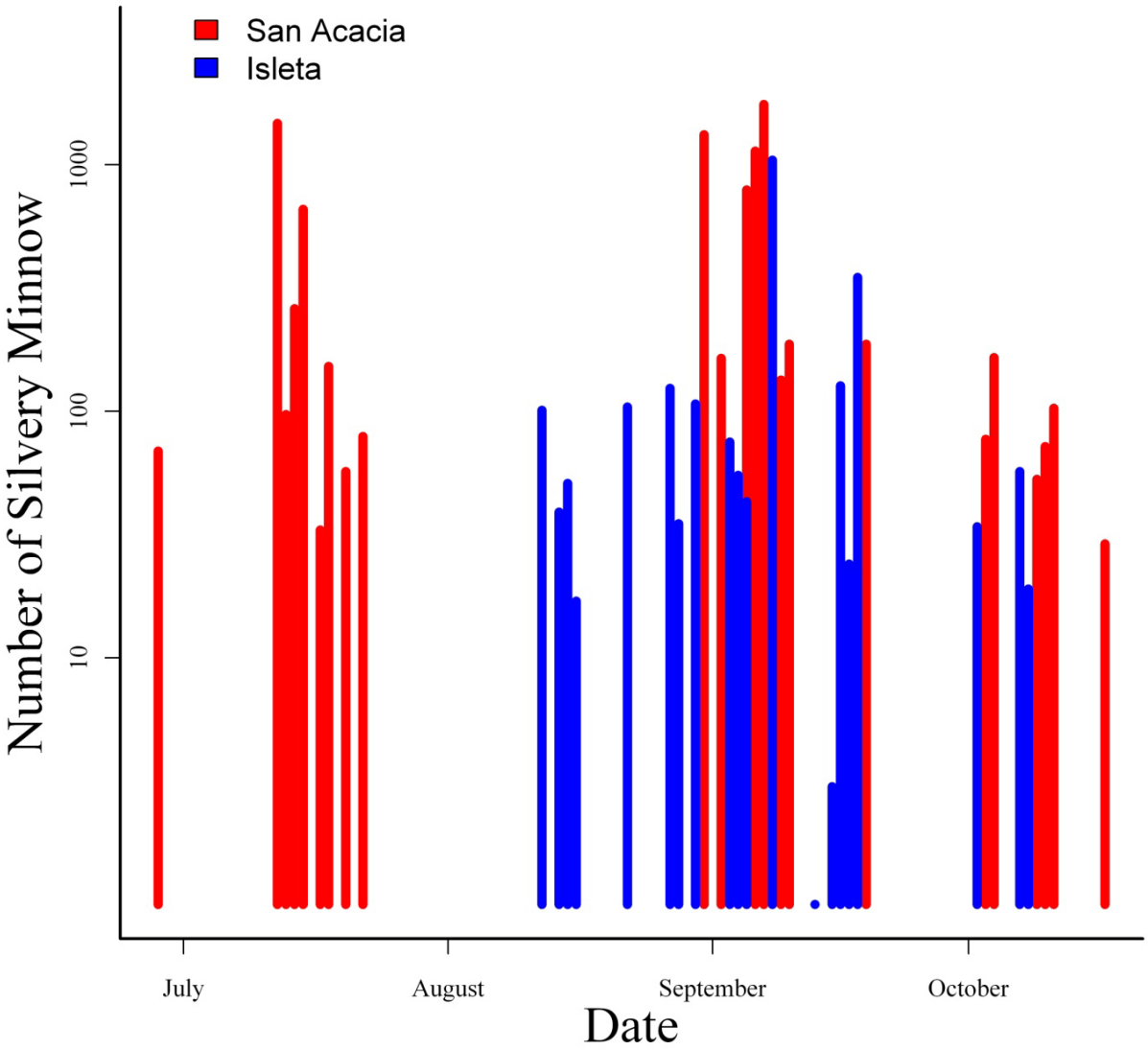

Figure 3-Daily number of RGSM encountered in isolated pools in the San Acacia and Isleta reaches of the Rio Grande, New Mexico.

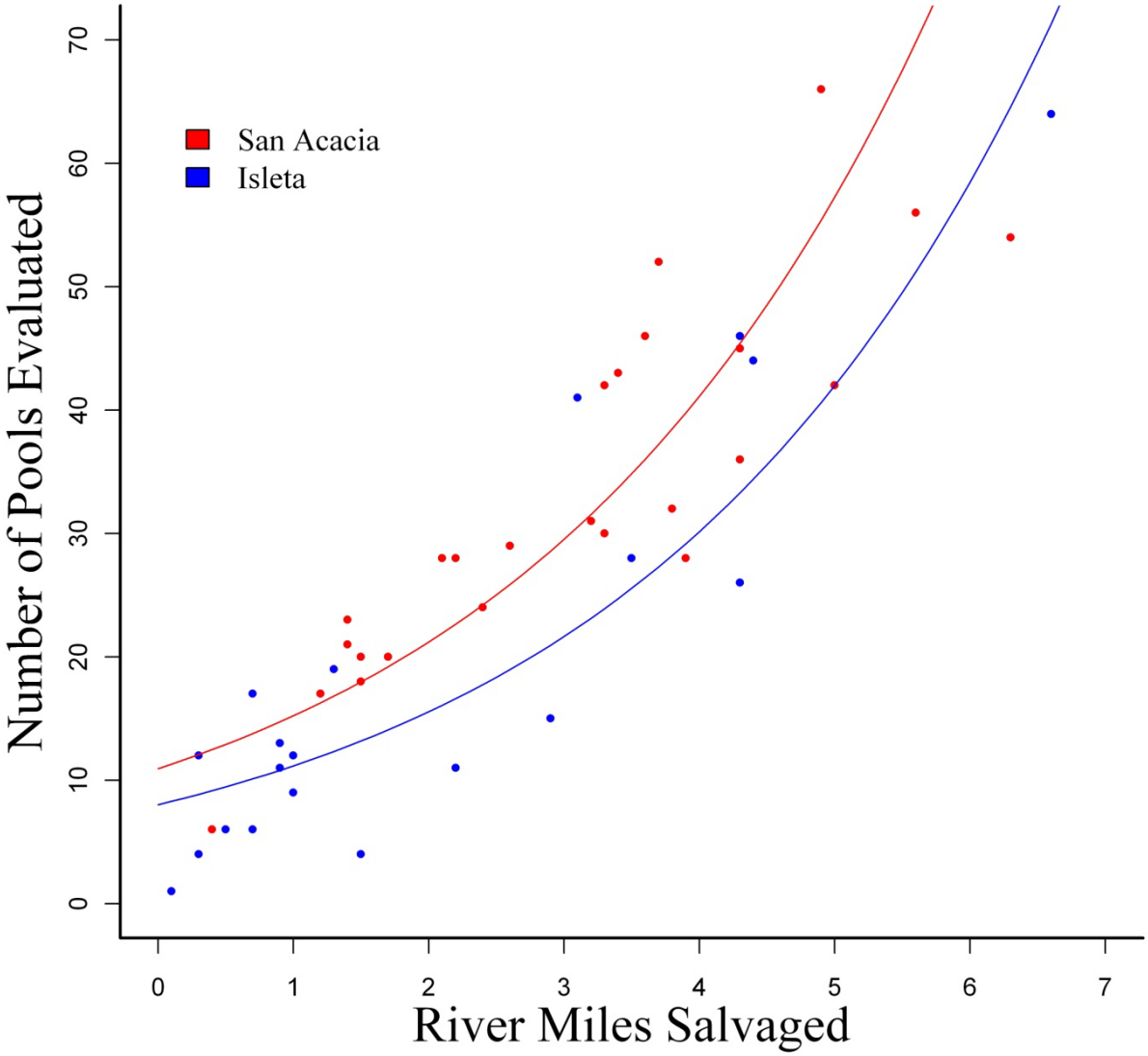

Figure 4- Relation between number of miles salvaged and the number of isolated pools evaluated, by reach, in the middle Rio Grande 2010, general linear model. Number of pools was not related to date (P=0.3805), but was different between reaches (P=0.0046) and increased with increasing miles salvaged (P<0.0001).

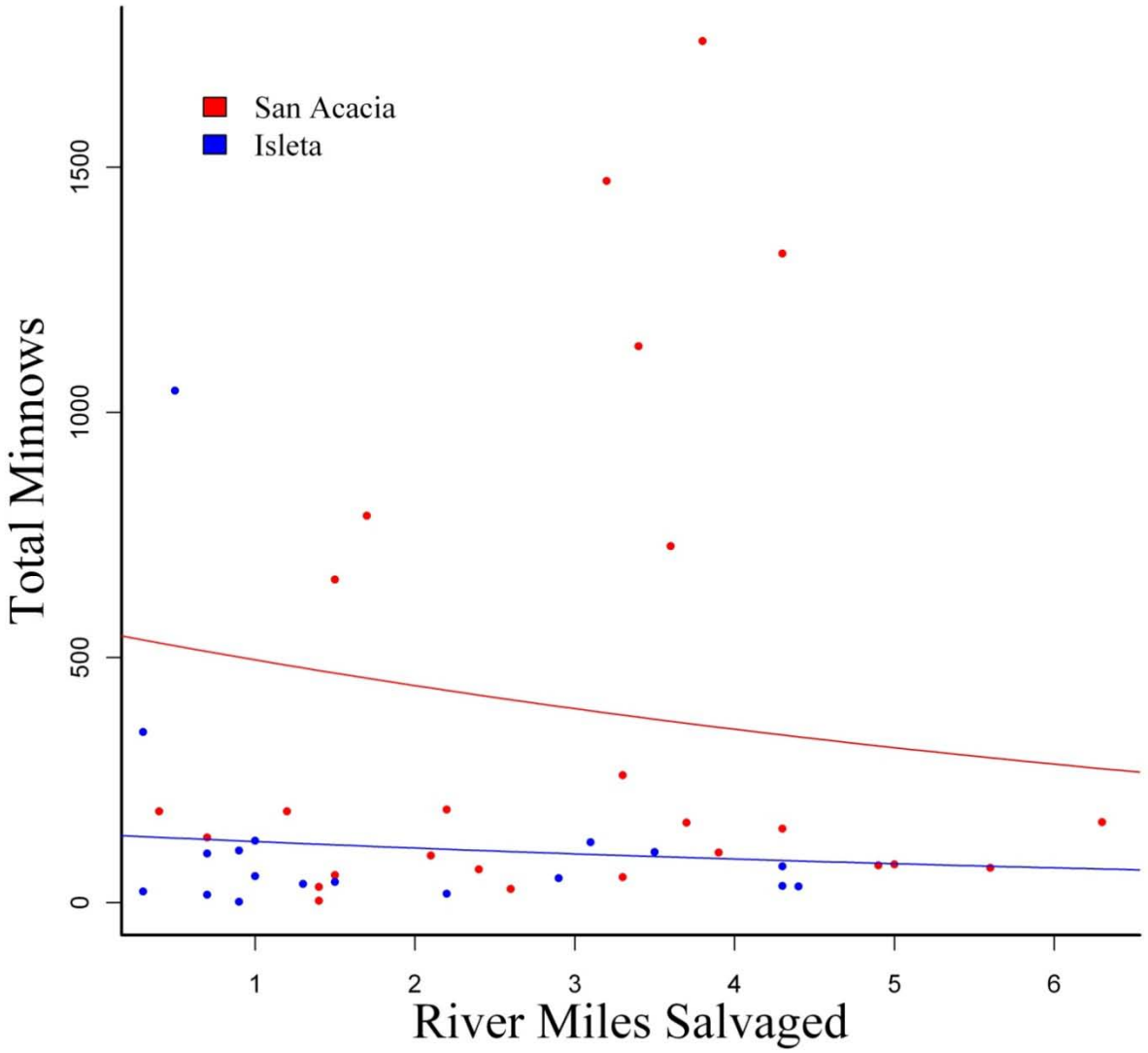

Figure 5- Relation between number of miles salvaged and the total number of Rio Grande silvery minnow encountered, by reach, in the middle Rio Grande, 2010, from general linear model. Total minnows differ by reach (*P*=0.0007), but are not related to number of miles salvaged (*P*=0.6413), or date (*P*=0.3675).

Table 1-Summary of salvage operations for Rio Grande silvery minnow in the Middle Rio Grande, 2010. Total salvaged RGSM does not include transport losses.

Reach	Number of Pools Evaluated	Miles Dried	Total Miles Salvaged	YOY <30mm SL	Dead/Sick Minnows	Incidental Take	Total Salvaged	Total Minnows
San Acacia	857	19.7	87.6	1139	774	88	7982	9983
Isleta	375	8.5	47.6	0	68	7	2291	2366
Total	1232	28.2	135.2	1139	842	95	10273	12349

Table 2-Parameter estimates for relation between log of estimated pool size (m^2) and date, reach, and depth (m) of pool. Regression equation log(Pool Size +1) = β_0 + β_1*Julian Date + β_2*Reach+ β_3*Depth. ($F_{3,1190}$ = 171.6, P = <0.0001 adjusted R^2 = 0.3002).

β	Mean	SE	t-value	P
β_0 (Intercept)	4.020	0.1232	32.65	<0.0001
β_1 (Julian Date)	-0.01272	0.0012	-10.55	<0.0001
β_2 (San Acacia)	-0.1811	0.0771	-2.351	0.0189
β_3 (Depth)	2.794	0.1430	19.54	<0.0001

Table 3-Negative binomial parameter estimates for relation between YOY RGSM in a pool and date, reach, depth of pool (m), and distance to top of drying (RM). Negative binomial regression equation YOY = $e^{\beta_0 + \beta_1 * \text{Julian Date} + \beta_2 * \text{Reach} + \beta_3 * \text{Depth}}$. Residual deviance 795.6 on 1158 degrees of freedom.

β	Mean	SE	z-value	P
β_0 (Intercept)	-1.554	0.297	-5.230	<0.0001
β_1 (Julian Date)	-0.0003	0.003	-1.115	0.908
β_2 (San Acacia)	2.373	0.190	12.543	<0.0001
β_3 (Depth)	2.897	0.318	9.099	<0.0001
β_4 (Top of Drying)	-0.194	0.056	-3.437	0.0006

Table 4- Negative binomial parameter estimates for relation between adult RGSM in a pool and date, reach, depth of pool (m), and distance to top of drying (RM). Regression equation Adults = $e^{\beta_0 + \beta_1 * \text{Julian Date} + \beta_2 * \text{Reach} + \beta_3 * \text{Depth}}$. Residual deviance 898.56 on 1,158 degrees of freedom.

$\boldsymbol{\beta}$	**Mean**	**SE**	**z-value**	**P**
$\boldsymbol{\beta}_0$ (Intercept)	1.425	0.270	5.287	<0.0001
$\boldsymbol{\beta}_1$ (Julian Date)	-0.002	0.002	-0.682	0.495
$\boldsymbol{\beta}_2$ (San Acacia)	-0.123	0.165	-0.746	0.456
$\boldsymbol{\beta}_3$ (Depth)	1.536	0.301	5.103	<0.0001
$\boldsymbol{\beta}_4$ (Top of Drying)	-0.306	0.052	-5.887	<0.0001

Table 5-Negative binomial parameter estimates for relation between total RGSM in a pool and date, reach, depth of pool (m), and distance to top of drying (RM). Regression equation Total Minnows = $e^{\beta_0 + \beta_1 * \text{Julian Date} + \beta_2 * \text{Reach} + \beta_3 * \text{Depth}}$. Residual deviance 1112.6 on 1158 degrees of freedom.

$\boldsymbol{\beta}$	**Mean**	**SE**	**z-value**	**P**
$\boldsymbol{\beta}_0$ (Intercept)	2.361	0.231	10.199	<0.0001
$\boldsymbol{\beta}_1$ (Julian Date)	-0.016	0.002	-7.141	<0.0001
$\boldsymbol{\beta}_2$ (San Acacia)	0.635	0.143	4.447	<0.0001
$\boldsymbol{\beta}_3$ (Depth)	2.072	0.259	8.000	<0.0001
$\boldsymbol{\beta}_3$ (Top of Drying)	-0.260	0.045	-5.815	<0.0001

Table 6- Negative binomial parameter estimates for relations between daily number of pools evaluated and date, reach, and number of miles salvaged. Regression equation Pools = $e^{\beta_0 + \beta_1 * \text{Julian Date} + \beta_2 * \text{Reach} + \beta_3 * \text{Miles}}$. Residual deviance 55.581 on 42 degrees of freedom.

$\boldsymbol{\beta}$	**Mean**	**SE**	**z-value**	**P**
$\boldsymbol{\beta}_0$ (Intercept)	2.164	0.1432	15.12	<0.0001
$\boldsymbol{\beta}_1$ (Julian Date)	-0.0014	0.0017	-0.877	0.3805
$\boldsymbol{\beta}_2$ (San Acacia)	0.2918	0.1028	2.837	0.0046
$\boldsymbol{\beta}_3$ (Miles Salvaged)	0.3389	0.0295	11.47	<0.0001

Table 7- Negative binomial parameter estimates for relation between YOY RGSM salvaged per day and date, reach, and number of miles salvaged. Regression equation Total Minnows = $e^{\beta_0 + \beta_1 * \text{Julian Date} + \beta_2 * \text{Reach} + \beta_3 * \text{Miles}}$. Residual deviance 55.837 on 42 degrees of freedom.

$\boldsymbol{\beta}$	**Mean**	**SE**	**z-value**	**P**
$\boldsymbol{\beta}_0$ (Intercept)	2.046	0.6059	3.377	0.0007
$\boldsymbol{\beta}_1$ (Julian Date)	0.0089	0.0074	1.208	0.2270
$\boldsymbol{\beta}_2$ (San Acacia)	2.494	0.4383	5.689	<0.0001
$\boldsymbol{\beta}_3$ (Miles Salvaged)	0.0447	0.1276	0.350	0.7262

Table 8- Negative binomial parameter estimates for relation between adult RGSM salvaged per day and date, reach, and number of miles salvaged. Regression equation Total Minnows = $e^{\beta_0 + \beta_1 * \text{Julian Date} + \beta_2 * \text{Reach} + \beta_3 * \text{Miles}}$. Residual deviance 56.047 on 42 degrees of freedom.

$\boldsymbol{\beta}$	**Mean**	**SE**	**z-value**	**P**
$\boldsymbol{\beta}_0$ (Intercept)	3.998	0.5707	7.005	<0.0001
$\boldsymbol{\beta}_1$ (Julian Date)	0.0111	0.0069	1.591	0.112
$\boldsymbol{\beta}_2$ (San Acacia)	0.5223	0.4124	1.266	0.205
$\boldsymbol{\beta}_3$ (Miles Salvaged)	-0.1351	0.1203	-1.123	0.261

Table 9- Negative binomial parameter estimates for relation between total RGSM encountered per day and date, reach, and number of miles salvaged. Regression equation Total Minnows = $e^{\beta_0 + \beta_1 * \text{Julian Date} + \beta_2 * \text{Reach} + \beta_3 * \text{Miles}}$. Residual deviance 55.700 on 42 degrees of freedom.

$\boldsymbol{\beta}$	**Mean**	**SE**	**z-value**	**P**
$\boldsymbol{\beta}_0$ (Intercept)	3.998	0.5707	7.005	<0.0001
$\boldsymbol{\beta}_1$ (Julian Date)	0.0111	0.0069	1.591	0.112
$\boldsymbol{\beta}_2$ (San Acacia)	0.5223	0.4124	1.266	0.205
$\boldsymbol{\beta}_3$ (Miles Salvaged)	-0.1351	0.1203	-1.123	0.261

Discussion

Compared to 2009 rescue operations, we surveyed more than twice as many pools (523 in 2009), conducted rescue on nearly twice as many days (23 in 2009), and salvaged more than twice as many river miles (65.0 in 2009). However, only about half as many fish were rescued (17,199 in 2009). Over the course of the summer, the average number of total RGSM (all salvage events combined) rescued from any river mile was 455, compared to 860 in 2009. The average number of fish rescued per mile was 92 compared to 284 in 2009. In spite of more than twice the effort in 2010, we collected about half the number of RGSM compared to 2009. As a comparison, the standard population monitoring overall catch rates in October prior to each salvage season were higher going into 2010 (16.24 RGSM/ 100 m^2) than in 2009 (7.96 RGSM/100 m^2) (Dudley, et al. 2008, 2009). Runoff and flows in spring 2009 were of higher magnitude and longer duration, likely resulting in increased recruitment in 2009 compared with 2010. This was likely one factor resulting in lower salvage numbers in 2010.

Estimated pool surface area decreased after each re-wetting event, and pools were smaller on average in the San Acacia reach. Observing smaller pools later in the season is likely due to decreased bank storage; the pools most likely dried faster after disconnection and were smaller at the time of salvage later in the summer, in spite of cooler temperatures. We found no evidence the number of pools that formed after each re-wetting decreased, but the number of pools that formed was greater in the San Acacia reach. As expected, the number of pools salvaged increased with the number of river miles salvaged.

We also found that the best predictor of the number of dead or alive fish observed in a pool was the depth of the pool, regardless of age-class. Additionally, the distance to the top of drying and reach influenced the number of fish per pool. There were fewer YOY and adults in pools as the distance to the top of drying increased. This could be explained by a couple of factors; first as salvage crews move closer to the top of drying and flowing sections of river, the time that any

pool and those fish would have been subjected to declining water quality, crowding, and predations would be lessened and second, it is hypothesized that as the river flows decrease, some RGSM (> 30 mm SL) move upstream following the receding river. There were more YOY RGSM per pool in the San Acacia reach. There was no trend for YOY or adults collected from pools over time; however, the total number of fish from a pool decreased over time. This is likely because of two reasons: YOY fish decreased over time as they recruited to adults, and the number of dead, sick, or dying fish collected decreased on each subsequent drying.

Curiously, although we were able to predict the number of fish coming from a pool based on reach and depth, we were unable to predict how many fish would be rescued per day with any of the variables we recorded. The number of adult fish rescued per day was best described by the mean number of miles salvaged, and was unrelated to the reach or to the number of miles salvaged. Similarly, more YOY were rescued per day in the San Acacia reach than Isleta, but there was no relation to date or to the number of miles salvaged. The total number of RGSM encountered per day was higher in the San Acacia reach, but was again not related to date or number of miles salvaged. The number of fish encountered on any given day is essentially random, and no variable we recorded could be used to predict the number other than the reach. This is readily apparent in Figure 5, which shows no increase in total minnows encountered with increasing miles salvaged. In most cases, we were able to salvage all the river miles dry in any one day but it is possible that the work load that higher densities of fish per pool put on the work crew mean that the total number of river miles salvaged that day would be reduced.

By systematically evaluating water quality, depth, surface area and number of RGSM being salvaged from each pool, we are able to predict how many fish can be rescued from each reach. This use of adaptive management has allowed us to salvage only those pools that will produce healthy fish. Additionally, changes to salvage protocol in 2007 were made in order to rescue and release fish with minimal stress in order to increase chances of survival. High survival after release can benefit the existing population. Analysis of data collected on pools salvaged will help us to continuously ensure high fish survival rates by maintaining and developing existing protocols.

In the future a study investigating the upstream movements of RGSM may prove to be valuable to salvage efforts. Knowing movement habits of RGSM may help to better predict how many fish can be salvaged in a reach at a particular time during drying. This would allow further prioritization of salvage efforts which would increase effectiveness.

Since 2007, the adoption of a new rescue and salvage protocol has allowed us to more effectively manage the effort to salvage RGSM. The total number of salvaged RGSM was likely lower than would have been compared to previous year's methods but we feel that current salvage numbers more accurately reflect the number of fish that could be and were rescued. A summary of salvage activities over the last 10 years is included for comparison (Table 10.) By prioritizing our efforts and the quality of fish that were salvaged, we believe there were higher survival rates after fish were released back in secure sections of the river (Caldwell, et al. 2010). In addition to the higher survival rates and benefit to the species achieved by our efforts, we also were able to cut down on workforce needs and expenses.

Table 10-Summary of Rio Grande salvage efforts 2001-2010.

Year	River Miles Salvaged	RGSM Salvaged*	Incidental Take	FWS Permit
2001	7.0	380	3	n/c!
2002	43.2	3,662	248	n/c!
2003	70.0	713	28	n/c!
2004	68.0	12,865	521	n/c!
2005	28.5	603,266**	5,640	n/c!
2006	26.0	69,875**	2,400	n/c!
2007	30.0	13,953	92	2,902
2008	0.75	3,561	5	544
2009	20.0	17,199	1,694	1,646
2010	28.2	9,667	95	1,966

*Number salvaged and released alive
**Included floodplain salvage
!prior to 2007, the number of FWS permit was not calculated.

While any number of RGSM salvaged in any reach during the course of the irrigation season is significant, it is unclear how this number would related to the population monitoring and/or population estimate numbers. The number of RGSM salvaged is a total calculated over the course of the season and should not be interpreted as an exact number alive at the end of the irrigation season. Subsequent to salvage activities, many RGSM would likely experience natural mortality, especially those that were salvaged earlier in the irrigation season.

Acknowledgments

The Middle Rio Grande Endangered Species Collaborative Program supported this work under Interagency Agreement 02-AA-40-8190 as administered by the Bureau of Reclamation. There were at least 10 people that contributed directly to the rescue effort, notably including personnel associated with the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers. The contributions of everyone are greatly appreciated. Success in RGSM operations during 2009 can be attributed to the tremendous cooperation and the professionalism of all involved.

Personnel of the New Mexico Fish and Wildlife Conservation Office served to plan and coordinate rescue operations, and represented the core of the rescue workforce, including Tristan Austring, Evan Anderson, Sara Blocker, Irene Roselli, Andy Dean, Erica Johnson, and Dustin Myers. Field assistance was also provided by Mark Brennan and Stacey Kopitsch of U.S. Fish and Wildlife Service New Mexico Ecological Services Office and the Army Corps of Engineers staff including Justin Reale, Jennifer Willard, and Sarah Beck. Special thanks to Bosque Del Apache National Wildlife Refuge for providing housing and logistical support.

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APPENDIX A: Chronology of salvage operations

Note: FWS permit includes those found dead that could not be attributed to Incidental Take including fish not salvaged due to health criteria, those sacrificed for research, or died prior to release. Salvaged fish are those release alive > 30 mm, number in parentheses is the number of adults. Release locations: [a]Isleta Diversion Dam, [b]Peralta Wasteway, [c]Highway 346 Bridge, [d]U.S. 60 Bridge, [e]1 mile below San Acacia Diversion Dam, [f]San Marcial Railroad Bridge.

28 June 2010	[e]San Acacia Reach	WJR10-920
Rio Grande silvery minnow – Salvaged		27(27)
Rio Grande silvery minnow – FWS permit		41
Rio Grande silvery minnow – Incidental Take		0

12 July 2010	[f]San Acacia Reach	WJR10-921
Rio Grande silvery minnow – Salvaged		183(24)
Rio Grande silvery minnow – FWS permit		870
Rio Grande silvery minnow – Incidental Take		0

13 July 2010	[f]San Acacia Reach	WJR10-922
Rio Grande silvery minnow – Salvaged		32(0)
Rio Grande silvery minnow – FWS permit		62
Rio Grande silvery minnow – Incidental Take		0

14 July 2010	[f]San Acacia Reach	WJR10-923
Rio Grande silvery minnow – Salvaged		62(32)
Rio Grande silvery minnow – FWS permit		198
Rio Grande silvery minnow – Incidental Take		0

15 July 2010	[f]San Acacia Reach	WJR10-924
Rio Grande silvery minnow – Salvaged		94(30)
Rio Grande silvery minnow – FWS permit		321
Rio Grande silvery minnow – Incidental Take		14

17 July 2010	[f]San Acacia Reach	TPA10-031
Rio Grande silvery minnow – Salvaged		12(11)
Rio Grande silvery minnow – FWS permit		18
Rio Grande silvery minnow – Incidental Take		2

18 July 2010	[f]San Acacia Reach	TPA10-032
Rio Grande silvery minnow – Salvaged		89(86)
Rio Grande silvery minnow – FWS permit		48
Rio Grande silvery minnow – Incidental Take		14

20 July 2010	[f]San Acacia Reach	WJR10-925
Rio Grande silvery minnow – Salvaged		25(20)
Rio Grande silvery minnow – FWS permit		20
Rio Grande silvery minnow – Incidental Take		11

22 July 2010	[f]San Acacia Reach	WJR10-926
Rio Grande silvery minnow – Salvaged		55(45)
Rio Grande silvery minnow – FWS permit		33
Rio Grande silvery minnow – Incidental Take		0

12 August 2010	[a]Isleta Reach	WJR10-938
Rio Grande silvery minnow – Salvaged		91(68)
Rio Grande silvery minnow – FWS permit		9
Rio Grande silvery minnow – Incidental Take		0

14 August 2010	[a]Isleta Reach	TPA10-033
Rio Grande silvery minnow – Salvaged		32(22)
Rio Grande silvery minnow – FWS permit		4
Rio Grande silvery minnow – Incidental Take		2

15 August 2010	[a]Isleta Reach	TPA10-034
Rio Grande silvery minnow – Salvaged		45(41)
Rio Grande silvery minnow – FWS permit		3
Rio Grande silvery minnow – Incidental Take		2

16 August 2010	Isleta Reach	TPA10-035
Rio Grande silvery minnow – Salvaged		0
Rio Grande silvery minnow – FWS permit		16
Rio Grande silvery minnow – Incidental Take		0

22 August 2010	[a]Isleta Reach	WJR10-939
Rio Grande silvery minnow – Salvaged		72(51)
Rio Grande silvery minnow – FWS permit		30
Rio Grande silvery minnow – Incidental Take		0

27 August 2010	[a]Isleta Reach	WJR10-947
Rio Grande silvery minnow – Salvaged		105(90)
Rio Grande silvery minnow – FWS permit		18
Rio Grande silvery minnow – Incidental Take		0

28 August 2010	[a]Isleta Reach	WJR10-948
Rio Grande silvery minnow – Salvaged		29(24)
Rio Grande silvery minnow – FWS permit		5
Rio Grande silvery minnow – Incidental Take		0

30 August 2010	[b]Isleta Reach	TPA10-037
Rio Grande silvery minnow – Salvaged		106(82)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

30 August 2010	[e]San Acacia Reach	TPA10-038
Rio Grande silvery minnow – Salvaged		3(1)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		0

31 August 2010	[e]San Acacia Reach	TPA10-039
Rio Grande silvery minnow – Salvaged		1272(109)
Rio Grande silvery minnow – FWS permit		52
Rio Grande silvery minnow – Incidental Take		0

2 September 2010	[e]San Acacia Reach	TPA10-040
Rio Grande silvery minnow – Salvaged		153(45)
Rio Grande silvery minnow – FWS permit		10
Rio Grande silvery minnow – Incidental Take		0

3 September 2010	[a]Isleta Reach	TPA10-041
Rio Grande silvery minnow – Salvaged		71(57)
Rio Grande silvery minnow – FWS permit		3
Rio Grande silvery minnow – Incidental Take		0

4 September 2010	[a]Isleta Reach	TPA10-042
Rio Grande silvery minnow – Salvaged		54(44)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

5 September 2010	[d]Isleta Reach	WJR10-953
Rio Grande silvery minnow – Salvaged		34(26)
Rio Grande silvery minnow – FWS permit		8
Rio Grande silvery minnow – Incidental Take		0

5 September 2010	[e]San Acacia Reach	WJR10-954
Rio Grande silvery minnow – Salvaged		761(171)
Rio Grande silvery minnow – FWS permit		16
Rio Grande silvery minnow – Incidental Take		12

6 September 2010	[e]San Acacia Reach	WJR10-955
Rio Grande silvery minnow – Salvaged		1098(371)
Rio Grande silvery minnow – FWS permit		27
Rio Grande silvery minnow – Incidental Take		10

7 September 2010	[e]San Acacia Reach	WJR10-956
Rio Grande silvery minnow – Salvaged		1725(902)
Rio Grande silvery minnow – FWS permit		32
Rio Grande silvery minnow – Incidental Take		0

8 September 2010	[c]Isleta Reach	EBA10-058
Rio Grande silvery minnow – Salvaged		1038(1029)
Rio Grande silvery minnow – FWS permit		6
Rio Grande silvery minnow – Incidental Take		0
8 September 2010	[e]San Acacia Reach	TPA10-043
Rio Grande silvery minnow – Salvaged		694(479)
Rio Grande silvery minnow – FWS permit		33
Rio Grande silvery minnow – Incidental Take		0
9 September 2010	[e]San Acacia Reach	TPA10-044
Rio Grande silvery minnow – Salvaged		101(79)
Rio Grande silvery minnow – FWS permit		32
Rio Grande silvery minnow – Incidental Take		0
10 September 2010	[e]San Acacia Reach	WJR10-957
Rio Grande silvery minnow – Salvaged		182(105)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		4
13 September 2010	Isleta Reach	WJR10-958
Rio Grande silvery minnow – Salvaged		0
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0
15 September 2010	[b]Isleta Reach	EBA10-069
Rio Grande silvery minnow – Salvaged		2(2)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0
16 September 2010	[a]Isleta Reach	WJR10-959
Rio Grande silvery minnow – Salvaged		122(92)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		3
17 September 2010	[a]Isleta Reach	EBA10-070
Rio Grande silvery minnow – Salvaged		23(17)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0
18 September 2010	[d]Isleta Reach	WJR10-960
Rio Grande silvery minnow – Salvaged		348(257)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

18 September 2010	[e]San Acacia Reach	WJR10-961
Rio Grande silvery minnow – Salvaged		187(97)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		2

19 September 2010	[e]San Acacia Reach	WJR10-962
Rio Grande silvery minnow – Salvaged		171(62)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		15

2 October 2010	[a]Isleta Reach	TPA10-052
Rio Grande silvery minnow – Salvaged		28(18)
Rio Grande silvery minnow – FWS permit		5
Rio Grande silvery minnow – Incidental Take		0

3 October 2010	[e]San Acacia Reach	WJR10-963
Rio Grande silvery minnow – Salvaged		74(21)
Rio Grande silvery minnow – FWS permit		26
Rio Grande silvery minnow – Incidental Take		0

4 October 2010	[e]San Acacia Reach	TPA10-053
Rio Grande silvery minnow – Salvaged		162(88)
Rio Grande silvery minnow – FWS permit		2
Rio Grande silvery minnow – Incidental Take		0

7 October 2010	[a]Isleta Reach	TPA10-054
Rio Grande silvery minnow – Salvaged		48(31)
Rio Grande silvery minnow – FWS permit		6
Rio Grande silvery minnow – Incidental Take		0

8 October 2010	[a]Isleta Reach	TPA10-055
Rio Grande silvery minnow – Salvaged		18(15)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

9 October 2010	[e]San Acacia Reach	TPA10-056
Rio Grande silvery minnow – Salvaged		51(8)
Rio Grande silvery minnow – FWS permit		1
Rio Grande silvery minnow – Incidental Take		0

10 October 2010	[e]San Acacia Reach	TPA10-057
Rio Grande silvery minnow – Salvaged		71(37)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		0

11 October 2010	[e]San Acacia Reach	EBA10-085
Rio Grande silvery minnow – Salvaged		100(18)
Rio Grande silvery minnow – FWS permit		0
Rio Grande silvery minnow – Incidental Take		2

17 October 2010	[e]San Acacia Reach	WJR10-964
Rio Grande silvery minnow – Salvaged		17(10)
Rio Grande silvery minnow – FWS permit		8
Rio Grande silvery minnow – Incidental Take		2

28 June – 17 October	**Rio Grande**	**2010 Totals**
Rio Grande silvery minnow – Salvaged		**9,667(4,844)**
Rio Grande silvery minnow – FWS permit		**1,966**
Rio Grande silvery minnow – Incidental Take		**95**

APPENDIX B: River Maps

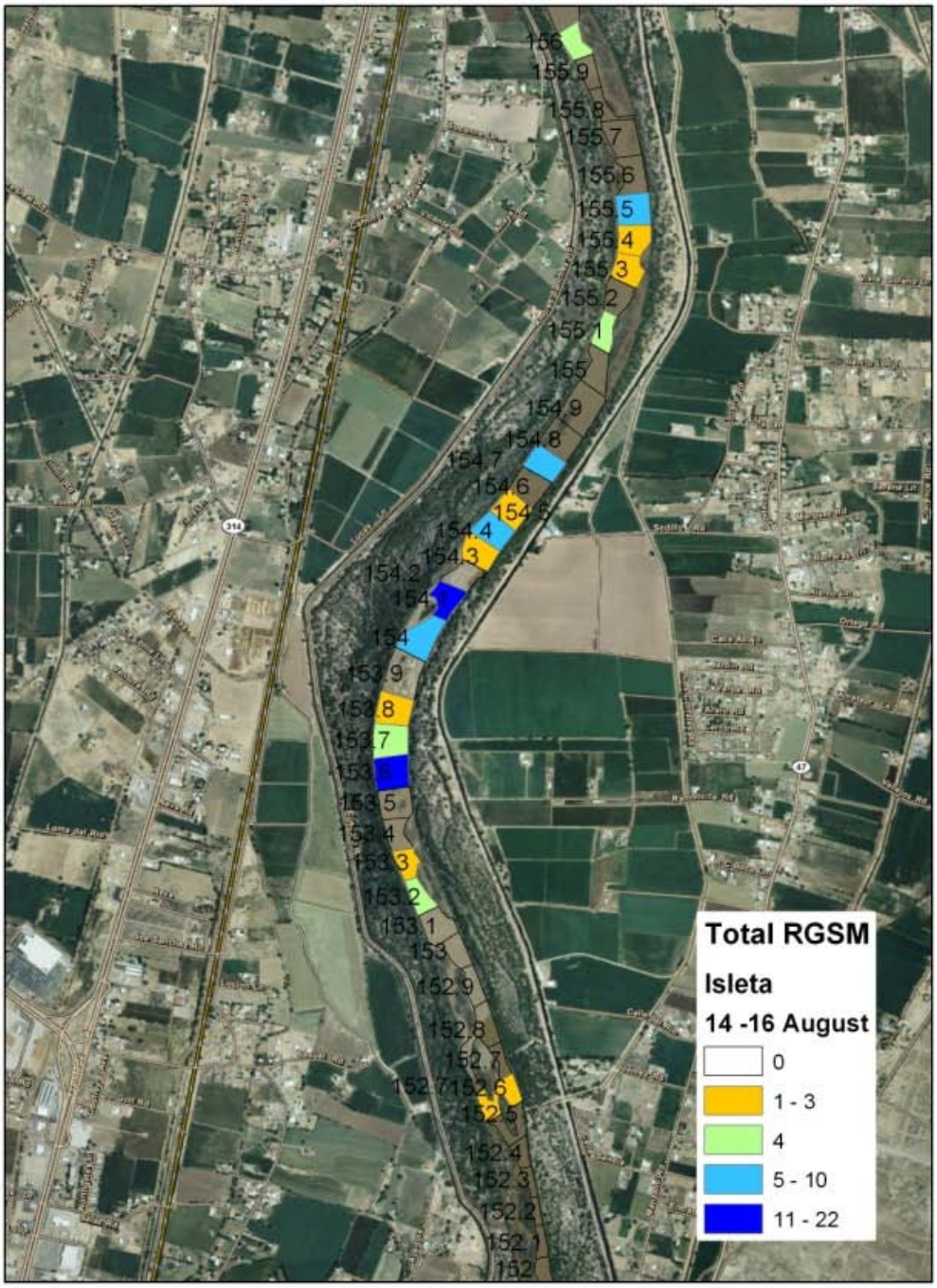

Figure 6-Total RGSM encountered in isolated pools the Isleta Reach, 14-16 August 2010.

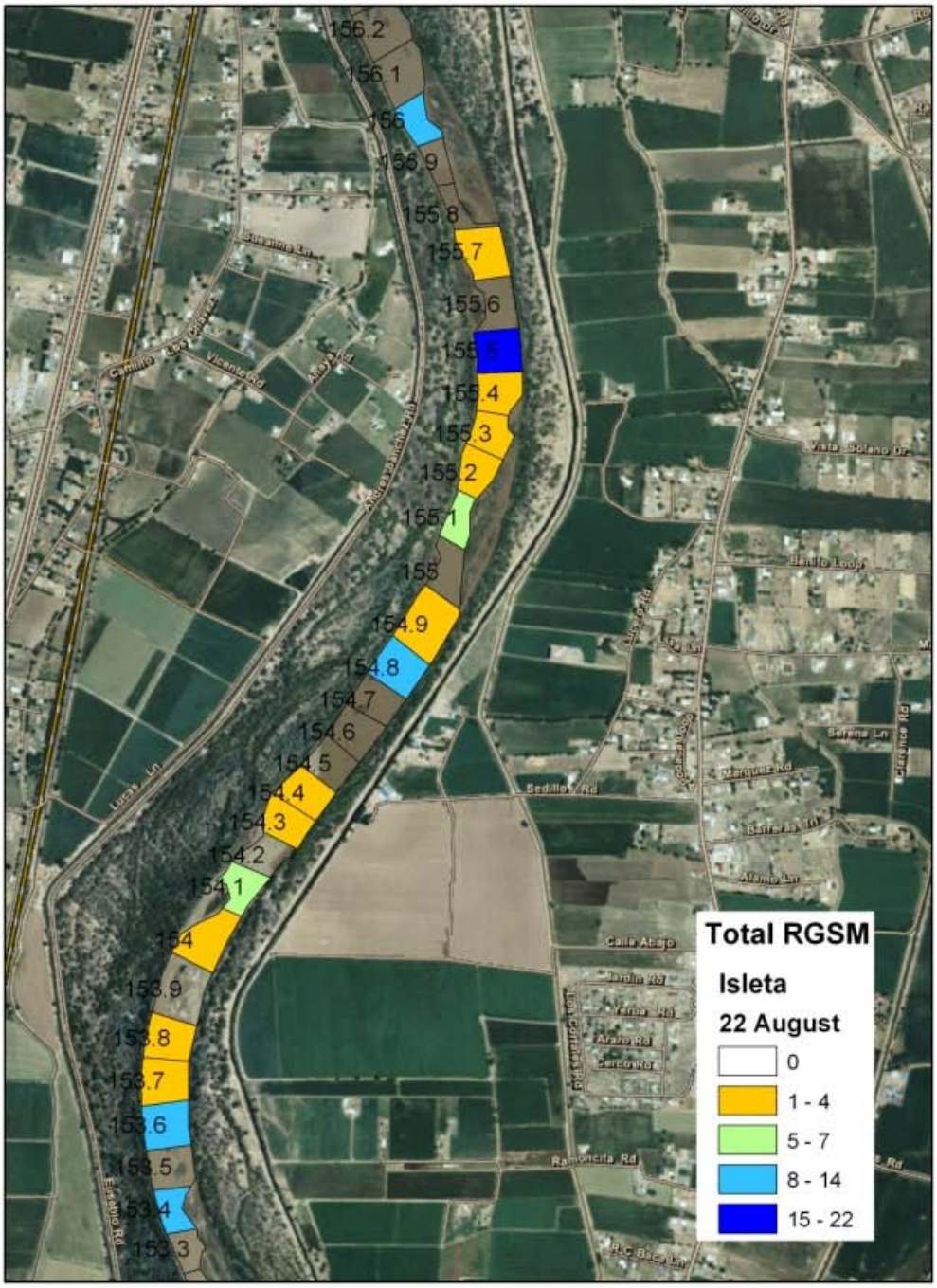

Figure 7-Total RGSM encountered in isolated pools the Isleta Reach, 22 August 2010.

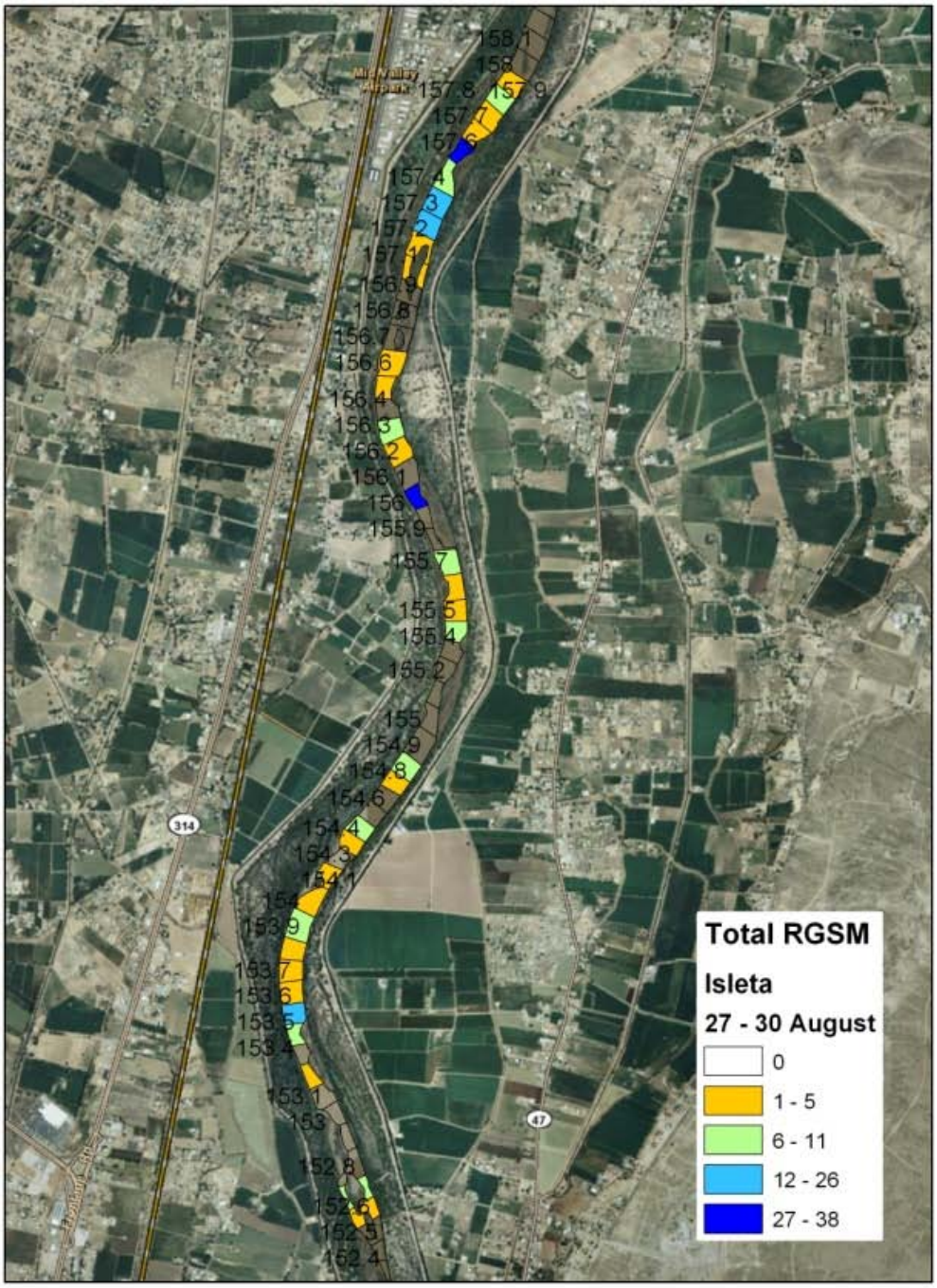

Figure 8-Total RGSM encountered in isolated pools the Isleta Reach, 27-30 August 2010.

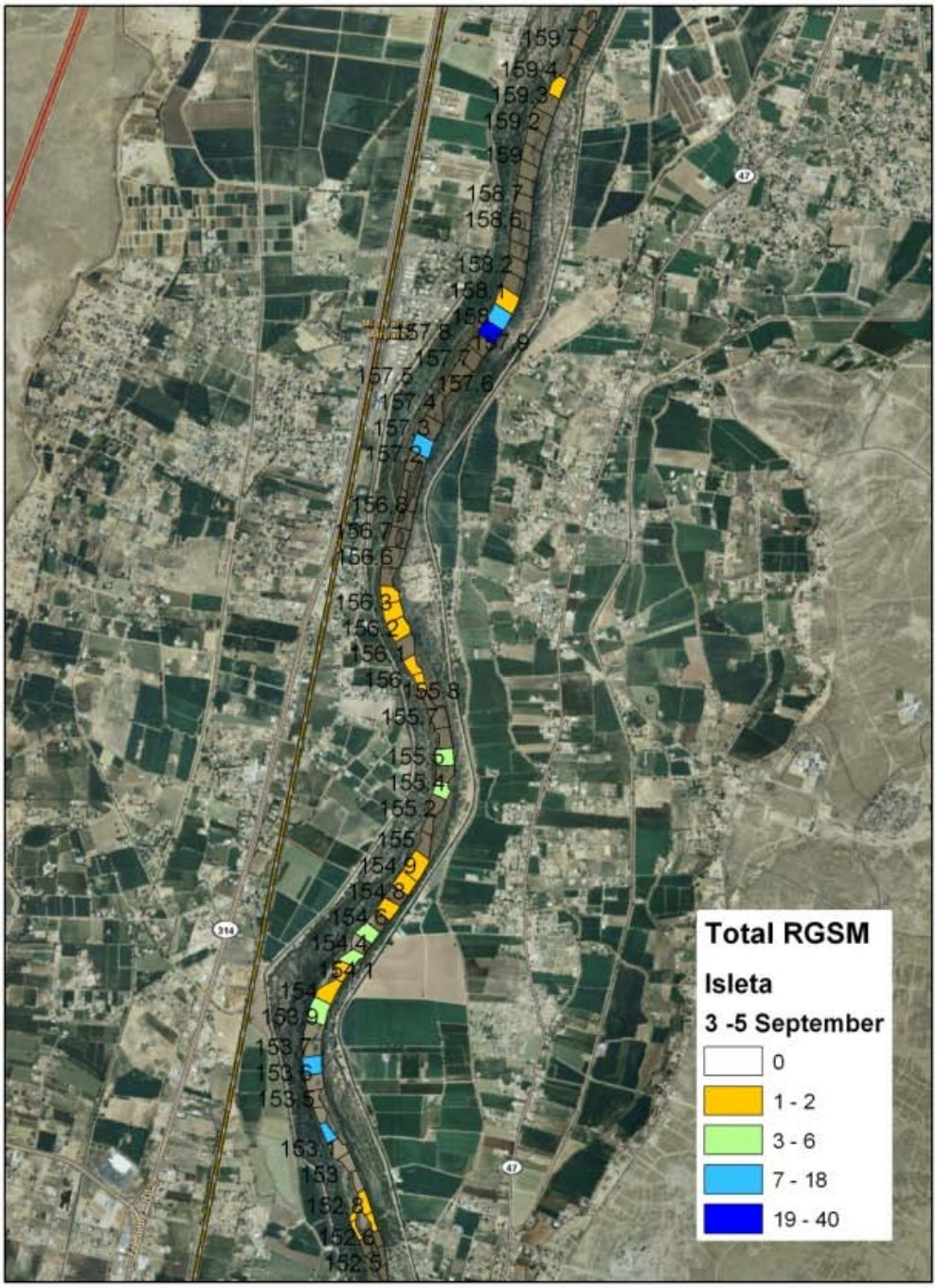

Figure 9-Total RGSM encountered in isolated pools the Isleta Reach, NM, 3-5 September 2010.

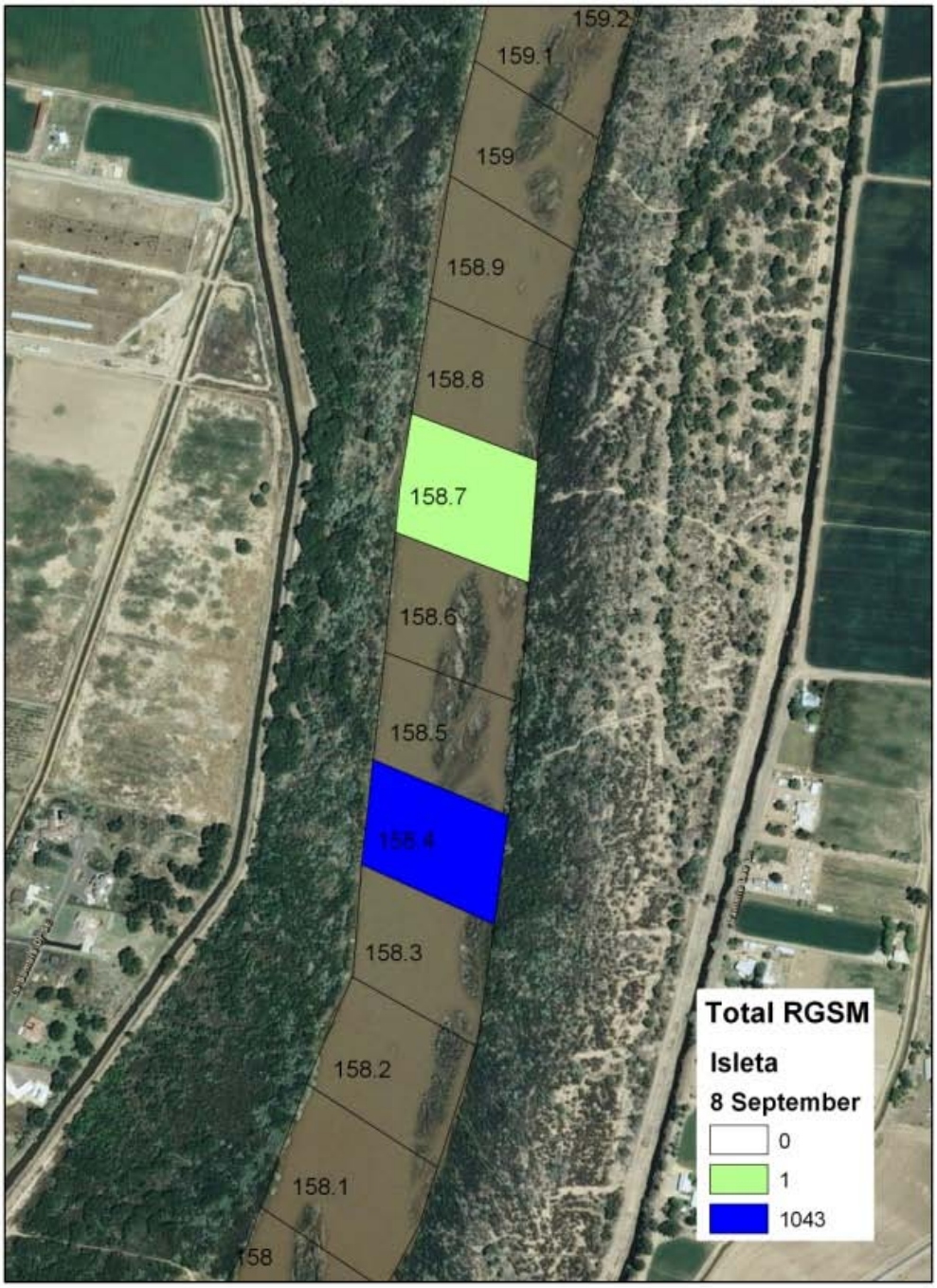

Figure 10-Total RGSM encountered in isolated pools the Isleta Reach, 8 September 2010.

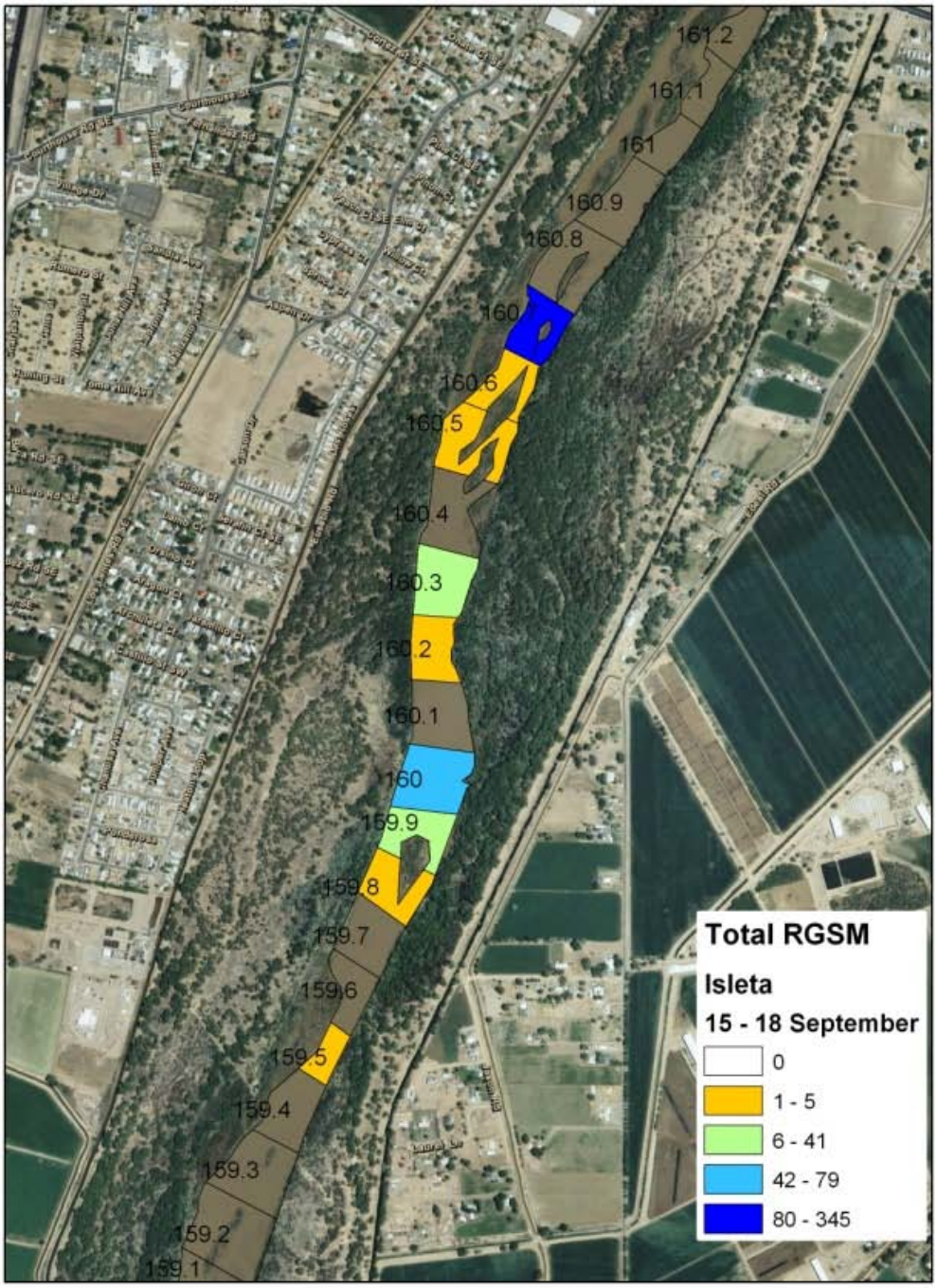

Figure 11-Total RGSM encountered in isolated pools the Isleta Reach, 15-18 September 2010.

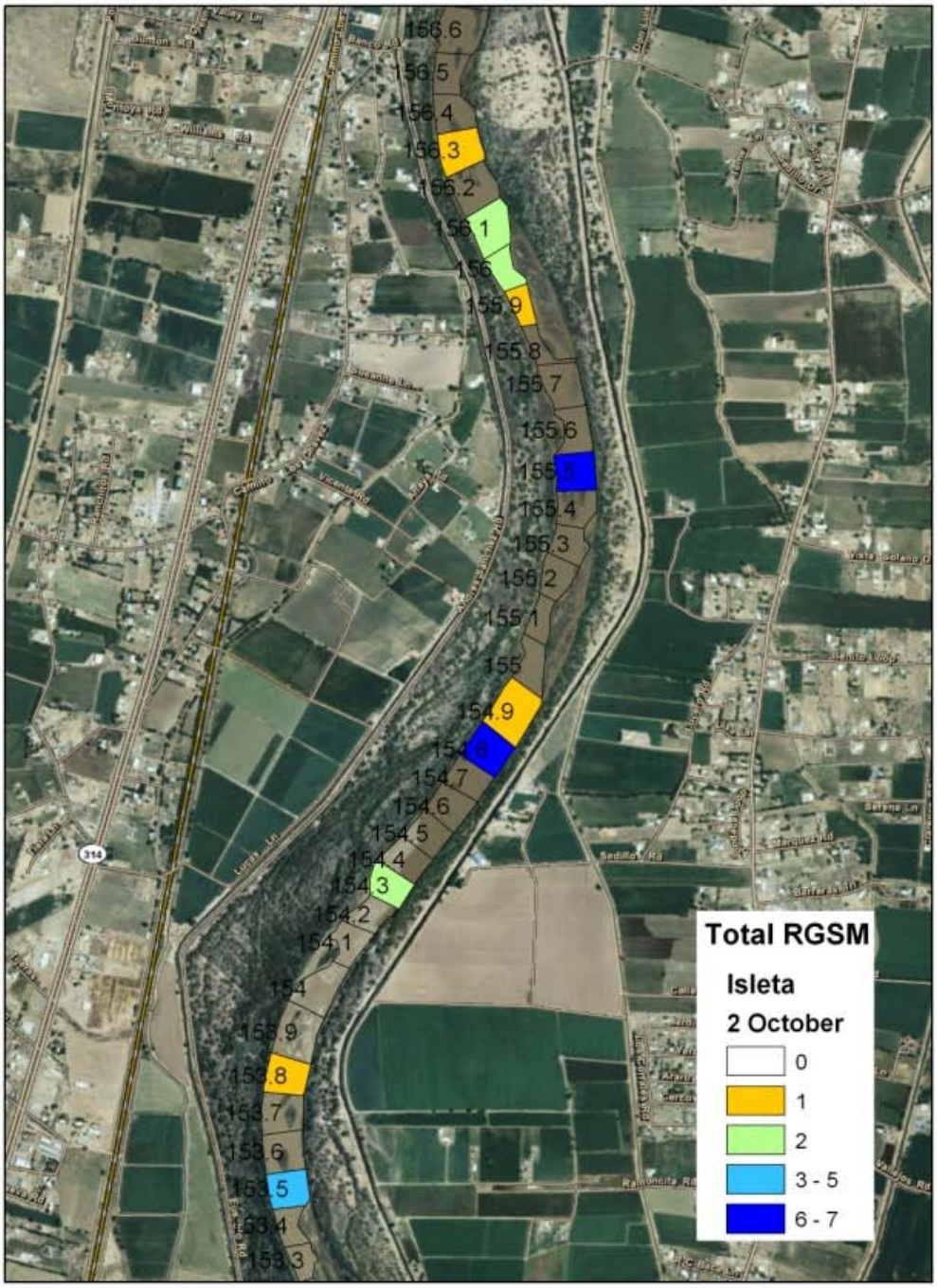

Figure 12-Total RGSM encountered in isolated pools the Isleta Reach, 2 October 2010.

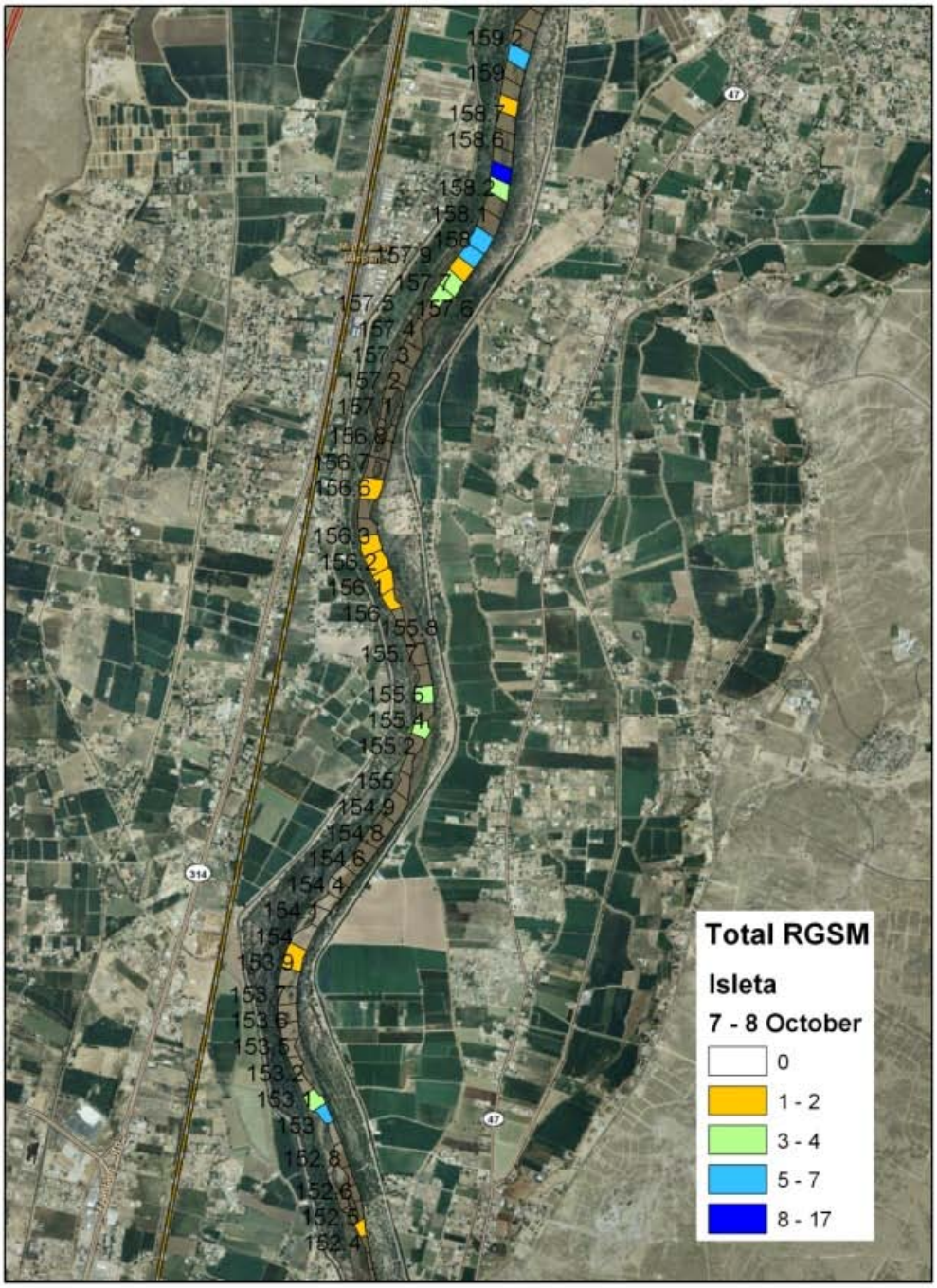

Figure 13-Total RGSM encountered in isolated pools the Isleta Reach, 7-8 October 2010.

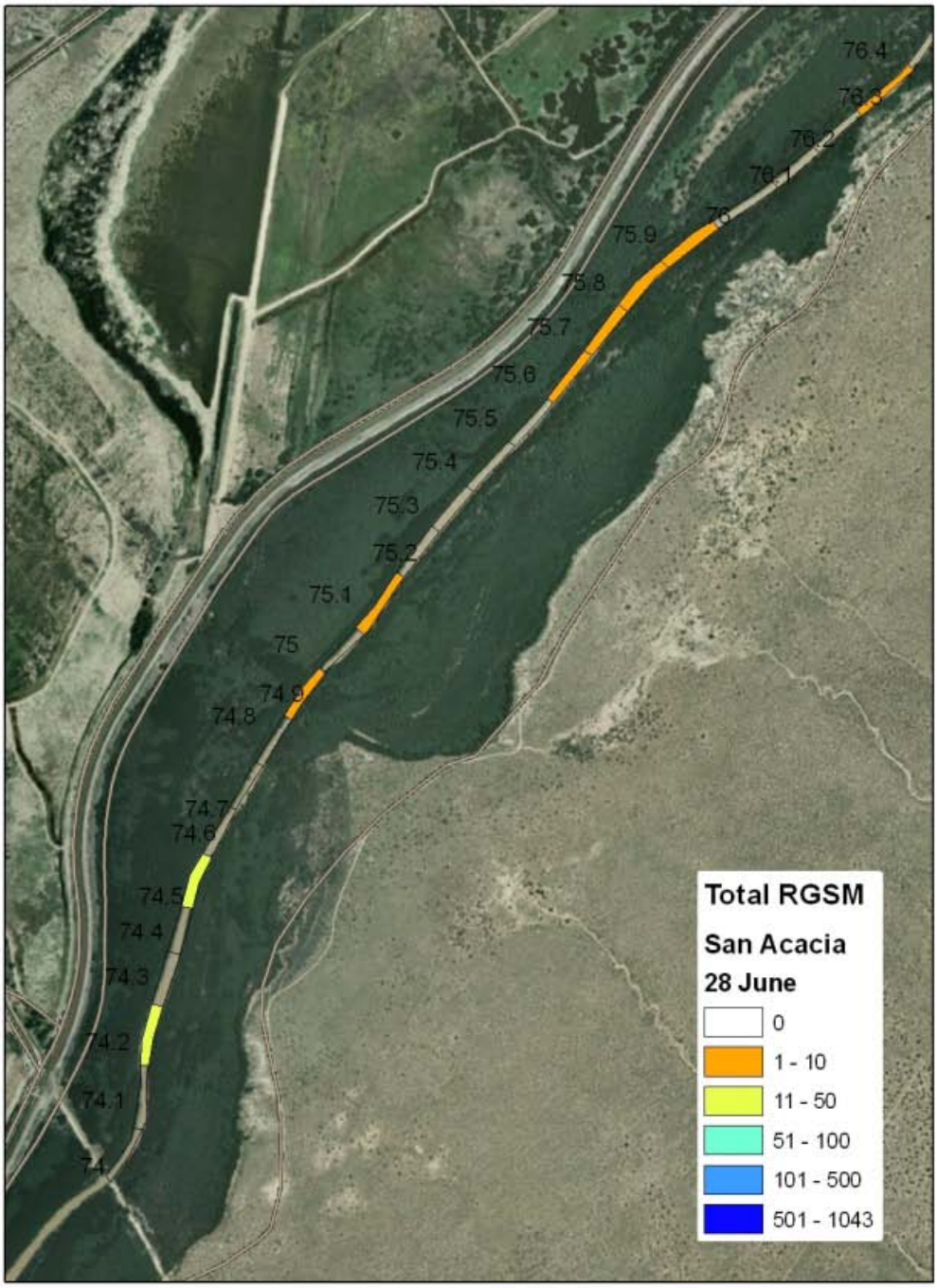

Figure 14-Total RGSM encountered in isolated pools the San Acacia Reach, 28 June 2010.

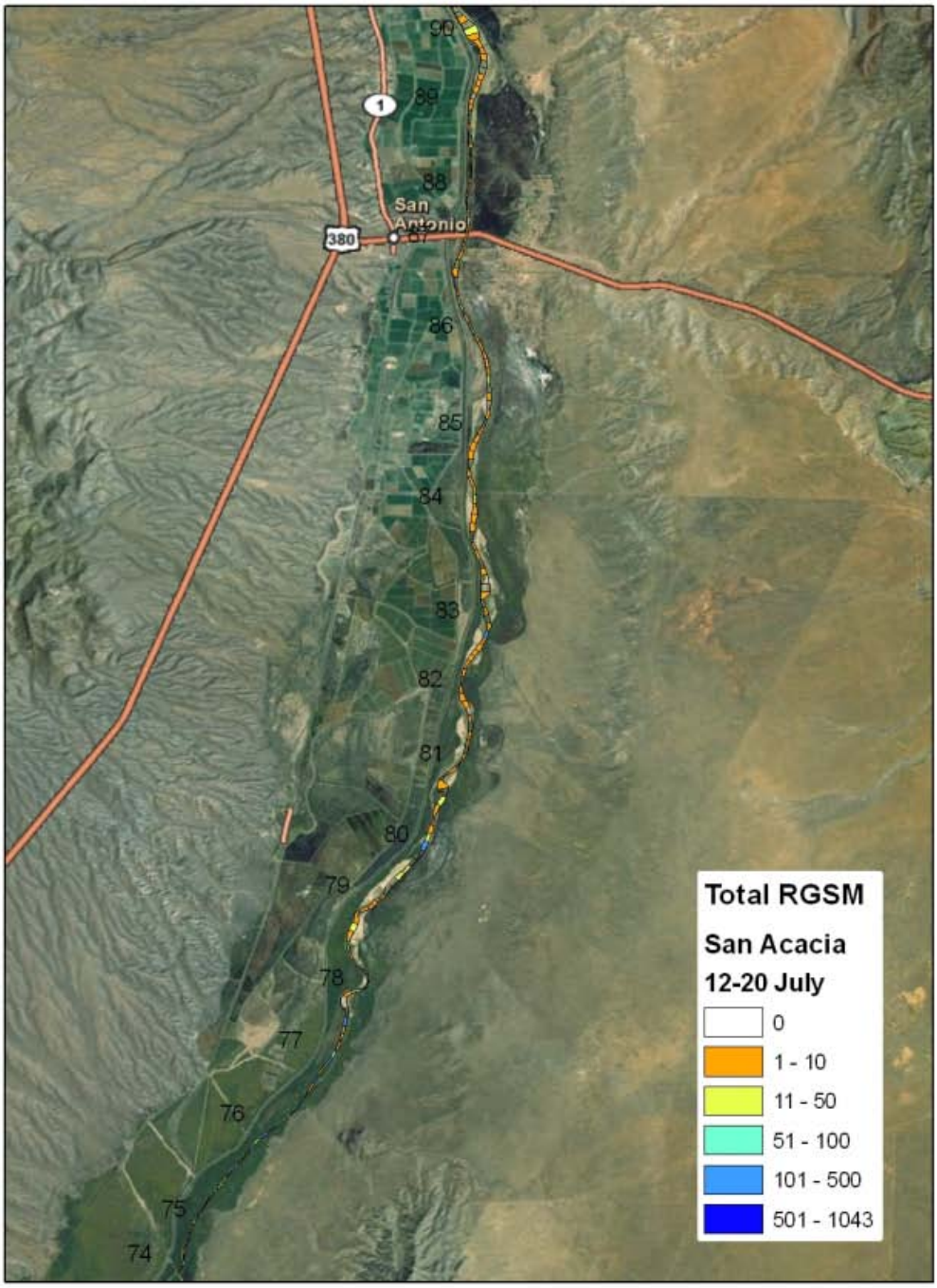

Figure 15-Total RGSM encountered in isolated pools the San Acacia Reach, 12-20 July 2010.

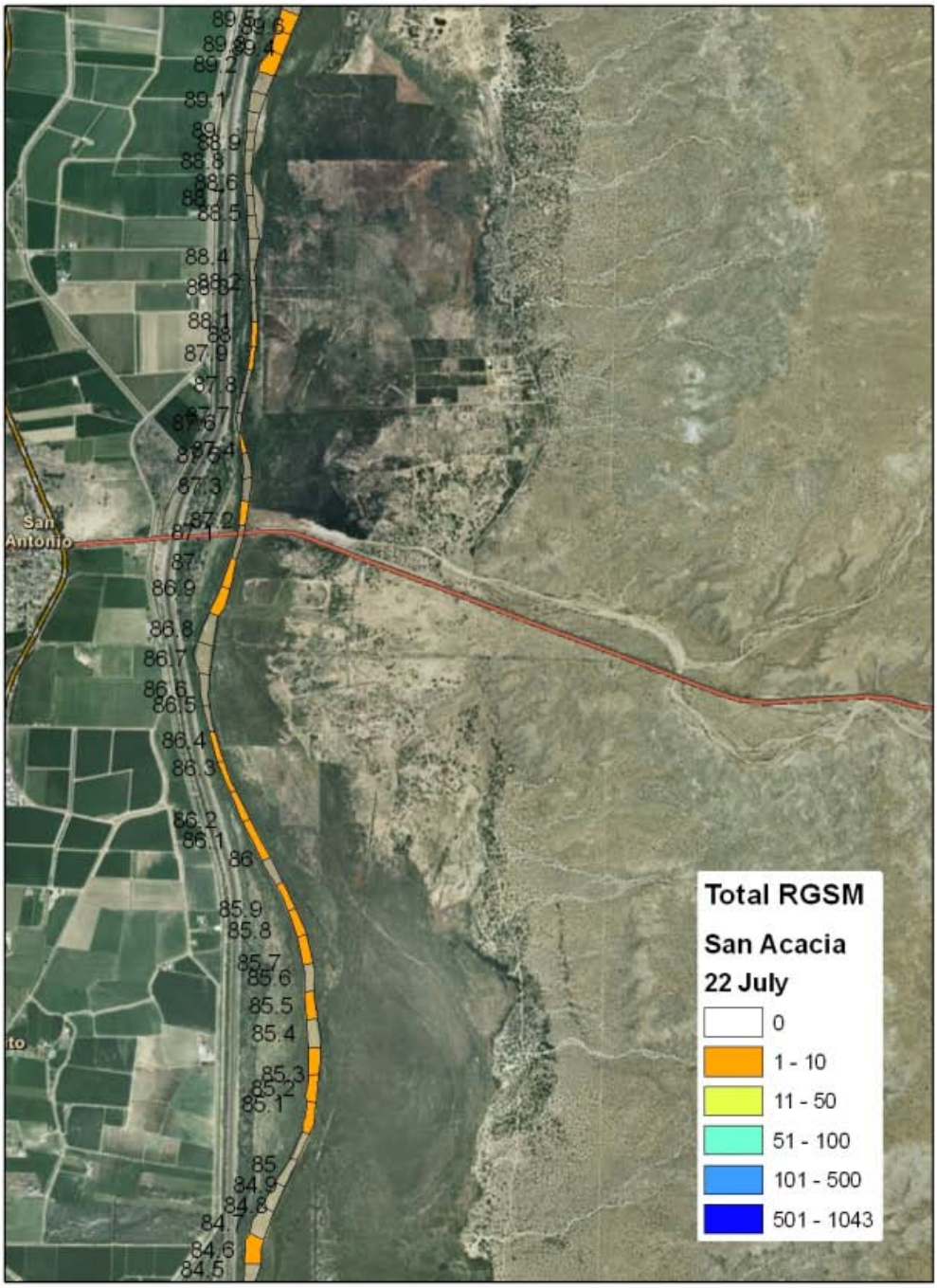

Figure 16-Total RGSM encountered in isolated pools the San Acacia Reach, 22 July 2010.

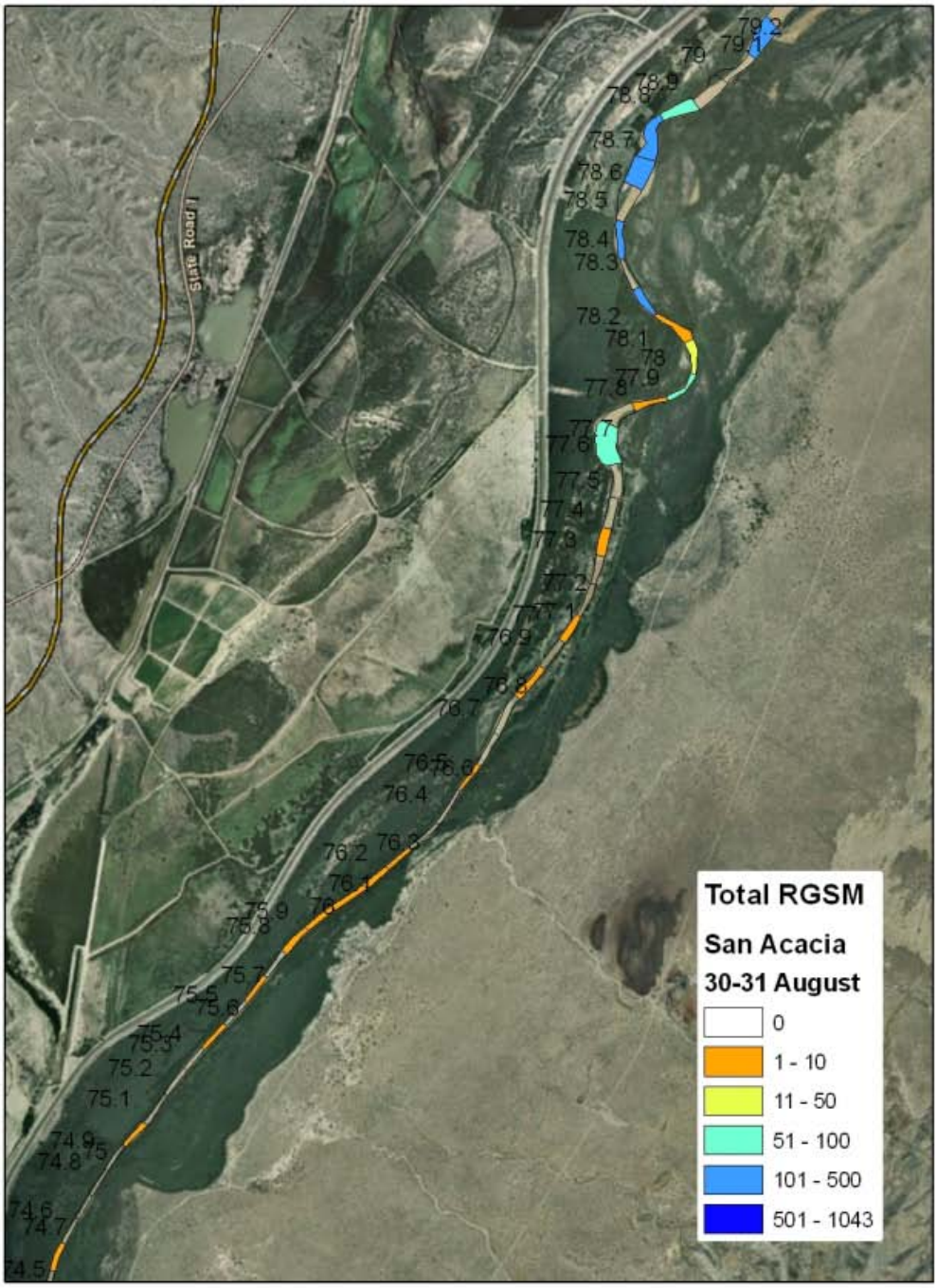

Figure 17-Total RGSM encountered in isolated pools the San Acacia Reach, 30-31 August 2010.

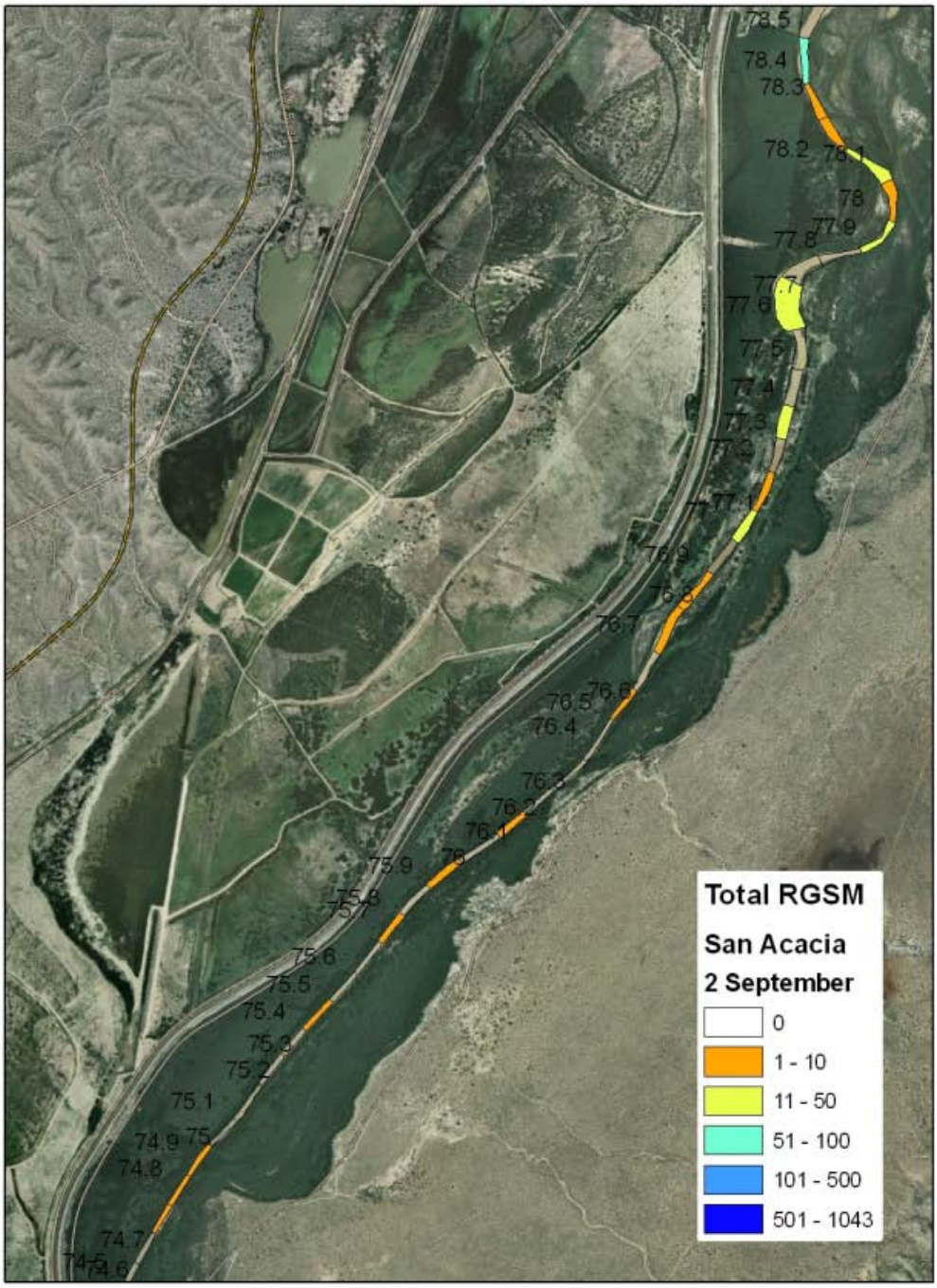

Figure 18-Total RGSM encountered in isolated pools the San Acacia Reach, 2 September 2010.

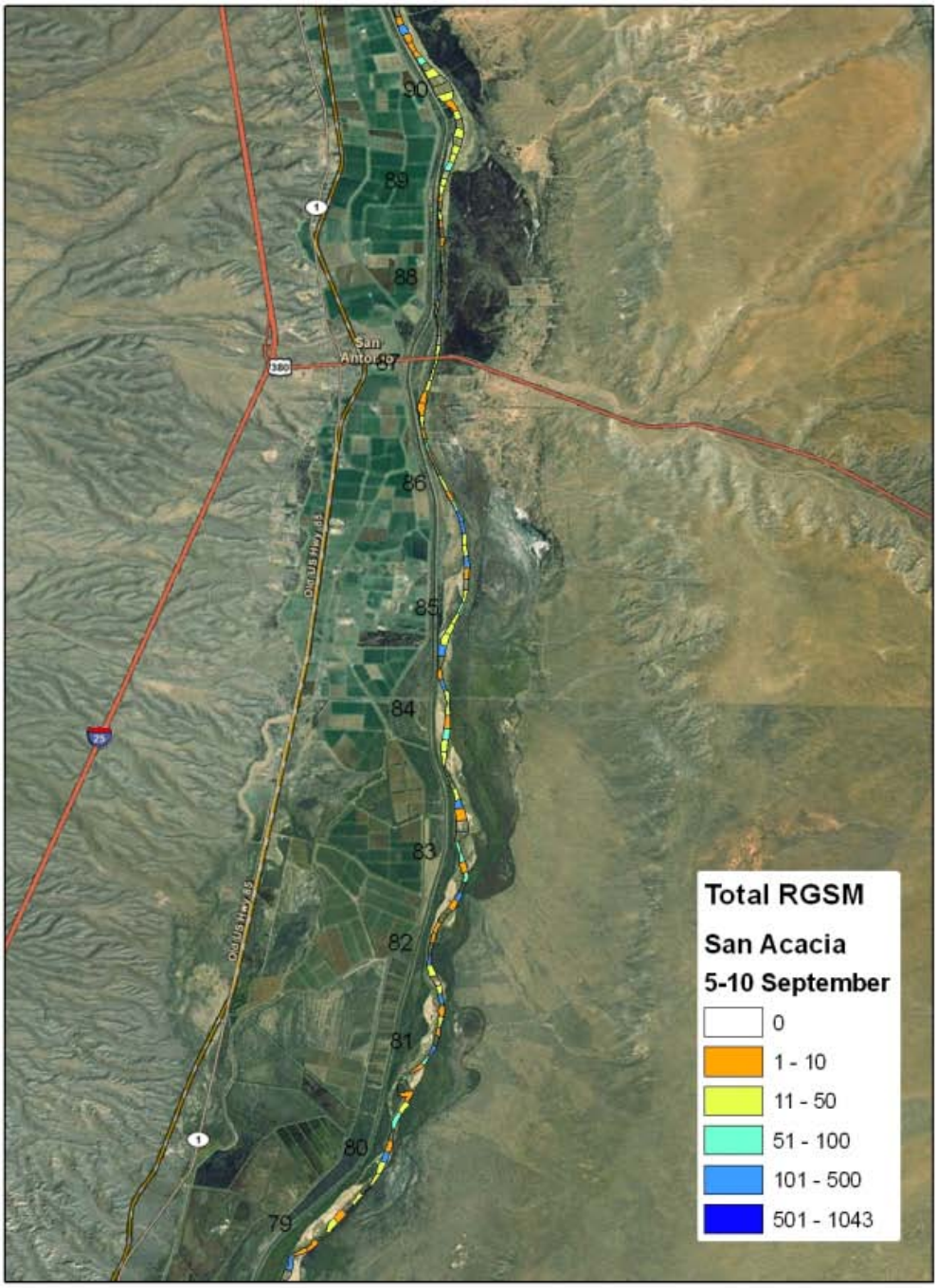

Figure 19-Total RGSM encountered in isolated pools the San Acacia Reach, NM, 5-10 September 2010.

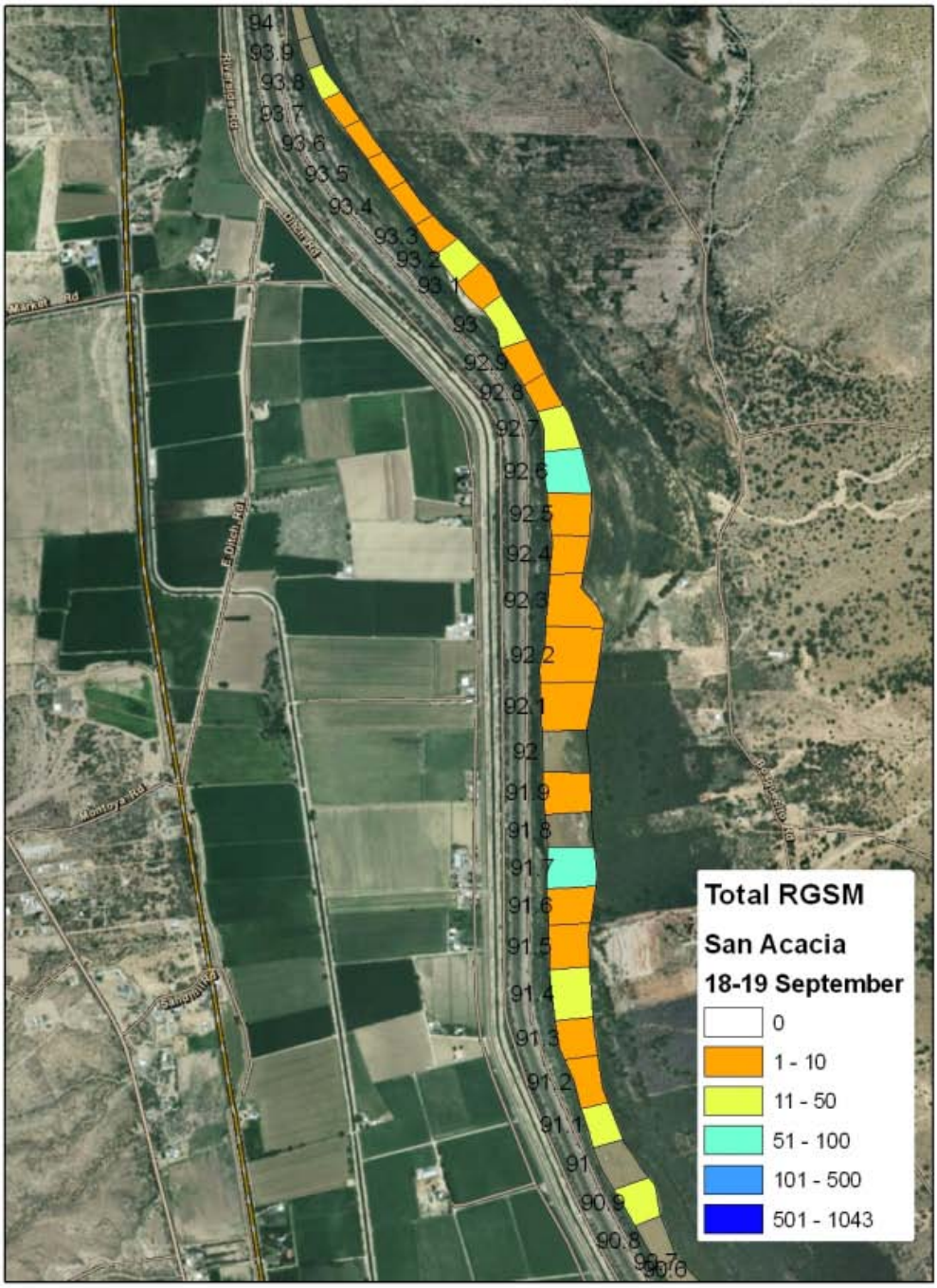

Figure 20-Total RGSM encountered in isolated pools the San Acacia Reach, 18-19 September 2010.

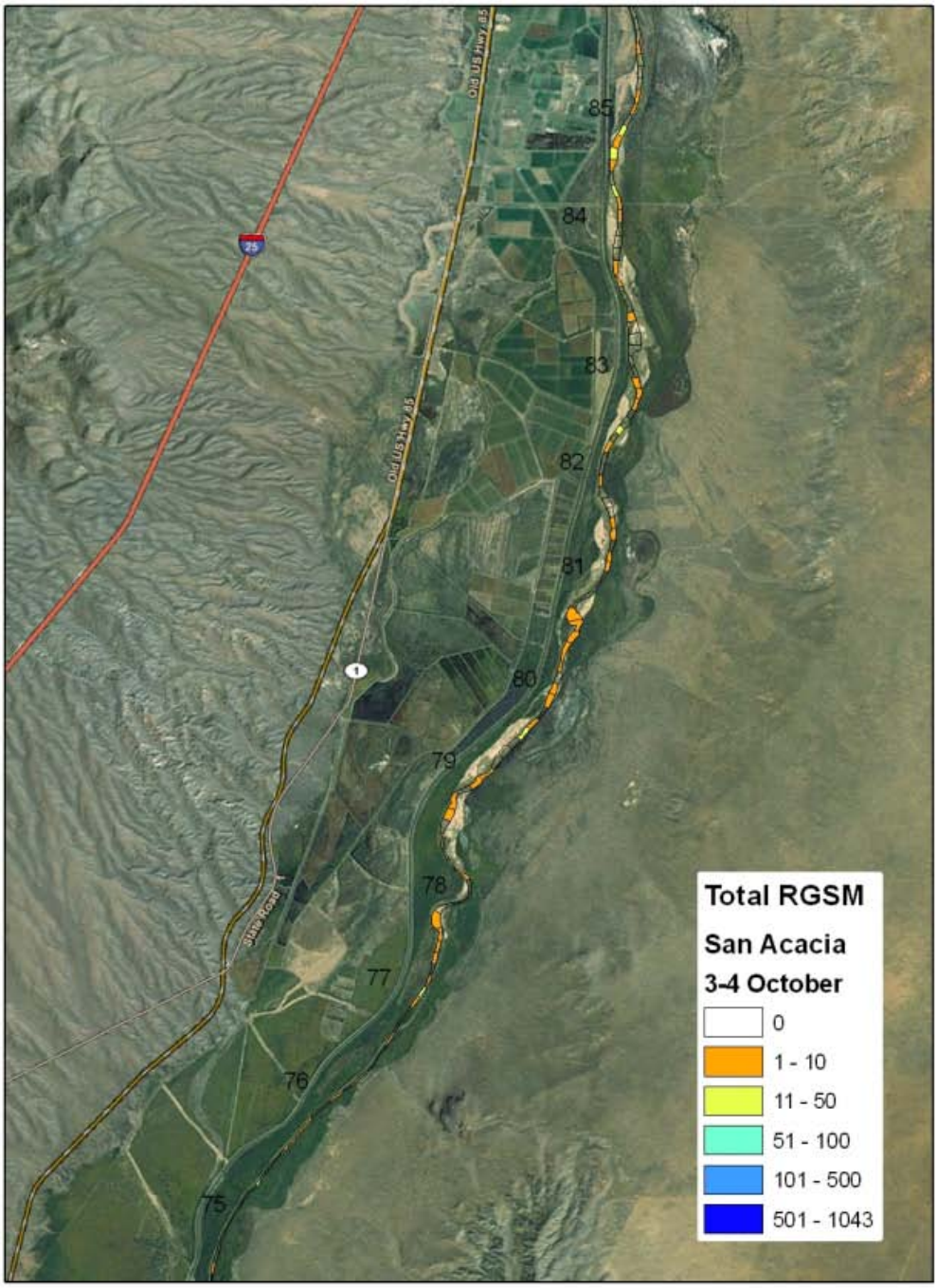

Figure 21-Total RGSM encountered in isolated pools the San Acacia reach, NM, 3–4 October, 2010.

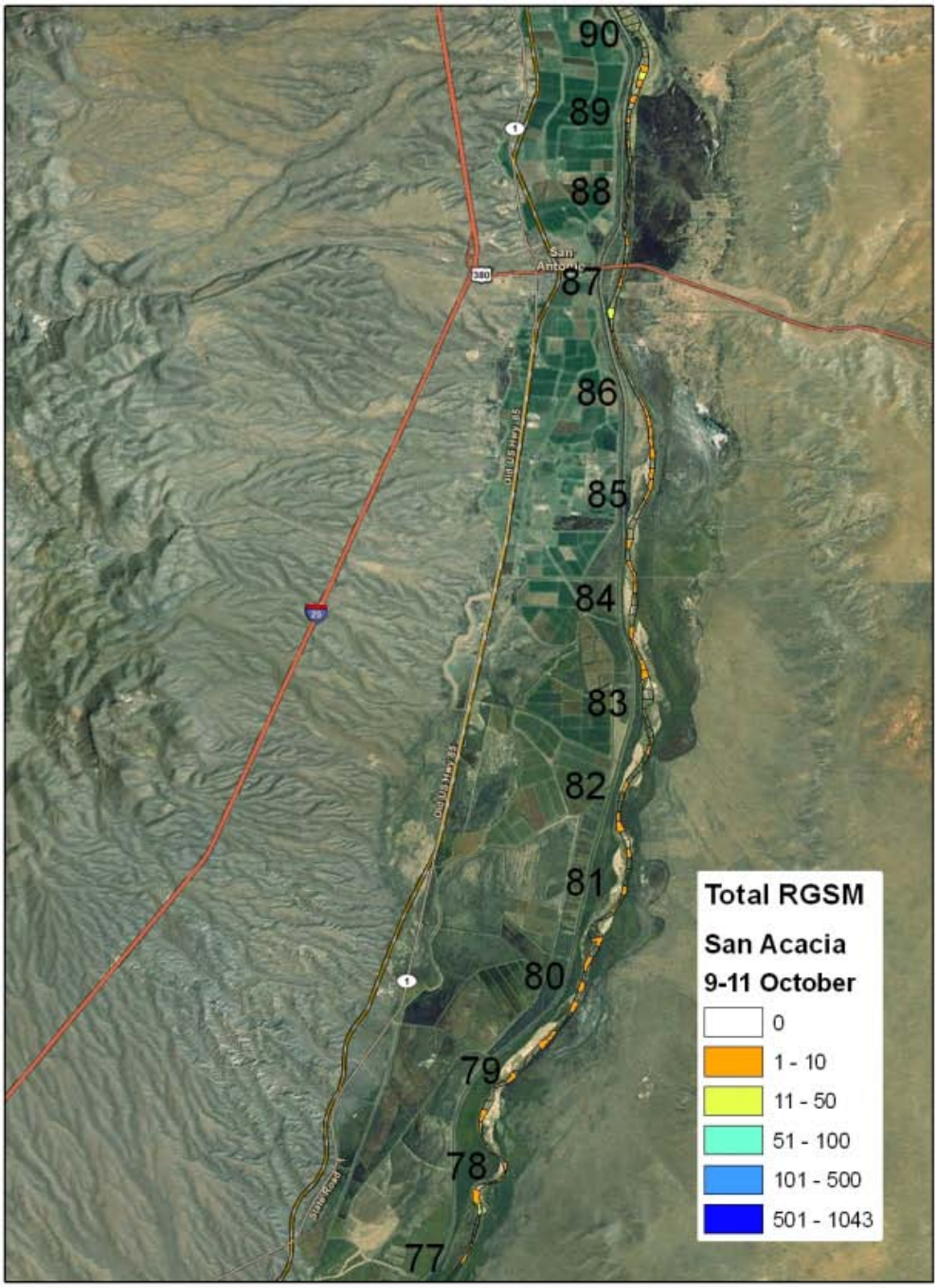

Figure 22-Total RGSM encountered in isolated pools the San Acacia reach, NM, 9–11 October, 2010.

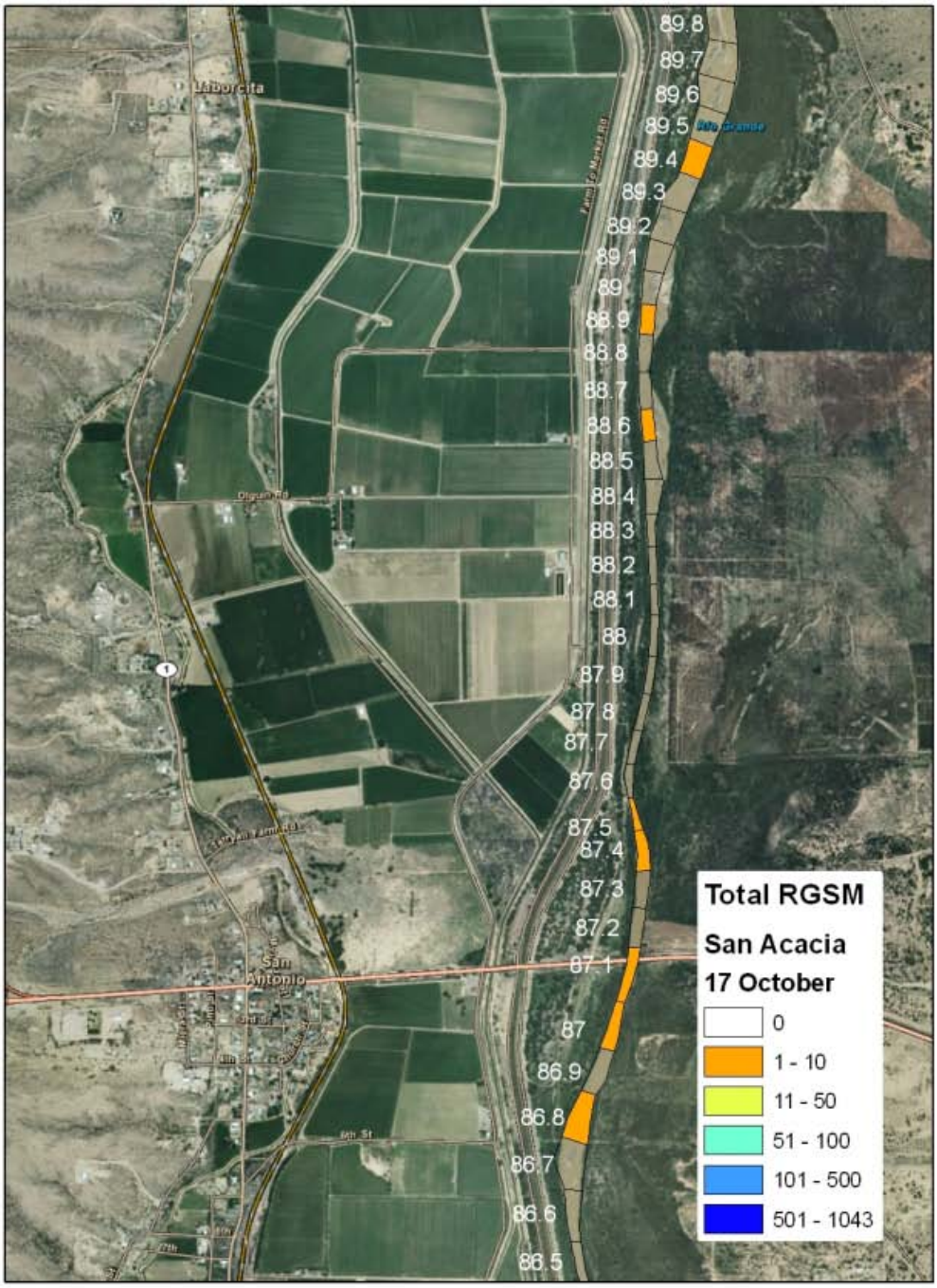

Figure 23-Total RGSM encountered in isolated pools the San Acacia reach, NM, 17 October, 2010.

APPENDIX C: Water Conditioning Formulations for Transport Tanks

Large Transport Tank:

Each half holds 211.2 liters (55.80 gallons) of water.
To render this volume a 1.0 percent salt solution requires 2,112 grams (2.1 kg) of NaCl, which volumetrically equals about 1.5 cups.
The prescribed amount of stress coat is 0.26 ml/liter (1.00 ml/gallon), with 56.00 ml (or approximately 0.25 cups) of stress coat added to each half of the large tank.
Optimal fish density for 211.2 liters @ 10 g/liter = 2,112 g. 4,000 young-of-year (35 mm TL = 0.5 g), or 700 adult (65 mm TL = 3.0 g)

Small Transport Tank:

The tank holds 196.8 liters (52 gallons) of water.
To render this volume a 1.0 percent salt solution requires 1,968 grams (1.9 kg) of NaCl, which volumetrically equals about 1 cup.
The prescribed amount of stress coat is 0.26 ms/liters (1 ml/gallon) and 52.00 ml (or approximately 0.12 cups) of stress coat will be added to the small tank.
Optimal fish density for 196.8 liters @ 10 grams/liters = 1,986 g. 2750 young-of-year (35 mm TL = 0.5 g), or 450 adult (65 mm TL = 3.0 g)